Status Report on Fluvial Arctic Grayling (*Thymallus arcticus*) in Montana

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Table of Contents

List of Tables

List of Figures

Introduction

The status of fluvial (permanently stream-dwelling) Arctic grayling, *Thymallus arcticus*, in Montana has been of increasing concern in recent years. While Arctic grayling (hereafter referred to as grayling) are widely distributed in the state as lacustrine populations (which live in lakes and spawn in streams), the only confirmed self-sustaining fluvial population still remaining exists in the Big Hole River in southwestern Montana. This single remnant population appears in decline; total numbers of individuals are unknown and estimated densities in the most highly populated reaches have continued to decrease over the past decade (Shepard and Oswald 1989). Because of the uncertain future of fluvial grayling in Montana, it has been designated a fish of "special concern" by the Endangered Species Committee of the American Fisheries Society, the Montana Chapter of the American Fisheries Society, the Montana Department of Fish, Wildlife and Parks (MDFWP), and the Montana Natural Heritage Society, and as a Category 2 (C2) species by the U.S. Fish and Wildlife Service (Deacon et al. 1979; Holton 1980; Johnson 1987; Williams et al. 1989; Clark et al. 1989).

Arctic grayling in Montana (hereafter referred to as Montana grayling) were mostly fluvial in distribution during the period of early European-American exploration and settlement of the region, starting with the Lewis and Clark Expedition in 1805. The only known indigenous lacustrine population was in Upper and Lower Red Rock lakes, and possibly nearby Elk Lake, of the Red Rock-Beaverhead River drainage. The situation has been reversed within this century. Populations have been established in many lakes in Montana and other states through introductions while fluvial Montana grayling have drastically declined to the present remnant population of the Big Hole River. Reasons for the decline of the fluvial populations are not well understood, but are thought to include a combination of competition from non-native salmonids, anthropogenic habitat alteration, and overfishing.

The purpose of this status report is to review the natural history and present distribution of fluvial Montana grayling, and factors that have affected the present distribution. The information compiled for this report is based on published articles, unpublished reports, personal communications with individuals, and the computer databases of the Montana Department of Fish, Wildlife and Parks. Several earlier reviews will be extensively cited. Earlier information on biogeography and natural history of grayling in Montana and Michigan were comprehensively reviewed and evaluated by Vincent (1962). Studies of Arctic grayling in North America were summarized by Hubert et al. (1985) and of the species in Alaska by Armstrong (1986). Recent field data on Big Hole River grayling and summaries of various aspects of their life histories were presented by Shepard and Oswald (1989).

IDENTITY OF FLUVIAL GRAYLING IN MONTANA

Taxonomy and Biogeography of Arctic Grayling

Arctic grayling are classified in the Subfamily Thymallinae, of the Family Salmonidae (salmon, trout, whitefish and grayling), Order Salmoniformes. The Subfamily Thymallinae contains only the genus Thymallus. After comparing the osteology of grayling and other Salmonidae, Norden (1961) concluded that:

> The grayling possesses only two invariable morphological differences from other salmonids. These are the absence of an orbitosphenoid bone and the presence of seventeen or more dorsal fin rays. In other characters, there is overlap with one or the other subfamilies.

Four species of Thymallus are generally recognized, two with very limited distributions in Asia and two widely distributed, one across Europe and the other across northern Asia and North America (Norden 1961; McAllister and Harington 1969). Thymallus nigrescens Dorogostaisky is known only from Lake Kosogol in Mongolia and T. brevirostris Kessler has a distribution limited to northwest Mongolia. The European grayling, T. thymallus Linnaeus, is distributed across northern and central Europe and the British Isles. The Arctic grayling, T. arcticus Pallas, is distributed from the Ural Mountains in central U.S.S.R., across Siberia, on Saint Lawrence Island in the Bering Strait, and across Alaska and Canada to Hudson Bay. Two geographically isolated populations of T. arcticus formerly existed south of Alaska and Canada, one in Michigan and the other in the upper Missouri River drainage in Montana. Grayling disappeared from Michigan about 1936 (McAllister and Harington 1969).

The Arctic grayling has been variously classified into several separate species, into several subspecies, and more recently, as a single species without subspecies. Arctic grayling from the Ob River in Siberia were first described and named Thymallus arcticus by Pallas in 1776. European-American discovery of Arctic grayling in North America is attributed to members of the Lewis and Clark Expedition, who caught fish that Meriwether Lewis described as a new, "whte speceis of trout" in the Beaverhead River of the upper Missouri drainage in 1805 (Moulton 1986). J. W. Milner provided the first formal scientific description of Montana grayling in 1872, from specimens caught in a tributary of the Missouri River near Camp Baker, and designated them T. montanus. This had been preceded by descriptions of Arctic grayling in Canada as T. signifer Richardson (1823), and in Michigan as T. tricolor Cope (1865). Thus, North

American grayling were formerly considered three separate species, *T. signifer* Richardson in Alaska and Canada, *T. tricolor* Cope in Michigan, and *T. montanus* Milner in Montana (Hensall 1907; Jordan and Evermann 1934). The monospecific designation of all Arctic grayling has been widely accepted since Walters (1955) described *T. signifer* as conspecific with *T. arcticus*. Present subspecific designations, including that of Montana grayling as *T. a. montanus* Milner (e.g., Williams et al. 1989), are of uncertain validity (Norden 1961; Scott and Crossman 1973) and not widely accepted.

The lack of presently accepted subspecific designations is based on morphological similarity among the disjunct populations which has persisted despite their long period of physical separation. Montana and Michigan populations of grayling were separated from more northern populations by the most recent continental glaciation, the Wisconsinan, which began about 80,000 years ago, reached a maximum about 18,000 years ago, and terminated about 10,000 years ago (Lindsey and McPhail 1986). Grayling in Mississippian drainages south of the ice sheet were separated from those in ice-free areas of "Berengia" (parts of Alaska, Canada, the Bering Land Bridge, and northeastern Siberia). Although grayling from Michigan and Montana have higher lateral line scale counts than those in northern Alaska and Canada, the higher counts are also found in populations in central and southern Alaska and Canada (McCart and Pepper 1971). No morphological characteristic has yet proven reliable in separating Montana or Michigan grayling from other Arctic grayling (Hubbs and Lagler 1958).

More recent comparisons using biochemical genetic techniques have demonstrated divergence of Montana grayling from Alaskan and Canadian grayling. Lynch and Vyse (1979) electrophoretically compared 36 protein loci and found that two loci have "undergone complete allelic substitution and can be used to separate Montana and arctic grayling." Everett and Allendorf (1985) examined 40 protein loci and concluded that (1) Montana grayling differ in genetic variation (percent of loci polymorphic and percent average heterozygosity per individual) from Alaskan or Canadian grayling, and (2) there is no evidence of genetic mixing of northern grayling into Montana populations despite at least one attempt to introduce Alaskan grayling into Montana.

Identity and Adaptation of Fluvial Grayling of the Big Hole River

Whether Montana grayling deserve some level of taxonomic distinction, they at least represent spawning populations or stocks discrete from other Arctic grayling. They are both geographically isolated and genetically identifiable from those further north in Canada and Alaska. Further, the Big Hole River population represents a separate stock from lacustrine populations of Montana grayling, in accordance with the concept of stocks as geographically or temporally separated spawning groups (Ricker 1972).

Biochemical genetic studies indicate that Big Hole River grayling are a stock genetically diverged from all other populations analyzed to date, and behavioral studies conducted in the field and in the laboratory indicate that they are adapted to inhabiting a stream environment. After electrophoretic comparisons of grayling from the Big Hole River and seven other populations from Wyoming, Montana, Alaska, and Canada, Everett and Allendorf (1985) concluded that:

> Currently the allele frequencies at variable loci in the Big Hole River population are significantly different from those of the other Montana and Wyoming grayling populations sampled. This population also has a variant allele at Ck-1 in low frequency that has not been seen in other populations.

Through further biochemical genetic comparisons, R. Leary (University of Montana, pers. comm.) more recently concluded that Montana grayling can be separated into two genetic groups, a Big Hole-Madison group and a second group consisting of fish from Red Rock Lake and from lacustrine populations established through stockings.

Two recent studies have provided evidence for adaptation of Big Hole River grayling to a stream environment. Shepard and Oswald (1989) reported extensive annual migrations of adults in the river. After comparing time and locations where grayling were tagged and recaptured, they concluded that at least some adults spend the winter in deep pools as far downstream as the Divide Dam, and move upstream in spring to spawn in the section of the river from the mouth of the North Fork to immediately above Wisdom (Figure 1). During years of average or greater stream flow adult grayling remain upstream through the summer and move back downstream in the fall. During years of low flow many move back downstream shortly after spawning. The longest movement recorded was about 82 km (51 miles) downstream. Some adults may overwinter in upstream reaches near Wisdom, in deep pools or areas of groundwater recharge or in tributaries.

Similar patterns of upstream migrations in spring and downstream in fall have been described for Alaskan fluvial grayling populations and appear adaptations for utilizing conditions in different parts of river systems and tributaries for spawning, feeding, and overwintering (Craig and Poulin 1975; Tack 1980, cited by Armstrong 1986; Hubert et al. 1985). Smaller, upstream segments or tributaries may provide more favorable conditions for spawning and for survival and growth of young, and large, deep, downstream pools may provide the best conditions for overwintering.

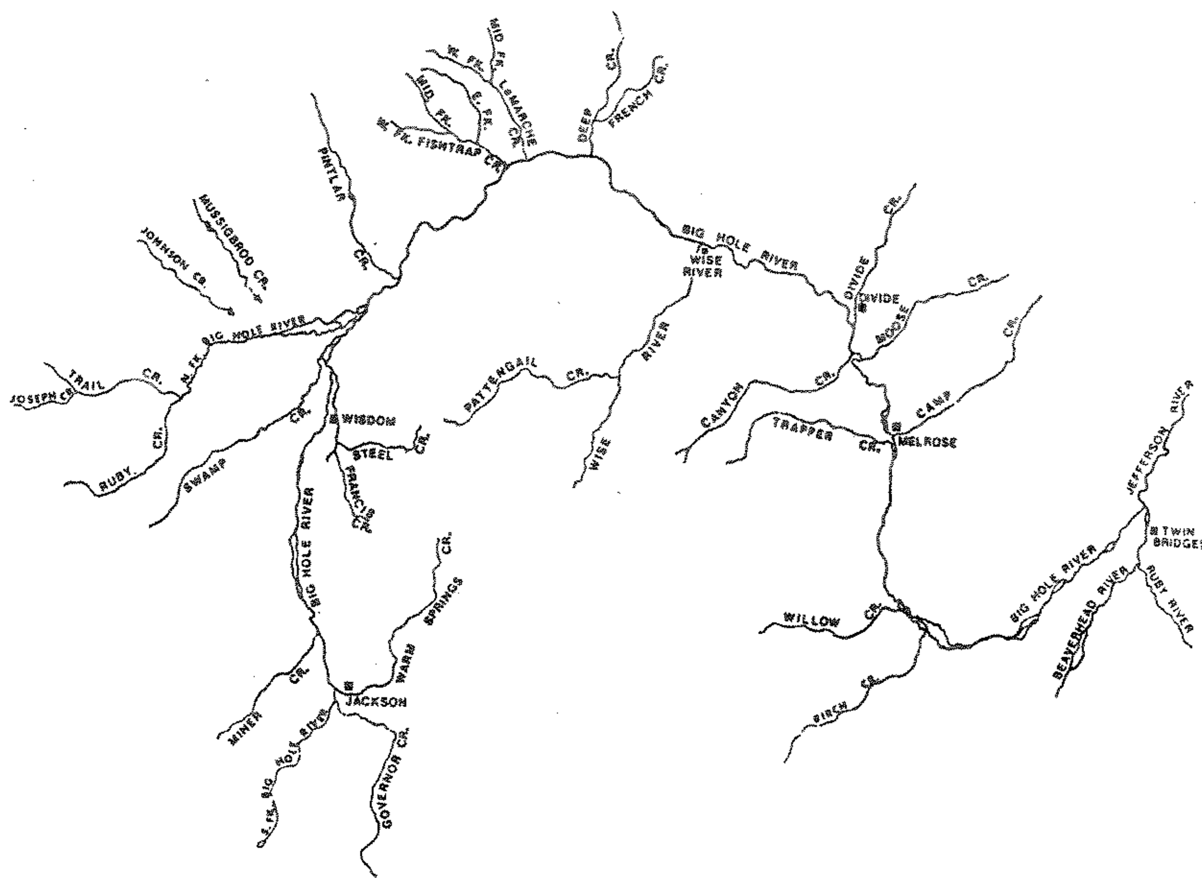


Figure 1. Map of the Big Hole River and tributaries.

A recent study (Kaya 1991) demonstrated that young Big Hole River grayling have genetically controlled behavioral responses to water current that are advantageous for living permanently in a stream. When tested in an artificial stream, young Big Hole River grayling had significantly greater tendency to hold position in water current and lesser tendency to swim downstream than did those from inlet-spawning populations of Red Rock Lake and Lake Agnes. These differences became increasingly greater with age from the first day the fish started swimming to about 9-10 weeks later, even though fish from the different populations had been incubated and reared under identical conditions. The genetic basis for such behavior also was indicated by a previous study (Kaya 1989). Young grayling from inlet- and outlet-spawning populations (Lake Agnes and Deer Lake) had significantly different tendencies to swim upstream and hybrids between the two populations had intermediate responses. The responses of the young Big Hole River grayling would tend to keep them within a stream, while that of the inlet- and outlet-spawning populations would take the young to the rearing lakes.

The importance of preserving this last indigenous population of fluvial Montana grayling is emphasized by these findings that they differ from all other populations analyzed, both genetically and in being adapted for riverine existence. Others have repeatedly stated the importance of managing and preserving individual stocks of salmonids in order to retain the ability of the species to occupy the varying habitats within its original distribution (Larkin 1972, 1979; Behnke 1972; Loftus 1976). The ability of Montana grayling to continue inhabiting streams may well depend on preserving the remnant fluvial population of the Big Hole River.

LIFE HISTORY

Life Cycles and Migrations

Montana grayling display all the categories of spawning-migratory life cycles listed by Varley and Gresswell (1988) for inland trout populations. Lacustrine populations live in lakes and most are adfluvial, migrating to spawn in inlet streams. A few are allacustrine, spawning in outlet streams. Fluvial grayling of the Big Hole River drainage either live, migrate and spawn entirely within the main stem (Shepard and Oswald 1989), or migrate into tributaries to spawn (Liknes 1981; Liknes and Gould 1987; Shepard and Oswald 1989).

Extensive migrations of fluvial grayling have been known to occur in Alaskan populations for some time, and have recently been confirmed to occur in the Big Hole River as well. The general pattern in Alaska (reviewed by Armstrong 1985) involves migrations upstream to spawning areas and tributaries, which may also serve as nursery waters for young fry, and migrations downstream to overwintering areas. They also migrate to summer feeding areas which may be different from either spawning or overwintering areas. The overwintering areas have extensive groundwater input to prevent complete freezing of the stream, or are the deeper waters of the main stem of larger streams. These migrations occur both within main rivers and between main rivers and tributaries, over distances ranging from a few km to between 130 and 160 km. Similar patterns of movement between wintering and spawning areas have been observed for Big Hole River grayling (Shepard and Oswald 1989).

