F2-2

TIMING, LOCATION AND POPULATION CHARACTERISTICS OF SPAWNING MONTANA ARCTIC GRAYLING (THYMALLUS ARCTICUS MONTANUS [MILNER]) IN THE BIG HOLE RIVER DRAINAGE, 1988

March 29, 1989

by

Bradley B. Shepard and Richard A. Oswald

Montana Department of Fish, Wildlife and Parks
1400 South 19th Street
Bozeman, Montana 59715

Funding Provided by:

Montana Department of Fish, Wildlife and Parks
Montana Natural Heritage Program - Nature Conservancy
U.S. Forest Service, Northern Region

EXECUTIVE SUMMARY

Spawning Montana Arctic grayling (Thymallus arcticus montanus [Milner]) within the upper Big Hole River drainage were sampled using electrofishing from April through June 1988. Sample sites included the main stem Big Hole River from Wise River up to Jackson and the lower portions of 11 tributaries to the river. Distribution of spawning grayling, habitat utilized for spawning, and characteristics of the spawning population were described.

Four hundred grayling were captured. The first ripe male and female were captured on April 20 and April 27, respectively, in the Big Hole River near the town of Wisdom. The numbers of captured ripe females peaked during the period between April 29 and May 11 with the first spent female captured on May 4. Spawning appeared to be triggered by a combination of declining river flows after the initial spring sub-peak flow caused by low elevation run-off and maximum daily water temperatures increasing to 50 F. The sex ratio of all captured fish identified as mature, ripe, or spent was 2.0 males:1.0 female. A large portion of age II fish were sexually mature. The average lengths and weights of ripe males (n = 158) and ripe females (n = 34) were 10.9 inches and 0.42 pounds and 11.3 inches and 0.51 pounds, respectively. Grayling spawned primarily within the main stem Big Hole River from the mouth of the North Fork Big Hole River upstream to 3 miles above Wisdom, in a few scattered side channels below the North Fork, and in the lower portions of Swamp, Big Lake, and Rock creeks.

Spawning sites were characterized as riffles with clean surface gravel which appeared "bright" near pool or run habitats, generally within actively degrading or aggrading side channels or alluvial gravel fans at the mouth's of tributaries. Most spawning grayling were captured in areas of hydrologic instability.

The age composition of the sampled population suggested that the 1987 and 1985 year classes (age I and III fish, respectively) were poor year classes. Conversely, the 1986 year class (age II fish) was a good year class. These relative year class strengths may be controlled by water flows during the first year of life.

Of eight fish tagged during the 1988 spawning run and recaptured later during the summer of 1988, two stayed in the upper river near spawning areas and five moved down river as far as Divide Dam. One fish which was tagged in Deep Creek on October 29, 1987 was recaptured near Wisdom on May 4, 1988

(where it moved to presumeably spawn), and then moved back to Deep Creek where it was captured on August 4, 1988. Of ten fish tagged during 1987 sampling and recaptured during the 1988 spawning season, half were tagged in the river near Fishtrap Creek either during the previous May or November, four were tagged in the Wisdom area during the previous May, and the other was the Deep Creek fish mentioned above. This tag return information lends support to observations by the authors that the Big Hole River supports a population of grayling which appear to use the entire river above Divide on a seasonal basis. A portion of this grayling population normally moves to the upper river (near Wisdom) during the spring and remains in this area of the river during the summer before emigrating down river to winter habitats.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The U.S. Forest Service, Montana Natural Heritage Program of the Nature Conservancy, and Montana Department of Fish, Wildlife and Parks provided funding for this project. The authors would especially like to thank Dave Genter of the Montana Natural Heritage Program; Don Bartschi of the U.S. Forest Service, Regional Office; Ron Prichard, the Beaverhead National Forest's Supervisor; Joe Spehar and the entire Staff of the Wisdom Ranger District; and Larry Peterman and Jerry Wells of the Montana Department of Fish, Wildlife and Parks for their support and encouragement. A special thanks to Fisheries Biologist Harold Stevensen for his field work and experience and to Ken DeCock, Greg Gibbons, and Tim Mosolf for their untiring and cheerful help in the field. Dave Genter, Don Skaar, and George Liknes reviewed early drafts of this report and their comments were invaluable and, in most cases, incorporated into this report.

Any reference to product names are intended to document the type of equipment used and do not represent a product endorsement.

INTRODUCTION

The last riverine (fluvial) native population of Montana Arctic grayling (Thymallus arcticus montanus [Milner]) in the contiguous 48 United States exists in the upper Big Hole River of southwestern Montana (Liknes and Gould 1987). The historic range of the fluvial grayling in the lower 48 states included most of the upper Missouri River basin above Great Falls and northern Michigan. The Michigan populations were extirpated around 1936 (Holton 1971; Scott and Crossman 1973). The distribution of fluvial grayling in Montana has progressively been reduced (Henshall 1906; Vincent 1962) until now the Big Hole River supports the only true fluvial population in the state. A population inhabiting a canal system (Sunnyslope Canal within the Sun River drainage) and a remnant population in the Madison River above Ennis Lake exist, however, the status of these populations are likely dependent upon reservoirs within their systems (Bill Hill, MDFWP, Choteau and Dick Vincent, MDFWP, Bozeman, personal communication). This dramatic reduction in range has led to the designation of the fluvial grayling as a "species of special concern" by the Endangered Species Committee of the American Fisheries Society (Johnson 1987), the Natural Heritage Program, and the Montana Department of Fish, Wildlife and Parks (MDFWP), as a "sensitive species" by the U.S. Forest Service, Northern Region (files, USDA Forest Service, Northern Region, Missoula, Montana), and a Category 2 species under consideration for ESA listing by the Fish and Wildlife Service (Federal Register).

Electrophoretic analyses conducted on seven Montana grayling populations (Grebe Lake, Lake Agnes, Rodgers Lake, Elizabeth Lake, Fuse Lake, Sunnyslope Canal, and the Big Hole River) and one Alaska population (Chena River) found that the lake populations were not greatly divergent from each other (Everett and Allendorf 1985). These authors found the Big Hole River, Chena River and Sunnyslope Canal populations were more different from the lake populations than from each other. Both the Big Hole and Chena populations are fluvial populations. The origin of the Sunnyslope Canal population is unknown, however, the most reasonable theory about their genetic make-up is that these fish undergo intense selective pressures because they live in a canal where all movement must be down stream and the canal is dewatered every fall. The above authors implied that the Big Hole River population has maintained its native fluvial genotypes even though adfluvial (lake) stocks may have been planted in the Big Hole River during the mid-1900's.

The MDFWP has attempted to monitor the abundance of the Big Hole River grayling population since the mid-1970's. Resulting data indicated a relative decline in abundance which prompted progressively restricting sport angling harvest from a 10 fish limit to a catch and release limit between 1975 and 1988 (Table 1). In addition to reducing limits, MDFWP initiated a graduate study on the population in conjunction with the Montana Cooperative Fisheries Research Unit (Montana State University, Bozeman, Montana) which was the first in-depth attempt to document grayling population abundance and distribution (Liknes 1981).

A literature review of grayling spawning requirements and timing found that grayling are annual spawners (Craig and Poulin 1975), likely home (Warner 1955; Craig and Poulin 1975; Tack 1980), migrate long distances to reach spawning grounds (Henshall 1907; Brown 1938; Nelson 1954; Reed 1964; Bishop 1971; Craig and Poulin 1975; Kratt and Smith 1977), initiate spawning migrations immediately prior to or during ice breakup of main stem rivers when water temperatures are 32 to 39 F (Brown 1938; Nelson 1954; Wojcik 1955; Warner 1955; Reed 1964; Schallock 1966; Williams 1968; Tack 1971; Bishop 1971; Tripp and McCart 1974; Craig and Poulin 1975; Krueger 1981; Falk et al. 1982), spawn at water temperatures between 36 to 50 F (Tryon 1947; Wojcik 1954; Rawson 1950; Warner 1957; Kruse 1959; Reed 1964; Williams 1968; Bishop 1971; Netsch 1975; Wells 1976; Falk et al. 1982), spawn over a 2 to 24 day period (Kratt and Smith 1977), and spawn in current velocities ranging from 1.1 to 4.8 ft/s (Krueger 1981). Selection of substrate for spawning varies widely. Spawning usually occurs over gravel substrates (Henshall 1907; Rawson 1950; Nelson 1954; Bishop 1971), but may occur over mud-bottomed pools with vegetation (Scott and Crossman 1973).

Liknes (1981) surveyed the Big Hole River grayling population during 1978 and 1979 by electrofishing and drift net sampling. He found grayling in three sections of the main stem Big Hole River and the lower reaches of 11 tributary streams and believed that the population was confined to the main stem Big Hole River and the lower portions of its tributaries above the mouth of the North Fork Big Hole River. Shepard (1987 and files, Beaverhead National Forest, Dillon, MT) found three additional streams, Fishtrap, O'Dell and Wyman creeks, and Wise River also contained grayling. The grayling in O'Dell and Wyman creeks and Wise River probably originated from grayling drifting out of mountain lakes within the upper Wyman creek drainage. Shepard's findings supported the contention of Liknes that grayling were confined mainly to the upper Big Hole River valley bottom, however, Shepard (1986, 1987 and files, Beaverhead National Forest, Dillon, MT) and Oswald (files, MDFWP, Dillon, MT) have documented grayling in most of the Big Hole River from Jackson downstream to its mouth.

Grayling in the Big Hole River appear to be concentrated between Divide and Wisdom and use this portion of the river seasonally by moving up into the Wisdom area during the spring with a significant portion of the population normally remaining in this area through the summer before migrating down river to winter habitats. Shepard (1987) radio tagged adult grayling during the fall of 1986 and found most radioed grayling moved down river out of the Wisdom area during October. Some years adult grayling do not remain in the Wisdom area during the summer, but move down river immediately after spawning. It is unclear what cues this early movement but preliminary observations indicate that it is related to severe reductions in flow.

Liknes (1981) sampled age 0 grayling within the Big Hole drainage and concluded that grayling spawned sometime during late April or early May. Shepard (1987) attempted to trap spawning grayling from April 7 through June 25, 1986, as they moved into several tributaries and a channel of the Big Hole River with little success. In 1987 a committee was organized by the MDFWP that included representatives of MDFWP; Population Genetics Laboratory, University of Montana; Montana Cooperative Fisheries Research Unit, Montana State University; Montana Natural Heritage Program - Nature Conservancy; U.S. Forest Service; U.S. Fish and Wildlife Service; National Park Service; and American Fisheries Society. This Committee recommended and organized a study to collect more detailed information to describe the locations, distribution, and site characteristics of grayling spawning sites within the Big Hole River drainage, and the timing and population characteristics of the spawning run. This report summarizes data collected during the first year of that effort.

