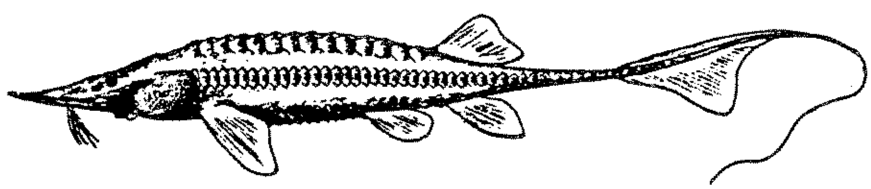
PROCEEDINGS OF THE FIRST JOINT MEETING

OF THE

MONTANA/NORTH DAKOTA PALLID WORKGROUP

AND THE

FLUVIAL ARCTIC GRAYLING WORKGROUP



January 18-19, 1995

Bozeman, MT

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INTRODUCTION

The Montana/North Dakota Pallid Sturgeon Workgroup and the Fluvial Arctic Grayling Workgroup met on January 18 and 19, 1995 in Bozeman, Montana. The purpose of the meeting was threefold; to report on the activites of biologists working on the recovery of these species, to develop workplans for the coming year and to provide an opportunity for communication between biologists involved in similar studies on different fish.

A very important outcome of the meeting is the publication of the proceedings. Over the past several years a great deal of work has gone into understanding these species, discovering the factors that have led to their decline and efforts to restore them. Unfortunately, this work has not been reported in a manner easily accessible to those interested in these species and their recovery. The publication of these proceedings should go a long way toward correcting this situation.

The first joint meeting of these two groups was very successful. Undoubtedly, similar meetings will be held in the future, either annually or biannually. We hope that these meetings will further the recovery of these species and that in time the meetings will not be necessary.

The success of the meeting and the publication of these proceedings is due to the efforts of those who participated (listed below), the authors and Liane Taylor, who edited the proceedings. I hope to see you all again at the next meeting in Miles City.

Chris Hunter
Montana Fish, Wildife & Parks

MEETING PARTICIPANTS

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EXPERIMENTAL INTRODUCTIONS OF FLUVIAL ARCTIC GRAYLING INTO THREE SOUTHWEST MONTANA STREAMS

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ABSTRACT

Experimental plants of fluvial Arctic grayling (Thymallus arcticus) were made into three streams located in southwest Montana to obtain a better understanding of survival, movement and growth following stocking. The establishment of self sustaining populations into the three streams was not a primary goal for these introduction efforts because introduced grayling were considered to have limited genetic diversity. Fluvial grayling were stocked into the Gallatin and East Gallatin rivers and Cherry Creek. The Gallatin River received 5,400 and 10,120 yearling Big Hole stock grayling in 1992 and 1993, respectively. The East Gallatin River received 10,000 and 10,500 yearling Big Hole stock grayling in 1993 and 1994, respectively. Cherry Creek received 1,450 yearling Madison River stock grayling in 1994. Grayling introduced into the Gallatin River exhibited a strong tendency to disperse downstream. Introduced grayling moved downstream an average distance of 26, 48, and 52 miles following one, two and three months, respectively, after initial stocking. The maximum observed distance moved by an individual grayling was 111 miles. Poor angler returns for grayling one year following stocking may be an indication of poor survival of stocked fish. Other possibilities for poor angler returns included reduced interest in the program by anglers fishing the Gallatin River or substantial downstream dispersion of stocked fish. Survival of grayling stocked into the East Gallatin remains questionable. Although downstream dispersion may be a partial explanation, electrofishing efforts on the river recaptured only two grayling from plants made in the previous year, indicating possible poor survival. Abundant brown trout and rainbow trout populations may make the Gallatin and East Gallatin rivers inhospitable for fluvial Arctic grayling. Electrofishing recapture data in the East Gallatin River suggested grayling held for two days of acclimation prior to being released exhibit either less of a tendency to disperse downstream or possibly better survival than grayling not acclimatized. Evaluation efforts on Cherry Creek have been limited because of the recent nature of the grayling introduction. Plans call for the East Gallatin River to receive additional yearling Big Hole stock grayling and for Cherry Creek to receive additional Madison stock grayling in 1995.

INTRODUCTION

The range of fluvial Arctic grayling (Thymallus arcticus) in Montana historically included most drainages in the upper Missouri basin located upstream of Great Falls, Montana (Kaya, 1990). Fluvial populations have declined since the early 1900's, however, and are now found only in the Big Hole River and possibly the Madison River. Because of their uniqueness, limited range and low numbers, the fluvial Arctic grayling has been designated a fish of "Special Concern" by the Montana Chapter of the American Fisheries Society, Montana Fish, Wildlife and Parks (FWP) and the Montana Natural Heritage Program. In addition, the Montana fluvial grayling was petition for listing under the Endangered Species Act and is currently categorized as C-1 (warranted but precluded) meaning that sufficient information exists on threats to the species to support listing as threatened or endangered (Hunter 1994).

A Montana Fluvial Arctic Grayling Workgroup comprised of representatives from Montana Fish, Wildlife and Parks; U.S. Fish and Wildlife Service; U.S. Forest Service; U.S. Bureau of Land Management; Montana State University; University of Montana; National Park Service; Montana Natural Heritage Program; Montana Chapter of the American Fisheries Society; Montana Power Company; and the Montana Council of Trout Unlimited have drafted a Fluvial Arctic Grayling Recovery Plan (Final Draft, March 1994). One objective included in this draft plan calls for the expansion of fluvial Arctic grayling into streams and rivers within their historic native range. To help achieve this objective, experimental plants of fluvial Arctic grayling were made into the Gallatin and East Gallatin rivers and into Cherry Creek to obtain a better understanding of survival, movement and growth following stocking. The establishment of self sustaining populations in the three streams was not a primary goal because the grayling were known to have limited genetic diversity and the three streams were known to contain substantial populations of non-native salmonids. Knowledge gained from these experimental plants will be used in future efforts to establish self sustaining fluvial grayling populations into waters identified by the Fluvial Arctic Grayling Workgroup.

DESCRIPTION OF INTRODUCTION SITES

Gallatin River

The Gallatin River originates in Yellowstone National Park and flows northerly for approximately 115 mi before joining the Madison and Jefferson rivers to form the Missouri River near the town of Three Forks (Figure 1). For about half of its length, the Gallatin River flows through a narrow canyon that is paralleled by U.S. Highway 191 prior to opening into the broad Gallatin Valley. The upper half of the river is surrounded by mostly public lands while the lower half flows through mainly private lands. The mean annual flow recorded at a USGS gage located near the mouth of the Gallatin Canyon was 808 ft^3/sec for a 63 year period of record (USGS 1994).

U.S. Highway 191 provides excellent access to the Gallatin River for public use and, as a result, fishing pressure on the river is relatively heavy. In 1993, the river received approximately 70,000 angler days of fishing pressure or about 700 angler days per river mile (FWP 1993). In the canyon section of the river, rainbow trout (Oncorhynchus mykiss) dominate game fish populations. Brown trout (Salmo trutta) is the dominate game fish species in the lower half of the river. Other game fish species found in the Gallatin River include mountain whitefish (Prosopium williamsoni), cutthroat trout (Oncorhyncus clarki), and brook trout (Salvelinus fontinalis).

In 1992, fluvial Arctic grayling were introduced into the Gallatin River at three sites within a 1.5 mile reach of river located immediately downstream from the Yellowstone National Park (YNP) boundary (T9S;R5E;Sec.7 & 18; T9S;R4E;Sec.12). In 1993, fluvial grayling were stocked into the river approximately 1 mile downstream of the YNP boundary adjacent to Snowflake Springs (T9S;R4E;Sec.12) and were also stocked approximately 47 miles downstream at the west county road bridge near the town of Gallatin Gateway (T3S;R4E;Sec.11).

East Gallatin

The East Gallatin River originates near the town of Bozeman and flows northwesterly for approximately 37 miles before entering the Gallatin River. The river flows through the broad Gallatin Valley, coursing through private agricultural lands and expanding subdivisions (Figure 1). The mean annual flow at the mouth of the river is estimated at 265 ft^3/sec (FWP 1989).

Fishing pressure is relatively light due to limited public access. In 1993, the river received approximately 5,500 angler days of fishing pressure or about 150 angler days per river mile. Rainbow trout is the predominate game fish found in the upper half of the river, while brown trout predominate in the lower half of the river. Other game fish species found in the East Gallatin River include mountain whitefish and brook trout.

Fluvial grayling were introduced into the East Gallatin River at two sites in 1993, one site located near the northern boundary of Bozeman (T1S;R6E;Sec.31) and the other located approximately two miles downstream at the county road bridge near Riverside (T1S;R5E;Sec. 26). In 1994, fluvial grayling were stocked into the river approximately one mile north of Bozeman (T1S;R5E;Sec.36).

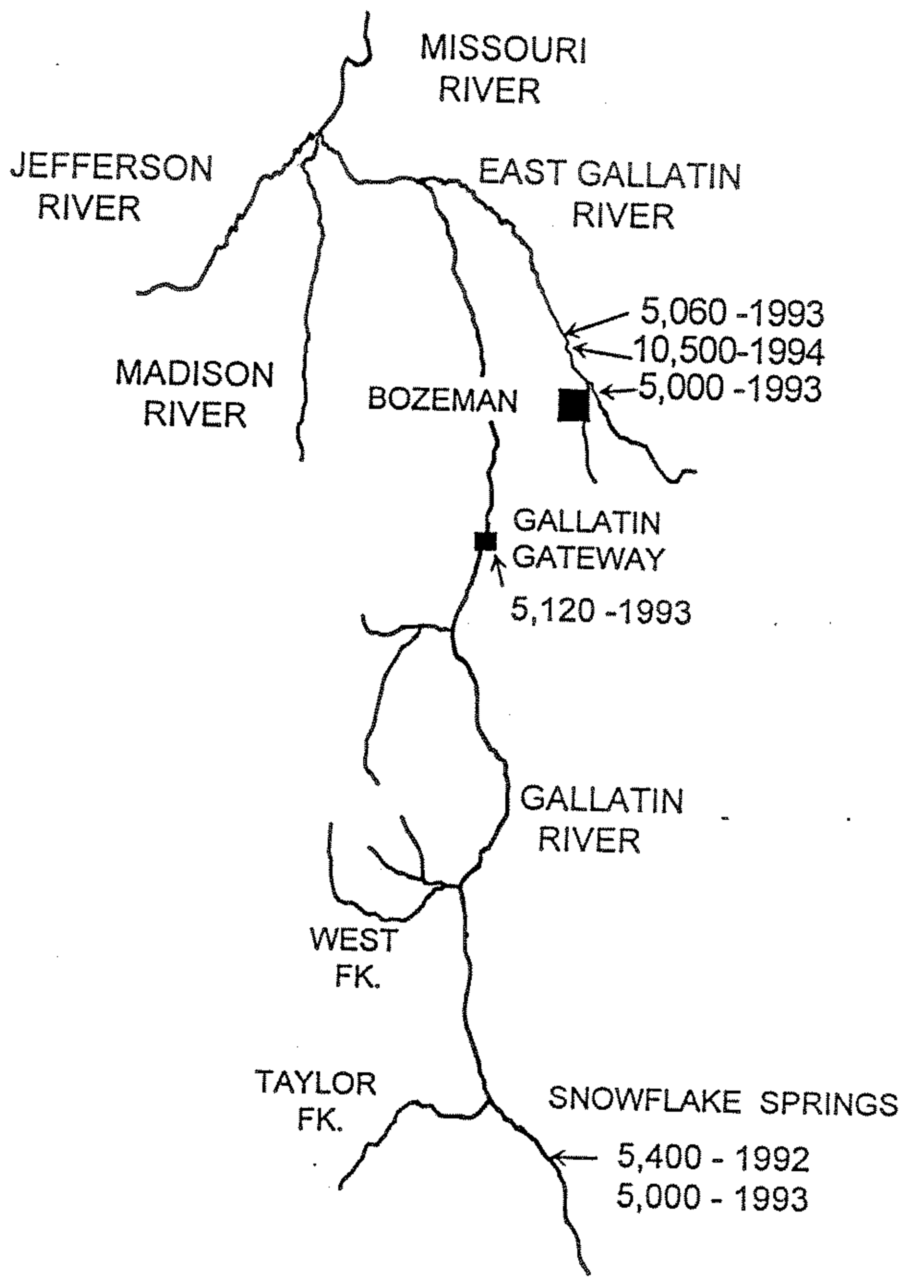

Figure 1. Map of the Gallatin and East Gallatin rivers showing fluvial Arctic grayling introduction sites.

Cherry Creek

Cherry Creek originates in the Madison Mountain Range approximately 10 miles northeast of the town of Ennis and flows northwesterly for approximately 21 miles before entering the Madison River (Figure 2). The estimated mean annual flow of Cherry Creek is about 35 ft^3/sec. (FWP 1989). With the exception of the headwaters, Cherry Creek flows through mostly private land with no public access. As a result, Cherry Creek receives very little fishing pressure.

Rainbow and brook trout are the only game fish found in the upper half of the stream. A waterfall located about 10 miles upstream from the mouth appears to act as a fish migration barrier. Downstream of this waterfall, brown trout and mountain whitefish are also found in the stream.

Grayling were introduced into a meadow section of Cherry Creek located approximately 11 miles upstream from the mouth in 1994 (T3S;R2E;Sec.23&26). This introduction site was located upstream from the barrier waterfall.

METHODS

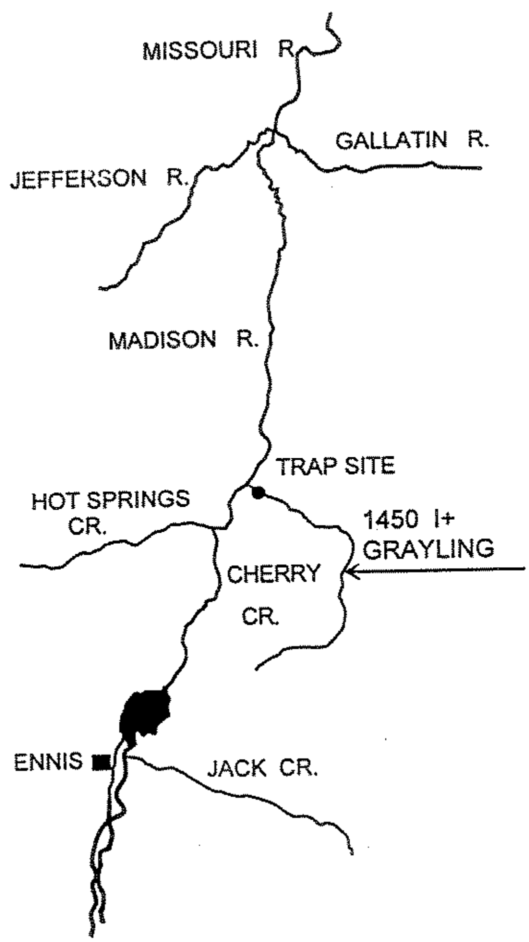

Figure.2. Map of Cherry Creek showing the fluvial Arctic grayling introduction site.

Grayling Introductions

A summary of experimental grayling introductions are presented in Table 1. Fluvial grayling planted into the Gallatin and East Gallatin rivers were from Big Hole River stock. These fish originated from either eggs taken directly from the Big Hole River or eggs taken from a Big Hole grayling reserve located at Axolotl Lakes near Ennis (T7S;R2W;Sec.8). The grayling reserve is a lake containing Big Hole grayling that have matured to an age where eggs can be taken. Eggs taken from both the river and reserve were reared at the Bozeman Fish Technology Center in Bozeman by the U.S. Fish and Wildlife Service. Grayling stocked into the two Gallatins were considered surplus fish as a result of efforts being undertaken at the Bozeman Fish Technology Center to develop a genetically diverse brood stock. These surplus grayling were considered to have limited genetic diversity since brood stock development has not yet been completed. All grayling stocked into the two Gallatins were yearling fish, ranging from approximately four to eight inches in total length.

All grayling planted into the Gallatin River in 1992 were marked with a coded wire tag placed in the snout of the fish (Table 2). In 1993, all grayling stocked in the Gallatin River near Gallatin Gateway received an adipose clip prior to stocking. In addition, all grayling planted into the East Gallatin River near Riverside received a right pelvic clip prior to stocking. In 1994, approximately 5,500 of the 10,500 grayling stocked into the East Gallatin River were held in two large live cars for approximately two days prior to being released into the river. Grayling held in the live cars were marked with an adipose fin clip prior to stocking.

Grayling planted into Cherry Creek were from Madison River stock. Eggs were taken from a reach of the Madison River located about one mile upstream of Ennis Lake. These eggs were from a limited parentage, consisting of approximately six females and 10 males. Eggs taken from the Madison River were reared mostly at the Bozeman Fish Technology Center, although they also spent a small portion of time at a couple of Montana Department of Fish, Wildlife and Parks hatcheries. Due to their limited parentage, these fish were considered to have limited genetic diversity. Grayling stocked into Cherry Creek were yearling fish, ranging from approximately four to eight 8 inches in total length.

Approximately 830 of the 1,450 grayling stocked into Cherry Creek were held in two large live cars for approximately two days prior to being released into the stream. Grayling held in the live cars were marked with coded wire tags placed behind the dorsal fin prior to stocking (Table 2). In attempt to improve survival of newly stocked grayling, a one mile section of Cherry Creek was electrofished five days prior to stocking with a mobile "Crawdad" system to remove as many brook trout and rainbow trout from the stream as possible. Electrofishing efforts removed approximately 2,165 brook trout and 1,310 rainbow trout. Although not measured, collected brook trout averaged approximately 6 inches in total length. Rainbow trout averaged about 8 inches in total length. Population estimates conducted by a private consulting firm in 1990 estimated about 5,000 trout per mile in this reach of Cherry Creek (unpublished data). Comparing the total number of trout removed to the population estimate indicated removal efforts were approximately 70% efficient.

Evaluation Efforts

Evaluation efforts for experimental grayling introductions have focused on survival, dispersion and growth. In the Gallatin River, evaluation efforts relied solely on a voluntary angler return program. News releases in local papers and signing at most fishing access points were used to inform anglers fishing the Gallatin River about the grayling introductions. Anglers catching grayling in the river were requested to voluntarily report to FWP where the fish was caught using the nearest highway road mile marker, when the fish was caught, an approximate length and any observation of missing fins.

For the East Gallatin River, evaluation efforts relied primarily on incidental catch of grayling through electrofishing. Electrofishing efforts were confined to a section of river starting at Riverside Bridge and

Table 1. A summary of experimental grayling introduction efforts undertaken in southwest Montana streams since 1992.

YEAR	STOCKING DATE	RIVER	NUMBER OF FISH	AGE AND ORIGIN
1992	7/01	Gallatin	5,400	yearling Big Hole stock
1993	8/17	Gallatin	10,120	yearling Big Hole stock
	8/17	East Gallatin	10,000	yearling Big Hole stock
1994	8/08	East Gallatin	10,500	yearling Big Hole stock
	7/19	Cherry Creek	1,450	yearling Madison stock

Table 2. Stocking locations and marking methods for experimental grayling plants in southwest Montana since 1992.

YEAR	RIVER	LOCATION	NUMBER OF FISH	MARKING METHOD
1992	Gallatin	Snowflake Sp.	5,400	Coded wire-snout
1993	Gallatin	Snowflake Sp.	5,000	None
		G. Gateway (Held)	5,120	Adipose clip
	E. Gallatin	Bozeman	5,000	None
		Riverside	5,058	Right Pelvic clip
1994	E. Gallatin	Reeves Rd (Held)	5,500	Adipose clip
		Reeves Rd	5,500	None
	Cherry Creek	Butler Sec. (Held)	830	Coded wire-dorsal plus adipose clip
		Butler Sec.	620	Adipose clip

extending downstream approximately two miles. Anglers were also requested through signing at major access sites to voluntarily report grayling catches to FWP.

Evaluation efforts on Cherry Creek were confined to operating a partial trap located near the mouth of the stream during August to monitor possible out migration of newly introduced grayling. The trap fence was constructed of cabled half inch conduit with half inch spacers. The trap fence and box extended across approximately 90% of the stream channel. The trap box was constructed using an angle iron framework with cabled conduit fence forming the sides. Limited voluntary angler returns also provided some data on grayling movement.

RESULTS

Gallatin River

Voluntary angler returns for grayling stocked into the Gallatin River at Snowflake Springs on July 1, 1992 and subsequently caught by hook and line are presented in Appendix Table 1. Anglers reported catching 121 grayling from the 1992 Gallatin River plant during 1992, 19 during 1993 and only one during 1994. The substantially lower returns reported in 1993 and 1994 indicate the possibility of poor survival, greater dispersion of stocked grayling and/or a decreasing interest by anglers in the program. Reported total lengths for angler caught grayling in 1992 averaged 6.9, 7.4 and 8.9 inches for July, August and September, respectively. During 1993, grayling up to 14.0 inches in total length were reported being caught by anglers.

Grayling stocked at Snowflake Springs in 1992 were found to disperse downstream at a fairly rapid rate (Figure 3). Grayling moved downstream an average distance of 15, 26, 48, and 52 miles for July, August, September and October, respectively. The maximum observed distance moved by an individual grayling was 111 miles. This fish moved approximately 75 miles down the Gallatin to the mouth of the East Gallatin River and then 36 miles upstream into the East Gallatin River.

Voluntary angler returns for grayling stocked into the Gallatin River at Snowflake Springs and Gallatin Gateway on August 17, 1993 and subsequently caught by hook and line are presented in Appendix Table 2. Anglers reported catching only 33 grayling from the 1993 Gallatin River plant during 1993 and none during 1994. All of the angler returns were reported during the last half of August or during September. The number of angler returns for the 1993 grayling plant were substantially less than returns for the 1992 plant. Poorer angler returns in 1993 may, in part, have been due to poor survival of stocked fish or to reduced interest in the program by anglers fishing the Gallatin River. Grayling from the 1993 plant that were caught by anglers during 1993 averaged approximately 5.9 inches.

East Gallatin River

Grayling relocations from electrofishing efforts on a two mile section of the East Gallatin River during October 1993 and 1994 are presented in Table 3. In the fall of 1993, 58 grayling were recaptured by electrofishing in the East Gallatin River. These fish were originally stocked on August 17, 1993 at two locations on the river separated by approximately two river miles. Of the 58 grayling recaptured in 1993, 29 were fish originally stocked at Riverside Bridge and 29 were fish originally stocked on the north border of Bozeman. Some grayling were dispersing at least two to three miles downstream following approximately 2 months after stocking. Grayling recaptured in October, 1993 averaged 7.1 inches in total length, ranging from 5.2 to 8.6 inches.

In 1994, 163 grayling were recaptured by electrofishing. Only two of these fish were from the 1993 plant, indicating either poor survival or substantial dispersal following stocking. Of the 160 recaptured grayling originally stocked in 1994, about 56% were fish that had been held in live cars for approximately two days prior to being released into the river and 44% were fish stocked into the river without acclimation. These data suggest grayling held for acclimation may either exhibit better survival or have less of a tendency to disperse downstream. Grayling recaptured in October, 1994 averaged 7.0 inches, ranging from 5.5 to 8.4 inches.

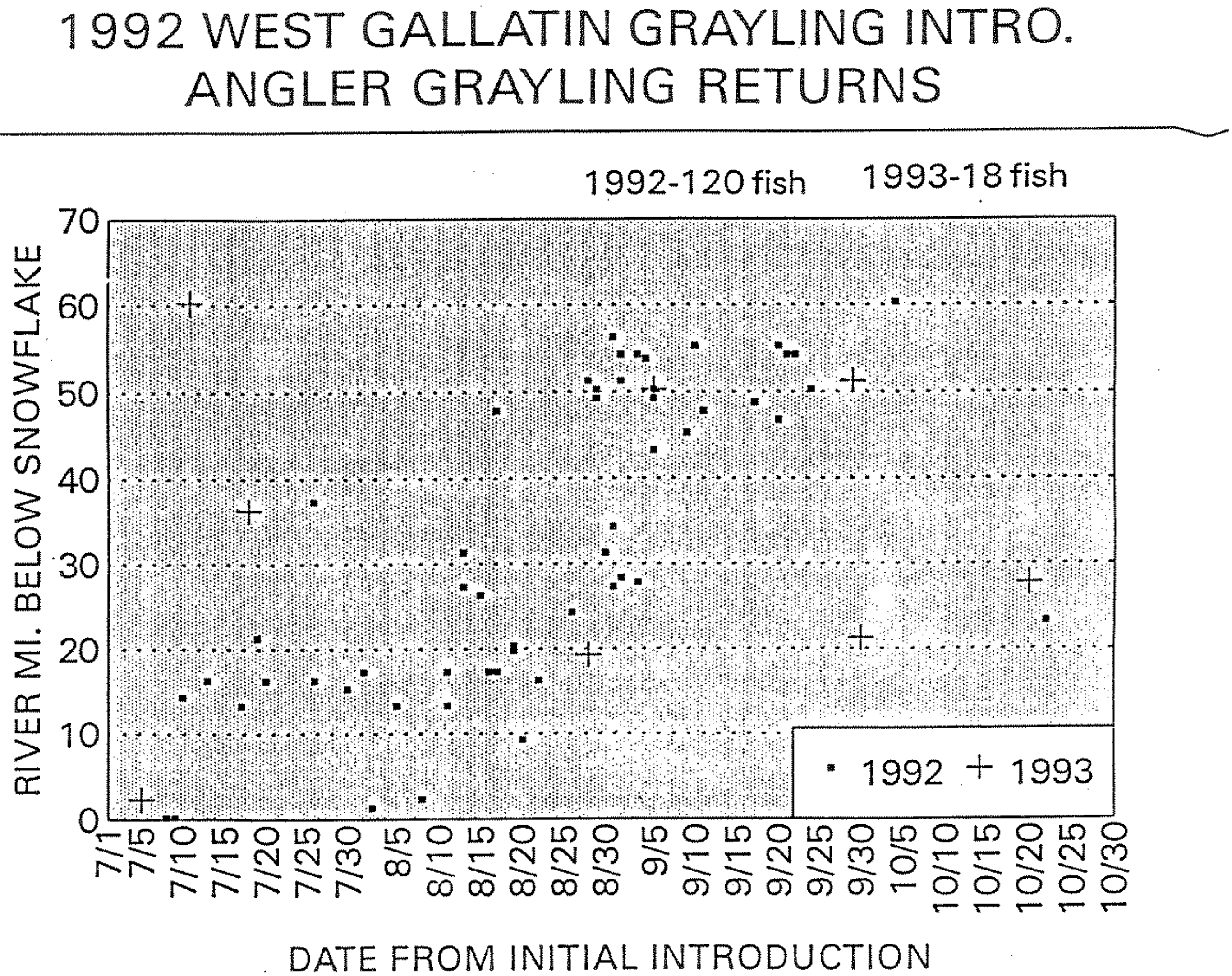

Figure 3. Downstream dispersion of fluvial Arctic grayling following initial introduction into the Gallatin River.

Table 3. Grayling relocations from electrofishing efforts conducted on a two mile section of the East Gallatin River located immediately downstream of Riverside Bridge during the fall of 1993 and 1994.

YEAR	NUMBER STOCKED RIVERSIDE	BOZEMAN	NUMBER OF GRAYLING RECAPS IN 1993	RECAPS IN 1994
1993	5,120	5,000	58	2
1994		10,500		161

Only 30 grayling were reported being caught by anglers in the East Gallatin River since stocking began in 1993. Twenty seven of these fish, with 20 reported by a single angler on September 28, 1994, were caught in the Riverside area. Angler returns are likely limited in the East Gallatin River as a result of restricted access onto private lands and the associated relatively light fishing pressure that the river receives. The maximum downstream movement observed by a grayling in the East Gallatin River was approximately 18 miles. Interestingly, a grayling was reported caught in Glen Lake, a gravel pit pond near Bozeman that is connected to the East Gallatin River by only a small drainage ditch. This grayling either traveled upstream in the ditch to enter the lake or was illegally transplanted by an angler. Grayling caught by anglers in the East Gallatin River averaged 5.9 inches in total length (from estimates reported by anglers).

Cherry Creek

Evaluation efforts on Cherry Creek have been limited because of the recent nature of the grayling introduction. A trap, located approximately nine miles downstream from the grayling introduction site near the conjunction with the Madison River, was operated from July 25 through August 29, 1994 to monitor possible downstream dispersion of newly introduced grayling. No grayling were captured while the trap was operated. Future evaluation efforts on Cherry Creek will focus on attempts to recapture grayling in the stream through electrofishing.

DISCUSSION

Although evaluation efforts have been limited, experimental introductions of fluvial Arctic grayling into the Gallatin and East Gallatin rivers and into Cherry Creek have provided a better understanding of survival, movement and growth following stocking. Newly introduced grayling into the Gallatin River appeared to exhibit a strong tendency to disperse downstream. The apparent downstream dispersion of grayling that were stocked into the upper Gallatin River may have been due to unsuitable habitat. The grayling appeared to move from the steeper gradient and faster velocities found in the upper river to the gradual gradient and slower velocities found in the lower river. However, upstream movements were not well documented because the voluntary angler return program ended at the border of Yellowstone National Park which is located about 1 mi upstream of the 1992 and 1993 introduction site (Snowflake Springs). Although data are lacking, grayling may be making spawning movements into the headwaters of the Gallatin. Lynn Keading from the National Park Service (pers. comm.) reported that grayling were caught from the Gallatin River within Yellowstone National Park at a much higher incidence in 1994 than in previous years. A majority of these grayling were reported to be of sufficient size for sexual maturity (12 inches and greater).

Grayling that moved downstream into the lower Gallatin River apparently have exhibited poor survival based on the scarce angler returns obtained in 1993 and 1994. Abundant brown trout and rainbow trout populations may make the lower Gallatin River inhospitable for fluvial Arctic grayling. Criteria developed by Kaya (1992) for assessing the reintroduction potential of Montana streams for fluvial Arctic grayling avoided water containing abundant non-native trout, especially brown trout. As a result, Kaya did not identify the Gallatin River as a potential introduction site.

The attempt at acclimating newly stocked grayling to the East Gallatin River prior to release appeared to slow the tendency for downstream dispersion. Kaya (1991) showed that Big Hole River grayling tended to increasingly hold position in water current with increasing acclimation time. Acclimation time for grayling introduced into the East Gallatin River was limited to only two days. Future introductions should attempt to acclimate for longer periods of time to further reduce the tendency for downstream dispersion.

Survival of grayling stocked into the East Gallatin remains questionable. Although downstream dispersion may be a partial explanation, electrofishing efforts conducted in the fall of 1994 collected only two grayling from the 1993 plant. Again, abundant populations of rainbow trout and brown trout found in the East Gallatin River may make for an inhospitable environment for fluvial Arctic grayling. The East Gallatin River was not identified by Kaya as a potential restoration site.

Cherry Creek was identified by Kaya as a potential reintroduction site for fluvial Arctic grayling. Because of their uncertain status, the Fluvial Arctic Grayling Workgroup decided to limit grayling introduction efforts into Cherry Creek, at least in the near term, to the Madison River stock. Although data addressing the fluvial nature of the Madison River grayling appear to be unclear and contradictory, it remains important to continue with evaluation efforts to obtain a better understanding of survival and behavior of newly introduced Madison grayling into Cherry Creek. Results of these efforts will undoubtedly influence introduction efforts proposed for the future.

Additional experimental introductions of fluvial Arctic grayling are planned for 1995. Plans call for the East Gallatin River to receive additional yearling Big Hole stock grayling and for Cherry Creek to receive additional Madison stock grayling.

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Appendix Table 1. Voluntary angler returns for grayling stocked into the Gallatin River at Snowflake Springs (River mile 87.3) on July 1, 1992.

DATE	RIVER MILE	NUMBER OF FISH	DISTANCE MOVED (MI)	MEAN LENGTH (INCHES)
7-08-92	87.0	1	0.1	7.0
7-09-92	87.0	1	0.1	--
7-10-92	73.0	1	14.3	--
7-13-92	71.0	1	16.3	8.0
7-17-92	74.0	1	13.3	7.0
7-19-92	66.0	1	21.3	5.0
7-20-92	71.0	1	16.3	8.0
7-26-92	50.0	1	37.3	7.5
7-26-92	71.0	1	16.3	--
7-30-92	72.0	2	15.3	5.5
8-01-92	70.0	1	17.3	6.0
8-02-92	86.0	1	1.3	10.0
8-05-92	74.0	1	13.3	8.5
8-08-92	85.0	4	2.3	7.0
8-11-92	70.0	1	17.3	7.5
8-11-92	74.0	2	13.3	--
8-13-92	60.0	1	27.3	6.5
8-13-92	56.0	1	31.3	6.5
8-15-92	61.0	1	26.3	--
8-16-92	70.0	1	17.3	--
8-17-92	70.0	4	17.3	8.5
8-17-92	39.5	1	47.8	6.0
8-19-92	67.0	1	20.3	9.5
8-19-92	67.5	3	19.8	--
8-20-92	78.0	2	9.3	6.5
8-22-92	71.0	7	16.3	7.5
8-26-92	63.0	1	24.3	8.0
8-28-92	36.0	12	51.3	10.5
8-29-92	37.0	1	50.3	--
8-29-92	38.0	2	49.3	6.0
8-30-92	56.0	1	31.3	4.5
8-31-92	53.0	1	34.3	--
8-31-92	31.0	2	56.3	--
8-31-92	60.0	1	27.3	--
9-01-92	36.0	2	51.3	9.0
9-01-92	33.0	4	54.3	--
9-01-92	59.0	2	28.3	--
9-03-92	33.0	7	54.3	--
9-03-92	59.5	1	27.8	--
9-04-92	33.5	1	53.8	7.5
9-05-92	37.0	10	50.3	10.0
9-05-92	38.0	3	49.3	10.0
9-05-92	44.0	4	43.3	10.0

Appendix Table 1. Cont.