The life history-migratory cycle of grayling in the tributaries of the Big Hole River has not been verified. Grayling appear confined mostly to the lower reaches of tributaries (Liknes 1981; Shepard 1987) and may thus be members of the main stem population. Grayling further upstream in Mussigbrod Creek and in the Wise River and two of its tributaries, O'Dell and Wyman creeks, may represent fish that have drifted downstream out of lakes. If fluvial grayling do exist which spend their entire life histories in smaller streams, they could be important to future efforts to restore fluvial grayling to streams outside the Big Hole River drainage. Candidate streams for such restorations would likely be smaller and not provide opportunities for extensive migrations.

It is not known whether fluvial grayling elsewhere in Montana also migrated over long distances. Indirect evidence for such movements come from "old-timer" accounts of grayling congregating below dams in the years shortly following their completion (Vincent 1962): a dam on the Smith River in 1899, Ennis Dam built on the Madison in 1900, and Lima Dam built on Red Rock River in 1902. Henshall (1907) believed that grayling spawning in Elk Creek above Upper Red Rock Lake had migrated through the Jefferson, Beaverhead, and Red Rock rivers and through Lower and Upper Red Rock lakes. However, Brown (1938) believed that those grayling originated locally, and spawning migrations into tributaries of Upper and Lower Red Rock lakes continue to the present, long after the construction of Lima Dam. The life history-migratory patterns of grayling that once existed in other drainages in Montana may never be known. It is possible that grayling that once lived in smaller streams like Bozeman and Bridger creeks in the Gallatin Valley may have been permanent residents with only localized movements. According to Vincent (1962) most fluvial grayling populations in Michigan were apparently non-migratory.

Movements of young grayling in the Big Hole River have only recently been studied. Liknes (1981) observed that some age-0 (young-of-year) grayling seemed to move downstream from tributaries into the Big Hole River soon after swimup (newly swimming, after emergence from incubation in or on the substrate), while others remained in the tributaries two months later. Young of lacustrine populations in Montana and Wyoming move into lakes at ages which differ among populations and even within a population, from day of swimup (Kruse 1959; Lund 1974; Wells 1976; Beauchamp 1981) to two to three weeks later (Nelson 1954), and up to possibly a year of age (author, pers. observ.; Deleray 1990). Some young Bighole River grayling move downstream from spawning areas, and some are thus lost through irrigation ditches (Shepard and Oswald 1989). Other age-0 grayling remain in the proximity of the spawning areas through summer, occupying riffle-pool complexes associated with areas in which ripe adults had been collected earlier (Skaar 1989; McMichael 1990). In the Big Hole River, age-0 young disappear from the Wisdom area during fall electrofishing surveys, suggesting that they may migrate downstream to overwintering areas at a similar time as those adults that do migrate (Shepard and Oswald 1989).

Reproduction

Grayling spawn over a period of nearly three months from late April to early July in both Montana and Alaska. Grayling populations in Alaska spawn from late April to early July, with a peak from mid-May to mid-June (Armstrong 1986). The earliest known spawning in Montana occurs in late April-early May in the Big Hole River (Liknes 1981; Liknes and Gould 1987). Lacustrine populations in Montana have been reported spawning from about mid-May to mid-July (Brown 1938; Peterman 1972; Lund 1974; Wells 1976). Time of spawning of a given population can vary by as much as 4-6 weeks in different years, depending on water temperature and, for lacustrine populations, the date when the lake becomes ice-free. For example, Deer

Lake grayling spawned in late May in 1987, mid- to late-June in 1988 and 1989, and early July in 1990 (author, pers. observ.). Spawning of grayling in Alaska may be triggered by water temperature of 4 ^{o}C and is also often associated with high flows and water turbidity of spring flooding (reviewed by Armstrong 1986). In Montana, spawning of Big Hole River grayling in 1988 occurred at mean daily water temperatures of 8.3 ^{o}C, during a period of reduced flows between an earlier increase in flow and the peak seasonal flow (Shepard and Oswald 1989). Spawning of lacustrine populations in Montana has been reported to occur at temperatures of about 4.4 to 10 ^{o}C (Brown 1938; Tyron 1947; Peterman 1972; Lund 1974; Wells 1976). The author observed intense spawning activity at 15.2 ^{o}C in the Deer Lake outlet on July 10, 1990, a year when spawning was delayed by cool late spring-early summer weather and late ice-out on Deer Lake. Spawning of these lacustrine populations often occurs during high flows of late spring-early summer, but movement into spawning tributaries appears stimulated by water temperature rather than increased stream flow (Peterson 1972; Wells 1976).

Spawning occurs predominantly in shallow water at moderate velocities, over gravel substrate. Information reviewed by Hubert et al. (1985) and Armstrong (1986) indicate spawning depths of 0.15 to 0.9 m (0.5 to 3 ft) and mean column velocities (measured at depth equal to 0.6 X the water depth at that location) of 30 to 120 cm/s (0.9 to 3.8 ft/sec). Grayling from Grebe Lake spawn at depths ranging from 1.5 m (5 ft) to water so shallow that dorsal fins of males extend out of the water (Kruse 1959). Spawning in extremely shallow water has also been observed of grayling from Rogers Lake (Tyron 1947) and Deer Lake. Many in the Deer Lake outlet spawn in water only about 8 cm (3 inches) in depth (author, pers. observ.). OEA and Fernet (1987) measured parameters of spawning sites used by grayling from Hyalite Reservoir and characterized the depths and velocities associated with marginal, good, or excellent sites, as indicated by intensity of use, in Hyalite Creek (Table 1).

Table 1. Use and categorization of spawning habitat used by grayling spawning in Hyalite Creek (OEA and Fernet 1987).

Habitat Class	Mean Depth (m)	Mean Column Vel. (m/s)	Nose Vel. (m/s)
Excellent	0.49	0.63	0.46
Good	0.37	1.09	0.55
Marginal	0.21	0.94	0.63

Arctic graying have also been reported to spawn within lakes in Alaska (Armstrong 1986) and Montana (Peterman 1972), but it has not been determined whether such spawning results in successful reproduction.

Grayling have most frequently been reported to spawn on fine gravel with diameters ranging from 0.5 to 3.8 cm (Hubert et al. 1985). Additionally, grayling have been reported to use a much greater variety of substrates than other fluvial salmonids for spawning, ranging from fine silt to large rubble and even vegetation (Scott and Crossman 1973; Armstrong 1986). They may be able to use a wide range of substrates because they do not excavate a redd, and therefore may not need a highly porous substrate to facilitate water flow to deeply buried eggs. However, reports of spawning over vegetation or fine silt should be regarded with caution unless verified by sighting of the actual spawning act. The author has seen large numbers of grayling eggs in the outlet of Deer Lake that have been displaced downstream from the actual spawning sites and have settled in various locations including among macrophyte vegetation and on fine silt.

Montana grayling have been observed to spawn on substrates ranging in size from sand to rubble (pebbles and cobbles). Lacustrine grayling in Red Rocks Creek most intensely used substrate composed of 33% rubble, 31% coarse gravel, 29% fine gravel, and 7% sand (Nelson 1954). Grayling from Hyalite Reservoir spawned most frequently on substrates consisting of less than 10% fine particles (less than 3mm) and 80% or more of particles 10 mm or greater in diameter (OEA and Fernet 1987 and unpublished material). Grayling in the main inlet to Lake Agnes do not have access to larger particles and spawn on coarse sand (Brown 1938; Peterman 1972), with 57% of the particles being from 2-10 mm in diameter and the rest of smaller size (Peterman 1972). Grayling from Deer Lake also do not have access to gravel and spawn over pebbles and cobbles that appear to mostly exceed 5 cm (2 inches) in diameter (author, pers. observ.). In the Big Hole River, ripe adults were found associated with gravel which had a bright appearance due to lack of periphyton growth, in areas of hydrologic instability such as recently formed side channels, areas below beaver dams or irrigation diversion structures, or near mouths of tributaries where alluvial fans had formed (Shepard and Oswald 1989). Substrate composition was 30% large gravel, 50% fine gravel, and 20% sand and finer particles. The sites on the Big Hole River associated with ripe adults had very little sand and silt in the upper 2.5-5.9 cm, while a site in the North Fork Big Hole River not used for spawning had an abundance of sand and silt near the surface. It appears that grayling will select clean gravel substrates when available, but will otherwise resort to the use of other substrates. The advantages of a clean gravel substrate seem apparent; this would increase the likelihood that eggs would be deposited in interstitial spaces, providing water flow around the eggs and protection from predation.

The spawning act of Arctic grayling has been described repeatedly and appears similar among populations in Montana (e.g., Brown 1938; Tyron 1947; Kruse 1959) and Alaska (reviewed by Armstrong 1986), and also similar to that of European grayling (Fabricus and Gustafson 1955). Males occupy and defend spawning territories against other males, and make lateral displays to passing or approaching females. The large, brightly-colored dorsal fins of the males are used in both agonistic displays against other males and in courting displays to females. The pair spawns over the substrate without excavating a redd. However, shallow burial of some eggs (down to about 4 cm) can result through positioning of the female's genital pore near interstitial spaces, and from the stirring up of substrate by the vigorous vibrations of bodies and caudal fins which occur during spawning (Brown 1938; Fabricus and Gustafson 1955; Kratt and Smith 1977).

The eggs are adhesive upon first being released and stick to the substrate, thus helping to prevent their downstream displacement (Brown 1938; Kruse 1959). The eggs become non-adhesive within about an hour as water hardening proceeds (Bishop 1971; author, pers. observ.). Unless buried or lodged in interstitial spaces in the substrate, the eggs can be readily displaced downstream. The author has observed displaced eggs in the Deer Lake outlet stream, and Nelson (1954) found grayling eggs in pools and at the downstream ends of riffles in Red Rocks Creek, apparently displaced from riffle spawning sites.

Eggs of Arctic grayling have been reported to range in diameter from 2.7 to 4.3 mm (Scott and Crossman 1973), although the smaller of these sizes may represent eggs that have not completed water hardening. Watling and Brown (1955) found that newly spawned eggs of grayling from Georgetown Lake, Montana were 2.4 mm in diameter and increased to about 3.8 mm after completion of water hardening, which took from 8 hours for unfertilized and 24 hours for fertilized eggs. The author (unpublished observations) has found the following mean diameters of water hardened eggs from different sources: Big Hole River 3.4 mm; Lake Agnes 3.6 mm; Deer Lake 3.9 mm; Red Rocks Lake 4.2 mm; and Hyalite Reservoir 4.2 mm. This progression of egg sizes also reflects increasingly larger females among these populations, but it is not known whether egg sizes are increasing with size of females or their nutritional status.

Individual fecundity varies greatly among females of different sizes (and probably nutritional status) and in Montana has been reported to range from about 400 eggs from a 0.15 kg fish to about 13,000 from a 0.91 kg fish (Brown 1938). Peterman (1972) found that Lake Agnes females had an average individual fecundity of 1,750 eggs (range 799 from a 22 cm fish to 4,346 from a 30.5 cm fish), or 12.6 eggs per gram (356 per ounce) of female weight. Relative fecundities of other populations in Montana appear similar. Three large, 0.9 kg females from Georgetown Lake averaged about 12.4 eggs per gram (351 per ounce) of body weight (Brown 1938). Seven females from Deer Lake had 7 to 16 eggs per gram (Deleray 1990).

Time required for embryonic development to hatching and to swimup varies with water temperature. Kratt and Smith (1977) reported 176.75 day-degrees (number of days X ^{o}C above $0^{o}C$) to hatching at a mean water temperature of 7 ^{o}C and swimup three days later. Other reported times include: 23 days to hatching at 9.1 ^{o}C (Tyron 1947); two weeks to hatching at 10 ^{o}C and swimup in an additional week to 10 days (Henshall 1907); 16

days to hatching at 10-14.4 ^{o}C (Watling and Brown 1955); 13.7 days average time to hatching at 8.8 ^{o}C (Bishop 1971); and 14 to 19 days to hatching at 8 ^{o}C and approximately 10 additional days to swimup (Wojcik 1955; Kaya 1989). Newly hatched yolksac larvae range from 0.7 to 1.1 cm in length (Watling and Brown 1955).

Growth

Big Hole River young are about 1 cm at swimup (Kaya 1991) and by the end of July have reached average lengths of 4.7 cm in the hatchery and 5.5-7.8 cm in the river (Table 2). This is an age of about 60 days for the

Table 2. Mean lengths of age-0 grayling from the Big Hole River, until about 60 days post-swimup (end of July), for hatchery fish and wild fish. Ages after swimup are for young incubated and reared in a hatchery. Ages for wild fish assume that they became free swimming on about May 30, similar to those in the hatchery. However, the wild fish may have been slightly older because of developing to swimup at a faster rate under warmer temperatures.

Rearing	Approximate Days after Swimup				Rearing	
Location	(0)	(20)	(40)	(60)	Temp.*	Reference
hatchery	1.0	1.8	3.0	4.7	10-12	Kaya 1990
wild		2.4	5.5	5.3	15-18	Liknes 1981
wild			6.2	7.6	15-18	Skaar 1989
wild			6.4	7.8		McMichael 1990

* For wild fish, average monthly temperatures for June and July in section near Wisdom (Liknes 1981; U.S. Geological Survey 1989).

hatchery fish, but probably slightly older for the wild fish. The difference in growth rates also is at least partially attributable to incubating and rearing temperatures, which were maintained at 8-12 °C in the hatchery while mean daily temperatures in the river for the years involved ranged from about 9.5 to 22 °C from early May to the end of July (Liknes 1981; Skaar 1989). Brown (1938) reported slower growth rates for young hatchery-reared grayling than these recent values for Big Hole River young. By the end of August, age-0 grayling in the Big Hole River have reached average lengths of 10.4-10.8 cm (Skaar 1989; McMichael 1990).

Examples of estimated lengths-at-annuli of grayling in Montana and Wyoming are given in Table 3. Big Hole River grayling grow at rates similar to or faster than grayling in these lacustrine populations, with the exception of those from Upper Red Rock Lake and Hyalite Reservoir, both known for their large grayling. Growth rates of Big Hole River grayling are also toward the upper end of the range reported for grayling in Alaska (Armstrong 1986). There are undoubtedly unstudied populations in certain high-elevation lakes in Montana with growth rates slower than those presented in Table 3.

Grayling in Montana do not appear long-lived and the oldest found by Brown (1943) was a fish from Grebe Lake (Wyoming) with 6 annuli. The oldest grayling reported in the Big Hole River was 5 years old (Liknes 1981). Nelson (1954) reported one fish from Lower Twin Lake (Madison drainage) with 10 annuli. Oldest fish found in other Montana lakes include 6 years in Lake Agnes (Peterman 1972) and 7 years in Elk Lake (Lund 1974). Grayling in Alaskan waters appear to commonly exceed 10 years of age (Armstrong 1986). Reported ages of oldest grayling in Montana may have been underestimated, since all studies of grayling age conducted in the state thus far have been based on interpretations of annuli on scales. Studies in Alaska and Canada have demonstrated that ages of older grayling tend to be underestimated when based on scales, in comparison to estimates based on otoliths (Craig and Poulan 1975; Sikstrom 1983).

