Missouri River Radio Telemetry and
Marias River Larval Fish Study
U.S. Bureau of Reclamation
2013 Progress Report
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Montana Fish, Wildlife and Parks for U.S. Bureau of Reclamation and PPL Montana

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Agreement R13AP60041

April 29, 2014

Summary

The study area is a 240-mile reach of the Missouri River in north central Montana, between Great Falls and the headwaters of Fort Peck Reservoir. Major tributaries in this reach include the Musselshell, Judith and Marias Rivers. The Bureau of Reclamation manages flows within the study area with Canyon Ferry Dam on the Missouri River (RM 2253), Gibson Dam on the Sun River (RM 101), and Tiber Dam on the Marias River (RM 80). PPL MT also operates hydropower dams on five small reservoirs immediately upstream of the study area. This report summarizes work done in 2013 and is a continuation of the telemetry and flow modification study conducted from 2005 – 2012 (Gardner and Jensen 2011, Tews and Jensen 2013). In 2013, flows were generally below average at both Fort Benton and Landusky (Fred Robinson Bridge). Peak flows were nearly average at Fort Benton but discharge at Landusky rose above flood stage in early June, primarily due to central Montana rainstorms.

Blue sucker, channel catfish, northern pike, pallid sturgeon and shovelnose sturgeon were followed with radio telemetry to evaluate fish behavior. A total of 151 radio-tagged fish were monitored in 2013. Most radio tagged species exhibited a variety of movement/spawning strategies including a downstream migration pattern to the Robinson Bridge vicinity during the spawning season. The Missouri River downstream from Roads End was used by many radio tagged fish and indicated that the interface between the Missouri River and Fort Peck is likely important fish habitat, especially for burbot and channel catfish. In 2013, with radio telemetry, we monitored the movements of three wild adult pallid sturgeon and 19 hatchery raised pallid sturgeon (HRPS) for 529 relocation events. Most (85%) of these relocations were obtained in the Fred Robinson Bridge section. A wild male pallid sturgeon, last captured in 2001 was netted in the vicinity of a radio tagged sexually mature male 1997 HRPS. One 1997 HRPS was relocated in the Marias River in August and September. Our focus in the future is to continue radio tagging 1997 HRPS for further research in cooperation with MSU.

The Marias River is an important tributary for sturgeon. This was the second sequential year of experimental spring flow releases from Tiber dam to evaluate sturgeon spawning. In 2012, there was 1,000 cfs released for 55 days, and, in 2013, Tiber outflows were raised to 2,000 cfs for 9 days. Shovelnose sturgeon did not appear to spawn during the controlled 7 week release in 2012. Sturgeon larvae and embryos were captured in the Marias in 2013; spawning appeared to occur at 1990 cfs. Radio telemetry data, collected since 2006, also indicates more adult shovelnose sturgeon migrate into the Marias River when flows reach 2,000 cfs. There appears to be a trigger flow between 1,000 and 2,000 cfs for adult shovelnose sturgeon to enter or to spawn in the Marias River. This contrasts with the mainstem Missouri where shovelnose sturgeon movements do not appear to be influenced by flow. As the HRPS mature it will be worthwhile to monitor their movements to see if they use the Marias and Teton Rivers for spawning. If pallid sturgeon spawned in these tributaries there should be sufficient larval drift distance for juvenile recruitment.

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Introduction:

This study was undertaken in cooperation with Montana Fish, Wildlife and Parks (FWP), Montana State University (MSU), PPL Montana (PPL), the United States Fish and Wildlife Service (USFWS) and the United States Bureau of Reclamation (USBR) to evaluate river regulation in the Upper Missouri River and Marias River and the related effects on pallid sturgeon and the associated aquatic ecosystem. There is a need to learn more about the life cycle requirements of the pallid sturgeon and other sensitive fish species in the Missouri and Marias Rivers with respect to regulated flows. Dams operated by both the USBR and PPL influence the study area. It is well known that large dams and reservoirs have significant effects on the physical and chemical conditions of the downstream river. Reservoir operations typically alter the downstream flow regime, and thereby influence the natural channel, floodplain and riparian characteristics and replace the system with a more static, less diverse condition (Ward and Stanford 1979, Hesse et al. 1989). The Upper Missouri River is the most natural free-flowing reach in the entire Missouri River. However, operations of USBR dams have still caused significant flow regime changes in this area (Scott et al. 1997). Ramey et al. (1993) reported that the effects of flow regulation by Canyon Ferry Dam have changed the flow patterns of the Missouri River at least as far downriver as Fort Benton. For instance, the 2-year recurrence interval flood has shifted to once every four years and the 5-year flood has shifted to once every 10 years. Normal flow patterns have also been altered in the Marias River as a result of Tiber Dam operations. These alterations in the flow regimes may influence the indigenous aquatic fauna, including the endangered pallid sturgeon. Alterations in the temperature and sediment load caused by the operations of Canyon Ferry and Tiber dams may be additional factors affecting the aquatic fauna. PPL was required by the Federal Energy Regulatory Commission (FERC) to develop and implement a comprehensive fisheries monitoring and evaluation program for the protection, mitigation and enhancement of the fisheries resources including this reach of the Missouri River when their 40-year operating license was reissued. PPL contracted with FWP to conduct this work beginning in 2001 to help meet the requirements of PPL's federal operating license (FERC Project 2188 Article 417) for five dams on the Missouri River in the Great Falls area. The objectives for this project are detailed in five-year fisheries protection, mitigation and enhancement plans developed by PPL in cooperation with state and federal resource agencies and approved by FERC. They include work on species of concern and common species in this reach.

The semi-regulated Upper Missouri River still has most of the native fish species known or expected to occur prior to water regulation development. Special status species found in this reach include the endangered pallid sturgeon, blue sucker, sauger, sicklefin chub and sturgeon chub. Shovelnose sturgeon were recently listed as a threatened species due to similarity of appearance to pallid sturgeon (Federal Register 2010), but this listing only applies to commercial fishing operations and should not impact shovelnose sturgeon management and sport fishing in Montana. The radio telemetry portion of this study builds on previous radio telemetry work (Gardner and Jensen 2011, Tews and Jensen 2013) to provide additional insight on migration patterns and spawning locations of sturgeon and other native species and continues the adaptive management studies in relation to varying flow conditions. The telemetry monitoring system of at least 10 land based stations located within the 240-mile study reach, including two tributaries, has been in place for several years. A total of 151 fish had active radios during the 2013 field season. On-going companion work includes a monitoring study and additional pallid sturgeon work (See Tews 2013 and 2013b for past results).

Wild pallid sturgeon are nearly extinct in this reach with only three wild individuals observed above Fort Peck Dam in the past two years. Hatchery raised pallid sturgeon have been stocked in the Upper Missouri River starting in 1998. This 1997 year class (1997 HRPS) is becoming sexually mature and offers an opportunity to identify pallid sturgeon spawning areas and spawning cues. From 1965 – 1990 (Gardner 1990) and throughout the 1990's (Gardner 1995), nearly all wild pallid sturgeon observations were less than 40 miles upstream from Fort Peck. However, prior to 1965, many observations were in the Fort Benton and Loma areas (Gardner 1990). The Marias has the potential to be important for pallid sturgeon reproduction and recruitment; it is the only tributary between Morony Dam and the headwaters of Fort Peck where sturgeon migration or reproduction have been documented. Shovelnose sturgeon have not been recorded in the Judith or Musselshell Rivers. From 2005 – 2010 FWP worked with the USBR and MSU to evaluate the spring rise in the Marias River with peak rises near 5,000 cubic feet per second (cfs) in 2006 and near 4,000 cfs in 2008 (Goodman et al. 2012, Gardner and Jensen 2011). The 5,000 cfs flow in 2006 was sufficient to produce many of the physical processes seen during high flow events and produced channel changes at the sand dominated site (Auble and Bowen 2008; Auble and Bowen 2009). This, and previous work (Berg 1981, Gardner 1998) has shown that shovelnose sturgeon spawn in the Marias River when peak flows approach 3,000 cfs and do not spawn at flows of 500 cfs (Goodman et al. 2012). Goodman et al. (2012) suggested a threshold flow of 990 cfs to initiate shovelnose sturgeon spawning in the Marias River. Our 2012 work indicated that 990 cfs was not sufficient for sturgeon spawning. This was the second sequential year of experimental flow releases from Tiber dam to evaluate sturgeon spawning. The data collected in 2013 indicates there may be a trigger flow between 1,000 and 2,000 cfs for adult shovelnose sturgeon to enter the Marias River. This contrasts with the mainstem Missouri where shovelnose sturgeon movements do not appear to be influenced by discharge (Richards et al. 2013). As the HRPS mature it will be worthwhile to monitor their movements to see if they use the Marias and Teton Rivers for spawning. If pallid sturgeon spawned in these tributaries there should be sufficient larval drift distance for juvenile recruitment.

Study Area:

The study area is a 240-mile reach of the Missouri River from Great Falls (river mile (RM 2106) to the Musselshell River confluence (RM 1867) (Figure 1). The study area also includes the lower Marias River from Tiber Dam (RM 80) to the confluence with the Missouri River (RM 2051). In 2013, work in the Marias focused on the lowest 12 miles of the Marias River. The Marias River is the largest tributary of the Missouri River upstream of the Fort Peck and has a significant influence on the Missouri River's physical condition and aquatic fauna. USBR operates three dams in the Missouri River system. These dams alter flow and other riverine physical/chemical characteristics within the study area. The largest dam on the system is Canyon Ferry Dam, located on the Missouri River near Helena (RM 2253). Total capacity of the reservoir is 1,891,888 acre-ft. at elevation 3,797 ft. (normal full pool). At full pool the reservoir covers about 33,500 surface acres and extends about 19 miles upstream from the dam (USBR 2009). Tiber Dam, located on the Marias River near Chester (RM 80), is the second largest USBR dam on the system. Total capacity of the reservoir is 967,319 acre-ft. at elevation 2993 ft. (normal full pool). The reservoir covers about 17,889 surface acres at full pool extending about 23 miles upstream from the dam (USBR 2009). Gibson Dam (RM 101) and associated off-stream storage reservoirs, Pishkun and Willow Creek, are USBR controlled projects located on the Sun River. Total capacity of the Sun River reservoir system is 178,100 acre-ft. PPL operates five hydropower dams immediately upstream of the study area. These reservoirs are small (125 – 400 surface acres), have short average retention times of 2 – 24 hrs and do not thermally stratify (Leathe 2011).

Objectives:

1. Maintain the radio telemetry land-base stations and gather and organize data into the existing data base. Manually track and locate radio tagged fish over the entire study area once/month, April-October.
2. Recapture adult pallid sturgeon and pallid sturgeon from the 1997 year class and take blood samples to monitor reproductive condition.
3. Locate spawning sites by tracking adults and the 1997 year class during the spawning period with a focus on known reproductively active pallid sturgeon.
4. Radio tag up to 35 pallid sturgeon. Track radio-tagged pallid sturgeon to monitor their movement patterns and habitat preferences.
5. In the lower Marias River, complete larval fish and sturgeon sampling in relation to a controlled flow of release 2000 cfs from Tiber Reservoir.
6. Radio-tag up to 10 burbot in 2013.
7. Collect information on general movement characteristics including: distribution, tributary use and seasonal movements of all radio-tagged fish.
8. Identify spawning habitat and use of shovelnose sturgeon.

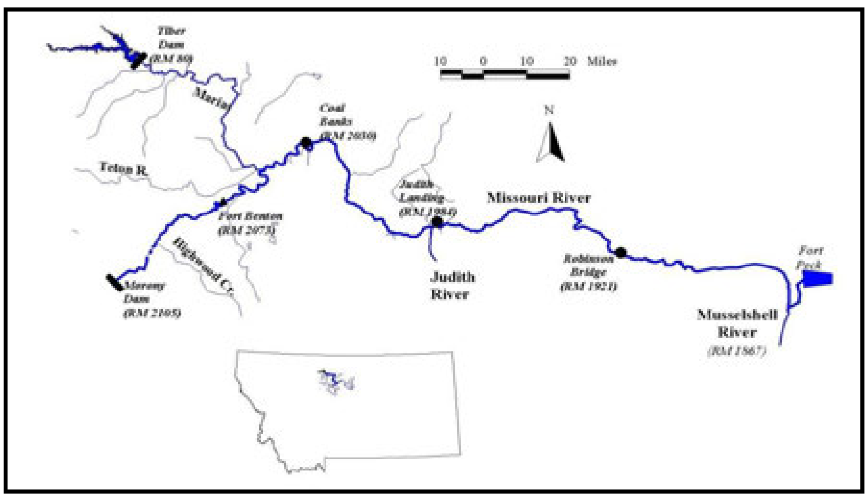

Figure 1. Map of Upper Missouri River Study area

Methods:

Radio Telemetry

In 2013, radio transmitters were installed in pallid sturgeon, shovelnose sturgeon, burbot and northern pike. The radio transmitters were manufactured by Lotek Wireless, LTD and were of varying sizes and configurations (Table 1). The transmitters were tuned to different frequencies based on species and all radios were factory programmed with a unique code for individual identification. Transmittered fish were manually tracked at least monthly from April–October. Radio-tagged fish had continuous coverage from the 10 -11 fixed remote radio receiving stations strategically located throughout the study area (Table 2). Transmitters were surgically implanted into the body cavities through a 1-2 inch incision anterior to the pelvic fins offset left from the ventral mid-line. The antenna was threaded through the body wall, posterior of the transmitter, using a shielded needle technique (Ross and Kleiner 1982). After a short recovery period in the holding tank the fish was released near the area of capture. Incisions were closed with surgical staples (sturgeon) or sutures (burbot, northern pike). Channel catfish radios included a mortality sensor to enhance identification of expelled transmitters. Channel catfish were captured and implanted with radio tags in past year years using setlines and by hook-and-line angling (Tews and Jensen 2013). In 2012, channel catfish radios were attached with an alternative method (Wendell and Kelsh 1999) to increase retention. Radios installed with this method were implanted in the abdomen and secured to the cleithrum. Sex could not be determined for catfish. Burbot and northern pike were captured using hoop nets, set lines and electrofishing. The 1997 HRPS and wild pallid sturgeon were the focus of transmitter installations for pallid sturgeon in 2013. One transmitter was installed in a previously tagged 1997 HRPS, nine in new 1997 HRPS and one in a wild fish. FWP plans to install up to 36 additional transmitters in 1997 HRPS (or adults) in 2014-2015, so they can be monitored for spawning movements as they mature. Pallid sturgeon were captured during standard monitoring methods (Tews 2013) following accepted pallid sturgeon handling protocols (USFWS 2012). Sex was determined, when possible, by direct observation of the gonads through the incision and a small number of eggs (> 10) were removed from most of the female sturgeon to determine stage. Blood was collected from HRPS and wild pallid sturgeon to determine reproductive status and was evaluated by Molly Webb's lab (USFWS). Additional work was conducted on this reach of the Missouri River during standard monitoring surveys. Onset tidbit temperature loggers were installed on the lower Teton (RM 2.3), the lower Marias Rivers (RM 3.0) and at 5 stations on the Missouri River between Morony Dam and Fred Robinson Bridge (Appendix 1).

Table 1**.** Model number and type of transmitters deployed in individuals, 2013. (SNS=shovelnose sturgeon; PS-A=pallid sturgeon (wild and hatchery reared), PS-Jv= juvenile pallid sturgeon (hatchery reared), CCAT=channel catfish, NP=northern pike, BSU=blue sucker).

Model Number	**Typical Life (years)**	**Transmitter size (mm)**	**Transmitter weight in air (gm)**	**Species**
MCFT2-3FM	2.3	11 x 59	11	PS-Jv
MCFT-3L	3.6	16 x 73	26	SNS, BSU
MCFT2-3L	8	16 x 73	25	PS-A, PS-Jv
MCFT2-3LM	3.2	12 x 69	13	Burbot
MCFT2-3BM	1.2	11 x 43	8.0	Burbot
MCFT2-3A	3.7	16 x 46	16	PS-Jv,NP
MCFT2-3A with motion sensor	3.7	11 x 59	10	CCAT
MCFT2-3FM with motion sensor	3.5	11 x 59	11	NP
MCFT2-3L with motion sensor	8	16 x 73	25	NP, CCAT

Marias River Controlled Release from Tiber Dam

A controlled release from Tiber Reservoir, with peak flows of approximately 2,000 cfs at Loma occurred from June 14 – June 24 2013 (Figure 2). Larval fish were collected at two sites on the Marias River (RM 0.4 and RM 1.5) and one on the Teton River (RM 0.1). Round plankton net samplers with a 6-foot long Nitex net (750 micron mesh) attached to a 20-inch diameter ring were used. In the Marias, nets were deployed off both sides of the boat simultaneously with 8 pound canon ball weights. The weight was attached about 18 inches in front of the larval net and lowered to the river bottom. Slack was removed from the rope and the boat held stationary in the current for 15 minutes. In the Teton, nets were deployed off a bridge just upstream from the mouth. In 2013, Teton samples were not collected after late June due to very low flows. Samples were preserved in a 10% formalin solution with phoxline B dye, and stored in whirlpacs. Samples were sorted in the lab and identified to at least the family level. The volume of water filtered was determined using a General Oceanic flow meter (Model 2030) suspended in the net opening. In addition to the radio telemetry work, the lower Marias River was sampled with 75 - 150 ft. long and 4 ft - 6 ft deep trammel nets to assess migratory fish presence in relation to flow, using the methods of Tews (2013).

Results

Physical parameters

In 2013, flows were generally below average at both Fort Benton and Landusky (Fred Robinson Bridge). Peak flows were nearly average at Fort Benton but discharge at Landusky was above flood stage in early June (Figure 2), primarily due to major June rains in central Montana. Flow in the lower Teton River was zero for much of the year (Figure 2). Temperature data was taken at 8 stations (Appendix 1) and daily maximum, minimum and mean temperatures are summarized in Appendix 2. Temperatures were above average from May – September, but were slightly below average in late April and early October (Lewistown area data files).

