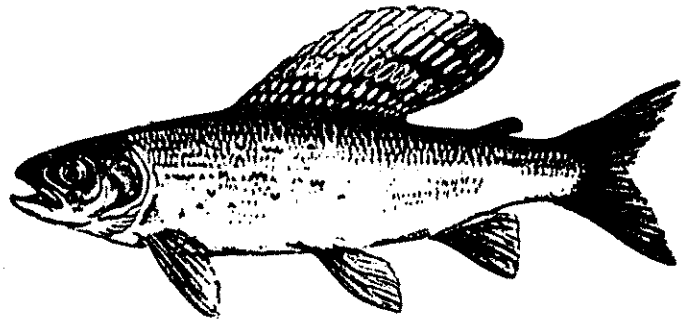
F-02-14
(F-6-21)
Subject to
Region 3

MONTANA FLUVIAL ARCTIC GRAYLING RESTORATION PLAN



Prepared By

MONTANA FLUVIAL ARCTIC GRAYLING WORKGROUP

November 1995

MONTANA FLUVIAL ARCTIC GRAYLING RESTORATION PLAN

MONTANA FLUVIAL ARCTIC GRAYLING WORKGROUP

November 1995

Montana Fish, Wildlife & Parks
1420 East Sixth Avenue
PO Box 200701
Helena, MT 59620-0701

COMMITTEE MEMBERS

SIGNATURE PAGE

MONTANA FISH, WILDLIFE & PARKS

MONTANA CHAPTER AMERICAN FISHERIES SOCIETY

U.S. BUREAU OF LAND MANAGEMENT

U.S. FISH & WILDLIFE SERVICE ECOLOGICAL SERVICES

YELLOWSTONE NATIONAL PARK

MONTANA NATURAL HERITAGE PROGRAM

CAL KAYA

ROBB LEARY

MONTANA POWER COMPANY

U.S. FISH & WILDLIFE SERVICE FISHERIES

U.S. FOREST SERVICE
NORTHERN REGION

STATEMENT OF INTENT

This Montana Fluvial Arctic Grayling Restoration Plan was prepared by an interagency workgroup chaired by Montana Fish, Wildlife and Parks. This Plan is intended to provide general guidance for the restoration of fluvial Arctic grayling in Montana. Individual agencies are encouraged to cooperate to meet the intent of this Plan and direct grayling restoration efforts within their areas of responsibility. The Plan also recommends that restoration of grayling in Yellowstone National Park be given priority consideration by the National Park Service. It is the hope of the Workgroup that the actions described in this plan will be implemented, leading to restoration of the Montana grayling. The Montana Fluvial Arctic Grayling Restoration Plan will be revised periodically as new information warrants.

Restoration of grayling will require the cooperation of all of the entities represented on the Workgroup, but especially the people of Montana.

The Workgroup believes that in order to be successful, restoration efforts must include:

- Research into the nature of competition between Montana grayling and non-native trout and the role of habitat degradation in this relationship.
- Implementation of appropriate management actions based upon the outcome of this research.
- Identification of the habitat needs of Montana grayling.
- Grayling habitat protection and restoration efforts.
- Cooperation of private landowners in restoration and management efforts.
- Experimental introductions within the historic range.

TABLE OF CONTENTS

I. INTRODUCTION

Montana's fluvial Arctic grayling (Montana grayling), formerly widely distributed in the Missouri River upstream of Great Falls and its major tributaries, is today apparently confined to the Big Hole River. In the mid to late 1980's, population densities of Montana grayling in the Big Hole declined, causing concern among resource agencies about the future of this population. As a result, a number of actions were initiated, beginning in 1987, in an attempt to ensure the protection and restoration of this population.

In October 1991, the U.S. Fish and Wildlife Service (USFWS) received a petition to list the Montana grayling throughout its historic range in the lower 48 states under the Endangered Species Act.

II. RESTORATION GOAL

Because of the uniqueness and importance of Montana grayling and because of their critically low numbers, they have 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, Montana Fish, Wildlife and Parks and the Montana Natural Heritage Program (Holton 1980; Williams et al. 1989; Clark et al. 1989). The United States Forest Service has classified the Montana grayling as a sensitive species. The USFWS classifies Montana grayling as a Category 1 species, which indicates that there is enough information on file to support a proposal to list it as threatened or endangered.

Such designations of special, protective status indicate the need to restore Montana grayling within their historic range. The Montana Fluvial Arctic Grayling Workgroup, whose membership includes representatives of Montana Fish, Wildlife and Parks (FWP), U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), U.S. Bureau of Land Management (USBLM), Montana Natural Heritage Program (MNHP), Montana State University (MSU), University of Montana (UM), Montana Chapter of the American Fisheries Society (MCAFS), Montana Power Company (MPC) and National Park Service (NPS) recommends the following restoration goal:

> The restoration goal for Montana grayling is the presence, by the year 2020, of at least five stable, viable populations distributed among at least three of the major river drainages (e.g., Big Hole, Jefferson, Beaverhead, Madison, Gallatin, Sun, Smith) within the historic range of Montana grayling in the Missouri River system upstream from Great Falls including those upper Missouri Basin waters within Yellowstone National Park. A population will be considered stable and viable in a stream when monitoring confirms that, for at least 10 years, successful stock recruitment exceeds mortality of reproductive adults to successfully compensate for stochastic factors and perpetuate the species within suitable habitats. As numeric recovery goals are developed by individual water the technical justification for those numbers will be attached to this plan.

With respect to the two other populations that may also have fluvial characteristics, the Madison River - Ennis Reservoir population and the Sunnyslope Canal population, we recommend the following:

(1) The Madison River - Ennis Reservoir population is currently being intensively studied, to elucidate its population and life history characteristics. At some time in the future, the Montana Fluvial Arctic Grayling Workgroup should discuss both the history of this population and results of the present and forthcoming investigations. If warranted, this population could be included toward fulfillment of restoration goals.

(2) The Sunnyslope Canal population should be further investigated and discussed. Although the canal is artificial, this population inhabits water diverted from the Sun River drainage, which is within the historic range of Montana grayling. If investigations and discussions so warrant, then this population could also be included toward fulfillment of restoration goals.

The purpose of this document is to describe the activities currently underway and planned to meet the restoration goal. The specific restoration tasks are listed in Table 1. These tasks are described in detail in the text following the number scheme in the table. This document constitutes the restoration plan of the Montana Fluvial Arctic Grayling Workgroup.

Table 1. Specific Restoration Tasks.