Table 3. Estimated lengths (cm) at annuli of grayling from the Big Hole River and from lakes and reservoirs in Montana.

Population	I	II	III	IV	V	Reference
Big Hole River	19.8	26.1	29.2	31.6	38.1	Liknes 1981
Big Hole River	14.5	24.9	29.7	32.2	34.0	Shepard and Oswald 1989
Rogers Lake	13.7	24.7	28.5	30.4		Brown 1943
Lake Agnes	10.3	20.6	24.7	26.5		Peterman 1972
Grebe Lake	11.1	22.6	28.4			Kruse 1959
Red Rock Lake	15.1	28.2	34.3	37.3	39.6	Nelson 1954
Hyalite Reserv.			36.0	39.7	41.7	Wells 1976

Age at maturity appears related to growth rate. Grayling in North America tend to become mature at older age under conditions associated with slower growth; overpopulation and higher latitudes (Hubert et al. 1985). In Alaska, grayling most commonly mature at ages of 4 to 6 in interior waters but at age 6 to 9 in North Slope waters (Armstrong 1986). Grayling in Montana and Wyoming most frequently become sexually mature at age 3 but some mature at age 2 (Brown 1938). Among spawners in tributaries of Upper Red Rock Lake, 4% were age 2, 92% were age 3, and 2% older (Nelson 1954). Among spawners from Lake Agnes, 6-9% were age 2, 31-38% age 3, and the remainder were older (Peterman 1972). All spawners from Hyalite Reservoir (Wells 1976) and Grebe lake (Kruse 1959) were age 3 or older. A high proportion of grayling in the Big Hole River become sexually mature at age 2. Shepard and Oswald (1989) found that 66% of age-2 fish were mature, at mean length of 24.8 cm (9.8 inches). After becoming sexually mature, grayling appear to spawn annually (Craig and Poulin 1975; Lund 1974; Deleray 1990).

HABITAT REQUIREMENTS

Stream Gradient, Velocity and Depth

According to Vincent (1962) fluvial Arctic grayling in Michigan and Montana inhabited streams with intermediate gradients of 9 to 38 m/km and velocities of 30.5 to 61 cm/s, rather than swift, high-gradient waters. In 1979 the greatest number of grayling found in the Big Hole River were in a section near Wisdom with a gradient of 29 m/km and mean velocity of 21 cm/s (Liknes 1981; Liknes and Gould 1987). Adult grayling in Alaska were reported to spend most of their time in similar current of 26 cm/s (Kreuger 1981, cited by Hubert et al. 1985). For adult grayling, mean column velocities higher than 240 cm/sec will prevent spawners from swimming upstream through culverts to spawn (Behlke et al. 1988, cited by Reynolds 1989).

Average depth of stream sections may not be a very meaningful habitat parameter, since grayling spend most of the time in pools rather than riffles (Hubert et al. 1986; Reynolds 1989). Among three sections of the Big Hole River, the one in which grayling were most common during summer had the highest pool:riffle ratio, and the lowest pool-riffle periodicity, the mean distance between pools and between riffles, measured in mean stream widths (Liknes 1981; Liknes and Gould 1986). Pools in the Big Hole River were defined by Liknes as areas with maximum depths ≥0.5 m, reduced water velocities, and smooth surfaces. Especially important as winter habitat for grayling in Alaskan rivers are large, deep pools with depth greater than 1.2 m and current velocities of less than 15 cm/s, or springfed reaches of small streams that do not freeze solid in winter and have current velocities <15 cm/s (Reynolds 1989). The requirement for large, deep pools as winter habitat also appears true for at least some grayling in the Big Hole River (Shepard and Oswald 1989).

Substrate and Vegetation

Sections of the Big Hole River in which the most grayling are found have substrate consisting mostly of gravel and rubble, with a small percentage of fine material and boulders (Liknes 1981; Liknes and Gould 1986). In Michigan fluvial grayling were most frequently associated with substrates of coarse sand with scattered gravel and gravel bars (Vincent 1962). According to Vincent (1962) many grayling streams in Michigan and Montana have had abundant macrophyte vegetation but grayling streams in Alaska typically lack macrophyte beds.

Temperature, Dissolved Oxygen, Turbidity

Available information suggests that fluvial Arctic grayling require clear, cool water, but may be able to tolerate lower levels of dissolved oxygen than other stream salmonids. Hubert et al. (1986) concluded that thermal habitat for grayling was optimal at average maximum water temperature between about 7 and 17 ^{o}C, but declined to being unsuitable at 20 ^{o}C for both adults and fry. Grayling can survive short term exposure (up to at least four days) to temperatures exceeding 20 ^{o}C. The median tolerance limit (50% mortality in 96 hours) of young fluvial grayling in Alaska appears between 21.2-24.2 ^{o} C for yolksac fry acclimated to 4-5 ^{o}C, over 25.3 ^{o}C for 5.5 cm juveniles acclimated to 9-10 ^{o}C, and between 23.7-24.2 ^{o}C for 12.2-24.4 cm fish acclimated to 3-7 ^{o}C (author's interpretation of data presented by LaPerriere and Carlson 1973). Feldmeth and Eriksen (1978) reported that the critical thermal maximum (at which equilibrium is lost as test temperature is continuously raised) of lacustrine Montana grayling acclimated to 13 ^{o}C is 26.9 ^{o}C for adults and 28.7 ^{o}C for fry. Maximum median tolerance limits and critical thermal maxima for grayling are probably slightly higher than reported in both these studies, since the fish tested were acclimated only to cool temperatures. It has been repeatedly demonstrated that thermal tolerances of fishes can be raised, up to species-specific and sometimes stock-specific limits, by acclimation to higher temperatures (e.g., Hutchison 1976; Kaya 1977).

Grayling appear to tolerate relatively low dissolved oxygen conditions, at least for short periods. Critical oxygen minima of adults range from 1.6 mg/l at 4-5 ^{o}C to 2.2 mg/l at 17-18^{o}C, and of fry from 1.4 to 1.8 mg/l, respectively (Feldmeth and Ericksen 1978). Grayling have been reported to survive dissolved oxygen content near zero in water beneath ice cover (Roguski 1972, cited by La Perriere and Carlson 1973). Their apparent tolerance for low dissolved oxygen is also supported by several anecdotal accounts by Lord (1932).

Turbidity $\leq$5 NTU is considered optimal for fluvial Arctic grayling in Alaska, and $\geq$25 is considered poor (Reynolds 1989). Arctic grayling avoid turbid streams in Alaska (Lloyd et al. 1987). Sublethal effects on growth, stress responses, and behavior have been reported on juvenile grayling at suspended sediments concentrations of 300 mg/l or greater (McLeay et al.

1984, cited by Lloyd 1987).

Requirements of Young, Age-0 Grayling

Stream areas with low current velocity appear important for young fry from swimup to several weeks of age. Nelson (1954) reported that lacustrine grayling fry in Red Rock Creek spent the first two to three weeks post-swimup in backwaters and other areas protected from fast currents. Deleray (1990) observed that young fry (less than three weeks post-swimup) in the Deer Lake outlet creek appeared to prefer velocities of ≤5 cm/s. Hubert et al. (1985) and Reynolds (1989) concluded that optimum habitat for fluvial grayling fry (less than 5.1 cm in length) are stream reaches with at least 30 percent of the area made up of pools, backwaters and sidechannels with mean column velocity less than 15 cm/s.

Importance of other habitat variables to grayling fry is presently not established. Fry in Alaska have been observed to select a wide range of water depths, from 0.09 to 0.85 m (Elliot 1980, cited by Hubert et al. 1985), and data are lacking to indicate substrate preferences (Hubert et al. 1985). Fry in the spawning tributaries of small lakes in the Big Hole River drainage have upper thermal tolerance slightly higher than that of adults (Eriksen 1975; Feldmeth and Eriksen 1978).

Age-0 juvenile grayling (≥5.1 cm in length) in the Big Hole River prefer water depths of about 0.15 to 0.40 cm, and mean column velocities of about 6 to 26 cm/sec (Skaar 1989; McMichael 1990). These values indicated that within the general stream sections, juveniles were selectively utilizing deeper water depths and faster velocities at higher frequencies relative to availability. The juveniles were found over coarser substrates ranging from small gravel to cobbles at higher frequencies than available, and over fine substrates of silt and sand at lower frequences than available (McMichael 1990). The cover type that juveniles were most frequently (80-85%) found close to (average distance about 0.3 m) was macrophyte vegetation. However, macrophyte vegetation made up 75 to 87% of available cover and thus may not have been deliberately selected by the juveniles.

DISTRIBUTION AND STATUS OF FLUVIAL MONTANA GRAYLING

Historical Trends of Fluvial Grayling in Montana

Montana grayling originally were mostly stream-dwellers, occupying waters of the upper Missouri River drainage upstream from the Great Falls of the Missouri River near the present city of Great Falls, Montana (Hensall 1907; Vincent 1962). They were not found above waterfalls, with the exception of the Great Falls itself, and the only lakes available and inhabited by grayling were Upper and Lower Red Rock lakes and possibly Elk Lake, near the headwaters of the Red Rock-Beaverhead drainage. The journals of Lewis and Clark (Moulton 1986) suggest that grayling were not abundant in the main stem of the Missouri River or the Jefferson and Beaverhead rivers in 1805, or at least were much less abundant than trout. The journals mention six occasions when trout (later identified as westslope cutthroat trout, Oncorhynchus clarki lewisi) were collected by angling or seining as the expedition progressed upstream from Great Falls along the Missouri, Jefferson, and Beaverhead rivers. In contrast, grayling were collected only once, on 22 August 1805, from waters around the former confluence of the Beaverhead and Red Rock rivers (presently submerged beneath Clark Canyon Reservoir). There were only 10 to 12 grayling among the 528 fish, mostly trout, collected.

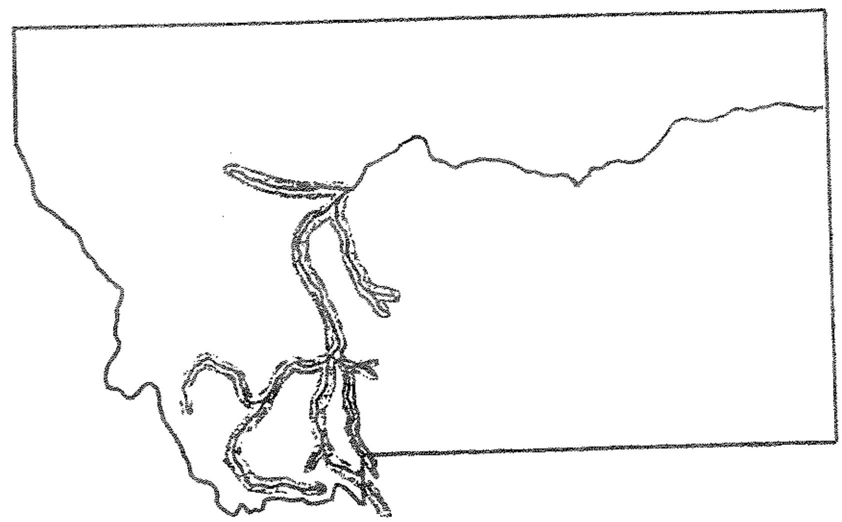
Grayling appeared irregularly distributed in the upper Missouri River and its tributaries above Great Falls and may have been most common in the Sun and Smith rivers and the drainages which make up the three branches of the Missouri, the Jefferson, Madison, and Gallatin drainages. According to Vincent (1962):

> The Sun and Smith Rivers were the only tributaries that had grayling below Three Forks. Reports of grayling in the Missouri River have come only from the vicinity of Craig. Evermann (1893) found none in tributaries below Three Forks or in the Blacktail, Ruby, or Boulder rivers of the Beaverhead-Jefferson drainage.

Grayling were also said to be abundant in the Canyon Ferry area of the Missouri River in the late 1870's and 1880's (Holton undated; Peterson 1981). Field surveys by Jordan (1891) and Evermann (1893) indicated that they were common and locally abundant in the upper Madison River and both its branches, the Gibbon and Firehole rivers, up to the first waterfalls above their confluence at Madison Junction. They also both reported that grayling were abundant in Horsethief Springs, a spring creek now submerged by Hebgen Reservoir on the upper Madison River. Evermann also visited Bozeman in August 1891 and reported that Bridger Creek and Bozeman Creek, "are said to be well filled with trout and grayling." Vincent (1962) reported that grayling were abundant in the Sun River until about 1908 and in the Smith River drainage until about 1910. The approximate distribution of fluvial grayling in Montana until around the start of the present century is depicted in Figure 2 (modified from Vincent 1962).

Although these early reports indicated that fluvial grayling were irregularly distributed but widespread and locally abundant in upper Missouri drainages until the end of the 19th century, this situation changed substantially over the next 40 to 50 years. On the Madison River, Fuqua (1929) described grayling as abundant in the deep holes of the river between Ennis Reservoir and Hebgen Dam. Elrod (1931) claimed that grayling

HISTORIC DISTRIBUTION



PRESENT DISTRIBUTION

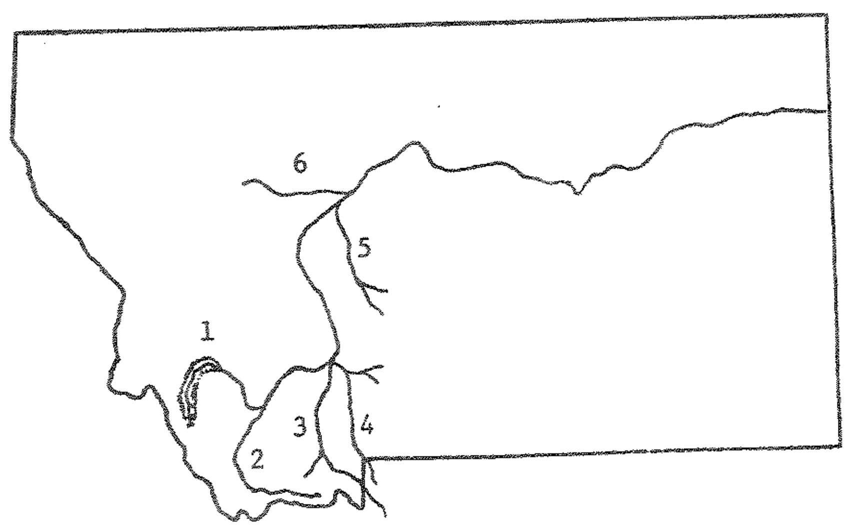


Figure 2. Approximate historic and present distributions of fluvial Arctic grayling in Montana. Major drainages of the upper Missouri River: (1) Big Hole, (2) Red Rock-Beaverhead-Jefferson, (3) Madison, (4) Gallatin, (5) Smith, and (6) Sun.

were still abundant and were "the principal fish in the South Fork of the Madison River" and also found in Grayling Creek, Fan Creek (Gallatin drainage?), and the lower Firehole and Gibbon rivers. By contrast, Vincent (1962) reported that grayling had become rare in the Madison River by 1940.