Radio Telemetry

A total of 151 radio-tagged fish were monitored in 2013. Seven burbot, 7 channel catfish and 19 1997 HRPS, 3 wild pallid sturgeon, 98 shovelnose, 13 northern pike and 11 blue sucker were followed during 2013. Summaries of the individual fish tagged, are included in Appendices 3-8. High flows inundated a station near LeClair Island and collapsed the bank where the station was located on the Judith River. Much of the equipment from those two stations was lost or ruined, so monitoring did not occur at those locations in 2013. The Carter Ferry station was dismantled in 2013 due to extremely few recording events after the sauger telemetry study was completed; during 2011 and 2012 combined there was only 2 non-sauger fish recorded at that station. In addition, it appears that the upper Marias remote station missed most radio-tagged fish; fish manually relocated upstream of the station were not shown in the station's computer records. Station data and deployment dates are in Table 2. Fish were also monitored by manual boat surveys (Table 3). There were 1,987 miles logged for manual surveys in 2013 for 900 relocations. Some of the manual surveys focused only on pallid sturgeon radio frequencies.

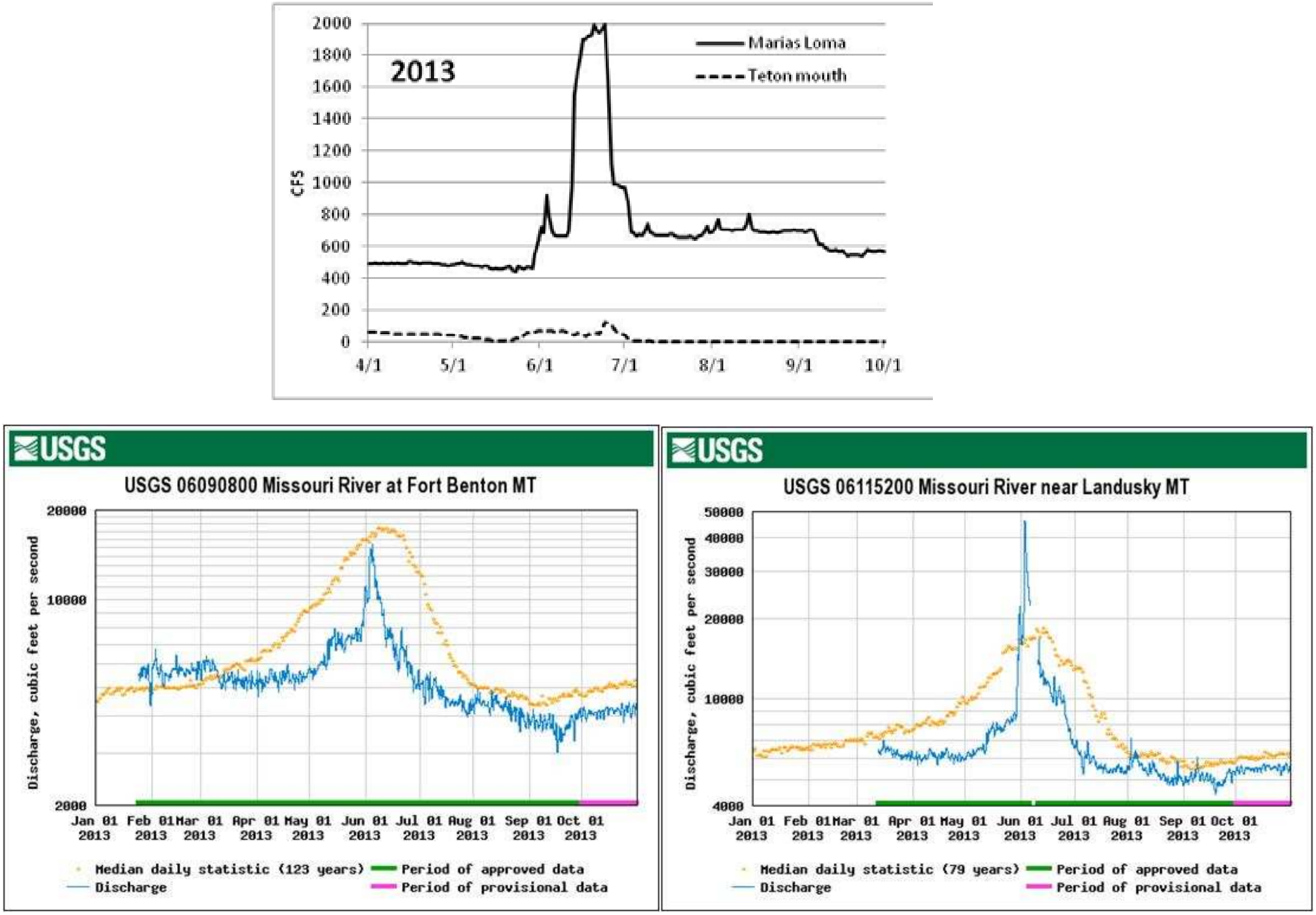

Figure 2. Mean daily flow statistics for 2013. Top graphs show flows from the, Teton River at Loma and the Marias at Loma. The bottom graphs are Fort Benton and Landusky flows compared with median flows (USGS data).

Table 2. Locations of the land-based radio receiving stations and list of radio contacts recorded by the land-based stations for each species, 2013. (pallid sturgeon=wild and HRPS).

	Location	Dates of operation		Number of contacts by species						
Station Name	**River Mile**	**Start Date**	**End Date**	**Pallid sturgeon n=22**	**Shovelnose sturgeon n=99**	**Blue sucker n=11**	**Burbot n=7**	**Channel catfish n=3**	**Northern pike n=13**	**Total Contacts n=155**
Roads End	1901.0	1/1/13	12/31/13	132	0	1	3	6	20	162
King Island	1919.5	1/1/13	12/31/13	76	39	5	2	7	24	153
Power Plant	1937.5	11/30/12	12/31/13	86	48	3	4	3	4	148
Stafford Ferry	1970.0	11/30/12	12/31/13	8	14	10	7	2	6	47
Judith Landing	1984.0	11/29/12	12/31/13	8	256	10	30	3	3	310
Judith River	Jud 3.3	11/29/12	5/28/13	0	0	0	0	0	0	0
Coal Banks Landing	2031.4	11/29/12	12/31/13	1	190	11	0	3	0	205
Marias confluence	MA 0.5	11/29/12	12/31/13	11	36	19	0	0	0	66
Marias RM 3.0	MA 3.0	11/29/12	12/31/13	0	1	0	0	0	0	1
Teton River	TE 2.3	5/23/13	9/23/13	0	0	0	0	0	0	0
Fort Benton	2074.3	11/29/12	11/19/13	0	5	5	0	0	0	10
Carter Ferry	2089.0	11/29/12	5/6/13	0	0	0	0	0	0	0
	Total contacts by species			322	589	64	46	24	57	1102

Table 3. Manual relocations of radio-tagged fish in 2013.

Survey date(s)	**Area surveyed (river miles)**	**Total mileage**	**Number of PS contacts**	**Number of SNS contacts**	**Number of BSU contacts**	**Number of CCAT contacts**	**Number of BUR contacts**	**Number of NP contacts**	**Total Contacts**
3/20	1995-1983.3	11.7	0	9	0	3	1	0	13
3/26	1983.3-1970	13.3	0	6	0	2	0	0	8
3/27	1937.8-1901	36.8	8	14	0	2	0	1	25
4/1	1931.2-1907	24.2	6	6	NA	NA	NA	NA	12
4/10-4/11	2073-1970	103	2	55	3	3	5	0	68
4/18	1907-1880	27	3	0	0	0	0	0	3
4/22	1970-1920.5	49.5	7	18	1	1	1	1	29
4/24[a]	1929.4-1919.5	9.9	5	NA	NA	NA	NA	NA	5
5/7[a]	1938.5-1904.5	34	11	NA	NA	NA	NA	NA	11
5/7	2074.3-2024	50.3	0	26	4	1	0	0	31
5/14-5/16	2031.3-1879.6	151.7	17	48	3	4	3	7	82
5/18[a]	1948.3-1920.5	27.8	7	NA	NA	NA	NA	NA	7
5/20-5/21	2089-2031	58	0	21	1	1	0	0	23
5/28-5/29	1983.4-18798.5	103.9	11	15	1	0	4	7	38
6/5-6/6	2074.3-2034	40.3	0	20	0	1	0	0	21
6/11	MA 0.0-11.5	11.5	0	0	0	0	0	0	0
6/11-6/13	2031-1901	130	7	29	3	2	4	1	46
6/17-6/18	2074.2-2031.5	42.7	0	18	0	1	0	0	19
6/18[a]	1923.8-1901	22.8	3	NA	NA	NA	NA	NA	3
6/19	MA 0.0-14.4	14.4	0	2	0	0	0	0	2
6/24-6/26	2031.3-1899.6	131.7	16	29	3	1	3	1	53
6/26	1941-1920	21	7	6	0	1	0	0	14
6/27[a]	1941.5-1920.5	21	4	NA	NA	NA	NA	NA	4
7/1-7/2	2074.3-2031	43.3	0	22	1	1	0	0	24
7/2	MA 0.0-9.0	9	0	2	0	0	0	0	2
7/2	1983-1937.8	45.2	4	5	0	0	0	0	9
7/9-7/10	2034-1920	114	11	45	7	2	2	0	67
7/17	2074.3-2031	43.3	0	22	1	2	0	0	25
7/23-7/24	2034-1937.5	96.5	8	29	7	1	2	0	47
7/29	1920.5-1899.0	21.5	10	6	0	1	0	2	19
8/20-8/21	2074.3-2024.3	50	1	18	0	0	0	0	19
8/22	2034-1983.2	50.8	3	27	5	1	0	0	36
8/27-8/28	1984-1899.5	84.5	11	21	2	1	3	3	41
9/18	1921-1870	51	5	2	0	0	1	3	11
9/23-9/25	2083-1983.3	99.7	5	27	0	0	0	0	32
10/1	1983.3-1926.7	56.6	11	8	1	0	3	2	25
10/10[a]	1938-1922	16	7	1	NA	NA	NA	NA	8
10/10	1922-1901	21	3	2	0	0	0	1	6
10/21[a]	1959.6-1919.9	39.7	10	NA	NA	NA	NA	NA	10
10/22[a]	1923.2-1919.5	3.7	2	NA	NA	NA	NA	NA	2
10/23[a]	1921-1916.7	4.3	2	NA	NA	NA	NA	NA	2
	Totals	1987 miles	207	559	43	32	32	29	902

Blue sucker

In continuation with previous years work we monitored 11 blue suckers in 2013 (Appendix 6). As detailed in Gardner and Jensen (2011), Tews and Jensen (2013) and outlined for 9 individuals in Figure 3, the movements of radio-tagged blue sucker in 2013 were consistent with years past. In general, overall movement patterns of blue sucker in this study exhibit high yearly spatial and temporal site fidelity to specific spawning and non-spawning sites. Figure 4 focuses on the April – October period in 2012 and 2013 for these same fish. Gardner and Jensen (2011) identified several spawning sites, based on movement patterns, and determined that spawning occurred from April – June when mean water temperatures were from 51.6 – 58.9°F. Water temperatures and previous work (Gardner and Jensen 2011) indicate the Robinson Bridge group of spawners migrates after spawning to upstream areas in late spring (May and early June) and then begin downstream movements to spawning areas near Robinson Bridge in the fall (late September and early October) of the same year (Figure 4). In contrast, long distance Marias migrants, BSU 753, 754 and 783 exhibit the opposite movement pattern (Figures 3 and 4). After these individuals spawn in or near the Marias River confluence they migrate downstream in late spring (May and early June). After spending the summer months downstream they start migrating upstream toward spring spawning areas in the fall (late September to early October). It is appears that migration cues for blue sucker vary by migration (reproductive) strategy. As illustrated in Figure 3, the annual upstream and downstream movements of the Fred Robinson Bridge spawners closely coincide with the rise (or fall) in water temperature. The Marias spawners usually migrate upstream prior water temperature increases and start their downstream migration well before the peak water temperature is reached (Figure 3). Further evaluation of date, water temperature or changes in discharge may help elucidate migration cues. There seems to be no relationship between Marias River flows or Missouri flow and intensity of use by blue sucker during the spawning period (Table 4). Blue sucker use on the Teton occurred when minimum flows were about 300 cfs in May or June. This is similar to the flows observed when shovelnose sturgeon use the Teton River (Tews and Jensen, 2013).

Table 4. Missouri River tributary use by radio-tagged blue sucker, 2006 - 2013

	2006	2007	2008	2009	2010	2011	2012	2013
No. Entered Marias	10	17	14	30	23	11	6	4
# of blue sucker tracked	28	49	55	58	52	32	29	11
% entered Marias R.	36%	35%	25%	52%	44%	34%	29%	36%
Marias mean April cfs	518	511	323	489	434	1,170	601	500
Marias mean May/June cfs	1,120	510	973	530	420	1,232	760	905
Marias peak May/June cfs	4,740	521	4200	639	570	2760	1030	1990
Robinson bridge mean May/June cfs	10,475	10,000	8,000	12,514	18,010	37,511	12,482	11,161
Robinson bridge peak May/June cfs	20,900	16,100	31,900	21,600	33,200	71,300	18,100	36,600
# Entered Teton R.				2	4	2	0	0
# Entered Judith R.			1	1	NA	0	1	NA

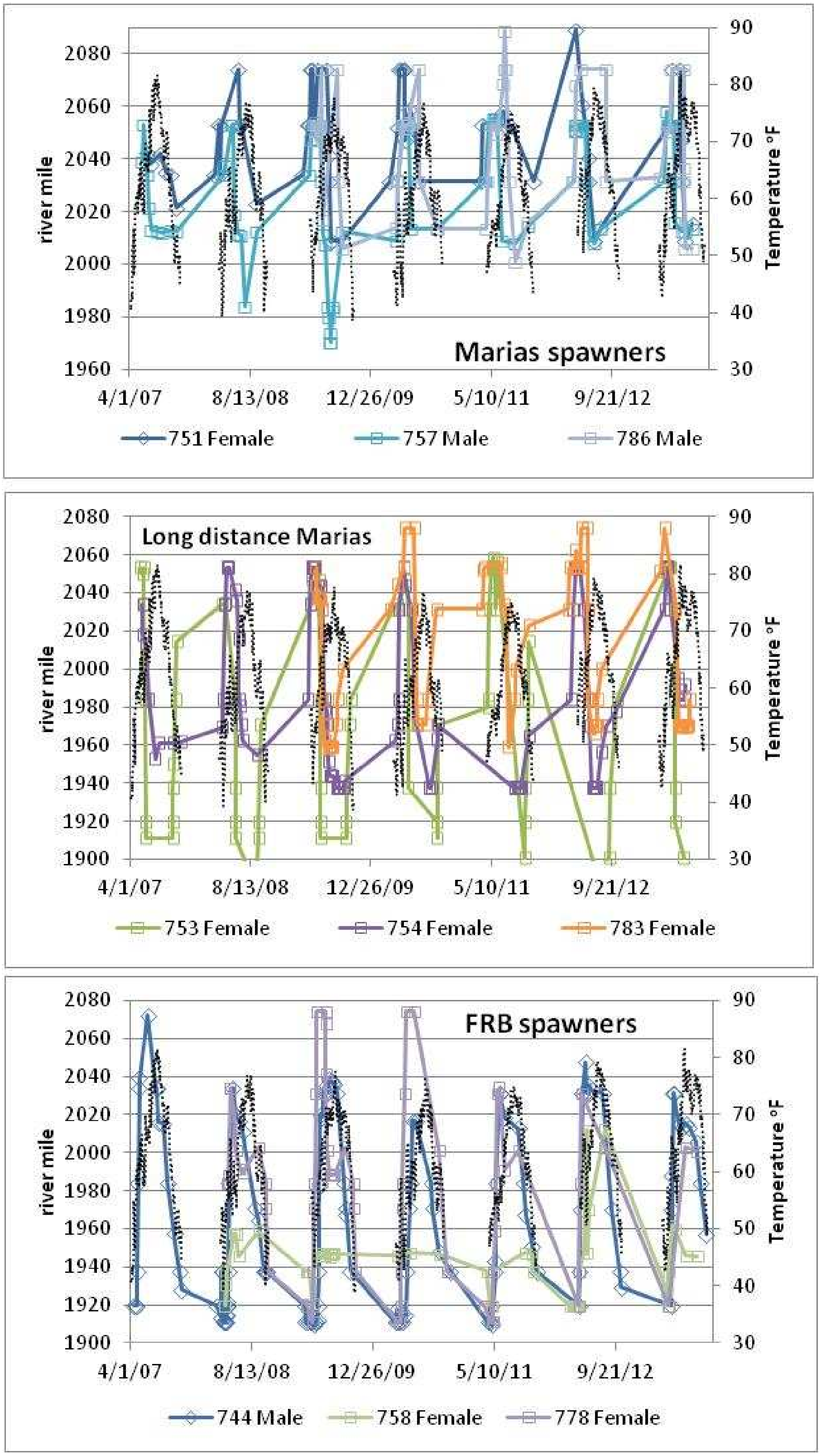

Figure 3. Blue sucker long term movements using three different strategies. Top graph Marias spawners that typically stay upstream of Judith landing. Middle graph Marias spawners with long movements. Fred Robinson Bridge (bottom).