III. BACKGROUND

The status of fluvial (stream-dwelling) Arctic grayling, Thymallus arcticus, in Montana has been of increasing concern. Once widely distributed in the Missouri River and its tributaries upstream from Great Falls, Montana grayling are now restricted to the upper reaches of a single tributary, the Big Hole River. They inhabit the river from about the town of Jackson downstream to the mouth of the Big Hole. The highest density of Montana grayling is concentrated in the area from Wisdom downstream to Divide. This is the only confirmed Montana grayling population still remaining south of Canada and Alaska. Using the limited information available, Varley and Schullery (1983) estimated that Montana grayling are reduced in distribution to only about 8% or less of their historical range. The only other "southern" grayling were formerly found in streams in Michigan, but underwent a similar, earlier decline and disappeared about 1936 (McAllister and Harington 1969). Repeated attempts to establish or restore stream populations in Michigan and portions of Montana and Wyoming within Yellowstone National Park have not succeeded. Montana grayling used in these attempts had not been obtained from fluvial populations, which may explain their failure. In the century between 1881 and 1980 more than 36 million grayling were stocked into Yellowstone National Park, primarily in stream systems, without any notable signs of success. Between 1975 and 1980, the park chemically treated Canyon Creek, a productive spring creek, and constructed a barrier falls to prevent non-native fishes from entering the stream. Sixty-thousand grayling from six different strains were transplanted into that drainage in an effort to establish a wild, self-reproducing fluvial grayling population. Unfortunately, these efforts were not successful. In marked

contrast to fluvial populations, lacustrine (lake dwelling) grayling in Montana have greatly increased in distribution and abundance within the present century. Native lacustrine populations in Montana may have been confined to Red Rock lakes (Upper and Lower) and possibly nearby Elk Lake (Vincent 1962), which were the only lakes in the upper Missouri drainage naturally accessible to fishes. With the initiation of hatchery culture of Montana grayling in 1898 (Henshall 1906) and continuing to the present, the species has been widely introduced to lakes in Montana and other states. They are thus present in drainages outside the native range of the upper Missouri drainage. Within Montana alone, there appear to be at least 30 lakes with viable populations of grayling, including the native waters of Upper Red Rock Lake. Other states also have viable lake populations of Arctic grayling.

The remnant population of the Big Hole River is unique and of much concern because of a combination of at least four characteristics: (1) it is the last confirmed fluvial population of Montana grayling; (2) the Montana grayling of the Big Hole River drainage are genetically different from other Montana grayling and Montana grayling are in turn genetically diverged from those in Alaska and Canada (Lynch and Vyse 1979; Everett and Allendorf 1985); (3) the population appears unique among Montana grayling in being adapted to a riverine existence (Shepard and Oswald 1989; Kaya 1991); and (4) the population has declined to critically low levels (Oswald 1990).

A recent evaluation of the status of Montana grayling confirmed that the only population proven to be completely fluvial, with fish spending their entire lives in a stream environment, is that of the upper Big Hole River (Kaya 1990). However, there are two other populations with at least partially fluvial characteristics. One is the population that inhabits the Madison River and Ennis Reservoir. Montana grayling are found in the Madison River upstream from the reservoir throughout the summer and into at least early fall, well beyond the spawning season (R. Vincent, FWP, pers. comm.; Byorth and Shepard 1990). The Madison River is native habitat for Montana grayling and the reservoir fills an area originally occupied, by the highly braided Madison River channel.

The other population is found in an unusual habitat, the Sunnyslope Canal below Pishkun Reservoir in the Sun River drainage. Observations by Bill Hill (FWP, pers. comm.) suggest that these fish live in a fluvial environment during the irrigation season, generally from early May to September, when water flows in large volumes through the canal.

Since grayling are virtually absent from Pishkun Reservoir, it is apparent that the young are produced and persist within a fluvial environment during this period of the year. However, during the remaining seven months of the year, much of the canal goes dry and the grayling live in isolated pools.

Although all Arctic grayling are considered to belong to the same species and no subspecies are currently recognized, protein electrophoretic techniques have demonstrated divergence of Montana populations from those in Alaska and Canada (Lynch and Vyse 1979; Everett and Allendorf 1985). Everett and Allendorf (1985) also concluded that Montana grayling from the Big Hole River were genetically diverged from all other populations they had examined from Montana, Alaska and Canada. The Madison River-Ennis Reservoir population was not examined by these earlier studies and more recent comparisons indicate that this population is very similar, although not identical, to that of the Big Hole River (R. Leary, U. Montana, pers. comm.). Possible reasons for this similarity include perpetuation of an original resemblance in the native stocks, random genetic changes in the Madison River population and successful introductions of Madison River fish into the Big Hole drainage.

The Sunnyslope Canal population is genetically more distinct from the Big Hole population than is the Madison River population. In addition, it is more distinct from the Big Hole River population than are some of the lake populations. While this may confuse the analyses from a genetics standpoint, it is important to understand that all of the genetic variation between grayling populations is quite small. The significant issue is behavior and life history characteristics - i.e. is a particular population adapted to complete its life cycle in a fluvial environment. Even this question is open to some debate as evidenced by the Madison River population. It is likely that individuals of this population historically wintered in large pools in the lower Madison upstream of the Beartrap Canyon. Today they appear to still winter in a large pool in this area created by Madison Dam.

Two recent studies have provided evidence for adaptation of Big Hole River grayling to a riverine environment. Shepard and Oswald (1989) described extensive annual migrations of adults in the river. Spawning occurs in upstream reaches near Wisdom

and some fish migrate downstream to overwinter in deep pools. Others remain in upstream reaches through winter, in deep pools, in areas of groundwater recharge, or tributaries. Similar seasonal patterns of upstream and downstream migrations have been described for populations in Alaska and appear to be adaptations for utilizing conditions in different parts of river systems for spawning, feeding and overwintering (Hubert et al. 1985).

Another recent study (Kaya, 1991) demonstrated that young Big Hole River grayling have innate, apparently genetically controlled behavioral responses to water current that are advantageous to riverine existence. Young Big Hole River grayling have a significantly greater tendency to hold position in water current and lesser tendency to move downstream than do those from an inlet-spawning lake population. Such a behavioral tendency would allow the young to remain within the stream and thereby enable the population to maintain a permanent, life-long presence in flowing water. The genetic basis for such behavior was also indicated by another study (Kaya 1989) which demonstrated differential responses between young from inlet- and outlet-spawning lake populations and intermediate responses of young resulting from reciprocal crosses between the populations. Field studies of distribution and habitat utilization by young-of-year grayling in the Big Hole River have confirmed that they do remain within stream reaches close to the spawning areas and use both riffle and pool habitats (Skaar 1989; McMichael 1990; Streu 1990).

Decline and Present Status of Big Hole River Grayling

Concerns over the status of the remnant Montana grayling population of the Big Hole River have been heightened in recent years by the low numbers and densities observed in population surveys. Surveys indicate that estimated numbers of age-1+ Montana grayling (age 1 and older, excluding only the young-of-the-year) in the Wisdom section of the Big Hole River, declined to very low levels where they appear to have stabilized (Table 2). The 1994 data indicate increased population levels of grayling in the Wisdom section.

Table 2. Estimated densities (number per mile) of age-1+ Montana 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, respectively (Oswald 1990, Byorth 1991).