In the Yellowstone National Park section of the upper Madison River, grayling may have been common until at least 1926 (Russell 1925 and Philips 1926, cited by Vincent 1962), but were greatly reduced by 1933 (McCarty 1933, cited by Vincent 1962). More than 6 million grayling fry were planted in this part of the river and the Gibbon River between 1933 and 1943 (Varley 1981). Benson et al. (1958) reported that small numbers of grayling were still being caught by anglers on the Madison River and its two tributaries, the Firehole and Gibbon rivers, between 1953 and 1957. In a 1957 electrofishing survey of sections of the Madison River between Madison Junction and West Yellowstone, Benson et al. (1959) captured 1320 brown trout, 560 rainbow trout, and only 1 grayling.

In other drainages, Vincent (1962) concluded that grayling were nearly gone from the Sun River by 1913, had undergone marked decline in Sheep Creek of the Smith River by 1915, and had taken a sharp drop in the Gallatin Valley (Gallatin River and Bridger Creek) by 1890-1900. "Old-timer" accounts indicate that grayling were abundant in the Smith River upstream from Fort Logan near White Sulfur Springs, but were no longer reported since at least 1950 (Holton undated). Brown (1943) reported that the distribution of fluvial grayling had been reduced to the Big Hole River drainage and the upper Gallatin River, with their presence in the latter due to plantings of fingerlings. Tyron (1947) confirmed the plantings of grayling fingerlings into the Gallatin River and also stated that "with few exceptions" (unspecified), grayling were only found in the upper Big Hole River and in lakes.

There have been contrasting reports, however, of grayling persisting in some streams until the 1950's or later. Game warden creel census indicate that grayling were present in the Sun River until 1954 (Hanzel 1959). Personal accounts mentioned by Peterson (1981) suggest that some grayling may have persisted in the Sun River until at least 1970 and in the Madison River and its South Fork (which flows into Hebgen Reservoir) until at least 1975. As will be described elsewhere in this report, such reports of grayling in streams may have been influenced by stockings from hatcheries, which began on large scale in the 1920's. An example, planting of grayling into the upper Gallatin River, has previously been mentioned. According to MDFWP fish planting records, grayling were planted in small numbers into the Madison River between Hebgen Reservoir and Ennis Reservoir in 1946 and 1966 and in large numbers (2,400,000 total) into the South Fork of the Madison in 1928, 1929, and 1938. The Smith River was stocked with grayling in 1933 and 1937 (2,200,000 total).

Other recent reports (since the 1950's) of grayling in streams outside the Big Hole River drainage appear to be of fish spending part of the time in streams, particularly during spring and early summer spawning periods, or drifting down out of lakes in the drainage. One possible exception could be the Madison River. Field surveys are presently being conducted (beginning from spring, 1990) to determine whether it contains a small remnant population. Also, a population inhabiting an irrigation canal below Pishkun Reservoir will be discussed later.

Given the present critical importance of fluvial grayling in the Big Hole River, it seems curious that little mention of this population is made in earlier reviews, including Vincent's (1962) comprehensive treatise.

Unlike the situation with other drainages like the Madison River, there appears to be a lack of references describing past abundance of grayling in the river. Whatever their former abundance in the river may have been, grayling appeared low in numbers in the upper river by the 1950's. An electrofishing survey in 1959 of four 90-m sections of the main river between Skinner Meadows and Swamp Creek Road yielded 3 rainbow trout (Oncorhyncus mykiss), 280 brook trout (Salvelinus fontinalis) and only 3 grayling, while 90-m sections of 13 tributaries between Deep Creek and Wise River yielded 197 rainbow trout, 589 brook trout and no grayling (Heaton 1960). Grayling were absent or scarce below the Divide Dam by 1964. An electrofishing survey of about 8 km of the main river near Melrose yielded 244 brown trout (Salmo trutta), 22 rainbow trout, 2 brook trout and no grayling (Wipperman 1965). The dominance of the salmonid community by brown and rainbow trout in this lower part of the river and the scarcity of grayling has continued in more recent surveys (Oswald 1986).

Results of electrofishing surveys from 1978 to 1989 have continued to indicate low and declining numbers of grayling in the Big Hole River and its tributaries. Among five sampling stations on the main river in 1978-1979, Liknes (1981) captured the largest number of grayling in the uppermost (just above Wisdom). He estimated the population in this section to be 35 per km (80% confidence interval of 24-46 per km). Numbers of grayling captured at the other stations were too low to permit population estimates. Liknes also found grayling in 11 tributaries, mostly near confluences with the Big Hole River. Presence of age-0 fish provided evidence of reproduction in 7 of these tributaries. Wells and Decker-Hess (1981) reported that among sections of 26 tributaries sampled, they found a few grayling in only four.

There appears a progressive downward trend from 1983 to 1989 in estimated numbers of age-1+ (age 1 and older) grayling in the Wisdom section of the Big Hole River where they appear most numerous (Table 4). Estimates have gone from about 69 per km (111 per mile) in 1983 to about 14 per km (22 per mile) in 1989. Density of age-0 grayling in this part of the river was estimated at 196 per km (316 per mile) in September 1989 (R. Oswald, MDFWP, unpublished data). Although this is a much higher density than of older fish, it is not known whether this represents a particularly strong year-class since earlier estimates of juveniles are not available.

Table 4. Estimated densities (number per km) of age-1+ grayling, age-2+ brook trout, and age-1+ rainbow trout in McDowell (8.0 km in length) and Wisdom (9.8 km in length) sections of the Big hole River upstream and downstream from the town of Wisdom (Oswald 1990, unpublished data).

		Estimated Number per Km		
Section	Year	Grayling	Brook	Rainbow
McDowell	1978	43	68	0
Wisdom	1983	69	146	9
Wisdom	1984	46	171	7
McDowell	1985	24	130	16
Wisdom	1985	20	207	3
McDowell	1986	32	132	17
McDowell-Wisdom	1987	19	51	2
McDowell-Wisdom	1989	14	39	2

Plantings of Grayling into Montana Streams

Numerous attempts to establish or restore grayling in streams in Montana, Michigan and other states through fish stockings have thus far been notably unsuccessful. Plantings of young (originating from Montana) into streams in Michigan were not successful (Kelly 1931) and the species continued its decline into extirpation in that state. Numerous plants of grayling into many different streams in Montana also have failed to establish fluvial populations. Appendix 1 lists the plants into streams that have been recorded in the MDFWP fish planting database. This list is incomplete, since old hatchery records may not provide complete stocking information and no entries are recorded before 1926. Also, information from certain hatcheries is lacking from the database, most notably from the federal hatchery in Bozeman which pioneered artificial culture of grayling and produced over 17 million young grayling between 1898 and 1907 (Hensall 1907) and has continued to intermittently produce grayling to the present. Some stream plantings listed were in lake-inlet streams and may have been intended to supplement lacustrine populations, for example, plants in Odell Creek above Ennis Reservoir and in Flint Creek and the North Fork of Flint Creek above Georgetown Reservoir. The available data indicate that millions of young grayling have been stocked into the Big Hole River and its tributaries, and millions more into at least 32 other streams in thirteen major drainages on both sides of the Continental Divide in Montana (Appendix 1).

A recent effort was conducted to establish a fluvial grayling population in Canyon Creek, a tributary of the Gibbon River (upper Madison River system) in Yellowstone National Park (Jones et al. 1977; Jones 1979). Canyon Creek was chemically treated to eliminate fishes and a barrier falls was constructed to prevent re-entry of brown, brook and rainbow trout from the Gibbon River. Grayling from four sources were planted in the creek: 2,863 young averaging 229 mm originating from Grebe Lake in 1976, 120 transplanted from the Big Hole River in 1976, 2,000 to 4,000 advanced eyed embryos from the Deer Lake outlet-spawning population in 1977, and 5,000 swimup fry from Red Rocks Lake stock in 1978. Electrofishing in 1978 revealed few grayling and many more brown, brook and rainbow trout. Although this effort seems to have failed, rumors have persisted of a few grayling being present in Canyon Creek. To date, attempts have not yet been made to survey the stream to confirm whether grayling are still present (R. Jones, U.S. Fish and Wildlife Service, pers. comm.)

Reasons why grayling plants into streams have failed to produce self-sustaining populations are not known. In many cases, the streams may have been too small and turbulent to provide good grayling habitat. This may have been a contributing factor in Canyon Creek and many of the smaller creeks in Appendix 1. However, this would not account for failures in large, former grayling streams like the Madison River.

Another possibility is that, with the exception of the effort at Canyon Creek and of a recent (1983) transplant of grayling from the Sunny Slope Canal to the upper part of the Sun River drainage, all the stockings in Montana and other states have been with young derived from inlet-spawning lacustrine stock. Most grayling planted were progeny of fish spawning in inlets of Georgetown, Agnes, Rogers, Grebe, Upper Red Rock, and Ennis lakes and reservoirs. With the exception of Upper Red Rock Lake, all these lacustrine populations directly or indirectly originated from Ennis Reservoir. Georgetown Lake was a primary source of fertilized eggs for the Anaconda Hatchery, which provided young for many of the transplants into streams and also for establishing populations in Agnes and Rogers lakes, which in turn became important sources of grayling spawn for state hatcheries (MDFWP fish planting database). The Georgetown Lake population was started in 1908 with young originating from fish spawning in Meadow Creek, an inlet to Ennis Reservoir (Meadow Lake) on the Madison River (Kelly 1931). The population of Grebe Lake in Yellowstone National Park was also started with plants of fish from Georgetown Lake (Varley and Schullery 1983). Grebe Lake became another important source of grayling eggs for stocking programs in other states.

Although grayling in Ennis Reservoir were derived from Madison River stock it is probably not appropriate to consider those that provided progeny for plants into most streams as having been derived from a fluvial stock. Ennis Reservoir was built in 1900 so the spawners in Meadow Creek from which eggs were taken in 1908 were almost certainly fish from Ennis Reservoir. Since most grayling in Montana first mature at age 3, the spawners taken in 1908 probably represented fish that were at least two generations removed from a fluvial ancestry. The extent to which the population in Ennis Reservoir may have changed its behavioral characteristics because of selection for lacustrine rather than fluvial characteristics is not known. In any case, further opportunity for loss of fluvial charactersitics occurred through additional generations spent in Georgetown and/or other lakes before young were taken for stocking into streams.

Recent studies have supported the possibility that grayling derived from lacustrine populations may not be suitable for stocking into streams. Unlike young from the Big Hole River population, young grayling from inlet-spawning lacustrine populations do not have a behavioral tendency to maintain position in water current, but instead tend to move downstream (Kaya 1990). Jones et al. (1977) also saw evidence of the unsuitability of lacustrine grayling planted in Canyon Creek and stated that:

> The apparent drift of Grebe Lake stock and maintenance of stream position by the Big Hole River grayling seems to lend credence to our hypothesis that important behavioral differences exist between fluvial and lacustrine ecotypes.

Another possible factor contributing to the failures may have been the earlier practice of planting very young fish, especially fry which had not yet absorbed their yolk sacs. Kelly (1931) described the prevailing practice in Montana up to that time as, "Because of the fact that no artificial feeding has proved successful with grayling, the fry are planted while in the 'yolk' stage." It is probable that survival in streams of such early fry was very low. After reviewing efforts in Alaska, Armstrong (1986) also concluded that stocking of grayling fry into streams has not proven successful. However, this cannot explain all failures since some later plantings were with larger juveniles up to 15 cm (Tyron 1947). The Canyon Creek effort also failed even though larger juveniles were stocked.

Interspecific interactions with non-native salmonids may also have prevented success of grayling plants into streams. It is not known whether grayling can be established in a stream which contains a population or community of non-native salmonids. Grayling were succcessfully introduced into Grebe Lake which already had an established population of non-native rainbow trout (Kruse 1959), but there are no examples of such success in a stream. If interspecific interactions were important contributors to the elimination of grayling from streams, then this same factor may have prevented establishment of grayling stocked into streams including their original habitats like the Madison, Gallatin, and Sun rivers.

Although not yet proven successful in establishing self-sustaining populations, stockings of grayling can provide temporary stream fisheries. Hatchery-reared grayling from 5.1-15.2 cm (2-6 inches) in length were planted into the upper West Gallatin River from 1938-1941 and resulted in "good grayling fishing" for up to 12-14 inch (30.5-35.6 cm) fish by 1941-1942 (Tyron 1947). In 1945 and 1946, however, grayling were no longer being caught. Armstrong (1986) also mentions examples of grayling surviving and growing in Alaskan streams when planted as fingerlings rather than as fry. Considering the numerous stockings of grayling into streams in Montana, the possibility of such planted fish surviving and growing makes it difficult to interpret the significance of reports of grayling persisting in some streams in the state until the 1950's or later.

Another aspect of past planting programs is the possible effect on the genetic integrity of Big Hole River grayling. Over 12 million grayling were planted into the Big Hole River and its tributaries between 1929 and 1957 (Appendix 1), and most of the planted fish were descendents of Georgetown Lake stock. Big Hole River grayling are genetically similar to, although identifiable from, the current population in Ennis Reservoir (Leary pers. comm.), and both populations are less similar to populations directly or indirectly derived from Georgetown Lake stock (Leary pers. comm.). This suggests that the Ennis Reservoir and Georgetown Lake populations diverged genetically after the latter was started through plants of progeny from the former, perhaps through genetic drift. The similarity between Big Hole River and current Ennis Reservoir populations may represent an original condition from which the Georgetown Lake population diverged, or may have resulted from change in the Ennis Reservoir population toward similarity with the Big Hole River population (Leary pers. comm.). In either case, the difference between Big Hole River grayling and the lacustrine populations started through plants of hatchery fish suggests that past plants of grayling into the Big Hole River and its tributaries probably also failed and had little or no effect on the indigenous population. Past stockings of grayling into the Big Hole River drainage may have failed for the same reasons as discussed for other stream plantings of the species - use of lacustrine stock, plantings of very young fry (as indicated by the June to early July stocking dates of most of the plants), and for the tributaries, unsuitable stream habitat.

Evaluation of Recently Reported Fluvial Populations

Streams in which grayling have been reported (Montana Interagency Stream Fishery Database), and which represent either confirmed fluvial populations or the possible existence of fluvial populations are listed in Table 5, according to major drainage. Not included are tributaries most obviously occupied only temporarily by lacustrine populations during spawning seasons.

Big Hole River Drainage

In addition to the main stream, grayling have been found in small numbers in at least 17 tributaries of the Big Hole River (Table 5). Whether any of the tributaries support self-sustaining populations is not known. In most of these tributaries, grayling appear generally confined to the lower reaches on the valley floor, near their confluence with the main river (Liknes 1981; Liknes and Gould 1987; Oswald and Shepard 1989). Furthermore, grayling marked in the main river have been recovered in tributaries. This suggests that there is only one population of fluvial grayling in the drainage, and that continued presence of grayling in the tributaries may depend on movements of fish from the main river.