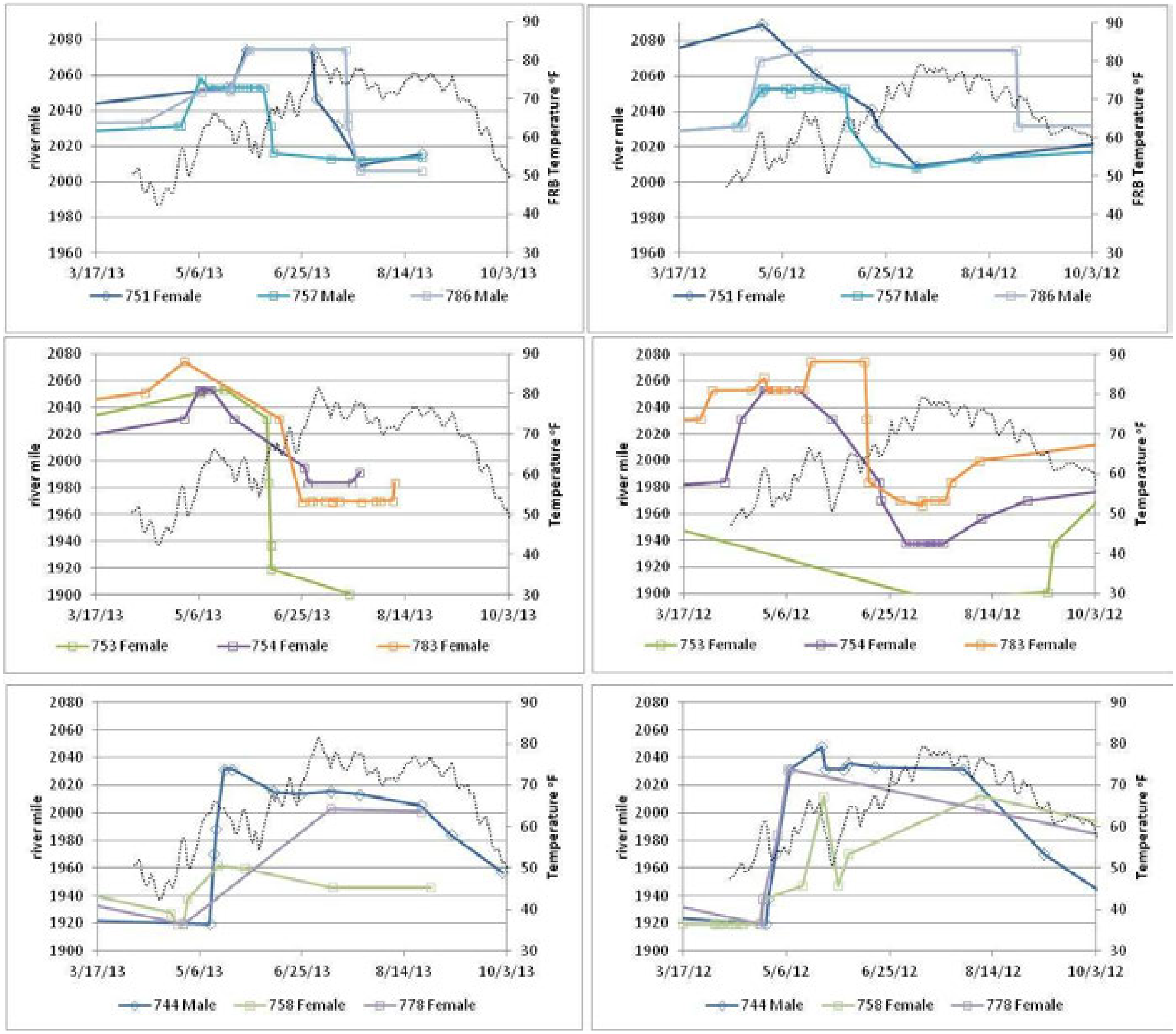

Figure 4. Movements during the spawning period for 2012 and 2013 for three different strategies; Marias river spawners upper river migration (top); Marias area spawners long migrations (middle); Fred Robinson Bridge spawners (lower).

Burbot

Seven burbot were tagged in 2013 near Judith Landing (between RM 1970 and 1984.5) (Appendix 4). This location was chosen based on past sampling and angler reports that suggest burbot are common in this reach. In 2012, the single tagged burbot apparently lost its tag in summer based on lack of movement. All of the 2013 burbot either had active radios or were missing by fall 2013 (Appendix 4). Five of the seven radio-tagged burbot exhibited downstream movements (Figure 5). Two burbot (624 and 632) immediately moved downstream during the spring. Burbot 632 moved 69 river miles downstream from its tagging location at river mile 1970.0 on 26 March 2013 to the lowest remote station (Roads End RM 1901.0) by 8 April 2013. Burbot 624 had only three post-tagging relocations, which were all obtained in late May. The other three burbot exhibited downstream movement much later in the year. Burbot 626 and 630 were tagged the last week of March 2013. They remained near their tagging areas until early July, when they started their synchronous downstream migration, as temperatures started to decline. Burbot 626 and 630 were observed at the Stafford Ferry remote station (river mile 1970.0) on 8 July and 9 July 2013, respectively. These burbot were observed at the Roads End remote station (river mile 1901.0) on 14 July (626) or 24 July 2013 (630). Burbot 631 started its downstream migration at the end of July. On 31 July 2013, this individual was recorded at the Stafford Ferry remote station (river mile 1970.0) and over the next month, burbot 631 moved downstream to its apparent summer area around river mile 1940 where it was relocated in August and October 2013. Two of the seven burbot remained near their tagging areas and had minor upstream or downstream movement during the field season (Figure 5). Burbot 629 resided in a 5.4 river mile reach between the Judith Landing (RM 1984.0) and river mile 1978.6. Burbot 633 had a four mile range in the same vicinity.

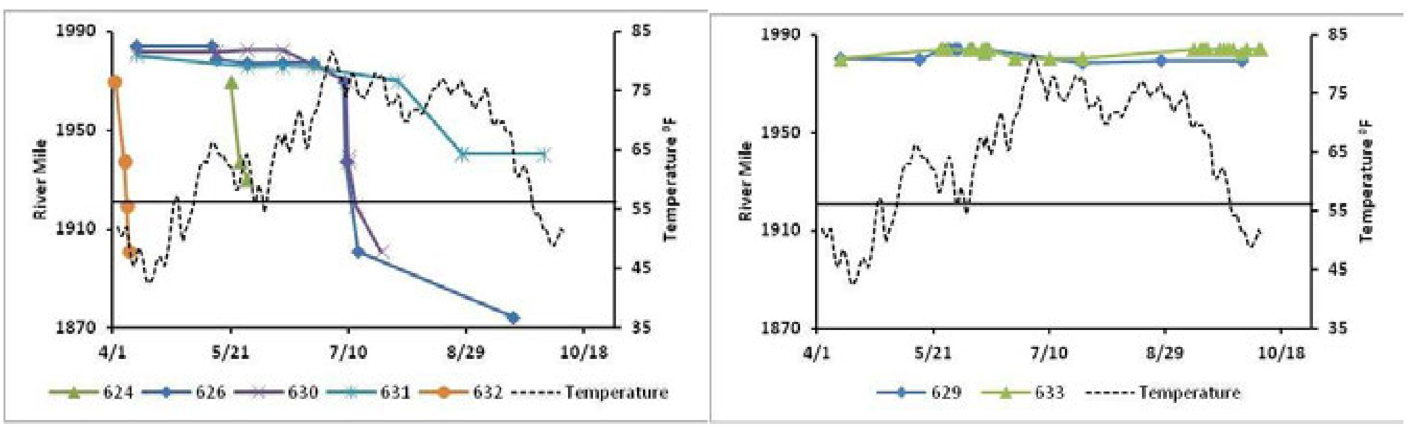

Figure 5. Burbot tagged in 2013 exhibited either downstream movements (left graph) or stayed close to their original capture location.

Channel catfish

We did not radio tag channel catfish in 2013. Our earlier work indicated unacceptable implant recovery or poor retention in channel catfish (Tews and Jensen 2013). By September 2012, 11 channel catfish still had active radios (Tews and Jensen 2013), of these, three retained radios for much of 2013, three fish lost their radios or died by August 2013 and five were not relocated in 2013. Three of the five missing fish were last recorded downstream of the Roads End remote station at river mile 1901.0. The three channel catfish that retained their radios were all tagged with the modified method of radio implantation. An additional fish (732) was tagged with the modified method on 29 May 2012 at river mile 1986.8 but was not relocated until 20 March 2013 at river mile 1989.0. These four fish exhibited very different movement patterns, but 3 of them migrated downstream of Roads End at least once in 2012 or 2013 (Figure 6). Catfish 71 initiated a rapid downstream migration in 2012 (June 6) and 2013 (June 5) within one calendar day but with a 7.5 ^{o} F difference in temperature. In 2012, the downstream movement started at 62.6 °F and in 2013 at 55.1°F (Loma Bridge temperatures). In both 2012 and 2013 CCAT 734 moved in the opposite direction of CCAT 71; this fish exhibited a general pattern of upstream movement into the study area during the spring or summer months and a downstream migration during the fall to an overwintering location outside the study area, below Roads End remote station. Catfish 734 was tagged at river mile 1923.6 on 11 April 2012 but was not relocated that far upstream until 29 July 2013. In 2013, this fish was downstream of Roads End until 25 July 2013. Interestingly, this individual was detected on 28 August 2012 (70.1°F) at river mile 1923.7 and at river mile 1923.6 on 28 August 2013(75.4°F). On 8 September this individual was observed at the Judith Landing remote station (river mile 1984.0) and two days later on 10 September 2013 it was detected leaving the study area by the Roads End remote station (river mile 1901.0). Channel catfish 732 apparently spent all of 2012 in the Judith River but decided to move into Fort Peck in 2013, after spending the summer near Judith Landing, where it was tagged. On 8 September this individual was observed at the Judith Landing remote station (RM 1984.0) and two days later on 10 September 2013 it was detected at Roads End.

Poor radio retention and poor post-surgical healing coupled with widely varying patterns make it difficult to draw many conclusions about channel catfish movements in this reach of the Missouri. It appears this species has many reproductive strategies that utilize most of the study area and many of its tributaries including the Judith (CCAT 732) and the Marias (young of the year channel catfish in 2013, see Marias section of this report); up and downstream spring migration patterns and locations throughout the river (Figure 6 and Tews and Jensen 2013) during the July spawning peak (Berg 1981). Initiation of migration or relocations in near-identical locations on nearly the same day despite different temperatures and flow patterns may indicate that photoperiod plays a role in migrations. It is clear that the headwaters of Fort Peck (downstream of Roads end) are a key habitat component for this species. In 2014, our channel catfish studies will focus on evaluating use of small external transmitters.

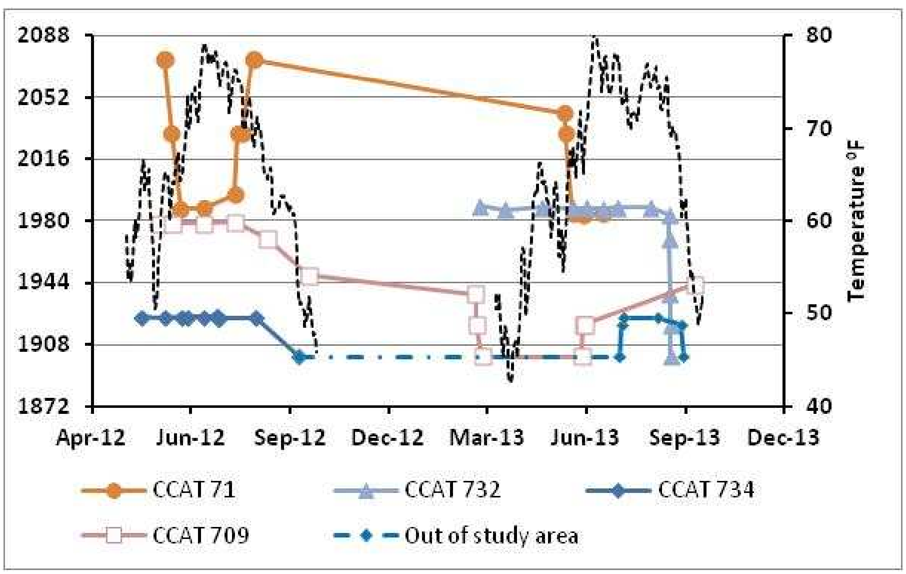

Figure 6. Movement patterns of four radio-tagged channel catfish with Missouri River water temperatures, 2012 and 2013. CCAT 709 was last monitored as a live fish in June 2013.

Northern Pike

Of the 13 northern pike followed in 2013 (Appendix 5), most had few relocations, stayed in the same location or moved a small amount downstream. Two fish moved upstream in mid-June and had ranges exceeding 80 miles.

Pallid Sturgeon

Our main focus in 2013 was monitoring previously tagged fish and implanting transmitters in new 1997 HRSP and wild adults. We placed transmitters in a new wild adult and in 2 recaptured and 9 new 1997 HRPS. In 2013, we used radio telemetry to monitor the movements of three wild adults and 19 hatchery-reared pallid sturgeon (Appendix 7). These 22 individuals accounted for 529 relocation events. Most (85%) of these relocations were obtained in the Fred Robinson Bridge section (RM 1867.0-1943.9). Our focus on the lower river for radio installations likely biases relocations towards the lower river. One 1997 HRPS of unknown stocking location was relocated in the Marias River from 15 August to 18 September 2013. These relocations were not obtained during the spawning or pulse period but are the first direct evidence of Marias River use by pallid sturgeon in this study (Figure 7).

We tracked the reproductive and movement history of a wild, female pallid sturgeon from 2010-2013 (Figure 8). In 2010, she was spawned at the Miles City hatchery. It was presumed that she was reproductively inactive in 2011. We recaptured her in the spring of 2012 and based on hormone analysis (Molly Webb, Bozeman fish technology center) it was determined that she was reproductively active. We closely followed her movements in 2012. She was relocated a number of times near Fred Robinson Bridge (RM 1924.0) during the presumed spawning season in the vicinity of a ripe male 1997 HRPS. Spawning was not conclusively documented for this individual. She was re-transmittered in the fall of 2013 as a black-egg female. We assumed she would be reproductively active in 2014. But histological analysis of her eggs in fall 2013 revealed a very low polarization index (PI= 0.17) for fall. This low index is confusing but indicates she may have spawned in 2012 and the egg maturation is delayed or she may have been atretic in 2012. We had planned to recapture her in spring 2014 to determine spawning status and continue reproductive and movement monitoring. However her carcass was found near RM 1921 in late April 2014.

Figure 9 shows the movement patterns of a reproductively inactive and a reproductively active (male) both 1997 HRPS. During the spawning period, targeted trammel netting was conducted near the reproductively active fish. An adult wild male pallid sturgeon that was last captured in 2001 was recaptured during this effort. The gametes from this male were cryopreserved in 2001 and his progeny have been recaptured below Fort Peck Reservoir. Some circumstantial evidence indicates that reproductively active individuals exhibit higher overall movement distances than reproductively inactive individuals. This suggests that there may be behavioral as well as physiological indicators for reproductive condition. We plan to continue to deploy many more radios in HRPS as they reach sexual maturity. This larger sample size will be useful to investigate both the physiology and behavior of spawning pallid sturgeon in future years. In 2014, we plan to work with an MSU graduate student to monitor existing and newly tagged pallid sturgeon and to continue to recapture individuals to assess spawning condition. Through these efforts we hope to identify spawning areas and potential upstream spawning areas.

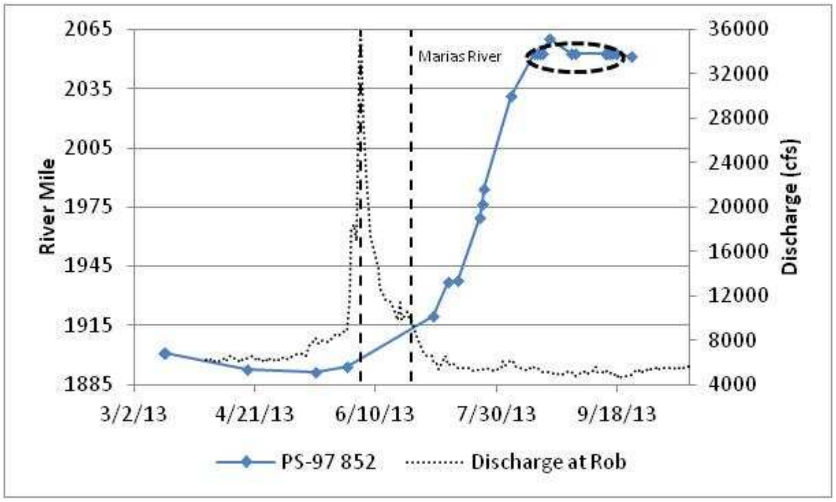

Figure 7. Movement history for a HRPS in the Marias River, 2013. The parallel vertical bars represent the presumed spawning season for pallid sturgeon based on temperature and flow. The circled area denotes the time that the individual spent in the Marias River.

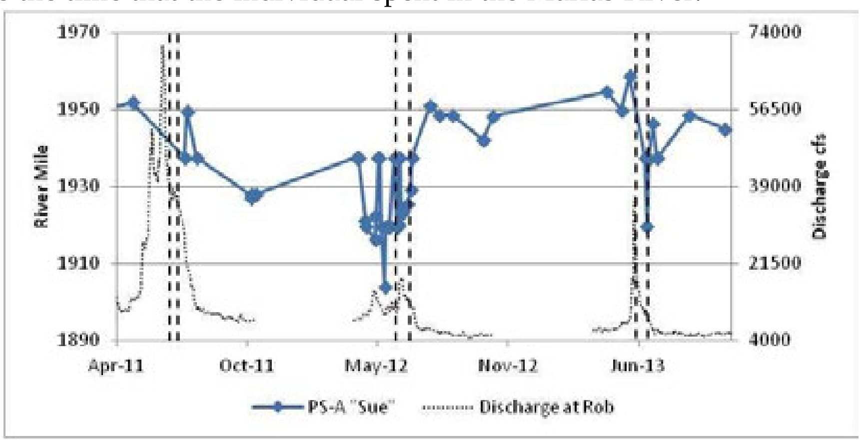

Figure 8. Reproductive movements of a wild, female pallid sturgeon, 2011-2013. The parallel vertical lines represent the yearly, presumed spawning periods.

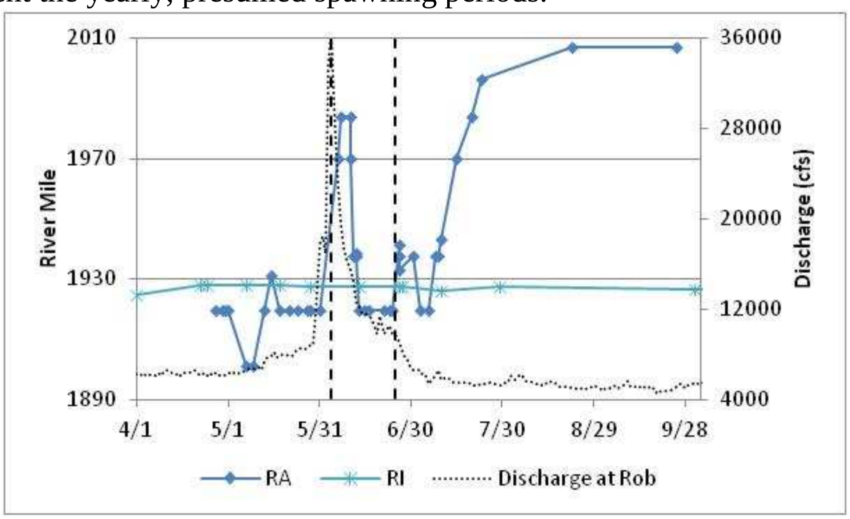

Figure 9. Movement comparison of a reproductively active (RA) and a reproductively inactive (RI) hatchery-reared pallid sturgeon, 2013. The parallel vertical lines represent the presumed spawning period.