DATE	RIVER MILE	NUMBER OF FISH	DISTANCE MOVED (MI)	MEAN LENGTH (INCHES)
9-09-92	42.0	1	45.3	9.5
9-10-92	32.0	1	55.3	--
9-11-92	39.5	1	47.8	9.0
9-17-92	38.5	6	48.8	8.0
9-20-92	40.5	3	46.8	--
9-20-92	32.0	1	55.3	7.0
9-21-92	33.0	3	54.3	--
9-22-92	33.0	1	54.3	--
9-24-92	37.0	1	50.3	--
10-04-92	27.0	2	60.3	8.5
10-14-92	**	1	123	9.0
10-22-92	64.0	1	23.3	--
11-28-92	62.0	1	25.3	10.0
1-21-93	78.0	5	9.3	8.0
4-03-93	39.0	1	48.3	9.0
4-06-93	24.0	1	63.3	--
7-05-93	85.0	1	2.3	--
7-11-93	27.0	1	60.3	11.0
7-18-93	51.0	3	36.3	10.0
8-14-93	53.0	1	34.3	9.0
8-28-93	44.0	1	43.3	14.0
8-28-93	68.0	1	19.3	11.0
8-30-93	?	1	?	11.0
9-29-93	36.0	1	51.3	10.5
9-29-93	66.0	1	21.3	9.0
10-20-93	59.5	1	27.8	13.5
9-5-94	37.0	1	50.3	14.0

** Grayling moved into the East Gallatin River.

Appendix Table 2. Voluntary angler returns for grayling stocked into the Gallatin River at Snowflake Springs (River mile 87.3) and Gallatin Gateway (River Mile 39.5) on August 17, 1993.

DATE	RIVER MILE	NUMBER OF FISH	DISTANCE MOVED (MILES)	MEAN LENGTH (INCHES)
8/17/93	87.3	12	0.0	6.0
8/21/93	39.5	3	0.0	8.0
8/25/93	79.0	8	8.3	5.0
9/3/93	85.5	3	1.8	6.0
9/3/93	34.0	2	5.5	6.0
9/3/93	33.0	1	6.3	5.5
9/5/93	39.5	1	0.0	5.0
9/5/93	66.0	3	21.3	5.5

BEHAVIORAL RESPONSES TO WATER CURRENT OF AGE-0 ARCTIC GRAYLING (Thymallus arcticus) FROM THE MADISON RIVER, AND THEIR USE OF STREAM HABITAT

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ABSTRACT

Behavioral trials and field observations were conducted on age-0 Arctic grayling from the Madison River/Ennis Reservoir (ME) population, to determine their riverine residence and characteristics. Field observations in 1994 indicated that age-0 ME grayling inhabited backwater pockets of the Madison River above Ennis Reservoir for about 38 days after becoming free swimming. They then disappeared from the river, and were collected by seining among beds of macrophyte vegetation in the reservoir. Downstream movements of age-0 grayling from the ME, Upper Red Rock Lake (RR), and Big Hole River (BH) populations were compared in Deep Creek, a tributary of the Missouri River, after they were incubated and reared together in the Fish Technology Center (FTC), U.S. Fish and Wildlife Service, Bozeman. All Big Hole River young were F_1 of parents originating as fertilized eggs from wild fish, but reared in Axolotl Lake (F_1AL) or at the FTC (F_1BZ). Downstream movement of released fish was monitored by nets at a weir about 1 km downstream from the release site. After acclimation in the stream for 7-14 days prior to release, age-0 RR and ME grayling had much higher tendencies to move downstream ($p<0.005$) than F_1 BH grayling. In each of four electrofishing surveys in Deep Creek after conclusion of behavioral trials, much greater numbers ($p<0.005$) of BH fish were recovered than ME or RR fish. Both behavioral trials and field observations indicate that, at least during their initial four months after swimup, the behavior and distribution of Madison/Ennis grayling are more characteristic of adfluvial lacustrine fish, rather than fluvial fish.

Arctic grayling, Thymallus arcticus, inhabiting Ennis (Madison) Reservoir may represent a residual population originating from fish in the Madison River prior to the construction of the dam in 1900. Although this population now appears lacustrine, with an adfluvial life history (living in the reservoir and ascending the river to spawn), adult grayling appear present in the river during non-spawning periods. Occasional specimens are captured in electrofishing surveys and by fishermen (R. Vincent, P. Byorth, P. Clancey, FWP, pers. comm.) between the reservoir and the West Fork of the Madison River. The extent to which grayling in the upper Madison River are fluvial in their life histories is not known, and would be of considerable relevance to the status of fluvial Arctic grayling in Montana. Distribution and numbers of fluvial Arctic grayling, defined as those spending their entire lives within riverine environments, have undergone a severe reduction in Montana (Vincent 1962; Kaya 1992), and the only known remnant population is in the Big Hole River. The objective of this study was to determine the life history of age-0 Arctic grayling in the Madison River above the reservoir, and to experimentally compare a critical aspect of their fluvial behavior--their tendency to remain within or move out of a stream--with those of grayling from the Big Hole River.

METHODS

Observations in the Madison River and Reservoir

Observations of age-0 grayling in the braided channels above the reservoir were initiated on 25 May, 1994 and continued until 12 July. The margins of the channels were visually searched for the presence of fry, from about 5 km above the reservoir at the start of Fletcher Channel, to the reservoir (Fig. 1). These channels, including "Grayling Alley", are the locations where ripe adults are most frequently captured and thus, appear to be the principal spawning areas (Byorth and Shepard 1990, P. Clancey, pers. comm.). Age-O young observed visually were sampled with a dip net to confirm their identities and for measurements. Backwaters and other slow moving waters were also sampled with a 30-ft, fine-meshed seine. A stationary drift net was placed at the lower end of "Grayling Alley", approximately 2.5 km above the reservoir (Fig. 1), starting from May 25. On July 12, the main river channels, including "Grayling Alley", were electrofished to search for age-0 and older grayling. Data on river flow into the reservoir and water temperature a short distance above "Grayling Alley" were obtained from the Montana Power Company.

Observations of age-0 grayling in the reservoir were initiated on 16 June and continued until 31 August. Grayling were collected with a seine along and near the shore, in depths of up to about 1.3, and with a purse seine in waters further off-shore, in depths of about 2 to 10 m.

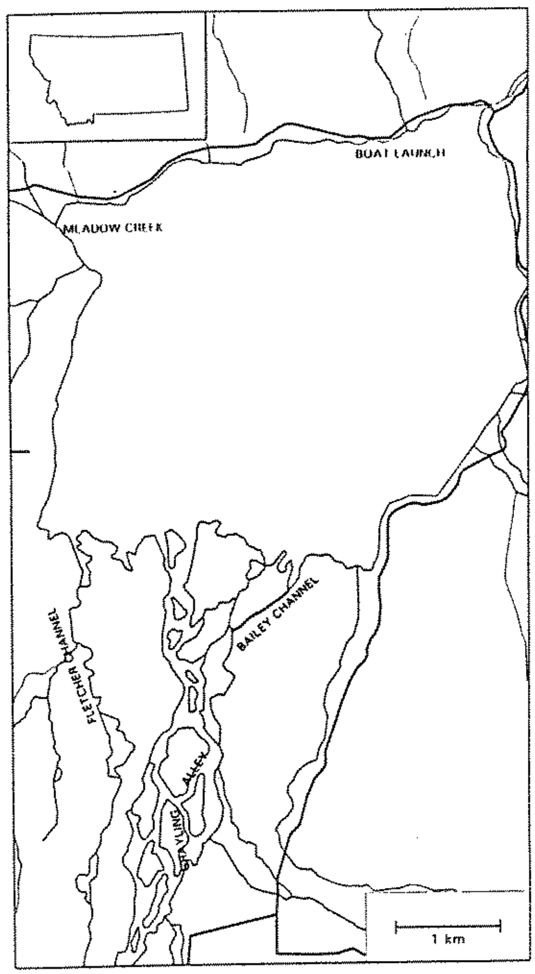

Figure 1. Map of the Madison Reservoir and the Madison River channels.

Field Trials in Deep Creek

To produce age-0 fish for field trials, fertilized eggs were obtained by stripping gametes from ripe adults captured from the Madison River/Ennis Reservoir (1993 and 1994), and Upper Red Rock Lake (1993) populations, and from Big Hole River broodstock in Axolotl Lake (1993) and at the Fish Technology Center (FTC), U.S. Fish and Wildlife Service, Bozeman. The adults in Axolotl Lake and the FTC originated as gametes from wild fish captured in the Big Hole River, and the progeny are hereafter referred to as either F_1AL (from Axolotl Lake) or F_1BZ (from FTC in Bozeman). The 1993 Madison/Ennis (ME) embryos and young were incubated and reared in state hatcheries, first at Big Timber and then at Great Falls. All other embryos and young-- the 1994 ME, the Upper Red Rock (RR), F_1AL, and F_1BZ--were incubated and reared at the Fish Technology Center (FTC).

Groups of young from each source were identified by being fin-clipped at the hatcheries. Fins clipped were pelvic, anal, adipose, and upper and lower lobes of the caudal fin. From one day to over a week later, groups of marked fish were taken to Deep Creek and placed into a holding pen located about 0.6 mile (about 1 km) upstream from a weir. Deep Creek is a tributary of the Missouri River, and is located near Townsend, Montana. Fish were released from the holding pen after 1 day to 14 days of acclimation. Those acclimated for only one day were not fed, while those held longer were fed on fine grained trout pellets. They fed readily and mortalities were very low during acclimation.

All releases occurred at about noon. Stream discharge, temperature, and turbidity on release dates are presented in Table 1. Temperatures were monitored with a Taylor recording thermograph located upstream from the weir, and turbidity was measured on acclimation and release dates with a Hach Model 16800 meter. Discharge was monitored at a gauging station located upstream from the weir. Gauge heights were calibrated against measurements of discharge volume at a transect site nearby. An electronic current meter was used to measure water velocities at the transect site.

Fry moving downstream were trapped at the weir with large drift nets. In 1993, about 9% of total stream flow was estimated to pass through each of the two or three nets used. In 1994, with reduced stream flows and with screens placed to prevent passage of fry through flow not sampled by drift nets, all fry moving down through the weir were directed into the nets. Fry traps at the weir were examined at 2-hour intervals until about sunset on the day of release, then at about sunrise the next morning, and then at least daily during the following two or more days. The stream reach between the weir and release site was surveyed by electrofishing, 9 and 11 days after the last trials of 1993, and 18 and 25 days after 1994 trials.

Numbers of fish from the different sources recovered at the weir in each trial and in each electrofishing survey of the stream were compared by chi-square analysis. Mean sizes of fish from different sources recovered in each trial were compared by one-way analysis of variance. For all comparisons, differences were considered significant when $p<0.01$.

The field observations, spawn-taking, incubation and rearing of young, and field trials were conducted with the cooperation and participation of personnel from Montana Fish, Wildlife & Parks, U.S. Fish and Wildlife Service, Montana State University, and Montana Power Company.

Table 1. Temperature, discharge, and turbidity of Deep Creek on dates of release of age-0 Arctic grayling from Upper Red Rock Lake, Ennis Reservoir, and F_1 Big Hole River populations, acclimated for 1-14 within an instream holding pen.

Release Date	Temp. °C	Volume m^3/s	Turbidity NTU
09 Aug 1993	15.8	1.81	31
14 Aug 1993	12.2	1.25	21
28 Aug 1993	13.0	2.30	32
09 Sep 1993	14.8	2.30	20
17 Sep 1994	19.4	0.62	21
24 Sep 1994	12.2	0.62	10

RESULTS

Observations in the Madison River and Reservoir

Age-0 Arctic grayling were seen on the first day of observations, on 25 May, in the "Grayling Alley" area. They averaged 21 mm in total length and, based on comparisons with ME fish incubated and reared at the FTC, appeared to be about 7-10 days post swimup in age. Embryos produced from gametes stripped from ripe fish captured in the river on 18-19 April 1994, started to hatch at the FTC on 5 May, and swimup of fry was observed on 16 May. Incubation and rearing temperatures at the FTC were about 10°C, similar to river temperatures during this period.

Observations on age-0 grayling in the river continued from 25 May until they disappeared about 21 June (Table 2). Age-0 grayling were seen throughout the lower 3.5 km of the Madison River above the reservoir, up to about 1.25 km below the formation of Fletcher Channel (Fig. 1). They were observed throughout the lower river, including in Fletcher Channel and the other channels of the river, with the exception of "Bailey Channel". They were most prevalent in the "Grayling Alley" area where ripe adults had also been most frequently collected in April by electrofishing.

Rearing habitat for age-0 grayling consisted of backwaters along the margins of the braided channels or "slackwater" created by mid-channel bars or debris and vegetation along banks. They had no apparent preference for depth, temperature, or type of cover used. They were seen most frequently in backwaters, and "slackwater" areas may have provided temporary shelter for fish moving downstream, or from one backwater to another.

In the backwater habitats, age-0 grayling were initially present in monospecific groups of 7 to 25. By the second and third weeks in June, when they had reached approximately 40 mm in total length they were found in mixed groups of grayling and mountain whitefish (Prosopium williamsoni). The age-0 grayling were observed feeding on surface food from the first day they were seen, on 25 May, until they disappeared about 21 June.

Table 2. Mean and range of total lengths (mm) of age-0 Arctic grayling and mountain whitefish in the Madison River, 25 May to 21 June, 1994.

	Grayling				Whitefish				
Date	Mean	(±SD)	Range	N	Mean	(±SD)	Range	N	Hab.
26 May	21	(3)	17-26	14	-		-	-	B.W.[1]
27 May	21	(4)	15-29	9	-		-	-	B.W.[2]
27 May	18		18	1	-		-	-	B.W.[3]
31 May	-		-	7-10[5]	-		-	-	B.W.[4]
2 June	-		-	20-25[5]	-		-	-	B.W.[2]
3 June	32	(3)	29-36	4	-		-	-	B.W.[2]
7 June	-		-	6[5]	-		-	-	M.C.B.[6]
7 June	35		35	1	-		-	-	D.N.[7]
8 June	38	(2)	36-40	3	-		-	-	M.C.B.[6]
9 June	37	(5)	29-45	15	42	(2)	40-46	7	B.W.[2]
13 June	42	(3)	39-46	4	-		-	-	B.W.[4]
16 June	51	(4)	48-55	3	54	(6)	47-59	3	B.W.[4]
21 June	57	(3)	54-60	4	50	(4)	38-58	24	B.W.[1]

[1]Collected with a macroinvertebrate kick net and a seine in backwaters of "Grayling Alley".
[2]Collected with a macroinvertebrate kick net and a seine in backwaters of Fletcher Channel.
[3]Collected with ichthyoplankton drift nets in thalweg of "Grayling Alley".
[4]Collected with a macroinvertebrate kick net and a seine in backwaters of the main channel of the Madison River.
[5]Visual observations in the Madison River.
[6]Collected with a macroinvertebrate kick net and a seine behind mid-channel bars of the main channel of the Madison River.
[7]Collected with ichthyoplankton drift nets in thalweg of Fletcher Channel.

The thalwegs of river channels were not thoroughly surveyed, because visual observations and fry sampling techniques were not effective in deeper, faster water. No grayling were collected from such habitat when the main channel was electrofished on 12 July. Only two age-0 young were captured in the drift net before it was removed on 17 June.

Age-0 grayling disappeared from backwaters on or around 21 June, concurrent with a substantial decrease in river discharge volume and increase in river temperature (Fig. 2). Mean daily temperatures increased from about 10-14 °C to about 16-17 °C. Age-0 mountain whitefish which had become common in the same habitats also disappeared at the same time.

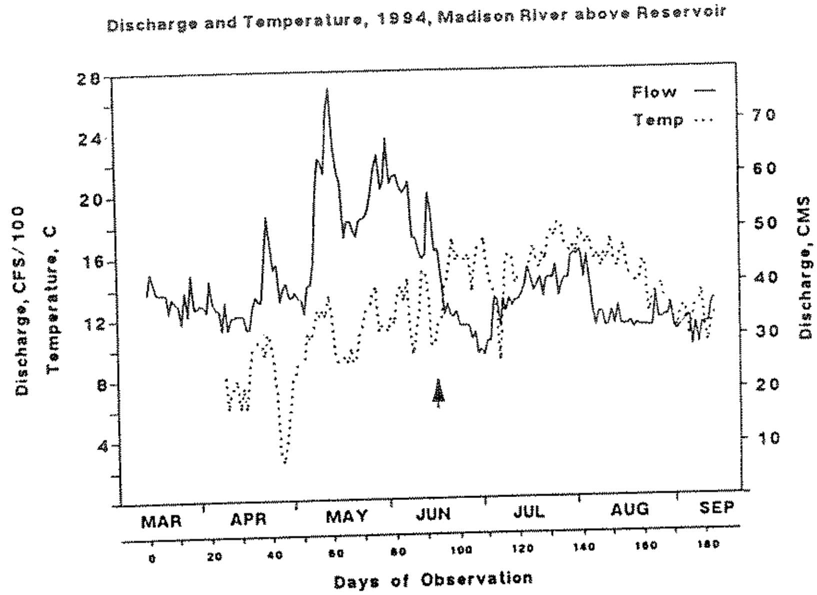

Figure 2. Discharge volume and mean daily temperatures in the Madison River above Ennis (Madison) Reservoir, 1994. The arrow indicates the approximate date (June 21) when age-0 grayling disappeared from the river and apparently migrated downstream to the reservoir.

Total lengths of age-0 grayling sampled in the river ranged from about 17-26 mm on 26 May near the start of observations, and 57-60 mm on 21 June as they disappeared from the river (Table 2, and Fig. 3). The relationship between total length (TL, in mm) and observation day (OD) during this stream residence was:

$$TL = 19.75 + 1.27OD; \; r = 0.896, \; df = 56$$

Observation day-0 is defined as the day when age-0 grayling were first seen, on 25 May.

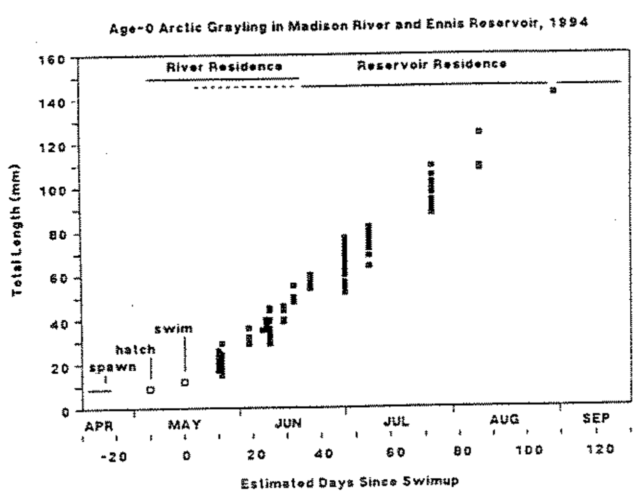

Figure 3. Distribution and sizes of age-0 Arctic grayling in the Madison River above Ennis (Madison) reservoir and in the reservoir, May through August, 1994. Also depicted are the spawning period, as indicated by captures of ripe adults in the river, and approximate dates and fish sizes at hatching and swimup, as indicated by embryos and larvae originating from fish artificially spawned at the river and incubated at the Fish Technology Center.

Initial surveys for age-0 grayling in the reservoir were conducted with seines from 16 June to 26 July, primarily along the north, west, and southeast shores. Age-0 grayling were first seen in the reservoir on 16 June (Table 3), in a shallow bay located 0.5 km west of the inlet of the main channel of the Madison River (Fig. 1). On this date, age-0 grayling were still present in the Madison River channels. In subsequent surveys in July and August, age-0 grayling were commonly taken among the macrophyte beds near the inlets of the main channels of the Madison River, the inlet of Fletcher Channel, west of the inlet of Bailey Channel, and the inlet of Meadow Creek. Typical habitats consisted of shallow, open water areas among the macrophyte vegetation. There was no indication of preference for particular types of macrophytes; most macrophyte beds consisted of mixtures of species and of broad-and narrow-leaf forms. Mountain whitefish were consistently captured in seines together with grayling.

No grayling were captured from near-shore areas starting east of the Baily Channel inlet, continuing around the east shore to the outlet of the reservoir toward the dam, and along the north shore to the boat launching area approximately 0.75 km west of the bridge (Fig. 1). These parts of the reservoir margin are typically deeper and without the extensive beds of macrophytes characteristic of the west and southwest areas.

Later seining (1 August-31 August) again yielded age-0 grayling in shallow, near-shore areas from the inlets of the Madison River channels to Meadow Creek. However, by this time the macrophyte vegetation had grown so thick that effectiveness of seining was substantially reduced.

A purse seine became available and was used from 10-31 August to sample the deeper, open waters. No grayling were captured in this type of habitat, but there were problems in trying to sample fish in such waters. Attempts to sample grayling in this type of habitat should be continued in the future.

Total lengths of age-0 grayling captured in the reservoir ranged from 52 to 77 mm on 1 July, to 142 mm on 31 August (Table 3, and Fig. 3). The relationship between total length (TL, in mm) and observation day (OD) for age-0 grayling in the reservoir was:

$$TL = 20.27 + 1.24OD; \quad r = 0.871, \ df = 68$$

Growth rates did not differ significantly between fluvial and lacustrine residence stages ($t = -0.32$, $p = 0.727$).

Field Trials in Deep Creek

All but 7 of 571 fish recovered at the weir in 1993, and 260 of 309 recovered at the weir in 1994, were netted between their release at noon and the following sunrise. Therefore, we based our comparisons of downstream movement of fish on numbers recovered at the weir by the first sunrise after release (Table 4). The ratio of 9 F_1BZ to 40 ME fish among the 49 fish captured later in 1994, over the following two days, would not change the results of comparisons between fish from these two sources.

More age-0 RR or ER fish than fluvial F_1AL or F_1BZ fish were recovered downstream at the weir in each trial ($p<0.005$), except in the first of the two 1-day acclimation trials, on 14 August 1993 (Table 4). The differing tendencies of the F_1AL (F_1 Big Hole River) and RR (Upper Red Rock Lake) fish to move downstream in Deep Creek were consistent with results of laboratory trials on age-0 fish from these same two native populations (Kaya 1991). The lesser tendency of age-0 F_1 fluvial fish to move downstream, compared to age-0 RR or ME fish, was evident in both 1993 and 1994 despite the differences in stream conditions and in sizes of fish tested between the 2 years.

Table 3. Mean and range of total lengths (mm) of age-0 Arctic grayling and mountain whitefish in Madison River, 16 June to 1 September, 1994.

	Grayling				Whitefish				
Date	Mean	(+SD)	Range	N	Mean	(+SD)	Range	N	Hab.
16 June	58	(1)	57-59	2	60	(1)	59-60	2	S.W.[1]
1 July	66	(6)	52-77	35	63	(7)	45-81	36	S.W.[2]
8 July	69		69	1	65	(7)	57-70	3	S.W.[2]
8 July	77	(3)	72-79	4	74	(7)	63-80	5	S.W.[3]
8 July	70	(6)	64-74	3	73	(5)	63-80	5	S.W.[4]
8 July	77	(4)	69-82	9	69	(7)	60-85	37	S.W.[1]
8 July	56	(9)	69-82	3	79	(3)	77-81	2	S.W.[5]
8 July	-		-	-	73		73	1	S.W.[6]
26 July	-		-	-	74		74	1	S.W.[2]
26 July	99	(7)	92-109	7	82	(6)	74-92	19	S.W.[3]
26 July	94	(4)	91-97	2	83	(5)	76-87	6	S.W.[1]
26 July	88		88	1	80	(5)	76-83	2	S.W.[5]
10 Aug	114	(9)	108-124	3	93	(6)	87-106	15	S.W.[3]
10 Aug	-		-	-	101		88-114	2	S.W.[7]
10 Aug	-		-	-	102	(9)	93-110	3	S.W.[8]
10 Aug	-		-	-	93		90-95	3	S.W.[1]
11 Aug	-		-	-	97	(4)	92-102	6	S.W.[5]
31 Aug	142		142	-	103		103	1	S.W.[3]
1 Sept	-		-	-	109		101-115	6	S.W.[5]
1 Sept	-		-	-	103		92-121	27	S.W.[8]

[1]Collected in the shallow water habitats with a beach seine near the mouth of Fletcher Channel.
[2]Collected in shallow water habitats with a beach seine near the mouth of Meadow Creek.
[3]Collected in shallow water habitats with a beach seine on the North shore of Meadow Creek Bay.
[4]Collected in shallow water habitats with a beach seine near Klutes Landing.
[5]Collected in shallow water habitats with a beach seine near the mouth of Bailey Channel.
[6]Collected in shallow water habitats with a beach seine near the mouth of Jourdain Creek.
[7]Collected in shallow water habitats with a beach seine near Lake Shore Lodge on the north shore of Madison Reservoir.
[8]Collected in shallow water habitats with a beach seine near the mouth of the main channel of the Madison River.

Effects of 1 day versus 7-14 day acclimation prior to release in 1993 differed between RR and F_1AL fish. Much higher numbers and percentages of both RR and F_1AL fish were recovered in the first of two 1-day acclimation trials (14 August) than in other trials (Table 4). Recoveries of fish from both sources were nearly identical ($p>0.500$) in the first 1-day acclimation trial. For RR fish, effects of acclimation among the remaining three trials in 1993 were inconsistent. Acclimation period had a more consistent effect on fluvial fish; fewer and lower percentages of F_1AL fish were recovered at the weir in both 7-14-day acclimation trials in 1993 than in both 1-day acclimation trials (Table 4). There was no paired comparison, with simultaneous acclimation and release, involving ME fish acclimated for only 1 day. Both trials in 1994, with ME and F_1BZ fish, involved acclimation of 7 days.

In all trials, downstream movement occurred predominantly during the first night following their release. Of 564 fish recovered at the weir by the first sunrise in 1993 (Table 4), only 19 were netted by the preceding sunset. All but 1 of these 19 were RR fish. In 1994, no fish appeared in nets at the weir by the first sunset.

Table 4. Downstream movement in Deep Creek of age-0 Arctic grayling from the Madison River/Ennis Reservoir (ME), Upper Red Rock Lake (RR) and Big Hole River populations after being simultaneously acclimated for 1 to 14 days. Fluvial fish are F_1 from parents reared in either Axolotl Lake (F_1AL), or at the Bozeman Fish Technology Center (F_1BZ). Downstream movement was monitored with nets at a weir 1 km downstream. Fish were released at noon and data indicate numbers recaptured by sunrise of the next day. Very few fish were captured at the weir after this initial period.

Fish Released at Noon				Released Fish Captured			
Origin	Acclimation (d)	Release Date	Number Released	Mean Length mm(SD)	Total	Percent of Fish Released	p[a]
RR	1	14 Aug 1993	594	58 (5)	175	29.5	
F_1AL	1	14 Aug 1993	542	63 (5)	176	32.5	>.500
RR	1	09 Sep 1993	317	50 (6)	43	13.6	
F_1AL	1	09 Sep 1993	318	55 (7)	15	4.7	<.005
RR	7	09 Aug 1993	549	51 (5)	52[c]	9.5	
ME[b]	14	09 Aug 1993	648	54 (4)	21[c]	3.2	
F_1AL	14	09 Aug 1993	550	46 (4)	5[c]	0.9	<.005
RR	11	28 Aug 1993	500	49 (5)	89	17.8	
F_1AL	11	28 Aug 1993	490	53 (5)	9	1.8	<.005
ME	7	17 Sep 1994	350	84 (6)	64[d]	18.3	
F_1BZ	7	17 Sep 1994	350	71 (7)	15[d]	4.3	<0.005
ME	7	24 Sep 1994	350	85 (7)	127[d]	36.3	
F_1BZ	7	24 Sep 1994	350	75 (7)	54[d]	15.4	<0.005

[a]Chi-square test of fish recovered.
[b]1993 ME fish reared in state hatcheries, first at Big Timber and then moved to Great Falls; all other fish reared at the Fish Technology Center (U.S. Fish and Wildlife Service) in Bozeman.
[c]Two nets at weir, other 1993 trials with three nets; each net sampled roughly 9% of total stream flow.
[d]Two nets at weir, which together sampled downstream migrants in 100% of the stream flow.

Table 5. Numbers of age-0 Arctic grayling originating from the Madison River/Ennis Reservoir (1993, 1994), Upper Red Rock Lake (1993), and Big Hole River (F_1 from adults in Axolotl Lake or at the Fish Technology Center, 1993, 1994) populations, captured and recaptured in electrofishing surveys from the weir to the release site. Electrofishing surveys were conducted after the last releases into Deep Creek, after 9 and 11 days in 1993, and after 18 and 25 days in 1994. The second survey in 1994 covered only the lower third of the stream reach, because of equipment failure.

Survey Date	F_1 Big Hole Capture	Recap	Upper Red Rock Capture	Recap	Madison/Ennis Capture	Recap
19 Sep 1993	21		1		0	
21 Sep 1993	20	8	1	0	0	0
Total	41	8	2	0	0	0
12 Oct 1994	13				5	
19 Oct 1994	7	0			1	0
Total	20	0			6	0

Results of the electrofishing surveys (Table 5) complemented the recoveries of fish at the weir. Many more F_1 fluvial than RR or ME fish were recovered by electrofishing between the weir and the release site in each of the four surveys ($p<0.005$). In 1993, 21 of the 22 fish collected in the first survey and 28 of 29 in the second survey, including 8 recaptured from the first survey, were fluvial. In 1994 fluvial fish accounted for 13 of 18 collected in the first survey and 7 of 8 in the second survey.

DISCUSSION

Results of field observations on the Madison River and behavioral experiments in Deep Creek indicate that the behavior of age-0 grayling from the Madison River/Ennis Reservoir population are more characteristic of young from a lacustrine, adfluvial population rather than from a fluvial population. Observations of distribution of age-0 grayling, summarized in Fig. 3, indicated that they remained in the river for only about 38 days after becoming free swimming, and then moved downstream to the reservoir. Byorth and Shepard (1990) captured very few age-0 grayling when they electrofished these same river channels during July and August 1990, and also concluded that age-0 grayling remained in the Madison River for only a short time before migrating to the reservoir. Age-0 Arctic grayling from some adfluvial populations appear to migrate downstream to lakes within the first few days after becoming free swimming. However, others have been observed to remain in streams for periods similar to the time spent by grayling in the Madison River in 1994. Kruse (1959) observed that age-0 grayling continued migrating downstream to Grebe Lake until they were about 36 days post-swimup in age, and about 43 mm in average length. Lund (1974) reported that some age-0 grayling migrated downstream to Elk Lake when they were about 26-32 days post-swimup in age, and averaged 42 mm in length. In contrast, age-0 young from the fluvial, Big Hole River population remain present in the vicinity of stream sections where spawning probably occurred, as indicated by previous capture of ripe adults, at least throughout their first summer (Skaar 1988; McMichael 1990).

In 1994, some age-0 grayling moved downstream into Ennis Reservoir before the remaining fish disappeared from the river channels. Age-0 grayling were collected when sampling was initiated in the reservoir on 16 June, about three weeks after age-0 grayling were first seen in the river and when they were still present in the river. Since the first young seen in the channels were already approximately 7-10 days post-swimup in age, it is possible that many had already emigrated downstream. The drift net was not installed earlier because of high stream flows. This possibility, of emigration of some age-0 grayling to the reservoir within the first few days after they become free swimming, should be further investigated.

After entering the reservoir, age-0 grayling inhabited shallow water in openings in macrophyte beds. Although they were not collected in deeper waters free from macrophytes, these small age-0 fish are more difficult to sample from such habitats. The distribution of age-0 grayling in deeper, open water in the reservoir should be further investigated. The presence of age-0 grayling in and near the inlet of Meadow Creek in the northwest part of the reservoir, far from the channels of the Madison River, suggests that grayling may also spawn in this stream. Although Meadow Creek provided important spawning habitat for the species in the past, such use has not been confirmed in recent years.

Differences in downstream movement among age-0 F_1 progeny of Arctic grayling from the Big Hole River and age-0 young from the Upper Red Rock Lake and Madison River/Ennis Reservoir populations, strongly reinforce earlier conclusions, based on laboratory tests, that age-0 grayling from the Big Hole River have innately stronger tendency to remain within a stream (Kaya 1991). The fluvial grayling had a much greater tendency to remain within the 1 km reach of stream, as indicated by numbers captured at the weir, and by the numbers captured in electrofishing surveys of the stream reach. Compared to F_1 BH fish, age-0 ME grayling had consistently and significantly higher tendencies to move downstream and were recaptured in significantly lower numbers in the creek. Innate behavioral tendency of young fish to remain within or move downstream out of a stream would be obviously advantageous to the respective life histories of fluvial and inlet-spawning lacustrine populations.

Although responses of age-0 ME grayling appeared to be intermediate between fluvial BH and lacustrine RR fish, the experimental conditions do not permit such conclusion at this time. In 1993, the pre-trial treatment of ME fish differed from that of BH and RR fish, because they were reared at a different hatchery. In 1994, trials were delayed by warm weather until mid-September, and stream flow, temperature, and turbidity during trials, as well as fish size and age, differed from those of 1993 trials.

The much greater downstream movements of age-0 fluvial grayling released after being acclimated for only about 24 hours suggest that behavioral response to water current can be modified by factors associated with their being taken from a hatchery environment and placed into a natural stream. It is possible that they needed more than 1 day to recover from effects of being netted, transported, and released into a new environment, and that the greater downstream movements were associated with stress. Acclimation duration had inconsistent effects on downstream movements of RR fish, perhaps because fish with a strong tendency to move downstream may do so regardless of acclimation to the stream.

The behaviors observed, of age-0 ME grayling in both Deep Creek and the Madison River, suggest that it may be difficult to establish self-reproducing populations in streams with grayling from this population. Even if older fish planted into a stream remain and survive to eventually spawn, the young may disappear downstream after a few weeks.

The observations also suggest that the larger, older grayling occasionally reported from the Madison River above the reservoir represent individuals that spent their earlier life in the reservoir. It is possible that the Madison\Ennis population retains a genetic disposition for a certain, unknown but probably small, percentage of fish older than age-0 to move into the river or to remain there beyond the reproductive season. If so, then it would be expected that more of these older grayling would be found in the river during years when the reservoir population was more numerous. Consistent with such a possibility, few grayling were reported from the river when numbers in the reservoir became severely reduced in the early 1980's, but reports have increased in recent years with an apparent increase in the reservoir population (Byorth and Shepard 1990; Vincent, pers. comm.).