Table 5. Streams in Montana with Reported Presence of Grayling[1].

Stream Name	Grayling Abundance	Stream Resident[2]	Near Lake[3]	Other Species[4]	Data Source
		Big Hole River Drainage			
Big Hole River	Rare to Uncommon	Yes	No	EB,BR,RB,CT, MT,BU,WS,LN, LD,MTS,MS	Database[5]
Odell Creek	Uncommon	Part?	Yes		Shepard, 1987
Wyman Creek	Uncommon	Part?	Yes		"
Wise River	Uncommon	Part?	No		"
LaMarche Cr.	Uncommon	Yes?	No	EB,RB,CT,BU, LN,MS	Database
Pintlar Creek	Rare	Yes?	Yes	EB,MS,BU,CT,LN	Database
Doolittle Cr.	Rare	Yes?	No	EB,MT,LS,LD, BU,MS	Database
N.F. Big Hole R.	Uncommon	Yes?	No	EB,MT,BU,LN, MS,LD	Database
Mussigbrod Cr.	Rare	Yes?	Yes	EB,BU,LN,MS	Database
Johnson Creek	Rare	Yes?	No	EB,MT,LN,BU, LD,MS	Database
Sandhollow Cr.	Common	Spawn	No	EB,LS,BU,LD	Database
Swamp Creek	Uncommon	Yes?	No	EB,CT,MT,BU, LN,LD,MS	Database
Steel Creek	Uncommon	Yes?	No	EB,MT,BU,LN, MS,LD	Database
Francis Cr.	Rare	Yes?	No	EB,MT,WS,LN, BU,MS	Database
Big Lake Cr.	Rare	Yes?	No	EB,MT,BU,LN, LD,MS	Database
Rock Creek	Uncommon	Yes?	No	EB,CT,MT,BU, LN,MS	Database

Stream Name	Grayling Abundance	Stream Resident[2]	Near Lake[3]	Other Species[4]	Data Source
Miner Creek	Uncommon	Yes?	Yes	EB,CT,BU,MS	Database
Governor Cr.	Uncommon	Yes?	No	EB,RB,MW,BU, LN,MS,LD	Database
		Red Rock River Drainage[6]			
Red Rock Creek					
above Upper L.	Abundant	Spawn	Yes	EB,CT,MS	Database
Up. to Low. L.	Uncommon	Temp.	Yes	EB,CT,WS,LN,BU	Database
below Low. L.	Uncommon	Temp.	Yes	EB,RB	Database
Tom Creek	Uncommon	Spawn	Yes	EB,LN,WS,MS	Database
Corral Creek	Uncommon	Spawn	Yes	EB,YC,MS	Database
Odell Creek	Common	Spawn	Yes	EB,CT,RB,MT, LN,WS	Database
Hell Roaring Cr.	Uncommon	Spawn	Yes	EB,CT	Database
		Madison River Drainage[6]			
Madison River, above Ennis R.	Uncommon	Spawn	Yes	EB,RB,BR,MT, LD,UT,MS	Database
North Meadow Cr.	Uncommon	Spawn	Yes	EB,RB,CT,BR, MT,MS	Database
Moore Cr.	Rare	Spawn?	Yes	RB	Vincent, pers. comm.
		Sun River Drainage[7]			
Sun Slope Canal	Common	Yes	Yes	RB,WS,NP,YP	Database

[1]Does not include streams in which grayling are obviously from lacustrine populations and in streams only temporarily, to spawn or as young fish

prior to migrating to lakes, or have drifted out of a nearby lake. Grayling are found seasonally in inlet or outlet streams, and sometimes the tributaries of these streams, of all the lakes with self-sustaining populations. See text for discussion of other streams in other drainages reported to contain grayling.

[2]Most probable occupancy of stream: Yes = confirmed complete life-cycle residence, partial = incomplete life-cycle residence (part, but not entire life cycle residence in stream, as with fish moving into the stream from a lake or contiguous stream), temporary = transient occupancy (for example, migrating through), spawn = present in creek only during spawning season and as young fry.

[3]Grayling found in proximity to lake or reservoir, in inlet or outlet tributary.

[4]EB = brook trout, LT = lake trout, RB = rainbow trout, YC = Yellowstone cutthroat trout, CT = unspecified cutthroat trout, BR = brown trout, MT = mountain whitefish, LN = longnose sucker, WS = white sucker, MTS = mountain sucker, BU = burbot, LD = longnose dace, UT = Utah chub, MS = mottled sculpin, YP = yellow perch, NP = northern pike.

[5]Montana Interagency Stream Fishery Database, information acccessed in July, 1990.

[6]Presence of permanently resident fluvial grayling questionable, and not confirmed for these drainages.

[7]See discussion of the Sun Slope (also known as Sunny Slope) Canal population in the text of this report.

Grayling are also present in the upper reaches of Mussigbrod, Odell, and Wyman creeks and in the Wise River below Wyman Creek. These fish, however, may originate from downstream drift of eggs or fish from mountain lakes in the drainages (Shepard 1987).

Red Rock River Drainage

Although streams in this drainage are sometimes listed among those with fluvial grayling populations, the presence of permanently resident stream fish has not been confirmed and is questionable. All the streams listed are either direct or secondary tributaries of either Upper or Lower Red Rock Lake, and are known to be used seasonally for spawning. Grayling become rare in these streams after the spawning season is over (R. Oswald, MDFWP, pers. comm.). Red Rock Creek above the upper lake is also occupied by grayling fry for a few weeks prior to their migration to the lake (Nelson 1954; author, pers. observ. 1988). Fry may similarly temporarily occupy some of the other streams in the Centennial Valley. Not listed in Table 5 are Narrows Creek and Limestone Creek, both spawning tributaries of Elk Lake, a short distance from Upper Red Rock Lake, and sometimes also listed among streams with grayling. These are very small creeks obviously occupied temporarily by spawning adults (Lund 1974).

Madison River Drainage

The best, although doubtful, possibility for existence of remnant fluvial Montana grayling outside of the Big Hole River drainage appears to be in the middle reaches of the Madison River. Grayling are occasionally captured during electrofishing surveys between the West Fork and Ennis Reservoir during non-spawning periods (R. Vincent, MDFWP, pers. comm.). However, evidence thus far suggests that grayling in the Madison River are associated with Ennis Reservoir. MDFWP personnel conducting a survey of grayling in the river during the summer of 1990 found only few, and these were in reaches close to the reservoir (P. Byorth, MDFWP, pers. comm.). The other Madison drainage streams in Table 5 are tributaries of Ennis Reservoir and may be used for spawning by a few grayling. Moore Creek was thought to possibly have resident grayling (Montana Interagency Stream Fishery Database). However, those grayling have virtually disappeared in recent years (R. Vincent, MDFWP, pers. comm.) and the few remaining are likely associated with the reservoir.

Canyon Creek in Yellowstone National Park, a tributary of the Gibbon River near the headwaters of the Madison River, may have a small fluvial population. As previously mentioned, grayling were transplanted into Canyon Creek in the mid-1970's in an effort to restore fluvial grayling to the upper part of the Madison River drainage. This effort was thought to have failed but unconfirmed rumors persist of grayling being present in the creek (Jones, pers. comm.) Occasional reports of grayling in the Gibbon River likely result from downstream drift of grayling from Wolf and Grebe lakes (Jones, pers. comm.).

Sun River Drainage

A transplanted population with partially fluvial characteristics is found in an irrigation canal, the Sunny Slope Canal (also referred to as the Sun River Slope Canal and the Sun Slope Canal), downstream from Pishkun Reservoir in the Teton River drainage. Grayling were planted into Pishkun Reservoir at least seven times from 1937 to 1943 (MDFWP fish planting database). The canal population was apparently established by fish that moved downstream from the reservoir. Observations by Bill Hill (MDFWP, pers. comm.) suggest that these fish exist in a situation which makes their life history partially, but not entirely, fluvial. They inhabit a fluvial environment during the irrigation season, generally from early May to September, when water flows through the canal. They also spawn during spring when water is flowing. During the remaining seven months of a year much of the canal goes dry and the fish inhabit isolated pools left within the canal. Many grayling fry appear to be displaced downstream and lost from the population during the summer flow. With this downstream loss of young, the population may be under continuing strong selection pressure for characteristics which enable them to persist in a fluvial environment when water flows through the canal. However, their presence in isolated pools for the majority of the year makes their life history also resemble that of lacustrine grayling. Interestingly, they have done better in the canal than the reservoir, from which they have nearly or entirely disappeared. The canal population appears genetically aberrant; they are not similar to fluvial Big Hole River fish, and have diverged from other Madison River derived stocks, perhaps as a result of random genetic drift (Everett and Allendorf 1985).

In 1983, young grayling from the canal were transplanted to the Sun River drainage, below the Diversion Dam where fluvial grayling were native, and into Rock Creek, a small upper tributary of the North Fork of the Sun River (Appendix 1). Transplants below Diversion Dam were not successful, and those placed into the small upstream tributary appeared to quickly move downstream into the North Fork, where some may still be present (Hill, pers. comm.).

Clarks Fork of the Yellowstone (not included in Table 5)

Grayling are reported as rare in two streams in this drainage, Skytop Creek and Broadwater River. Skytop Creek flows between Skytop Lake and

Broadwater Lake, and Broadwater River flows from Broadwater Lake and Curl Lake into the Clarks Fork of the Yellowstone. Grayling are present, although considered uncommon, in both Broadwater and Curl lakes (Montana Interagency Lake Fishery Database) and may also be present in Skytop Lake (unpublished notes, MDFWP files). The few grayling found in these streams, as well as occasional grayling reported in the Clarks Fork in this vicinity, probably originate from these lakes.

Flathead River Drainage (not included in Table 5)

Streams reported with grayling in the drainage of North Fork of the Flathead River are the main river down to Camas Creek and Red Meadow Creek. They are considered rare in both streams. These grayling probably originate in Red Meadow Lake, in which grayling are abundant (Montana Interagency Lake Fishery Database). Red Meadow Creek flows from the lake and enters that part of the North Fork from which the few grayling have been reported.

Streams reported with grayling in the drainage of the South Fork of the Flathead River are the main river above Hungry Horse Reservoir, and Quintonkin, Sullivan, Wheeler, and Graves creeks, tributaries of Hungry Horse Reservoir. Grayling are considered uncommon to rare in all the streams, and are considered to represent spawning fish or temporary residents. Graves Creek flows from Handkerchief Lake, in which grayling are considered abundant (Montana Interagency Lake Fishery Database), and flows into Hungry Horse Reservoir. The other streams may be used for spawning, or occupied by small numbers of grayling from the reservoir.

Distribution of Currently Confirmed Fluvial Grayling Populations in Montana

This evaluation of reported presence of grayling in Montana streams indicates that the current distribution of fluvial grayling, defined as those confirmed to be spending their entire life cyles in a flowing-water environment, is limited to the upper Big Hole River and its tributaries near their confluence with the river (Figure 2). Unless it can be demonstrated otherwise, the grayling in the tributaries should be assumed to represent the same population as those in the main river. Thus, fluvial Montana grayling are apparently reduced to a single population occupying a small part of their original distribution. Using the limited information available, Varley and Schullery (1983) estimated that fluvial Montana grayling are reduced in distribution to only about 8% or less of their historical range.

Lacustrine Populations

In contrast to fluvial grayling, the distribution and abundance of lacustrine grayling in Montana has been greatly expanded, through stocking programs, beyond the original presence in Red Rock and Elk lakes. As previously described for grayling planted into Montana streams, most of the grayling planted into lakes in the state appear to have originated indirectly from fish spawning in an inlet of Ennis Reservoir on the Madison River. Although this report is on the status of fluvial grayling in Montana, Table 6 is included to indicate the lakes and reservoirs in which Arctic grayling are considered to be common to abundant. This list was complied mostly from the Interagency Lake Fishery Database and may not be complete. For example, Deer Lake and Emerald Lake in the Gallatin drainage were not in the database as of July 1990, even though grayling are abundant in both (author, pers. observ.) Lakes in which grayling are listed as uncommon or rare in the database are not included in Table 6, because they may not represent viable populations. There appear to be approximately 30 lakes

Table 6. Lakes In Montana with Grayling Reported to be Common to Abundant.

Lakes East of Continental Divide

Lake Name	Elev. (m)	Area (hect.)	Other Species[1]	Data Source
		Big Hole River Drainage		
Agnes	2088	40	none	Database[2]
Odell	2515	14	none	Database
Mussigbrod	1977	81	EB,BU,LN	Database
Schwinegar	2476	2	none	Database
Bobcat	2530	2	none	Database
Hamby	2466	16	CT,EB	Database
Boot		14	CT,RB	Database
		Red Rock, Beaverhead Drainage		
Elk	2033	95	CT,LT,BU,LN,WS	Database
Upper Red Rock	2015	893	EB,YC,BU,LN,WS	Database
		Madison Drainage		
Ennis Reservoir	1468	1530	RB,BR,LN,WS, UT,MW	Database
		Gallatin Drainage		
Hyalite Reservoir	2042	250	YC, EB	Database
Deer	2834		none	Pers. Observ.
Emerald	2362		none?	Pers. Observ. MDFWP files[3]
		Upper Missouri Drainage		
Park		1	RB,WS	Database

		Clarks Fork of the Yellowstone Drainage		
Dollar	2719	0.4	YC	Database
Lone Elk	3069	7	EB	Database
Rough	3094	41	EB	Database
Sedge	2774	2	YC	Database
Cliff	2606	7	none	Database
Lower Cliff	2585	0.4	none	Database
Fox	2455	45	RB,EB	Database
Widewater	2441	45	RB,EB,YC	Database
Lakes West of Continental Divide				
		Clearwater, Blackfoot River Drainage		
Heart	1914	11	none	Database
		Flathead River Drainage		
Rogers	1191	96	RS	Database
Sylvia	1500	9	none	Database
		South Fork Flathead River Drainage		
Handkerchief	1170	13	RB,WC	Database
		North Fork Flathead River Drainage		
Cyclone			WC	MDFWP files
		Rock Creek, Clark Fork Drainage		
Fuse[4]			none	MDFWP files
		Belly River Drainage, Glacier National Park		
Elizabeth Lake			RB	L. Marnell, pers. comm.

[1]EB = Brook Trout, LT = Lake Trout, RB = Rainbow Trout, YC = Yellowstone Cutthroat Trout, WC = Westslope Cutthroat Trout, CT = unspecified Cutthroat Trout, BR = Brown Trout, MT = Mountain Whitefish, LN = Longnose Sucker, WS = White Sucker, UT = Utah Chub, RS = Redshide Shiner, BU = Burbot

[2]Montana Interagency Lake Fishery Database, information accessed in July, 1990.

[3]Miscellaneous written material in files of Montana Department of Fish, Wildllife and Parks, with varying dates.