Shovelnose Sturgeon

In 2013, 98 radio-tagged shovelnose sturgeon were monitored (Appendix 8). Staffing constraints limited the field effort spent manually tracking these fish. We plan to complete an in-depth analysis of the movement patterns of shovelnose sturgeon in a later report. Most of the shovelnose radios will be expiring soon. We want to look at long term migration patterns of some fish, and therefore installed new radios in 5 shovelnose sturgeon (Appendix 8). Spawning periodicity of several years is well accepted for female shovelnose sturgeon (Wildhaber 2011, Papoulias et al. 2011). We took blood to determine reproductive status on the retagged fish and on one additional female (130). Only one fish, 735, was ripe (male) in 2013. The migrations patterns of these fish are shown in Figure 10. It is apparent that shovelnose sturgeon, in the mainstem, do not migrate in response to high flows (Figure 10) as determined by Richards et al. 2013. However, there are strong indications that they respond to tributary discharge as discussed in the Marias River sturgeon spawning section of this report

Marias River Controlled Spring Release – Sturgeon Spawning

Historical review of sturgeon larval fish work – Goodman et al. (2012) found that shovelnose sturgeon spawned in 2006 and 2008 when the spring hydrograph peaked around 4,000 cfs. Sturgeon reproduction in the Marias has been verified by larval fish sampling in 1978 (Berg 1981), 1996 and 1997 (Gardner 1998). Acipenseridae eggs were also found in 1996 and 1997 in the Teton and Marias Rivers. Sturgeon spawning was not documented in years when peak flows only reached 500, 700 or 1,000 cfs (Goodman et al. 2012, Gardner 2010, Tews and Jensen 2013). In all cases sturgeon spawning was documented in the Marias when the spring rise reached at least 3,000 cfs.

Larval Fish - A total of 123 larval fish samples were taken from May 28 – July 30, 2013. Eleven samples were collected from the Teton River (RM 0.1) and the remainder from two locations on the Marias River (Table 5). Teton River samples were not taken during extremely low flows. Physical parameters measured during larval fish sampling are shown in Table 5. Teton River larval fish samples contained far fewer larvae than the Marias River collections, totaling 94 larvae. These low numbers were due in part to low sample volumes (Table 5). A total of 1,909 larval fish were sampled in the Marias River and 1,753 of these were Catostomidae (Tables 6-8). Larval Catostomidae (sucker) densities peaked in the Marias River in mid June and again in early July (Figure 11). Catostomid densities were quite high during the first Teton sampling event (Figure 11). Other families sampled included 138 Cyprinidae (minnow); 27 Hiodontidae (goldeye), 2 Percidae and 9 Acipenseridae sampled in the Marias/Teton (Tables 6-8). Additionally, 10 Ictaluridae juvenile (catfish) were collected in the Marias; all sampled mid to late July. Both the eggs and larvae of Acipenseridae (sturgeon) were sampled in 2013, indicating sturgeon reproduction (Table 8). The timing of sturgeon larvae in the samples coincided with the increase in Marias River flows at Chester, from 728 cfs on 10 June to 1,910 cfs on 17 June (Table 5 and Figure 2). Flows First reach 1900 cfs at Loma on June 16. It takes at least four days for shovelnose sturgeon embryos to develop into larvae at 68 ˚F (Columbo et al. 2007) so spawning appears to have started immediately when discharge reached 1900 cfs. This indicates that approximately 1,900 cfs may be a threshold level to initiate successful shovelnose sturgeon spawning in the Marias River. During 2013, temperatures considered optimal (60 – 68 ˚F) for shovelnose and pallid sturgeon embryo development (Kappenman et al. 2013) occurred before and during peak flows in the Marias River and remained suitable (53.5 – 75˚F) during most of the descending limb of the hydrograph (Figure 12).

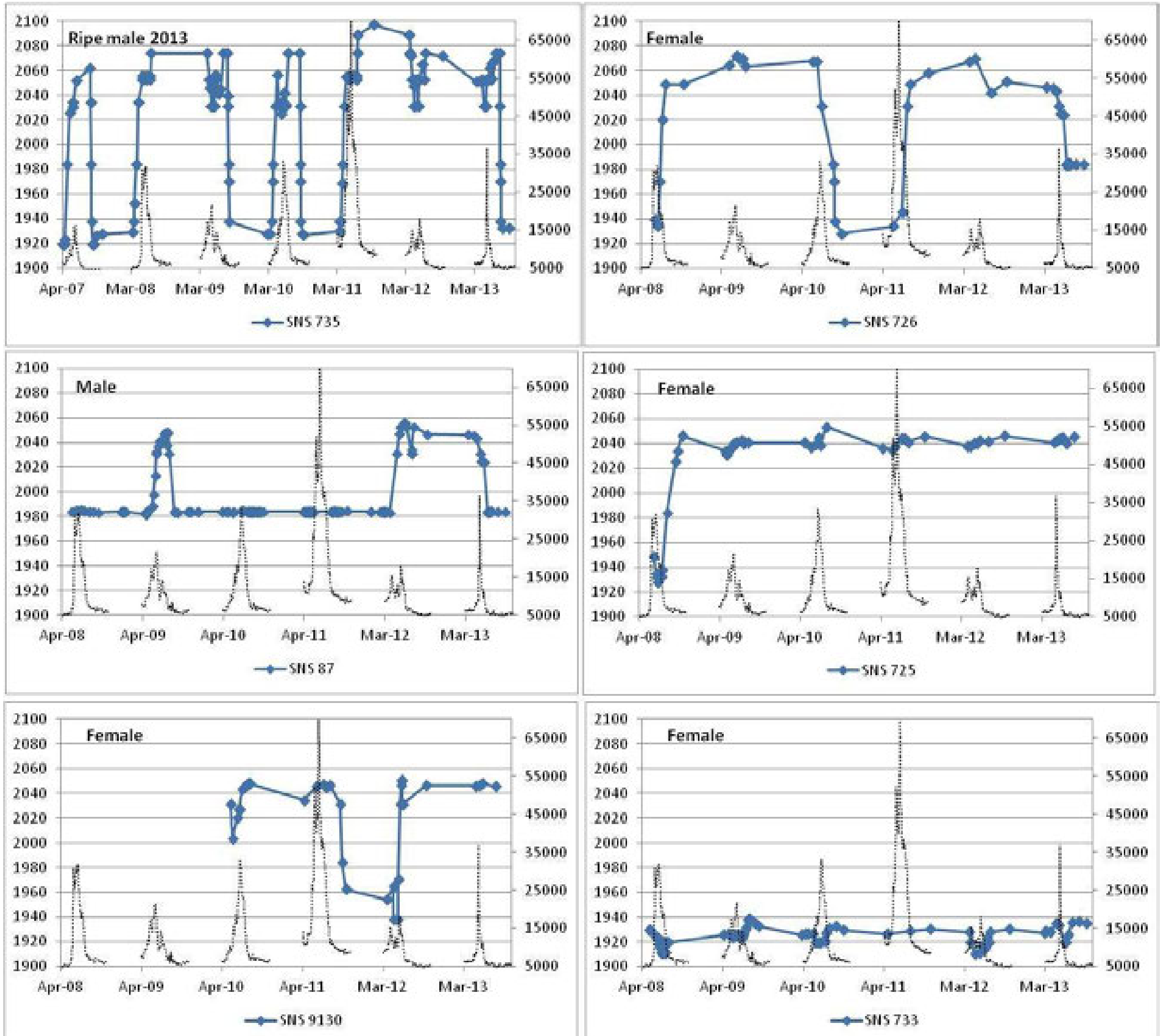

Figure 10. Movement histories of 5 shovelnose sturgeon re-tagged in 2013 plus an additional long term tag (6507). Only one fish was reproductively active in 2013.

Adult shovelnose sturgeon migration - We evaluated adult shovelnose sturgeon use of the lower Marias River in relation to discharge. Netting surveys in the lower Marias have not been standardized so CPUE does not necessarily reflect sturgeon abundance. Therefore, in addition to trammel netting we looked at migration of radio-tagged adult shovelnose sturgeon into the lower Marias in relation to flow. Trammel netting was conducted from June 10 – July 18 2013 in the Marias River. Shovelnose sturgeon catch rates tend to be higher during higher Marias spring flows (Table 9). In 2013, 89 shovelnose sturgeon were captured in the Marias during 17 drifts for a recent record high of 5.2 per drift (Table 9). In recent years there have been over 100 radio-tagged shovelnose sturgeon in the Missouri River above Fort Peck. We compared the number of shovelnose found in the mainstem Missouri above Little Sandy Creek (RM 2025) to the number entering the Marias. Less than 15% of radio tagged adult shovelnose sturgeon that were recorded upstream of Little Sandy Creek in the Missouri entered the Marias during low flow (1,000 cfs or less) years; At least 30% entered the Marias during years where flow exceeded 1,900 cfs (Table 10). This indicates there is a trigger flow between 1,000 and 2,000 cfs for adult shovelnose sturgeon to enter the Marias River. It seems likely this flow is closer to 2,000 cfs based on the flows observed during shovelnose sturgeon spawning. This behavior differs from that seen in this reach of the mainstem Missouri, where shovelnose movements do not appear to be influenced by low or high discharge (Richards et. al 2013).

Table 5. Physical parameters for larval fish sampling in the Marias and Teton Rivers, 2013. (Note that Marias Lower flows (RM 0.4) = Marias Upper + Teton flows)

Station	Location	# of Samples	Average Net Velocity (cm/s)	Total Net Volume (m^3)	Average Discharge (cfs)	Average Sta. Depth (m)	Average Temperature (°C)	Average Secchi (m)
Teton RM 0.1	47.93263 110.51436	11	23.6 (0.2-52.5)	114.8	69 (44-125)	0.9 (0.8-1.1)	--	0.20 (0.05-0.40)
Marias RM 0.4	47.92865 110.50134	56	67.4 (0.6-126.3)	1099.4	1033 (468-2125)	0.9 (0.6-1.2)	19.5 (11.8-25.8)	0.37 (0.05-0.91)
Marias RM 1.5	47.93980 110.51872	56	56.3 (34.5-84.2)	986.0	992 (468-2000)	0.8 (0.5-1.0)	19.7 (12.2-25.8)	0.40 (0.03-0.91)

Table 6. Average number of larvae, average larvae total, sucker and minnow densities sampled at the Marias-Lower Station (RM 0.4), Marias River, 2013.

Date[1]	Total Number	Larval Density (#/m^3)	Catostomidae Density (#/m^3)	Cyprinidae Density (#/m^3)	Other Density (#/m^3)	Other Families (count)	River Flow (cfs)
5/28	1	0.013	0.013	0	0		529
6/4	25	0.644	0.618	0	0.026	1Unk	857
6/10	92	1.190	1.100	0.013	0.077	4Ge, 2Sgr	728
6/17	375	6.118	6.118	0	0	0	1949
6/20	22	0.414	0.301	0	0.113	6Ge	2043
6/24	35	0.472	0.121	0.243	0.108	3Ge, 6Sns	2125
6/27	73	0.824	0.519	0.294	0.011	1Sns	1076
7/1	183	2.002	1.728	0.197	0.077	5Ge, 2Sns	1011
7/3	426	5.517	5.517	0	0		703
7/10	77	0.873	0.850	0.023	0		697
7/16	36	0.414	0.380	0.034	0		672
7/18	32	0.321	0.261	0.060	0		679
7/22	14	0.155	0.133	0.022	0		659
7/30	1	0.010	0.010	0	0		730

1 Sampling was attempted but halted on 6/13 due to debris clogging the nets on repeated sampling attempts

Table 7. Average number of larvae, average larvae total, sucker and minnow densities sampled at the Marias-Upper Station (RM 1.5), Marias River, 2013.

Date[1]	Total Number	Larval Density (#/m^3)	Catostomidae Density (#/m^3)	Cyprinidae Density (#/m^3)	Other Density (#/m^3)	Other Families (count)	River Flow (cfs
5/28	6	0.073	0.073	0	0		468
6/4	23	0.313	0.300	0.013	0		787
6/10	73	0.634	0.608	0	0.026	3Ge	663
6/17	46	0.914	0.914	0	0		1910
6/20	6	0.152	0.076	0	0.076	3Ge	1990
6/24	9	0.170	0.094	0.057	0.019	1Sns	2000
6/27	47	0.656	0.572	0.084	0		989
7/1	74	1.286	1.164	0.122	0		967
7/3	108	1.730	1.586	0.144	0		691
7/10	67	0.970	0.854	0.116	0		690
7/16	35	0.438	0.413	0.025	0		670
7/18	12	0.166	0.152	0.014	0		678
7/22	11	0.131	0.120	0.011	0		659
7/30	0	0	0	0	0		

1 Sampling was attempted but halted on 6/13 due to debris clogging the nets during repeated sampling attempts

Table 8. Temporal distribution and developmental condition of Acipenseridae eggs and larvae for larval fish collections sampled in the lower Marias River at varying flow conditions during 2013.

Date	Total Number	Stage	Condition	Sample #	Marias River mouth flow (CFS) (includes Teton)
6/10	0				728
6/17	1	Egg	Blastopore	61704	1910
6/20	0				2043
6/24	1	Egg	Embryo	62403	2125
	1	Larval	0-1day	62402	2125
	1	Larval	0-1day	62403	2125
	1	Larval	1-2day	62403	2125
	2	Larval	0-1day	62404	2125
	1	Larval	0-1day	62406	2000
6/27	1	Larval	0-1day	62706	1076
7/1	1	Larval	0-1day	70101	1011
	1	Larval	0-1day	70102	1011
7/3	0				691

Table 9. Marias River use by shovelnose sturgeon 2006-2013.

	2006	2007	2008	2009	2010	2011	2012	2013
Number of SNS that entered Marias River from telemetry (≥RM 0.5)	6	2	9	5	2	15*	4	4**
Total number of SNS netted in the Marias R.	31	1	332	20	9	36	135	89
Catch rate (No./drift) of SNS sampled in the Marias River	1.0	T	3.9	0.8	0.3	1.2	4.2	5.2
Chester peak flows June	4,740	521	4,200	639	570	Variable	1,030	1,990
Spring-rise condition of Missouri River	Low	Low	High	Med.	High	Extreme	Med.	Med.

*8 went upstream of Teton River; 10 in Teton 2011 (7 not recorded in Marias upstream of the Teton). ** upper station not working properly, 14 SNS recorded at RM 0.5.

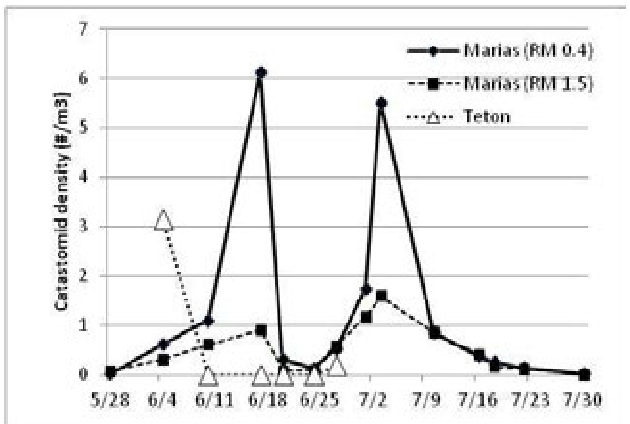

Figure 11. Catostomid density in the Marias and Teton Rivers 2013.

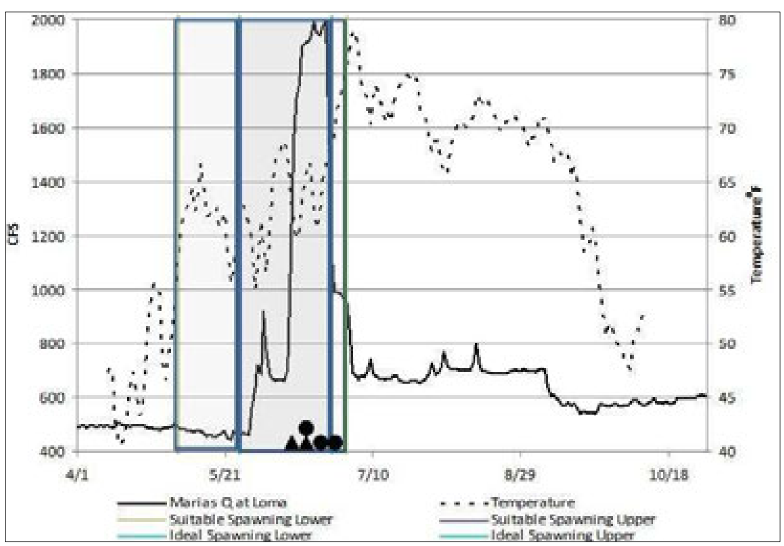

Figure 12. Mean daily flow (CFS) on the Marias at Loma (USGS data) and temperature (˚F) at RM 3.0 in 2013. Temperatures suitable (light box) and optimal (dark area) (Kappeman et al. 2013) for sturgeon embryo development are shown. Presence of Acipenseridae eggs (triangle) and larvae (circle) in samples for a given date is indicated.

Table 10.Percent of radio-tagged shovelnose sturgeon (SNS) that were relocated above Little Sandy Creek on the Missouri River (RM 2025) that entered the Marias River by year, compared with evidence of sturgeon reproduction.