		Estimated Number per Mile		
Section	Year	Montana Grayling	Brook	Rainbow
McDowell	1978	69	109	0
Wisdom	1983	111	234	14
Wisdom	1984	74	274	11
McDowell	1985	38	208	26
Wisdom	1985	33	331	5
McDowell	1986	51	211	27
McDowell-Wisdom	1987	30	82	3
McDowell-Wisdom	1989	22	62	3
McDowell-Wisdom	1990	34	65	6
McDowell-Wisdom	1991	34	-	-
McDowell-Wisdom	1992	31	94	2
McDowell-Wisdom	1993	32	134	2
Wisdom	1994	64	240	6

Estimates have gone from about 111 per mile in 1983 to about 22 to 34 per mile in 1989 to 1991. These are estimates for the stream sections near the town of Wisdom, where Montana grayling appear most abundant. If these estimates of about 30 per mile are extrapolated to the approximately 50 to 70 miles of stream inhabited by Montana grayling, this leads to an estimate of approximately 1,500 to 2,100 age-1+ Montana grayling in the entire Big Hole River.

Reasons for declines of Montana grayling populations, either in the entire upper Missouri River drainage or within the Big Hole River, are not well understood but are thought to include a combination of competition from non-native salmonids, overfishing, drought, and habitat degradation (Vincent 1962; Kaya 1990). Montana grayling are easily caught by anglers and this may have contributed in the past to overharvest of these fish in Montana streams (Vincent 1962; Wipperman 1965). Regulations have allowed only catch-and-release fishing on the Big Hole River since 1988. Non-native salmonids have been widely introduced to virtually all former Montana grayling streams in Montana and have probably been a major factor contributing to the decline of Montana grayling (Vincent 1962; Kaya 1990).

Since the Montana grayling are remnant populations from the last ice age and are at the extreme southern edge of the species, they may have been gradually on the decline. Montana has been in a drought situation since the mid-1980's. Flows in the fall/winter and spring/summer have ranged from 80-86% and 42-54% of the long term average monthly flows respectively (Table 3). This broad scale environmental change, with consequent reductions in spawning, rearing and winter habitat, could well explain the decline of all fish population densities shown in Table 3. The current low population densities may be a natural response by all three salmonid species to drought related low flows. According to Vincent (1962), agricultural activities were an important contributor to degradation of Montana grayling habitat in Montana. Such habitat degradation in Montana appears most frequently to have been related directly or indirectly to agricultural irrigation. Important disturbances have been reduction in stream flows through withdrawals of water for irrigation, blockage of streams by diversion structures and loss of small Montana grayling to irrigation canals.

Table 3. Big Hole River monthly average flows at Melrose (cubic feet per second).

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
1984	554	539	459	394	386	400	1842	2555	1601	322	322	465
1985	604	410	333	334	363	958	1919	2842	3775	966	346	584
1986	643	556	335	296	352	530	1258	1379	826	434	240	175
1987	240	293	252	228	290	317	1425	1920	1601	302	88	114
1988	241	330	240	222	212	439	1371	1726	2065	600	325	298
1989	390	454	374	374	326	426	1542	1173	2223	649	372	298
1990	357	432	258	268	278	333	855	2108	4239	1099	269	231
1984-1990 Ave.	433	431	322	302	315	486	1459	1958	2333	625	280	309
Long term Ave. (1937-1986)	530	520	400	350	370	470	1500	3600	4400	1500	520	410
1984-1990 % of long-term average flow	82%	83%	80%	86%	85%	103%	97%	54%	53%	42%	54%	75%

Dewatering of rivers and tributary streams during summer by irrigation diversions cause several problems for Montana grayling (Heaton 1960; Vincent 1962; Liknes 1981; Shepard and Oswald 1989). In addition to reduction in available habitat for Montana grayling of all ages, other possible effects of dewatering include interference with seasonal migrations, 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, irrigation diversions can also cause loss of Montana grayling, especially young fish. Montanagrayling fry and juveniles are found in diversion 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).

Information is not available on whether other parameters such as stream temperatures have been increased through human activities and have contributed to the decline of Montana grayling. Water withdrawals from streams can aggravate warm temperatures during summer through a relationship between reduced flows and increased stream temperatures (Dorris et al. 1963). Present midsummer water temperatures in the upper Big Hole River may be at times marginal for Montana grayling and drought combined with stream dewatering may be contributing to elevated temperatures. Liknes and Gould (1987) suggested that higher numbers of Montana 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°C (72°F) during July 1988 and reached a maximum of 24.5°C (80°F). Although 24.5°C (80°F) is below levels that would produce a thermal kill of grayling (Feldmuth and Eriksen 1978), temperatures above 20°C (72°F) are not optimum for the species (Hubert et al. 1985).

Interactions between Montana grayling and non-native fishes, especially salmonids, could include competition and/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. Montana grayling may be 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.

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 aggressive 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.
According to Vincent (1962), Montana grayling of the upper Missouri River drainage were originally sympatric with only ten other species of fish, including two native salmonids, westslope cutthroat trout (Oncorhynchus clarki lewisi) and mountain whitefish(Prosopium williamsoni). Additionally, lake trout (Salvelinus namaycush) may have also been sympatric with lacustrine grayling in Elk Lake. 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 Montana grayling of the Madison River had become rare, except in Ennis Reservoir. 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 (Vincent 1962). The introduction of non-native fishes, especially salmonids, may be the most critical factor affecting the decline of Montana grayling. One "common denominator" underlying all streams in Montana from which Montana grayling have disappeared is the presence of one or more introduced salmonids -- rainbow trout, brown trout, or brook trout. Additional evidence for the importance of competition with non-native fish in the decline of Montana grayling comes from

Yellowstone National Park. Montana grayling have been completely extirpated from the Madison and Gallatin drainages in Yellowstone although habitat degradation has been limited in the Park. The two principal cultural factors that could have led to the decline are sport harvest and introduction of non-native salmonids.

IV. RESTORATION TASKS

In 1987, the Montana Fluvial Arctic Grayling Workgroup was formed to coordinate research and restoration efforts designed to stabilize and enhance the last known Montana grayling population in Montana. In addition to coordinating population estimates and sponsoring investigations into Montana grayling spawning and rearing habitat requirements, representatives of FWP, MNHP, MSU, USBLM, USFWS, USFS, UM and MCAFS developed a long-term restoration plan, began development of a refuge population in a barren lake and a broodstock at the U.S. Fish and Wildlife Service Fish Technology Center in Bozeman. In 1991-1992, the Working Group proposed that grayling restoration actions occur inside Yellowstone National Park. In 1993, a representative from the National Park Service was added to the Working Group.

In 1991, the FWP, USFWS, USFS, USBLM, MCTU and MCAFS signed a five year Memorandum of Understanding establishing the Big Hole Restoration Plan. A technical subcommittee was established which oversees the research/restoration program and approves workplans. A financial subcommittee, which has obtained 501-C-3 nonprofit corporation status, has begun fund raising and public information efforts.

The activities described below have and are being undertaken as part of normal management tasks and the Montana grayling restoration plan.

A. MANAGEMENT

It seems likely that restoration of Montana grayling will not succeed without efforts to manage non-native salmonids which appear to have played a role in their decline.