Table 1. Summary of angling regulations for Arctic grayling in the Big Hole River from 1970 through 1990.

Regulation years	Grayling regulation
1970/71 - 1977/78	Ten pounds and one fish or 10 fish in combination with brown, cutthroat, and rainbow trout.
1978/79 - 1980/81	Five fish with only one fish exceeding 18 inches in combination with brown, cutthroat, and rainbow trout.
1981/82 - 1982/83	Five fish with only one fish exceeding 18 inches in combination with brown, cutthroat, and rainbow trout except from Divide Dam to Melrose Bridge where it was three fish under 13 inches and one fish over 22 inches in combination with brown, cutthroat, and rainbow trout.
1983/84	One grayling either under 13 or over 22 inches.
1984/85 - 1987/88	One grayling over 13 inches.
1988/89 - 1989/90	Catch and release for grayling.

STUDY SITE DESCRIPTION

The study area included the upper Big Hole River drainage above Divide, Montana (Figure 1). Sampling was concentrated within the main stem Big Hole River between the towns of Wise River and Jackson and in the lower portions of its tributaries including the North Fork Big Hole River, Big Lake Creek, Deep Creek, Fishtrap Creek, Governor Creek, Rock Creek, Sandhollow Creek, Seymour Creek, Steel Creek, Swamp Creek, and Warm Springs Creek. During sampling, Big Hole River flows and water temperatures ranged from 618 to 3320 cfs and 33 to 75 F, respectively, using preliminary data supplied by the USGS from a gauge located at the Highway 43 bridge near Wisdom (Figure 2).

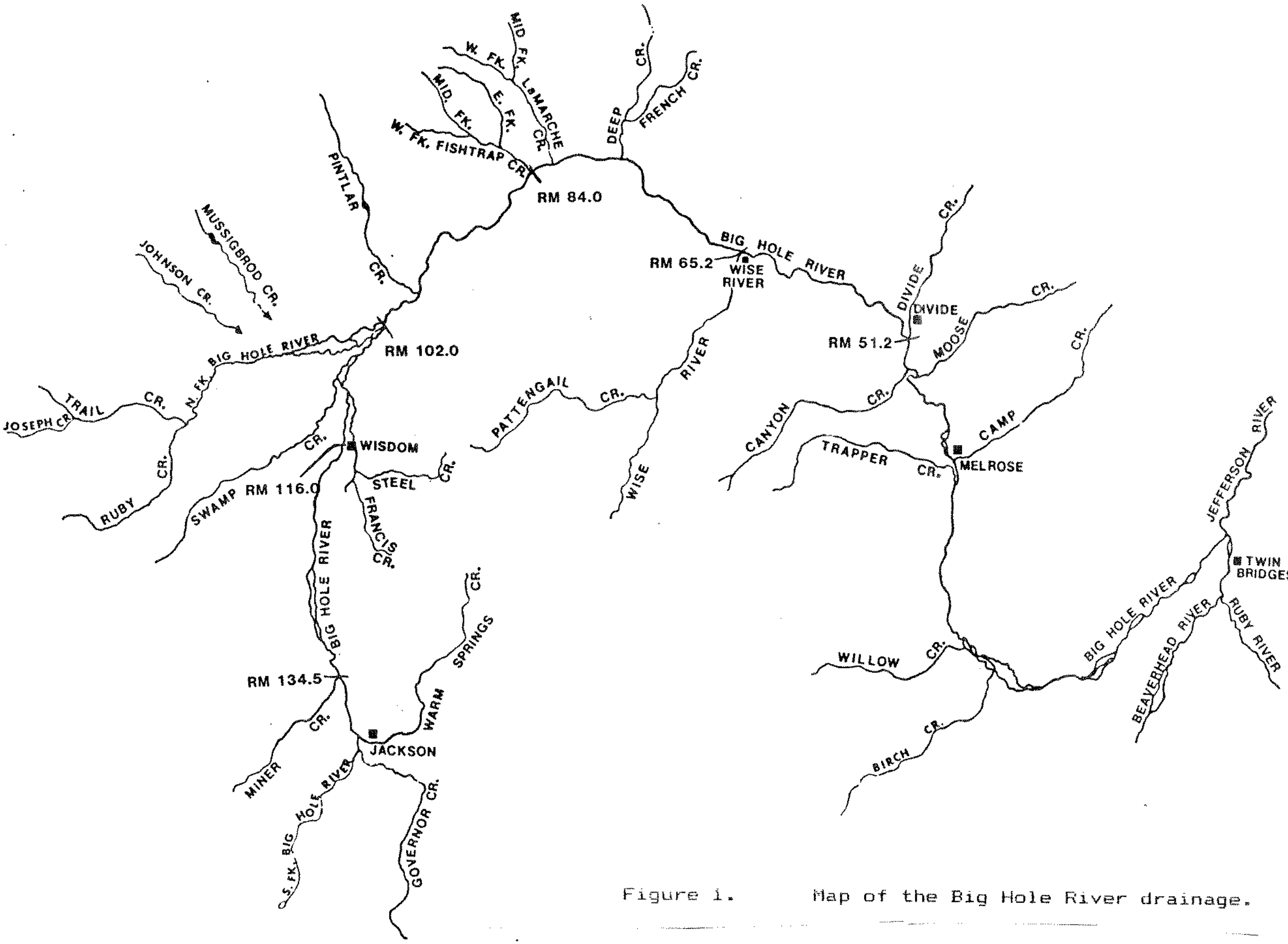

Figure 1.   Map of the Big Hole River drainage.

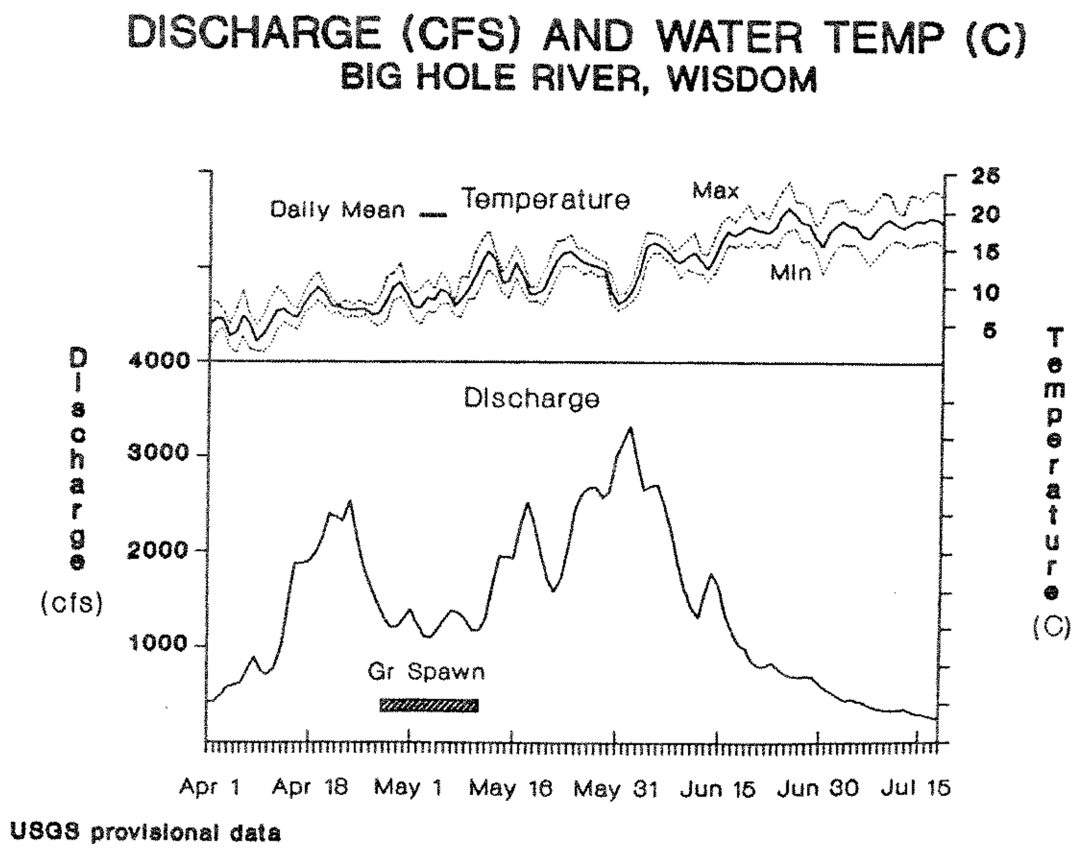

Figure 2. Daily discharge (cfs) and mean, minimum, and maximum water temperatures in the Big Hole River near Wisdom, Montana from April through June 1988. Preliminary data collected by the USGS. The time of grayling spawning is shown in the cross-hatched block above the X-axis.

METHODS

FISH COLLECTION

Grayling were captured using either boat mounted electro-fishing gear (either a Buffalo Drift boat or Coleman Crawdad outfitted with a 240 watt gas powered generator connected to a Harvey Leach constructed variable voltage pulsator with mobile anodes) or a backpack electrofisher (Coeffelt BP-1C) electro-fished in a downstream direction. Sampling began on April 6, in an area of the Big Hole River free of ice, and continued through June 29 (Table 2). Two crews operated during the peak of the spawning run. A total of approximately 54 miles of river and 20 miles of tributaries were surveyed during the spawning season.

Stunned grayling, rainbow trout, and brook trout were captured, except as noted on Table 2. For all captured fish, length was measured to the nearest 0.1 inch and weights were recorded to the nearest 0.01 pound.

Sex and state of maturity (immature; mature, but not ripe; ripe; or spent) was recorded for all grayling. Sex determination was based on extrusion of gametes, the ability to feel eggs within the body cavity, and the shape of the dorsal fins as documented by Rawson (1950). Ripeness of female grayling was difficult to determine until immediately prior to and during spawning. It was difficult to determine if males were spent because sperm could still be extruded from spent fish. Smaller grayling (fish less than 10.0 inches) were not checked for sex and state of maturity during the early part of the sampling (prior to April 27).

Scale samples were removed from grayling and scale impressions were made in acetate. Scale samples were later read for age determination. Age interpretation from scale samples up to age IV was believed relatively accurate, while estimation beyond age IV was suspect. Growth interpreted from scales should be reliable because scale samples were obtained in the spring during annulus formation.

All grayling and rainbow trout longer than 8.0 inches were tagged with a "spaghetti-type" numbered anchor tag. Recaptures of previously tagged fish were noted. Points of capture for grayling were visually noted and recorded in the field. Recorded information included the general habitat type and streambed condition where fish were captured and the location by river landmark. These capture locations were later converted to rivermile locations using USGS maps (scale: 1:24,000) and a Rivermile index.

Table 2. Electrofishing sampling dates, locations, and approximate length of sample sections for electrofishing sampling of the 1988 spawning Arctic grayling population in the Big Hole River. "NOSN" indicates no other fish species netted during that sampling.