It should be recognized, however, that if fluvial grayling are present farther upstream in the Madison River, then their presence could be overlooked by the methods employed in this study. The ripe adults from which gametes were stripped were captured by electrofishing within the braided channels of the river, within about 3 km of the reservoir. Adults captured in this area would most likely be adfluvial fish entering the river to spawn. The distribution and behavior, in nature or under experimental conditions, of young fish produced from such parents would, therefore, represent their adfluvial, lacustrine origins. If there are fluvial grayling farther upstream in the river or in tributaries such as the West Fork, they may spawn in other locations and the behavior of their age-0 young may resemble that of fish from the Big Hole River. However, the occasional reports of grayling farther upstream in the Madison River or in the West Fork do not presently provide good evidence for the presence of fluvial Arctic grayling in these waters.

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BIG HOLE RIVER ARCTIC GRAYLING RECOVERY PROJECT: ANNUAL MONITORING REPORT 1994

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ABSTRACT

Primary objectives included in this report included monitoring water temperatures and discharge in the upper Big Hole River, monitoring Arctic grayling population abundance, and maintaining minimum instream flows. Severe drought returned to the Big Hole basin in 1994: runoff of sub-normal snowpack occurred approximately six weeks before long-term average and lack of summer precipitation resulted in critically low stream flows. Discharge fell below the minimum "survival" flow of 20 cfs on 11 days in June due to irrigation withdrawals and on 55 days from August to October, primarily due to withdrawals of stock water. Water temperatures reached lethal levels in late July, resulting in an extensive fish kill. Attempts to preserve instream flows included eliciting cooperation from water users and providing alternative means of watering cattle. The grayling spawning population was lightly sampled, but age structure was balanced with the bulk of spawners age 3 and 4. Spawning success appeared to be good as indicated by the catch-per-effort of young-of-the-year grayling in Fall surveys. Fall population surveys in the Wisdom section indicated an increase in grayling abundance to 65 ± 50 age 1+ per mile. Age structure was well balanced. Investigations of the fall migration into Deep Creek were inconclusive. Surveys of grayling released into Skinner Meadows indicated that limited numbers returned to the release site after wintering elsewhere. The Axolotl Lake reserve brood was characterized and gametes were collected.

INTRODUCTION

Since 1991 the Arctic Grayling Recovery Program has endeavored to protect and restore the fluvial Arctic grayling (Thymallus arcticus) of the Big Hole River. This population is the only remaining, strictly fluvial, Arctic grayling population in the 48 contiguous United States (Kaya 1992). During the 1980's this population declined to low densities. The interagency recovery program was designed to monitor the population, to develop a brood stock to conserve their genetic integrity, to research limiting factors and develop strategies to mitigate them, and to reintroduce fluvial grayling into suitable streams within their native range (Byorth 1991). Progress of these efforts has been reported annually since 1991 (Byorth 1991, 1993, 1994, Magee and Byorth 1994). Activities conducted in 1994 were directed by the following objectives:

- Monitor water temperatures and discharge in the Big Hole River,
- Maintain minimum instream flows by promoting water conservation among Big Hole basin water users,
- Monitor population abundance and distribution in the Big Hole basin,
- Test the efficacy of using traps to sample spawning grayling,
- Investigate the fall grayling migration into Deep Creek,

- Monitor the grayling released into the Big Hole River at Skinner Meadows,
- Monitor and collect gametes from the reserve stock of grayling at Axolotl Lakes,
- Characterize and quantify grayling habitat in the Big Hole River and develop an integrated habitat database, and
- Analyze microhabitat selection by grayling and test for potential competitive exclusion by sympatric species.

Data reported below were collected from October, 1993 to November, 1994. Results for the above objectives are reported herein. Analysis of data under remaining objectives will be reported separately.

METHODS

Discharge and Water Temperature

Discharge and water temperatures in the upper Big Hole River have been monitored annually (Byorth 1993). Water temperatures were recorded by Omnidata DP-212 thermographs at four locations (stations 1, 3, 4, and 5 - Figure 1). Thermographs recorded temperature at 120 minute intervals on memory chips that were replaced every 85 days. Hourly water temperature and discharge were recorded at a U.S. Geological Survey (USGS) gaging station located near Wisdom, MT (station 2). These data were provided by USGS and were provisional during preparation of this report. Both data sets were downloaded to and analyzed using DBase IV (Ashton-Tate, Scotts Valley, Ca.).

Population Monitoring

The Arctic grayling population and its distribution in the Big Hole basin are monitored by electrofishing and trapping. A mobile-anode electrofishing unit mounted on a drift boat or Coleman Crawdad was used as described by Byorth (1993). Fish captured during sampling were held in a live-car until processing. Fish were anesthetized in a tricaine methanesulphonate (MS-222) bath, measured to the nearest 0.1 inches, and weighed to the nearest 0.01 lb. Fins were clipped as temporary marks. We tagged each grayling with a visible implant tag (Northwest Marine Technology, Inc.). We collected scale samples from most fish for age determination. However, scale samples were not available for aging during preparation of this report. Age determinations of spawning fish were based on lengths. A portion of each length group was assigned to an age class based on proportions comprised by each age class in scale samples collected from 1988 to 1993.

We attempted to sample the grayling spawning migration with traps to minimize the impacts of electrofishing on spawners. Traps were modified from Hetrick (1994) and Seelbach and Lockwood (1985). A trap was placed in the Big Hole River approximately 100 yds upstream from its confluence with Steel Creek. A second trap was placed in Steel Creek approximately 100 yds above the confluence. Each trap consisted of a 4 x 4 x 4 ft trap box and a weir constructed of electrical metal tubing strung on aircraft cable. We placed the trap at the upstream end of the weir which was placed diagonally across the channel. Traps were monitored daily from April 14 to April 26, 1994, and intermittently until May 1.

Due to high flows the traps were rendered ineffective. In order to sub-sample the spawning run sufficiently, we electrofished three subsections in a single pass: Wisdom West (Big Hole River), Clam Valley (lower 4.2 miles of the North Fork Big Hole River), and Rock Creek. We electrofished between April 18 and 26, 1994.

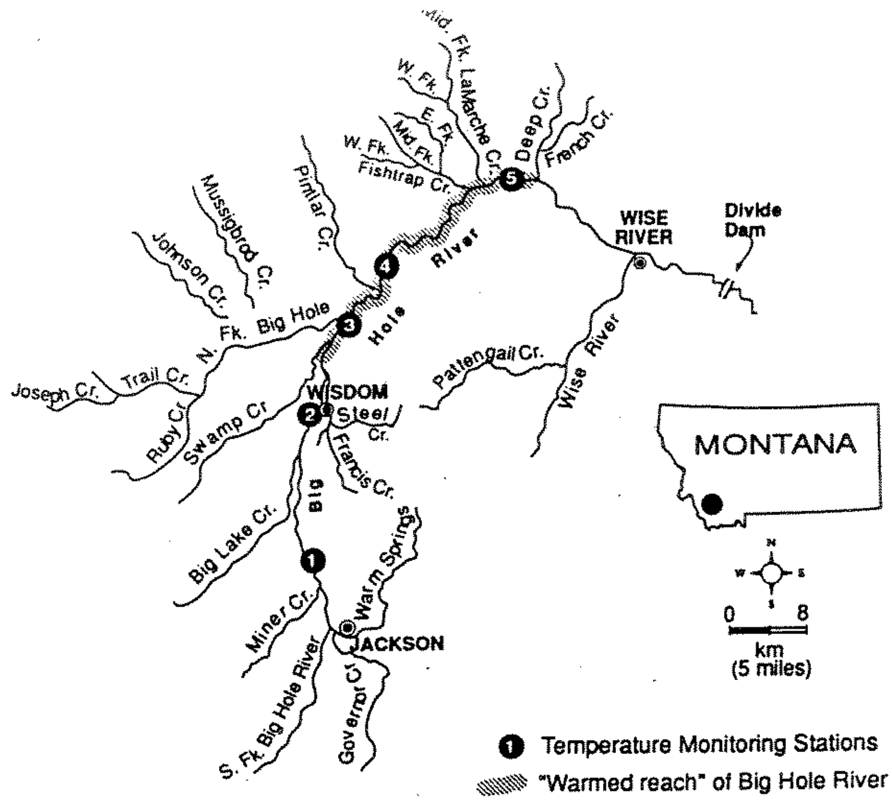

Figure 1. Map of study area indicating thermograph stations, USGS gage station, and the warmest reach of the Big Hole River. The Wisdom sampling section extends from the town of Wisdom to the upstream end of the warmest reach.

Fall population surveys were restricted because of extreme drought conditions. We postponed our limited surveys until flows improved in early October. Electrofishing was restricted to the Wisdom Section (East and West combined) and the Pools (Fishtrap, Sawlog, and Sportsmans Park). Fish were marked October 4 - 7 and recaptured October 27 and 31. We calculated a population estimate for the Wisdom Section using the Chapman Modification of the Peterson estimator (Chapman 1951, Vincent 1971).

We installed a trap to assess the fall migration of grayling into Deep Creek reported by Byorth (1994). The trapping apparatus was similar to that described above, except a trap was positioned at each end of the weir to capture up- and down- stream migrants. The trap was installed in Deep Creek at the Highway 43 bridge crossing, approximately 100 yds upstream from the mouth. We operated the trap intermittently between October 1 and 26, 1994.

In September, 1993 approximately 300 yearling grayling were released into the headwaters of the Big Hole River at Skinner Meadows. These fish had been the subjects of a study on competitive interactions between brook trout and grayling (Magee and Byorth 1994). After research was completed, the grayling were released to assess their survivability. In October, 1993 and May and July, 1994 we surveyed the area by walking the banks, by electrofishing, and snorkeling.

Axolotl Lake Brood

The Axolotl Lake brood reserve provides young grayling for brood stock and for experimental reintroductions. Grayling were sampled during May, 1994 using fyke nets and by hook-and-line. Initial catches were processed as indicated above, marked, and released for population estimation. Later catches were sorted by sex and held in large live cars in the lake. On May 17, 1994 Ennis National Fish Hatchery personnel spawned grayling by stripping eggs from a female grayling into a vial and fertilized them with milt from several males collected and pooled in an aspirator. Eggs were rinsed after a fertilization period, packaged, and transported to the USFWS Fish Technology Center in Bozeman for rearing. Samples of ovarian fluid and fecal material were collected for disease testing. A sample of grayling was also sacrificed for disease analysis. The remaining grayling were released back into the lake.

RESULTS

Discharge and Water Temperature

The hydrograph of the Big Hole River illustrates the severity of drought conditions in 1994 (Figure 2). Due to meager snowpack and warm, dry conditions in April, runoff peaked unusually early. The instantaneous peak discharge recorded at the Wisdom gage was 976 cfs on April 23. A second brief pulse peaked at 818 cfs on May 20. The first peak occurred during spawning, while the second occurred 9 days after the predicted date of emergence of newly-hatched grayling. Due to the early runoff and lack of mid-summer precipitation, flows became critically low in late June.

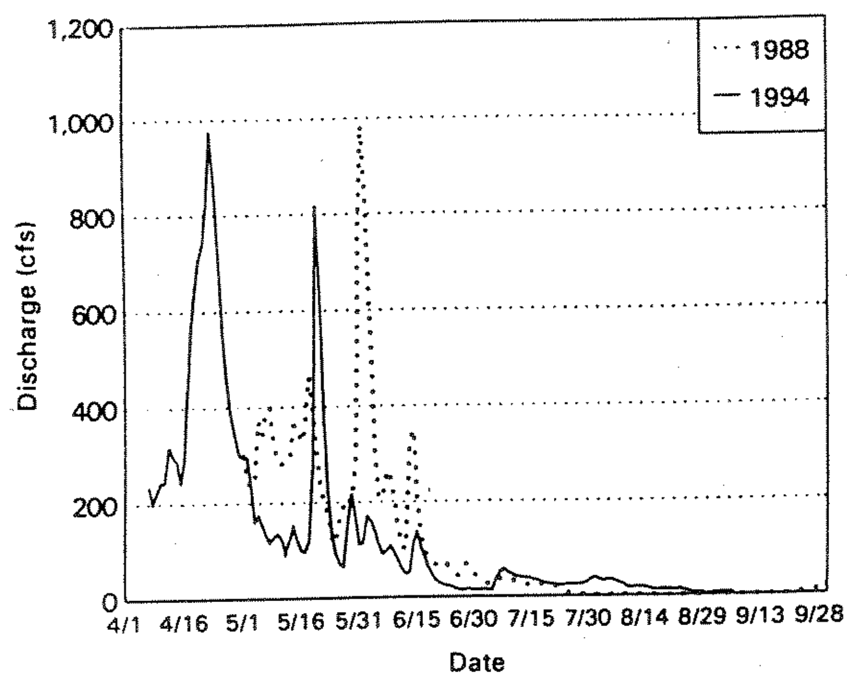

Figure 2. Mean daily discharge (cfs) of the Big Hole River measured at Wisdom gage station, April through September, 1988 and 1994.

We consider the minimum flow (measured at Wisdom), below which fish survival is severely threatened, to be around 20 cfs. Discharge fell slightly below that level for 11 days in June, during the last two weeks of the irrigation season. After the majority of irrigation withdrawals were discontinued and a rainstorm on July 6, flows increased to 57 cfs. Discharge began a steady decline thereafter and was below 20 cfs from August 9 through October 4, a total of 55 days. The minimum flow recorded in 1994 was 1.9 cfs on August 30. In 1988, discharge was recorded at 0 cfs on 24 days and was less than 20 cfs for 78 days.

Efforts to maintain instream flows entailed personal contacts with water-users to encourage conservation. In addition, a grant was secured from the Governor's Environmental Contingency Fund to exchange stock tanks and well development for water diverted from the Big Hole River. These efforts are described in greater detail in Appendix A.

The severity of drought in 1994 was also manifested in high water temperatures. A maximum temperature of 79.7°F was recorded on July 25, 1994 at the Christianson Ranch thermograph station (Table 1). This exceeded the upper incipient lethal temperature reported by Lohr et al. (in review - see appendices of Byorth 1994). Lethal temperatures were also exceeded or nearly exceeded at the Wisdom Bridge (station 2) and Buffalo Ranch (station 3) (Figure 1). The period of highest water temperatures occurred between July 21 and 26. Water temperatures exceeded lethal limits for greater than 4.2 hours, the median resistance time reported by Lohr et al. (in review, Byorth 1994), on three days at station 4 and on 1 day at station 3. The highest mean daily temperature was also recorded at station 4, 71.2°F on July 25, 1994. Temperatures at station 5, the furthest down river, were more moderate than all but the uppermost station.

We investigated a fish kill on July 27, 1994 near the confluence of Pintler Creek, approximately mid-way between thermograph stations 3 and 4 (Figure 1). We counted 96 mountain whitefish (Prosopium williamsoni), 4 white suckers (Catostomus commersoni), 12 longnose suckers, (Catostomus catostomus), over 60 longnose dace (Rhynichthys cataractae), 18 burbot (Lota lota), over 100 mottled sculpin (Cottus bairdi), and 2 brook trout (Salvelinus fontinalis) while walking 500 yards along each river bank. Mortalities were representative of all age classes and had apparently occurred over several days as evidenced by varying degrees of decomposition. Mortalities were observed intermittently for up to 2 miles below the confluence of Pintler Creek, where two yearling grayling and several brook trout were found dead. At the Highway 43 bridge near the mouth of Squaw Creek only 1 mottled sculpin mortality was found. We also surveyed segments of the Big Hole River near Sawlog Creek and at Sportsmans Park and observed a total of 3 mountain whitefish and one mottled sculpin mortality. On July 28, we surveyed the area near thermograph station 3. Three white suckers, 1 longnose sucker, 1 mountain whitefish, 1 brook trout, and 1 unidentifiable mortality were observed there. The extent of the fish kill between the mouth of the North Fork Big Hole River and Pintler Creek is unknown.

Table 1. Maximum daily (T_{max}) and maximum mean daily water temperature and days over lethal thresholds at thermograph stations in the Big Hole River 1994.

Station	T_{max} (°F)	Max T_{mean} (°F)	Days > 77°F	Lethal Periods*
1	75.2	65.8	0	0
2	77.7	69.4	4	0
3	77.0	70.4	2	1
4	79.7	71.2	7	3
5	76.1	66.1	0	0

* Number of days with periods of 4 hours or greater in which temperatures exceeded lethal levels (Lohr et al. in Byorth 1994).

In response to the thermal stress placed on fish due to low flows and near lethal temperatures, the fishing season was closed on July 30 by order of the Montana Fish, Wildlife, and Parks Commission. The closure extended from the confluence of the North Fork Big Hole River to Dickie Bridge. The remainder of the Big Hole River was closed to angling on August 29.

Population Monitoring

Spawning and Recruitment

We captured a total of 87 spawning grayling: 22 in traps and 65 by electrofishing. Of the electrofishing sample, 41 were captured in the Wisdom Sections and 22 were captured in the North Fork Big Hole River, which appears to provide important spawning habitat. The sex ratio of the combined sample was 1.87 males per female. The bias toward males indicates that sampling was conducted prior to the peak of spawning, when sex ratios are close to 1:1. We believe that peak spawning occurred on April 26. During spawning discharge ranged from 200 to 976 cfs. Shepard and Oswald (1989) reported that grayling generally spawn between lowland and highland runoff peaks. This year, the grayling appeared to spawn during peak flows when water temperatures ranged between 34 and 56°F.

Age ratios demonstrate that the grayling population is stabilizing. The spawning population consisted of 19% Age 2, 40% Age 3, 33% Age 4, and 10% Age 5. This age structure is very similar to that of the 1993 spawning run (Figure 3).

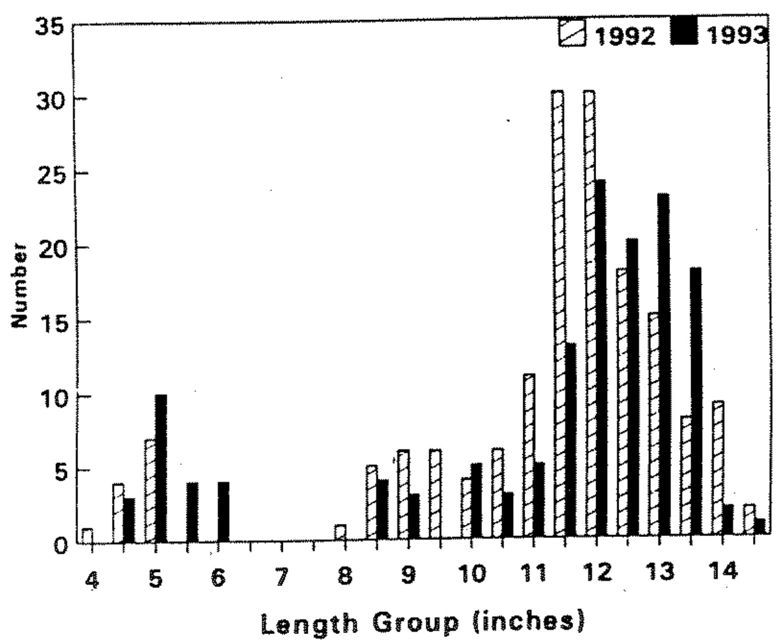

Figure 3. Length frequency histogram of spawning Arctic grayling sampled in the Big Hole River and tributaries, 1993 and 1994.

The efficacy of trapping spawning grayling in the Big Hole River is questionable. Due to abnormally high flows during spawning the traps were rendered ineffective. Trapping may be feasible under a more typical hydrograph.

The second runoff event may have impacted spawning success. Grayling larvae should have hatched between May 7 and 9, based on degree-days, and emerged on May 10 through 12 (Wojcik 1955, Kratt and Smith 1977, Byorth 1993). A major peak in flows occurred on May 20 when flows increased by 700 cfs. However, catch rates of young-of-the-year (YOY) grayling in limited fall surveys indicate moderately successful recruitment relative to past years (Table 2). A total of 39 YOY grayling were captured in two passes.

Population Estimates

Due to extreme drought conditions, we limited our fall sampling to the Wisdom sections (East and West) and The Pools survey. The density of Age 1+ grayling in the Wisdom sections was estimated to be 65 (± 50) per mile. This estimate is an approximate two-fold increase over estimates calculated from 1989 to 1993 surveys. The grayling population has apparently increased to levels last observed in 1984. Parameters used to calculate the estimate are listed in Table 3.

While yearling grayling were predominant in the Wisdom Section sample, older and larger fish (> 13 inches) were more abundant in the Pools areas (Figure 4). The combined sample indicates a well-balanced age distribution. Contrary to indications that recruitment was poor in 1993, yearling grayling were abundant in the 1994 survey (Byorth 1994).

Table 2. Catch rates (catch-per-effort (CPE)) of young-of-the-year (YOY) grayling captured in the McDowell and Wisdom sections of the Big Hole River, 1983 - 1994.

Year	McDowell Section			Wisdom Section		
	# YOY	# Runs	CPE	#YOY	# Runs	CPE
1983	---	---	---	2	6	0.33
1984	---	---	---	5	7	0.71
1985	0	3	0	0	3	0
1986	145	4	38.2	---	---	---
1987	3	1	3.0	0	1	0
1988	---	---	---	---	---	---
1989	178	2	89.0	90	2	45.0
1990	58	2	29.0	98	4	24.5
1991	10	2	5.0	41	2	20.5
1992	42	2	21.0	83	4	20.75
1993	2	2	1.0	31	4	7.75
1994	---	---	---	39	2	17.5

Table 3. Parameters used to estimate Arctic grayling density in the Wisdom Section during Fall, 1994: M = number grayling marked, C = number captured in 2nd pass, R = number marked grayling in 2nd sample.

Age	M	C	R	Ñ	Ñ/mi	95% CI
0	29	10	2	109	22	18.6
1	39	24	3	249	51	40.8
2+	17	14	3	67	14	9.3
Age 1+				316	65	50.1

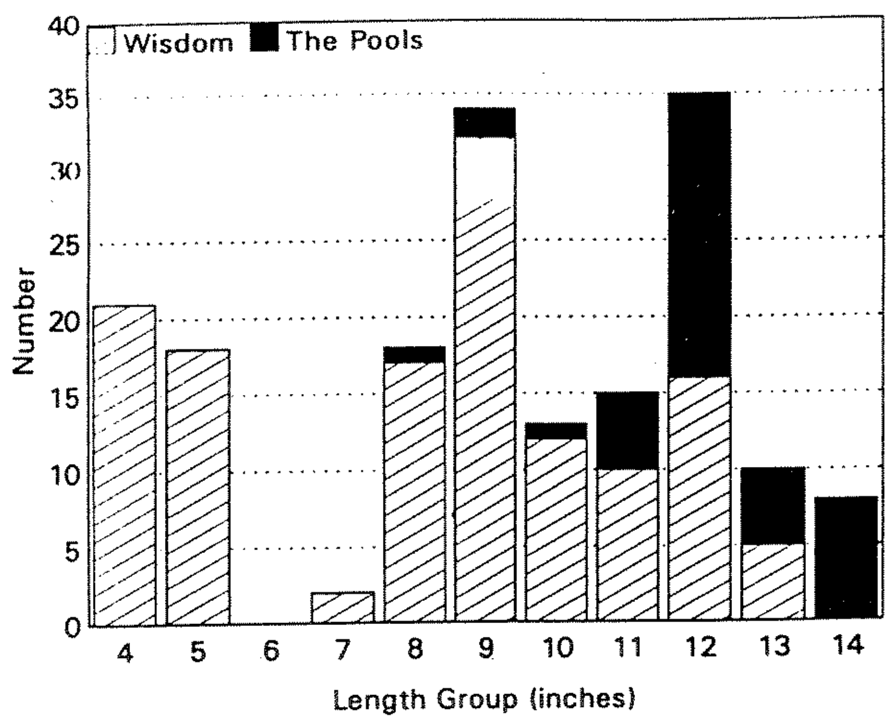

Figure 4. Length frequency histogram of Arctic grayling captured in Fall 1994 electrofishing surveys of the Big Hole River.

Deep Creek Migration

In 11 trap-days of effort in Deep Creek, we captured 12 grayling, 56 brook trout, 13 brown trout (Salmo trutta), 20 rainbow trout (Oncorhyncus mykiss), 289 mountain whitefish, 83 longnose suckers, 61 white suckers, and 1 burbot. The majority of fish were captured between October 6 and 12, as maximum daily temperatures decreased to under 50°F. Daily trapping records are summarized in Appendix B. Nine of 12 grayling and 95% of white and longnose suckers were captured in the downstream trap, although a grayling was captured in the upstream trap as late as October 26. This apparent out-migration occurred while brook trout spawned, but prior to mountain whitefish or brown trout spawning. About 2/3 of mountain whitefish were captured after October 20, indicating that they probably spawned a minimum of two weeks after the brook trout. The migration reported in Byorth (1994), must have occurred prior to trapping; therefore, the grayling migration must occur independently of spawning activities of other species. The majority of fall grayling movements reported by Byorth (1991) also occurred in early October. Of all rainbow trout captured, 95% were captured in the upstream trap. They may be exploiting the spawning runs as a food source or using Deep Creek for winter habitat. Few brown trout were captured entering Deep Creek. Either brown trout spawning is limited in Deep Creek or traps were removed prior to the peak of immigration and spawning.

Skinner Meadows Reintroduction

In October 1993, 6 weeks after 300 grayling marked with VI tags were released into the Big Hole River at Skinner Meadows, we counted 146 in the vicinity of their release. Of those observed, 66% remained in the study reach of Magee and Byorth (1994). The remainder had moved downstream as far as 0.5 miles. During May, 1994, no fish were observed in the study reach or nearby. This is consistent with observations of brook trout made in June 1993: winter habitat is limited in the area and adult fish winter elsewhere. We electrofished Skinner Creek, a spring fed stream, and captured 73 brook trout and no grayling. During a July 1994 survey, 8 grayling were in the study reach and 1 grayling was observed in beaver ponds 0.25 mi downstream of the study reach.

Axolotl Brood Reserve

We sampled the Axolotl Lake brood reserve to determine the status of the 1988 year class, survivorship of yearling grayling planted in 1993, and to collect gametes for experimental introductions. A mark/recapture experiment indicated that approximately 290 (± 152) Age 6 grayling from the 1988 cohort remain in Axolotl Lake. Their average length was 13.5 inches (range: 12.7 - 14.6 inches, N = 98), which indicates that they did not grow significantly since 1993. The sex ratio of Age 6 grayling favored males by 2.25 to 1.

Approximately 3,000 age 1 grayling were planted in the lake in 1993. Half originated from the Axolotl Lake brood and half from the Big Hole River. Based on differential fin markings, approximately 840 (± 417: N=365) of Big Hole origin and 371 (± 265: N=122) of Axolotl brood origin survived to Age 2. Their mean length was 8.6 inches (range: 7.0-10.3 inches). Growth rates did not differ significantly between groups. Approximately 5% of age 2 grayling were immature; therefore, probability of capture was not equivalent for the entire cohort and the sample may have been biased.

Eggs were collected from 16 age 6 and 5 age 2 females and fertilized with 30 males from both cohorts. After hatching it was apparent that gametes from the Age 2 grayling had limited viability (W. P. Dwyer, pers. comm.).

DISCUSSION

While the drought of 1994 was second only in severity to 1988 in this century (USGS files), its impact on the Arctic grayling population was moderated by an improved age structure and efforts to maintain minimum flows (Table 4). Discharge in the upper Big Hole River near Wisdom during the years 1988 to 1994 generally reached critical levels (i.e. less than 20 cfs) in August and September. Irrigation of hay crops is generally discontinued in early July. Diversions for irrigation have resulted in critical flows in only 2 of the last 7 years (Table 4). In years of moderate precipitation, snow-pack is sufficient to supply irrigation requirements and maintain stream flows. In extremely dry years, water conservation practices will be necessary to maintain flows.

Critical flows in late summer were attributable to lack of precipitation and diversions for stock water. Our efforts to encourage stockgrowers to minimize late summer diversions and toward developing alternative sources of stock water resulted in maintaining flows at levels much less severe than 1988 (Appendix A). In 1988, discharge fell to 0 cfs at the Wisdom bridge for 27 days. Water yield, or total volume of water passing the gage, in August and September, 1988 was only 213 acre-ft (Table 4). In contrast, the 1994 minimum flow was 1.9 cfs on 1 day and August-September water yield was 1821 acre-ft. Alternative sources of stock water, such as wells and pipelines, along with conservative withdrawals from the river should be sufficient to maintain flows above 20 cfs even in the driest years.

Water temperatures reached lethal levels during July 1994. The Big Hole River from the mouth of the North Fork to Squaw Creek acts as a heat sink because of its braided, broad, shallow channel morphology. A combination of this channel shape, long, hot days, and low flows led to water temperatures near 80°F. The resultant fish kill was substantial, affecting all age classes of all species resident in the warmed reach of the Big Hole River. Temperature problems may be alleviated by increasing flows and/or concentrating flows into a single channel.

Table 4. Comparisons of Big Hole River discharge parameters measured at the USGS gage at Wisdom, 1988 to 1994. Yield is the total volume of water passing the Wisdom gage during August and September.

Year	# Days less than 20 cfs		Max Flow (cfs)	Min Flow (cfs)	Dates at Min	Yield Aug-Sept (ac-ft)
	Apr-June	July-Sept				
1988	0	78	1080	0	8/27-9/21	213
1989	0	4	978	12	8/20	3790
1990	1	0	667	18	5/23	5820
1991	0	16	4300	10	9/4	3690
1992	18	32	479	3.3	5/26	2760
1993	0	0	1700	55	10/5	17490
1994	11	55	976	1.9	8/30	1821

In spite of the severity of drought conditions in 1994, the Arctic grayling population appears to be increasing. For the first time since 1984 the estimated age 1+ population has surpassed 60 per mile in the Wisdom Section. The 1994 estimate may be somewhat biased because we delayed sampling until October. Grayling are known to move considerably during October (Byorth 1991). However, the parameters used to estimate the population are comparable to those of past years (Table 3). The apparent increase is attributable to a balanced age distribution. After poor recruitment to the population from 1983 to 1987, the population declined. After the decline, the spawning population was skewed toward age 2 and 3 grayling. Because age 2 fish are not fully mature, their contribution to spawning success is questionable. In effect, only one significant age class was contributing significantly to spawning. Since 1992, however, Age 3+ fish have comprised over 80% of the spawners (Byorth 1993, 1994). Three mature age classes: age 3, 4, and 5 have been represented in the past two spawning years.

Our index of recruitment is catch-per-unit-effort of YOY grayling in fall surveys (Table 2). In the Wisdom Section, that index has been stable since 1989, except in 1993. Recruitment in the McDowell section has been less stable. The 1993 survey draws the index into question. Whereas the catch of YOY in 1993 was low, our 1994 population estimate reveals an abundant yearling age class. Apparently, the higher flows during 1993 rendered our sampling less effective. Young-of-the-year grayling were also distributed more uniformly throughout the basin than in past years (Byorth 1994). Nevertheless, excellent 1992 and 1993 year class strength and good potential recruitment in 1994 should result in a continued strengthening of the fluvial Arctic grayling population of the Big Hole River.

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APPENDIX A

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PROJECT SUMMARY

The Big Hole River of southwestern Montana sustains the last remnant population of fluvial, or river-dwelling, Arctic grayling in the 48 contiguous United States. In the mid-1980's, this population underwent a serious decline in abundance. An interagency recovery program led by Montana Fish, Wildlife, and Parks (FWP) was instituted in 1988 to address the factors responsible for the decline and to devise a program to conserve this unique native salmonid. In October 1991, a petition was submitted to the U. S. Fish and Wildlife Service (USFWS) requesting fluvial Arctic grayling in Montana be classified as "Endangered" and be given full protection under the Endangered Species Act. The status review of the grayling resulted in a finding, published in the Federal Register, that "...listing...is warranted but precluded..." The rationale behind the finding included a lessening threat to the population "...primarily as a result of the cooperative efforts that have been initiated..."(Nordstrom 1994).

A predominant factor limiting Arctic grayling in the Big Hole River during the 1980's has been drought. Water yield in the Big Hole Basin was the lowest on record between 1988 and 1994 (USGS Files). During years of poor snowpack and scarce mid-summer precipitation, increased agricultural demand for water resulted in periodic dewatering of the upper Big Hole River, particularly between July and September. Diminished flows contribute to high water temperatures, higher susceptibility to predators, decreased habitat volume, and increased mortality of very old and very young fish. Water temperatures lethal to grayling have been documented in 5 of the last 7 years in the upper Big Hole River (Byorth 1994).

It is well documented that fish abundance is regulated by food and space which are primarily determined by water volume (Chapman 1966). Limits of productivity in a riverine fish community are set by discharge during critical periods. Nelson (1980) described two minimum flow levels for salmonid populations: an "absolute minimum" below which standing crops of fish are reduced and a "most desirable minimum" which are necessary to maximize standing crops. In the Big Hole River the absolute minimum was determined to be 60 cfs in a reach near Wisdom (Mt. Dept. of Natural Resources and Conservation (DNRC) 1992). However, in 6 of the past 7 years, discharge in the upper Big Hole River at Wisdom has been under 60 cfs on a majority of days between June and October. During extremely dry years it is appropriate to define a third critical flow level. This "minimum survival" flow would merely maintain a wetted channel and facilitate survival of the fish population only in a short term. This level was estimated to be 20 cfs. Our goal during Summer 1994 was to maintain instream flows above this level to mitigate further declines in, or reduce the risk of extinction of the Arctic grayling population. Flows were monitored at a U. S. Geological Survey (USGS) gage located at Wisdom (Figure 1).