Management of the fisheries of the Big Hole River corresponds to direction set out in the Big Hole River Management Plan. This document was completed in 1989 and is operative for the period spanning September 1989 to September 1994. The management plan is updated or modified on a five year basis (it will be updated in 1995). It was developed with public input and reflects the approval of most anglers who use the river. Montana grayling are given high priority throughout the management plan under their current designation as a "Species of Special Concern". As such, the plan specifies that Montana grayling are to be managed under catch and release protection throughout the Big Hole drainage.

For purposes of management planning, the Big Hole River was divided into four reaches. The two downstream reaches contain few Montana grayling although that segment of the population is also under the protection of catch and release regulation. Reach 3, Divide to Dickie Bridge, supports populations of Montana grayling estimated to be between 10 and 25 per mile. While the primary management emphasis within this reach is not centered on Montana grayling, present management which favors populations of larger rainbow and brown trout is being evaluated by FWP. Montana grayling are managed under a catch and release regulation within management Reach 3.

Reach 4, Dickie Bridge to Jackson, supports the highest densities of Montana grayling in the Big Hole system. It also provides all of the known spawning and rearing habitat for the species. The stated management objective for this reach is the protection and enhancement of Montana grayling habitat and Montana grayling populations over all other species. This management reach provides the focal point of Montana grayling research in the Big Hole. In addition to catch and release protection, the plan commits FWP to several other management options that favor Montana grayling over other species. An annual plant of catchable hatchery rainbow trout in the vicinity of a large popular campground was discontinued to provide a better competitive advantage to Montana grayling in the area. The population of eastern brook trout, thought to compete with Montana grayling,

is managed under a very liberal limit, 20 fish or 10 pounds, to encourage harvest and control or reduce numbers. Finally, all tributary streams from Pintlar Creek upstream remain open year round for brook trout to further encourage harvest of that species.

As part of the Madison-Missouri River hydropower facility re-licensing process, MPC is working with the public and management agencies to develop a mitigation and enhancement plan. The plan includes several features directly tied to Madison River grayling management as outlined below.

1. MPC will fund a fisheries biologist and technician (including all operations) to work on fisheries issues related to reservoir and river management. It is anticipated that these positions will begin in 1997. A significant portion of this crew's efforts will be directed toward Montana grayling restoration.

2. Since 1990, MPC has funded a researcher and a fisheries fieldworker on the Madison to work strictly on Madison River grayling research/restoration. This position is funded through 1995. It is anticipated that Montana grayling restoration will be well on its way when the mitigation and enhancement biologist is hired.

3. MPC is studying movement of Montana grayling downstream over Madison Dam. Using radio telemetry, it will be determined if Montana grayling are moving downstream and are, thereby, lost to the upstream spawning population. If this study indicates that downstream movement is a significant problem, MPC will investigate two options to correct the problem. A fish ladder would be considered, as would a weir where fish could be trapped and manually moved up into the reservoir.

4. The Montana Power Company has formed a Madison Technical Committee as part of the re-licensing process to provide recommendations for management of this reach of river. One suggestion is to manage the bypass reach between Ennis Dam and the powerhouse (approximately 7,400 feet) as a Montana grayling restoration area.

Yellowstone National Park primarily protects native species in their native habitats, including Arctic grayling. Sport harvest of non-native trout is allowed in some park waters, but grayling have been subject to catch and release regulations throughout Yellowstone National Park for more than two decades. The park has not stocked or augmented populations of non-native species since the 1950's, except when specifically called for under a restoration plan.

B. HABITATPROTECTION/ENHANCEMENT

Habitat protection is a critical component of Montana grayling restoration. Efforts in the Big Hole to work with private landowners are described below. Similar efforts are being initiated in the Madison River drainage. Water reservations and water leasing are aspects of this effort.

Habitat protection on public and private lands within the historic range of the Montana grayling is and will be accomplished largely through existing programs. The Montana Stream Protection Act and Natural Streambed and Land Preservation Act are designed to protect the bed and banks of Montana streams. These acts are administered by FWP and the local conservation districts, respectively.

Public lands within the historic range of the Montana grayling are administered largely by the USFS and BLM. Both federal agencies have recognized the Montana grayling as a sensitive species. Administrative guidelines have been developed to protect Species of Special Concern during land management activities.

The BLM has established land acquisition along the Big Hole as one of its highest priorities. Since 1988, the BLM has acquired over 17 acres of land, primarily river frontage, for fisheries habitat management along the Big Hole.

Inside Yellowstone National Park all land is federally owned and protected and no impoundments or diversions occur such as could affect grayling populations. No deliberate human alteration of the environment is allowed unless specifically called for

in a restoration plan for native species. At this time, the National Park Service does not believe that habitat degradation has contributed to the decline of grayling inside Yellowstone National Park, nor do they plan for any aquatic habitat enhancement.

C. HABITATMANAGEMENTAND IMPROVEMENT

1. Big Hole River Habitat Management Projects

This section summarizes several habitat management/improvement projects that have been accomplished in the Big Hole River. As waters are selected for establishing Montana grayling populations, habitat projects must be identified and implemented.

Habitat improvement is an important aspect of restoration, particularly as it relates to competition with non-natives. Much of the scientific literature regarding invasion of non-native species indicates that habitat degradation may provide the invader a competitive advantage over the native species (Baltz & Moyle 1993, Orians 1986, Elton 1958). Current research into Montana grayling habitat requirements will provide additional information to guide habitat projects so they will benefit Montana grayling.

Several habitat protection and improvement projects have been undertaken and completed on the Big Hole River through a blend of participants from the public and private sector and have, in some cases, included grant monies specified for habitat improvement or soil and water conservation. One such project maintained streamflow and brought stability to a two channel system near Melrose. This project resulted in the maintenance of known Montana grayling pool habitats throughout a three mile reach of river. Another project resulted in the removal of a barrier dam and a considerable conservation of water by remodeling an irrigation system near Glen. A third project resulted in the installation of bank barbs to maintain Montana grayling habitat and stop bank erosion in known Montana grayling habitat near Wisdom. This project was undertaken as an alternative to rock rip rap which probably would have destroyed existing Montana grayling habitat at the site.

Three other projects, undertaken by private landowners with FWP cooperation, have sought to stabilize Montana grayling habitat in the Wisdom and Wise River areas. One project used bank barbs and rock shears to concentrate streamflow and stabilize banks in major channels where prior disturbance had resulted in an unstable braided channel. This project will provide better Montana grayling habitat along a three to four mile reach. A second private project returned flow to an approximately four mile river reach through excavation of a gravel plug and rebuilding of an old gravel bar. This project saved important adult habitat as well as critical spawning and rearing habitat for Montana grayling. The third project used rock shears to replace a bank to bank earthfill dam which blocked migration corridors and caused extreme dewatering. The project also improved Montana grayling summer and winter habitat in a pool immediately upstream. Conservation easements, which include protection of riparian corridors, have been granted on two contiguous ranch properties spanning a reach of about eight miles within Montana grayling habitat up- and downstream from the mouth of the North Fork of the Big Hole River.