Date	Location	Section length (mi)	Comments
4-06-88	Big Hole R. - Mallon's scales to Stanchfield's	1.8	No grayling NOSN
4-12-88	Big Hole R. - Seymour Ck to Dickie Bridge	5.8	No grayling Massive ice flows NOSN
4-12-88	Big Hole R. - Pool at Sportman's Park	0.2	One grayling Massive ice flows NOSN
4-13-88	Fishtrap Ck. - Above Highway 43	1.0	No grayling Lots of ice
4-14-88	N Fk Big Hole R. - below Else's Ranch	0.1	No grayling
4-20-88	Big Hole R. - above Highway 43 bridge by Wisdom	5.0	3 grayling
4-21-88	Big Hole R. - Squaw Ck to Fishtrap access	8.1	3 grayling NOSN
4-21-88	Sandhollow Ck - below N Fk Big Hole Rd	0.2	No grayling
4-21-88	Big Hole R. - 40 Bar Ranch to Fred Hirschy's	4.3	No grayling 1 rainbow
4-22-88	Swamp Ck. - N Fk Big Hole Rd to mouth	2.0	5 grayling
4-22-88	Big Hole R. - Swamp Ck to Sandhollow Ck	0.2	1 grayling
4-26-88	Seymour Ck. - above and below Highway 43 bridge	0.3	No grayling
4-26-88	Fishtrap Ck. - side channel at Access site	0.1	No grayling 19 rainbow

Table 2. (continued).

Date	Location	Section length (mi)	Comments
4-26-88	Sandhollow Ck. - above N Fk Big Hole Rd	0.5	No grayling
4-27-88	Big Hole R. - Steel Ck mouth to above cemetery	2.0	13 grayling
4-27-88	Steel Ck. - Steel Ck Rd to Big Hole R	1.2	6 grayling
4-27-88	Big Hole R. - Sandhollow Ck to Doolittle Ck	9.6	40 grayling NOSN
4-28-88	N Fk Big Hole R. - upper to lower N Fk roads	6.0	Sampled about 3.0 mi. No grayling
4-29-88	Big Hole R. - above Highway 43 bridge at Wisdom	5.0	45 grayling
5-02-88	Big Hole R. - below Highway 43 bridge at Wisdom	5.4	52 grayling
5-03-88	Rock Ck. - lower end above mouth at Big Lake Ck	0.8	15 grayling
5-03-88	Big Lake Ck. - below Rock Ck	0.1	4 grayling
5-03-88	Sandhollow Ck. - N Fk Big Hole Rd		Creek dry
5-04-88	Big Hole R. - above Highway 43 bridge at Wisdom	5.0	35 grayling
5-04-88	Big Hole R. - below Highway 43 bridge at Wisdom	5.4	39 grayling NOSN
5-05-88	Big Hole R. - 40 Bar Ranch to Fred Hirschy's	4.3	No grayling 6 rainbow
5-06-88	Big Hole R. - Doolittle Ck to Squaw Ck	6.6	11 grayling NOSN
5-09-88	Swamp Ck. - N Fk Big Rd to mouth	2.0	23 grayling

Table 2. (continued).

Date	Location	Section length (mi)	Comments
5-09-88	Big Hole R. - Swamp Ck to Sandhollow Ck	0.2	3 grayling
5-09-88	Big Hole R. - Squaw Ck to Fishtrap access	8.1	14 grayling NOSN
5-10-88	Big Hole R. - North Fork Big Hole to Doolittle Ck	1.0	3 grayling
5-10-88	N Fk Big Hole R. - lower N Fk Rd to mouth	3.5	1 grayling near mouth
5-11-88	Governor Ck. - T. Clemow Rd to Warm Springs Ck	0.5	1 grayling
5-11-88	Warm Springs Ck - Governor Ck to mouth	0.5	No grayling
5-11-88	Big Hole R. - Warm Springs Ck to Twin Lks Rd	2.5	No grayling 2 rainbow
5-11-88	Big Hole R. - Sandhollow Ck to Doolittle Ck	5.5	19 grayling NOSN
5-16-88 5-17-88	Deep Ck. - Ski Rd bridge to mouth at Big Hole R.	2.0	2 grayling 43 rainbow
6-13-88	Big Hole R. - above Highway 43 bridge at Wisdom	5.0	7 grayling
6-15-88	Big Hole R. - Fishtrap access to Sportsman's Park	3.0	12 grayling
6-21-88	Big Hole R. - Wisdom Cemetery to Doolittle Ck	9.8	15 grayling
6-29-88	Big Hole R. - Dickie bridge to Jerry Ck	8.4	1 grayling

SPAWNING SITE CHARACTERIZATION

Sites where ripe grayling were captured were visually characterized including habitat type (riffle, pool, etc.), substrate type (size category ranked into one or more of the following size classes: silt, sand, gravel, cobble, or boulder), and channel type (main channel, side channel, braided channel). In addition, ten streambed samples were taken from one known grayling spawning site in the Big Hole River and a similar habitat type unused by spawning grayling in the North Fork of the Big Hole River with a hollow-core sampler (modified from McNeil and Ahnell 1964). These core samples were oven dried and sieved through 2.0, 1.0, 0.5, 0.37, 0.25, 0.09, 0.03, and 0.003 inch mesh sieves and the material retained on each sieve was weighed to the nearest 0.01 pound. Material left suspended in the water during sampling was estimated according to methods presented in Shepard et al. (1984). The percentage of each size class of material was calculated for each core and averaged by site.

RESULTS

TIMING OF SPAWNING

The first ripe male grayling was captured on April 20 in the Big Hole River above the Highway 43 bridge near Wisdom (Figures 1 and 3). The first female grayling identified as ripe was captured in the Big Hole River on April 27 near the Wisdom Cemetery in the east channel. The numbers of ripe females peaked during the period between April 29 and May 11. The numbers of ripe males peaked during the period between April 22 to May 17. The first spent female was captured on May 4.

CHARACTERISTICS OF THE SPAWNING RUN

The sex ratio of all fish identified as mature, ripe, or spent was 2.0 males:1.0 female (Table 3). Length and age frequency information for mature fish illustrated that a large portion of the age II fish were sexually mature (Table 3 and Figure 4). The fact that the sex ratios change between age classes suggests that not all female grayling were maturing at age II and that female grayling may be suffering higher mortality than males after age IV (Table 3). The average length and weight of ripe males (n = 158) was 10.9 inches and 0.42 pounds, respectively. The average length and weight of ripe females (n = 34) was 11.3 inches and 0.51 pounds, respectively. The majority of growth in length was attained at by age III with the fastest growth occurring during the first and second years of life (Figure 5).

DISTRIBUTION OF SPAWNING WITHIN THE DRAINAGE

The majority of grayling spawning during 1988 occurred within the main stem Big Hole River between the North Fork of the Big Hole River upstream to approximately 3.0 miles above the Highway 43 bridge near the town of Wisdom and in the lower portions (generally from their mouth upstream one to two miles) of Swamp, Big Lake, and Rock creeks (Figure 1). Isolated spawning areas were observed in side channels within the main stem Big Hole River above the Highway 43 bridge near Squaw Creek and between Sawlog and Fishtrap creeks.

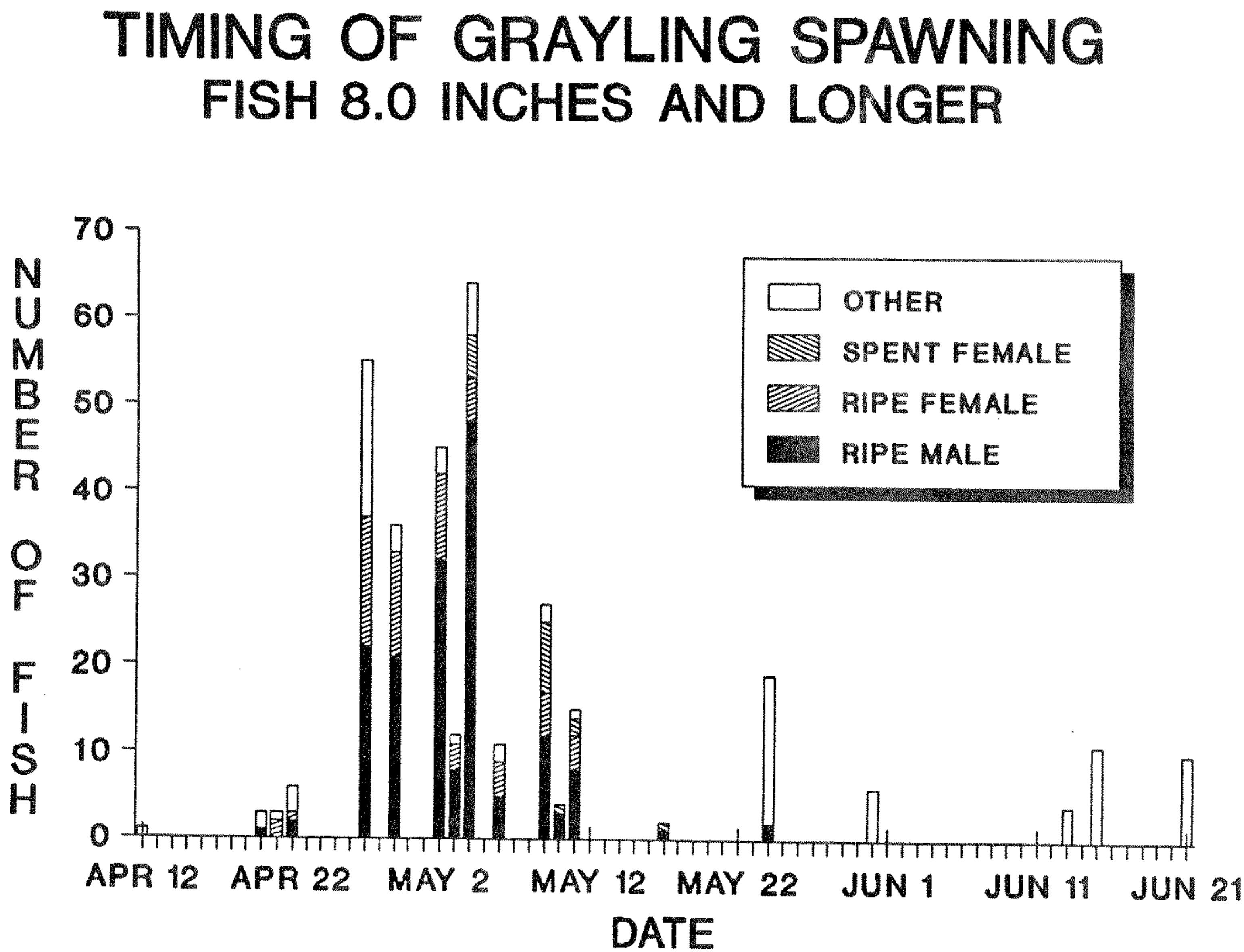

Figure 3. Catch of grayling 8.0 inches and longer in the Big Hole River and its tributaries by date during 1988. Grayling are segregated into ripe male, ripe female, spent female, and other classes.