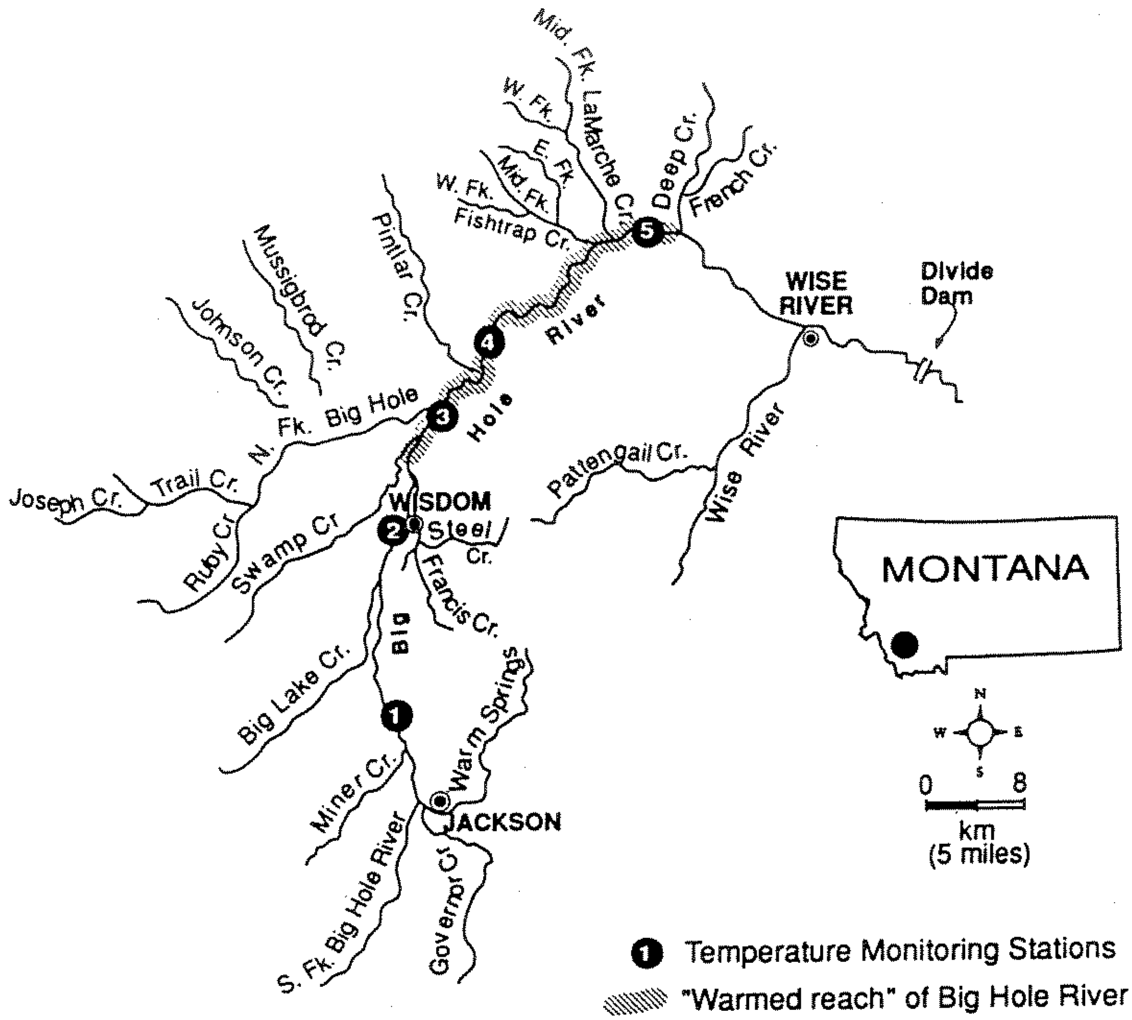

Figure 1. Map of the upper Big Hole River study area including thermograph stations, USGS gage station (2), and warmest reach of the Big Hole.

Due to early snow-melt and lack of rain, water withdrawals for agriculture were the primary regulator of instream flows in the Big Hole River and its tributaries. Therefore, to maintain minimum survival flows, it was necessary to seek cooperation from the agricultural community in conserving the limited available water. We contacted water-users, in person and by phone, requesting that they minimize their withdrawals. In spite of efforts to conserve water, however, flows became critical in early August. By that time, irrigation season had ended but water was still being diverted for stock. It was apparent that the only way to maintain a minimum flow was to find alternative sources of stock water.

The upper Big Hole River has been dewatered most severely in the reach near Wisdom, which is among the most critical habitats for Arctic grayling. Several diversions and canals upstream of Wisdom are used to transport water over long distances to cattle. Evaporation and leakage renders this water delivery system extremely inefficient. To provide an alternative to diverting water, we contacted water-users on three ranches and offered to supply stock water in tanks. After a ranch owner expressed interest in cooperating, we requested financial support for the project from the Environmental Contingency Grant Program through the Governor's Office and DNRC. The grant was secured which enabled FWP to purchase ten 1,000 gallon stock tanks and to lease a tank truck and driver from the East Bench Irrigation District. Eight stock tanks were installed in several large pastures which were kept filled by water truck from September 7 through October 1, 1994. Water was pumped into the tanker from the Big Hole River at the ranchers' established points of diversion. Two additional stock tanks were placed at an existing well site, which we developed to constantly supply tanks with water.

RESULTS

Discharge in the upper Big Hole River declined to critical levels during two periods in 1994. Mean daily flows were below 20 cfs from June 25 through July 5 (Figure 2). The lowest flow during this period was 14 cfs. Diverting water to irrigate hay was a primary factor reducing stream flow. In the upper Big Hole Basin, the irrigation season traditionally extends from May to early July. After water users were contacted, on June 28 and July 6, the majority of irrigation diversions were closed. A rain storm also occurred as irrigation season ended and flows increased to 57 cfs by July 8 (Figure 2).

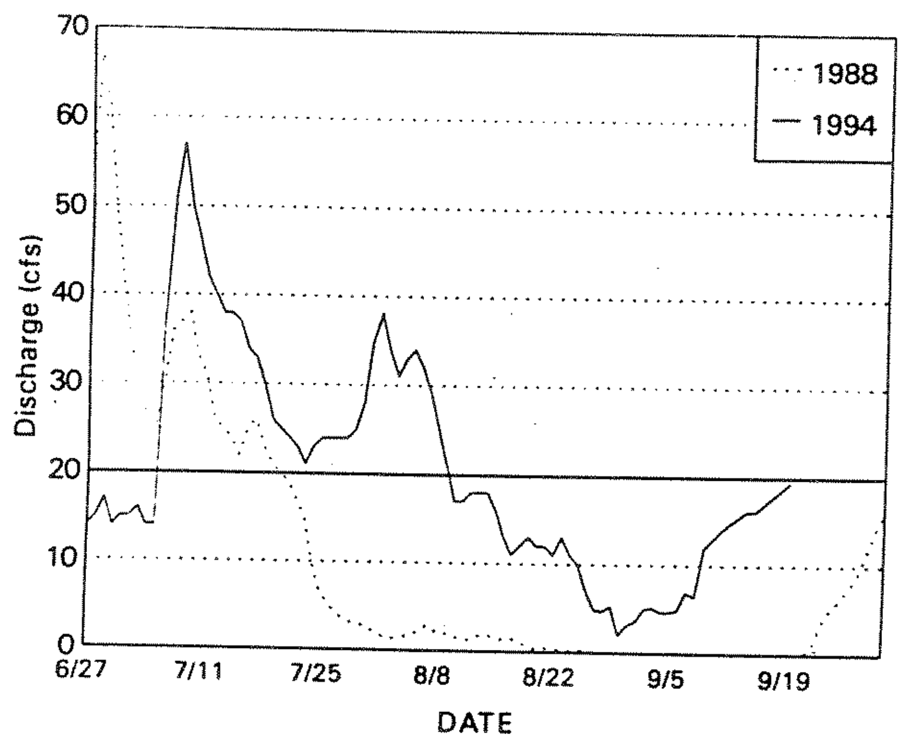

Figure 2. Mean daily discharge of the Big Hole River measured at the USGS gage near Wisdom, June 27 to September 30, 1988 and 1994.

A second critical flow period began in late July as hot, dry weather persisted. Between July 24 and 27, a fish kill due to lethal water temperatures was documented near the confluence of the Big Hole River and Pintler Creek. Several hundred fish of most resident species and age classes were found dead. The full extent of the fish kill was unknown, but mortalities were documented from the mouth of the North Fork of the Big Hole River to the Squaw Creek area, a distance of approximately 13 miles (the "warmest reach" in Figure 1). In response to critical conditions, Governor Racicot convened a public meeting in Butte to discuss strategies to address the drought, especially in the Big Hole and Clark Fork basins. He emphasized using cooperative efforts to alleviate water shortages. On July 30, the Fish, Wildlife, and Parks Commission closed the fishing season from the mouth of the North Fork to Dickie Bridge to protect the Arctic grayling population. FWP initiated a second round of water-user contacts requesting increased water conservation. FWP also hired a water commissioner to survey Big Lake and Big Swamp Creeks for surplus water. As a result of these efforts, flows increased to 38 cfs by August 1 (Figure 2). However, flows returned to critical levels by August 10.

While very little water was entering the Big Hole River from tributaries or precipitation, stock water was still being diverted in mid-August. By August 25, water users were contacted a third time to reduce consumption. In spite of those efforts, a water-user opened a diversion on August 30 in an unsuccessful attempt to divert water to cattle. As a result, flows reached the low point of 1.9 cfs on that date. In response to FWP's calls for assistance, that diversion and eight others were closed or reduced to a minimum to keep the Big Hole River flowing.

After the Environmental Contingency Grant was secured, stock tanks were distributed and filled by September 7. As a result, the "Spokane" ditch was closed. Prior to its closing, approximately 5 cfs had been diverted and transported over 8 miles to water approximately 2,500 cattle. After the Spokane ditch and the other diversions were closed or withdrawals reduced, flows at Wisdom increased to near 20 cfs by September 16. Flows fluctuated between 15 and 20 cfs until early October, when fall precipitation provided relief from drought conditions.

The success of delivering water to stock tanks as an alternative to providing water through ditches is illustrated by Table 1. We delivered water to stock tanks for 25 days. Had the Spokane ditch remained open at a rate of 5 cfs, approximately 81 million gallons of water would have been diverted from the Big Hole River. We delivered approximately 227,375 gallons of water over the 25 day period in addition to approximately 150,000 gallons provided by a well. The volume of water required via the alternative means was approximately 0.5% of that required by ditch delivery.

The summer of 1988 provided a useful comparison to gauge the success of this summer's efforts. In 1988, the Big Hole River ceased to flow (i.e. 0 cfs) at Wisdom for 24 days in August and September. In 1994, flows were as low as 1.9 cfs on one day, and were below 5.0 cfs on only 6 days.

Table 1. Comparison of efficiency of providing stock water via ditch at 5.0 cfs versus delivering water by stock tanks and a well between September 7 and October 1, 1994.

Water Volume	Ditch	Tanks	Well	Tank + Well
Flow (cfs)	5.0	0.014	0.005	0.019
Gallons per Day	3,231,580	9,095	3,000	12,095
Total Gallons	8.1×10^7	227,000	150,000	377,000
% of Ditch Volume	100	0.34	0.19	0.53

While substituting water delivery for stock water canals proved to be a successful way of maintaining a minimum instream flow, it was merely an emergency measure. The expense and limited scope would render water delivery ineffective in the long term. More permanent solutions to water allocation during drought years must be addressed. A positive step was made during 1994 as water-users made an effort to conserve water. An increased awareness of the status of the Arctic grayling population and a conscious effort to mônitor water consumption will facilitate future efforts at preserving in-stream flow. The efficacy of providing water via wells and pipelines was tested and will be pursued further. Plans to drill wells and pump water to cattle served by the Spokane Ditch are in development. The concept of "conjunctive use", or tapping deep aquifers in drought years, is also being investigated.

The Arctic grayling population of the Big Hole River has recently shown signs of increasing abundance (Byorth 1995). Fall 1994 sampling revealed an increase in grayling abundance to approximately 65 per mile in the Wisdom area, a level last observed in 1984. Continued recovery of the population depends on providing a satisfactory minimum instream flow. While 20 cfs may allow the grayling population to survive critical periods in a short-term crisis, the "absolute minimum" flow of 60 cfs should be our goal in the future. By seeking out alternatives for watering stock and through improved conservation in irrigation practices the last fluvial Arctic grayling population in the lower 48 United States will remain a testament to Montana's commitment to its natural heritage.

BUDGET SUMMARY

The Environmental Contingency Grant was $ 7,245.00. Total expenses for the project at completion were $ 8,970.52. We had estimated costs based on delivering water for two weeks. However, the drought persisted and we continued delivering water for two additional weeks. The major additional expense was providing wages for water truck drivers. While only 40 hours per week were allotted, drivers delivered water up to 19 hours per day. Additional driving time was provided by FWP fisheries personnel. FWP also provided additional funding for a water commissioner and rented high volume pumps to fill the water tank more efficiently.

Table 2. **Summary of budget and expenses for the upper Big Hole River Flow Protection Project.**

Item	$ Budgeted	$ Spent	
		E.C.G Grant	FWP
Stock Tanks (10)	2250.00	2269.00	
Delivery	150.00		
Truck Drivers	600.00	1623.08	1367.00
Water Truck	2800.00	3150.00	
Maintenance/Repair	500.00	200.94	270.50
Contingency	945.00		
Water Commissioner			90.00
TOTAL	7245.00	7243.02	1727.50

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APPENDIX B.

Appendix B. Daily catches of grayling (GR), brook trout (EB), mountain whitefish (MWF), brown trout (LL), rainbow trout (RB), longnose sucker (LNSU), and white sucker (WSU) in upstream (up) and downstream (dn) traps in Deep Creek, October, 1994. Recaptured fish are excluded.

Date	GR		EB		MWF		LL		RB		LNSU		WSU		Water Temp (°F)	
	up	dn	up	dn	up	dn	up	dn	up	dn	up	dn	up	dn	max	min
10/1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	73	43
10/3	0	0	0	1	0	0	0	0	0	0	1	0	0	1	58	38
10/6	1	7	13	12	16	8	2	0	7	1	1	43	1	48	48	31
10/7	0	1	7	2	43	1	2	0	5	0	1	7	2	7		
10/10	0	0	0	0	0	1	0	0	0	0	0	6	0	2	52	36
10/12	1	0	4	1	5	2	0	0	4	0	0	0	0	0	48	44
10/17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	33
10/18	0	0	4	5	0	0	1	0	0	0	0	0	0	0	44	37
10/20	0	1	0	0	71	77	3	0	3	0	0	4	0	0	47	38
10/21	0	0	0	6	0	0	0	5	0	0	0	0	0	4	44	32
10/26	1	0	0	0	2	63	0	0	0	0	0	0	0	0	42	33
Total	3	9	29	27	137	152	8	5	19	1	3	60	3	58		

COMPETITIVE INTERACTIONS OF ARCTIC GRAYLING AND SYMPATRIC SPECIES IN THE BIG HOLE RIVER DRAINAGE, MONTANA

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ABSTRACT

We compared micro-habitat positions of Arctic grayling, eastern brook trout, rainbow trout, mountain whitefish, white suckers, and longnose suckers in Deep Creek, a tributary of the Big Hole River. We also compared grayling and brook trout micro-habitat positions in Deep Creek with those of a controlled study in the upper Big Hole drainage completed in 1993. Grayling and brook trout exhibited spatial segregation for micro-habitat positions. In the controlled study, grayling used faster focal and mean column velocities and higher focal elevations, and brook trout inhabited deeper areas. Results were similar for grayling and brook trout positions in Deep Creek with respect to focal velocity, mean column velocity and focal elevation but there were no differences in total depth preferences. Grayling and native sympatric species (whitefish and Catostomus ssp.) also exhibited spatial segregation by using different optimum velocities and depths. Grayling and rainbow trout had the highest potential for competitive exclusion by using similar focal velocities, mean column velocities, and focal elevations.

INTRODUCTION

Historically in Montana, fluvial Arctic grayling (Thymallus arcticus) were intermittently distributed throughout the Missouri River drainage above Great Falls. Arctic grayling were indigenous to the Big Hole, Red Rock, Beaverhead, Jefferson, Madison, Gallatin, Smith, and Sun rivers (Kaya 1992a). Currently the only strictly fluvial, self-sustaining population exists in the Big Hole River drainage. The reduction in native range of grayling has been attributed to overharvest, climatic change, habitat alteration, and competition with introduced species (Vincent 1962).

Species native to the Big Hole River included Arctic grayling, westslope cutthroat trout (Oncorhynchus clarki lewisi), longnose dace (Rhinichthys cataractae), mountain whitefish (Prosopium williamsoni), white suckers (Catostomus commersoni), longnose suckers (Catostomus catostomus), mottled sculpins (Cottus bairdi), and burbot (Lota lota). Westslope cutthroat trout are now rare, however introduced eastern brook trout (Salvelinus fontinalus), rainbow trout (Oncorhynchus mykiss), and brown trout (Salmo trutta) are present in moderate to high densities (Montana Department of Fish, Wildlife and Parks and Shouse 1989).

The introduction of non-native fishes has dramatically affected native species in North America (Moyle et al. 1986). Introductions often result in competition for preferred habitats between exotic and native species. Species evolving sympatrically develop mechanisms of resource partitioning (Nilsson 1967). Interspecific competition should be greater for those species with similar life histories which did not co-evolve (Hearn 1987, Fausch and White 1986). Exotic species may displace natives from preferred habitats or exploit limited resources more efficiently than indigenous species (Fausch 1988, Hearn 1987, Moyle et al. 1986).

In the Big Hole River, species distribution suggests grayling are displaced from certain habitats by introduced species. Low grayling densities occur below Dickie Bridge where rainbow and brown trout are the predominant fishes. The highest grayling densities occur in the upper Big Hole River near Wisdom, where brook trout are the predominant species (Liknes 1981, Shepard and Oswald 1989, Byorth 1994). To date, there is little documentation of interspecific interactions in the Big Hole River. Skaar (1989) found brook that trout utilized higher velocities, closer to cover than grayling. McMichael (1990) found that grayling showed preference for surface-borne organisms while brook trout selected subsurface drift organisms during summer months in the Big Hole River. McMichael (1990) and Streu (1990) documented limited predation on age 0 grayling fry by brook trout.

In this study we investigated potential competitive interactions and habitat overlap between grayling, native, and introduced sympatric species by comparing micro-habitat positions in Deep Creek, a tributary of the Big Hole River. We also compare grayling and brook trout positions in Deep Creek to a controlled study in the upper Big Hole drainage completed in 1993 (Magee and Byorth 1994).

STUDY AREA

The study site consisted of approximately 1000 m of Deep Creek. Deep Creek arises in the Anaconda-Pintlar range and flows south 15 km to its confluence with the Big Hole River. The site was chosen because of water clarity, stream size and species composition. Water clarity and stream size made snorkeling observations possible. Species composition consisted of Arctic grayling, brook trout, rainbow trout, mountain whitefish, white suckers, longnose suckers, longnose dace, mottled sculpins, and burbot. Brown trout were not seen during the study period but make a spawning migration into Deep Creek in the fall. The riparian area in the study section was healthy and dominated by willows (Salix ssp.) and sedges (Carex ssp.).

METHODS

To investigate species interactions and habitat overlap we measured micro-habitat parameters of Arctic grayling, brook trout, rainbow trout, mountain whitefish, and longnose and white suckers. Micro-habitat sites were measured by snorkeling on 12 occasions from 14 July to 15 August 1994. Snorkeling occurred between 10:00 and 16:30 when direct sunlight provided the best visibility. Visibility measurements were taken daily and ranged from 5.25-8.50 ft (mean = 6.50 ft). The snorkeling team entered the lower end of the study section and moved upstream. Snorkel reaches within the study section were contiguous and snorkeled consecutively until the entire study section was surveyed 3 times.

To measure micro-habitat positions of fish, a diver moved upstream, thoroughly inspecting banks, cover areas, and open water. Upon locating a fish, the diver monitored it for at least 2 minutes to ensure it was undisturbed. The diver identified species of fish, it activity (e.g. resting, feeding, hiding), and estimated its length and focal point elevation (distance above the substrate). The diver carried a meter stick to facilitate accurate measurements.

Fish positions were marked with an individually numbered and colored stone. We identified the habitat type (pool, riffle, or run (Bisson et al. 1982)), measured substrate composition and aquatic vegetation cover within 20.0 inches of the focal point, and identified type of the nearest cover. Cover was defined as any object that could conceal fish from overhead view and was differentiated into 3 categories: depth, turbulence, and structural. We considered depth as cover if water was greater than 2.0 feet deep. We defined turbulence as sufficient agitation of the water surface to obscure fish from view. Examples of structural cover include aquatic or overhead vegetation, woody debris, rocks, or undercut banks. The diver relayed all data to a recorder on the bank.

Following each snorkel event we measured water column (total) depth, mean water column velocity (0.6 depth), and focal point water velocity. Water velocities were measured using a Price AA current meter. Each snorkeling event lasted 1 hour, thereafter a new diver would proceed.

To account for differences in focal point elevation and species length estimates, each diver was tested prior to initiation of the study. Testing consisted of estimating length and focal point elevation of dummy fish strapped to a bar randomly placed along the stream channel. Estimated fish lengths were within 1.0 inch of actual length on 80% of estimates and never greater than 2.0 inches from actual measurements. Estimated focal elevations were within 1.5 inches of actual elevation on 88% of test points below 20.0 inches (mean = 0.37 inches), and averaged 1.33 inches for elevations above 20 inches.

Data were entered into dBASE IV files (Borland International Inc. 1992), Lotus 1-2-3 spreadsheets (Lotus Development Corp. 1992), and analyzed with STATISTIX 4.0 (Analytical Software 1992). We used a nonparametric, two-sample (Mann-Whitney) analysis to test for differences between positions of longnose and white suckers. We used a Chi-square analysis to test for independence between species and habitat type. To compare micro-habitat use and mean lengths between species we used a Kruskal-Wallis one-way nonparametric ANOVA and Least significant difference (LSD) or Tukey (HSD) pairwise tests. Levels of significance was held at $\alpha=0.05$ for all tests.

Grayling and brook trout positions were compared with those reported by Magee and Byorth (1994) for a controlled study at the headwaters of the Big Hole River.

RESULTS

A total of 274 fish positions were characterized. Catostomid observations were pooled because there was no significant differences in focal elevation, focal velocity, mean column velocity, or total depth between white and longnose suckers. Mean lengths for rainbow trout were significantly smaller than other species. Mountain whitefish were significantly larger than other species except the catostomids. Grayling, brook trout, and catostomid mean lengths were similar (Table 1).

Table 1. Number of snorkeling observations, mean length, standard deviation (SD) and range for each species in Deep Creek, summer 1994.

SPECIES	N	MEAN LENGTH (INCHES)	SD	RANGE (INCHES)
brook trout	93	8.1	1.9	4.0-16.0
Arctic grayling	77	8.9	1.7	2.0-13.0
rainbow trout	43	5.4	1.5	4.0-10.0
mountain whitefish	46	10.3	3.4	3.0-15.0
Catostomids	15	8.9	3.4	4.0-17.0

Habitat Types

Our observations of habitat usage suggests both spatial overlap and segregation occurred between certain species (Table 2). Usage of habitat type was not independent of species which suggests each species preferred certain habitat types (p = 0.00; Chi-square = 140.1). Grayling selected an almost equal ratio of pools and runs and were seldom found in low gradient riffles (LGR). Grayling and rainbow trout had similar preferences for runs; however, rainbow trout used pools less and LGR more than other species. Brook trout used pools more and runs less than grayling and could be found more often in LGR. Both whitefish and catostomids primarily used pools. While whitefish used a broader range of habitat types, catstomids were rarely observed outside pool habitats and never in LGR.

Table 2. Percent of fish observations in habitat types (pool, run, low gradient riffle (LGR)) by species in Deep Creek, Summer 1994.

SPECIES	POOL (%)	RUN (%)	LGR (%)
Arctic grayling	46.8	48.0	5.2
brook trout	53.7	36.6	9.7
rainbow trout	23.3	46.5	30.2
mountain whitefish	69.6	15.2	15.2
Catostomids	93.3	6.7	0.0

A species' preference for habitat type is reflected in their usage of total depths (Table 3). Catostomids and whitefish used significantly deeper total depths than other species. Total depths of grayling and brook trout were not significantly different. They both used intermediate total depths which illustrated pool and run preferences. Rainbow trout used significantly shallower areas than other species, reflecting a preference toward runs and LGR.

We found 2 groups in which mean column velocities were significantly different (Table 4). Rainbow trout, grayling and whitefish were found in areas of similar higher velocities and brook trout and catostomids were found in lower velocities. Brook trout appear to seek out lower velocities than grayling at similar total depths. Rainbow trout used the fastest mean column velocities which may be expected at shallower total depths in runs and LGR.

Although whitefish preferred pool habitats with total depths similar to catostomids, they used areas with significantly higher mean column velocity. Catostomids were found in deep, low velocity pool habitats.

Table 3. Least significant difference pairwise comparison of mean total depth, by species, in Deep Creek, Summer 1994. Groups with I's in same column are not significantly different (p < 0.05).

SPECIES	MEAN (ft)	HOMOGENEOUS GROUPS		
Catostomids	2.55	I		
mountain whitefish	2.44	I		
Arctic grayling	2.08		I	
brook trout	1.99		I	
rainbow trout	1.45			I

Table 4. Tukey (HSD) pairwise comparison of mean column velocity, by species, in Deep Creek, Summer 1994. Groups with I's in same column are not significantly different ($p < 0.05$).

SPECIES	MEAN (ft/s)	HOMOGENEOUS GROUPS	
rainbow trout	1.28	I	
Arctic grayling	1.20	I	
mountain whitefish	1.18	I	
brook trout	0.91		I
Catostomids	0.68		I

Micro-Habitat

Pairwise comparisons of focal elevations revealed three homogenous groups (Table 5). Grayling used the highest focal elevations and hence were the most surface-oriented. In contrast, whitefish and the catostomids were the most substrate oriented. Grayling had significantly higher focal elevation than all species except rainbow trout. While brook trout used intermediate focal elevations similar to rainbow trout and whitefish.

Focal velocities used by grayling were not significantly different than rainbow trout or mountain whitefish (Table 6). Grayling used significantly higher focal velocities than brook trout and the catostomids. Focal velocity usage reflected that of mean column velocity; rainbow trout occupied the highest velocities followed by grayling, whitefish, brook trout and the catostomids, respectively. We compared mean column and focal velocities and found that all species utilized slower focal velocities than mean column velocities. Specifically, grayling used focal velocities 28% slower than mean column velocities; rainbow trout 30% lower, brook trout 36% lower, whitefish 44% lower, and the catostomids 49% lower.

Table 5. Tukey (HSD) pairwise comparisons of mean focal elevation, by species, in Deep Creek, Summer 1994. Groups with I's in same column are not significantly different ($p < 0.05$).

SPECIES	MEAN (ft)	HOMOGENEOUS GROUPS		
Arctic grayling	0.35	I		
rainbow trout	0.28	I	I	
brook trout	0.23		I	I
Catostomids	0.19		I	I
mountain whitefish	0.18			I

Table 6. Tukey (HSD) pairwise comparisons of mean focal velocity, by species, in Deep Creek, Summer 1994. Groups with I's in same column are not significantly different ($p < 0.05$).

SPECIES	MEAN (ft/s)	HOMOGENEOUS GROUPS			
rainbow trout	0.92	I			
Arctic grayling	0.84	I	I		
mountain whitefish	0.66		I	I	
brook trout	0.58			I	I
Catostomids	0.35				I

Substrate, Vegetation, and Cover

Rubble, cobble and gravel were predominant substrate types observed at locations of all species. No major differences occurred in substrate usage between species; however, this may be attributed to availability. The study section was uniform in gradient and substrate type was consistent throughout the study reach.

Limited aquatic vegetation occurred throughout the study reach. For 86% of fish observations aquatic vegetation covered less than 20% of the immediate substrate. The catostomids used vegetated areas slightly more than other species. This may be attributed to increased substrate vegetation in low velocities pools.

Use of cover by species is shown in Table 7. Grayling and whitefish used almost identical cover types: primarily depth and turbulence and seldom structural cover. Brook trout were associated with structural cover more than any other species. Cover used by rainbow trout and catostomids reflect habitat type preferences (Table 2). Rainbow trout inhabited higher velocity habitats and primarily used turbulence as cover. Catostomids, a pool-oriented species most often used depth as cover; however, they also used structural objects (especially woody debris) on 33% of observations.

Table 7. Percentage of cover type used by species in Deep Creek, Summer 1994. Structural objects include: aquatic and overhead vegetation, woody debris, rocks and undercut banks.

COVER TYPE (%)	Arctic grayling	brook trout	rainbow trout	mountain whitefish	Catostomids
depth	55.0	35.0	14.0	56.0	67.0
turbulence	36.0	27.0	65.0	35.0	0.0
structural objects	9.0	38.0	21.0	9.0	33.0

Experiment vs In Situ

We compared sympatric grayling and brook trout micro-habitat positions from a controlled study in the upper Big Hole River (Magee and Byorth 1994) with Deep Creek observations (Table 8). Grayling and brook trout used lower focal elevations and higher mean column and focal velocities in Deep Creek. However, grayling used deeper total depths and brook trout shallower total depths in Deep Creek than in the controlled study. Differences in micro-habitat parameter means between the study sites indicated depths and velocities in Deep Creek and the controlled study were dissimilar.

Although micro-habitat parameter means differed, results were similar between the controlled study and in situ. Grayling used significantly higher focal elevations, higher focal and mean column velocities than brook trout in both studies. Brook trout used significantly deeper total depths in the controlled study, however, we found no difference of total depth use between species in Deep Creek (Table 8).

Table 8. Comparison of micro-habitat observations between grayling in sympatry and allopatry and brook trout in sympatry in a controlled study in the upper Big Hole Drainage 1993, and Deep Creek 1994. Significant differences (*) at $p < 0.05$.

SPECIES	N	FOCAL ELEVATION (ft)	FOCAL VELOCITY (ft/s)	TOTAL DEPTH (ft)	MEAN COLUMN VELOCITY (ft/s)
Arctic grayling (controlled study)	97	0.49	0.63	1.80	0.72
brook trout (controlled study)	81	0.30	0.35	2.32	0.43
results		GR>EBT*	GR>EBT*	EBT>GR*	GR>EBT*
Arctic grayling (Deep Creek)	77	0.35	0.84	2.08	1.20
brook trout (Deep Creek)	93	0.23	0.58	1.99	0.91
results		GR>EBT*	GR>EBT*	NO DIFF	GR>EBT*

DISCUSSION

Both grayling and brook trout are known to use pool and run habitats (Butler and Hawthorn 1968, Griffith 1972, Cunjak and Greene 1983, Hubert et al. 1985, Skaar 1989, Hughes and Dill 1990). However, we found evidence that their usage of depth and velocities within these habitats may differ.

Magee and Byorth (1994) detected spatial segregation between grayling and brook trout in a controlled study in the upper Big Hole River. Grayling used faster velocities at shallower depths and were more surface oriented than brook trout. Brook trout, in contrast, used lower velocities in deeper habitats while maintaining positions closer to cover and substrate. Skaar (1989) also detected distinct differences in habitat utilization of age 1 and older grayling and brook trout in the Big Hole River. However, he reported brook trout had a tendency to occupy faster water than grayling but remained close to cover. However, techniques differed between studies. McMichael (1990) investigated food habits of grayling and brook trout and reported that age 1 and older grayling selected a higher proportion of surface food while brook trout consumed a larger proportion of subsurface items during summer months in the Big Hole River.

Our results in Deep Creek were similar to those of the controlled study (Magee and Byorth 1994) (Table 8). Grayling used faster mean column and focal velocities and were more surface-oriented than brook trout. We found no differences in usage of total depths contrary to the earlier controlled study. Brook trout used significantly deeper habitats than grayling in the controlled study. One explanation may be that in the controlled study there were fewer pools and less riparian cover than in Deep Creek. Brook trout may have positioned themselves in the deepest available habitats for protection. In Deep Creek, riparian vegetation and woody debris provided abundant cover, allowing brook trout to use a broader range of micro-habitats.

Our categories of cover type may not be specific enough to describe a species' association with cover. Depth and turbulence may be less effective cover than structural objects (e.g. undercut banks, rocks, woody debris, aquatic or terrestrial vegetation). Brook trout are known to be closely associated with cover (Butler and Hawthorn 1968, Griffith 1972, Cunjak and Greene 1983). In the Big Hole drainage, Magee and Byorth (1994) and Skaar (1989) found brook trout were more closely associated with cover than grayling. Although our cover type categories differ, results in Deep Creek are similar if only structural cover types were measured; grayling were seldom and brook trout were often associated with structural cover types.

The results of the earlier study did not detect a shift in micro-habitat positions of grayling or brook trout at different levels of sympatry (Magee and Byorth 1994).. Both species used different micro-habitat positions regardless of interspecific densities. Similar results in Deep Creek further confirm spatial segregation for micro-habitats between grayling and brook trout. Although this study examines only one life stage and season it has important management implications. Kaya (1992b) identified potential reintroduction streams in Montana to increase fluvial grayling distribution. Among the criteria used to evaluate potential sites was the presence of exotic species. Our results suggest spatial segregation occurs between adult grayling and brook trout during summer months. Until further knowledge of interactions at additional life history stages is gathered, streams that have been precluded from reintroduction solely on the presence of brook trout should be reexamined.

Evidence of spatial segregation between co-evolved sympatric species has been well documented (reviewed by Hearns 1987). In Deep Creek we found spatial segregation between the resident native species; grayling, whitefish, and catostomids. Although some overlap in habitats occurred, each species used different depths or velocities. Grayling and whitefish were segregated by depth preferences. Grayling inhabited higher focal elevations and used shallower total depths than whitefish. Grayling and catostomids were separated by both velocities and depth usage. Grayling were more surface-oriented, using higher velocities at shallower depths, than catostomids. Whitefish and catostomids used deep pools and were substrate oriented but catostomids used the deepest, slowest velocity habitats. In contrast, whitefish preferred higher velocities and used a broader range of habitat types. Differences in micro-habitat positions reduces potential competition between native sympatric species.