Future projects being discussed for funding with the Big Hole River Foundation include a vegetative and rock/vegetation bank stabilization project near Melrose and a riparian protection/enhancement project near Wisdom. The Montana grayling biologist will continue to identify and work with landowners to implement habitat improvement projects.

2. Madison River Habitat Projects

MPC will provide $50,000 annually for habitat restoration/enhancement activities on the Madison River. These funds are not earmarked for Montana grayling but could be used on Montana grayling projects if approved by a MPC's Technical Advisory Committee. A possible project is on North Meadow Creek which, at one time, harbored a thriving Montana grayling population but is now populated largely by brown trout. Habitat projects combined with possible reintroduction of Madison River grayling could be a long term project.

3. Ennis Reservoir Winter Water Levels

Winter management of Madison Reservoir will be changed to better protect Montana grayling habitat. In the past, the reservoir, which has a maximum depth of approximately 20 feet, has been dropped 2 feet in the fall and held at this level through spring ice breakup. This was done to minimize shore erosion. This operation reduced the amount of habitat available during winter months. The new operation will consist of dropping the reservoir level 1 foot in the fall. The reservoir level will be dropped the second foot in the spring just prior to ice-off. This will lead to increased habitat during the winter.

D. WATER MANAGEMENT

1. Cooperative Water Management

Through the process of informational meetings with the upper Big Hole River landowners, methods of cooperative water management have been pursued. Such meetings have been conducted from 1988 to the present. The resulting changes in irrigation methods benefit Montana grayling and are designed to fit within irrigation management.

In 1989, the upper river ranchers adopted a policy under which flows are not fluctuated dramatically for irrigation during the critical Montana grayling spawning period near the end of April. In cold or normal springs, irrigation withdrawal is not a factor. In warm or dry springs, irrigation withdrawal commences before or after the period marked by the trough between the lowland and upper elevation runoff peaks. This effort is coordinated by the ranchers.

In response to impending drought conditions during the 1992 summer, the ranchers acted upon an FWP request to coordinate and minimize withdrawals after the first week of July to ensure sufficient flow to maintain critical Montana grayling habitat in the Wisdom area. This effort is also led and coordinated by the local landowners in cooperation with FWP.

Drought conditions in 1994 necessitated intensive efforts to maintain minimum stream flows in the Big Hole. As flows at Wisdom approached 20 cfs, water users were contacted and asked to conserve water by minimizing withdrawals. Assistance was offered in adjusting headgates and funding a water commissioner. Attempts to preserve instream flow were made by providing alternatives to watering stock through ditches. A total of 10 stock tanks were acquired and distributed. An abandoned well was developed to pump water to two of the tanks. The remaining tanks were filled using a 1.000 gallon tank trunk. The volume of water required via this alternative means was approximately 0.5% of that required by ditch delivery.

There is a continuing need to work with irrigators on individual diversions. This will be a high priority, on-going task for the Montana grayling restoration biologist.

2. Water Reservations and Leasing

The concept of water leasing (as authorized by the Montana Legislature) was investigated as an option to improve Montana grayling habitat in the Big Hole River through its tributary streams. Swamp Creek, a tributary in the Wisdom vicinity, was considered for water leasing because of its flow contribution to critical Montana grayling habitat in the Big Hole and the spawning - rearing habitats and summer adult habitats represented in the stream. This lease has been pursued but has not been perfected to date. Potential water leasing opportunities to benefit Montana grayling should be identified and pursued in those waters where attempts will be made to establish Montana grayling populations.

Instream flow requirements for habitats supporting trout in the Missouri River and all of its major tributaries were calculated and applied for as flow reservations by FWP. The reservation process was established by the Montana Legislature and the instream flow reservations were granted, largely as applied for, by the Board of Natural Resources and Conservation in 1992. These reservations set a priority date to which any future water use developments will be junior and, as such, ensure that trout habitat, including Montana grayling habitat, in the mainstem and tributaries will not be further impaired due to additional

consumptive water withdrawal. These instream flows, as requested and granted for fish and wildlife needs, are defined in documents associated with the reservation process (FWP 1989).

In Yellowstone Park, the National Park Service is solely responsible for the management of water and, save for minor withdrawals to serve administrative purposes (park housing and lodging developments), no withdrawal of surface water occurs.

E. RE-ESTABLISHING POPULATIONS

The most important component of this restoration plan, beyond protection of the Big Hole and Madison populations and their habitat, is re-establishment of Montana grayling. This must be successfully accomplished to meet the restoration goal. Experimental efforts have begun with the intent to investigate techniques to ensure that future re-establishment efforts are successful.

1. Broodstock Development

A broodstock is currently being developed for Big Hole grayling. In order to preserve the genetic integrity of Montana grayling in Montana, a Big Hole River broodstock is being developed to guard against extinction and to provide a source of Montana grayling for future re-establishment and enhancement efforts. Development of the broodstock is being guided by a plan developed by the University of Montana Wild Trout and Salmon Genetics Lab which will ensure that the genetic variation within the Big Hole River grayling population is replicated in the broodstock.

The plan calls for a broodstock derived from gametes taken from spawning Big Hole grayling. Currently, reserve stocks are held at the USFWS Fish Technology Center and the 1988 year class was planted in one of the Axolotl Lakes in the Gravelly Range. An effective founding population of 50 parent Big Hole grayling (25 pairs) is considered necessary to capture the genetic variability of the wild population. When a sufficient parent population is acquired, year classes will be crossed to convert between-year-class-variability to within-population-variability. To prevent domestication of the brood, wild genes will be infused at least every ten years. Gametes are to be collected from reserve stocks annually and from wild Big Hole grayling as needed. Fertilized eggs will be hatched at the USFWS Fish Technology Center. Progeny of eggs taken will be used to augment brood reserve stocks and for reintroduction.

MPC will provide $50,000 annually for Montana grayling restoration in the Madison River drainage. This money can be spent as deemed appropriate by a technical advisory committee. One suggestion is to develop an egg taking station and develop a Madison River broodstock. This broodstock could be used for making re-introductions within the Madison River drainage if considered appropriate and necessary.

2. Identification of Streams Suitable for Reintroduction/Introduction

Selection and prioritization of candidate streams for potential introductions will be based on recommendations of potential sites identified in a recent study (Kaya 1992) and on other information as it becomes available. All recommendations will be reviewed and screened annually by the committee, incorporating up-to-date information and review of field data. After the work group annual review process has identified candidate streams, plants will be analyzed through the appropriate NEPA, MEPA, public, and agency review processes. The committee has identified three waters as priorities for introduction in 1997. These streams are the East Gallatin, upper Ruby and upper Gibbon in Yellowstone National Park. Figure 1 displays the present distribution of fluvial grayling and potential restoration sites identified by Kaya (1992).