Table 3. Mean length, length range, and sex ratio information by age for the portion of the Big Hole River Arctic grayling spawning run sampled during 1988.

Age class	Number sampled	Mean length (inches)	Length range (inches)	Percent mature	Sex ratio (male:female)
1	67	5.7	4.4 - 7.2	None	
2	169	9.8	8.1 - 11.2	66	3.7:1.0
3	25	11.7	10.2 - 12.8	92	1.9:1.0
4	61	12.7	11.6 - 14.9	97	1.0:1.0
5 +	24	13.4	12.6 - 14.6	100	2.4:1.0
Total	346				2.0:1.0

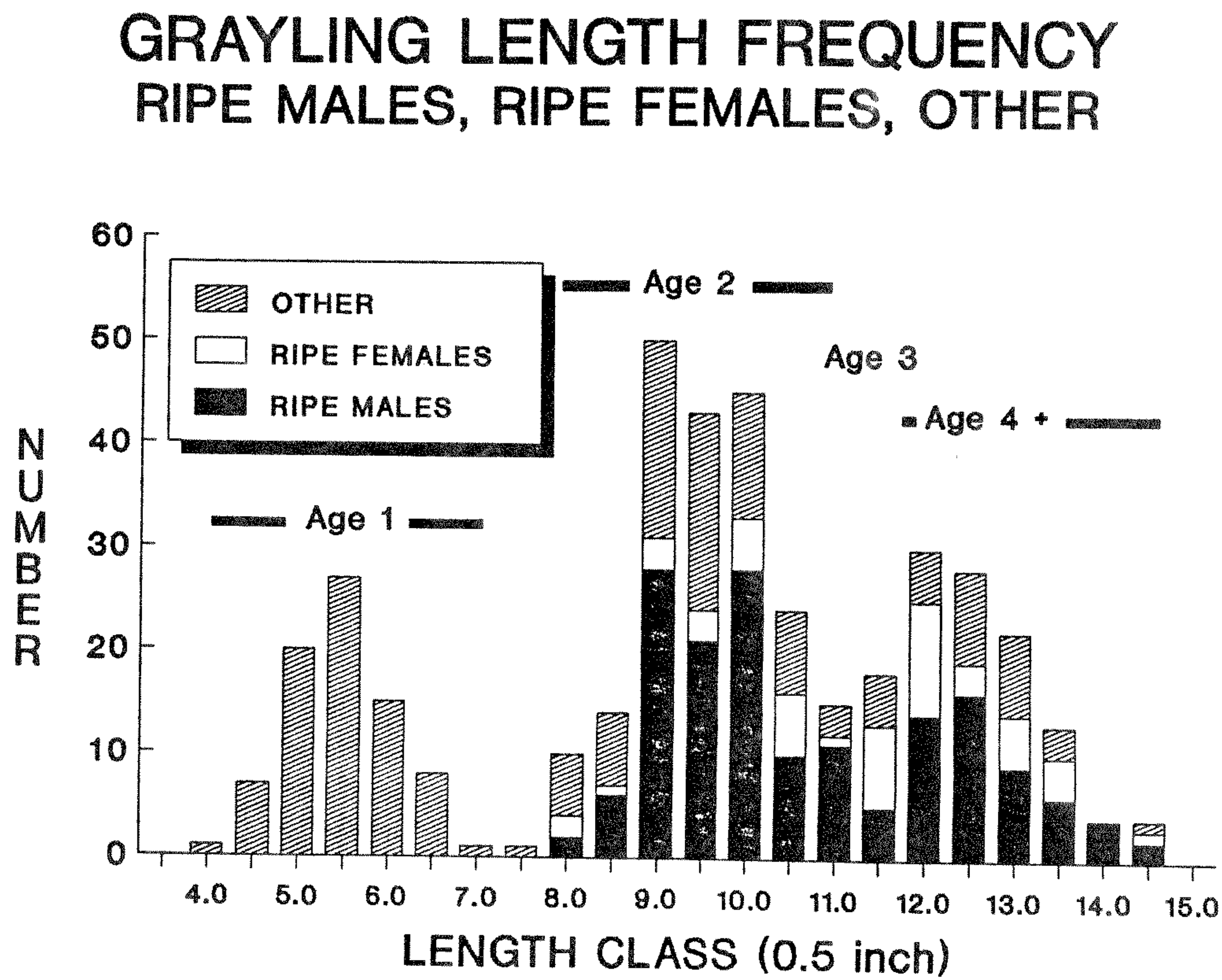

Figure 4. Length frequency of Arctic grayling captured during the 1988 spawning run by half inch length group. Grayling are segregated into ripe male, ripe female, and other classes. Ripe fish include all fish identified as either mature, ripe, or spent.

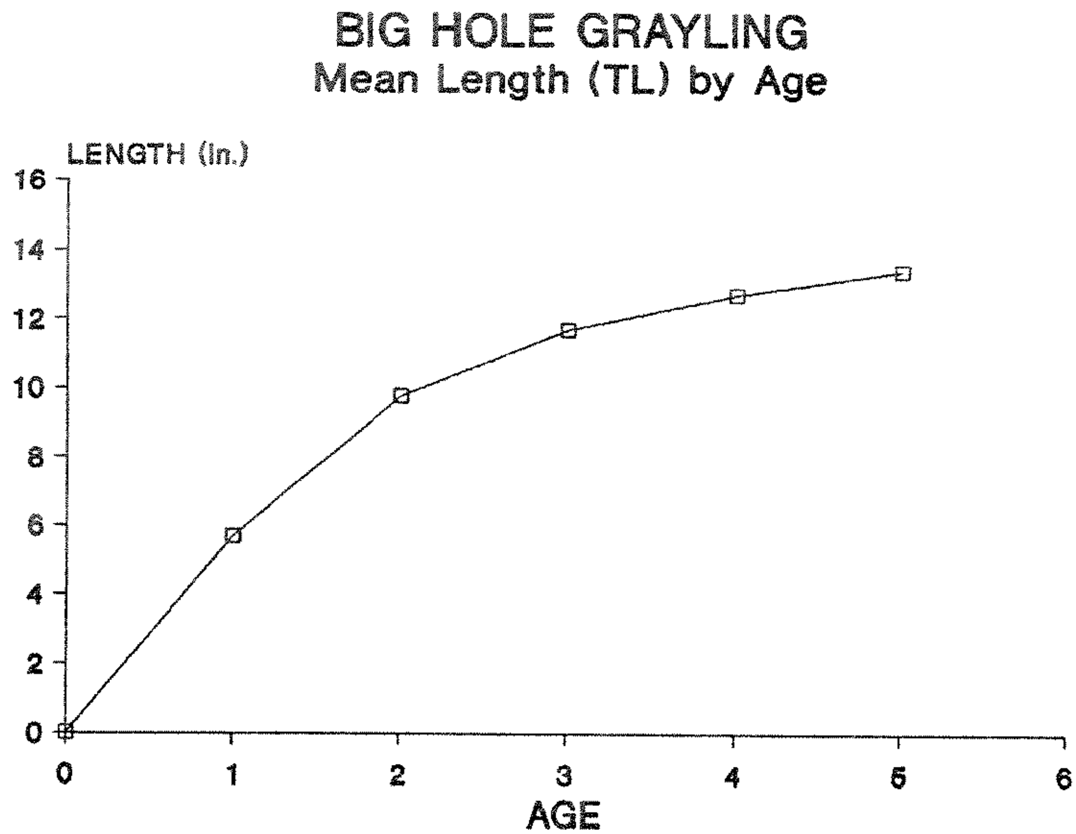

Figure 5. Growth of grayling in the Big Hole River drainage estimated from mean lengths at age.

MOVEMENT ASSESSED USING TAG RETURNS

A total of 30 grayling were recaptured during this sampling. Twenty of these recaptures were tagged within the same year (1988) and ten were tagged in previous years (Table 4). Of the ten grayling tagged during 1987 and recaptured during our sampling, five were tagged in the river between Fishtrap Creek and Sportsmen's Park either during the previous May or November, four were tagged in the Wisdom area during the previous May, and one was tagged in Deep Creek the previous October (Figure 6 - A). All fish tagged during the winter (November) and recaptured during our spring sampling had moved up river. Subsequent returns of seven fish tagged during our spring electrofishing by anglers found that over half the fish tagged and recaptured (four of seven) moved down river as far as the Divide Dam and the longest recorded down river movement was 51 miles (Figure 6 - B). The other three were captured in the Wisdom area from May to early July. To summarize this tag return data, during 1988 the majority of mature-sized grayling (fish 8.0 inches and longer) moved upstream in the early spring to spawning areas (primarily from the North Fork up to Wisdom) from wintering areas within the lower river (from as far downstream as Divide Dam), spawned, and then moved down river or into tributaries after spawning (Table 4 and Figure 6). During past years mature-sized grayling spent the entire summer within the upper portion of the drainage in the Wisdom area as documented by summer and fall electrofishing (Liknes 1978; Oswald 1984; Oswald 1986).

CHARACTERISTICS OF SPAWNING SITES

Visual Characteristics

Grayling usually were found spawning in riffle areas over gravel which appeared "bright" due to the absence of periphyton and/or silt and sand sized material on the surface of the streambed. These riffle areas of "bright" gravel were often associated with recently created side channels, below beaver dams and irrigation diversion structures, and/or near mouths' of tributaries where alluvial gravel fans had formed. Mature grayling were collected near each riffle of clean gravel below every beaver dam in a recently formed side channel below Wisdom which contained numerous beaver dams. By the middle of the spawning season electrofishers became relatively efficient at identifying areas where ripe grayling were likely to be captured. These areas could be characterized as being in areas of hydrologic instability, often in recently cut side channels where a riffle with "bright" gravel was situated near a pool or run.

Table 4. Summary of tag return information for recaptured arctic grayling captured during the spring of 1988.