The potential for competition should be greater for species with similar life histories which did not co-evolve (Hearns 1987, Fausch and White 1986, Moyle et al. 1986). In the Big Hole River this includes; brook trout, rainbow trout and brown trout. We found spatial segregation between grayling and brook trout. The greatest potential for competitive interactions occurred between grayling and rainbow trout. These two species did not significantly differ in usage of focal elevations, or focal or mean column velocities. However, rainbow trout used shallower total depths and were found more often in riffles and less in pools than grayling. Grayling were larger (mean = 8.9 inches) than rainbow trout (mean = 5.4 inches) and thus may have a competitive advantage. Deep Creek provides summer habitat for all life stages of grayling but is primarily a rearing area for rainbow trout. Observations of rainbow trout and grayling of more equal sizes are necessary to identify their competitive interactions.

Until additional studies can determine outcomes of grayling-rainbow trout interactions, managers must assume rainbow trout have a competitive advantage over grayling. Rainbow trout distribution in the Big Hole River suggests displacement of grayling from certain habitats. Our data suggest that there is potential for competitive exclusion. Recent surveys indicate increasing encroachment of rainbow trout above Dickie Bridge. A management priority is to maintain and increase productive grayling habitats in the Big Hole River and should include limiting rainbow densities upstream of Dickie Bridge.

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SUMMARY OF MADISON RIVER/ENNIS RESERVOIR GRAYLING STUDIES, 1990-94

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ABSTRACT

Studies of resident Arctic grayling (Thymallus arcticus) of the Madison River/Ennis Reservoir have been directed primarily at the spring spawning run. Population statistics are derived from fish captured during spawning. Fish are tagged with visual implant tags for individual identification and population estimation. The Madison grayling population is estimated to be between 500 and 1000 2-year old and older fish. At present population levels, the spawning population is composed almost exclusively of 2 and 3 year old fish. Madison grayling average approximately 6 inches at first annulus and 12 inches at second annulus. Growth rate decreases radically after age 2. Male:female ratios have ranged from 2.2:1 to 3.8:1. In 1993 and 1994, gametes were collected and used to supply fish for juvenile behavioral studies and for reintroduction of 1 year old grayling into a tributary of the lower Madison River. Adult grayling are caught by anglers as far as 35 miles upstream of Ennis Reservoir in the summer and fall. This behavior is inconsistent with adfluvial lacustrine behavior, which young-of-the-year Madison grayling have been documented to exhibit.

INTRODUCTION

In 1990, the Montana Power Company (MPC) and Montana Fish, Wildlife, and Parks (FWP) agreed to initiate fieldwork on the Madison River/Ennis Reservoir Arctic grayling (Thymallus arcticus) population (Byorth and Shepard 1990). MPC owns and operates Hebgen and Ennis (Madison) dams on the Madison River and an additional seven dams on the Missouri River. This hydropower system is presently undergoing the Federal Energy Regulatory Commission (FERC) relicensing process. MPC's dams and resultant reservoir operations may have significant affects on fish populations in the rivers and reservoirs. The U.S. Fish and Wildlife Service has reviewed the fluvial Arctic grayling for addition to the Threatened and Endangered Species List, and made a "warranted, but precluded" determination (Federal Register 1994). The Big Hole River in southwestern Montana is the sole remaining location in the contiguous United States with a population of fluvial Arctic grayling. MPC and FWP agree that the Madison River population warrants study to determine whether it is fluvial, and to address the potential affects that listing the species could have on reservoir operations, river flows, and other fisheries and recreation issues, while working to maintain and increase the grayling population.

Historic information regarding Madison grayling is mostly anecdotal. Long time residents of the Ennis area, referring to grayling, have stated that they remember catching "gunny-sacks full of natives" in the Madison River as children. Vincent (1962) reported on the relative abundance of grayling in the Madison River and Ennis Reservoir, citing accounts from as far back as 1875. Byorth and Shepard (1990) trace the historical abundance of Madison grayling.

STUDY AREA

The Madison River has its headwaters in Yellowstone National Park (YNP) where the Gibbon and Firehole Rivers converge. It flows northward in southwestern Montana between the Madison Mountains on the east and the Gravelly and Tobacco Root Mountains on the west until it converges with the Jefferson and Gallatin Rivers to form the Missouri River. Historic use of the Madison Valley has been primarily agricultural, but outdoor recreation and seasonal homeownership have recently become more important to the economy of the valley. Two man-built reservoirs and one naturally formed lake impound waters of the Madison River. Hebgen Dam, a 13,000 acre storage facility, impounds the river near West Yellowstone, Montana. Ennis (Madison) Dam, a 3,740 acre electrical generation facility, impounds the river near Ennis, Montana. Both dams are owned and operated by MPC. Earthquake Lake, aka Quake Lake, was formed in August, 1959, when an earthquake caused a mountainside to crumble. An estimated 44 million cubic yards of rock- 80 million tons- slid northward, perpendicular to the local direction of the river, running up the mountain on the opposite side of the canyon (Christopherson 1962). The boulders and debris dammed the river and created Quake Lake, a body of water over 120 feet deep. Average annual flow of the Madison River at McAllister during the base period (1937-86) was 1800 cubic feet/second (USGS 1989).

METHODS

During the course of the Madison grayling studies, the principal method used to capture adult grayling has been a driftboat mounted mobile anode electrofishing system used primarily during the spring spawning run. Secondary methods used in the Madison River channels area have been trapping and hook-and-line. Sampling in Ennis Reservoir has been conducted using jetboat mounted boom electrofishing in and around the mouths of the channels of the Madison River as they enter Ennis Reservoir, gill and trammel netting, and beach and purse seining.

Captured fish are weighed, measured, sexed, tagged behind one or both eyes with individually numbered visual implant (V.I.) tags, and released. During 1993 and 1994, eggs were stripped from females, fertilized with sperm pooled from males, and sent to the Bozeman Fish Technology Center, or other selected hatcheries, for rearing. The resulting fry were used for behavioral comparisons with progeny of known fluvial and lacustrine populations, and for introduction into streams deemed suitable for fluvial grayling in attempts to expand the range of the grayling.

Estimates of the spawning population of Madison grayling have been conducted by Byorth and Shepard (1990), Clancey (1995) and in this report. The modified Petersen equation is used for the estimates:

$$N=([(M+1)(C+1)]/(R+1))-1$$

$$V_N=N^2(C-R)/[(C+1)(R-2)]$$

where N= estimated population number
M= number of fish marked in the marking run (year x)
C= number of fish captured (marked + unmarked) in the capture run (year x+1)
R= number of marked fish in the capture run
V= Variance of N

To conduct the estimate, grayling captured in the spawning run one year serve as the marked population, and grayling captured in the spawning run the next year serve as the capture population. To conduct the estimate, it is necessary to remove 2 year old fish from the capture population, since, as 1 year olds, they were not available to be marked in the first years spawning run.

In July, 1993, four grayling were implanted with radio transmitters using the technique described by Ross and Kleiner (1982). Attempts to track these fish were conducted on foot and by canoe.

Juvenile grayling studies were initiated on Madison grayling in 1993 and 1994. Personnel from the Montana

State University (MSU) Biology Department conducted this portion of the study through a graduate program (Kaya and Jeanes 1994), and consultants retained by MPC have assisted in field efforts and conducted snorkel surveys in the reservoir for juvenile grayling (R2 Resource Consultants, Inc. 1994). The intent of these studies is not only to describe behavior and habits of juvenile grayling, but also to help address the question of the fluvial nature of the Madison grayling population.

Stocking records of the Montana Fish, Wildlife, & Parks show 24 occurrences of planting grayling into waters of the Madison drainage between 1928 and 1983. The source (lake, river, or stream) of these grayling is not identified.

RESULTS AND DISCUSSION

Grayling spawning in the Madison River occurs primarily in April. Grayling spawn in the few miles of river between Valley Garden Fishing Access Site and Ennis Reservoir, mostly in the 1/2 mile just above the reservoir. Temporal distribution, by sex, is listed in Table 1. Recaptures of spawning grayling within any particular year show that they readily move between various areas of the Channels section of the Madison River. Recaptured grayling are listed in Table 2. Because of this propensity to move about, grayling may occupy a specific channel one day, but not the next. So, depending on the specific route taken during any particular day's electrofishing, few grayling may be captured, even at the height of the run. Conversely, a relatively high number may be caught despite the apparent small size of the population. Byorth and Shepard (1990) calculated a population size of 545 fish larger than 10 inches, but recognized the limitations of conducting an estimate on a small population. A population size of 996 $\pm$423 (80 % confidence limits) was calculated for the 1992 spawning population. The estimate for the 1993 spawning population is 619 $\pm$290 (80 % C.I.). There are obvious shortcomings to this population estimation procedure. The one year time lag necessary to collect the capture population may preclude detecting any potential problems within the population. Additionally, the "tightness" of the estimate is questionable because it is subject to such large variation in either the marked population or the capture population. The 1993 estimate is poor, and the 1994 estimate can be expected to be poor, due to the extremely small number of grayling captured in 1994, only 29 fish. This was due to the rapid onset and short duration of the spawning run. Daily monitoring is required to detect the initiation of the run. The manpower available to work the run is not consistent, either in availability or experience. It is for reasons such as these that trapping will be used in an attempt to increase efficiency in capturing spawners in the 1995 run.

Age structure of spawning grayling is outlined in Table 3. Grayling captured in 1991 that were larger than 13.8 inches were not aged due to the misplacement of their scale card. In 1992 and 1993, when the spawning runs were relatively strong, 2 year old fish were the strongest cohort. In 1990, when the run was weak, 3 year old fish were the strongest cohort. This was probably also the case in 1991, but cannot be confirmed due to the loss of the scale card for fish 13.8 inches and greater. In 1994, despite the low number of fish captured, 3 year old fish were the most common. The 1994 run was probably stronger than the 1990 and 1991 runs, but the effort in 1994 was low. Table 4 contains the backcalculated length-at-age data for each annual spawning run. Firm conclusions regarding growth are difficult to draw with the small sample sizes found in some years. Generally, the only recognizable growth pattern is the noticeable decrease in annual growth after age 2, which occurs in both sexes.

Hundreds of suckers and some trout, but no grayling, were captured in an upstream trap installed in a channel of the Madison River in 1994. Construction of the trap was not completed until near the end of the grayling spawning run. Subsequently, it was placed in the river after the run was over. It was very efficient in capturing white suckers (Catostomus commersoni) during their spawning run. Additionally, rainbow trout (Oncorhynchus mykiss), brown trout (Salmo trutta), and longnosed suckers (Catostomus) were captured.

Table 1. Temporal distribution of spawning grayling, by sex, 1990-94.

	M	F	U
1990			
4/05			1
4/12	1	1	
4/18			1
4/20	2	3	4
4/21	1		
4/22	1		
4/24	5	1	1
4/25	2		
	12	5	7
1991			
4/15	1		
4/16	4	5	
4/22	1	1	
4/23	8	1	
4/30	1		
5/1	10	3	
	25	10	
1992			
4/2	8	2	
4/3		1	
4/6	19	16	
4/9	20	4	
4/14	15	4	
4/15	12	2	
4/17	9	1	2
4/21	3		
	86	27	2
1993			
4/19	8	10	
4/21	27	17	
4/23	23	6	
4/27	15	4	
4/29	15	6	
5/3	3		
	91	43	
1994			
4/18	6	3	
4/19	11	3	
4/21	4		
4/25	2		
	23	6	

Table 2. Recaptures of tagged grayling in the Madison drainage, 1990-94. Any recaptures made within the same calendar year as the tagging date are not reported.

Tag date	location	length	weight	sex	Recapture date	length	weight	location
1991								
5/1	Channels	12.6"	0.58lbs.	M	4/24/93	15.0"	1.0	Channels
1992								
4/2	Channels	12.8"	0.65	M	4/21/93	14.3	0.88	Channels
4/6	Channels	12.6	0.66	F	4/29/93	14.7	0.98	Channels
	"	14.8	1.08	M	5/3/93	--	--	Fletchers
	"	15.1	1.00	M	4/19/93	16.1	1.18	Channels
	"	12.6	0.66	M	4/18/94	15.6	1.22	Channels
4/9	Channels	11.5	0.46	F	4/21/93	13.1	0.80	Channels
4/14	Channels	11.4	0.53	M	4/19/93	12.8	0.80	Channels
4/15	Fletchers	15.3	1.08	F	4/19/94	15.9	1.10	Fletchers
1993								
4/19	Channels	13.9	0.80	M	4/21/94	15.2	1.01	Channels
4/21	Channels	14.2	0.81	M	4/21/94	15.2	0.99	Channels
4/23	Fletchers	11.2	0.50	F	3/14/94	12.2	0.62	Bypass
4/27	Channels	12.7	0.60	M	4/19/94	14.5	0.80	Fletchers
	"	11.7	0.56	M	9/30/94	~16[1]	--	Reservr.

[1]Angler report

Table 3. Age structure and average length of grayling captured in the spawning run in the Channels section of the Madison River, 1990-94.

	1990			1991		1992		
Age	M	F	U	M	F	M	F	U
I			7.2 n=3 (6.6-7.7)					7.6 n=2 (7.2-8.0)
II	14.6 n=2 (14.6& 14.6)	11.9 n=1		12.4 n=14 (11.5- 12.8)	12.5 n=2 (12.2- 12.8)	12.4 n=43 (11.8- 13.3)	12.1 n=13 (10.4- 13.5)	
III	15.0 n=9 (14.2- 15.6)	14.3 n=4 (13.6- 14.9)	14.7 n=4 (14.2- 15.1)	13.8 n=1 (11.2- 15.9)	--- n=0 (13.7- 15.7)	14.2 n=36	14.3 n=14	

	1993		1994	
Age	M	F	M	F
I	0	0	0	0
II	12.1 n=48 (11.0- 13.2)	11.3 n=19 (10.2- 12.1)	11.9 n=5 (11.5- 12.1)	-- n=0
III	13.7 n=31 (11.0- 15.8)	13.5 n=16 (11.4- 14.9)	14.4 n=10 (13.8- 14.8)	13.6 n=4 (13.5- 13.8)
IV	15.1 n=5 (13.2- 16.1)	14.6 n=4 (13.8- 15.9)	15.4 n=6 (14.6- 15.9)	15.4 n=1
V				16.2 n=1

Table 4. Length-at-age (backcalculation) of grayling captured during the spawning run, 1990-93.

	M	F	U
1990			
I			
@I n=3			7.2 (6.6-7.7)
II			
@I	8.0 n=2 (8.0 & 8.0)	6.0 n=1	
@II	14.6 (14.6 & 14.6)	11.9	
III			
@I	6.4 n=9 (5.3-7.7)	5.4 n=4 (4.4-6.4)	6.9 n=4 (5.6-7.9)
@II	12.4 (11.5-13.1)	12.0 (10.1-13.1)	13.0 (12.1-13.8)
@III	15.0 (14.2-15.6)	14.3 (13.6-14.9)	14.7 (14.2-15.1)
1991			
II			
@I	5.8 n=14 (4.9-6.9)	6.3 n=2 (5.6-6.9)	
@II	12.4 (11.5-12.8)	12.5 (12.2-12.8)	
III			
@I	6.6 n=1		
@II	12.4		
@III	13.8		
1992			
I			
@I			7.6 n=2 (7.2-8.0)

II		
@I	6.5	6.6
	n=43	n=13
	(4.9-7.3)	(4.4-7.6)
@II	12.4	12.1
	(11.8-13.3)	(10.4-13.5)
III		
@I	5.8	6.1
	n=36	n=14
	(4.2-7.8)	(5.2-7.0)
@II	12.2	12.3
	(8.7-14.2)	(11.6-14.1)
@III	14.2	14.3
	(11.2-15.9)	(13.7-15.7)
1993		
II		
@I	6.3	6.3
	n=48	n=19
	(4.8-7.7)	(5.4-6.7)
@II	12.1	11.3
	(11.0-13.2)	(10.2-12.1)
III		
@I	6.3	6.1
	n=31	n=16
	(5.3-8.0)	(5.3-7.2)
@II	12.2	11.8
	(9.8-13.7)	(10.4-12.9)
@III	13.7	13.5
	(11.0-15.8)	(11.4-14.9)
IV		
@I	5.6	5.4
	n=5	n=4
	(4.5-6.1)	(4.7-5.8)
@II	12.3	11.6
	(10.6-13.1)	(10.6-12.7)
@III	14.1	13.5
	(12.1-15.3)	(13.0-14.2)

@IV	15.1 (13.2-16.1)	14.6 (13.8-15.9)
<u>1994</u>		
II		
@I	5.6 n=5 (5.0-5.9)	
@II	11.9 (11.5-12.1)	
III		
@I	6.2 n=10 (5.2-6.6)	5.9 n=4 (5.3-6.6)
@II	12.1 (10.3-14.3)	11.7 (11.2-11.9)
@III	14.4 (13.8-14.8)	13.6 (13.5-13.8)
IV		
@I	6.2 n=6 (5.5-7.3)	6.5 n=1
@II	12.4 (11.8-12.9)	12.8
@III	14.5 (14.2-15.0)	14.4
@IV	15.4 (14.6-15.9)	15.4
V		
@I		5.4 n=1
@II		11.9
@III		14.7
@IV		15.6
@V		16.2

Conversations with anglers revealed that grayling are readily caught in and around the mouths of the Madison River channels at the south end of Ennis Reservoir. Hook and line sampling was effective in capturing adult grayling at the mouth of Fletchers Channel in July, 1993. Of the 10 grayling captured, four were implanted with radio transmitters using the shielded-needle technique described by Ross and Kleiner (1982). Attempts to relocate these fish beginning three days after implanting the transmitters were unsuccessful. The fate of these fish is unknown. Failure to relocate any of them may have been due to movement of the fish, especially if they moved downstream into Bear Trap Canyon below the Madison powerhouse. Grayling tagged in Ennis Reservoir or the Channels section of the river have been captured in the Bypass reach of the river. It is more likely that they were not relocated due to the inability to thoroughly search the reservoir and river because of the lack of appropriate watercraft and the expense required to hire an aircraft to conduct an aerial survey.

Males outnumber females each year. The sex ratio has varied from 2.2:1 in 1990 & 1993 to 3.8:1 in 1994 (Table 5).

During 1993 and 1994, eggs were stripped from females, fertilized with sperm pooled from males, and sent to the Bozeman Fish Technology Center, or other selected hatcheries, for rearing. The resulting fry were used for behavioral comparisons with progeny of known fluvial and lacustrine populations, and for introduction into streams deemed suitable for fluvial grayling in attempts to expand the range of the grayling, namely Cherry Creek, a tributary to the lower Madison River. Results of the behavioral comparisons conducted with juvenile grayling are reported by Kaya and Jeanes (1994).

Initial intentions to reduce the density of rainbow and brook trout in the Butler reach of Cherry Creek in June, 1994, were thwarted by rain and high water. The effort was completed in July when approximately 1300 rainbow and 2200 brook trout were removed from the stream by electrofishing, and 1450 age 1 grayling were released into Cherry Creek. Eight hundred of the grayling were held for 48 hours in live cages before release, and 650 were released directly into Cherry Creek. A downstream migrant trap was installed in Cherry Creek from July 25 to August 29, 1994. No grayling, or any other fish, were captured. The landowner along the Butler reach reported catching and releasing grayling in September.

In the spring of 1994, personnel from FWP and MSU spent much time locating and monitoring the rearing and growth of young-of-the-year (y-o-y) grayling in the Madison River channels area and in Ennis Reservoir (Kaya and Jeanes 1994). They found y-o-y grayling use small blind backchannels of the Madison River for rearing, and are closely associated with y-o-y mountain whitefish (Prosopium williamsoni). Both species remained in these backchannels until mid to late June. At that time, y-o-y of both species abandoned these rearing areas. Beach seining was first conducted in the shoreline areas of Ennis Reservoir on June 16, when y-o-y grayling and whitefish were captured in the backwater areas at the head of the reservoir (the south end). Additionally, 30 y-o-y grayling were captured at the mouth of Meadow Creek on July 1, indicating the possibility of a grayling spawning run up that stream. Plans for the 1995 field season include assessing grayling movements up this stream. Beach seining and purse seining in the reservoir throughout the summer and into the fall of 1994 became more difficult and less efficient as the macrophytes developed. Adult and juvenile grayling were captured in beach seines, but none were captured in purse seine efforts. Kaya and Jeanes (1994) concluded through behavioral trials and field observations that the Madison/Ennis grayling population is most likely of an adfluvial lacustrine nature rather than of a fluvial nature, at least in the first four months after swim-up. However, each summer and fall since 1992, fishing guides and anglers on the Madison River report catching adult grayling in "pods" as far as 35 miles upstream of Ennis Reservoir during the summer and fall. This behavior is inconsistent with behavior of fish in adfluvial populations. Additional fieldwork is being designed to determine the long-term movements of grayling in these pods to address the possibility of a fluvial component of the Madison grayling population.

It is clear that the Madison grayling population is small, less than 1000 individuals of spawning age. The timing of the spawning run is consistent each year, and, despite the small number of spawning fish, apparently widespread throughout the Channels section of the Madison River.

Table 5. Sex ratio (m:f) of spawning grayling captured by electrofishing in the Channels section of the Madison River, 1990-94.

Year/date	males	females	unknown	
1990				
4/5	0	0	1	
4/12	1	1		
4/18	0	0	1	
4/20	2	3	4	
4/21	1	0		
4/23	1	0		
4/24	4	1	1	
4/25	2	0		
Total	11	5	7	m:f= 2.2:1
1991				
4/15	1	0		
4/16	4	5		
4/22	1	1		
4/23	8	1		
4/30	1	0		
5/1	8	3		
5/2	2	0		
Total	25	10		m:f= 2.5:1
1992				
4/2	8	2		
4/3	0	1		
4/6	19	13		
4/9	19	4		
4/14	2	4		
4/15	10	2		
4/17	8	1	2	
4/21	3	0		
Total	79	27	2	m:f= 2.9:1
1993				
4/19	8	10		
4/21	26	15		
4/23	23	6		
4/27	14	4		
4/29	15	6		
5/3		3	0	
Total	89	41		m:f= 2.2:1
1994				
4/18	6	3		
4/19	11	3		
4/21	4	0		
4/25	2	0		
Total	23	6		m:f= 3.8:1

CONCLUSIONS

Substantial information still needs to be collected to determine the fluvial nature of the population. Behavior both consistent with, and contradictory to, a fluvial nature is exhibited by the population. To determine whether the Madison grayling should be considered for classification under the Endangered Species Act, this seemingly contradictory characteristic of the population must be examined and clarified.

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MAINTAINING MINIMUM INSTREAM FLOWS TO PROTECT FLUVIAL ARCTIC GRAYLING IN THE UPPER BIG HOLE RIVER DURING SEVERE DROUGHT IN 1994

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ABSTRACT

The Big Hole River sustains the only remaining strictly fluvial population of Arctic grayling in the 48 contiguous United States. During the 1980's, the population severely declined in abundance. One factor in the decline was critically low mid-summer stream flows due to severe drought and withdrawals of water for agriculture. In order to maintain a minimum "survival" flow of 20 cfs, we worked with water users to conserve water and secured a grant to provide stock water in exchange for ditch closures. In spite of our efforts, flows fell below 20 cfs on 55 days. The lowest flow recorded was 1.9 cfs in contrast to 1988 when the Big Hole River ceased to flow for 24 days. Diversion of river water for stock is extremely inefficient when compared to providing water in tanks through delivery or groundwater. Development of wells and other sources of stock water, along with cooperative efforts to conserve limited water is critical to the recovery of fluvial Arctic grayling in the Big Hole River.

Fluvial, or river dwelling, Arctic grayling (Thymallus arcticus) were once widespread in the upper Missouri River drainage in southwest Montana. During the 20th century, however, the range of fluvial Arctic grayling in the lower 48 United States became solely restricted to the Big Hole River. The loss of range was attributed to habitat degradation, competition with non-native fishes, over-harvest, and climatic change (Vincent 1962).

The grayling population of the Big Hole River declined to low levels in the early 1980's. In response to the decline, an interagency committee convened in 1988 to develop strategies to protect, restore, and research the population. Since that time the Fluvial Arctic Grayling Workgroup has developed a restoration plan and instituted a coordinated recovery program (Fluvial Arctic Grayling Workgroup 1994). The grayling population of the Big Hole River was listed as a "Category 1" species under the Endangered Species Act. In 1991, a petition was submitted to upgrade the status of the grayling to "endangered" (Nordstrom 1993).

A primary objective of the restoration plan is to identify and mitigate limiting factors. Water quantity and quality have emerged as important factors impacting the abundance of grayling in the Big Hole River. Extreme flood flows during incubation and hatching periods of young grayling was hypothesized as a severe detriment to reproduction in the early 1980's (R. Oswald, Montana Fish, Wildlife, and Parks, personal communication). Clark (1994) found similar negative effects of high flows on grayling recruitment in Alaskan rivers. Extreme drought followed flood years and contributed further to declines in grayling numbers. Impacts of drought were exacerbated by withdrawals of stream flow for agriculture. In the upper Big Hole basin, irrigating hay meadows traditionally extended from May through early July, while diverting water for stock continued through October. In several recent drought years, withdrawals for agriculture led to extremely low flow conditions in critical grayling habitats. Low flow conditions also led to water temperatures exceeding thermal tolerances of grayling (Byorth 1994).

Drought conditions in 1994 necessitated intensive efforts to maintain minimum stream flows in the Big Hole River to protect the grayling population. This paper documents those efforts and proposes longer-term solutions for solving water shortages in dry years.

STUDY AREA

The upper Big Hole basin is a wide intermontane valley in southwestern Montana. Much of the valley floor lies at elevations greater than 6,000 feet. The Big Hole River emanates from the Beaverhead Mountains of the Bitterroot Range and flows northerly approximately 65 miles before arching to the east into a narrow canyon. A 10 mile reach of the upper Big Hole River centered at Wisdom provides habitat for the highest density of Arctic grayling and a majority of their spawning habitat (Figure 1). Cattle ranching and hay production are the primary land uses of the valley floor. Much of the stream flow appropriated for agriculture is diverted upstream from the town of Wisdom and impacts primary grayling habitat.

METHODS

Discharge was recorded hourly at a U. S. Geological Survey (USGS) gaging station at Wisdom (Figure 1). We also monitored the gage daily to track flows. Water temperatures were measured at the USGS gaging station and 4 thermograph stations. Temperature and discharge data were provided by USGS and were provisional during preparation of this report. Thermographs were Omnidata DP-212 units which recorded water temperature at 120 min intervals from April through October.

Nelson (1980) described two flow levels to protect salmonid habitat: an "absolute minimum" below which standing crops of fish decrease and a "most desirable minimum" which maximizes standing crops. In the upper Big Hole River, these flows were determined to be 60 cfs and 160 cfs, respectively (Mt. Dept. of Natural Resources and Conservation 1992). However, during 6 of 7 years between 1988 and 1994, flows near Wisdom have been under 60 cfs for the majority of days between June and September. During drought years a minimum survival flow was necessary. We estimated that 20 cfs would provide the minimum flow necessary to maintain a wetted channel and ensure survival of the grayling population during brief, critical periods.

To maintain a minimum flow of 20 cfs we elicited cooperation from water users in the upper Big Hole basin. As flows approached 20 cfs, we began to contact water users requesting that they conserve water by minimizing withdrawals. We also offered assistance in adjusting headgates, funded a water commissioner, and assisted in acquiring permits for maintenance on a diversion to allow water to pass downstream.

A second phase of efforts consisted of attempts to preserve stream flows by providing alternatives to watering stock through ditches. A grant was secured from the Environmental Contingency Grant Fund to purchase stock tanks, develop a well, and lease a tank truck and driver to deliver water to tanks. A total of 10 stock tanks were distributed over approximately 2,500 acres. An abandoned well was developed to pump water to two tanks installed at the site. The remaining tanks were filled by a 1,000 gallon tank truck which delivered water from established points of diversion on the Big Hole River from September 7 through October 1, 1994.

RESULTS

The hydrograph during 1994 illustrates drought conditions (Figure 2). Instantaneous peak discharge was 976 cfs on April 23, 1994. A second brief peak in discharge of 818 cfs occurred on May 20. Each of the peaks were approximately 6 weeks earlier than those of years with a more typical hydrograph. The timing of these pulses may have impacted spawning success: the first peak coincided with spawning and the second occurred shortly after young grayling hatched. A similar pattern was observed in 1988, another severe drought year. The implications of early runoff were that below normal snowpack (71% of 25-year average on March 1: USGS Files) was depleted more than a month earlier than usual.

Flows declined steadily and fell below 20 cfs on 11 days during June. A combination of water user contacts, the end of irrigation season, and a substantial rain storm resulted in discharge increasing to 57 cfs by July 6 (Figure 3). Decreasing flows resulted in lethal water temperatures. Temperatures as high as 79.7°F were recorded at thermograph station 4 (Figure 1). Lethal temperatures resulted in a fish kill between July 24 and 27 that affected all resident fish species in all age classes. Mortalities were observed intermittently from the mouth of the North Fork of the Big Hole River to the mouth of Pintlar Creek.

Due to critical conditions, water users were asked a second time to restrict their water withdrawals to a minimum. Among known contributions to augment stream flows, approximately 15 cfs was returned to the North Fork and an estimated 2 cfs was passed down Big Lake Creek. The Governor of the State of Montana convened a public meeting to discuss potential solutions to mitigate drought conditions. In order to protect grayling and other fishes from additional stress due to angling, the Montana Fish, Wildlife, and Parks Commission closed the fishing season July 30, 1994 from the mouth of the North Fork to Dickie Bridge.

The Big Hole River increased to 38 cfs due to conservation efforts, but declined to below 20 cfs again by August 10. By August 25, water users had been approached again, but flows continued to decline. The lowest discharge in 1994 was recorded on August 30, at 1.9 cfs (Figure 3). In response to further requests for water conservation, 9 diversions were closed or reduced to augment instream flows.

The Spokane Ditch was also closed on September 7 in exchange for stock tanks and water delivery provided by FWP through the Environmental Contingency Grant. Prior to its closing, approximately 5 cfs was diverted into the Spokane Ditch from the Big Hole River. As a result, flows increased to near 20 cfs by September 16 and continued to fluctuate between 15 and 20 cfs until early October when fall rains relieved drought conditions.

The success of delivering water to stock tanks as an alternative to providing water through ditches is illustrated in Table 1. We delivered water to stock tanks for 25 days. Had the Spokane ditch remained open at a rate of 5 cfs, approximately 81 million gallons of water would have been diverted from the Big Hole River. We delivered approximately 227,375 gallons of water over the 25 day period in addition to approximately 150,000 gallons provided by a well. The volume of water required via the alternative means was approximately 0.5% of that required by ditch delivery.

DISCUSSION

During the last decade drought has persisted in the Big Hole River basin. Of recent drought years, 1988 and 1994 were the most severe (Table 2). In both years poor snowpack, early runoff, and lack of mid-summer precipitation resulted in extremely low flows. However, efforts to conserve water and protect instream flows mitigated the severity of drought in 1994. For example, in 1988 flows diminished to 0 cfs for 24 days, while the lowest discharge recorded in 1994 was 1.9 cfs on 1 day.

Protecting instream flows in drought years is a function of awareness of the need for water conservation and cooperation from water users. In the Big Hole basin, irrigating hay crops generally coincides with runoff and generally does not dewater the Big Hole River. In dry years, stream flow is impacted only at the end of the irrigating season. Diversions for stock water, however, may severely impact stream flows from July through September. During drought years, transporting water through ditches over long distances is extremely inefficient. Only a small fraction of the volume of water that would have been diverted from the river was necessary to provide sufficient water to stock tanks. Future efforts should pursue development of groundwater resources to provide stock water and preserve instream flows.

Our efforts to maintain minimum instream flows were successful in protecting the Arctic grayling population of the Big Hole River during Summer 1994. While the Big Hole River flowed below the 20 cfs "survival flow" on 55 days, the Arctic grayling population appears to have successfully endured the drought. Fall population surveys indicated that grayling densities in the Wisdom area are increasing. The age structure of the population is well balanced, with a full complement of age classes from age 0 to 5 (Byorth 1995). Preservation of minimum instream flows in the Big Hole River through improved water conservation and developing alternative means of watering stock will be critical to the continued survival of fluvial Arctic grayling.

ACKNOWLEDGMENTS

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Table 1. Comparison of efficiency of providing stock water via ditch at 5.0 cfs versus delivering water by stock tanks and a well between September 7 and October 1, 1994.

Water Volume	Ditch	Tanks	Well	Tank + Well
Flow (cfs)	5.0	0.014	0.005	0.019
Gallons per Day	3,231,580	9,095	3,000	12,095
Total Gallons	8.1×10^7	227,000	150,000	377,000
% of Ditch Volume	100	0.34	0.19	0.53

Table 2. Comparisons of Big Hole River discharge parameters measured at the U.S.G.S. gage at Wisdom, 1988 to 1994. Yield is the total volume of flow passing the Wisdom gage during August and September.