Year	High June Q Chester CFS	Mean June Q Chester CFS	Teton high June Q CFS	Teton mean June Q CFS	Mean June temp F Mouth Marias	# SNS >RM 2025	# Mar RM 0.5	Larval sturgeon sampled	% of SNS above RM 2025 in the Marias
2006	4,740	1583	338	99	66.8	19	8	Yes	42.1
2007	521	504	37	10	69.4	28	4	No	14.3
2008	4,200	1,512	459	256	63.7	53	16	Yes	30.2
2009	639	568	121	88	66.3	66	9	No	13.6
2010	570	517	293	146	65	80	5	Not evaluated	6.3
2012	1,030	972	122	65	65	51	5	No	9.8
2013	1,990	1,500	125	65	64.9	46	14	Yes	30.4

Summary

The study area is a 240-mile reach of the Missouri River in north central Montana, between Great Falls and the headwaters of Fort Peck Reservoir. Major tributaries include the Musselshell, Judith and Marias Rivers. The USBR manages flows within the study area with Canyon Ferry Dam on the Missouri River (RM 2253), Gibson Dam on the Sun River (RM 101), and Tiber Dam on the Marias River (RM 80). PPL also operates five hydropower dams immediately upstream of the study area. The PPL hydro dams are dependent on operations (water releases) of Canyon Ferry and have significant senior instream water rights that many times influences flow releases from Canyon Ferry.

In 2013, sturgeon eggs or larvae were collected at most of the sampling dates during the period June 17- July 1. This coincided with the experimental Marias River high flow release period, indicating that a minimum flow release with a magnitude of 1,900 cfs and duration of 9 days was sufficient to stimulate sturgeon spawning (most likely shovelnose) in the Marias. Flows did surpass 2000 cfs at the mouth of the Marias. In 2012, no evidence of sturgeon reproduction in the Marias River was documented by larval fish sampling. In 2012, Marias River flows during sturgeon spawning season (June/July) peaked at approximately 1,000 cfs and were maintained for 55 days. In summary, it appears that June/July Marias River flows of 1,000 cfs are inadequate for sturgeon reproduction, however, a June/July flow of 1,900 cfs for at least 9 days is adequate for initiating sturgeon reproduction. Sturgeon reproduction appears to have commenced immediately at the 1900 cfs level, but it is unknown if a flow of 1,900 cfs is large enough and what the minimum duration would have to be to provide for adequate larval production to maintain the existing population.

A large number of radio-tagged fish utilized the area downstream of Roads End (RM 1901). During this study Roads End was more than 30 miles upstream of the Fort Peck headwaters but is just upstream of Fort Peck Lake at full pool. Additional work downstream of Roads End may be needed; relatively little is known about fish use or the importance of this headwater area. Most of the radio tagged channel catfish and burbot migrated into that area. New methods for radio-tagging channel catfish should be explored. The methods used to evaluate spawning movements of shovelnose sturgeon in this report are inadequate to effectively evaluate movements of the 100+ radio-tagged shovelnose sturgeon. Additional analysis of the data should be considered. Potential sturgeon habitat and associated flow needs in the Teton River should be explored.

Current research indicates a long term stocking program is required to maintain pallid sturgeon above Fort Peck. On-stream reservoirs such as Fort Peck act as “recruitment sinks” due to long larval pallid sturgeon drift estimates (Braaten et al. 2012). Braaten et al.’s (2012) research suggests a minimum drift distance of well over 100 miles. In 2012, reproductively active pallid sturgeon were located near Robinson Bridge about 35 miles upstream from the Fort Peck headwaters. Even in the most optimistic scenario, it is unlikely pallid sturgeon would successfully recruit from this location and may explain the lack of recruitment over the last 50 years. Historically, pallid sturgeon were relatively common at the mouth of the Marias. The Marias River mouth is about 160 miles upstream from the Fort Peck headwaters. Suitable spawning habitat conditions for pallid sturgeon in the Teton River could add an additional 100 miles of drift distance. Past work indicates sturgeon will migrate up the Teton when flows reach approximately 300 cfs. Sturgeon larvae have been sampled from the Teton during high flow years (Gardner 1998). The Teton has major dewatering problems, but in high flow years can have flows well above 300 cfs for weeks. The historical use of the Marias by pallid sturgeon and the current use of the Teton/Marias by shovelnose sturgeon under adequate flow conditions suggests this area should be evaluated for pallid sturgeon spawning as the HRPS mature. Tiber discharges of at least 2,000 cfs for several days during optimal sturgeon spawning temperatures would be a good starting point for such a study.

Recommendations

- A spring rise in the Marias of 2,000 to 5,000 cfs should be implemented when water supply conditions are adequate
- Continue with experimentation of flow scenarios and adaptive management strategy. As HRPS mature there will be an opportunity to better evaluate pallid sturgeon spawning habitat.
- USBR should operate Canyon Ferry and Tiber Dams in the most practical manner possible that encourages pallid sturgeon recovery in this reach of the Missouri River. Development of an adaptive management plan will be beneficial for achieving this goal.
- USBR needs more latitude to operate Tiber Dam and Canyon Ferry Dam for a spring-rise flow for pallid sturgeon habitat improvements. The USBR was required to provide replacement storage by the ACOE, in Tiber Reservoir in 2011, which consequently reduced flows below those suitable for sturgeon spawning in the lower Marias River. Flows were also reduced in 1997 for replacement storage. These actions provided little flood relief and require evaluation regarding overall flood storage efficacy. The cost/benefit values of replacement storage at Tiber Reservoir for ACOE flood operations needs to be weighed against the value of potential pallid sturgeon habitat improvements in the Marias and Missouri River.
- Update the FWP, Tiber Reservoir/Marias River recommended operating guidelines for Fish, Wildlife and Recreation. The document was last updated in 1998 and may things have changed including; hydropower at Tiber Reservoir; improved tailwater trout fishery and better knowledge of benefits of increased spring discharge.

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Acknowledgements:

Randy Rodencal, Mike Wente, Derrick Miller, Nick Larson of FWP and Steve Leathe (PPL) assisted with field work. Thanks also to Dr. Molly Webb and her lab including Mariah Talbott for evaluating hormone levels in sturgeon blood and evaluating spawning status.

Special funding for this project was provided by the USBR and PPL_MT. Additional funding was provided by FWP and the USFWS.

Appendix 1. Locations, dates deployed and collection interval for temperature logger stations on the Marias Teton, Judith and Missouri Rivers, 2013.

Site	River-river mile	Location	Date deployed	Date retrieved	Collection interval
Circle Bridge	Marias- 57.9	N 48.25923 E 110.87516	5/29/13	10/6/13	30 min
Morony Dam	Missouri ~2105.0	N 47.59823 E 111.05121	4/1/13	10/16/13	15 min
Loma Bridge	Missouri -2053.0	N 47.92141 E 110.49576	4/11/13	10/7/13	15 min
Marias River	Marias –3.0	N 47.94710 E 110.52927	4/11/13	10/9/13	15 min
Teton River	Teton- 2.3	N 47.92288 E 110.53532	4/11/13	10/8/13	15 min
Judith Landing	Missouri- 1984.0	N 47.73933 E 109.62495	4/1/13	10/29/13	15 min
Stafford Ferry	Missouri -1970.0	N 47.74023 E 109.38870	4/23/13	10/29/13	15 min
Robinson Bridge	Missouri- 1921.0	N 47.62961 E 108.68105	4/4/13	10/9/13	15 min

Appendix 2 Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Marias River upstream of Teton River Confluence , Marias River RM 3.0

2013	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1				42.2	46.7	50.8	52.8	57.2	62.0	71.1	75.6	80.2	67.3	68.7	71.0	64.1	68.1	72.1	47.0	49.6	52.6
2				42.6	49.0	55.4	58.5	61.4	64.3	72.4	77.1	82.1	64.5	66.7	68.8	66.1	69.1	72.1	46.3	49.6	52.9
3				48.8	51.0	52.8	56.3	59.1	62.1	74.4	78.7	82.8	63.7	65.6	67.9	65.4	69.1	72.8	46.9	48.1	50.3
4				50.7	53.7	57.2	53.9	56.5	60.1	76.2	79.0	82.5	61.2	65.8	70.8	68.1	70.8	74.1	45.0	47.9	50.9
5				51.2	56.8	62.9	54.6	59.6	64.9	73.8	76.8	79.4	63.8	68.0	72.0	67.1	70.5	73.6	43.9	47.6	51.1
6				54.6	60.3	66.0	59.5	64.0	69.2	70.2	74.0	77.3	65.5	69.1	73.0	67.8	70.9	74.3	46.7	50.3	54.0
7				57.1	62.3	67.6	63.9	67.2	70.4	68.7	73.5	78.5	66.2	69.7	73.6	68.0	69.8	71.5	48.4	51.3	54.2
8				57.3	62.4	67.7	63.5	67.2	71.3	70.7	72.4	75.5	67.0	70.5	74.3	67.2	69.0	71.0	49.1	51.3	53.2
9				58.2	63.5	69.2	63.9	68.2	72.4	65.8	70.3	74.8	67.2	70.5	73.9	64.3	66.8	69.4	44.3	52.8	61.3
10				59.7	64.3	68.9	64.3	68.8	73.8	67.7	72.5	77.6	67.5	70.1	73.1	62.8	67.0	71.1			
11	41.9	47.3	50.5	57.7	62.2	66.4	65.8	67.7	69.7	70.6	73.9	76.8	67.5	69.9	72.0	64.0	67.6	71.5			
12	44.4	47.8	51.8	59.2	64.0	67.9	62.6	64.8	67.2	69.6	73.2	76.9	67.0	70.4	74.6	63.5	67.2	70.8			
13	44.0	47.2	50.4	62.0	66.7	72.0	59.5	61.3	63.6	68.9	72.1	75.6	68.1	71.2	74.4	63.9	67.4	70.9			
14	40.4	42.1	46.1	59.8	63.6	68.0	58.2	59.6	61.2	66.8	70.6	74.3	69.8	73.0	77.0	65.1	67.7	70.5			
15	38.2	41.0	44.3	56.8	61.8	65.8	57.9	60.8	64.2	67.1	71.4	75.9	68.6	72.4	75.8	61.8	65.3	68.8			
16	38.0	40.6	43.3	58.4	62.0	65.1	60.9	63.6	66.8	66.3	70.5	74.9	68.2	72.2	76.5	62.7	66.3	70.4			
17	37.2	41.2	46.7	58.2	62.8	67.1	62.3	65.0	67.8	67.8	72.0	76.7	68.8	72.1	74.8	62.5	64.8	67.0			
18	38.7	43.8	48.6	60.4	62.5	65.1	64.6	66.8	69.1	69.7	73.4	77.5	69.2	72.5	76.0	58.3	61.8	64.3			
19	43.2	45.8	48.0	59.4	60.7	63.0	65.2	66.7	68.4	69.3	73.8	78.3	67.6	71.4	74.9	55.0	58.5	62.4			
20	44.6	47.5	50.5	58.3	61.5	65.7	61.4	62.7	65.1	70.1	74.6	79.2	67.5	71.2	74.9	54.3	58.6	62.7			
21	43.9	45.6	47.6	57.5	62.1	67.2	58.0	60.5	63.1	70.5	74.9	79.3	66.2	70.1	73.9	55.0	59.0	62.6			
22	39.6	43.4	46.7	55.7	58.7	61.5	60.0	62.1	64.5	70.9	74.7	78.2	65.6	69.6	73.4	57.6	60.7	64.3			
23	39.1	43.6	47.5	55.0	55.5	57.8	61.7	64.7	68.2	69.7	74.3	79.1	68.1	70.6	73.0	56.9	59.4	61.6			
24	43.1	47.7	53.0	52.8	56.9	61.8	64.8	66.6	68.6	70.5	74.6	79.0	66.9	70.5	74.2	54.6	56.4	58.3			
25	46.7	51.2	56.0	55.7	59.7	64.1	65.5	67.7	70.4	70.4	74.2	78.6	67.2	70.7	74.3	53.1	54.7	56.1			
26	49.2	54.7	60.5	57.0	62.1	67.4	66.2	68.4	71.2	66.5	71.3	76.0	67.8	71.3	74.9	50.4	51.8	53.1			
27	53.0	55.4	57.4	61.3	62.9	64.7	64.9	69.1	73.6	66.1	70.8	75.7	67.5	71.1	74.4	47.4	50.7	54.0			
28	51.1	55.6	60.9	59.3	62.0	64.4	66.8	71.5	76.5	67.6	70.8	74.1	67.0	70.0	72.5	49.0	52.0	54.4			
29	51.0	54.2	56.6	58.7	61.0	63.4	68.8	73.0	77.1	66.3	68.6	71.6	65.8	69.7	73.7	49.9	51.6	53.2			
30	46.9	48.4	50.8	57.4	59.8	62.0	70.1	74.0	78.7	65.2	67.7	70.8	66.5	69.9	73.3	48.7	50.2	52.6			
31				54.0	55.0	57.3				64.4	68.9	73.9	64.8	68.6	72.2						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013..

Circle Bridge , Marias River RM 57.9

2013	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1							50.2	54.2	59.1	59.6	64.4	68.3	55.9	58.3	62.3	56.2	59.2	61.8	49.3	51.8	54.6
2							54.3	55.9	58.5	60.7	64.2	67.7	55.2	56.6	58.2	58.3	60.4	61.8	51.0	53.3	55.7
3							49.9	51.3	54.2	60.4	63.9	66.9	54.0	57.1	60.1	58.1	60.4	62.4	50.4	51.4	53.7
4							48.3	52.0	57.5	61.5	64.1	66.1	55.7	58.7	62.9	58.2	60.5	62.2	49.3	51.6	54.6
5							51.8	55.5	59.1	59.9	62.7	64.8	58.3	60.6	62.1	57.9	60.3	62.4	50.4	52.2	53.9
6							54.8	58.0	61.2	58.0	61.1	63.8	57.2	60.4	63.2	60.5	62.3	64.2	52.8	53.2	53.6
7							55.7	58.0	60.2	57.9	60.8	64.2	58.1	61.0	63.2	61.1	62.0	63.0			
8							54.5	57.6	61.2	56.8	59.5	63.0	59.2	61.4	63.5	60.0	60.9	62.0			
9							57.2	59.4	61.6	55.7	59.4	64.3	57.8	60.7	63.1	56.6	59.2	61.4			
10							55.8	58.7	61.6	58.8	61.8	64.5	57.8	60.3	62.2	58.5	60.4	62.7			
11							53.2	55.8	59.9	59.5	61.4	63.6	58.5	60.1	61.7	58.4	60.3	62.3			
12							52.3	55.3	58.0	57.2	60.5	63.4	57.7	60.5	63.3	58.0	60.0	62.0			
13							54.4	56.3	58.3	57.4	60.0	62.4	57.9	61.6	64.1	58.3	60.0	61.5			
14							54.2	56.9	59.8	56.3	59.7	63.5	59.5	61.6	63.0	58.8	60.3	62.2			
15							53.6	57.9	62.2	58.8	61.6	64.8	57.5	60.4	63.0	56.2	58.7	60.9			
16							55.0	59.0	63.3	57.9	60.8	63.5	58.1	61.0	62.9	58.9	60.7	62.9			
17							55.7	59.7	63.0	58.4	61.7	64.6	58.7	61.0	62.7	57.0	58.6	61.0			
18							55.7	59.8	63.6	60.0	62.9	65.2	58.5	61.3	63.9	53.1	55.7	56.9			
19							55.7	59.5	62.9	59.1	62.2	64.7	57.9	61.0	63.4	51.8	54.5	57.9			
20							55.4	57.2	59.4	59.5	62.5	65.3	58.6	61.3	63.4	54.0	56.3	58.3			
21							53.9	57.8	62.3	58.9	62.4	65.3	57.1	60.1	62.0	55.0	56.4	57.6			
22							55.9	59.7	63.7	59.7	61.8	64.1	56.9	59.8	62.1	56.0	57.1	58.8			
23							57.0	61.0	65.5	56.6	60.7	65.1	59.1	60.8	61.8	54.4	56.0	57.5			
24							57.9	61.5	65.0	59.7	62.8	65.5	57.6	60.4	63.3	52.5	53.4	55.1			
25							57.4	61.4	64.5	59.5	62.5	65.0	58.2	60.6	62.1	51.7	52.9	53.5			
26				57.3	58.8	60.1	57.0	60.4	63.6	58.2	61.8	65.1	58.6	60.9	63.0	50.8	52.1	53.7			
27				55.7	56.5	57.8	56.6	60.9	65.1	59.2	62.0	64.5	57.4	60.3	62.3	49.5	52.0	54.6			
28				52.2	54.2	55.7	58.1	62.4	65.9	59.1	61.1	62.8	57.6	59.7	61.2	51.5	52.9	53.8			
29				53.1	54.2	55.9	58.3	62.4	65.4	57.2	59.2	61.2	56.3	59.5	62.5	50.5	52.0	53.1			
30				51.1	53.0	54.5	58.7	63.2	66.9	56.1	58.9	61.5	58.3	60.8	62.5	49.6	51.3	53.7			
31				49.4	50.4	51.4				57.2	60.3	63.4	57.0	59.7	61.8						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Loma Bridge, Missouri River RM 2053.0