	Tagging information				Recapture information			
Tag	Length	Weight	Date	Location	Length	Weight	Date	Location
YF205	8.7	0.20	5/ 6/88	BHR - RM93.7	8.7	0.20	5/ 9/88	BHR - RM86.0
YF198	9.2	0.24	5/ 4/88	BHR - RM110.0	9.4	0.21	5/ 9/88	SWAMP - CM0.2
LBF228	9.2	0.27	5/12/87	BHR - RM115.0	10.6	0.38	5/ 4/88	BHR - RM111.0
GF185	9.3	0.25	4/27/88	BHR - RM114.0	9.2	0.21	5/ 4/88	BHR - RM115.0
GF182	9.3	0.24	4/27/88	BHR - RM114.0	9.3	0.22	5/ 4/88	BHR - RM112.0
GF161	9.7	0.24	5/ 2/88	BHR - RM111.0	12.0	-	8/ 8/88	BHR - RM60.5
LBF97	9.7	0.25	4/27/88	BHR - RM107.0	9.8	0.27	5/ 9/88	SWAMP - CM1.5
GF147	9.8	0.20	4/29/88	BHR - RM110.0	9.7	-	5/ 4/88	BHR - RM116.6
LBF84	10.0	0.30	4/21/88	BHR - RM91.0	10.1	0.32	5/ 2/88	BHR - RM110.0
LBF118					10.2 13.0	0.32 -	5/ 4/88 8/ 4/88	BHR - RM116.6 DEEP - CM4.0
GF160	10.2	0.30	5/ 2/88	BHR - RM111.0	-	-	6/27/88	BHR - RM126.0
GF216	9.9	0.29	5/ 4/88	BHR - RM118.2	10.2	0.30	5/24/88	BHR - RM117.2
LBF242	10.5	0.42	5/18/87	BHR - RM85.0	12.1	0.53	5/ 4/88	BHR - RM114.0
GF31					11.0	0.43	4/27/88	BHR - RM104.0
GF28					11.2	0.42	4/27/88	BHR - RM104.0
GF163	11.1	0.38	5/ 2/88	BHR - RM111.0	11.1	0.40	5/ 4/88	BHR - RM112.0

Table 4. (continued).

	Tagging information				Recapture information			
Tag	Length	Weight	Date	Location	Length	Weight	Date	Location
GF144	11.4	0.56	4/29/88	BHR - RM116.0	11.9	0.60	6/13/88	BHR - RM117.2
GF53	11.6	-	10/23/87	BHR - RM87.0	11.7	0.45	5/ 4/88	BHR - RM111.0
GF124	11.9	0.54	4/27/88	BHR - RM113.0	12.1	0.47	5/ 4/88	BHR - RM115.0
GF208	11.9	0.58	5/ 4/88	BHR - RM116.6	11.9	0.55	6/13/88	BHR - RM83.0
GF123	12.0	0.56	4/27/88	BHR - RM113.0	12.0	0.45	5/ 2/88	BHR - RM111.0
GF162	12.1	0.60	5/ 2/88	BHR - RM111.0	12.1	0.61	5/ 4/88	BHR - RM112.0
LBF102	12.3	0.51	5/18/87	BHR - RM84.0	13.0	0.62	5/ 4/88	BHR - RM115.0
LBF225	12.3	0.57	5/ 5/87	BHR - RM120.0	12.3	0.57	5/ 4/88	BHR - RM116.6
GF198	12.7	0.60	4/22/88	SWAMP - CM1.0	14.0	-	5/23/88	?
GF145	12.7	0.68	4/29/88	BHR - RM116.0	11.0	-	6/ 9/88	BHR - RM65.0
GF184	12.8	0.62	4/27/88	BHR - RM114.0	12.8	0.58	5/ 4/88	BHR - RM114.0
LBF203	11.7	0.64	5/12/87	BHR - RM115.0	12.7	0.60	5/24/88	BHR - RM116.6
GF106	12.9	0.70	4/29/88	BHR - RM116.6	12.8	-	5/ 4/88	BHR - RM117.7
LBF233	13.0	0.62	5/12/87	BHR - RM114.0	13.5	0.71	4/29/88	BHR - RM116.0
GF149	13.0	0.61	4/29/88	BHR - RM116.0	13.5	-	5/ 4/88	BHR - RM116.6
LBF192	13.3	0.80	4/27/88	BHR - RM102.0	13.2	0.70	5/ 6/88	BHR - RM96.3
GF176	13.7	0.80	4/22/88	SWAMP - CM1.5	13.7	0.75	5/ 9/88	SWAMP - CM0.2
YF224	14.3	1.02	5/11/88	BHR - RM107.0	14.0	-	7/ 2/88	BHR - RM55.8

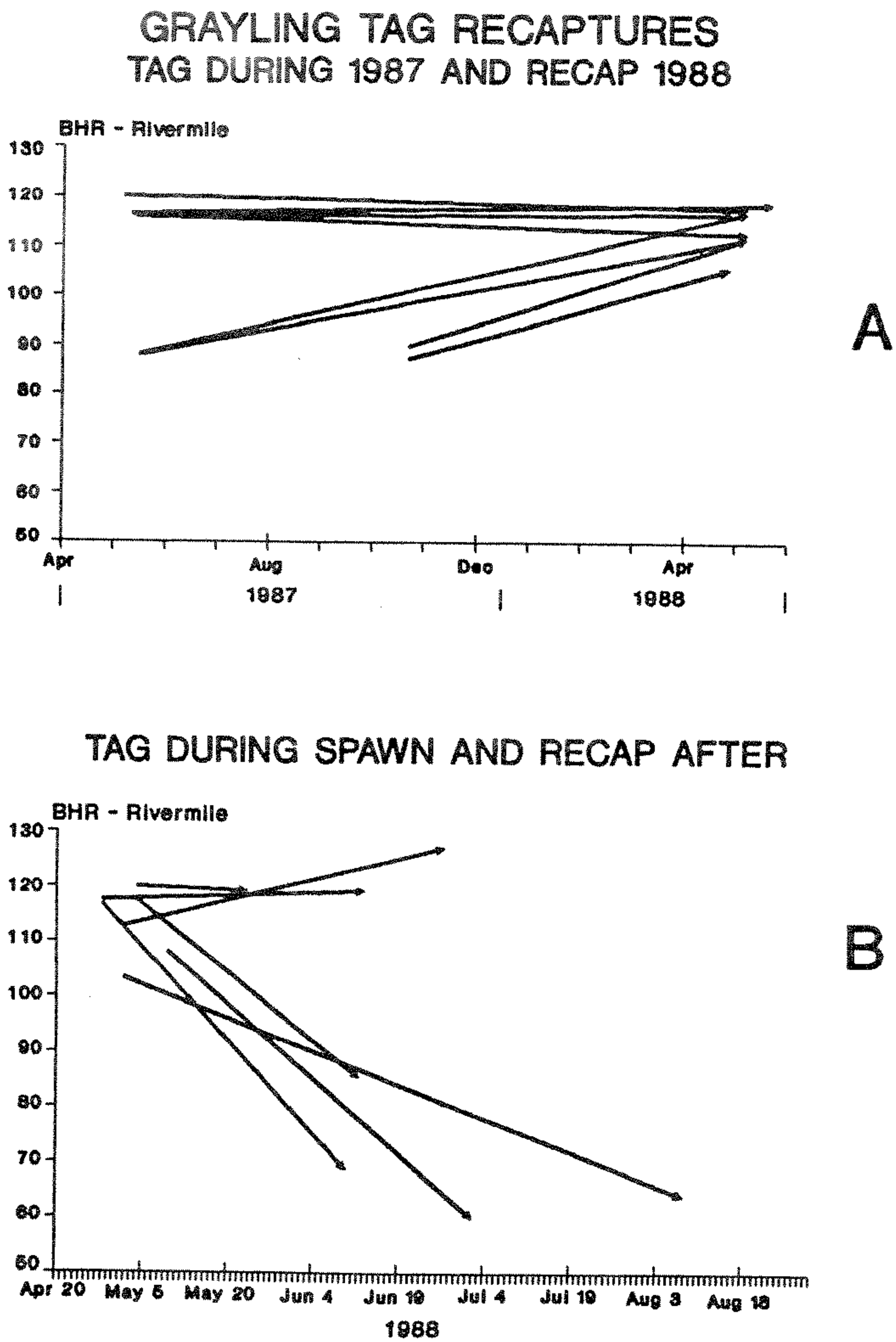

Figure 6. Grayling movement assessed from tag return data for grayling tagged during 1987 and recaptured during the spring of 1988 (A) and tagged during the spring of 1988 and recaptured later in 1988 (B). The origin of arrows is the tagging location and the arrow heads indicate recapture locations.

Streambed Composition

The streambed within a known grayling spawning riffle in the Big Hole River contained 30% large gravel (particles between 6.0 and 0.5 inches), 50% fine gravel (particles between 0.5 and 0.09 inches), and 20% sand and silts (particles less than 0.09 inches), while a similar site not used by grayling in the North Fork Big Hole River contained 30%, 40%, and 30% of the same size classes, respectively (Figure 7). There were lower percentages of fine material (smaller than 0.25 inches in diameter) in the Big Hole spawning site (30%) versus the North Fork site not used for spawning (43%). There were statistically significant differences between the two sites for the cummulative percentages of material less than 0.374 inches ($p < 0.02$), less than 0.25 inch ($p < 0.002$), less than 0.09 inches ($p < 0.004$) based on Mann-Whitney tests (Daniels 1978) computed using a STATGRAPHICS computer package version 2.6 (STSC 1986). There were no significant differences between cummulative percentages for the other size classes analyzed.

During the extraction of the sample material we observed that a real difference existed between the two sites. The main stem Big Hole River site (where grayling were spawning) had very little sand and silt material in the upper one to two inches of the streambed, but did have an abundance of sand and silt below that level. The North Fork Big Hole River site (where no grayling spawning was observed) had abundant sand and silt observed on the surface.