Year	# Days less than 20 cfs		Max Flow (cfs)	Min Flow (cfs)	Dates at Min	Yield Aug-Sept (ac-ft)
	Apr.-June	July-Sept.				
1988	0	78	1080	0	8/27-9/21	213
1989	0	4	978	12	8/20	3790
1990	1	0	667	18	5/23	5820
1991	0	16	4300	10	9/4	3690
1992	18	32	479	3.3	5/26	2760
1993	0	0	1700	55	10/5	17490
1994	11	55	976	1.9	8/30	1821

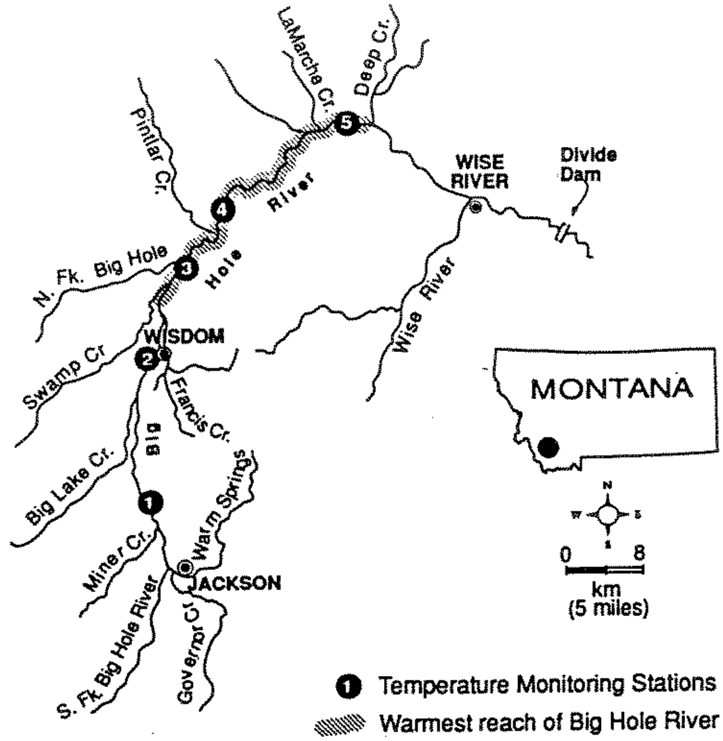

Figure 1. Map of the upper Big Hole River study area including thermograph stations, USGS gage station (2), and warmest reach of the Big Hole.

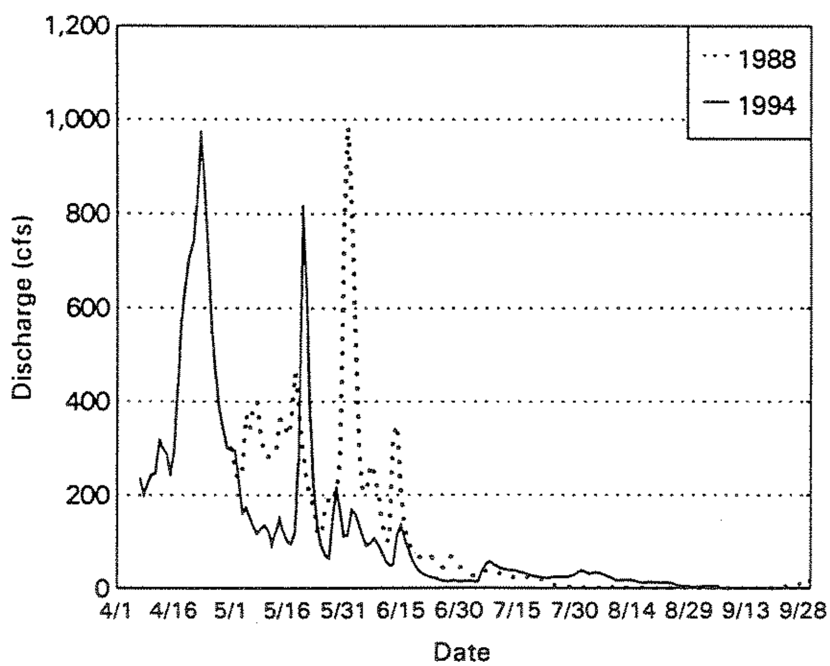

Figure 2. Mean daily discharge (cfs) of the Big Hole River measured at Wisdom gage station, April through September, 1988 and 1994.

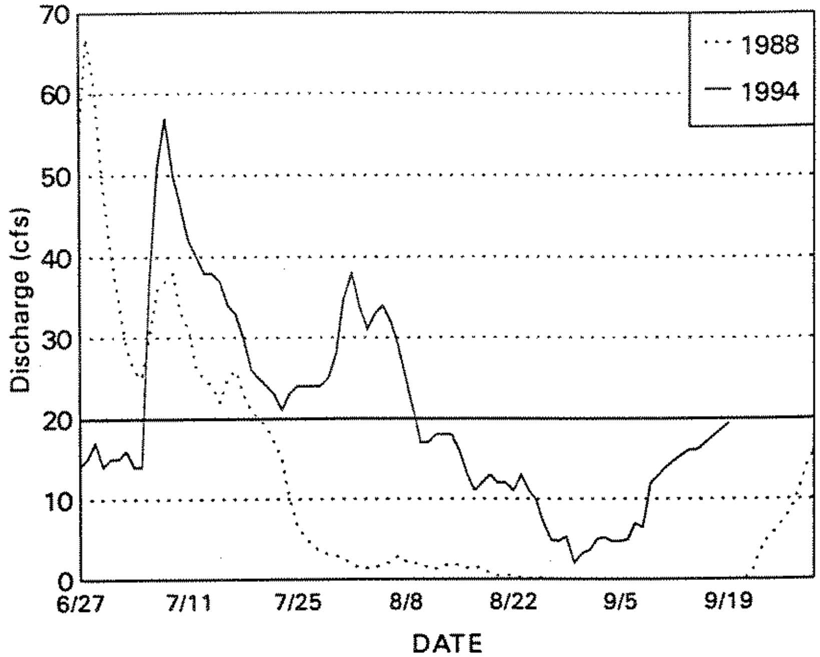

Figure 3. Mean daily discharge of the Big Hole River measured at the USGS gage near Wisdom, June 27 to September 30, 1988 and 1994.

BROODSTOCK DEVELOPMENT PLAN FOR THE FLUVIAL ARCTIC GRAYLING IN MONTANA

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ABSTRACT

The Big Hole River fluvial Arctic grayling Thymallus arcticus is the last surviving remnant population of a fish which was once found throughout the Missouri River drainage upstream from Great Falls, Montana. The number of grayling in the Big Hole River has declined drastically in the last 10-20 years. One of the primary elements in the recovery process is to develop and maintain a captive broodstock at the Fish Technology Center in Bozeman, Montana. Development of a grayling broodstock will require specific safeguards in order to genetically represent the entire population and avoid a bottle neck which would decrease genetic diversity. Precautions are being taken to prevent problems and to provide direction for the program. They include:

- The Big Hole River grayling will be spawned until an effective founding size of at least 50 fish have contributed to the captive reserve.
- Eggs from each mating will be incubated separately so that the number of parents successfully contributing to a year class is known.
- The contribution of each successful mating to a year class should be kept nearly equal if possible.
- In order to convert year class genetic differences into within population genetic diversity, different year classes will be crossed.
- To prevent brood stock from becoming highly adapted to the hatchery environment, gametes from Big Hole River fish will be infused at least every ten years for three successive years.

INTRODUCTION

The distribution of the Arctic grayling Thymallus arcticus is very different today than in historic times. The Big Hole River Arctic grayling is the last strictly fluvial population of a species which was once found throughout the Missouri River drainage upstream from Great Falls, Montana. Competition from non-native salmonids (brook, brown, and rainbow trout), habitat degradation, irrigation practices, and susceptibility to over fishing have resulted in the elimination of grayling in most riverine habitats (Kaya 1990). Over the last 15-20 years the numbers of these fish have severely declined. Based, on recent population estimates, there are about 100-200 fish per river mile for a total population of 2000-4000 fish (Byorth 1993).

Efforts to restore the population are under way. One of the primary elements in the recovery process is to develop and maintain a captive broodstock at the Fish Technology Center in Bozeman, Montana. These fish will be used as a refugia population in case of extinction in the wild, as a source of fish for attempts to establish other fluvial populations, and if circumstances do not improve, to supplement the existing population.

Broodstock Development

In order to begin developing a captive broodstock, wild fish have been captured by electrofishing at spawning time in May. The fish are weighed and measured and checked for maturity. All ripe fish are anesthetized for ease of handling and to prevent injury. Eggs are gently expressed from females into a small plastic bowl. Milt is expressed from the males directly onto the eggs. The eggs from one female are fertilized with the milt from one male. If additional males are available, two males may be used to fertilize the eggs from a single female. If there is difficulty in obtaining sufficient milt, an aspirator is used.

After the eggs and sperm are gently mixed, 30-50 ml of water is added and the gametes are allowed to sit quietly for 3-5 minutes and are then rinsed. Fertilized eggs from each female are then placed in a 500-1000 ml container for transport to the Center.

Genetic Criteria

Development of a grayling broodstock will require specific safeguards in order to genetically represent the entire population and avoid a bottle neck which would decrease genetic diversity. This could have serious effects on an already declining population.

The following is a list of precautions that have been taken to prevent problems and to provide direction for the program.

- The Big Hole River grayling have been spawned over a number of years until at least 25 males and 25 females (25 pair) or an effective founding size of at least 50 fish contributed to the captive reserve.

- Eggs from each mating were incubated separately so that the number of parents successfully contributing to a year class is known. Each family group was kept separate until the eggs reached the eyed stage of development when equal aliquot of eggs from each spawn was collected and pooled for further rearing.

- Since practically all eyed eggs hatched, the contribution of each successful year class mating was kept as nearly equal as possible increasing the effective population size.

- In order to convert year class genetic differences into within population genetic diversity it is necessary to cross the different year classes being held as a reserve. Progeny of the first crossing of year classes of which 25 males and 25 females have equal or nearly equal contributions, will be considered a genetically complete broodstock.

- To prevent broodstock from becoming highly adapted to the captive environment, gametes from Big Hole River fish will be infused into it at least every ten years for three successive years. However, it will be important to prevent perpetuating the reserve from a small number of parents. Therefore, infused genes from the Big Hole River fish will at most represent only 10% of all genes in a year class. That is, at most only 20% of all matings should involve fish taken from the Big Hole River or their progeny.

Current Broodstock Program and Problems

Arctic grayling broodstocks have not been established as far as we have been able to determine. Millions of fry derived from wild fish have been reared and released, but records do not show cases where broodstock have been maintained. Current problems which must be addressed include the susceptibility to fungus. Special needs include raceway covers to protect the fish from direct sunlight, undue disturbances, and bird predators. Diet is also of special concern as normal trout production diets have been shown to cause steatitis in young of the year fish accompanied by high mortality.

The overall objectives of the recovery efforts are to reestablish a viable, self sustaining fluvial Arctic grayling population in the Big Hole River and attempt to establish additional self-sustaining fluvial populations in other river drainages. In order to accomplish the latter we have developed captive broodstock populations in Axolotl Lake and at the Center.

Big Hole River fish were successfully spawned fish during the annual spring run in 1988, 1990, 1991, and 1992. Eggs were transported to the Center for incubation, hatch, and rearing. At the present time we are holding future broodstock from each of the above years. In 1988, 4 pair were spawned and the progeny were stocked into Axolotl Lake to establish a captive broodstock. At the present time a conservative estimate of the number of Big Hole River fish contributing significant offspring held at the Center or Axolotl Lake is as follows: 1992= 6 pair, 1991=12 pair, 1990=4 pair, and 1988=4 pair for a total of 26.

In May 1992, the fish in Axolotl Lake were spawned and an aliquot from 50 pair crosses were retained and held as future broodstock since the fish in the lake were 4+ and longevity is unknown. Severe problems were encountered when the 1990 year class came into spawning condition. The fish were extremely sensitive to handling and developed a fungus and secondary bacterial infection. Mortality rate was 60-70%. The fish had been held in creek water through the winter months in order for them to experience a natural water temperature regime. However, pathogens are more prevalent in creek water than in the spring water.

Efforts to spawn fish from the 1990 and 1991 year classes were unsuccessful in 1993, but, there was less mortality. The fish were maintained over much of the winter in 7-8° C spring water in order to avoid the pathogens in the creek water. Perhaps they require a lower temperature for proper egg development. These procedures were modified in an effort to meet with better success in 1994.

All year classes will be crossed in 1994 and 1995 (Table 1). We will attempt to get at least 100 spawns from 100 pair. At that time there will be no need to keep families separate; it will be necessary keep the crosses separate but not each family. Each cross (year class) should have an equal contribution to the final broodstock.

Table 1. In 1994-1995 the modified diallele crosses will be made using the 1988 year class from the 1992 mating, and the 1990, 1991, and 1992 year classes from the captive broodstock.

		Female			
	Year Class	1988	1990	1991	1992
M	1988*	O	X	X	X
a	1990	X	O	X	X
l	1991	X	X	O	X
e	1992	X	X	X	O

* The 1988, year class which was stocked into Axolotl Lake is represented by a 1992 spawning of those fish. A portion of the progeny of 50 pair has been retained as broodstock.

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PRELIMINARY REPORT
FORT PECK PALLID STURGEON STUDY - 1994

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INTRODUCTION

This study was designed to investigate the relationships between shovelnose sturgeon, pallid sturgeon, other associated fish species and aquatic organisms in the lower 245 mile reach of the Missouri River between Fort Peck Dam and Lake Sakakawea and the lower Yellowstone River between Intake and the river's confluence with the Missouri River. Funding was provided by the Bureau of Reclamation and the Western Area Power Administration.

The primary objectives were to:

- Investigate the relationships between the distribution and abundance of shovelnose and pallid sturgeon, other fish species and aquatic organisms in comparison with river reach, discharges, habitat types, season and physical characteristics of the lower Missouri and Yellowstone rivers. This also included invertebrate sampling in the Missouri River above the Yellowstone confluence to establish baseline information relative to the abundance and number of invertebrate species present which may be of importance to sturgeon;

- Monitor larval drift of sturgeon and other species in the Missouri River between Fort Peck and the Yellowstone confluence;

- Identify pallid sturgeon spawning sites in the Missouri River above the Yellowstone confluence;

- Assess the population status of adult pallid sturgeon.

DESCRIPTION OF STUDY AREA

The study area was divided into 7 sections on the Missouri River, from Fort Peck Dam to the head of Lake Sakakawea. The sections were:

- Fort Peck Dam to Milk River - 8.5 miles;

- Milk River to Wolf Point - 53.5 miles;

- Wolf Point to Redwater River - 25 miles;

- Redwater River to Big Muddy Creek - 52.6 miles;

- Big Muddy Creek to Yellowstone River confluence - 48.4 miles;

- Yellowstone River confluence to Highway 85 bridge - 29 miles;
- Highway 85 bridge to head of Lake Sakakawea - approximately 23 miles, depending on lake elevation.

The Yellowstone River comprised sections 8 and 9. Section 8 was from Intake to the Highway 23 bridge - 41.6 miles, and Section 9 was from the Highway 23 bridge to the confluence - 29.5 miles. Total distance from Fort Peck Dam to Lake Sakakawea is about 240 miles and from Intake to the Yellowstone River confluence, 71.1 miles.

PRELIMINARY RESULTS

Drift netting 75-foot trammel and 80-foot experimental gill nets was the principle method used to capture a variety of fish species. The trammel nets were 1-inch bar inner mesh and either 8- or 10- inch outer bar mesh. The gill nets had alternating 20-foot panels of 1- and 2- inch bar mesh. The standard drift was for 10 minutes or 400 yards.

Standard sampling sites were chosen randomly in each section based on ease of access, river morphology, flows, and incidence of snags. Attempts were made to sample each site on a monthly basis but low flows as the summer progressed, particularly in the Yellowstone River, necessitated altering or in some cases, abandoning sampling sites.

A total of 238 drifts, representing 35.5 hours of effort, captured 843 fish for an average catch rate of 3.5 fish per drift. Seventeen species of fish were caught. Shovelnose sturgeon were the most abundant species netted with a total of 444 fish captured. Numbered spaghetti tags were attached through the base of the dorsal fin on each fish. Other species netted included 82 river carpsucker, 78 goldeye, 72 channel catfish, 31 smallmouth buffalo, 30 bigmouth buffalo, 24 sauger, 21 blue sucker, 19 longnose sucker, 11 carp, 10 pallid sturgeon, and lesser numbers of flathead chub, shorthead redhorse sucker, freshwater drum, paddlefish, walleye, and white sucker. All fish were weighed, measured and released at the capture site.

Nine of the pallid sturgeon were captured in the Missouri River below the Yellowstone confluence and one was netted in the Yellowstone River 2.5 miles above the confluence. All were captured during September and October. The fish ranged in weight from 19.5 pounds to 70.5 pounds. Five of the pallids were recaptures and five were "new" fish. The oldest recapture was initially captured February 10, 1991, by Pat Clancy while SCUBA diving in the Missouri River about one mile below Fort Peck Dam and weighed 22.9 pounds. This fish was recaptured October 5, 1994, approximately 194 miles downstream and weighed 25.0 pounds. The new pallids were implanted with coded PIT tags and a numbered Endangered Species tag was attached through the base of the dorsal fin.

Aquatic invertebrate sampling was done at all standard sampling sites on a monthly basis from June through September, primarily in the Missouri River above the Yellowstone confluence. A total of 22 kick samples and 14 Ponar Dredge samples were taken. Seven orders of aquatic insects, 5 orders, 2 classes, and 1 phylum of other aquatic organisms were identified. Ephemeroptera was the most common order with 10 families and 14 genera present. Seven families and 10 genera of Trichoptera, 5 families of Diptera, 3 families and 3 genera of Hemiptera, 2 families and 2 genera each of Coleoptera and Odonata and 1 family and 1 genera of Plecoptera were also identified. Other aquatic organisms found included Nematoda, 2 classes of Annelida [Hirudinea, Oligochaeta], as well as representatives of Cladocera, Hydracarina, Amphipoda, and Hydroida.

Larval fish were sampled from June through August at standard sampling sites in the Missouri River above the Yellowstone confluence. Attempts were made to sample locations approximately every 10 days. One-half meter circular and 0.8-meter D-ring plankton nets were used. A total of 65 half-meter and 22 D-ring samples were taken and captured 22 larval fish and 28 eggs and 10 larval fish and 13 eggs, respectively. Approximately 4,087 cubic meters of water were sampled with the half-meter nets and 1,303 cubic meters of water with the D-ring nets. Four sturgeon and two paddlefish larvae were captured, all at the farthest downstream sampling site in Section 5, about 3 miles above the Yellowstone confluence. Other larval fish caught included 18 catastomids, 4 cyprinids, 1 stonecat, 3 unidentified, and 41 unidentified eggs.

Beach seining was done at standard sampling sites and other locations throughout the Missouri and Yellowstone river study areas. The standard haul was approximately 50 yards in length. A total of 89 hauls were made and captured 28 species of fish. Longnose and white suckers were the most abundant species with a total of 3,441 fish captured for a CPUE of 38.7. Over 84 percent were captured in river sections 1 and 3. Flathead chub were the second most common species with 3,286 fish captured for a CPUE of 36.9. Over 50 percent were seined in Section 3. River carpsucker were also quite abundant with a total of 639 seined. Almost 42 percent were captured in Section 3 and about 38 percent were found in Section 9. Rainbow trout young-of-year were quite prevalent in Section 1 with 165 fish captured and an additional 10 more caught about one mile downstream from the mouth of the Milk River in Section 2. Species of special concern captured included 29 sicklefin chub, 3 sturgeon chub, and 1 young-of-year blue sucker. Twenty-one of the sicklefin chub were seined in Section 6 below the Yellowstone confluence and the one blue sucker was seined in Section 2. No young-of-year sturgeon were captured although 6 juvenile shovelnose sturgeon were seined. Other species captured included goldeye, cisco, northern pike, carp, creek chub, lake chub, emerald shiner, spottail shiner, brassy minnow, silvery minnow, longnose dace, buffalo species, shorthead redhorse sucker, channel catfish, stonecat, burbot, white bass, sauger and walleye.

No pallid sturgeon spawning sites were identified in the Missouri River above the Yellowstone confluence. No pallids were captured during drift netting efforts and none were observed in this reach of the river. The population status of adult pallids remains unknown at this time.

DISCUSSION

Although efforts to capture juvenile or adult pallid sturgeon in the Missouri River above the Yellowstone River confluence were unsuccessful during this field season, at least two radioed pallids were known to have migrated upstream in this stretch of the river during late summer (Bramblett, personal communication). The probability of pallids spawning in the river above the Yellowstone confluence seems remote but should not be discounted at this point. The Prairie Elk and Frazer rapid areas would seem to hold the most promise as possible pallid spawning sites in this stretch of the Missouri River. However, the cool water temperatures and relative lack of turbidity may be limiting factors. The Milk River may also provide the necessary requirements for pallid sturgeon reproduction, i.e. high spring flows, warmer water temperatures than the Missouri River, high turbidities, and rocky riffle substrate. These areas definitely need more attention in the future to determine, if in fact, favorable conditions exist for pallid reproduction.

The sampling of aquatic invertebrates in the Missouri River above the Yellowstone River confluence will provide baseline information relative to the variety of food organisms available to sturgeon. In addition to further sampling, particularly in Section 4 where collections were not made, it would be of interest to initiate a food habit study of shovelnose sturgeon in this reach of the river. This data may have relevance concerning food organism preference of shovelnose and possibly pallid sturgeon.

The capture of four larval sturgeon at the farthest downstream sampling area (Section 5) in the Missouri River above the Yellowstone confluence was of particular interest. These were the only sturgeon captured and appeared to be three to five days old. Three were taken in a July 14 sample and one was captured July 28, indicating a somewhat later spawning period than would be expected. The prevailing cooler water temperatures and relatively stable flows in this reach of the river may have somewhat of a delaying effect on sturgeon spawning. Larval sampling should be continued in the future with additional emphasis on the Milk River. This will possibly provide information relative to the importance of these streams for sturgeon reproduction and perhaps suggest measures for enhancing the potential for successful sturgeon spawning.

Seining should also continue in the future and extend to the lower reaches of the Milk River as well. The absence of sicklefin chub and sturgeon chub from the Wolf Point section [Section 3] upstream to Fort Peck may be a result of the prevailing cooler water temperatures and comparative low turbidities. There was also a noticeable decline in flathead chub numbers above this section, perhaps for the same reasons. Again, the Milk River may provide suitable habitat for these species and should be intensively sampled. However, the extreme low flows experienced on a regular basis, particularly during the summer months due to irrigation demands, may severely limit the amount of quality habitat for these species.

THE STATUS OF THE PALLID STURGEON POPULATION IN THE UPPER MISSOURI RIVER

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ABSTRACT

A study to evaluate the population status of pallid sturgeon in the upper Missouri River was conducted 1990-1994. A total of 24 different pallids were captured in a 175-mile reach. Seventy-six percent of these fish were between 50 and 56 inches fork length, near maximum size and most likely older age fish. A sample of 162 shovelnose and 24 pallids were measured using a character index analysis and three sturgeon scored values of 323-354, indicative of intermediate morphometric values or hybridization between the two species. A comparison of upriver migration by pallids to the magnitude of spring run-off conditions showed that for the year with the higher spring flows, during the months of May, June and July pallids moved an average of 3.2, 12.9 and 17.6 miles farther upriver, respectively. Micro- habitat use studies showed that pallid sturgeon did not show any selection preferences except for water depth, where in the Stafford Ferry section the pallid sturgeon average depth value was 7.1 ft. compared to the average depth of 5.5 ft. characteristic of this section. Pallids also displayed noticeable differences in micro-habitat use over time. Pallids were found at an average depth of 8.1 ft. in May, 7.5 ft. in June and 6.5 ft. for July. Correspondingly, pallids were found associated with larger substrate sizes and in areas with wider channels increasing from May through July.

INTRODUCTION

Pallid sturgeon are found in the Wild and Scenic portions of the upper Missouri River in Montana. They presently exist in low numbers throughout their geographic range (Pflieger 1975) as is probably the case in this section of the Missouri River. In 1990 the U.S. Fish and Wildlife Service listed the pallid as "endangered" under the Endangered Species Act 1973. Reasons for listing are habitat modification and apparent lack of reproduction. Reports of pallid sturgeon sightings have also declined dramatically in the last 20 years (U.S. Fish and Wildlife Service, 1989). The pallid sturgeon has been listed as a class A "species of special concern" in Montana since 1973 (Holton, 1980).

Montana Fish, Wildlife and Parks initiated a fisheries study during 1989 to determine the past and present status of the pallid sturgeon in the 175 mile reach of river between Fort Benton and Fort Peck Reservoir. This report is a summary of biological information collected dealing with the status of pallid sturgeon found in the study area.

Results from the study will be used to develop a status report and will aid in devising management and recovery plans to maintain and enhance the pallid population in the upper Missouri River.

DESCRIPTION OF STUDY AREA

The upper Missouri River is one of the least man-altered reaches of river within the pallid sturgeon's geographic range. But in spite of this claim there have been considerable man-made developments that have seriously affected the natural character of this reach of Missouri. Figure 1 is a map of the study

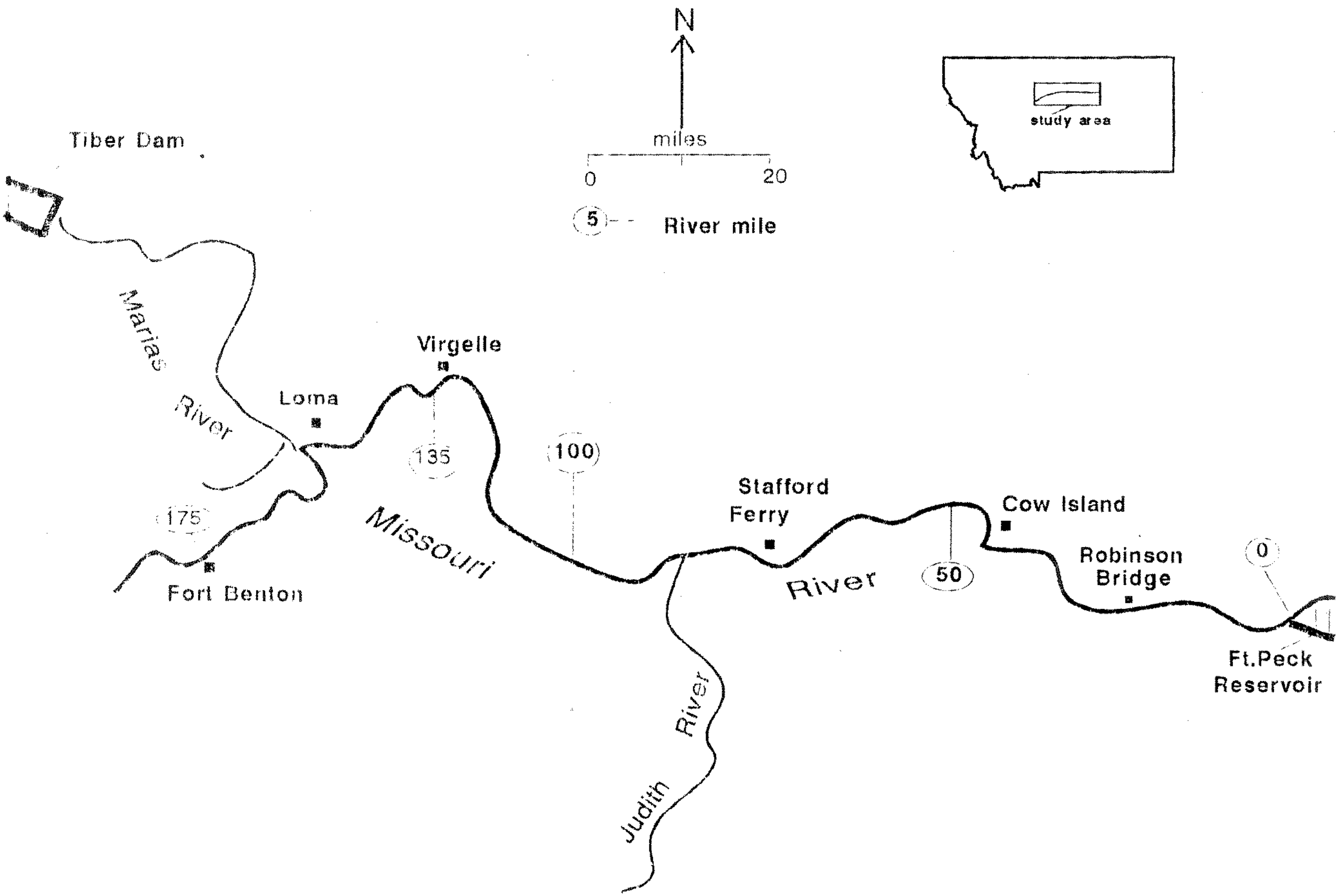

Figure 1. Map of study area.

area. A major dam on the main stem, Canyon Ferry Dam located 200 miles upstream of Fort Benton, has a significant effect on the flow and sediment regimens. Fort Peck Dam, just downstream of the study area isolates pallid sturgeon in this area from other downriver populations, thereby potentially decreasing the genetic diversity of this isolated population. The 130 miles of river channel the impoundment has inundated is also considered a serious loss of pallid habitat. The Marias River is the largest tributary to the Missouri in the study area and it augments Missouri flows by 14%. This tributary is also impounded and is completely regulated by Tiber Dam. Tiber has considerable storage capacity and can substantially reduce the magnitude of spring flows downstream. For example on June 23, 1991 the inflow to Tiber Reservoir was 12,000 cfs compared to the outflow from Tiber Dam of 2,000 cfs (U.S.Geological Survey, 1992).

The upper Missouri River is a deeply entrenched river, having a narrow floodplain. The uppermost 50 miles flows through soft erodible shale formations, while the next 90 miles is contained in the resistant Eagle Creek sandstone formation. The remaining 35 miles once again meanders through soft shale formations. These changes in rock formations greatly affect the character of the river and consequently pallid sturgeon distribution. The entire study area is within the National Wild and Scenic river system and Charles M. Russell National Wildlife Refuge and therefore, significant protection is afforded this reach. The study area represents one of six recovery-priority management areas for the pallid sturgeon (U.S. Fish and Wildlife Service, 1993)

RESULTS

A total of 24 different pallids were captured in the 175-mile reach. Thirty-three percent were recaptured at least once and 13% were caught more than once. The total number of pallid captures (including recaptures) equaled 48; 45 of these occurred in the lower 50 miles of the study area (Figure 2).

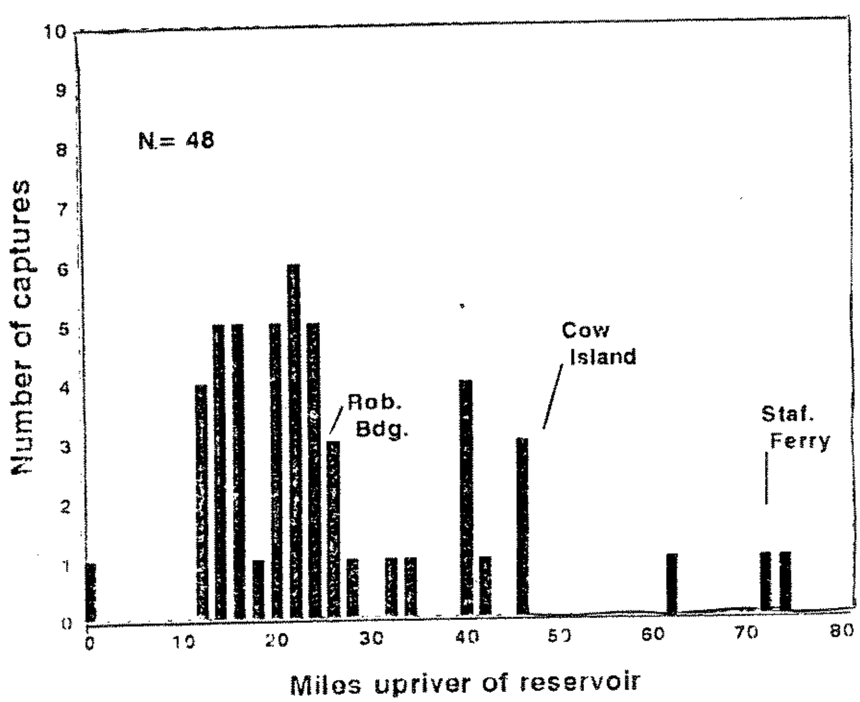

Figure 2. Frequency distribution and locations of pallid sturgeon capture sites sampled with trammel nets and setlines in the upper Missouri River, 1990-94.

The farthest upriver capture occurred 74 miles above Fort Peck Reservoir near Stafford Ferry, and the most downstream capture was at the headwaters of the reservoir. Radio telemetry relocations of the 14 transmittered pallids (discussed later) exhibited a nearly identical longitudinal distribution as described by the capture locations.

Thirty-five of the 48 pallid captures were sampled while drifting trammel nets and the remaining 13 captures were sampled using baited setlines. Most of the pallid sturgeon sampled were large size; 76% of the catch were between 50 and 56 inches fork length (Figure 3). Based on the large sizes of pallids captured, the population appears to be comprised mostly of older age groups. The average fork length and average weight was 52.5 inches and 33.4 lbs. The smallest pallid was 43 inches fork length and 13.2 lbs. and the largest measured 60 inches and 50 lbs. There were four pallids that weighed less than 23 lbs., possibly young fish, and therefore indicating that reproduction occurred perhaps 10-20 years ago. However, three of these smaller pallids exhibited morphometric characteristics of hybrids.

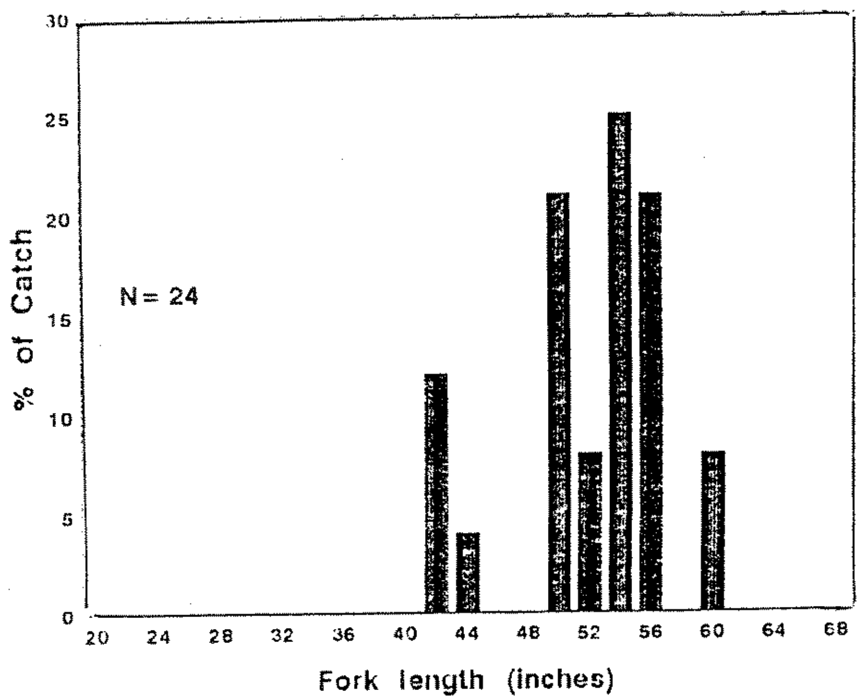

Figure 3. Length frequency distribution for pallid sturgeon sampled in the upper Missouri River, 1990-94.