[4]The Fuse Lake population was established with a planting in 1952, of grayling from Saskatchewan, Canada (Holton, undated), and are the only non-Montana grayling known to exist in the state.

with viable, self-sustaining populations of grayling in Montana, although one of these, Fuse Lake, contains fish derived from Canadian, rather than Montana stock (Holton undated).

Although grayling appear reasonably secure as lake populations in Montana, this is a situation which needs to be monitored. The species has had a history of thriving for a time in certain lakes, only to severely decline or disappear. The best example of this is Georgetown Lake, into which grayling were first planted in 1908. Grayling became so abundant that for many years fish spawning in its inlets provided most of the millions of grayling eggs taken for hatchery purposes in Montana. However, grayling have declined so severely in Georgetown Lake that they may have disappeared entirely, and this lake does not appear among those listed in the Montana Interagency Lake Fishery Database for the species. This decline may have been caused at least partially by a combination of fishing overharvest, a serious winterkill during the winter of 1936-37, and subsequent competition with other fishes (Beal 1953). Another similar situation may be occurring at present in Rogers Lake, also an important source of grayling eggs in the past, whose population appears to be undergoing sharp decline in apparent response to predation of fry by introduced yellow perch, *Perca flavescens*, (R. Domrose, MDFWP, pers. comm.)

OVERVIEW OF FACTORS ASSOCIATED WITH GENERAL DECLINES OF FLUVIAL GRAYLING IN MONTANA AND MICHIGAN

Explanations for the decline of fluvial grayling in Michigan and Montana have focused on three categories of human-related factors: fishing overharvest, habitat degradation, and introductions of non-native fish, especially other salmonids. It is difficult to determine the relative contribution of any of these factors to the decline of fluvial grayling since the three tend to occur together with increased human development and exploitation of a river and its drainage. Effects of different factors could be related. For example, a population being overharvested could be more susceptible to competition from introduced salmonids or to habitat degradation. A major difficulty in evaluating possible reasons for decline of fluvial grayling in Montana is the general lack of field or laboratory studies demonstrating causal relationships. Fluvial grayling underwent decline and elimination from most of their former range in Montana before their status could be evaluated through field surveys. The major part of Vincent's (1962) thesis dealt with possible contributions of such factors to decline (and in Michigan, eventual extirpation) of fluvial grayling in both areas. Vincent compiled an impressive collection of data from published and unpublished sources, including personal accounts from individuals. Except where indicated otherwise, the following material on factors underlying past decline of grayling in Michigan and Montana are from his comprehensive review and analysis. Vincent had to rely largely on circumstantial evidence for his evaluation since there has been a general lack of field or laboratory studies to isolate and identify the effects of a particular factor on a grayling population. This same lack of "hard" information continues to the present.

Fishing Exploitation and Overharvest

Arctic grayling have a reputation for being easily caught by anglers, and several studies in Alaska (summarized by Armstrong 1986) have demonstrated that angling pressure can detrimentally affect both lacustrine and fluvial populations. Heavy exploitation and overharvest by sports and commercial fishermen may have been an important factor contributing to past declines of fluvial grayling populations. An example in Michigan was the Au Sable River, where heavy commercial and sport fishing appeared the major reason for the disappearance of grayling from this stream where they were formerly abundant. The disappearance of grayling from this river was first evident in the 1870's near the town of Grayling, where much of this exploitation was centered, and progressed downstream through the 1880's. Neither logging nor competition with brook trout could explain the early decline of grayling, but both may have been contributing factors after 1880. Grayling appeared extirpated from the Au Sable River by 1904.

Vincent (1962) had less evidence for a role of fishing pressure on fluvial grayling in Montana. On the Madison River decline of grayling occurred as fishing pressure increased, as indicated indirectly by license sales in Montana and numbers of visitors to Yellowstone National Park. Grayling were common in the river until about 1920 but were severely reduced by 1940, with the exception of those in Ennis Reservoir. However, rainbow and brown trout, first introduced into the Madison River drainage in 1889 (Jordan 1891), were well established in the Madison River by 1940 and could have contributed to this decline. Although fishing pressure may have contributed to decline of grayling from other streams in Montana, information is not generally available to demonstrate such a relationship. For some streams, overharvesting may not have been a major factor. For example, unlike the Madison River, much of the Smith River has not been easily accessible to the public and even at present much of the river is accessible to the general public only by floating through in boats.

Habitat Degradation

According to Vincent (1962), logging activities were the most important contributors to degradation of stream habitat for grayling in

Michigan, while agricultural activities have been most important in Montana. In Michigan, log drives may have disrupted grayling spawning and caused erosion of stream beds and banks. This erosion would produce increased silt deposition into streams, removal of instream debris used for shelter by grayling, and dislodging of eggs and fry from gravel beds. Other possible effects of logging included increased inputs of silt from removal of vegetation from watersheds and disturbance of ground surface, and increased water temperatures from removal of vegetative canopies.

In Montana, degradation of fluvial grayling habitat appears most frequently to have been related directly or indirectly to agricultural irrigation. The most important disturbances have been reduction in stream flows through withdrawals of water for irrigation, blockage of streams by dams for reservoirs and diversions, and flooding of streams by reservoirs. Partial dewatering of streams reduces habitat available for fish and the invertebrates they feed on, and can also result in increased water temperatures during summer. Dams to impound or divert stream waters can block migrations of salmonids to spawning, wintering, or summer feeding areas and the importance of such migrations to fluvial grayling in Montana and Alaska have been previously described in this report.

Vincent (1962) presents a number of examples in which habitat alterations appear to have had major adverse effects on fluvial grayling in Montana. Filling of Hebgen Reservoir in 1915 inundated Horsethief Springs, a tributary of the upper Madison River in which grayling had been abundant. In the Gallatin River and its tributaries, decline of grayling by about 1900 was associated with greatly expanded diversions of water for irrigation. Introductions of brook, rainbow and brown trout into this drainage began in 1897-1899, toward the end of the period of apparent grayling decline. In the Sun River and in Sheep Creek, a tributary of the Smith River, grayling appeared abundant until the early 1900's but had seriously declined by about 1913-1915. By then both streams and their tributaries had been extensively dammed and diverted for irrigation, and Willow Creek Reservoir had been built (1911) on one major tributary of the Sun River. Non-native trout (rainbow and brook trout) were planted in the Smith River drainage in 1898 and the Sun River about 1913, and in both grayling had declined before these introduced species had become common. Stream dewatering, possibly accompanied by increases in water temperatures during summer, were probably important in the Gallatin, Smith (Sheep Creek drainage), and Sun River drainages. Blockage of instream migrations by dams may have also been important in the Sun River and Sheep Creek.

On the other hand, it appears that grayling can disappear without local instream habitat degradation. The upper Madison River within Yellowstone Park, including the lower reaches of the Firehole and Gibbon Rivers, appear to have remained essentially unaltered since Jordan (1891) and Evermann (1893) mentioned that grayling were common in these waters. Hebgen Reservoir, located just downstream from the park boundary, was filled in 1915 and its relationship to decline of grayling upstream within Yellowstone Park is unknown.

Interactions with Non-Native Fishes

Interactions between grayling and non-native fishes, especially salmonids, could include competition or predation. Competition occurs through common use of limited resources including food, shelter, and spawning areas and can lead to decline or elimination of less successful competitors. Grayling may be highly susceptible to predation, especially in early stages of development. Eggs are broadcast over the substrate instead of being buried, and young grayling fry are smaller and are weaker swimmers than trout fry.

According to Vincent (1962), fluvial grayling of the upper Missouri River drainage were originally sympatric with only ten other species of fish, including two native salmonids, westslope cutthroat trout (*Salmo clarki lewisi*) and mountain whitefish (*Prosopium williamsoni*). Additionally, lake trout (*Salvelinus namaycush*) may have also been sympatric with lacustrine grayling in Elk Lake. The introduction of non-native fishes, especially salmonids, is thought to be an important, and perhaps the most critical, factor affecting the decline of fluvial grayling in Montana. If there is one "common denominator" underlying all streams in Montana from which grayling have disappeared, it is the presence of one or more introduced salmonids - rainbow trout, brown trout, or brook trout.

Observations by Lee (1985) provide evidence that Arctic grayling can compete effectively with native sympatric salmonids. In a study of age-0 grayling and two other species in Alaska, chinook salmon (*Oncorhynchus tshawytscha*) and round whitefish (*Prosopium cylindraceum*), Lee found that grayling was the most agggressive species and dominated equal-sized individuals of the other two species. Grayling appeared able to displace round whitefish from preferred habitat. In the field, spatial segregation among the three species appeared to reduce their interactions and competition.

Rainbow, brown and brook trout were introduced into grayling streams of the upper Missouri River drainage by 1900. All three species had been introduced into tributaries of the upper Madison River within Yellowstone Park by 1890 (Jordan 1891), and brown and rainbow trout were common in the upper and middle (near Ennis) parts of the River by about 1915 (Vincent

1962). The Madison River became known for its rainbow and brown trout fisheries and by about 1940 the once-abundant grayling of the Madison River had become rare, except in Ennis Reservoir.

For other waters in Montana, the evidence for a relationship between establishment of non-native salmonids and decline of grayling appears less conclusive. Introductions of brook, rainbow and brown trout began in the Gallatin and Smith River drainages in 1897-1898, and into the Sun River in 1913, but grayling appeared already undergoing serious declines in those drainages by that time. In addition to the Madison River, the best examples for an association between increase in competing salmonids and decline of grayling were in Michigan. There the competitor was the brook trout. Grayling were in serious decline in waters like the Jordan River and Boyne River by the 1870's, before habitat degradation or angling pressure could have had important effects.

POSSIBLE CONTRIBUTING FACTORS ON THE BIG HOLE RIVER

Fishing Pressure and Harvest

Before the adoption of more restrictive angling regulations, grayling may have been caught and harvested at disproportionately high ratios from the Big Hole River. Grayling accounted for a much higher proportion of anglers' catches than obtained through electrofishing surveys in 1959. Grayling made up 6% of 500 salmonids reported in MDFWP warden creel census of the Big Hole River above Pintlar (Wipperman 1965), in contrast to 1% in the electrofishing surveys that same year in a similar portion of the river (Heaton 1960). In the nine years from 1954 to 1962, the average percentage of grayling among salmonids caught in the Big Hole River was about 10% between Divide Dam and Pintlar Creek (annual range 2.6-22.4%) and about 13%

from Pintlar Creek upstream (annual range 1.1-44.9%) (Wipperman 1965). Varley (1977) reported that grayling made up only about 0.5% of fish sampled by electrofishing in the upper river, but were the predominant fish in catches of fishermen interviewed in the same area.

These figures suggest that grayling were easier to catch than trout and were being removed from the fish community at a disproportionately high rate. However, it is possible that the actual proportion of grayling in the salmonid community was higher than indicated by electrofishing, if they were concentrating in the larger, deeper pools that could not be effectively electrofished (Wipperman 1965). Regulations on angler harvest of grayling from the Big Hole River have become increasingly more restrictive in recent years: five fish (in combination with trout) up to 1983, one grayling from 1983-84 to 1987-1988, and catch and release since 1988-89. Thus far the grayling population of the Big Hole River has not responded to the more restrictive regulations and has apparently continued to decline between 1983 to 1989 (Shepard and Oswald 1989).

Habitat Alteration

Among the factors most commonly cited as being detrimental to Big Hole River grayling is the partial dewatering of the river and its tributaries during the summer by irrigation diversions (Heaton 1960; Liknes 1981; Shepard and Oswald 1989). In addition to reduction in available habitat for grayling of all ages, other possible effects of dewatering include stranding of incubating eggs or young fish, increased predation on young through their being concentrated in remnant waters with adults and other fishes, reduced food availability through habitat reduction for aquatic invertebrates, and increased maximum daily temperatures. The mechanisms through which reductions in stream discharge volume may influence Big Hole

River grayling have not been investigated, but it appears that weak year classes are associated with lower flows and strong year classes with flows normal to slightly above average (Shepard and Oswald 1989).

In addition to stream dewatering, the diversions are also causing loss of grayling, especially young fish. Grayling fry and juveniles are found in the ditches and may be carried into irrigated fields or left stranded in the ditches when headgates are closed at the end of the irrigation season (Shepard and Oswald 1989). While the magnitude of this loss is not known, an earlier study of trout in irrigation diversions from Montana streams indicates that such loss can be substantial (Clothier 1953).

Another major alteration on the river is the presence of Divide Dam near the town of Divide. The dam was originally built in 1899 (M. Patterson, Butte Water Company, pers. comm.) by the Butte Water Company to divert water into its municipal supply system. A second, hydroelectric dam built a short distance upstream a few years later by the Montana Power Company was destroyed by a flood in 1927. The migrations of grayling between upstream spawning and downstream wintering areas in the Big Hole River (Shepard and Oswald 1989) and in Alaskan rivers (Armstrong 1986) have been previously mentioned. It is possible that migrations up and down the Big Hole River were originally more extensive than at present and included movements between the lower and upper reaches now separated by a dam. Although grayling may be able to swim over the dam during periods of high water flow, it is a general barrier to upstream migration (Heaton 1960; Wippperman 1965). Rainbow and brown trout replaced grayling in the lower river sometime after construction of these dams, perhaps because grayling declined from having their access to upstream spawning areas restricted, and/or through interspecific interactions with non-native salmonids.

The Divide dams could have had two contrasting effects on grayling in the upper river. Without the fish being able to move between upper and lower sections of the river, each section of river alone may represent marginal quality habitat for fluvial grayling. On the other hand, it is possible that the Divide dams have had a role in preserving the grayling population by inhibiting free upstream movement of non-native trout, especially brown trout, into the upper river. These two roles are not necessarily mutually exclusive; the dams could have confined the grayling within marginal quality habitat but helped to save them there by inhibiting upstream colonization by brown trout.

Information is not available to determine whether other habitat parameters such as stream temperatures or turbidities of the Big Hole River have been degraded through human activities and have contributed to the decline of grayling. Present midsummer water temperatures in the upper Big Hole River may be at times marginal for grayling, and stream dewatering may be contributing to elevated temperatures. Liknes (1981) suggested that higher numbers of grayling in the Wisdom area than in areas further downstream could be related to cooler temperatures. However, temperatures may also become marginal in the Wisdom section. For example, continuous recordings by the U.S. Geological Survey (1989) indicate that maximum daily water temperatures in the Wisdom area consistently exceeded 20 ^{o}C during July 1988 and reached a maximum of 24.5 ^{o}C. Although 24.5 ^{o}C is below levels that would produce a thermal kill of grayling (Feldmeth and Eriksen 1978), temperatures above 20 ^{o}C may be higher than optimum for the species (Hubert et al. 1986).

Feldmeth and Eriksen (1978) hypothesized that warmer temperatures may favor non-native salmonids over native grayling and cutthroat trout in

Montana. They measured upper critical thermal maxima of 26.9 °C for adult grayling and 28.7 °C for grayling fry acclimated to about 13 °C, compared to critical thermal maxima of 29.8, 29.6, and 31.6 for brook, rainbow, and brown trout, respectively. They concluded that the lower thermal tolerance of grayling would make them susceptible to being replaced by the non-native salmonids at warmer temperatures.