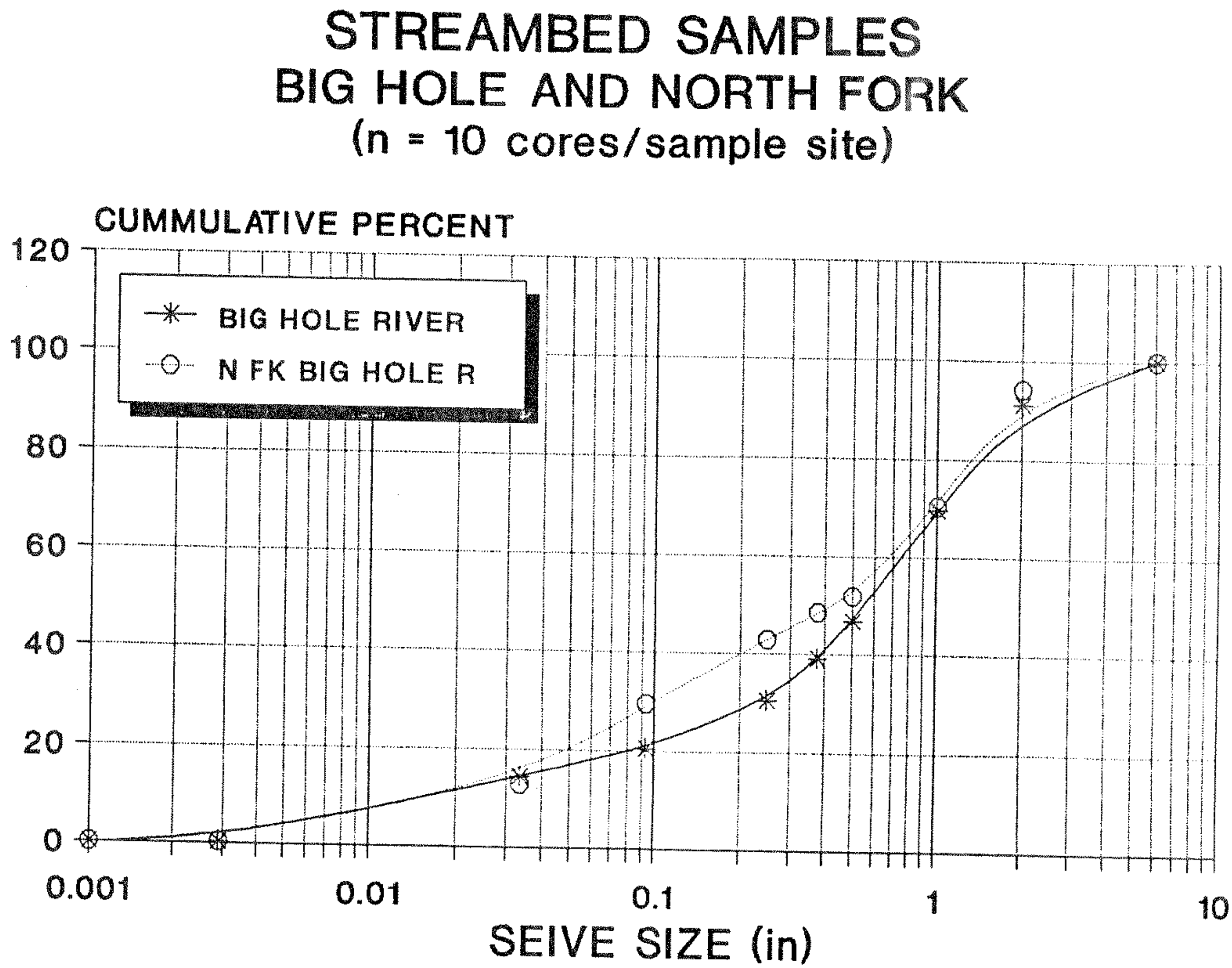

Figure 7. Composition of a typical riffle streambed site where grayling were found spawning in the main stem Big Hole River and in a similar site where no grayling spawning was documented in the North Fork Big Hole River. All streambed compositions were determined from ten hollow core (McNeil and Ahnell 1964) samples.

DISCUSSION

TIMING OF SPAWNING

Grayling spawning in the Big Hole appeared to be triggered by a combination of water temperature and river discharge (Figure 2). Daily maximum water temperatures at Wisdom rose above 50 F on April 16 for the first time (reaching 52 F) and remained above 50 F from then until April 18, however, river flows also rose rapidly during this time period from 1,900 cfs to 2,140 cfs and continued to rise to 2,530 cfs by April 22. Daily maximum water temperatures again rose higher than 50 F on April 27 (52 F) and remained over 50 F for the remainder of April. River flows, meanwhile, dropped from the early peak of 2,530 cfs down to 1,660 on April 25 and stabilized at around 1,300 cfs between April 26 to May 13. This suggests that grayling initiated spawning in response to the combined cues of daily maximum water temperatures rising above 50 F in conjunction with the falling limb of the initial spring sub-peak flow event that is characteristic of the upper Big Hole River hydrograph. Spawning then occurred during a relatively stable flow period between the initial spring sub-peak flow and the main higher spring peak flow that occurred during late-May and early-June. Mean daily water temperatures during the peak of spawning activity (April 27 to May 10) averaged 47 F, but during the last five days of April (when spawning was initiated) mean daily water temperatures averaged 48 F.

A review of previous studies found time of spawning was variable. Environmental factors that cued spawning activity were suggested to be water temperature and flow changes. Brown (1938) stated that "The actual period of spawning for the Montana grayling has been found to vary greatly between different years and between different localities in the same year." Previous studies of grayling in Montana found that spawning occurred from mid-March through July. Specifically spawning occurred, mid-March to April 24 in Odell Creek, a Madison River tributary, peaking around April 16 (Brown 1938); from mid-May to early June in Narrows Creek, a tributary to Elk Lake in the Centennial Valley of southwest Montana (Lund 1974); from early May through May in an inlet of Rogers Lake in the northwest portion of the state (Tryon 1947); through early July with the time of initial spawning unknown in three high mountain lake inlets within the Wise River drainage, a tributary to the Big Hole River (Eriksen 1975); from mid-May to late June in tributaries to Grebe Lake in Yellowstone National Park (Kruse 1959); from May 19 to June 6 in Red Rock Creek and from May 23 to June 1 in Antelope Creek, both tributaries to Upper Red Rock Lake in the Centennial Valley of southwest Montana (Nelson 1954); from early June through late June in an inlet stream to Lake Agnes in southwest Montana (Peterman 1972); and from mid-July through late July in an inlet to Hyalite Reservoir, near Bozeman, Montana (Wells 1976). A review of grayling studies conducted in Alaska found the majority of those grayling populations spawned from mid-May to mid-June, however, some populations were found to spawn as early as late April and others as late as early July (Armstrong 1986). A review of studies conducted in Canada found that spawning generally occurred from April through June (Rawson 1950; Bishop 1971; McCart et al. 1972; de Bruyn and McCart 1974; Tripp and McCart 1974; Kratt and Smith 1977; Falk et al. 1982).

In past studies of grayling in Montana spawning was found to commence when water temperatures reached the 40-50 F range and the upper end of this range was the suggested temperature where most spawning activity was observed by the majority of the authors (Brown 1938; Tryon 1947; Nelson 1954; Kruse 1959; Holton 1971; Peterman 1972; Lund 1974; Wells 1976). Lund (1974) also documented that grayling began their spawning runs on declining stream flows in inlets to Elk Lake, Montana when daily stream and lake temperatures averaged approximately 45 F. Water temperature and spring flooding were believed to be factors that stimulated spawning in Armstrong's (1986) review of the Alaska studies on grayling. Specifically, Tack (1973) believed that a water temperature of around 39 F triggered grayling spawning in interior streams of Alaska which was also the temperature Alt (1976) suggested grayling spawned in western Alaska. Warner (1955) also found grayling spawning at around 39 F in some inlets to Fielding Lake, Alaska. Bishop (1971) noted that grayling moved onto spawning grounds at water temperatures of 46 to 50 F and that spawning took place at 50 F. Canadian studies have reported water temperatures between 39 to 50 F to be an important cue for the initiation of grayling spawning (Rawson 1950; Tripp and McCart 1974; Stuart and Chislett 1979).

CHARACTERISTICS OF THE SPAWNING RUN

The sex ratio for the Big Hole grayling spawning population was 2.0 males:1.0 female. Kruse (1959) documented sex ratios of spawning runs into Grebe Lake, Yellowstone Park, spawning grounds to be 2.0:1.0 in 1953 and 0.9:1.0 in 1954. Lund (1974) found that females outnumbered males in spawning populations of grayling entering Narrows Creek from Elk Lake, Montana at a ratio of 2.1:1.0 and 1.7:1.0 in 1972 and 1973, respectively. Bishop (1971) found a sex ratio of spawning grayling entering Providence Creek, a tributary to Great Slave Lake in Canada to be 1.3 males:1.0 female. Ward (1951) found the sex ratio changed during the course of the spawning run in an Alberta tributary from 3.0 males:1.0 female early in the run to 5.0 males:1.0 female late in the run.

The grayling in the Big Hole River system became sexually mature at age II. Hubert et al.'s (1985) review of riverine grayling studies found that age at sexually maturity varied, dependent upon latitude and population density. In general, the above authors reported that grayling populations with low to moderate densities at lower latitudes attained sexual maturity at age II to III, while in northern latitudes or high population densities fish matured at age IV and older, not reaching sexual maturity until age VI in many Alaskan waters. Tack (1974) concluded that angler harvest may have been responsible for grayling maturing at a smaller size (earlier age) in the Chena River than in other waters of Alaska.

The growth curve for grayling in the Big Hole system illustrates that the majority of growth is put on during their first two years (Figure 5). The presence of some juveniles in tributaries to the river and the interpretation of early growth from a few scales suggests that a small segment of the juvenile population may rear for up to two years in river tributaries. In Hubert et al.'s review (1985) of riverine populations they reported that grayling in Montana and Wyoming reach 7.2 to 9.8 inches in 2 years and from 11.2 to 14.7 in 4 years. Growth for the Big Hole grayling population appears to be toward the upper end of this range through age II (9.6 inches), while the average length of age IV grayling (12.7 inches) lies in the middle of the range reported by Hubert et al. (1985).

DISTRIBUTION OF SPAWNING WITHIN THE DRAINAGE

The distribution of spawning grayling within the Big Hole drainage shows that areas above the North Fork of the Big Hole River were more intensively used for spawning. Precise reasons for this distribution of spawning are unknown at this time, however, the following speculation may encourage further investigation. One possible explanation for the spawning distribution could be the high fine sediment load contributed to the Big Hole from the North Fork watershed. This drainage is underlain by highly erosive granitic batholithic material and has recently experienced more intensive land-use. Previous streambed sampling by the senior author in 1987 found that a riffle area within the river near Wisdom contained only 16% fine material (material less than 0.25 inch), while a riffle located above the Highway 43 bridge near Squaw Creek (an area below the North Fork) contained 29% fine material, and a riffle near Sportsmen's Park contained 21% fine material (files, Beaverhead National Forest, Dillon, MT). Another potential explanation for this spawning distribution is that the portion of the river above the North Fork may be inherently less stable resulting in more areas of "hydrologic instability" which creates preferred spawning habitat.

MOVEMENT

The movement patterns observed through recaptures of tagged fish and by the authors during their work on the Big Hole suggests that a segment of the riverine Big Hole grayling population spend the winter in deep pools in the portion of the river below the Wisdom area as far as the Divide Dam and perhaps in the lower portions of some tributaries which have deep pools or areas of groundwater recharge. During the spring, the majority of the mature grayling move up river and spawn in the portion of the river from the mouth of the North Fork up to immediately above Wisdom, and in the lower portions of Swamp, Steel, Big Lake, Rock, and Sand Hollow creeks.