The shovelnose is a closely related species to the pallid sturgeon. Shovelnose are very common throughout the study area. Differences between these species include features of the head; such as rostrum length, length and placement of barbels and mouth size. I used 6 morphometric features for distinguishing between the pallid and shovelnose sturgeon as suggested by Bailey and Cross (1954). Morphometrics were calculated as a percentage of the standard length so the effects of length were factored out. These measurements were scored and summed to come up with a total character index value. Scores between 150-300 are characteristic of shovelnose, while the ones with higher scores 400-600 are pallids.

This character index was previously used by Carlson and Pflieger (1981) for distinguishing pallid sturgeon hybrids in the state of Missouri. Figure 4 is a histogram of character index values for the two sturgeon populations in the study area. There are 3 sturgeon that had values between the pallid sturgeon and shovelnose scores. I suspect these are hybrids.

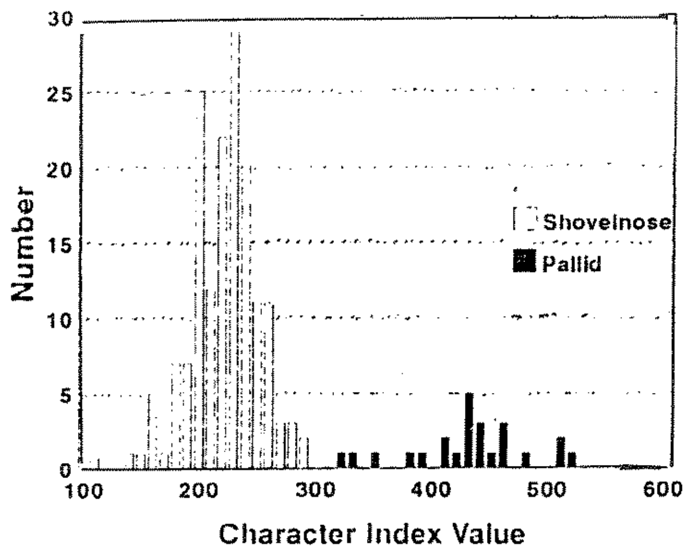

Figure 4. Character indices scores for shovelnose and pallid sturgeon sampled in the upper Missouri River, 1993.

Early life history work has also been conducted sampling the larval and juvenile stages. I used the methods that were developed for paddlefish larval sampling (Gardner, 1991). Half-meter plankton nets were positioned near the bottom while sampling for sturgeon larvae. Additionally, a larger, D-shaped net was used for comparing sampling efficiencies between these two net-types. A total of 3 sturgeon larvae were collected during 1993, however, distinction between pallid and shovelnose sturgeon could not be made at this time due to the lack of known taxonomic differences for these early developmental stages. I have also been experimenting with a 6 ft beam trawl attempting to capture young sturgeon. Only 1 YOY shovelnose sturgeon (4 inches long) was sampled in 140 trawl hauls.

Radio telemetry offers an excellent opportunity to study the individual migratory movements and micro-habitat use of pallid sturgeon. From 1990 to 1993 we worked at developing a system that had minimal effects on the pallid and would work in deep, highly conductive waters. I believe we presently have a fairly good system. The system I used was comprised of radio transmitters that were either surgically implanted or attached to the dorsal fin. Initial tests revealed that both types of transmitter placements did not affect fish behavior or cause significant irritation or harm. However, since then I have noticed that the dorsal transmitters did cause irritation problems and I have discontinued using them.

Movement and micro-habitat information was collected in 1992 and 1993 using radio telemetry techniques. The results of this work was based on monitoring 14 pallids sturgeon. The two years that telemetry studies were conducted were two extremely different ones. During the 1992 spring run-off period river flows were exceptionally low, averaging 27% of normal. In sharp contrast, the 1993 spring run-off period was near normal, averaging 83% of normal flows. The response by the transmittered pallids to these two different flow years demonstrated that pallid sturgeon respond positively to high flow conditions. Figure 5 compares pallid sturgeon upriver movement with flow conditions. During May, June and July the pallid sturgeon average monthly locations were 3.2, 12.9 and 17.6 miles farther upriver, respectively, in 1993 than for the low spring run-off year of 1992. The positive relationship between spring flows and upriver migration is not unique to pallid sturgeon. Berg (1981) reported that paddlefish in this study area required a higher flow than base levels. He determined that a minimum flow of 15,300 cfs (at the Robinson Bridge) during mid-May through early July was necessary to trigger paddlefish movement upriver to spawning areas. The paddlefish spawning flow is a fairly common high flow averaging 72% of normal. A normal high spring run-off flow also appears to be important for a timely upriver migration by pallid sturgeon. This observation of the pallid sturgeon's upriver migration dependence on spring flows has implications for water management of river impoundments in the system. The information here supports the need for a natural high spring flow hydrograph so that pallid sturgeon migration will not be affected.

The reason for the furthest upriver average location occurring in July is unclear. Pallid sturgeon spawning probably occurs during June and therefore spawning is most likely not the reason for the attraction to the upriver area. Pallids may have moved to this upriver area post-spawning to forage on minnows. More work will have to be directed at evaluating other factors that may be influencing pallid use in this area before an explanation for the attraction to this area can be made. Observations of the transmittered pallids after July are limited because the transmitter battery life usually ceased after 90 days (first part of August). However, the few observations that were collected noted that two transmittered pallids returned to the downriver locations where they were initially captured.

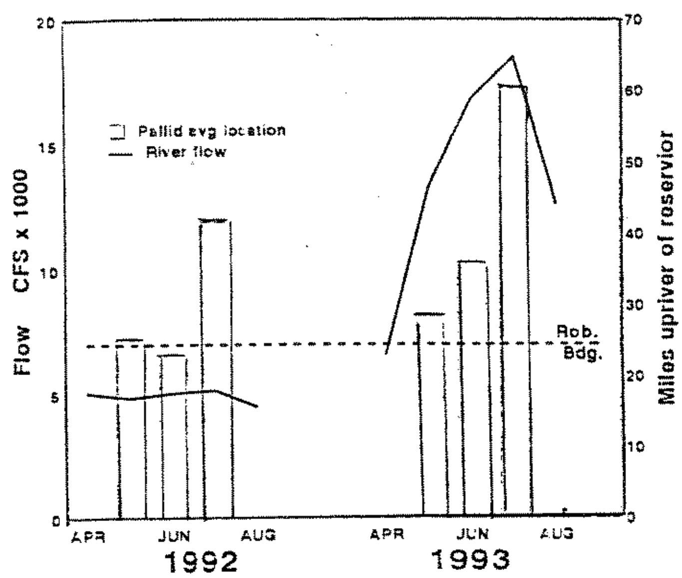

Figure 5. Comparisons between 1992 and 1993 for pallid sturgeon monthly average rivermile location and river flows, upper Missouri River. The dashed line labeled Rob. Bdg. references the rivermile location of Robinson Bridge. A total of 151 radio telemetry contacts were used in the results.

Pallid sturgeon micro-habitat use was evaluated by monitoring the radio transmittered fish. The physical habitat conditions where the transmittered pallid was located were recorded and compared to the overall average physical conditions in the study section so that habitat selection by pallid sturgeon could be evaluated. Pallid sturgeon were found only in the lower two study sections, Stafford Ferry and Robinson

Bridge. Table 1 is a comparison between pallid sturgeon micro-habitat use and the average habitat conditions found in the section. For the four physical conditions evaluated it appeared that pallids selected for the deeper water areas in the Stafford Ferry section. Pallids were found to be at depths that averaged 7.1 feet compared to an average depth of 5.5 feet characteristic of this section.

Table 1. Micro-habitat conditions recorded for transmittered pallid sturgeon compared with the physical habitat conditions in the Stafford Ferry and Robinson Bridge study sections of the upper Missouri River, MT, 1992-93.

	Width (ft)	Depth (ft)	Velocity (ft/s)	Substr. 1/
Stafford Ferry (21 contacts)				
Pallid sturgeon avg. micro-habitat use -	668	7.1	3.4	5.0
Avg. physical condition of channel -	668	5.5	3.7	4.7
Robinson Bridge (93 contacts)				
Pallid sturgeon avg. micro-habitat use -	544	7.8	3.0	1.8
Avg. physical condition of channel -	539	7.6	3.0	1.5

1/ - Brusven index method used to number code substrate size; 0=silt, 1=sand, 2=small gravel, 3=med. gravel, 4=lg. gravel, 5=sm. cobble, 6=med cobble, ect.

Transmittered pallid sturgeon in the Robinson Bridge section used micro-habitat conditions that were typical of the physical conditions found in this section. The most striking difference in micro-habitat conditions used by pallid sturgeon between the two sections was the association with larger substrates in the Stafford Ferry section. The average substrate size where pallid sturgeon were found in the Stafford Ferry section was 5.0 (small cobble) compared to an average substrate size of 1.8 (small gravel) for pallids in the Robinson Bridge section. The association of pallids with large substrate that was observed during June and July in the Stafford Ferry section is considered unique. Very little is known about the pallid sturgeon habitat preferences, but most researchers believe that pallid sturgeon are commonly associated with sandy substrates. Bailey and Cross (1954) reported that pallids live in strong currents over a firm sand bottom in channels of large rivers.

Mr. R. Bramblett (personal communication; Montana State University) conducted a pallid sturgeon habitat preference study in the lower Yellowstone and Missouri rivers, MT and ND, 1992-93. He found that pallids were associated with sand substrate over 90% of the time. The present study found that 90% of the pallids that were captured occurred in a the river section that had an average substrate type of 1.5 (between sand and small gravel). The occurrence of pallid sturgeon in the rocky Stafford Ferry section, a canyon landscape, was unexpected and more investigation will be required for understanding its significance. It could be possible that pallid sturgeon may not have been attracted to the large substrate, but rather to other habitat conditions or possibly a food source that was more available in this area.

Table 2 shows pallid sturgeon micro-habitat use for the months of May, June, July and October. There are noticeable changes in water depth conditions going from relatively deep conditions with an average value of 8.1 ft. in May to a more shallow habitat depths of 6.5 ft. in July. Correspondingly, average substrate size and channel width values increased. The reason for the observed seasonal changes in micro-habitat conditions was related to the migration of the transmittered pallids from the Robinson Bridge section, upriver to the canyons of the Stafford Ferry section.

Table 2. Monthly average micro-habitat conditions of transmittered pallid sturgeon in the Stafford Ferry and Robinson Bridge study sections of the upper Missouri River, MT, 1992-93.

	Number contacts	Width (ft)	Depth (ft)	Velocity (ft/s)	Substr.
MAY	32	541	8.1	3.1	1.7
JUNE	32	563	7.5	3.0	2.3
JULY	32	639	6.5	3.5	5.5
OCTOBER	8	420	8.3	2.6	0.9

In summary, there does appear to be a significant population of pallid sturgeon that utilize at least 75 miles of the upper Missouri River reach. The population is comprised mostly of larger, most likely older age fish. The only evidence of possible reproduction within the past 10-20 years is the capture of 3 suspected hybrid sturgeon and one 22 lb. pallid. The micro-habitat variable that showed the most consistent trend regardless of its availability was depth; pallids preferred deep water areas registering an overall average depth of 7.5 ft.

RECOMMENDATIONS

Concentrate sampling efforts in the canyon section attempting to capture pallids and to evaluate other important physical and biological factors that may be influencing pallid sturgeon use in the area.

Complete sampling for pallids in the lower portion of the river and headwaters of Ft. Peck Reservoir to determine if this area is important habitat.

Continue to radio tag pallids so that improvements in the system can be made, improve chances for capture of other pallids and monitoring migratory movements.

If time permits, more sampling should be done near the Marias River confluence area. This area is suspected as being an important staging area because several sightings have been recorded here in the past (Gardner, 1990), and the tributary is important for shovelnose spawning and may also be important for pallid sturgeon. The 1993 pallid sturgeon recovery plan emphasized selecting pallid sturgeon recovery-priority management areas at confluence sites of major tributaries because of their importance as feeding and nursery areas for large river fish.

As reported earlier, it was noted that transmittered pallid sturgeon responded to increased flows. It appears that high flows in the late spring may be important for pallids. Considering this, it is important that the USBR continue providing high flushing flows in the Marias River below Tiber Dam during this period with the anticipation that the more natural flows may be beneficial for triggering pallid sturgeon migration and creating new pallid habitat. A river management plan for the Marias River/Tiber Dam should be developed with the USBR so that spring-time high water releases can be scheduled for pallid sturgeon migration. A coordinated approach will insure that water releases will be maximized and that impacts on other water uses will be minimal.

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EFFECTS OF INTAKE DIVERSION DAM ON PALLID AND SHOVELNOSE STURGEON IN THE LOWER YELLOWSTONE RIVER

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ABSTRACT

Pallid sturgeon are rare in the Yellowstone River upstream of Intake Diversion Dam and may require above average river flows to reach upstream points. Small shovelnose sturgeon are abundant downstream of Intake and uncommon upstream. Intake Diversion Dam probably is a partial blockage to movement of both pallid and shovelnose sturgeon.

The pallid sturgeon (Scaphirhynchus albus) received federal endangered status in October 1990. A recovery plan was finalized in 1993 (USFWS 1993). The recovery plan recommended studies to determine the need for fish passage at Intake, a low-head irrigation diversion dam on the Yellowstone River 18 miles northeast of Glendive Montana. The work reported here was funded by the Bureau of Reclamation to determine the relative abundance of pallid sturgeon upstream of Intake Diversion Dam and the possible need for provision of fish passage.

STUDY AREA

The study area included the first five Yellowstone River miles immediately downstream of Intake Diversion Dam (IDD) and upstream to the Cartersville Diversion Dam - 171.3 river miles (river mile 66.1 to 237.4) (MDNRC 1976). Also included were the lower portions of the Tongue River (river mile 0.0 to 20.4) and Powder River (river mile 0.0 to 8.4).

Intake Diversion Dam extends the full width of the river channel. It is composed of wood covered with large rock. It creates a cascade causing the water surface to drop approximately 1.2m in 30m. A high water channel which begins to flow at a discharge of 23,000 cfs, bypasses IDD to the south. (Graham and Penkal 1978).

METHODS

Sturgeon were captured using drifted trammel nets and gill nets. All nets were of the sinking type. Trammel nets were 100-150 feet long by six feet deep with 2 inch (bar) inner mesh and 12 inch outer mesh. Gill nets were 50-150 feet long with 3 inch mesh. Gill nets were used primarily in the Tongue and Powder Rivers and in the Yellowstone River when the debris load was heavy. Gill nets tended to catch less drifting debris. Nets were drifted up to 45 minutes before lifting, but usual drift times were only a few minutes.

In 1992 and 1993 all sturgeon collected downstream of IDD were obtained from anglers. These were sturgeon snagged incidentally to snagging for paddlefish. In 1994, 36 sturgeon were obtained in this manner downstream of IDD. The remainder of sturgeon collected were obtained by netting.

Sturgeon fork length was measured in millimeters and weight in grams. Pallid sturgeon were tagged with PIT tags and shovelnose sturgeon (S. platorynchus) collected downstream of IDD were marked with individually numbered "cinch-up" tags (Flag Tag Co). Sturgeon weighing less than 200 grams were not tagged.

All river flows for the Yellowstone River are from the USGS gauge at Miles City.

RESULTS

Pallid sturgeon are at least uncommon, and possibly rare, upstream of IDD. Only one was captured in four years of sampling (Table 1). This fish was captured in July 1991 following a period of above average river flow. Paddlefish are able to move upstream of IDD through the high water channel when river flows reach 45,000. Possibly pallid sturgeon are able to do the same. Only in 1991 when Yellowstone River discharge reached 55,900 cfs (Table 1) was a pallid sturgeon captured upstream of Intake. In the years 1992-1994 when May - June flows did not exceed 38,700 cfs, no pallids were found upstream of IDD.

Pallid sturgeon are seasonally present in the Yellowstone River immediately downstream of IDD each year (Table 2). At least one or two are snagged by paddlefish anglers each year. Probably not all angler snagged pallids below IDD are shown in Table 2. Unverified reports of angler snagged pallid sturgeon are received each year, but all of these have been downstream and none upstream of IDD.

Density of pallid sturgeon upstream of IDD seems much lower than in the area immediately downstream. A total of 144.4 netting hours upstream in the years 1991-1994 captured only one pallid sturgeon. In 1994, 35.9 hours of netting effort downstream captured three pallid sturgeon. This was a 12-fold difference in capture rate. Total netting effort for all areas is given in Table 3.

Average size of shovelnose sturgeon downstream of IDD is much smaller than for upstream areas (Table 4). This has been true for all years of shovelnose sturgeon sampling. The smallest sturgeon (weighing less than 1,000 grams) are absent in upstream areas and common downstream of IDD (Table 4).

This situation is displayed in a different way in Table 5, which shows percentages of shovelnose sturgeon weighing less than 907 and less than 454 grams both upstream and downstream of IDD. Both these size groups are uncommon upstream while downstream, sturgeon of these sizes make up a significant fraction of samples. The smaller mean size of shovelnose sturgeon downstream (Table 4) is largely effected by the paucity of small fish in upstream areas.

A number of shovelnose sturgeon, but no pallid sturgeons, tagged downstream of IDD have been recaptured upstream (Table 6). It is clear that shovelnose sturgeon, of at least some sizes, can move upstream over IDD, without using the high water channel that flows only at discharge above 23,000 cfs. Three shovelnose sturgeon moved upstream over IDD when there was no flow in the highwater channel (Table 6).

Of the nine fish in Table 6, all but one are "medium" sized shovelnose sturgeon of 0.7 kg to 2.34 kg. The largest sturgeon (4.2 kg) had access to the high water channel for movement upstream of IDD.

DISCUSSION

It is unlikely that any pallid sturgeon are resident upstream of IDD and migrants may require above average streamflows to move upstream (Table 1). Based on drift net catch rates upstream and downstream IDD is probably a barrier to upstream movement, at least in years when the bypass high water channel does not flow significantly. The importance of access upstream of IDD to the continued existence of pallid sturgeon between Garrison and Fort Peck Dams is unknown.

The status of shovelnose sturgeon upstream and downstream of IDD may be helpful in understanding the ability of pallid sturgeon to move upstream. The smallest shovelnose sturgeon (under 0.45 kg) are virtually absent upstream of IDD, but common downstream (Table 5). Possibly pallid sturgeon weighing less than 0.45 kg (if actually present in the system) would have difficulty moving upstream of IDD also.

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Table 1. Number of pallid sturgeon captured from the Yellowstone River upstream from Intake and hours of netting effort in May, June and July 1991 - 1994.

Year	Number	Hours	Max Flow (cfs -May/June)[a]
1991	1	72.2	55,900
1992	0	38.8	38,700
1993	0	25.4	38,700
1994	0	8.0	33,200

[a]From USGS gauge at Miles City

Table 2. Known pallid sturgeon observed from the Yellowstone River in the first three miles downstream of Intake Diversion Dam May, June and July 1991 - 1994.

	Method		
Year	Angler Snagging	Netting	Netting Effort (hours)
1991	2	0	0.0
1992	1	0	0.0
1993	2	0	0.0
1994	1	3	35.9

Table 3. Netting effort (hours) in April through August 1991 - 1994.

	Yellowstone River			
Year	Above Intake	Below Intake	Tongue River	Powder River
1991	95.0	0.0	19.2	4.2
1992	61.3	0.0	7.4	4.7
1993	40.6	0.0	12.7	2.8
1994	19.3	35.9	0.0	0.0

Table 4. **Maximum, minimum and mean fork length (mm) and weight (kg) of Yellowstone River shovelnose sturgeon upstream and downstream of Intake.** [a]

	Upstream of Intake				Downstream of Intake			
Year	Max	Min	Mean	N	Max	Min	Mean	N
				Length				
1991	994	330	775	349	-	-	-	-
1992	1062	358	771	1082	989	268	650	467
1993	985	396	761	663	950	275	683	234
1994	1000	455	725	695	965	210	652	1426
				Weight				
1991	5.67	0.12	2.44	349	-	-	-	-
1992	8.17	0.15	2.17	1082	5.22	0.03	1.31	467
1993	6.82	0.20	2.12	663	4.20	0.06	1.37	234
1994	5.23	0.34	2.08	695	3.90	0.06	1.23	1426

[a]Fish obtained by netting except in 1992 and 1993 downstream of Intake. These fish were incidentally snagged by anglers.

Table 5. **Percentage of shovelnose sturgeon weighing less than 907g and 454g, upstream and downstream of Intake.**

	Upstream of Intake			Downstream of Intake		
Year	<907g	<454g	N	<907g	<454g	N
1992	6.8	0.6	1082	32.1	14.6	467
1993	2.9	0.5	663	17.1	8.2	234
1994	5.9	0.6	695	35.1	11.1	1426

Table 6. **Recovery at upstream points of shovelnose sturgeon tagged downstream of Intake Diversion Dam.**

Tagged			Recaptured			
Date	L[b]	W[c]	Date	L[b]	W[c]	Max Flow (cfs)[a]
						Recaptured in 1992
05-17-79	685	0.95	6-15-92	774	2.05	50,000 +
10-29-77	543	0.41	6-15-92	807	2.34	50,000 +
06-07-92	740	1.80	7-29-92	732	1.99	38,700
						Recaptured in 1993
5-17-92	702	1.42	5-13-93	716	1.56	38,700
						Recaptured in 1994
10-29-77	990	3.09	8-12-94	905	4.20	50,000 +
5-17-94	558	0.60	8-02-94	577	0.70	34,400
6-21-94	608	0.94	8-09-94	630	1.10	15,900
6-15-94	728	1.82	8-10-94	705	1.60	22,500
6-16-94	761	1.92	8-12-94	763	2.19	22,500

[a]Maximum discharge of Yellowstone River between tagging and recapture.
[b]Fork length in millimeters.
[c]Weight in kilograms.

STURGEON BROODSTOCK DEVELOPMENT

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ABSTRACT

Wild adult shovelnose sturgeon have been captured from the Yellowstone and Missouri Rivers with the assistance of personnel of Montana Fish, Wildlife, and Parks. Fish have been collected by drifting gill nets and trammel nets over suspected spawning areas. The majority of these fish have been from the Yellowstone River, in the vicinity of Miles City, MT. Adult shovelnose sturgeon have been transported to the Bozeman FTC and held in 10' diameter tanks.

Induced Ovulation/Spermiation

Bozeman FTC has conducted basic research investigating a variety of parameters related to the culture and propagation of shovelnose sturgeon. The effectiveness of luteinizing hormone-releasing hormone analogue (LHRHa) and carp pituitary to induce spermiation in male shovelnose and ovulation in females has been established. Both male and female sturgeon have been injected with hormone to induce spermiation and ovulation, respectively. The literature indicates that either carp pituitary or LHRHa is effective in inducing gamete maturation in sturgeon. Of the two compounds, carp pituitary has been the most widely used. In the shovelnose sturgeon, however, LHRHa appears to be much more effective than carp pituitary in inducing both spermiation and ovulation. Virtually every shovelnose sturgeon that has received an injection of LHRHa at 10-20 ug LHRHa/kg body weight, has responded by completing gamete maturation. LHRHa appears to work equally well for either males or females.

Studies have also shown that water temperature is critical to the response to LHRHa treatment. If females are held at 55°F following LHRHa injection, they do not respond to hormone treatment (i.e. ovulation does not occur). If females are held at 60°F following LHRHa injection, ovulation occurs approximately 48 hr later. If females are held at 65°F following treatment, ovulation is generally complete within 24 hr.

Observation of female shovelnose sturgeon following LHRHa treatment has shown that females that have ovulated are considerably more active than fish that have not yet ovulated. Following egg release, female shovelnose sturgeon become very active and spend most of their time high in the water column, while continuously circling the tank. This is in sharp contrast to fish that have not ovulated, which spend most of their time lying motionless on the tank bottom. This marked change in fish behavior and activity level has been used to distinguish "ripe" females, even though manual massage of the abdomen of these same fish has not indicated egg release.

Spawning Techniques

Surgical techniques established for the spawning of white sturgeon have been used to spawn shovelnose sturgeon. While these techniques have provided excellent results as far as egg collection and egg viability are concerned, post-surgical mortality of females has been found to be a problem. Typically, females have survived only 5-15 days following C-section procedures. Even though fish have received antibiotic treatment, they appear to be susceptible to severe systemic bacterial infection. In an attempt to reduce spawning associated mortality, various modifications of standard C-section procedures have been attempted. Currently, eggs are aspirated through an abdominal incision using a section of tygon tubing. While this procedure requires a considerably smaller incision than spoon collection techniques and has resulted in excellent egg viability, it has had no positive effect on post-spawning survival. Further modification of C-section procedures, or possibly the development of non-surgical techniques, may be required to reduce mortality of post-spawn female sturgeon.

It has been apparent from the very beginning of sturgeon studies that wildstock shovelnose sturgeon poorly tolerate the handling and stress associated with captivity. While this may be true regardless of holding facility location and water supply, it is likely that the Bozeman FTC is a particularly stressful environment for this large-river species. Not only are wild fish confined in small fiberglass tanks, they are held in a combination of warm spring, cold spring, and mountain stream water that bears little resemblance to their natural environment. Hence, it is probably not too surprising that wild caught females captured in spawning condition and transported 350 miles, placed in a totally foreign environment, injected with a spawning hormone, and subjected to major surgery, have a somewhat diminished resistance to stress associated disease parameters. For these reasons, five wildstock females captured from the Yellowstone River in spawning condition were transported and held at the Miles City SFH. The Miles City SFH is only 30 miles from the capture location and the hatchery water supply is the Tongue River, which is a major tributary to the Yellowstone River. The fish were injected with LHRHa, spawned using C-section procedures, and immediately released in a hatchery pond. Although the pond was still an un-natural environment for this riverine species, it was certainly more natural than conditions at the Bozeman FTC. Three of the females died within a matter of a few days. The remaining two females, however, survived and were in excellent condition when removed from the pond 70 days post-spawning. These fish are currently being held at the Bozeman FTC and are doing well. These data offer encouraging evidence that if fish are maintained in a suitable environment, shovelnose sturgeon females can survive C-section procedures.

Egg Incubation

Fertilization and egg incubation techniques established for white sturgeon have also been found to produce very good results with shovelnose sturgeon. The development of sturgeon embryos to the neurulation stage has been excellent (over 90%). As long as fungus is controlled by adequate rolling of eggs, percent hatch has also been found to be excellent (over 90%). It has been found that it is best to roll shovelnose eggs gently <u>immediately</u> following introduction to the egg jar. As embryo development advances to the neurulation stage, eggs can then be rolled more vigorously.

Milt Storage

In conjunction with work done evaluating spermiation of males, studies have been conducted evaluating the non-frozen low temperature and cryopreservation of sturgeon sperm. The endangered pallid sturgeon is a prime example of a species or management program that would benefit from successful cryopreservation techniques. In fact, cryopreserved pallid sturgeon milt may very likely be one of the key factors involved in the recovery/restoration of this valuable species.

Non-frozen storage techniques appear to have the capability of maintaining <u>good</u> sperm viability for up to 20 days post-collection. Best results have been obtained when milt has been stored in a thin layer (0.5 cm or less), under an oxygen atmosphere, at 4°C. Maximum storage duration with some degree of sperm viability has been 29 days.

Preliminary studies have been conducted to investigate the potential of using cryopreserved sperm to propagate shovelnose/pallid sturgeon. Initial studies have centered on utilizing cryopreservation procedures that have already been reported for the cryopreservation of salmonid milt (Scott and Baynes, 1980; Erdahl, 1982; and Cloud et al., 1990). Parameters evaluated have included extender media, cryoprotectant concentration, egg yolk as extender media additive, freeze configuration, and freeze-thaw rates. Extender 6 (Erdahl, 1982), 300mM glucose, 600mM glucose, and Hanks Solution have all been used as extender media for the dilution of milt. In all trials, milt was diluted in extender media at a ratio of 1:1. Dimethyl sulfoxide (DMSO) has been evaluated as a cryoprotective agent at final concentrations of 3.75, 5, 7.5, and 10% (V/V). The effect of adding egg yolk to the extender to enhance freeze/thaw protection was also evaluated. Final egg yolk concentrations of 7.5 and 10% were evaluated. Milt was frozen in both 1/2 ml plastic straws and 0.1 ml pellets placed on dry ice. After reaching dry ice temperature (-79°C), the samples were placed in liquid nitrogen (-196°C) for extended storage. Straws were thawed in a water bath at either 4 or 10° C. Pellets were thawed in additional extender media at 20°C or exposed to air at room temperature. All cryopreserved milt samples were evaluated immediately post-thaw. Fertilization trials were also conducted immediately upon thawing of milt.

Somewhat unexpectedly, post-thaw motility of sturgeon sperm (both pallid and shovelnose) was found to be surprisingly good. Some level of motility was observed in all thawed samples, with certain freeze\thaw regimes resulting in a percent motility that was virtually identical to that of pre-freeze milt. All extender media with the exception of 600mM glucose resulted in good post-thaw semen motility. DMSO concentration (3.75-10%) did not appear to effect sperm survival. However, the addition of egg yolk to the extender media did appear to be critical to post-thaw viability. Motility of sperm frozen in extender media containing egg yolk was 70-80%, whereas a split sample of the same milt frozen in extender media without egg yolk was only 30-40%. Final concentration of egg yolk (7.5 or 10%) did not appear to effect sperm viability. Overall, motility of sperm frozen in the 1/2 ml plastic straws was superior to that of sperm frozen in pellets. The temperature of the water bath used to thaw the straws (4 or 10°C) did not appear to effect sperm motility. However, motility of pellets that were thawed exposed to room air (slow thaw) was superior to that of pellets thawed in additional extender at 20°C (rapid thaw).

Frozen shovelnose sturgeon sperm was also used to conduct fertility trials using freshly collected eggs. Although motility of frozen thawed sperm used in these tests was good (similar to as stated above), fertility was poor. Frozen sperm resulted in only 1-4% fertilized eggs. Although these results were somewhat discouraging, particularly with respect to good post-thaw motility that was observed, it does indicate that frozen pallid sturgeon sperm could likely be used in a gene banking program or to establish an artificial propagation program.

Results of this work is similar to studies that have recently been conducted with white sturgeon sperm. Although it has been reported that post-thaw motility of white sturgeon sperm is good, to date, such sperm has resulted in no fertilization when introduced to freshly collected eggs.

Captive Broodstock

A number of sturgeon were being maintained at the Center for the development of a captive shovelnose sturgeon broodstock (1992 and 1993 year class). The 1992 year class fish were 20 months old, approximately 13-15" in length, and weighed about 225 g each. Unfortunately, both year classes were lost in March 1994 due to as yet unidentified fish health problems (suspect systemic bacterial infection). Although a serious setback, efforts to develop a captive shovelnose sturgeon broodstock are being continued with 1994 year class fish. In addition to the future domestic broodstock, wild-caught adult sturgeon are also being held at the Center in an attempt to condition them to the hatchery environment. Although preliminary efforts have indicated that adult wild-caught shovelnose sturgeon do not adapt readily to the hatchery environment, a number of fish are consuming live feed (small trout) and appear to be in good health. Wildstock shovelnose sturgeon maintained at Bozeman FTC for 1 year have been found to produce viable milt following treatment with LHRHa.

Enzyme-linked Immunosorbent Assay for the Detection of Vitellogenin

Studies have also been conducted investigating the development of an enzyme-linked immunosorbent assay (ELISA) for the detection of blood plasma vitellogenin in the shovelnose and pallid sturgeon. Detection of the reproductive condition of adult wild sturgeon is essential for wildstock propagation programs. At the present time, the only method available for determining fish sex or reproductive state is surgical biopsy. This invasive procedure has the potential to severely compromise fish health, an unacceptable condition in recovery programs involving threatened/endangered fishes. The development of an ELISA for the direct measurement of plasma vitellogenin would require that only a small blood sample be collected from captured fish, substantially reducing fish handling requirements and associated stressors.

Six previtellogenic females or adult male sturgeon were implanted with cellulose pellets containing 17B-estradiol to induce synthesis of vitellogenin. Each fish received a single 21 day release pellet containing 5 mg of 17B-estradiol. Plasma samples were collected from each fish immediately prior to pellet implant, and biweekly for 60 days post-implant. The plasma is currently in storage at -80°C, and will be used for purification of vitellogenin using gel filtration and ion exchange chromatography. Purified vitellogenin will then be used for the production of a vitellogenin specific polyclonal antibody. These components will then be used to develop an indirect competitive ELISA for sturgeon plasma vitellogenin. Laboratory analysis will be conducted with the assistance of the University of California, Davis. Concurrent with the development of the vitellogenin ELISA, an assay to determine reproductive state based on total plasma calcium will be evaluated.

As part of this work, adult wild shovelnose sturgeon have been captured monthly from the upper Missouri River near Judith Landing, Montana. Fish were collected during a 9 month period. Blood plasma, gonadal tissue, and a section of pectoral fin ray were collected from all fish. Cursory examination of gonadal tissue indicated that a variety of stages of gonadal maturation were obtained from both male and female sturgeon. Comparison of plasma and gonadal tissue will be used validate (hopefully) the ELISA. Pectoral fin ray sections will be used to establish age structure data with respect to shovelnose sturgeon. Preliminary fin ray data indicate that like other sturgeons, the shovelnose is a long-lived, late-maturing species.

Photo-documentation of Larval Development

Studies to establish a photo-documentation of shovelnose and pallid sturgeon embryology and larval development are continuing at the Center. Morphometric parameters will be characterized using a video calipers. This work will provide a photo-record of the embryology and larval development of shovelnose sturgeon. General protocol is similar to the work of Beer (1981) and Wang (1984) that investigated similar parameters in the white and lake sturgeon, respectively.