In an earlier and more intensive study, however, McCauley (1958) derived lower short-term lethal temperatures for brook trout than Feldmeth and Ericksen. Upper lethal temperatures in his study were about 27.0 and 25.5 °C for brook trout (juveniles?) acclimated to 20 and 10 °C, respectively. These values indicate that brook trout may have lower, rather than higher, tolerance for warm temperature than do grayling. This suggests that brook trout would be more adversely affected than grayling by warm summer temperatures. If so, then warm summer temperatures of the upper Big Hole River would not account for the dominance of brook trout over grayling (and over rainbow and brown trout) in the salmonid community of the upper Big Hole River.

Interactions with Non-Native Species

The best evidence for detrimental effects of interactions with non-native fishes in the Big Hole River is provided by the lower river below Divide Dam. Grayling have become rare in these lower reaches, which are dominated by brown trout and in which rainbow trout are also abundant (Oswald 1984, 1986). Very limited information suggests that grayling were largely replaced in these reaches by rainbow trout before brown trout were introduced. According to S. J. Seidensticker of Twin Bridges (pers. comm.), grayling were abundant and easily caught in his grandparents' time, in the 1890's, near the family ranch in waters around the confluence of the

Big Hole River and the Jefferson River. By his boyhood in the late 1920's, grayling had become relatively uncommon and the main sportfish caught was rainbow trout. He also related that in the late 1920's to early 1930's, a local sportmen's club introduced brown trout into the lower Beaverhead River near its confluence with the Big Hole River, and that this may have been their first introduction into these waters. Brown trout had become the predominant salmonid at least by the 1950's (Heaton 1961; Wipperman 1965). Thus it appears that species interactions in the lower river have followed a pattern consistent with other former grayling streams in the upper Missouri drainage; establishment of brown or rainbow trout associated with disappearance of grayling. It is not known whether the few grayling present in the lower river originate locally or whether they represent fish which have moved down from reaches further upstream.

Interactions with non-native salmonids may also be important in the upper Big Hole River. According to a personal account cited by Liknes (1981), brook trout have been in the river since about 1929. Since at least the 1950's and continuing to the present, brook trout have been the dominant salmonid in the upper river and small numbers of rainbow trout are also present (Heaton 1961; Wipperman 1965; Oswald 1984, 1986). A recent upstream expansion of brown trout distribution in the Big Hole River represents obvious additional concern. Brown trout were not seen above Divide Dam in electrofishing surveys in 1959 and 1964 (Heaton 1961; Wipperman 1964), but started being seen in small numbers in later surveys (Wells and Rehwinkel 1980; Liknes 1981).

If species interactions are contributing to the low densities and apparent continuing decline of fluvial grayling in the upper Big Hole River, only the brook trout appears sufficiently numerous to be exerting such an effect. However, data are lacking on mechanisms of possible interactions between grayling and brook trout and the relations between the two species are not understood. Nelson (1954) reported finding a few grayling fry in the stomachs of brook trout in the spawning tributary of Upper Red Rock Lake, but this observation did not necessarily indicate that grayling fry are particularly vulnerable to predation. McMichael (1990) found sucker fry (unidentified Catostomus species), longnose dace (Rhinichthys cataractae), and young mountain whitefish, but no grayling in the stomachs of 35 brook trout collected from the upper Big Hole River. Skaar (1989) found differences in habitat occupied by brook trout and grayling in the upper Big Hole River. Age-1+ brook trout were most abundant in higher gradient sections and faster flowing water, while grayling were more typically found in slow runs or pools with depths of 0.6 m or greater. It is not known whether this difference in habitat use results from difference in preference between the two species or from competitive displacement of one by the other.

It is interesting to speculate on possible reasons for the persistence of fluvial grayling in the upper Big Hole River despite the long presence of non-native salmonids, contrary to their disappearance from all other streams in Montana and Michigan. One possibility is that the present situation represents the final stages of the complete replacement of this fluvial grayling population by the non-natives. Vincent (1962) concluded that it takes about 40 years for fluvial grayling to be replaced by introduced species. Grayling have persisted in the Big Hole River longer than this prediction, however, since brook trout appear to have been present in the river for about 60 years.

Another possibility is that the upper Big Hole River is marginal quality habitat for salmonids in general, and that fluvial grayling have persisted there because they are as able or better able to withstand certain unfavorable conditions, such as partial stream dewatering, than brown or rainbow trout. This hypothesis is indirectly supported by the situation previously described for the Sunny Slope Canal, where grayling persist despite severe seasonal dewatering and where rainbow trout are present in only small numbers. Marginal habitat conditions may thus have a dual effect on grayling in the upper river, serving both to depress the grayling population while preventing their replacement by non-native salmonids. As with other potential factors, however, evidence is lacking for the role or mechanisms of interactions between grayling and non-native salmonids in the upper Big Hole River.

CONCLUSIONS

1. Montana grayling are genetically divergent from northern populations in Alaska and Canada, and the remnant fluvial grayling of the Big Hole River drainage is a genetically identifiable stock of Montana grayling that is adapted for permanently inhabiting a stream environment.
2. Evaluation of reported presence of Montana grayling in streams indicates that the only confirmed, self-sustaining population which lives continuously and permanently in a flowing-water environment is that of the upper Big Hole River and lower parts of its tributaries.
3. The Big Hole River population appears to be in continuing decline. Estimated densities of age-1+ fish in the most heavily occupied section of the upper river, near Wisdom, have decreased progressively from an already low level of about 69/km in 1983 to a critically low level of about 14/km in 1989.

4. Age-0 fingerlings are most common near the known spawning areas near Wisdom, where their estimated density was about 196/km in September 1989.
5. At least part of the population undergoes migrations between spawning areas upstream in the Wisdom area and wintering areas up to about 65 km downstream near the Divide Dam.
6. Effects on Big Hole River grayling of the present and former Divide Dam are not known. On one hand, it is possible that the dams have interrupted what were once more extensive migrations involving the lower river and may have contributed to decline of Big Hole River grayling. On the other hand, the dams may have contributed to the persistence of grayling in the upper river by inhibiting upstream colonization by brown trout.
7. Attempts to establish or restore self-sustaining populations in streams in Montana and other states through stocking programs have thus far proven unsuccessful. Major contributing reasons for these failures may have been the planting of fish derived from lacustrine populations, the planting of predominantly very young fry, and the presence of non-native salmonids in the streams planted.
8. Lacustrine populations of Montana grayling have been greatly expanded in distribution through introductions into lakes in Montana and other states and appear in no present danger. However, their status also needs to be monitored since grayling have had a history of thriving for a time in certain lakes in Montana and then declining sharply. Most of these lacustrine populations appear to be descendents of fish originally spawned in a tributary of Ennis Reservoir on the Madison River.

9. Very little is known about the factors responsible for the disappearance of grayling from most streams it formerly inhabited in Montana, or which presently may be producing the low numbers, low densities, and apparent continuing decline of fluvial Montana grayling in their last refuge, the upper Big Hole River. Physical habitat alterations, interactions with non-native salmonids, and past fishing overharvest may all have contributed to this decline but the evidence in each of these categories is inconclusive and often speculative. It can even be hypothesized that marginal habitat conditions for salmonids in the upper Big Hole River may be contributing to the persistence of fluvial grayling by inhibiting the non-native salmonids.

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CURRENT ACTIONS

In response to repeated designations, by state and national agencies and organizations, of fluvial Montana grayling as a fish of "special concern" and to recent field surveys indicating continuing decline of the only known population, in the Big Hole River, the following are among measures that have been undertaken or initiated recently:

1. An interagency Montana Arctic Grayling Committee was established in 1987, consisting of representatives from the Montana Department of Fish, Wildlife and Parks, Montana State University, University of Montana, Montana Cooperative Fishery Research Unit, U.S. Fish and Wildlife Service, U.S. Forest Service (Beaverhead National Forest), U.S. Bureau of Land Management, and the Montana Natural Heritage Foundation. This committee periodically evaluates information on the status of fluvial Montana grayling, is constructing a Restoration Plan (latest version in Appendix 2), and serves as the focus of recovery efforts.
2. Monitoring of the Big Hole River population through electrofishing mark-and-recapture methods is being conducted by personnel of the Montana Department of Fish, Wildlife and Parks and Beaverhead National Forest (most recently by Richard Oswald and Brad Shepard). These efforts have also recently resulted in initial identification of wintering and spawning areas and demonstrated migrations between areas.
3. Discussions have been initiated with major irrigators to attempt to provide more stable flows during the spring spawning and incubation period, and also to facilitate return of grayling into the river from irrigation ditches by incrementally reducing flows in diversions during fall shut-down (Shepard and Oswald 1989).

4. Regulations were changed to allow only catch-and-release fishing for grayling on the Big Hole River, effective from 1988-1989.

5. To investigate factors that may be affecting production and survival of age-0 and older grayling in the river, field studies on distribution, abundance, and habitat utilization were initiated in the summer of 1988 and have continued in 1989 and 1990, These studies have been supported by the Montana Natural Heritage Foundation, Montana Department of Fish, Wildlife and Parks, Montana Cooperative Fishery Research Unit, and the Beaverhead National Forest, and have been coordinated by the Montana Natural Heritage Foundation.

6. A program has been initiated to supplement the Big Hole River population with hatchery-reared fish of this same stock:

(A) On August 31, 1988, approximately 2800 three-month-old Big Hole River fingerlings were planted into one of the Axolotl Lakes in Madison County. These were progeny from eggs of 15 fish (6 females) from the Big Hole River. The eggs were incubated and young reared at the Fish Technology Center (U.S. Fish and Wildlife Service) in Bozeman by the author and hatchery personnel. The fish in the lake averaged about 27 cm in length in samples taken in the early summer of 1990 (Oswald, pers. comm.), and it is hoped they will become sexually mature in spring, 1991. An effort is planned to obtain as many eggs as possible from these fish, starting in 1991, rear the young at the hatchery to a juvenile stage, and then release them into the river.

(B) An additional, captive brood stock is being started from progeny of Big Hole River fish spawned in 1990 (from a parental pool of about 10 fish). Approximately 700 young were being reared at the Fish Technology Center as of mid-September 1990 (P. Dwyer, U.S. Fish and

Wildlife Service, pers. comm.) and some of these will be retained and reared as captive brood stock. The remainder will be released into Axolotl Lake to increase the number of founding individuals of the population. It is hoped that the captive brood stock will also provide young for release into the river.

RECOMMENDATIONS

1. The planned augmentation of the Big Hole River population with first generation progeny derived from this same population should be carried out. It should be recognized, however, that this measure is a temporary one intended to augment the population and prevent its extirpation while other long-term measures are taken to identify and correct the underlying problems. This is not intended to be an indefinitely long program to artificially sustain the Big Hole River population.
2. To address the latter, long-term measures, the other aspects of the recovery plan outlined by the Montana Fluvial Arctic Grayling Committee (Appendix 2) should be pursued. These recommendations, too numerous to repeat here, have a target goal of 250 age-1+ grayling/mile (155/km). It is hoped that this can be achieved through improving stream habitat for grayling in the upper Big Hole River, determining mechanisms of interaction with non-native salmonids, controlling or eliminating non-native salmonids, preventing fishermen harvest of grayling, and increasing public awareness of the value and plight of this indigenous fish. Some measures have already been initiated.
3. To evaluate the responses to recovery measures of not only the grayling population but also the overall salmonid community, monitoring of the

status of fish in the Big Hole River should continue. It may be important to keep note of the possibility that measures to improve salmonid habitat could turn out to better benefit the non-native brook, rainbow, or brown trout and thereby actually work to the detriment of grayling through increased negative interspecific interactions.

4. Interactions between grayling and non-native salmonids present in the upper Big Hole River, particularly the numerically dominant brook trout, should be determined. Such information may indicate whether recovery efforts can succeed in the presence of non-native salmonids, and provide the biological justification for efforts to eliminate or drastically reduce their numbers should such measures be undertaken in the future.

5. Another objective of the Montana Fluvial Grayling Committee should be pursued, to identify additional drainages that could support fluvial grayling and establish populations in those drainages. Two questions should be investigated as part of such efforts: (1) Can Big Hole River grayling exist as fluvial fish in smaller streams that do not provide the opportunity for extensive migrations between downstream wintering areas and upstream spawning and rearing areas? This may be addressed by experimental introduction of Big Hole River fish into a candidate stream. (2) If not, are there alternative populations that could exist in smaller waters, for example, are there self-sustaining populations in tributaries of the Big Hole River?

6. The genetic characteristics of Big Hole River grayling should continue to be examined. Because millions of young indirectly derived from the Madison River drainage were planted in the Big Hole River in the past, hybridization between these stocks may have occurred. If the two

drainages still contain genetically divergent populations, then introductions of Big Hole grayling into streams of the Madison River drainage, such as into tributaries of the upper Madison River in Yellowstone National Park, may not be desireable. Instead, it may be preferable to use grayling which have fluvial characteristics and which are derived from the Madison River drainage. One candidate source would be the outlet-spawning Deer Lake population, which is in the genetic group of populations indirectly derived from the Madison River drainage (Leary, pers. comm.) and whose young have fluvial characteristics (Kaya 1989; Deleray 1990).

Appendix 1

Recorded plantings of grayling into Montana streams (data from MDFWP fish planting database unless otherwise noted).