During years of average and above average river flows most of those grayling that moved up river during the spring remain in the upper portion of the river throughout the summer to feed before moving back down river in the fall (usually sometime during October) to return to winter habitat areas. The exact mechanism which triggers this down river movement is not known, but is suspected to be a combination of rising river flows (resulting from either fall rains, increased return flows from irrigation, or a combination of the two) and declining water temperatures. During years of extreme low flow we have observed that a large portion of the grayling which moved up river during the spring migrate back down river immediately after spawning. This movement pattern was observed in 1985, 1987, and 1988, all years of low flow. What triggers this immediate down river migration is unclear, but may be related to drastic reductions in river flow during the late spring/early summer period.

At the present time, we are unsure if juvenile grayling follow this same migration pattern in the Big Hole system. We have not captured many juvenile grayling in the lower portions of the Big Hole, but have frequently captured juveniles in the Wisdom area. It may be that juvenile grayling in the Big Hole either rear up through age II in the upper portion of the drainage, or follow similar movement patterns as adults. During electrofishing sampling in the fall of 1986, juvenile (age 0) grayling disappeared from the Wisdom area between the mark and recapture sampling. This would support the latter of the above two theories.

Other authors have noted this type of annual migration pattern in other riverine grayling populations. The following discussion of grayling movements in Alaska systems is taken from Armstrong (1986). He summarized the reasons for these "complex migrations to overwintering, spawning, and feeding sites" to be "adaptions to different systems or different parts of the same system" which "enables the young [which "emerge early and develop rapidly"] to leave systems before they become frozen and uninhabitable in winter." He further states that "entire populations of grayling migrate downstream and out of certain tributaries and enter" main stem rivers for the winter. These populations leave streams which dry up or freeze solid, but also leave spring-fed streams. In conversations with Steve Tack (Fairbanks, Alaska) Armstrong and Tack speculated that the reason grayling leave these spring-fed streams is that these streams often have extensive frazil ice in winter. Armstrong also states that in larger unsilted rivers in Alaska (the Big Hole would most closely resemble these systems) most grayling inhabit the upper reaches during the summer and migrate down stream to overwinter in the deeper water of the main stem.

The majority of these Alaska populations begin this down stream movement in September, similar to the time Big Hole grayling population moved down river from the upper basin in previous normal flow years. Grayling in Alaska were found to migrate from a few miles up to 100 miles to reach overwintering habitat. In these unsilted Alaska rivers grayling use different portions of the system during the summer depending upon their age and maturity. Young-of-the-year tended to remain near areas where they emerged, usually in the upper reaches of the system. Juveniles (ages I, II, and III) used the lower portions of the rivers and their tributaries. Adults either moved upstream to feed in the upper reaches of the rivers, or if they spawned in the upper reaches, remained there throughout the summer. The grayling in Alaska were found to return annually to feeding areas and it was suggested that they probably show similar fidelity to spawning sites.

Hubert et al.'s (1985) review documented the same types of migration patterns and clarified the following. Downstream migration to wintering areas was found to occur when water temperatures approached 32 F (Yoshihara 1972). All ages of grayling moved downstream to overwintering areas in large streams and rivers during late summer and fall (Yoshihara 1972; Kratt and Smith 1977; Tack 1980). Wintering areas included pools of intermittent and flowing streams, as well as spring-fed bog streams (Craig and Poulin 1975) which did not freeze to the bottom during winter months (Krueger 1981).

SPAWNING SITE CHARACTERISTICS

We found Big Hole grayling spawning over gravel that was very clean on its surface. Spawning occurred in riffle areas in close proximity to pool or deep run habitats. Most previous investigators have found that grayling spawned in riffles or in transition zones between riffles and pools (Henshall 1907; Rawson 1950; Nelson 1954; Bishop 1971). Eggs and spawning have generally been found on gravel and not on mud, silt, sand, or clay substrates (Henshall 1907; Rawson 1950; Nelson 1954; Warner 1955; Bishop 1971; Tack 1971; Tack 1973; Kratt and Smith 1977), however, Brown (1938) found the Agnes Lake, Montana spawners spawning over silt and sand at a ratio of 3:1 in the inlet, Curtis (1977) found grayling from Wyoming lakes in inlet and outlet streams spawning over a sand/fine gravel substrate, Bendock (1979) found a lake population of grayling spawning over a wide variety of material from large rubble to vegetated silt within the lake, Reed (1964) found grayling spawning over mud in a side slough, and Tack (1980) found grayling spawning on sedges in a stagnant pond. To summarize, it appears that lake populations of grayling may have adapted to spawning over fine material, while river and stream populations generally spawn over gravel in riffle areas. There has been little work done to evaluate spawning success in different substrate conditions. This question should be addressed in future research.

STATUS OF POPULATION AND ENHANCEMENT FEASIBILITY

We will give a brief assessment of our opinion on the present status of the riverine grayling population in the Big Hole River system and briefly explain recent attempts directed at enhancement of this population. We will also briefly discuss the problems which will likely be associated with attempting to re-establish riverine populations of grayling into other waters in the state. The following is speculation based on observation and a review of the literature.

The riverine population which exists in the upper Big Hole River system above Divide, Montana appears to be a single population and at least a portion of this population uses the entire upper river system on a seasonal basis. This population is presently at a low level and the recent trend (from 1983 to the present) has been a decline (Oswald in prep.). Year class strengths and weaknesses appear to be linked to river flows with below average flows producing weak year classes and normal and slightly above average flows producing strong year classes. Ironically, it appears that flows which are way above average may also produce weak year classes. Grayling are notoriously vulnerable to angling (Falk and Gillman 1974; Tack 1974; Grabacki 1981) and recent regulation restrictions have attempted to remove that component of mortality from the riverine Big Hole population (Table 1). The other three potential avenues for preserving and/or enhancing this population are: 1) habitat enhancement, either through the enhancement of river flows or direct habitat enhancement by creating more preferred habitats; 2) population enhancement through releases of riverine stock grayling fry into the system; and 3) control of competitors and predators, if further research finds these two types of interactions contribute significantly to overall mortality. We will discuss each of these options in detail.

One of the most likely candidates for preserving and/or enhancing populations is to provide more stable river flows and reduce potential loss of grayling in irrigation ditches. By providing more stable flows, particularly during the relative short spawning and incubation period, survival from eggs through the first summer of life should be enhanced. More work is needed to confirm our observations from 1988 and further refine the relationship between the timing of spawning and river flows and water temperatures. If we can accurately predict when spawning will occur, we can work with local irrigators to provide for more stable river flows from the initiation of spawning through the time fry emerge (a two to three week time period). The senior author has already approached irrigators in the upper Big Hole valley near Wisdom and received a very positive response to this concept. There appears to be a very real possibility of initiating this type of management.

Another potential source of mortality is the loss of grayling, particularly fry and juveniles, into irrigation ditches. One way to limit this loss would be to attempt to return any grayling fry or juveniles back to the river from irrigation ditches before these ditches are shut down for haying or at the end of the season. Work done in the Gallatin River system found that an incremental shut-down of ditches over a two to three day period triggered trout to move up the ditch and return to the river (Clothier 1953 1954; Kraft 1972). Orientation of irrigation diversions relative to the river channel can also reduce loss of fish into ditches (Spindler 1955). Again, the senior author approached the irrigators of the upper Big Hole drainage and these irrigators agreed to begin implementing the incremental shut-down of ditches immediately, and were willing to discuss orientation and operation of diversion structures to minimize fish loss. The loss of grayling migrating down river during the fall to seek overwinter habitat into irrigation ditches does not appear to be a concern in the upper Big Hole drainage (from Jackson down to Squaw Creek). The irrigators in this portion of the drainage indicated that their irrigation diversions were shut off either in July prior to haying (and not turned back on again) or around Labor Day in September, prior to the initiation of down river movement by grayling.

Direct habitat enhancement would depend upon better defining habitat requirements of this population and determining if physical habitat was limiting populations. If this was the case, a habitat improvement program could be initiated. This option would rely on the collection of more information.

Direct enhancement of riverine grayling populations in the Big Hole River could be accomplished by supplementing the existing population with other riverine stock or with fry hatched from eggs taken from Big Hole grayling. There is a risk in the first option in that it could potentially introduce undesirable genetic material into the present population and alter the genetic makeup of the existing native population. The second option is the more preferable, however, one problem with this option is that the availability of eggs to supplement the population is presently limited due to the low numbers of mature females in the population and the difficulty in obtaining eggs during the extremely short spawning period. During the 1988 spawning season approximately 5,000 fertilized eggs were obtained from the Big Hole grayling population for fry behavior research conducted by Dr. C. Kaya (Montana State University, Bozeman). After Dr. Kaya had completed his experiments and these fry had suffered some mortality due to disease, approximately 3,000 fry remained. These fry were released into a lake which was previously barren of fish. This lake has an inlet which should provide suitable spawning habitat for these grayling. This release should provide additional fry for the Big Hole system. Our plan is to return to the lake when these fry mature (in two to three years) to obtain fertilized eggs by trapping the inlet stream. It is hoped that during the course of maturing these released fry do not lose too much of the genetic component that makes them riverine Big Hole River stock due to adaption to the lake environment. The objectives of this release were two-fold. One was to provide a source of fry to stock back into the Big Hole system so that we could enhance the Big Hole population while we were investigating how to enhance survival within the Big Hole system. The other objective was to preserve some genetic material from the Big Hole grayling population in an isolated location so that if the Big Hole population suffered a catastrophic decline to extinction we would have a source for re-introducing grayling back into the Big Hole. Since the 3,000 fry which were stocked into the lake in 1988 were the progeny of only six females, we plan to spawn some additional females during 1989 to increase the genetic variability within this lake population.

We do not plan to allow these fish more than two generations, and preferably only one, of lake residence prior to our returning for eggs to supplement the Big Hole population. The exception to that would be if the Big Hole grayling population went extinct due to a catastrophic event.

The issue of competition and predation will have to be addressed by conducting the research to determine if these two factors contribute to significant mortality within the Big Hole River grayling population. It would be premature at the present time to suggest acting on this possibility without further evidence.

The possibility of re-establishing riverine populations of grayling into waters in Montana which do not presently support them should be addressed. At the present time it appears that re-establishing grayling populations will be difficult, at best. The experience that U.S. Fish and Wildlife Service biologists had in Yellowstone National Park trying to re-establish a grayling population into Canyon Creek, a tributary to the Firehole River, suggests that riverine populations require relatively large drainage systems that are accessible. In the Canyon Creek experiment, a falls on lower Canyon Creek was enhanced to provide a total barrier to upstream migration so that exotic species of fish could not ascend Canyon Creek and compete or prey on the grayling population re-introduced into Canyon Creek. An attempt was made to remove all fish within Canyon Creek prior to the introduction of grayling which were obtained from the Big Hole River. However, it appears that these introduced grayling moved out of Canyon Creek, probably seeking winter habitat, and could not return. This suggests that it will not be possible to re-establish populations of riverine grayling into small isolated tributaries, but will require medium to large river drainages which can provide spawning, summer feeding, and overwintering habitats. The effort to accomplish this type of re-introduction would be immense and may mean that existing fish species could not be removed prior to grayling re-introduction. The potential for re-establishing riverine grayling in Montana where they do not presently exist will require more research and a strong commitment to that type of effort.