Therapeautants for Sturgeon Culture

The successful culture of sturgeon will likely require the use of chemotherapeutants to maintain general fish health and reduce the threat of disease. The effect of such compounds on shovelnose sturgeon is currently unknown. Studies have been conducted to determine the toxicity of formalin, chloramine-T, and salt on fingerling shovelnose sturgeon. Preliminary data indicates that although shovelnose sturgeon are more tolerant than rainbow trout to formalin and Chloramine-T, they are less tolerant to salt. In fact, it was found that a 3% salt treatment for 30 minutes resulted in significant mortality of fingerling shovelnose. Future studies are planned that will focus on the efficacy of "breakpoint concentrations" of each compound.

Disease Susceptibility/Transmission of Shovelnose Sturgeon

Development of hatchery technologies for the culture of sturgeon has led to a growing industry. One aspect of sturgeon culture that has received interest is the polyculture of white sturgeon with rainbow trout. Observations suggest that sturgeon and trout can cohabitate with benefits to both species. However, there are concerns regarding disease susceptibility and transmission between the two species. A study was conducted to determine the susceptibility, pathology, and the reservoir host status of shovelnose sturgeon following exposure to infectious hematopoietic necrosis virus (IHNV). Preliminary data indicate mortality of shovelnose sturgeon exposed to IHNV, although replication of the virus was not detected. This work was conducted in cooperation with Clear Springs Foods, Inc., Research Division, Buhl, Idaho (CSF).

White sturgeon iridiovirus (WSIV) has been shown to cause mortality in hatchery-reared juvenile white sturgeon. It is unknown if WSIV may also impact the culture of shovelnose sturgeon. To determine the effect (if any) of WSIV on juvenile shovelnose sturgeon, an infectivity study is currently being conducted. This work is also being done in cooperation with CSF.

Support Provided to Other Sturgeon Research Projects

Shovelnose sturgeon larvae, fry and fingerlings have been provided to a number of organizations involved in the research and/or promotion of sturgeon including:

1. Researchers at the University of California, Davis, CA investigating formation and deposition of retinal pigments in sturgeon.

2. Researchers at the Larval Fish Development Lab, FT. Collins, CO investigating embryo and larval development in sturgeon.

3. Researchers at the National Contaminant Research Center - Columbia investigating the effects and tissue residue levels of contaminants with respect to sturgeon.

4. Researchers at Kentucky State University investigating parameters related to the hatchery culture of sturgeon.

OBSERVATIONS AND FINDINGS OF THE MISSOURI RIVER FISH & WILDLIFE ASSISTANCE OFFICE

Confluence Region of the Yellowstone and Missouri Rivers

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INTRODUCTION

The Missouri River Fish & Wildlife Management Assistance Office personnel have conducted studies on the native fish populations in the Yellowstone and Missouri River confluence region since 1988. Primary emphasis at that time was the collection of paddlefish (Polydon spathula) for propagation purposes. Prior to the listing of the pallid sturgeon (Scaphirynchus albus) in 1991, work began to develop sampling methods for pallids effectively. Surveys and sampling methodology have emphasized developing a clearer understanding of population dynamics of the native fish within these two rivers.

Procedures

This year began with expanding on current studies to quantify spawning habitat for sturgeon or paddlefish. This was done by anchoring 'egg mats' below or at suspected spawning areas. These mats were derived from ideas that are currently being used to assess white sturgeon spawning habitat on the Columbia River. Mats consist of a frame with a commercial 'hogs hair' air filter stretch within the frame. Mats are reported to be effective in sampling sturgeon eggs. (Lance Beckman pers. comm.) Another sampling method initiated this year was the use of larval light traps. Although this method does not appear to work well with sturgeon species, they worked for the catostomids and cyprinids of the Missouri River. Drift samples for larval fish were collected to further identify possible spawning sites. The data complemented a study being done on paddlefish by North Dakota Game and Fish Department and Montana Fish, Wildlife & Parks. Identification of species composition from these methods will be reported after specimen identification is completed.

Pallid sturgeon assessment has continued and intensified. Work continues on monitoring current population status. This includes assessing the population size, habitat use, and distribution. Gill and trammel nets have proven to be the most effective method of capturing adult pallid sturgeon. Trammel nets with twelve inch bar measure walls and a two inch bar measure center panel and variegated gill nets 120 feet in length by six to eight feet in depth with 2, 3, 4, and 5 inch bar measure mesh and ¾, 1, 1½, 2, 3 inch bar measure mesh are drifted with the current through likely areas. These areas include the main channel side of islands, main channel chutes, and areas immediately downstream of sandbars. All pallids are placed into a six foot tank and taxonomic measurements are taken. Measurements include all those recommended by the endangered species permit protocol as well as habitat characteristics and effort. All measurements are recorded in millimeters and weight is recorded in pounds to the nearest half pound and converted to grams. A Biosonic® passive integrated transponder (PIT tag) is injected into the base of the left side of the dorsal fin. Other fish captured are noted and released.

Description of Project Area

The Yellowstone and Missouri Rivers in eastern Montana and northwest North Dakota are a unique and valuable resource. The Missouri River from below Ft. Peck Dam to the headwaters of Lake Sakakawea and the Yellowstone River from it's confluence of the Tongue River to the confluence of the Missouri River are probably one of the last strongholds of the pallid sturgeon, as well as other native species. However, little is known about the fish populations that exist in these stretches and how the dynamics of these rivers relates to these species. The Yellowstone River is the last largest untamed big river in the country. Other than the diversion at Intake, MT and the tributary dams, the Yellowstone's hydrograph is probably very similar to pre-settlement days. The early spring rise is dependant on prairie moisture and a later rise is a result of high mountain snow pack melt. On the Missouri River, the flows are totally dependant on the operation of Ft. Peck Dam. This has dramatically altered the flow regime, sediment load, and temperature in this stretch of river. Pallid sturgeon use of the Missouri River from Ft Peck Dam to the confluence is still uncertain at this time, however, according to Bob Bramblett (pers. comm.) there is some use. There are approximately 200 river miles from the confluence of the Tongue and Yellowstone to the confluence of the Missouri and Yellowstone River. There are approximately 189 river miles from Ft. Peck Dam to it's confluence of the Missouri and Yellowstone Rivers. An additional 30 to 60 river miles exist from the confluence of the Missouri and Yellowstone to the headwaters of Lake Sakakawea. The available riverine habitat below the Yellowstone confluence is dependent on the pool level of the reservoir above Garrison Dam.

The diversity of habitat within the Yellowstone River appears to be the result of unaltered flows. From preliminary observations, it appears that during increased flows, gravel beds in main channel areas are exposed. These gravel beds have sand deposited on them during the lower flows of late summer and fall.

RESULTS AND DISCUSSION

Pallid sturgeon work started this year with attempting to capture gravid fish for spawning purposes and to document potential spawning areas. Although no gravid fish were captured, one fish was netted and subsequently an external radio transmitter was attached for further tracking purposes. Another pallid was observed as paddlefish anglers were landing the fish at Sundheim Park. This fish was previously tagged with an external dangler tag in 1989 below Ft. Peck Dam. A PIT tag was inserted and the fish was released. On a separate survey in June, four fish were sampled in the Yellowstone at river mile 5.5, two of these pallids were recaptures. At least two of the fish were ripe males from the evidence of sperm when it was expressed. Bob Bramblett, working on a telemetry study in the same vicinity, had locations of four additional pallids within the same area. Bramblett also netted two additional pallids within the same week. This appears to be a likely area of congregation during the late spring months. Further effort will be directed to this area in future surveys to determine if and where spawning is occurring.

Total catch of pallids for this office is listed in Table 1. Length frequency of all pallids captured by survey crews from 1989 to present were calculated and is represented in Figure 1 and 2. From 1994 data, it appears that 88% of the pallids caught, were in the range of 1200 - 1450 millimeters fork length.

Recaptured pallid can provide significant knowledge for the recovery of pallid sturgeon. Recaptures allow population estimates to be made as well as monitor the condition of fish previously tagged. As a result of the number of recaptures over the last two field seasons, a population estimate was calculated (Table 2). A Schnabel multiple-census estimate was calculated over the span of four years. This was done to develop a population trend and to better understand the status of the pallid in this section of the Missouri River (Figure 3). From the data collected in 1994, there are approximately 230 (165 - 330, 95% CI) fish in the stretch of river surrounding the Yellowstone-Missouri River confluence. This estimate assumes no tag loss and no mortality and that this is a closed population. Mortality may be minimal due to the longevity of this species, (30 - 50 years). In 1993, a total of seventeen pallids were known to be snagged by paddlefish anglers. Only two were known to be snagged during the 1994 season (Greg Powers, pers. comm.). Mortality due to snagging does not appear to be an immediate concern, however, wound site would play an important factor in the recovery of an individual fish. Additional information is needed. Tag loss is an unknown factor due to differing tagging techniques amongst researchers. Trials conducted at Gavins Point National Fish Hatchery on juvenile sturgeon indicate tag loss for PIT tags used on juvenile fish should be less than five percent.

Although sampling efficiency has increased since the first years of sampling for pallids, the total effort has remained fairly constant for the last two years. A sampling effort of one year was required to determine the population estimate. To complement the Schnabel estimate, a modified Peterson estimate (Bailey, 1951) was also calculated. This was done by sampling for fish previously tagged. In November, a netting effort consisted of netting the same areas as a September survey. A total of three pallids were sampled; one new fish, one fish tagged in 1992, and one from September. This estimate used the total number of marked fish in this section of river for an estimate of 150 fish. The coefficient of variability from this calculation was calculated at .25.

Bailey index (1951)

M = number of fish initially marked and released
C = number of fish captured and examined in second survey
R = number of recaptures found in C

$N = M(C + 1) / (R + 1)$
$N = 113 (3 + 1) / (2 + 1)$
$N = \mathbf{150}$

with variance $V(N) = \frac{M^2 (C+1)(C-R)}{(R+1)^2 (R+2)} = 1418$

standard deviation $\sqrt{V(N)} = 37.7$

The population estimates will be re-analyzed using current catch data on an annual basis to monitor the population status of pallid sturgeon.

Determination of spawning areas is a critical component in the protection and enhancement of pallid sturgeon habitat. Results from surveys conducted in 1993 and 1994 delineated potential spawning habitat on U.S.G.S. maps of the area (Figure 4). This should assist researchers in concentrating efforts in areas to quantify spawning habitat and document recruitment.

Using length and weight data from pallids captured in the confluence area, relative weights (Wr) were calculated over the past several years (Table 3). This information will provide an index of the overall health of the pallid sturgeon population. Relative weight is based on a percentage of a weight for a standard length with >90 to <110 being optimum. Less than 90 indicates lack of forage or too many fish in the population. Greater than 110 indicates that the forage is probably under-utilized. Gravid females should have Wr's that can exceed 110. Measuring inaccuracy can also lead to misleading Wr's. The regression equation calculated from 40 pallids from North Dakota used to calculate the relative weights is as follows:

$$\log Ws = -7.7302 + 3.8009 \log L$$

Recapture data is listed in Table 4 and 5. Table 4 lists the capture location, capture distance, capture date, and capture duration. This table is not meant to depict movement of pallids, only the duration between capture and recapture. A total of 27 individually PIT tagged pallids have been recaptured. Time between capture and recapture ranged from three days to 2,250 days. Distance between capture and recapture site ranged from 220 miles to recapture at the same location. Table 5 lists pallids that have been recaptured with the respective length/weight information. Discrepancies with data on recaptured pallids is probably a result of errors in field measurements. Relative weights indicate that the pallids within this stretch of river are in good condition. However, there is still limited information as to what pallid sturgeon are utilizing for forage.

Flows on the Missouri and Yellowstone Rivers are recorded by the U.S. Geological Survey at Sidney and Culbertson, MT. The Sidney, MT station is located on the Yellowstone River approximately 30 miles upstream from the Missouri and Yellowstone confluence. The Culbertson, MT station is located on the Missouri River about 40 miles upstream the Missouri and Yellowstone confluence. The flows indicated in Table 6 are the flows at the station on the date of capture. The time lapse for the flows recorded at each station to capture location would run approximately one to two days. Preliminary results would indicate that pallid sturgeon are using the Yellowstone River during the higher flows. This would be expected if the Yellowstone River is the primary spawning area.

During a concerted effort in late September, catch per effort for pallid sturgeon was calculated at 2.4 fish per day of effort. Catch per effort was calculated at 2.7 pallids per day of effort for pallid sturgeon work conducted in November or one pallid per 510 meters of drift effort with variegated gill nets (2,3,4,5 inch bar measure)

Recommendations for Future Pallid Work

1. Intensively sample suspected spawning areas this spring to document and quantify spawning sites.

2. Expand juvenile surveys to begin after the spawning period and continue for two weeks a month until fall of the year.

3. Conduct spawning operations during 1995 for pallid sturgeon that result in progeny of North Dakota/Montana pallids.

4. Conduct surveys to determine forage utilization by pallid sturgeon.

5. Investigate the drift distance of pallid sturgeon larvae upon hatching and investigate if imprinting is occurring during early stages of development for pallid sturgeon.

6. Change survey time period for adult pallid sturgeon to prior to spring rise and during the fall of the year.

7. Develop an augmentation plan for the upper basin population.

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PADDLEFISH SNAGGER CREEL
and
INCIDENTAL STURGEON SNAGGING SURVEY

SUNDHEIM PARK
MAY 15 THROUGH JUNE 14, 1994

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INTRODUCTION

The Yellowstone-Sakakawea stock of paddlefish inhabits Lake Sakakawea, the Missouri River upstream of Sakakawea to below Fort Peck Reservoir, the "Dredge Cuts" below Fort Peck, and the Yellowstone River. The fish in this stock typically migrate between feeding areas in Lake Sakakawea and spawning areas in the Yellowstone River and Missouri River below Fort Peck Reservoir. Most successful paddlefish spawning apparently occurs in the Yellowstone River in Montana upstream of the confluence of the Yellowstone and Missouri Rivers.

Paddlefish snagging is permitted in North Dakota on this stock of spawning paddlefish during the annual upstream spawning migration each spring. The North Dakota Game and Fish Department (NDGFD) first permitted paddlefish snagging in the Missouri-Yellowstone Rivers in 1976. The open area for snagging is contained in the area of the Missouri River lying west of the US Highway 85 bridge and in that portion of the Yellowstone River in North Dakota. During the first 15 years paddlefish snagging was permitted, the annual paddlefish harvest fluctuated from year to year, but remained relatively constant (Tenney and Power, 1992).

Only since 1988 have creel or telephone surveys been conducted on the North Dakota paddlefish snagging season. Total harvest in 1988 was estimated to be 650 fish, and in 1990 the estimate was 762 fish. In 1991, a year of especially high discharge in the Yellowstone River, the catch was 1,460 fish (Owen and Hendrickson, 1992). The 1992 harvest was an estimated 1559 fish (Ryckman, 1993). The 1993 harvest was estimated to total 2,039 fish, with most of these, as in 1992, harvested in the Confluence area (Ryckman et al, in press).

Historically, most of the snagging activity and paddlefish harvest has focused on the Confluence area, as the recent creel surveys have documented. Other primary snagging areas are at the "pumphouse", an area just to the west of Highway 85 on the Missouri River, and at Sundheim Park, a public access site on the Yellowstone River just east of Fairview.

In 1993, an apparently greater paddlefish snagging effort and larger harvest occurred at Sundheim Park than in previous years. In addition, there were several reports and documented occurrences of paddlefish snagging activity resulting in the incidental snagging of pallid sturgeon at the Sundheim Park area. The fate of each of these incidentally snagged pallid sturgeon in 1993 is unknown, but there were no reports of any mortality or illegal creel of any of the pallids by paddlefish snaggers.

The pallid sturgeon was listed as an endangered species under authority of the Endangered Species Act in 1990. NDGFD had provided some regulatory protection to the pallid prior to this listing. With the start of the 1985-86 fishing season (May 4, 1985), angler harvest of any sturgeon greater than 36 inches in length was prohibited. With the start of the 1990-91 fishing season (May 5, 1990), there was a total ban on the harvest of any sturgeon anywhere in North Dakota. These fishing regulation changes were implemented primarily for the purpose of preventing mortality of pallid sturgeon through angler harvest. After federal listing of the pallid as endangered, no angler harvest is permitted by federal law, either.

NDGFD recognizes the importance of properly protecting pallid sturgeon. In an effort to document the extent of incidental snagging of pallid sturgeon by paddlefish snaggers, and to document the extent of injuries to individual fish as a result of the snagging, a creel survey was conducted at Sundheim Park from May 15 through June 14, 1994. This period of time was selected since it covers the final 4 weeks of the paddlefish snagging season, which corresponds to the period of time when the vast majority of the paddlefish snagging has historically occurred at Sundheim Park. The Yellowstone River is generally unregulated, and thus displays seasonally high flows of turbid waters. Paddlefish snagging in this area is dependent upon a variety of environmental factors which affect the movement of paddlefish during their spawning migration.

Description of Creel Survey Area

Sundheim Park is a public use area on the west side of the Yellowstone River straight east of Fairview, Montana. The park's river frontage for shore angling is bordered on the north by the Highway 200 bridge and the south by the abandoned Burlington Northern Railroad bridge. Access to the Park is good via a short, all-weather, graded road off Highway 200. A seasonal boat ramp at the Park allows for boating access to the river. Other public use facilities include picnic tables, a vault restroom facility, and a large area for primitive camping within the Park. The vast majority of the Park's angling and overall use occurs during the paddlefish snagging season period.

Although snagging from a boat is illegal, a relatively small number of paddlefish snaggers use the boat ramp to access other portions of the Yellowstone River for snagging. The survey area included all of the area between the two bridges along both sides of the river.

METHODS

A creel survey was conducted at Sundheim Park from May 15 through June 14, 1994. Survey dates and times were stratified by weekday and weekend days or holidays, and then randomly selected, because it is known that more effort occurs on weekends and holidays. Eight hour days (8:00 AM to 4:00 PM or 2:00 PM to 10:00 PM) were assigned. Survey dates and times were randomly selected, but then modified slightly to allow for scheduling conflicts of the creel clerk. Appendix A is a schedule of survey dates and times. A standard interview form (Appendix B) was developed and used exclusively for the paddlefish snagger survey. The clerk was equipped with binoculars to assist with observation of snagging activity and snagger counts in the survey area, especially the area across the river from Sundheim Park.

The creel clerk was equipped with an Avid Power Tracker II multimode identity tag reader, for use in documenting the presence of PIT tags in any pallids he might encounter. The creel clerk was given a supply of AVID PIT tags with instructions on the technique for tag implant on any untagged fish. Pertinent general and physical data for any pallids encountered were recorded.

The clerk conducted hourly counts of all boat trailers and visible shore anglers on both sides of the river to get effort estimates. In addition, interviews of all paddlefish snaggers were conducted when the snaggers had completed their snagging efforts for the day, or just prior to the end of the scheduled creel survey period. All of the data entered on the survey form were verified at the end of the creel survey period. All collected data were then entered into and reduced by using dBASE IV software.

Angler Effort

The hourly counts of paddlefish snaggers were used to estimate total effort. This effort information was summed and expanded to obtain an estimate of total effort (snagging hours) during the month long survey period. "Snagging" days of effort were estimated by dividing the total number of snagging hours by the mean number of reported hours snagged per angler.

Catch Rate

Snaggers were interviewed to obtain information needed to estimate the snagging rate and harvest of paddlefish. Only those fish snagged and subsequently landed and creeled were considered "snagged". The survey did not attempt to document the number or percent of fish which were "snagged" but then lost before they could be landed and creeled. An estimate of the total number of paddlefish harvested was obtained by multiplying the snagging rate (number snagged and creeled per hour) times the estimated snagging effort (total hours).

Pallid Sturgeon/Incidental Snagging Information

The creel clerk monitored the paddlefish snagging activities to document any snagging of sturgeon, and specifically pallid sturgeon, during the creel survey periods. In addition, several questions were asked of interviewed snaggers regarding pallid sturgeon which may have been incidentally snagged. The questions concerning the current trip were the # of sturgeon snagged, and the number of sturgeon snagged over 36" in length. Also asked were questions regarding previous trips, including whether any sturgeon had been snagged while paddlefish snagging earlier this year, or in previous years.

Additional questions asked whether the snaggers could identify North Dakota's only endangered fish species, whether the snagger thought that recovery of pallid sturgeon and other rare native fish species should be a high priority for NDGFD, and whether the snagger supported the elimination of gaffs for landing paddlefish in order to provide additional protection for pallid sturgeon.

Other Angler Interview Information

Snaggers also were interviewed to determine a number of snagger characteristics and to gather information regarding a number of pertinent issues relating to their paddlefish snagging activities. A number of questions were asked concerning the composition of each snagging party, including the total number, the number with paddlefish tags, the number of residents/nonresidents, the number of males/females, and the number less than 16 years of age. Also asked were the one way distance travelled, hours spent snagging, number of paddlefish caught, number of jaw tagged paddlefish caught, and the number of other fish caught.

Snaggers were also asked several additional use and attitude questions. The additional use questions covered such issues as whether the harvested paddlefish were going to be taken to the caviar operation at the Confluence to be processed, and whether any jaw tagged paddlefish had been caught, and if so, reported. Additional attitude questions asked whether the snagger had heard of the proposed paddlefish management plan, and whether the snagger would continue to snag for paddlefish if the annual limit was reduced from 2 to 1 fish.

RESULTS

Interviews

A total of 88 paddlefish snagging parties, encompassing 303 individuals, were contacted during the survey. Fifty of the interviews were complete trip interviews encompassing 136 individuals, 118 (87%) of which had paddlefish tags. The 38 incomplete trip interviews encompassed 167 individuals, 122 (73%) of which had paddlefish tags.

Angler Effort

Determining accurate angler (snagger) effort in terms of angler hours and catch for paddlefish fisheries is extremely difficult due to the nature of the fishery. Nonetheless, 1944 hours of snagging were estimated for those snaggers in the Sundheim Park area from 8 AM to 10 PM, May 15-June 14, 1994.

Catch Rate

The overall catch and the catch rate are also very difficult to accurately determine given the limited amount of creel survey data. Nonetheless, a total of 80 paddlefish were estimated to have been harvested in the Sundheim Park area during the survey period, with the creel clerk sampling 16 (20%) of these fish. The catch rate based on these estimates was thus 1 fish for every 24.3 hours of snagging effort.

Pallid Sturgeon/Incidental Snagging Information

The creel clerk documented a total of two pallid sturgeon which were incidentally snagged by paddlefish snaggers during his scheduled creel survey work. One of these individuals was snagged in the Park area on May 15, shortly after he began his first day of the creel survey. The incidental snagging of this fish was also documented by a US Fish and Wildlife research crew which was on site at the time. The Service crew obtained all pertinent information and measurements on this fish. The other pallid was snagged on the east side of the Yellowstone River across from Sundheim Park on May 22. This fish was documented with the use of binoculars by the creel clerk, and was reported to be an estimated 5 feet in length. This fish was released back into the Yellowstone as soon as it was unhooked.

A total of 76 snaggers responded to the question as to whether they had snagged a sturgeon while snagging for paddlefish in North Dakota this year. Eight (11%) of the respondents indicated that they had snagged a sturgeon. The clerk obtained the following information regarding approximate length, date, and location where 6 of these sturgeon were reportedly caught:

Date	Approximate Length	Snagging Location
4/21/94	2.5'	Sundheim Park
4/21/94	3.0'	Sundheim Park
4/25/94	3.5'	Sundheim Park
5/02/94	6.0'	Sundheim Park
5/04/94	6.0'	Sundheim Park
5/15/94	5.0'	Sundheim Park

The first three sturgeon were reportedly caught prior to the start of the paddlefish snagging season on May 1, and were likely hooked on conventional angling gear rather than incidentally snagged. They also were likely shovelnose sturgeon. The final three fish were likely pallids; the last fish on the list was a pallid which was snagged while the creel clerk and a US Fish and Wildlife Service research crew were on site. The Service crew collected all of the pertinent information from this fish. It carried a PIT tag, # 7F7F06617F.

A total of 77 snaggers responded to the question as to whether they had ever snagged a sturgeon while paddlefishing in North Dakota. Twenty six (34%) of the respondents indicated that they had snagged sturgeon in previous years. The clerk obtained the following information regarding when and where 10 of these sturgeon had been snagged, and their approximate length:

Date	Approximate Length	Snagging Location
1982	6.0'	Lewis & Clark Bridge
1989	6.0'	Pumphouse
1991	5.0'	Sundheim Park
1992	6.0'	Sundheim Park
1992	4.0'	Sundheim Park
1992	5.0'	Sundheim Park
5/92	5.0'	Sundheim Park
1993	6.0'	Sundheim Park
1993	4.0'	Sundheim Park
1993	5.0'	Sundheim Park

A total of 80 snaggers responded to the question as to whether they could name North Dakota's only endangered fish species. Seventy (88%) said that they could and were able to do so. A total of 78 snaggers responded to the question as to whether they thought that recovering pallid sturgeon and other rare native fish species should be a high priority of NDGFD. Fifty nine (76%) responded that this should be a high priority. A total of 79 snaggers responded to the question as to whether they supported the elimination of gaffs in order to provide additional protection for pallid sturgeon. Forty seven (59%) support the elimination of gaffs for this reason.

Other Angler Interview Information

A total of 10 snaggers with paddlefish responded to the question as to whether they planned to take their paddlefish to the caviar operation for cleaning. Eight (80%) of the respondents indicated that they planned to do so. A total of 77 snaggers responded to the question as to whether they had ever snagged a jaw tagged paddlefish. Seven (9%) answered that they had. Five of seven of the snaggers reported that they had reported their jaw tagged fish to either Montana Game, Fish and Parks or to NDGFD. Another of these snaggers had in his possession a jaw tagged fish, resulting in 6 (86%) of the jaw tagged fish being reported.

A total of 80 snaggers responded to the question as to whether they had heard of the proposed paddlefish management plan. Twenty one (26%) indicated that they had heard of it. A total of 78 snaggers responded to the question as to whether they would continue to paddlefish in North Dakota if the annual limited was reduced from two to one tag. Seventy two (92%) indicated that they would continue to fish, even if only allowed to buy only one tag.

DISCUSSION

NDGFD has conducted limited creel or phone surveys of paddlefish snaggers annually since 1988, except for 1989. This creel survey of snaggers at Sundheim Park represented a survey of only a small percentage of the active snaggers in 1994. The results of this survey estimated a total of 80 paddlefish harvested with 1944 hours of snagging effort. This represents only a small portion (5.5%) of the overall estimated harvested of 1,462 paddlefish for the 1994 season throughout the legal snagging area. The creel survey results, and the snagger interviews, both indicated that there was less snagging effort and paddlefish harvest at Sundheim Park in 1994 than in 1993.

This creel survey documented that pallid sturgeon are indeed incidentally snagged by paddlefish snaggers. Both of the documented pallids which were snagged were released back into the Yellowstone apparently unharmed. (Add estimates of possible total # snagged based upon angler effort information). The snagger interviews provided additional documentation of incidental snagging of sturgeon, although the validity of the snagger responses can not be confirmed. All of the reported incidental snagging of pallid sturgeon in 1994, and most (80%) of the reports of incidental snagging of pallids in previous years for which specific information was provided, were at Sundheim Park. Theses creel survey results correspond to most pre-survey reports of pallids being incidentally snagged, primarily at Sundheim Park.

Although 34% of the interviewed snaggers indicated that they had snagged a sturgeon while snagging for paddlefish in North Dakota, many of these sturgeon were likely shovelnose, since the shovelnose sturgeon are much more abundant. There were certainly many more reports of incidentally snagged pallid sturgeon at Sundheim Park during the 1993 paddlefish snagging season. This is likely the result of a combination of factors, including multiple reports of the same fish, likely greater incidence of incidental snagging in 1993, and likely the greater concentration and thus vulnerability of pallids to incidental snagging in 1993.

Additional reports of incidentally snagged or angler caught pallids in recent years are also quite likely the result of a much greater presence of NDGFD, US Fish and Wildlife Service, and other research staff in the paddlefish snagging area during the last few years. This creel survey documented that incidental snagging of pallids does occur, but it did not document any mortality of pallids as a result of being incidentally snagged. In addition, no reports of dead pallids have ever been received in any portion of the Missouri-Yellowstone Rivers open to paddlefish snagging either during or after the paddlefish snagging season. In addition, several confirmed and unconfirmed reports of pallid sturgeon being caught by conventional angling methods are received by NDGFD. There has been no documentation of any injury or mortality to any of the pallid sturgeon which have been caught in this manner, either.

A large majority (88%) of the snaggers interviewed could name the state's only endangered fish species, which indicates at least some knowledge of the precarious status of the pallid sturgeon. A somewhat smaller but still sizable majority (76%) thought that recovering pallid sturgeon and other rare native fish species should be a high priority of NDGFD, which certainly indicates that the NDGFD should become more actively involved in recovery efforts for this species.

Only 59% supported the elimination of gaffs in order to provide additional protection for pallid sturgeon, however. Some of the snaggers indicated that they did not support this prohibition simply because they would only use a gaff to land paddlefish, and thus did not see any reason for this regulation. Perhaps NDGFD should do more to explain the purpose of the regulation prohibiting gaffing in the Sundheim Park area, and could promote the use of other types of landing gear which could be used but which would not harm pallids that were incidentally snagged.

Although the sample size was small, 80% of the snaggers indicated that they intended to take their paddlefish to the caviar operation to be cleaned. This percentage is the same as the percentage of paddlefish reportedly taken to the caviar operation for cleaning obtained during a random phone survey of the overall population of paddlefish snaggers who caught fish during the 1994 season. This indicates that most anglers are aware of, utilize, and support the caviar operation by having their fish cleaned in this manner.

Data from the caviar operation showed a total of 60 fish coming from snagging area #5, which includes the Sundheim Park area, during the creel survey period. The 60 fish represent 75% of the estimated harvest during this period, which is close to the 80% figure given by interviewed snaggers when asked if they planned to take their fish to the confluence caviar operation. The caviar operation's data for the 1994 season also indicated that the Sundheim Park area likely experienced much greater snagging activity and harvest prior to the initiation of the creel survey on May 15. A total of 136 paddlefish cleaned at the caviar operation were reportedly snagged in snagging area #5. Over half (seventy six or 56%) of these fish were cleaned during the first two weeks of the snagging season prior to the initiation of the creel survey.

A large majority (92%) indicated that they would continue to fish, even if only allowed to buy one tag, instead of 2, for the season. This response likely indicates a genuine concern for the future of this paddlefish stock, but also that the reduction to 1 tag, if implemented, would not appreciably reduce the number of paddlefish snaggers. Since only a small percentage of active paddlefish snaggers actually harvest 2 fish, the reduction to one tag might also not appreciably reduce the paddlefish harvest. Consequently, if future regulation of the paddlefish snagging season is designed to reduce the paddlefish harvest, then additional regulatory changes would likely be required to significantly reduce the harvest.

SUMMARY

The results of this creel survey indicated limited paddlefish snagging activity and harvest in the Sundheim Park area during the survey period of May 15 through June 14, 1994. Extrapolation of the survey data resulted in an estimated totals of 1944 hours of snagging effort and the harvest of 80 paddlefish. The creel clerk confirmed the incidental snagging of two pallid sturgeon while on duty. Several snaggers indicated that they had incidentally snagged sturgeon in North Dakota in 1994 prior to being interviewed, and numerous snaggers indicated that they had incidentally snagged sturgeon in previous years. It is assumed that many of these fish were shovelnose, not pallids, however. Additional reports of other pallids being snagged during the 1994 paddlefish snagging season were received by NDGFD personnel.

Most (88%) of the snaggers interviewed were able to correctly name North Dakota's only endangered fish species, and most (76%) responded that they thought recovering pallid sturgeon and other rare native fish species should be a high priority of the NDGFD. Over half (59%) responded that they supported the elimination of gaffs in the Sundheim Park paddlefish snagging area in order to provide additional protection for pallid sturgeon.

Most (80%) of the snaggers interviewed who had harvested paddlefish planned to take their fish to the confluence caviar operation to be processed, and most (86%) of the snaggers who indicated that they had caught jaw tagged paddlefish reported or had reported the catch. Only 26% of the snaggers interviewed reported that they had heard of the proposed paddlefish management plan, while most (92%) indicated that they would continue to snag for paddlefish even if only allowed to buy one tag.

Continued monitoring of the paddlefish snagging season at Sundheim Park, and throughout the paddlefish snagging area, is warranted. There is a great need to monitor the paddlefish snagging season to insure that the paddlefish harvest is not excessive, and to provide greater documentation regarding the extent of conflicts between paddlefish snagging and the incidental snagging of pallid sturgeon. This survey, although documenting the incidental snagging of a few pallids, did not document any injury to or mortality of pallids as a result of being incidentally snagged.

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Appendix A. Paddlefish snagger survey schedule for Sundheim Park, May 15-June 14, 1994

DATE		TIME
May	15	8:00 AM - 4:00 PM
May	16	2:00 PM - 10:00 PM
May	17	8:00 AM - 4:00 PM
May	19	8:00 AM - 4:00 PM
May	21	2:00 PM - 10:00 PM
May	22	8:00 AM - 4:00 PM
May	23	8:00 AM - 4:00 PM
May	25	8:00 AM - 4:00 PM
May	26	8:00 AM - 4:00 PM
May	28	8:00 AM - 4:00 PM
May	29	2:00 PM - 10:00 PM
June	01	8:00 AM - 4:00 PM
June	02	8:00 AM - 4:00 PM
June	03	8:00 AM - 4:00 PM
June	04	2:00 PM - 10:00 PM
June	06	2:00 PM - 10:00 PM
June	08	8:00 AM - 4:00 PM
June	09	8:00 AM - 4:00 PM
June	10	8:00 AM - 4:00 PM
June	11	2:00 PM - 10:00 PM
June	12	2:00 PM - 10:00 PM
June	14	8:00 AM - 4:00 PM