FLUVIAL MONTANA GRAYLING
Present Distribution and Potential Restoration Sites

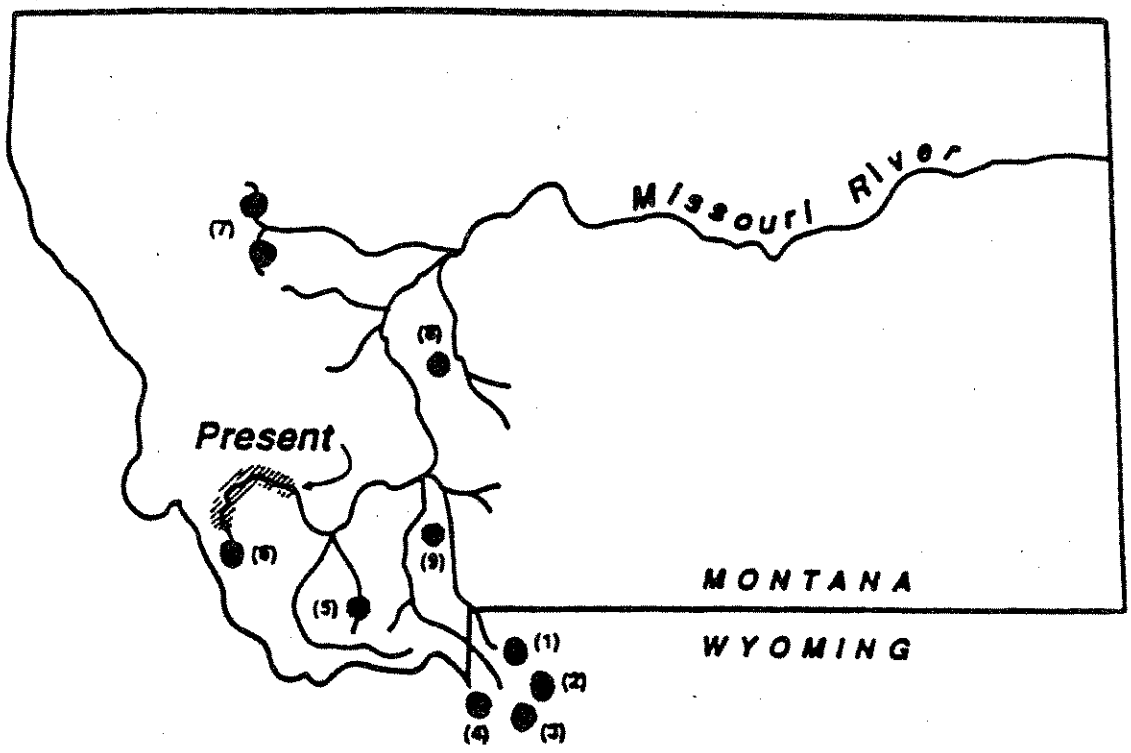


Figure 1. Present distribution of fluvial Arctic grayling in the upper Big Hole River, and potential restoration sites within the native range of the Missouri River basin above Great Falls. (1) Cougar Creek, (2) Virginia Meadows reach of the Gibbon River, (3) Canyon Creek, tributary of the Gibbon River, (4) Firehole River above Kepler Cascades, (5) upper Ruby River above Ruby Reservoir, (6) Big Hole River above Jackson, (7) North Fork and South Fork of the Sun River, (8) Elk Creek, tributary of Hound Creek of the Smith River, (9) Butler Reach of Cherry Creek, tributary of the Madison River. Not indicated on the map are the populations of Madison River/Ennis Reservoir, and the Sunny Slope Canal, both discussed in this report.

3. Experimental Introduction Procedures

After selection and review, a reintroduction plan will be developed by the agency or agencies with jurisdiction over the candidate stream. Each reintroduction plan will be designed to preserve the genetic/adaptive fluvial characteristics of any extant stocks of graying in the drainage, with a goal of gathering pertinent data and establishing self-sustaining populations.

Each plan should also contain the following elements:

a. Select suitable stream reach.
b. Mark fish for future identification.
c. Acclimate on site based on current knowledge and availability of facilities.
d. Document variables such as water temperatures and discharge.
e. Monitoring surveys will be conducted. These should include fall population monitoring of all species present. A spring spawning survey is recommended. Monitoring efforts to determine dispersal/distribution of the introduced grayling are encouraged.
f. Plants should be repeated annually, depending on availability of fish, for at least 4 years to provide a sufficient core population and range of year classes to observe a response and to provide genetic variability to the population.

4. Reintroduction Efforts

a. Gallatin and East Gallatin Rivers - On July 1, 1992, approximately 5,400 yearling Montana grayling from the Big Hole reserve stock were released in the Gallatin River above the Taylor Fork. This reach was chosen on the basis of available habitat, low resident fish populations and no possibility of genetic contamination of other Montana grayling stocks. Grayling were planted there in the 1940's, apparently not with a fluvial stock, which failed after 3 years.

The success of the current plant will be monitored in fall 1992, spring and fall 1993. A plant of approximately 10,000 yearling Montana grayling was made in 1993. An additional 10,000-12,000 Montana grayling were planted in the East Gallatin in 1993. Information gathered from monitoring will be used to guide future reintroductions. Both the Gallatin and East Gallatin were included in Dr. Kaya's review of streams for restoration of Montana grayling. Neither water received a high priority rating due to the presence of non-native trout. Planting of these waters proceeded because both rivers have contained Montana grayling in the fairly recent past (20 years) and Montana grayling suitable for restoration plants were available due to a very successful egg take from Axolotl Lake of the Big Hole River fish. The committee feels that it is important to learn whether grayling reintroductions in large streams and rivers can be successful in the presence of wild non-native trout. Those fish were not genetically suitable for planting to the Madison or Big Hole. Fishing for Montana grayling in streams will be strictly on a catch and release basis to promote establishment of these populations.

b. Big Hole River - On July 2, 1992, 214 yearling grayling of the Big Hole reserve stock were released into the Big Hole River. Each fish was marked with a numbered VI (visible implant) tag. The goal of this plant is to test the survivability of the planted fish and observe their movements. The small number planted will minimize possible genetic impact to the wild population. Information from monitoring efforts will assist in developing techniques for future plants.

c. Cougar Creek - The National Park Service, in cooperation with the U.S. Fish and Wildlife Service and the Montana Fish, Wildlife and Parks, planted 800 fluvial grayling into Cougar Creek in August of 1993 and again in 1994. Cougar Creek supports a population of hybrid Yellowstone/westslope cutthroat. Cougar Creek becomes subterranean before reaching the confluence with any stream that now contains non-native fish species, thus providing an effective barrier to non-native competitors. The park plans to continue stocking grayling again in 1995 and 1996, and will monitor and evaluate the success of the transplant efforts.

d. Cherry Creek - A Madison River tributary, received a plant of Madison River grayling in 1994. Electrofishing was utilized to remove non-native trout from the stream prior to the plant.

F. Research

Research is an important component of the restoration program. The intent of the research is to define ecological factors limiting the distribution and abundance of Montana grayling in the Big Hole drainage and throughout its native range. As limiting factors are identified, results of research will be applied to guide management in protecting and restoring grayling

populations. Research projects listed below are defined and prioritized in Byorth (1992). This listing is not comprehensive and will be amended as restoration proceeds.