LITERATURE CITED

Alt, K T. 1976. Inventory and cataloging of sport fish waters of western Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1975-1976. Project F-9-8, 17(G-I-P): 156, Juneau, Alaska.

Armstrong, R. H. 1986. A review of Arctic grayling studies in Alaska, 1952-1982. Biological Papers of the University of Alaska, Number 23, Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska.

Bendock, T. N. 1979. Inventory and cataloging of arctic area waters. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979. Project F-9-11, 20(G-I-I), Juneau, Alaska.

Bishop, F. G. 1971. Observations on spawning habits and fecundity of the Arctic grayling. Progressive Fish-Culturist 33:12-19.

Brown, C. J. D. 1938. Observations on the life-history and breeding habits of the Montana grayling. Copiea 3:132-136.

Clothier, W. D. 1953. Fish loss and movement in irrigation diversions form the West Gallatin River, Montana. Journal of Wildlife Management 17:144-158.

Clothier, W. D. 1954. Effect of water reductions on fish movement in irrigation diversions. Journal of Wildlife Management 18:150-160.

Craig, P. C., and V. A. Poulin. 1975. Movements and growth of Arctic grayling (Thymallus arcticus) and juvenile Arctic char (Salvelinus alpinus) in a small arctic stream, Alaska. Journal of the Fisheries Research Board of Canada 32:689-698.

Curtis, M. 1977. The age, growth and management of the Arctic grayling (Thymallus arcticus) in Wyoming. M.S. Thesis, University of Wyoming, Laramie, Wyoming.

Daniel, W. W. 1978. Applied nonparametric statistics. Houghton Mifflin Company, Boston, Massachusetts.

deBruyn, M., and P. McCart. 1974. Life history of the grayling (Thymallus arcticus) in Beaufort Sea drainages in the Yukon Territory. Pages 92-130 in Arctic Gas Biological Report Series, Volume 20, Aquatic Environments Limited, Calgary, Alberta.

Eriksen, C. H. 1975. Physiological ecology and management of the rare "southern" grayling Thymallus arcticus tricolor Cope. Verh. Internat. Verein. Limnol. 19:2448-2455.

Everett, R. J., and F. W. Allendorf. 1985. Population genetics of Arctic grayling:Grebe Lake, Yellowstone National Park. Population Genetics Laboratory Report 85/1. University of Montana, Missoula, Montana.

Falk, M. R. and D. V. Gillman. 1974. Impact of a sport fishery on Arctic grayling in the Brabant Island area, Northwest Territories. Canada Department of the Environment, Fisheries and Marine Service, Fisheries Operations Directorate, Data Report Number CEN/T-74-7, Toronto, Canada.

Falk, M. R., M. M. Roberge, D. V. Gillman, and G. Low. 1982. The Arctic grayling, Thymallus arcticus, in Providence Creek, Northwest Territories, Canada, 1976-1979. Western Region, Department of Fisheries and Oceans, Canadian Manuscript Report, Fisheries and Aquatic Sciences Number 1665, Winnipeg, Manitoba, Canada.

Grabacki, S. T. 1981. Effects of exploitation on the population dynamics of Arctic grayling in the Chena River, Alaska. M.S. Thesis, University of Alaska, Fairbanks, Alaska.

Henshall, J. A. 1906. A list of the fishes of Montana. Bulletin of the University of Montana, Missoula, Montana.

Henshall, J. A. 1907. Culture of the Montana grayling. U.S. Bureau of Fisheries, Document 628, Washington, D.C.

Holton, G. D. 1971. The lady of the stream. Montana Outdoors 2(5):18-23.

Hubert, W. A., R. S. Helzner, L. A. Lee, and P. C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves:Arctic grayling riverine populations. U.S. Fish and Wildlife Service, Biological Report 82(10.110), Fort Collins, Colorado.

Johnson, J. E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, Maryland.

Kraft, M. E. 1972. Effects of controlled flow reduction on a trout stream. Journal of the Fisheries Research Board of Canada 29:1405-1411.

Kratt, L. F., and R. J. F. Smith. 1977. A post-hatching sub-gravel stage in the life history of the Arctic grayling, Thymallus arcticus. Transactions of the American Fisheries Society 106:241-243.

Krueger, S. W. 1981. Freshwater habitat relationships, Arctic grayling, Thymallus arcticus. Unpublished Report, Alaska Department of Fish and Game, Habitat Division, Juneau, Alaska.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. Fishery Bulletin 149, Volume 59, U.S. Fish and Wildlife Service, Washington, D.C.

Liknes, G. A. 1981. The fluvial Arctic grayling (Thymallus arcticus) of the upper Big Hole River Drainage, Montana. M.S. Thesis, Montana State University, Bozeman, Montana.

Liknes, G. A., and W. R. Gould. 1987. The distribution, habitat and population characteristics of fluvial Arctic grayling (Thymallus arcticus) in Montana. Northwest Science 61:122-129.

Lund, J. A. 1974. The reproduction of salmonids in the inlets of Elk Lake, Montana. M.S. Thesis, Montana State University, Bozeman, Montana.

McNeil, W. J., and W. H. Ahnell. 1964. Success of pink salmon spawning relative to the size of spawning bed materials. U.S. Fish and Wildlife Service Special Scientific Report - Fisheries 469.

Nelson, P. H. 1954. Life history and management of the American grayling (Thymallus arcticus tricolor) in Montana. Journal of Wildlife Management 18:324-342.

Netsch, N. F. 1975. Fishery resources of waters along the route of the trans-Alaska pipeline between Yukon River adn Atigun Pass in north central Alaska. U.S. Fish and Wildlife Service Resource Publication 124:1-45.

Oswald, R. A. 1984. Inventory and survey of the waters of the Big Hole and Ruby River drainages. Job Progress Report, Federal Aid in Fish and Wildlife Restoration Acts, Project Number F-9-R-31 and 32, Job Number 1-b, Bozeman, Montana.

Oswald, R. A. 1986. Inventory and survey of the waters of the Big Hole, Beaverhead and Ruby River drainages. Job Progress Report, Federal Aid in Fish and Wildlife Restoration Acts, Project Number F-9-R-34, Job Number 1-b, Bozeman, Montana.

Peterman, L. G. 1972. The biolcgy and population characteristics of the Arctic grayling in Lake Agnes, Montana. M.S. Thesis, Montana State University, Bozeman, Montana.

Rawson, D. S. 1950. The grayling (Tymallus signifer) in northern Saskatchewan. Canadian Fish Culturist 6:3-10.

Reed, R. J. 1964. Life history and migration patterns of Arctic grayling, Thymallus arcticus (Pallas), in the Tanana River drainage of Alaska. Alaska Department of Fish and Game Research Report Number 2, Juneau, Alaska.

Schallock, E. W. 1966. Investigations of the Tanana River and Tangle Lakes Fisheries:Migratory and population study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1965-1966. Project F-5-R-7, 7(16-B):231-247, Juneau, Alaska.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Bulletin 1984. Ottawa, Canada.

Shepard, B. B. 1986. Beaverhead National Forest and Montana Department of Fish, Wildlife and Parks Cooperative Fishery Program. First Annual Report covering the period August 15 to December 31, 1985. Beaverhead National Forest, Dillon, Montana.

Shepard, B. B. 1987. Beaverhead National Forest fisheries: Second annual report covering the period January to December 1986. Cooperative study between the Beaverhead National Forest and the Montana Department of Fish, Wildlife and Parks, Beaverhead National Forest, Dillon, Montana.

Shepard, B. B., S. A. Leathe, T. M. Weaver, and M. D. Enk. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake and impacts of fine sediment on bull trout recruitment. Pages 146-156 in F. Richardson and R. H. Hamre, editors. Proceedings of the Wild Trout III Symposium held September, 1984 in Yellowstone National Park, Wyoming.

Spindler, J. C. 1955. Loss of game fish in relations to physical characteristics of irrigation canal intakes. Journal of Wildlife Management 19:375-382.

STSC Inc. 1986. Statgraphics: Statistical graphics system. Statistical Graphics Corporation, Rockville, Maryland.

Stuart K. M, and G. R. Chislett. 1979. Aspects of the life history of Arctic grayling in the Sukunka drainage. Final Report, British Columbia Fish and Wildlife Branch, Prince George, British Columbia.

Tack, S. L. 1971. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971. Project F-9-3, 12(R-I), Juneau, Alaska.

Tack, S. L. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973. Project F-9-5, 14(R-I), Juneau, Alaska.

Tack, S. L. 1974. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1973-1974. Project F-9-6, 15(R-I), Juneau, Alaska.

Tack, S. L. 1980. Migrations and distribution of Arctic grayling, Thymallus arcticus (Pallas), in interior and arctic Alaska. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(R-I), Juneau, Alaska.

Tripp, D. B., and P. J. McCart. 1974. Life histories of grayling (Thymallus arcticus) and longnose suckers (Catostomus catostomus) in the Donnelly River System, Northwest Territories. Pages 1-91 in Arctic Gas Biological Report Series, Volume 20, Aquatic Environments Limited, Calgary, Alberta.

Tryon, C. A. Jr. 1947. The Montana grayling. Progressive Fish-Culturist 9:136-142.

Vincent, R. E. 1962. Biogeographical and ecological factors contributing to the decline of Arctic grayling, Thymallus arcticus (Pallas), in Michigan and Montana. Ph.D. Dissertation, University of Michigan, Ann Arbor, Michigan.

Ward, J. C. 1951. The biology of the Arctic grayling in the southern Athabasca drainage. M.A. Thesis, University of Alberta, Edmonton, Alberta, Canada.

Warner, G. W. 1955. Spawning habits of grayling in interior Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-5, Work Plan E, Job Number 1, 5(2), Juneau, Alaska.

Warner, G. W. 1957. Movements and migrations of grayling in interior Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-6, Work Plan C, Job Number 3, 6(4), Juneau, Alaska.

Wells, J. D. 1976. The fishery of Hyalite Reservoir during 1974 and 1975. M.S. Thesis, Montana State University, Bozeman, Montana.

Williams, F. T. 1968. Grayling investigations on Tolsona and Moose Lakes. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968. Project F-5-R-9, 9(14-B):257-264, Juneau, Alaska.

Wojcik, F. J. 1954. Spawning habits of grayling in interior Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-3, Work Plan 1, 3(3), Juneau, Alaska.

Wojcik, F. J. 1955. Life history and management of the grayling in interior Alaska. M.S. Thesis, University of Alaska, Fairbanks, Alaska.

Yoshihara, H. 1972. Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972. Project F-9-4, 13(G-111-A), Juneau, Alaska.