2013

	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1				47.1	49.2	51.0	54.9	56.6	58.7	73.9	76.5	79.3	68.6	70.8	72.0	67.8	70.6	73.8	49.9	51.1	52.5
2				48.3	50.9	53.3	57.3	58.0	58.6	74.6	77.7	81.1	67.0	68.2	69.6	69.3	71.4	74.1	49.8	51.3	53.2
3				50.0	51.3	52.2	54.6	56.1	57.6	76.7	79.1	82.2	67.3	68.7	70.5	68.5	70.7	73.0	48.9	50.1	51.2
4				49.5	51.2	53.1	53.0	54.1	55.4	77.3	79.5	82.4	66.8	69.5	72.5	70.0	71.7	74.3	47.2	49.2	51.1
5				51.6	53.9	56.4	53.0	55.1	57.5	76.0	77.6	79.7	68.6	70.5	72.7	70.2	72.2	74.6	48.3	49.9	51.5
6				53.3	55.9	58.6	55.2	57.4	60.1	73.3	75.2	77.7	68.0	70.3	72.9	70.2	72.2	75.2	49.1	51.1	53.3
7				55.9	58.0	60.5	58.4	60.0	61.8	72.7	75.7	79.2	68.5	70.9	73.7	70.2	71.4	73.3	50.4	51.8	53.5
8				56.8	59.0	61.2	60.5	62.5	64.8	72.6	75.1	77.0	69.3	71.4	74.1	69.4	70.5	71.6			
9				58.4	60.6	62.7	62.7	64.5	66.3	69.9	73.5	77.2	69.0	71.1	73.9	67.7	68.7	69.9			
10				60.1	61.8	63.9	63.8	65.7	67.5	72.6	75.5	79.0	68.7	71.0	73.9	67.0	69.1	71.5			
11	45.9	47.5	49.8	58.1	60.3	61.8	64.3	65.3	66.8	73.2	75.3	77.6	70.1	71.6	73.1	67.0	69.2	71.6			
12	45.3	46.9	48.1	60.2	62.1	63.8	63.7	65.0	66.1	71.7	74.1	77.1	69.7	71.9	74.8	65.6	67.9	70.1			
13	45.9	47.4	49.0	61.6	63.3	65.1	63.0	64.0	65.1	71.1	73.2	75.8	70.5	72.7	75.4	66.1	68.0	70.1			
14	42.8	44.6	46.3	61.2	62.3	63.7	61.5	62.6	63.7	70.0	72.0	74.6	71.1	73.1	75.9	66.8	68.0	69.6			
15	41.8	43.4	45.2	59.1	60.6	61.6	60.3	62.3	64.4	69.0	72.4	76.7	70.8	73.1	75.7	64.8	66.6	68.7			
16	42.1	43.2	44.3	59.9	60.8	61.7	62.1	63.7	65.1	69.3	72.4	76.1	70.6	73.3	76.5	65.3	67.7	70.8			
17	40.6	42.4	44.4	59.7	61.2	62.6	62.7	64.9	67.1	69.4	72.5	76.1	71.7	73.8	75.9	65.8	67.3	68.4			
18	41.9	43.9	46.1	59.6	60.5	61.7	65.4	67.7	70.2	72.1	74.4	77.6	71.7	73.7	76.1	61.2	63.8	65.7			
19	43.6	44.4	45.1	57.8	59.1	59.8	66.8	68.4	70.2	71.0	74.2	77.7	71.5	73.2	74.9	59.7	61.7	64.0			
20	44.5	45.7	47.3	57.0	58.5	60.5	63.6	64.7	66.8	71.8	75.1	78.6	70.8	72.7	74.8	60.0	62.4	65.3			
21	43.9	44.5	45.2	57.2	59.0	60.8	61.8	63.8	66.1	72.8	75.7	79.0	70.0	72.1	74.2	59.7	62.1	64.5			
22	43.0	45.2	47.9	56.0	56.8	58.5	63.7	65.2	66.6	72.4	74.8	77.8	69.4	71.6	73.8	60.3	62.2	64.7			
23	45.5	46.9	48.8	55.5	55.8	56.4	63.4	65.3	67.2	71.7	74.7	78.2	70.7	72.1	73.5	58.9	60.6	62.0			
24	45.7	48.2	50.9	54.4	56.5	58.9	65.6	66.3	67.4	73.0	75.5	79.1	70.2	71.8	73.7	57.3	58.2	58.8			
25	49.1	50.8	53.1	57.0	58.4	59.9	65.9	67.7	69.8	73.2	75.4	78.3	70.4	72.1	74.0	55.9	57.3	57.8			
26	49.6	52.0	54.7	57.2	59.2	60.9	67.2	68.3	69.6	69.6	72.6	75.6	70.3	72.4	74.9	53.7	54.9	55.8			
27	52.4	53.5	54.8	58.8	59.5	60.4	66.0	68.6	71.3	69.8	73.1	76.9	70.0	72.3	74.9	52.1	53.9	55.7			
28	51.2	53.8	56.8	58.5	59.5	60.3	69.0	71.9	75.1	72.0	73.9	76.6	69.9	71.6	73.6	52.9	54.2	55.5			
29	50.5	53.6	55.2	58.2	59.1	59.7	70.5	73.0	76.1	70.1	71.3	73.0	68.8	71.4	74.6	51.6	52.9	53.9			
30	48.8	49.7	50.5	57.3	58.7	59.9	71.9	74.5	77.6	68.7	70.9	73.6	70.0	72.5	75.6	50.8	51.6	52.9			
31				55.6	56.2	57.2				68.6	71.7	75.2	69.2	71.5	74.0						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Morony Dam , Missouri River RM 2105.0
2013

	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1	46.3	47.3	48.4	48.5	49.4	50.8	55.8	56.6	57.5	71.7	73.1	74.5	68.7	69.0	69.3	68.3	69.3	70.8	50.0	50.6	51.6
2	45.7	47.1	48.6	47.5	48.9	50.4	56.8	57.4	58.5	73.3	74.6	76.2	67.6	68.4	69.5	68.4	69.2	70.5	49.6	50.4	51.6
3	46.9	47.9	49.2	48.2	48.8	49.3	55.6	56.4	57.2	74.9	76.0	77.4	66.5	67.2	68.6	68.3	69.2	70.4	49.6	49.9	50.0
4	47.5	48.6	49.8	48.8	49.6	50.8	54.8	55.3	56.0	75.6	76.5	78.2	66.2	67.4	68.9	68.6	69.4	70.7	48.7	49.6	50.7
5	48.5	49.3	50.7	49.3	51.2	52.9	54.5	55.1	55.7	73.8	76.3	77.6	66.7	67.9	69.5	68.8	69.9	71.3	48.6	49.3	50.7
6	48.7	49.4	50.6	51.5	53.4	55.3	55.3	57.0	58.2	73.5	75.0	76.3	67.1	68.3	69.6	69.2	70.2	71.7	49.5	50.4	51.8
7	46.7	48.1	48.9	54.0	55.7	57.2	57.9	60.0	61.6	73.0	73.8	74.9	67.8	69.0	70.5	69.5	70.3	71.5	50.1	50.8	51.9
8	44.6	45.7	46.7	56.1	57.6	59.0	61.2	62.5	63.8	71.4	73.0	74.1	68.7	69.9	71.1	68.8	69.8	71.6	50.8	51.5	52.7
9	43.1	44.1	45.2	57.2	58.8	60.5	63.1	64.1	65.1	71.1	71.9	73.1	69.0	70.0	71.4	67.2	68.3	69.3	50.9	51.4	52.5
10	42.5	43.9	45.4	58.5	59.5	60.9	63.8	64.6	65.7	70.7	71.9	73.1	69.3	70.1	71.2	65.8	67.1	68.7	50.6	51.4	52.6
11	43.9	44.9	46.6	58.6	59.5	60.7	63.9	64.6	65.7	71.4	72.4	73.3	69.6	70.3	71.4	65.6	66.7	67.8	50.7	51.3	51.9
12	44.9	46.1	47.5	58.5	59.5	60.4	63.3	64.1	65.6	70.8	71.8	73.2	69.4	70.3	71.4	65.3	66.5	67.8	50.0	50.6	51.5
13	46.3	47.2	48.5	59.6	60.5	61.6	63.0	63.5	64.0	69.7	70.9	71.9	69.1	70.2	71.3	65.3	66.5	67.7	49.7	50.1	50.8
14	45.3	46.4	47.2	59.0	59.6	60.5	60.9	62.0	62.9	69.5	70.4	71.8	69.3	70.4	71.6	66.1	67.1	68.4	49.6	49.9	50.8
15	43.2	44.2	45.2	58.0	59.1	60.4	59.6	60.6	61.6	69.6	70.6	72.2	69.6	70.8	72.2	66.0	67.1	68.4	49.1	49.8	51.0
16	42.3	42.7	43.4	58.6	59.5	60.6	59.4	61.0	62.7	69.6	70.3	71.6	70.2	71.4	72.7	65.8	67.0	68.4	48.4	48.9	49.2
17	41.1	41.9	43.1	58.6	59.2	60.4	61.4	63.2	65.1	70.0	71.0	72.4	71.0	71.8	73.0	65.6	66.1	66.7			
18	40.3	41.7	43.4	57.8	58.5	59.6	64.2	65.8	67.5	70.5	71.6	73.1	71.0	72.0	73.3	63.3	64.6	65.9			
19	42.0	43.0	43.9	56.8	57.3	57.8	66.1	67.0	68.3	71.1	72.2	73.8	70.5	71.5	72.8	61.2	62.5	63.6			
20	43.7	44.8	46.3	55.6	56.7	58.1	64.2	65.4	66.3	71.6	72.6	73.9	70.1	71.0	72.4	59.6	60.8	62.1			
21	45.3	46.2	46.8	55.0	56.3	57.9	61.9	63.1	64.3	72.0	72.9	74.2	69.0	69.9	71.0	59.6	60.7	62.0			
22	45.3	46.3	47.7	55.9	56.9	58.2	60.6	61.5	62.5	72.4	73.4	74.7	68.7	69.6	70.8	59.8	60.6	61.6			
23	45.1	46.3	47.8	55.2	55.9	57.0	61.1	62.5	63.8	72.4	73.3	74.7	69.2	69.7	70.9	59.3	59.9	60.9			
24	46.3	47.3	48.7	54.8	56.0	57.2	62.8	64.4	66.3	72.3	73.3	74.6	68.7	69.6	70.9	58.0	58.6	59.4			
25	46.3	47.7	48.9	55.8	56.7	57.9	65.4	66.6	67.8	72.3	73.2	74.2	68.7	69.5	70.7	56.2	57.1	58.0			
26	48.3	50.1	52.0	55.8	57.0	58.2	65.8	66.5	67.9	71.9	73.2	74.6	68.3	69.5	70.7	54.2	55.4	56.2			
27	50.9	52.1	53.4	57.5	58.4	59.3	65.4	66.8	68.6	72.0	73.1	74.3	68.7	69.6	70.7	52.6	53.6	54.7			
28	52.2	53.1	54.3	57.9	58.4	59.0	66.3	68.0	69.6	71.7	72.5	73.8	69.1	69.9	71.7	52.2	52.6	53.1			
29	52.0	52.8	54.3	58.1	58.6	59.5	68.4	69.9	71.5	70.6	71.4	72.2	69.3	70.3	71.7	51.3	51.9	52.3			
30	49.7	51.0	52.0	57.5	58.1	58.5	69.9	71.4	73.0	69.3	70.2	70.8	69.6	70.5	72.0	50.4	51.1	52.2			
31				56.0	56.7	57.5				68.4	69.5	70.7	69.1	69.9	71.3						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Teton River, Teton River RM 2.3

2013		April			May			June			July			Aug			Sept			Oct	
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1				38.4	46.1	52.6	52.3	60.6	70.6	73.0	81.0	89.8									
2				40.9	51.0	61.6	60.1	64.3	69.1	71.8	81.5	91.9									
3				48.4	52.0	54.8	55.4	58.1	62.1	74.2	81.8	90.1							45.1	47.1	50.1
4				49.5	55.0	61.0	52.6	58.2	65.9	73.9	81.0	90.8							40.6	46.4	53.7
5				48.7	58.9	70.0	54.0	63.5	73.9	71.8	77.7	85.3							39.8	46.3	53.4
6				52.9	62.9	73.9	61.0	68.4	77.3	66.2	74.6	85.0							44.5	50.6	57.9
7				55.4	63.9	73.6	63.6	69.9	77.3	67.3	77.3	89.1							45.4	50.5	55.9
8				53.1	63.0	73.9	62.1	68.7	75.1	70.3	74.6	80.4							42.8	53.1	63.0
9				55.9	65.6	76.7	63.3	70.8	78.9	63.8	74.2	86.0									
10				57.0	64.9	73.6	63.3	71.3	80.8	67.3	78.0	89.8									
11	41.7	49.8	57.0	54.5	63.0	73.0	64.7	68.9	72.1	70.3	77.4	83.7									
12	44.0	49.0	54.5	57.9	66.2	73.9	64.4	69.3	77.3	66.8	75.7	86.3									
13	44.0	48.6	53.4	61.0	68.7	78.2	63.8	66.1	68.5	67.6	74.3	83.0									
14	37.8	41.3	46.2	55.4	63.2	72.1	60.1	64.2	69.1	65.0	73.3	84.3									
15	34.7	39.8	45.9	53.1	62.7	72.7	56.5	65.4	75.7	66.5	74.9	86.3									
16	36.7	40.8	45.9	57.0	63.9	70.9	60.4	69.4	78.2	62.7	72.2	83.0									
17	34.7	41.0	49.5	57.3	65.5	74.5	62.1	71.5	81.4	68.2	73.9	83.0									
18	35.8	44.5	53.4	59.9	63.4	68.2	65.9	73.9	83.0	70.6	75.7	82.0									
19	42.6	46.7	49.5	57.9	60.1	62.7	66.5	72.3	80.8	67.3	72.8	80.8									
20	45.4	49.3	54.8	57.0	62.8	70.9	61.6	65.2	69.1	67.9	72.3	76.7									
21	40.9	43.8	46.7	55.4	64.1	75.1	57.6	64.6	73.3	67.3	73.0	77.6									
22	37.0	44.1	52.0	53.7	59.7	65.9	60.1	68.0	76.4	69.1	74.4	79.5									
23	38.6	45.8	51.7	53.7	54.8	57.9	62.4	69.9	76.7	Discharge (USGS)=0.0 cfs on July 23											
24	43.1	50.1	58.1	51.2	58.4	67.3	67.3	71.6	76.4												
25	47.0	53.7	61.6	54.5	61.8	70.6	68.2	72.3	77.6												
26	47.6	56.4	65.9	55.6	64.1	73.3	66.2	70.7	75.7												
27	52.3	56.0	59.6	60.7	64.0	67.9	65.0	72.1	79.5												
28	49.2	56.1	65.3	56.5	61.8	66.2	67.6	75.5	84.0												
29	47.9	53.2	58.7	57.9	61.5	65.9	68.8	76.8	85.3												
30	43.4	46.1	49.5	56.5	59.4	62.4	71.2	78.9	88.0												
31				53.7	54.6	56.5															

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Judith Landing, Missouri River RM 1984.0

2013

	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1	46.0	48.5	51.1	46.1	48.7	51.0	54.9	56.5	58.6	74.7	78.2	81.8	71.2	72.2	73.8	68.6	71.5	73.8	49.3	50.9	52.2
2	46.5	49.1	51.5	46.8	50.3	54.0	58.4	59.0	59.9	76.9	79.8	82.5	68.9	69.8	71.2	69.0	71.4	73.6	49.0	50.9	52.7
3	48.3	50.4	53.0	50.4	52.1	53.4	56.5	58.0	59.6	78.1	80.8	83.4	67.8	68.5	69.4	69.4	71.8	74.1	49.4	50.2	51.5
4	47.8	49.7	51.0	52.0	53.9	56.2	55.6	56.0	56.5	78.3	79.9	81.5	66.8	69.4	72.2	71.1	72.8	74.9	47.5	49.1	50.4
5	48.4	50.3	52.3	51.4	54.7	57.9	55.1	56.2	57.8	77.2	79.0	80.6	68.8	71.3	73.7	71.1	73.5	75.7	46.3	48.0	49.3
6	48.8	50.7	52.3	53.6	57.2	61.1	57.1	58.5	60.7	74.5	76.6	78.6	69.6	71.5	73.5	71.9	74.0	75.9	47.0	49.4	51.9
7	50.0	51.5	53.3	56.5	59.8	62.8	59.8	60.9	62.5	73.8	76.2	78.4	69.3	71.8	74.6	72.1	73.1	74.3	49.3	51.1	52.8
8	47.1	48.4	50.6	58.4	61.2	63.9	61.8	62.9	64.4	74.0	75.4	77.2	69.9	72.2	74.6	69.8	71.2	72.8	49.9	51.4	52.9
9	43.4	45.5	47.4	58.7	61.7	64.6	62.5	64.8	67.4	70.5	73.8	76.9	70.1	71.5	73.1	67.8	69.0	70.5	49.2	50.6	51.9
10	41.6	44.1	46.4	60.3	63.0	65.7	65.5	67.4	69.6	73.0	76.2	79.5	69.3	71.0	72.9	66.4	68.9	71.4	48.4	50.1	51.6
11	44.3	46.0	48.0	59.7	61.9	64.1	66.2	66.7	68.1	74.6	77.1	79.3	69.4	71.2	72.2	67.2	69.5	71.8	48.9	49.7	50.4
12	45.7	48.1	51.1	59.7	62.5	64.7	65.4	66.8	68.7	74.4	76.8	79.2	69.9	72.0	74.3	67.0	69.1	71.0	47.5	48.9	50.2
13	46.9	48.2	49.4	62.7	65.4	68.4	64.4	66.1	67.0	74.2	75.8	77.5	70.2	72.7	74.9	66.3	68.5	70.1	48.1	49.3	50.3
14	42.4	44.0	46.8	63.1	65.0	66.6	63.1	64.1	65.4	70.7	72.6	74.9	71.7	73.9	75.9	67.5	69.0	70.8	48.5	49.3	50.1
15	41.6	42.6	43.6	61.6	63.6	65.2	61.0	63.1	65.4	69.9	73.0	76.2	72.4	74.7	76.8	64.9	67.0	68.4	46.8	48.5	50.0
16	41.0	42.2	43.3	61.5	63.2	64.9	63.3	65.4	67.6	69.4	71.8	74.0	71.7	74.7	77.3	65.0	67.2	69.3	45.8	46.5	48.4
17	41.0	43.2	46.1	61.3	63.2	64.9	64.6	66.8	69.1	70.0	72.7	75.9	72.7	75.2	77.4	65.2	66.3	68.0	44.5	45.2	45.7
18	41.5	44.1	46.4	61.9	62.6	63.3	66.3	68.5	70.8	72.0	74.4	76.6	73.5	76.0	78.3	61.5	64.3	65.9	44.1	45.5	47.1
19	43.5	45.1	46.3	60.6	61.6	62.5	68.4	70.1	72.1	72.1	75.0	77.8	72.8	75.2	77.1	58.8	60.6	62.4	44.8	46.3	47.5
20	44.6	46.4	48.5	59.2	61.1	63.4	67.0	68.4	70.0	73.2	76.3	79.1	72.0	74.7	77.1	57.8	60.3	62.7	46.7	47.6	48.5
21	44.6	45.9	47.7	59.2	61.4	63.6	63.0	64.6	66.9	74.4	76.9	79.2	71.5	74.0	76.4	58.2	61.0	63.3	47.1	48.1	49.0
22	42.7	44.5	46.5	57.9	59.1	60.9	61.7	63.7	65.9	74.0	76.4	78.4	70.6	72.9	74.4	60.3	62.3	64.5	47.4	48.8	50.2
23	42.1	44.6	46.8	55.3	56.4	58.4	64.1	67.0	70.2	72.7	75.9	78.9	71.1	73.5	76.1	60.2	61.8	63.6	48.0	49.4	50.7
24	44.6	47.3	50.3	54.1	56.6	59.4	66.7	68.2	69.7	74.3	76.9	79.8	71.6	74.1	76.5	57.9	59.2	60.1	48.1	49.4	50.5
25	47.8	50.2	52.8	56.9	59.1	61.0	66.7	68.9	71.0	74.3	76.5	78.8	72.2	74.5	77.0	56.6	57.8	59.0	47.3	48.8	50.3
26	50.3	53.5	56.8	59.1	61.1	63.2	68.4	70.3	72.3	70.7	73.2	75.4	71.9	74.6	77.1	52.9	54.8	56.6	46.7	48.2	49.6
27	53.8	55.3	56.8	60.6	62.1	64.1	68.8	71.1	73.5	68.5	71.5	74.3	72.3	74.6	76.7	51.1	53.1	54.9	45.9	47.1	48.3
28	53.0	55.4	58.2	60.5	61.9	63.3	70.0	72.9	75.9	70.0	72.6	75.4	70.9	72.9	74.6	52.0	53.6	54.9	41.8	43.5	45.9
29	52.0	54.5	56.1	60.2	60.9	62.0	72.2	75.4	78.9	70.6	72.7	74.5	69.9	72.7	75.6	53.2	54.0	54.6	39.9	40.9	41.8
30	49.3	50.3	51.9	57.8	59.2	60.4	74.3	76.8	79.3	70.8	72.8	74.8	70.5	73.1	75.4	50.9	52.1	53.1			
31				55.9	56.6	57.8				69.2	72.3	75.1	70.2	72.5	74.3						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Stafford Ferry, Missouri River RM 1970.0