1. Competitive Interactions

Current research is directed at two aspects of how interactions with non-natives may affect Montana grayling. During 1993 and perhaps beyond, research will be conducted to investigate the interactions between brook trout and Montana grayling in the upper Big Hole. The current research program involves observation of grayling/brook trout interactions in the field. Montana grayling were placed in three sections of the upper Big Hole occupied by brook trout. Brook trout were removed from one section, depleted by 50% in a second and depleted by 25% in a third. Attempted movement out of the sections was monitored and interactions were observed via snorkeling.

A second related research effort will be conducted on the Sunnyslope Canal in 1994 and 1995. This population has been self-sustaining under unusual habitat conditions for over 20 years. However, no other fish occupy this system. A study of the life history and ecological requirements of this population may provide information on the role of habitat vs. competition in the decline of Montana grayling. It may also provide information useful in managing and improving habitat for Montana grayling.

2. Environmental Limiting Factors

a. Physical Habitat Requirements

i. Habitat Assessment. Montana grayling habitat was quantified and rated in the Big Hole basin from the Jackson area downstream to Dickie Bridge in 1994. This survey is necessary to determine Montana grayling carrying capacity versus existing population, determine limiting factors, identify habitat problems and determine potential habitat improvement projects.

ii. Geohab Cooperative Habitat Study. A cooperative study was conducted in 1993 by a U. S. Geological Survey research team. This study focused on physical, chemical, geomorphological, and invertebrate characteristics of different reaches of the Big Hole River.

iii. Microhabitat Usage. Document Montana grayling habitat usage by snorkeling observations and measurements.

b. Biological Limiting Factors

i. Interspecific Interactions. Determine the potential role of other species of fishes in limiting the abundance and range of Montana grayling through research on competition and predation.

ii. Seasonal Movements and Macrohabitats. A sample of Big Hole River adult grayling was fitted with radio transmitters in 1991 and 1992 to follow their movements to winter habitats. In addition, grayling captured during sampling have been tagged to provide information on seasonal movements throughout the upper Big Hole Basin. Seasonal habitats will be characterized and applied to the habitat assessment program outlined above.

iii. Thermal Tolerance Bioassays. Bioassays were conducted in 1993 to determine thermal tolerance of Montana grayling and the suitability of the Big Hole River to support grayling.

iv. Effects of Angling. To determine the influence that angling has on the Big Hole grayling population, a comprehensive research project was conducted in 1992 and 1993. This research was used to determine the proportion of the grayling population affected by anglers and mortality attributable to angling.

3. Adaptations and Genetic Identities of Grayling Stocks

a. Genetic Assessment of Grayling Populations - Clarify the relationships of Montana grayling stocks using techniques such as protein electrophoresis and mitochondrial DNA analysis. These relationships are a key to conserving the unique genetic and behavioral characteristics of fluvial Montana grayling.

b. Behavioral Responses of Grayling to Water Current - MPC is funding a two year graduate study with Montana State University. The study is "Behavioral Responses on Water Current of Arctic Grayling (Thymallus arcticus) from the Madison River and Their Use of Stream Habitats." This study began in 1993.

c. Interactions with Lacustrine Grayling. - A number of lakes in the Big Hole River drainage contain Arctic grayling (Table 4). Because of differences in life history characteristics, it is believed that these lake populations could threaten the genetic character of the fluvial Big Hole River population. The lakes containing Arctic grayling and the potential genetic risk to Montana grayling from these populations are evaluated in Table 4. In 1992, sampling and genetic analysis of fish from Pintlar, Hamby and Schwinegar lakes was undertaken. Electrofishing of Wyman and Odell creeks will be undertaken to determine migration of Arctic grayling downstream from Odell Lake. Management actions will be developed to reduce or eliminate the threat from those populations that pose a potential effect on Big Hole grayling.

Table 4. Big Hole River drainage lakes containing Arctic grayling.

LAKE	GENETIC THREAT	ACCESS TO BIG HOLE	VEHICLE ACCESS	COMBINED THREAT
Bobcat South	none	yes	no	none
Bobcat North	none	yes	no	none
Bobcat West	none	yes	no	none
Hamby	unknown	may	no	unknown(1)
Miner	minor	yes	yes	may
Mussigbrod	minor	may	yes	may(4)
Odell	threat	yes	no	yes
Schwinegar	unknown	yes	no	yes
Twin	unknown	yes	yes	no(2)
Grayling	unknown	-	no	no(3)
Pintlar	unknown	-	yes	-
Agnus	threat	yes	no	yes(4)

(1) No grayling found in 1981 survey.
(2) No grayling found in 1964, 1970, 1980, 1986, 1990 surveys
(3) It is believed that the grayling are now extinct in this lake.
(4) Access to the Big Hole River would be very difficult especially during the summer irrigation season.

4. Madison River

The status of the Madison River grayling is described above under Section III. Background. A program for restoration of the Madison River grayling has been initiated and is being funded by Montana Power Company (MPC). MPC is in the process of re-licensing their hydropower projects on the Madison and Missouri Rivers. The two facilities that MPC owns and operates on the Madison River are Hebgen and Madison dams.

G. MONITORING AND REPORTING

1. Population Monitoring - Big Hole River

a. Electrofishing - Electrofishing has been the most effective technique for monitoring riverine grayling populations. The technique has been scrutinized for its potential to cause spinal injury in fishes. Dwyer and White (1993) documented significant reductions in growth rates of juvenile grayling when subjected to electroshock. However, Holmes et al. (1990) and Fredenberg (1992) indicated that grayling are highly resistant to electroshock-induced acute injury and to long-term effects. We feel it is prudent to minimize the exposure of Montana grayling populations to injury and recommend electrofishing be used conservatively.

b. Spawning Surveys - Surveys during the spawning season are an important indicator of the composition of the adult grayling population and to gather gametes for the brood stock. In years when no gametes are needed, spawning surveys should be limited to a few sub-sections and conducted before spawning commences to minimize potential impacts of electrofishing.

c. Fall Population Surveys - Monitoring of the grayling population is critical to the restoration program to identify trends and responses to restoration efforts. Annual censuses will be conducted. The population estimates derived for McDowell-Wisdom Section will be used as an index of the grayling population. At a minimum of every 3 to 4 years, and as flow conditions delegate, a broader ranging census should be conducted over the majority of the upper Big Hole River.

d. Basin-Wide Distribution Surveys - Occasional reports are received of grayling being captured outside the current "known" range within the Big Hole Basin. Surveys of tributaries and reported areas will be conducted as necessary.

2. Temperature and Discharge Monitoring

Water temperatures will be monitored from April through October annually at 5 sampling stations. Daily discharge is monitored at USGS gauging stations at Wisdom and Glen.

3. Reporting

a. Annual Monitoring Reports - Results of population surveys and monitoring will be reported annually. Reports will be submitted to the Montana Fluvial Arctic Grayling Workgroup and made available to the public.

b. Project Reports - Results of research projects will be reported on completion of projects. All project reports will be submitteded to the Workgroup and made available to the public.

c. Committee Reports - Annually, each entity involved in grayling restoration shall summarize their activities pertaining to restoration tasks. This information will be submitted to the chair of the

Workgroup who will collate the information into a grayling restoration accomplishments report. The report will be distributed to all members of the Workgroup and be made available to the public.