Location	Date	Hatchery	Number
Big Hole River Drainage			
Big Hole R.	6/03/37	Anaconda	1,200,000
"	6/19/37	"	1,200,000
"	6/20/37	"	1,000,000
"	6/17/38	"	160,000
"	7/05/43	"	222,600
"	6/21/45	"	105,000
"	6/09/46	"	150,000
"	6/20/46	"	300,000
"	6/27/46	"	500,000
"	6/13/47	"	160,000
"	6/26/48	"	528,000
"	6/30/48	"	475,000
"	8/07/48	"	3,600
"	6/22/49	"	245,000
"	6/27/49	"	400,000
"	6/27/50	"	300,000
"	7/03/50	"	500,000
"	7/05/50	"	300,000
"	6/14/51	"	540,000
"	6/19/51	"	250,000

Big Hole R.	8/03/51	Anaconda	90,000
"	6/04/52	"	940
"	6/05/52	"	1,880
"	6/06/52	"	376
"	5/18/53	"	2,000
"	7/01/53	"	637,521
"	10/08/57	"	1,448
"	5/17/62	Somers	1,080
Odell Creek	6/26/29	Anaconda	1,000,000
Wise River	6/10/35	"	152,000
"	6/16/52	"	500,000
California Creek	6/23/37	"	750,000
Deep Creek	6/23/37	"	750,000
"	10/01/37	"	1,920
N. Fork Big H.	7/05/43	"	222,600
"	6/30/44	"	200,000
"	6/15/46	"	175,000
"	6/30/48	"	250,000
"	6/22/49	"	196,000
"	6/14/51	"	270,000
"	6/06/52	"	3,766
"	6/10/52	"	220,000
Governor Cr.	6/21/45	"	300,000
Lion Creek	6/26/51	"	200,000
Pintlar Cr.	8/03/51	"	500
Swamp Creek	6/06/52	"	5,646

Beaverhead River Drainage			
Bloody Dick Creek	6/17/37	Anaconda	600,000
Alder Gulch Creek	9/23/46	Ennis	12,000
Jefferson River Drainage			
Boulder River	6/24/41	Anaconda	100,00
Madison River Drainage			
Madison R.	6/07/34	Anaconda	80,000
"	10/24/46	Ennis	2,100
"	6/07/66	"	2,247
S. Fork Mad.	6/21/28	"	1,000,000
"	6/23/29	"	1,000,000
"	6/11/38	"	400,000
Odell Creek	6/16/48	"	10,080
"	6/16/48	"	6,480
"	6/18/48	"	3,360
"	6/23/48	"	50,000
"	6/25/48	"	50,000
"	7/19/61	"	299
Gallatin River Drainage			
Gallatin River	1938	Bozeman[1]	25,931
"	1939	"	45,800
"	1940	"	31,600
"	1941	"	24,350
"	7/19/61	Ennis	10,004

Sun River Drainage			
Sun River	6/24/28	Anaconda	1,000,000
"	4/29/83	(wild)[2]	636
"	10/13/83	(wild)[2]	406
Smith River Drainage			
Smith River	6/05/37	Anaconda	1,200,000
"	10/03/38	Big Timber	35,250
"	9/13/38	Great Falls	29,000
"	5/25/39	"	2,500
"	6/19/41	(not given)	3,000
N. F. Smith	6/11/33	Anaconda	1,000,000
Deep Cr.	6/09/35	"	570,000
Mitchell Gulch	6/09/70	"	5,000
Milk River Drainage			
Little Box Elder	8/09/34	(not given)	3,570
"	8/12/34	(not given)	6,300
Peoples Creek	8/10/34	(not given)	4,620
Little Peoples Cr.	8/13/34	(not given)	4,200
Beaver Creek	8/16/34	(not given)	60,196
Other Missouri River Tributaries			
Big Spring Creek	10/03/34	Big Spring	15,000
Cow Creek	8/10/34	(not given)	2,856
Warm Springs Cr.	6/27/37	Anaconda	300,000
Silver Creek	6/09/70	Somers	10,000

Yellowstone River Drainage

Yellowstone R.	10/07/38	Big Timber	21,750
Rock Creek	6/22/35	Anaconda	250,000
Big Timber Creek	10/10/38	Big Timber	3,000
Bluewater Creek	5/23/63	Somers	2,000

Clark Fork Drainage

Warm Springs Cr.	9/02/37	Anaconda	6,800
"	10/04/37	"	1,080
"	7/06/45	"	1,275
Flint Creek	6/18/48	"	225,000
"	6/28/48	"	300,000
"	7/01/53	"	636,773
"	7/03/53	"	180,000
N. F. Flint Cr.	6/29/49	"	400,000
"	6/26/50	"	500,000
"	6/30/50	"	500,000
"	7/13/50	"	250,000
"	6/18/51	"	750,000
"	6/20/51	"	330,000
"	6/17/52	"	300,000
"	6/19/52	"	500,000
"	6/20/52	"	400,000
"	6/25/52	"	200,000
Stuart Mill Creek	7/06/52	"	336,072

Bitterroot River Drainage			
Mine Creek	6/26/48	(not given)	123,760
Rombo Creek	6/26/48	"	18,016
Flathead River Drainge			
Bond Creek	6/06/35	Somers	120,000
Kootenai River Drainage			
Pipe Creek	7/05/43	(not given)	25,000

[1]Plantings in the upper Gallatin River with grayling from the federal hatchery in Bozeman, reported by Tyron (1947).

[2]Wild fish transplanted from Sunny Slope Canal.

RESTORATION PLAN

MONTANA FLUVIAL ARCTIC GRAYLING
(Thymallus arcticus montanus)

Prepared By: Fluvial Arctic Grayling Workgroup
Spring 1990

INTRODUCTION

Distribution in Montana

The presence of Arctic grayling in Montana is a result of the last continental glaciation some 12,000 - 15,000 years ago. During glacial ages arctic and subarctic plants and animals move alternately southward and northward with the advance or retreat of the ice front. Thus the grayling were pushed south by the advancing ice sheets of the Wisconsin glaciation. When the ice retreated relict populations of Arctic grayling were isolated in Montana and Michigan along the southern edge of the range of the species.

When Lewis & Clark travelled through Montana in 1805 they caught grayling in the Beaverhead River near what is now Clark Canyon Reservoir. It is generally believed that at that time the grayling was distributed throughout the Missouri River drainage upstream of the Great Falls. Although abundant in some drainages such as the Madison, Gallatin and Jefferson Rivers, distribution was irregular. For instance, grayling were found in only two Missouri River tributaries, the Smith and Sun Rivers, downstream of the three forks of the Missouri. The grayling were part of a cold water fishery characterized by low species diversity. Other fish included cutthroat trout and whitefish as well as sculpin. The native Montana grayling was principally river dwelling (or fluvial), the only lakes to which it had access were the Red Rocks Lakes in the Centennial Valley.

The distribution of the Arctic grayling in Montana is very different today than it was in 1805. Being at the edge of its range, and believed to have a narrow ecological amplitude due to a limited gene pool, the grayling has not adapted well to changes in its environment (R.E. Vincent. 1962. Biogeographical and Ecological Factors Contributing to the Decline of Arctic Grayling in Michigan and Montana). Competition from non-native salmonids (brook, rainbow and brown trout), habitat degradation and susceptibility to overfishing have resulted in the elimination of grayling from most of its riverine habitat. The only self-sustaining fluvial grayling populations are found in the upper Big Hole drainage. A number of lake dwelling populations have been established through an aggressive stocking program. The original stock that has formed the basis of most of these plants is believed to have originated from Madison River and Red Rocks Lakes populations.

Taxonomy

The genetic relationships between the North American grayling stocks have been debated for many years. At one time the Arctic, Michigan and Montana populations were considered separate species. Today all North American grayling are included together as Thymallus arcticus.

Electrophoretic investigations conducted by F.W. Allendorf and his associates at the University of Montana have shown that the amount of genetic variation in Arctic grayling is low compared to other salmonids. However, the lake populations in Montana and Wyoming are considered different genetically from the Big Hole River population. The Big Hole River grayling sample upon which this conclusion was made was taken from the upper river. Madison River-derived hatchery grayling have been planted in this section of the river. The researchers concluded that these plants either did not take or did not contribute overwhelmingly to the spawning population. The researchers stated "currently the allele frequencies at variable loci in the Big Hole River population are significantly different from those of the other Montana and Wyoming grayling populations sampled".

The conclusions of the geneticists have been buttressed by behavioral work conducted by Dr. Cal Kaya at Montana State University. This work compared the response of young grayling from the Big Hole River and from inlet- and outlet-spawning lacustrine populations to flowing water. The experiments showed that Big Hole grayling have a higher tendency to maintain position in a current, than the other grayling. Since all young were incubated and reared in the laboratory under identical conditions, these behavioral differences appear innate and genetically based. These results support the hypothesis that grayling in the Big Hole River have adaptations necessary for permanent residence in a stream environment.

Previous Efforts at Restoration and Protection

Concern over the fate of the Montana form of the Arctic grayling has been expressed for a number of years. J.L. Kelley, Montana Fish and Game Commissioner, wrote in a 1931 issue of Montana Wildlife that the "tribe of Thymallus is decreasing" and that "stocking efforts are critical to the survival of this royal member of the piscatorial family". Dr. C.J.D. Brown wrote in 1949 "It is urgent that steps be taken immediately to insure the preservation of this species . . .. There are certainly a few streams which could be reserved for grayling or grayling and cutthroat to the exclusion of other species. The upper Big Hole River and tributaries are definitely indicated."

Discussions began in 1957 and continued through 1960 regarding the possibility of having the Red Rock Lakes Wildlife Refuge considered a grayling refuge as well as a trumpeter swan refuge. This effort proved unsuccessful due to the lack of interest by the refuge manager at the time.

In the early 1960's there was growing concern about rare and endangered fish and wildlife species. The states were asked to develop lists of fish species considered rare. The Arctic grayling and cutthroat were the species listed by Montana for inclusion in the first USFWS Red Book. Dr. Robert Miller's 1972 paper titled Threatened Freshwater Fishes of the United States included the Arctic grayling in Montana as 'rare'. In 1989, the American Fisheries Society Endangered Species committee published Fisheries of North America Endangered, Threatened or of Special Concern: 1989. The article lists the Montana grayling as a species of special concern. The Montana Chapter AFS, Montana Natural Heritage Program and Montana Department of Fish, Wildlife and Parks have long considered the Arctic grayling a Class A species of special concern. The Montana Arctic Grayling is classified C2 by the U.S. Fish and Wildlife Service. The U.S. Forest Service considers the Montana Arctic grayling a sensitive species.

Objectives

1. Increase population numbers, improve habitat and expand the range of Montana fluvial Arctic grayling so that they are no longer in danger of extinction.

2. Establish a viable, self-sustaining fluvial Arctic grayling population in the Big Hole River (mean density of 250 Age 1+ grayling in the reach from Clemow Lane to Dickey Bridge).

This objective will be attained within 25 years (2015).

3. Establish viable, self-sustaining populations in additional drainages within the historic range of the grayling that have the potential to support self-sustaining fluvial populations. This objective will be completed by ________________.

4. Maintain the genetic integrity of Montana fluvial Arctic grayling in the Big Hole and in additional drainages where populations are established.

The Restoration Plan consists of six basic elements:

- A broodstock/genetic reserve element to guarantee the genetic integrity of the Montana fluvial Arctic grayling and provide fish for re-stocking the Big Hole River and other drainages believed to be capable of supporting self-sustaining populations of fluvial Arctic grayling.

- Fish population management, principally through regulations, to protect the Big Hole River Arctic grayling population while reducing populations of competing introduced species.

- Habitat management strategies and studies that will maintain and improve Big Hole River Arctic grayling habitat.

- Studies to determine the factors that currently limit the Big Hole River Arctic grayling population. These studies will focus on elucidating grayling habitat requirements by life stage and season, habitat mapping and determining the role of interspecific competition with introduced species in limiting the Big Hole River Arctic grayling population.

- Monitoring of Big Hole River Arctic grayling populations to keep track of the status of the population and evaluate success of restoration efforts.

- Public information and education program to inform the public of the status of the Arctic grayling, the restoration efforts underway and how the public can help in these efforts.

ACTION ITEMS

MONITORING

(from prioritized listing sent by Oswald & Shepard to Peterman - December 1989)

1990	1991	1992	1993	1994	1995
1. Fall population estimate and tagging.					
2. Early summer population estimate and tagging.					
3. Monitor characteristics of the spawning population of grayling in the Big Hole from Clemow Lane to Fish Trap Creek.					
4. Late summer-early fall population estimate of YOY grayling.					
5. Monitor populations of planted and wild grayling to assess restocking program.					

ACTION ITEMS
MONITORING (CONTINUED)
(from prioritized listing sent by Oswald & Shepard to Peterman - December 1989)

1990	1991	1992	1993	1994	1995
6. Conduct a voluntary creel study of angler catch of grayling utilizing outfitters and interested anglers.	→	→	→	→	→

ACTION ITEMS
STUDIES
(from prioritized listing sent by Oswald & Shepard to Peterman - December 1989)

1990	1991	1992	1993	1994	1995
1. Collect hollow core substrate samples from several spawning sites. Collect eggs and fry from same locations. Develop relationship between substrate composition and egg and fry production.	1. Assess potential for electrofishing/tagging mortality on grayling.	1. Habitat type the Big Hole River from Twin Lake Road to Dickie Bridge. Integrate data with other habitat and population data.	→	→	1. Habitat type lower reaches of Big Hole tributaries.
2. Localized habitat streamflow and temperature data collection. Relate this data to YOY survival and adult populations.	2. Determine grayling winter habitat preferences.	2. Lab and field study of brook, rainbow, and brown trout, mountain whitefish and grayling competition.			
		3. Study of brook trout predation on YOY grayling in an artificial channel.	→	1. Food habitats study of Artic grayling, brook trout and mountain whitefish.	→

ACTION ITEMS
STUDIES (CONTINUED)
(from prioritized listing sent by Oswald & Shepard to Peterman - December 1989)

1990	1991	1992	1993	1994	1995
3. Prepare a habitat map encompassing the historic and present range and distribution of fluvial Arctic grayling in Montana.					
4. Prepare a map showing introductions of exotic species that may have influenced the decline of the fluvial arctic grayling.					

ACTION ITEMS
FISH/POPULATION MANAGEMENT

1990	1991	1992	1993	1994	1995
1. Maintain catch and release regulation on Big Hole grayling until mean density of Age 1+ reaches 250 per mile.					
2. Maintain liberal limits to promote harvest of introduced potentially competitive species.					
3. Request Red Rocks Refuge personnel to manage the Refuge with grayling in mind.					
	1. Test whether electrofishing or chemical removal of exotic species has potential as a means to enhance grayling populations.				

ACTION ITEMS
HABITAT MANAGEMENT

1990 | 1991 | 1992 | 1993 | 1994 | 1995

1 Seek to obtain conservation easements along the Big Hole River with particular emphasis on Jackson to Squaw Creek. Easements should incorporate sound grazing and land management practices.

2. Actively pursue water leasing.

3. Institute a voluntary program of cooperative irrigation management.

4. Actively monitor all land use activity within the basin and restrict any activity that could negatively affect grayling habitat.

ACTION ITEMS
HABITAT MANAGEMENT (CONTINUED)

1990	1991	1992	1993	1994	1995
		1. Identify irrigation ditches posing greatest threat to grayling and assess entrainment of YOY grayling in these canals.			1. Enhance spawning, rearing and overwintering habitats.

ACTION ITEMS
BROODSTOCK/GENETIC RESERVE

1990	1991	1992	1993	1994	1995
1. Select a second refuge site. (Odell Lake, Wade Lake)	1. Check Axolotl Lake for spawning grayling. Conduct egg collection if possible.	1. Axoltl Lake egg collection.	1. Axolotl Lake egg collection.	→	→
2. Conduct spring Big Hole River egg take. Raise fry in hatchery.	2. Plant Axoltl fingerlings in Big Hole River.	2. Check 2nd site for spawning grayling.	2. 2nd site egg collection.	→	→
3. Plant fingerlings in Axolotl Lake, new site and Big Hole River.		3. Plant fingerlings in Big Hole River.	3. Plant fingerlings in Big Hole River.	→	→
4. Meet with Axolotl Lake landowners; arrange for P.R. and catch & release signing.					4. If Big Hole River population is increasing, plant a portion of the fingerlings in identified drainages.
5. Develop genetic management plan for Big Hole River broodstock.					
6. Identify drainages that could support self-sustaining fluvial Artic grayling populations.	→	→			

ACTION ITEMS
PUBLIC INFORMATION AND EDUCATION

1990	1991	1992	1993	1994	1995
1. Voluntary creel census (see Monitoring above.					
2. Film and distribute video of irrigation management.					
3. Montana Outdoors article describing plight of grayling and recovery plan.					

169.2