2013	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1				46.3	49.4	52.5	54.5	56.3	58.4	75.0	78.8	83.0	71.4	72.2	73.7	70.4	71.6	72.7	54.0	54.6	55.4
2				46.9	50.7	54.9	57.9	59.2	60.5	76.6	80.1	84.0	69.9	70.3	71.4	70.5	71.5	72.4	53.3	54.0	54.6
3				50.7	52.0	53.3	54.4	56.6	59.6	77.5	81.1	85.3	69.6	69.9	70.4	70.5	71.6	72.8	52.8	53.3	54.4
4				51.8	54.1	57.1	53.0	54.1	55.4	78.1	79.5	81.4	68.7	69.3	70.1	71.1	72.0	73.1	51.9	52.5	53.1
5				52.1	55.5	59.4	53.1	55.4	58.0	76.8	78.0	79.9	69.4	70.0	71.0	71.4	72.8	74.3	51.1	51.8	52.8
6				53.6	57.3	61.5	57.1	59.0	61.2	74.1	76.4	78.6	69.8	70.5	71.1	72.0	73.2	74.7	50.8	51.6	52.5
7				56.4	59.7	63.6	60.6	61.9	63.2	73.8	76.1	79.0	69.8	70.6	71.4	72.1	72.6	73.6	51.5	52.3	53.2
8				57.9	60.8	64.5	62.0	63.5	65.2	74.1	75.2	77.2	70.2	71.0	71.9	71.1	71.5	72.0	52.2	52.8	53.3
9				58.7	61.3	64.1	62.8	65.2	67.6	72.1	73.2	74.3	70.1	70.9	71.7	70.2	70.6	71.4	51.8	52.4	53.1
10				60.0	62.5	65.8	65.0	67.5	70.1	72.8	75.0	79.0	69.6	70.3	71.1	69.0	69.6	70.2	51.2	51.9	52.6
11				59.2	62.1	65.4	65.3	66.4	68.2	74.3	76.8	78.9	69.8	70.5	71.1	69.1	69.7	70.1	51.2	51.5	52.1
12				60.1	62.6	65.2	64.8	66.5	69.1	74.1	77.2	81.6	70.0	70.8	71.7	68.7	69.4	70.0	50.3	50.8	51.5
13				62.1	64.7	68.0	64.3	66.1	67.5	73.5	76.0	79.3	70.2	71.2	72.4	68.6	69.2	69.8	50.1	50.6	50.9
14				63.1	64.9	66.6	62.7	63.9	65.4	70.0	72.4	75.4	71.3	72.2	73.4	68.7	69.2	69.6	50.3	50.6	50.9
15				61.8	63.6	65.4	61.0	63.5	65.9	69.0	73.6	79.3	71.8	72.7	73.7	67.7	68.4	69.3	49.3	50.1	50.7
16				61.9	63.4	65.7	63.0	65.5	68.2	70.8	73.6	77.0	72.1	72.9	73.7	67.3	68.0	68.7	48.7	49.3	50.4
17				61.9	63.6	65.7	64.7	67.4	70.2	69.4	72.9	77.6	72.6	73.3	74.0	67.5	67.9	68.7	47.7	48.0	48.7
18				62.1	62.7	63.1	66.7	69.4	72.9	72.6	73.7	74.9	73.0	73.7	74.7	65.7	66.7	67.5	47.1	47.6	48.2
19				60.9	61.6	62.3	68.6	71.0	74.1	72.8	73.9	75.2	73.0	74.0	74.7	63.6	64.3	65.7	47.2	47.8	48.4
20				59.4	61.1	63.3	67.4	68.6	69.8	73.1	74.8	77.3	72.8	73.9	74.7	62.3	63.1	64.2	48.0	48.4	49.1
21				59.3	61.5	64.0	63.5	65.4	67.6	73.9	75.8	77.7	72.4	73.5	74.4	62.0	62.8	63.5	48.5	48.9	49.4
22				58.8	60.0	61.2	61.6	63.7	65.7	73.5	75.8	78.4	71.7	72.8	74.0	62.5	63.1	63.9	48.9	49.4	50.1
23	42.2	45.3	49.0	56.1	57.2	59.1	63.4	66.8	70.4	72.9	75.5	77.9	72.1	72.8	73.6	62.8	63.3	63.8	49.6	50.0	50.5
24	44.3	47.2	50.7	54.8	57.2	59.8	67.0	68.8	71.3	73.9	75.7	77.8	72.2	73.0	74.0	61.3	61.9	63.1	49.5	50.0	50.5
25	47.2	50.2	53.6	57.0	59.5	62.5	67.4	69.4	71.6	74.0	75.5	77.2	72.4	73.5	74.8	60.5	61.0	61.6	49.2	49.8	50.3
26	49.5	53.6	58.5	59.0	61.4	64.5	68.7	71.0	73.6	71.7	73.6	75.8	72.7	73.8	74.9	59.0	59.6	60.4	48.7	49.4	50.0
27	53.3	55.6	58.5	61.0	62.6	64.4	68.9	71.9	75.2	69.7	72.1	74.4	73.0	74.1	75.2	57.7	58.2	59.0	48.2	48.7	49.6
28	53.0	56.0	60.3	60.9	62.6	64.3	69.9	73.7	77.8	71.0	72.5	74.3	72.4	73.3	74.4	57.3	57.7	58.2	45.1	46.5	48.1
29	51.2	54.7	56.9	60.6	61.1	62.4	72.2	76.3	80.9	71.0	72.5	74.3	71.8	72.5	73.3	56.7	57.1	57.7	44.0	44.4	45.1
30	48.9	50.4	51.7	57.6	58.9	60.6	73.8	77.5	81.6	71.2	72.7	74.1	71.9	72.8	73.8	55.4	55.9	56.6			
31				55.3	56.4	57.5				70.7	72.7	74.9	71.5	72.5	73.5						

Appendix 2 continued. Minimum, mean and maximum daily water temperatures (^{0}F) for the Marias, Teton and Missouri Rivers, 2013.

Robinson Bridge, Missouri River RM 1921.0
2013

	April			May			June			July			Aug			Sept			Oct		
Date	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1				47.5	49.7	51.7	54.4	56.1	58.3	76.3	79.0	81.7	72.6	73.8	75.4	70.5	72.2	73.5	50.0	51.4	52.8
2				48.3	51.4	54.4	57.8	59.1	60.3	78.2	80.4	82.6	69.6	70.7	72.6	70.2	72.0	73.5	49.7	51.5	53.3
3				51.1	52.7	53.9	55.0	57.7	60.1	79.7	81.6	83.3	69.0	70.0	71.1	71.1	73.0	75.1	49.4	50.6	51.7
4	49.1	50.6	52.2	52.8	54.2	56.1	53.9	54.5	55.3	80.1	80.8	82.0	68.2	70.0	72.0	72.3	73.6	74.7	47.5	49.1	50.5
5	49.4	50.6	51.7	52.5	55.7	58.9	54.4	55.7	57.5	78.2	79.5	80.7	69.9	71.5	73.2	72.3	74.2	76.3	47.2	48.8	50.5
6	50.0	51.7	53.3	55.3	58.2	61.2	56.9	58.8	61.2	76.3	77.9	79.7	70.8	71.6	72.6	73.8	75.6	77.5	47.5	49.7	52.2
7	50.5	52.0	53.6	57.5	60.4	63.2	60.1	61.7	63.8	75.4	77.0	78.5	70.5	71.7	72.6	72.6	74.3	76.0	48.6	50.4	52.5
8	46.4	48.4	50.5	60.1	62.2	64.4	62.3	63.5	64.9	75.1	76.1	77.2	70.8	71.8	72.9	71.1	71.9	73.2	50.5	51.9	53.6
9	44.1	46.2	48.3	60.3	62.9	65.5	63.8	65.4	67.9	72.0	74.0	75.7	71.1	71.8	72.6	68.7	69.7	71.1	49.7	51.2	52.5
10	43.6	45.5	47.2	61.8	63.2	64.9	65.8	67.5	69.6	73.5	75.8	78.2	70.2	71.0	72.0	67.0	69.1	71.4			
11	44.7	46.4	48.6	60.9	62.9	64.9	63.2	67.4	69.0	76.0	77.7	79.1	69.9	71.4	72.6	67.9	70.0	72.3			
12	46.9	48.5	50.8	61.8	64.4	66.7	63.5	65.9	67.9	75.7	77.8	79.7	71.1	72.6	74.4	67.6	69.6	71.4			
13	46.6	47.9	48.6	64.1	66.3	68.7	67.0	67.8	69.0	75.7	77.2	78.5	71.4	73.2	75.1	67.9	69.6	71.4			
14	45.0	46.6	48.0	64.9	66.2	67.6	64.9	66.1	67.6	73.8	74.8	76.6	73.2	74.5	75.7	68.7	69.7	70.8			
15	43.0	43.6	44.7	63.5	65.4	67.3	62.9	64.7	66.4	70.8	74.0	77.2	73.2	75.3	77.5	66.4	67.9	69.3			
16	41.6	42.5	43.3	63.2	64.2	65.8	63.8	65.9	68.2	71.4	74.0	76.0	73.5	75.3	76.9	65.8	68.0	70.5			
17	41.6	42.6	43.8	62.6	64.0	65.2	65.8	67.8	69.9	72.6	73.7	74.7	73.5	75.5	77.9	67.0	68.0	69.0			
18	41.3	43.4	45.5	63.8	64.3	64.6	68.2	70.0	72.3	72.0	74.4	76.9	74.4	76.7	78.8	62.1	65.6	67.6			
19	44.4	45.6	46.9	62.1	62.9	63.8	69.9	71.8	73.8	72.9	75.4	77.9	74.7	77.0	78.8	59.8	61.2	62.6			
20	44.7	46.5	48.6	61.5	62.4	63.5	69.9	70.5	72.0	74.1	76.7	79.4	74.1	76.4	78.5	58.1	60.5	62.9			
21	46.1	46.9	47.7	60.3	62.2	64.1	66.1	67.6	70.2	75.7	78.0	80.4	73.5	75.4	76.9	58.9	61.3	63.8			
22	44.4	45.8	47.7	60.3	61.5	62.6	63.8	65.2	66.1	75.1	77.7	80.1	72.3	74.4	76.0	60.6	62.2	63.8			
23	43.0	45.3	47.5	57.5	58.3	60.6	63.8	66.1	68.7	74.7	77.2	79.4	73.2	75.0	76.6	61.2	62.4	64.1			
24	45.2	47.1	49.1	56.7	58.3	60.3	67.3	69.5	72.0	75.7	77.8	80.1	73.2	75.1	76.9	58.9	60.5	61.8			
25	46.9	49.5	52.5	57.8	59.8	61.5	69.3	70.8	72.0	76.0	77.1	78.8	73.2	75.3	77.5	58.1	59.0	60.3			
26	50.3	53.3	56.7	60.1	61.8	63.5	69.9	71.4	72.9	72.3	74.1	76.3	74.4	76.4	78.5	54.4	55.8	57.8			
27	54.2	56.2	58.6	61.8	63.7	65.8	70.5	72.5	74.1	70.2	72.6	74.7	74.7	76.7	78.5	52.8	54.3	55.8			
28	55.6	57.2	58.9	63.2	64.2	65.5	71.4	74.1	76.6	71.7	73.2	74.7	73.5	75.4	76.9	52.2	54.0	55.6			
29	54.2	56.6	58.3	62.1	63.0	64.4	74.1	76.4	78.8	71.1	72.8	74.1	72.9	74.3	75.7	53.9	54.6	55.3			
30	49.7	51.4	53.9	57.8	59.9	61.8	75.4	77.2	78.8	71.7	73.4	75.7	72.9	74.6	76.3	51.7	52.7	53.9			
31				55.0	56.3	57.8				72.0	74.2	76.6	72.6	74.0	75.1						

Appendix 3 summary of individual channel catfish radio-tagged in 2011 and 2012 with radio frequency, code, model number, date capture, tagging location, total length (TL) in inches, weight (WT) in pounds, date of last valid relocation, current known radio status and number of non-mortality code relocations in the Missouri River, 2013.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	TL (in)	WT (lbs)	Last Location	Fate/status[a]	Number of Relocations 2013 only
Channel catfish									
149.600	1[b]	MCFT2-3FM	9/7/11	1925.7	28.6	8.72	5/15/12	M	0
149.700	1	MCFT2-3A	5/31/12	2093.8	28.0	10.82	7/13/13	A	7
149.700	2	MCFT2-3A	6/5/12	2047.9	22.2	3.66	7/17/13	E	5
149.700	3[b]	MCFT2-3A	6/13/12	2054.0	26.8	7.60	10/16/12	E	0
149.700	4	MCFT2-3A	5/30/12	1972.0	24.5	7.29	10/16/12	E	0
149.700	5	MCFT2-3A	4/25/12	2068.4	27.2	9.68	6/5/13	E	4
149.700	6	MCFT2-3A	5/22/12	1923.0	26.5	6.93	2/22/13	E	3
149.700	7	MCFT2-3A	5/15/12	1930.8	24.7	5.52	10/6/12	E	0
149.700	9	MCFT2-3A	5/17/12	1977.4	27.5	8.31	6/23/13	E	6
149.700	10	MCFT2-3A	5/29/12	1975.1	24.7	6.54	9/8/12	M	0
149.700	28	MCFT2-3L	5/23/12	1931.5	35.1	22.85	7/19/12	M	0
149.700	29	MCFT2-3L	5/15/12	1930.8	30.1	9.81	10/15/12	M	0
149.700	32	MCFT2-3L	5/29/12	1986.8	29.5	10.71	9/10/13	A	13
149.700	34	MCFT2-3L	4/11/12	1923.6	27.1	8.05	9/21/13	A	6

[a] A = fish active
R= radio recovered
E= expelled/mortality sensor
M= missing fish (no relocations during summer or fall relocation efforts) June-October

X[b]= did not use modified technique of radio implantation on these individuals

Appendix 4. A summary of individual burbot radio-tagged and monitored in 2013 with radio frequency, code, model number, date captured, tagging location, total length (TL) in inches, weight (WT) in pounds, sex, number of relocations and current known radio status in the Missouri River, 2013.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	TL (in)	WT (lbs)	Sex[a]	Number of Relocations	Fate/status[b]
Burbot									
149.600	24	MCFT2-3LM	3/26/13	1980.0	22.4	2.28	Unk	3	M
149.600	25	MCFT2-3LM	4/10/12	1914.8	19.8	2.59	Unk	0	E
149.600	26	MCFT2-3LM	3/20/13	1984.5	18.2	1.55	Unk	10	A
149.600	29	MCFT2-3BM	3/28/13	1980.0	17.7	0.92	Unk	13	A
149.600	30	MCFT2-3BM	3/28/13	1978.0	19.0	1.35	Unk	9	A
149.600	31	MCFT2-3BM	3/28/13	1982.2	17.8	1.14	Unk	8	A
149.600	32	MCFT2-3BM	3/27/13	1970.0	27.4	4.36	Unk	6	M
149.600	33	MCFT2-3BM	3/26/13	1980.0	17.9	1.07	Unk	27	A

Appendix 5. A summary of northern pike radio-tagged and monitored in 2013 with radio frequency, code, model number, date captured, tagging location, total length (TL) in inches, weight (WT) in pounds, sex, number of relocations and current known radio status in the Missouri River, 2013.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	TL (in)	WT (lbs)	Last Location	Fate/status[a]	Number of Relocations 2013 only
Northern pike									
149.600	7	MCFT2-3FM	9/28/12	~1928.0	26.3	4.00	Unk	0	E
149.600	11	MCFT2-3FM	8/23/12	1918.3	21.4	2.33	Unk	0	E
149.600	12	MCFT2-3FM	9/19/12	1930.0	26.1	3.20	Unk	5	A
149.600	27	MCFT2-3LM	8/23/12	1921.2	20.4	1.97	Unk	5	M
149.600	28	MCFT2-3LM	8/23/12	1928.6	20.7	1.77	Unk	9	A
149.700	23	MCFT2-3L	9/19/12	1930.0	27.0	4.57	Unk	0	E
149.700	36	MCFT2-3L	9/20/12	~1926.0	27.7	4.06	Unk	0	M
149.600	34	MCFT2-3A	5/1/13	1914.4	23.0	2.81	Unk	1	M
149.600	35	MCFT2-3A	5/1/13	1914.4	24.7	3.72	Unk	2	M
149.600	36	MCFT2-3A	5/1/13	1914.4	22.5	2.59	Unk	16	A
149.600	37	MCFT2-3A	4/30/13	1922.0	24.0	3.08	Unk	1	Harvested
149.600	38	MCFT2-3A	5/1/13	1914.4	23.4	2.89	Unk	4	A
149.600	39	MCFT2-3A	5/21/13	1924.3	23.4	2.72	Unk	3	M
149.600	40	MCFT2-3A	5/22/13	1922.7	37.6	12.23	Unk	2	M
149.600	41	MCFT2-3A	5/21/13	1924.3	23.5	2.90	Unk	9	A
149.600	42	MCFT2-3A	5/21/13	1924.3	24.1	2.96	Unk	13	A
149.600	43	MCFT2-3A	5/21/13	1924.3	23.1	2.65	Unk	12	A?

[a] A = fish active; E= expelled/mortality radio; M= missing fish (no relocations during summer or fall relocation efforts) June-October

Appendix 6. A summary of blue sucker radio-tagged and monitored in 2013 with radio frequency, code, model number, date captured, tagging location, total length (TL) in inches, weight (WT) in pounds, sex, number of relocations and current known radio status in the Missouri River, 2013.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	TL (in)	WT (lbs)	Last Location	Fate/status[a]	Number of Relocations 2013 only
Blue sucker									
149.700	44	MCFT-3L	4/16/07	1921.0	31.25	8.35	M	12	A
149.700	51	MCFT-3L	5/7/07	2052.5	33.8	11.80	F	9	A
149.700	53	MCFT-3L	5/7/07	2052.5	33.3	12.55	F	8	A
149.700	54	MCFT-3L	5/7/07	2052.5	34.7	12.50	F	12	A
149.700	57	MCFT-3L	5/7/07	2052.5	30.1	8.15	M	17	A
149.700	58	MCFT-3LL	4/22/08	1919.5	32.2	12.09	F	8	A
149.700	64	MCFT-3LL	4/25/07	1921.0	31.2	10.40	F	2	A
149.700	78	MCFT-3L	5/6/08	1984.0	30.0	8.27	F	3	A
149.700	83	MCFT-3L	5/11/09	MA 0.5	31.9	12.20	F	15	A
149.700	86	MCFT-3L	5/11/09	MA 0.5	30.4	8.18	M	9	A
149.700	91	MCFT-3L	4/17/09	1982.5	32.2	> 11.0	F	12	A

[a] M = male
F= female

[b] A = active fish

Appendix 7. A summary of individual pallid sturgeon radio-tagged and monitored in 2013 with radio frequency, code, model number, date of last capture, tagging location, fork length (FL) in inches, weight (WT) in pounds, sex and known reproductive potential, number of relocations and current known radio status in the Missouri River.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	FL (in)	WT (lbs)	Sex[a]	Number of Relocations	Fate/status[b]
Pallid									
149.800	10	MCFT2-3FM	4/13/11	1920.0	23.3	1.41	Unk	19	B
149.800	11	MCFT2-3L	4/11/12	1922.0	35.7	2.95	Unk	15	A
149.800	12	MCFT2-3L	9/19/11	1922.2	44.4	14.53	M	15	A
149.800	13	MCFT2-3L	5/10/12	2039.5	NA	36.00	GVDF	16	R/H/A
149.800	29	MCFT-3L	7/29/10	2048.0	34.5	6.02	Unk	7	A
149.800	52	MCFT2-3A	8/30/12	1916.3	34.9	5.65	Unk	25	A
149.800	57	MCFT2-3L	4/4/13	1921.9	35.3	6.18	Unk	12	A
149.800	59	MCFT2-3L	4/4/13	1921.9	38.8	7.66	Unk	22	A
149.800	60	MCFT2-3L	4/3/13	1910.3	38.0	7.24	Unk	11	A
149.800	61	MCFT2-3L	4/3/13	1912.2	35.1	5.42	Unk	13	A
149.800	62	MCFT2-3L	4/23/13	1888.0	42.1	10.57	Unk	12	A
149.800	63	MCFT2-3L	4/23/13	1908.9	40.1	9.09	Unk	26	A
149.800	66	MCFT2-3L	4/24/13	1927.7	42.1	13.10	RM	42	A
149.800	67	MCFT2-3L	9/6/12	1908.9	36.0	6.36	Unk	12	A
149.800	68	MCFT2-3L	4/30/13	1900.7	37.7	7.72	Unk	20	A
149.800	70	MCFT2-3L	9/5/12	1911.3	35.4	5.94	M	9	A
149.800	72	MCFT2-3L	4/19/12	1898.6	46.0	16.27	M	1	A
149.800	74	MCFT2-3L	10/23/13	1916.7	42.6	12.95	Unk	70	R/A
149.800	75	MCFT2-3L	6/27/13	1941.5	52.4	NA	M	6	A
149.800/149.900	26/6	MCFT2-3L	10/21/13	1944.9	~53.3	41.9	F	12	R/RT/A
149.800/149.900	19/9	MCFT2-3L	10/22/13	1923.2	36.4	6.50	Unk	26	R/RT/A
149.800	55/54	MCFT2-3A	9/17/13	1901.0	31.7	3.77	Unk	70	A
149.800	18/58	MCFT2-3L	10/29/12	1913.6	42.2	11.35	Unk	22	A
149.800	17/65	MCFT2-3L	10/30/12	1936.8	41.8	10.42	Unk	20	R/A

M = male
Unk = unknown sex
GVDF= gravid female (reproductively active at time of tagging)
RM = reproductively active male
F = female

[b]A = active fish
RT=individual was retransmittered
R = recaptured for reproductive assessment
H=taken to hatchery and spawned
M = missing individual (no relocations during summer or fall relocation efforts)

Appendix 8. A summary of individual shovelnose sturgeon monitored in 2013 with radio frequency, code, model number, date of last capture, tagging location, fork length (FL) in inches, weight (WT) in pounds, sex and known reproductive potential, number of relocations and current known radio status in the Missouri River.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	FL (in)	WT (lbs)	Sex[a]	Number of Relocations	Fate/status[b]
Shovelnose									
149.700	66	MCFT-3LL	4/29/08	1928.5	28.9	4.50	GVDF	2	A
149.700	67	MCFT-3LL	4/29/08	1928.5	30.8	5.62	GVDF	2	A
149.700	79	MCFT-3LL	4/29/08	1928.5	28.9	4.68	GVDF	9	A
149.700	80	MCFT-3LL	6/30/08	MA 4.4	31.4	5.78	M	14	A
149.700	81	MCFT-3LL	6/30/08	MA 3.7	30.0	4.56	M	3	A
149.700	82	MCFT-3LL	4/29/08	1928.5	30.0	4.70	GVDF	2	M
149.700	88	MCFT-3L	4/20/09	2031.4	33.7	6.61	IF	7	A
149.700	90	MCFT-3L	4/17/09	1982.5	31.0	5.55	IF	16	A
149.700	92	MCFT-3L	4/17/09	1982.5	31.0	5.56	IF	22	A
149.700	93	MCFT-3L	4/14/09	1928.0	32.1	5.60	IF	5	A
149.700	94	MCFT-3L	4/16/09	1928.0	34.2	6.30	IF	15	A
149.700	95	MCFT-3L	4/17/09	1982.5	33.3	6.40	IF	23	A
149.700	96	MCFT-3L	4/21/09	2031.4	34.6	7.08	IF	0	M
149.800	16	MCFT-3L	10/20/09	1927.0	33.2	6.80	SF	9	A
149.800	20	MCFT-3L	10/20/09	1927.0	37.6	10.72	GVDF	0	B/M
149.800	30	MCFT-3L	6/7/11	2052.1	35.8	10.8	GVDF	13	A
149.800	35	MCFT-3L	5/7/08	2031.2	31.5	4.50	M	0	M
149.800	42	MCFT-3LL	4/23/08	1921.0	33.6	6.28	GVDF	0	M
149.800	44	MCFT-3LL	5/7/08	2031.2	30.5	4.45	M	5	A
149.800	46	MCFT-3LL	5/21/08	1982.0	33.8	7.00	GVDF	0	A
149.900	41	MCFT-3L	5/3/07	1921.0	37.2	10.10	GVDF	11	A
149.900	47	MCFT-3L	9/4/13	1920.3	31.1	5.48	GVDF	1	A
149.900	57	MCFT-3L	5/9/07	1978.5	27.1	3.65	M	0	M
149.900	59	MCFT-3L	5/9/07	1978.5	27.2	3.60	M	67	A
149.900	67	MCFT-3LL	9/25/07	1914.8	32.6	5.80	GVDF	6	A
149.900	74	MCFT-3LL	5/21/08	1982.5	33.8	7.00	GVDF	6	A
149.900	75	MCFT-3LL	5/15/08	1983.5	32.0	6.00	M	2	M
149.900	76	MCFT-3LL	5/7/08	2031.2	30.0	4.50	M	10	A
149.900	77	MCFT-3LL	4/26/08	2034.0	31.0	5.10	GVDF	2	M
149.900	78	MCFT-3LL	4/29/08	1982.5	29.8	4.15	GVDF	0	M
149.900	79	MCFT-3LL	4/26/08	2035.0	34.5	7.25	GVDF	7	A
149.900	80	MCFT-3LL	4/26/08	2029.1	33.0	8.10	M	8	A
149.900	81	MCFT-3LL	4/26/08	2033.0	32.0	5.60	GVDF	2	M
149.900	82	MCFT-3LL	4/25/08	1984.0	31.0	5.90	GVDF	0	E
149.900	83	MCFT-3LL	4/24/08	1979.5	35.0	7.50	GVDF	9	A
149.900	84	MCFT-3LL	4/25/08	1984.0	33.8	6.80	GVDF	9	A

[a]M = male
GVDF= gravid female (reproductively active at time of tagging)
[b]A = active fish
M = missing individual (no relocations during summer or fall relocation efforts)
E=Expelled
B=Radio battery likely expired

Appendix 8 continued. A summary of individual shovelnose sturgeon monitored in 2013 with radio frequency, code, model number, date of last capture, tagging location, fork length (FL) in inches, weight (WT) in pounds, sex and known reproductive potential, number of relocations and current known radio status in the Missouri River.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	FL (in)	WT (lbs)	Sex[a]	Number of Relocations	Fate/status[b]
Shovelnose									
149.900	86	MCFT-3LL	4/26/08	2030.0	32.5	6.23	GVDF	42	A
149.900	87	MCFT-3LL	4/26/08	2031.0	32.5	6.60	GVDF	10	A
149.900	88	MCFT-3LL	4/26/08	2032.0	31.8	5.70	M	8	A
149.900	89	MCFT-3L	5/15/08	1983.0	30.1	5.20	GVDF	15	A
149.900	90	MCFT-3L	5/15/08	1983.0	34.6	7.84	GVDF	2	M
149.900	91	MCFT-3L	4/26/08	2036.0	31.8	5.25	GVDF	5	A
149.900	92	MCFT-3L	5/14/08	1928.5	31.2	4.95	M	10	A
149.900	93	MCFT-3L	5/21/08	1982.5	30.4	5.18	M	17	A
149.900	94	MCFT-3L	5/14/08	1928.5	34.9	9.30	GVDF	8	A
149.900	95	MCFT-3L	5/14/08	1928.5	33.5	6.35	GVDF	9	A
149.900	96	MCFT-3L	4/14/09	1928.0	32.5	8.10	GVDF	10	A
149.900	97	MCFT-3L	4/14/09	1928.0	30.8	5.35	GVDF	14	A
149.900	98	MCFT-3L	4/14/09	1928.0	29.6	4.75	GVDF	19	A
149.900	99	MCFT-3L	4/14/09	1928.0	30.5	5.80	GVDF	2	M
149.900	100	MCFT-3L	4/14/09	1928.0	30.0	6.20	GVDF	7	A
149.900	101	MCFT-3L	4/15/09	1928.0	38.0	11.40	GVDF	2	M
149.900	102	MCFT-3L	4/15/09	1928.0	35.6	10.45	GVDF	9	A
149.900	103	MCFT-3L	4/15/09	1928.0	29.9	5.14	GVDF	9	A
149.900	104	MCFT-3L	4/15/09	1928.0	29.1	4.80	GVDF	11	A
149.900	105	MCFT-3L	4/15/09	1928.0	27.5	4.70	GVDF	18	A
149.900	106	MCFT-3L	4/20/09	2031.4	31.1	5.62	GVDF	12	A
149.900	107	MCFT-3L	4/20/09	2031.4	33.8	8.37	GVDF	1	A
149.900	108	MCFT-3L	4/20/09	2031.4	30.5	5.84	GVDF	7	A
149.900	109	MCFT-3L	4/20/09	2031.4	36.3	9.37	GVDF	9	A
149.900	111	MCFT-3L	4/20/09	2031.4	33.9	7.39	GVDF	18	A
149.900	112	MCFT-3L	4/21/09	2031.4	31.7	6.31	GVDF	0	M
149.900	113	MCFT-3L	4/21/09	2031.4	30.7	5.84	GVDF	12	A
149.900	114	MCFT-3L	4/13/09	1984.0	29.6	5.60	GVDF	11	A
149.900	115	MCFT-3L	4/16/09	1984.0	31.0	5.20	GVDF	12	A
149.900	116	MCFT-3L	4/16/09	1984.0	33.6	7.92	GVDF	7	A
149.900	117	MCFT-3L	4/16/09	1984.0	30.8	5.60	GVDF	29	A
149.900	118	MCFT-3L	4/16/09	1984.0	33.7	7.80	GVDF	0	M
149.900	119	MCFT-3L	4/17/09	1982.5	35.0	7.70	GVDF	12	A
149.900	120	MCFT-3L	4/17/09	1982.5	34.0	8.00	GVDF	7	M

[a]GVDF= gravid female (reproductively active at time of tagging)
M = male
[b]A = active fish
[b]M = missing individual (no relocations during summer or fall relocation efforts)

Appendix8 continued. A summary of individual shovelnose sturgeon monitored in 2013 with radio frequency, code, model number, date of last capture, tagging location, fork length (FL) in inches, weight (WT) in pounds, sex and known reproductive potential, number of relocations and current known radio status in the Missouri River.

Frequency	Code	Radio Model Number	Date of Capture	Release Location	FL (in)	WT (lbs)	Sex[a]	Number of Relocations	Fate/status[b]
Shovelnose									
149.900	121	MCFT-3L	4/17/09	1982.5	35.0	8.66	GVDF	13	A
149.900	122	MCFT-3L	4/17/09	1982.5	Unk	Unk	GVDF	0	M
149.900	123	MCFT-3L	4/17/09	1982.5	32.0	6.20	GVDF	15	A
149.900	124	MCFT-3L	4/21/09	2031.4	32.1	6.94	GVDF	9	A
149.900	125	MCFT-3L	4/21/09	2031.4	32.9	7.17	GVDF	49	A
149.900	126	MCFT-3L	5/7/10	2025.5	34.8	7.78	GVDF	8	A
149.900	127	MCFT-3L	5/7/10	2025.5	32.8	6.61	GVDF	1	M
149.900	128	MCFT-3L	5/7/10	2025.5	31.0	5.33	GVDF	9	A
149.900	130	MCFT-3L	5/8/13	2034.5	33.7	6.15	GVDF	4	R/A
149.900	131	MCFT-3L	5/7/10	2034.5	29.8	5.71	GVDF	37	A
149.900	133	MCFT-3L	5/7/10	2034.5	33.7	7.78	GVDF	8	A
149.900	134	MCFT-3L	4/26/10	1983.0	33.5	6.95	GVDF	14	A
149.900	135	MCFT-3L	4/26/10	1983.0	31.7	5.64	GVDF	10	A
149.900	136	MCFT-3L	4/26/10	1983.0	32.8	6.60	GVDF	1	A
149.900	137	MCFT-3L	4/26/10	1983.0	31.0	5.36	GVDF	14	A
149.900	138	MCFT-3L	4/26/10	1983.0	33.5	7.95	GVDF	9	A
149.900	139	MCFT-3L	4/26/10	1983.0	30.4	5.31	GVDF	39	A
149.900	140	MCFT-3L	4/26/10	1978.8	33.3	7.15	GVDF	9	A
149.900	141	MCFT-3L	5/12/10	1970.0	34.2	7.94	GVDF	3	A
149.900	142	MCFT-3L	4/27/10	1982.9	31.3	5.61	GVDF	12	A
149.900	143	MCFT-3L	4/26/10	1978.8	32.5	5.93	GVDF	36	A
149.900	144	MCFT-3L	5/10/10	1916.0	36.0	9.58	GVDF	2	A
149.900	145	MCFT-3L	6/7/11	2052.1	38.5	11.60	GVDF	10	A
149.900	146	MCFT-3L	6/7/11	2052.1	34.2	9.50	GVDF	12	A
149.900	147	MCFT-3L	5/20/10	1921.0	30.0	5.11	GVDF	6	A
149.900	148	MCFT-3L	5/20/10	1921.0	32.1	5.55	GVDF	5	A
149.900	149	MCFT-3L	5/20/10	1926.7	28.4	4.95	GVDF	14	A
149.900	150	MCFT-3L	5/20/10	1926.7	32.7	5.92	GVDF	13	A
149.900	151	MCFT-3L	5/19/10	1925.6	37.9	9.16	GVDF	6	A
149.900	152	MCFT-3L	5/19/10	1925.6	32.0	7.03	GVDF	9	A
149.900	153	MCFT-3L	5/20/10	1926.7	29.8	5.14	GVDF	9	A
149.900	154	MCFT-3L	5/7/10	2034.5	30.9	4.92	GVDF	7	A
149.900	155	MCFT-3L	5/11/10	2034.1	33.5	7.65	GVDF	4	A
149.900/149.800	71/7	MCFT2-3FM	5/9/13	2045.8	30.5	4.06	M	19	RT/A
149.800/149.700	1/35	MCFT2-3L	5/7/13	2050.0	34.9	8.84	RM	23	RT/A
149.900/149.700	90/25	MCFT2-3L	5/22/13	2040.7	34.9	7.23	F	6	RT/A
149.900/149.700	72/26	MCFT2-3L	5/8/13	2069.8	36.6	10.80	F	14	RT/A
149.900/149.700	78/33	MCFT2-3L	4/24/13	1927.5	30.3	5.55	F	12	RT/A

[a]GVDF= gravid female (reproductively active at time of tagging)
[b]A = active fish
M = missing individual (no relocations during summer or fall relocation efforts)
R = recaptured for reproductive assessment; 9130 was not reproductive in 2013 from blood results