H. PUBLIC INFORMATION

Public information efforts will take many forms for different purposes. Over 200 copies of a draft of this document were sent to individuals to inform them of the planning effort. Public open houses were held in Dillon, Ennis, Bozeman, Butte and Great Falls to discuss the plan and elicit public response.

In order to comply with NEPA and MEPA, EA's are prepared and circulated prior to initial restoration planting. The public has the opportunity to comment on these environmental assessments.

FWP, through newspaper releases and articles in its magazine, Montana Outdoors, has published information describing the status of Montana grayling, the issues surrounding listing and restoration and the elements of the restoration plan.

Several projects to inform the public about the Montana grayling restoration project and to raise funds to help defray costs of the project have been undertaken.

The July 1992 issue of Fly Fisherman contained an article describing the Big Hole River grayling and the restoration project. Written by a Financial Committee member, this article has generated numerous offers to help financially. A T-shirt was developed and is selling well in local stores in southwestern Montana. In addition, MCAFS has produced a limited edition Montana grayling belt buckle which is also selling well. Proceeds from these sales go directly into Montana grayling restoration. The Financial Committee has commissioned nationally known artist Monte Dolack to paint a Big Hole Grayling poster. Dolack's posters are in great demand nationwide. We expect the Montana grayling poster, which became available in the spring of 1993, will be an excellent fund raising and educational tool.

Member agencies of the Working Group will continue public education and information programs related to grayling restoration goals, including building support for possible management of non-native fish species that may compete with grayling. Yellowstone National Park provides interpretive programs and messages to educate the public on protecting native species in their habitat.

VI. SUMMARY

Through the cooperative efforts of several state and federal agencies with legal responsibility for land, water and fishery management and private companies, organizations and individuals, restoration efforts for Montana grayling are well underway in the Big Hole and Madison rivers. Efforts are underway to identify appropriate streams and reintroduce Montana grayling to meet the restoration goal of this plan. The first such reintroduction occurred in July 1992.

The Montana grayling restoration plan will continue to focus on re-introduction within the fish's historic range in Montana, habitat protection, public information and education.

Literature Cited

Baltz, D. and Peter B. Moyle. 1993. Invasion Resistance to introduced species by a native assemblage of California stream fishes. Ecological Applications 3(2) pp 246-255.

Byorth, P. A. 1992. Big Hole Arctic grayling restoration project work plan: 1992 - 1995. Submitted to: Fluvial Arctic Grayling Workgroup and Montana Fish, Wildlife, and Parks, Bozeman.

Byorth, P. A. 1991. Population surveys and analysis of fall and winter movements of grayling in the Big Hole River: 1991 Annual Report. Submitted to: Fluvial Arctic Grayling Workgroup, Helena, Montana.

Byorth, P. A. and B. B. Shepard. 1990. Ennis Reservoir/Madison River Fisheries Investigation. Draft Final Report: 1990. Submitted to: Montana Power Company, Butte, Montana.

Clark, T. W., A. H. Harvey, R. D. Dorn, D. L. Genter, and C. Groves, eds. 1989. Rare, sensitive and threatened species of the Greater Yellowstone Ecosystem. Northern Rocky Conservation Cooperative, Montana Natural Heritage Program, The Nature Conservancy and Mountain West Environmental Studies.

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

Dorris, T. C., B. J. Copeland and G. L. Lauer. 1963. Limnology of the middle Mississippi River. IV. Physical and chemical limnology of river and chute. Limnology and Oceanography 8:79-88.

Dwyer, W.P. and R.G. White. 1995. Influence of electroshock on short-term growth of adult rainbow trout and juvenile Arctic grayling and cutthroat trout. North American Journal of Fisheries Management 5:148-151.

Elton, C.S. 1958. The Ecology of Invasions by Plants and Animals. London: Chapman and Hall.

Everett, R. J. and F. W. Allendorf. 1985. Population genetics of Arctic grayling: Grebe Lake, Yellowstone National Park. Genetics Laboratory Report 85/1, Zoology Department, U. of Montana, Missoula, MT. 27 pp.

Feldmuth, C. R. and C. R. Eriksen. 1978. A hypothesis to explain the distribution of native trout in a drainage of Montana's Big Hole River. International Vereinigung fur theoretische und angewandte Limnologie Verhandlungen 20:2040-2044.

Fredenburg, W. . 1992. Evaluation of Electrofishing-Induced Spinal Injuries Resulting from Field Electrofishing Surveys in Montana. Montana Fish, Wildlife & Parks.

Heaton, J. R. 1960. Southwestern Montana fishery study. Federal Aid Project F-9-R-8, Job No. I. Montana Fish, Wildlife and Parks, Helena.

Henshall, J. A. 1906. Culture of the Montana grayling. Report of the Commissioner of Fisheries for the Fiscal Year 1906 and Special Papers. U.S. Bureau of Fisheries, Document 628, Washington, D.C.

Holmes, R., D.N. McBride, T. Viavant and J.B. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Division of Sportfish, Alaska Department of Fish and Game.

Holton, G. D. 1980. The riddle of existence: fishes of "special concern". Montana Outdoors 11(1):2-6.

Hubert, S. A., R. S. Helzner, L. A. Lee and P. C. Nelson. 1985. Habitat suitability index models and instream suitability curves: Arctic grayling riverine populations. U.S. Fish and Wildlife Service Biological Report 82(10.110). 34 pp.

Jordan, D. S. 1891. A reconnaissance of the streams and lakes of the Yellowstone National Park, Wyoming in the interest of the United States Fish Commission. Bulletin of the U.S. Fish Commission 9:41-63.

Kaya, C. M. 1989. Rheotaxis of young Arctic grayling from populations that spawn in inlet of outlet streams of a lake. Transactions of the American Fisheries Society 118:474-481.

Kaya, C. M. 1990. Status report on fluvial Arctic grayling (Thymallus arcticus in Montana. Report to: Montana Fish, Wildlife and Parks, Helena. 97 pp.

Kaya, C. M. 1991. Rheotactic differentiation between fluvial and lacustrine populations of Arctic grayling (Thymallus arcticus) and implications for the only remaining indigenous population of fluvial "Montana grayling". Canadian Journal of Fisheries and Aquatic Sciences 48:53-59.

Kaya, C. M. 1992. Restoration of fluvial Arctic grayling to Montana streams: assessment of reintroduction potential of streams in the native range, the upper Missouri River drainage above Great Falls. Prepared for: Montana Chapter American Fisheries Society, Montana Dept. of Fish, Wildlife, and Parks, U. S. Fish and Wildlife Service, and U. S Forest Service, Bozeman, MT. 102 pp.

Lee, K. M. 1985. Resource partitioning and behavioral interactions among young-of-year salmonids, Chena River, Alaska. M.S. Thesis, University of Alaska, Fairbanks.

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

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

Lynch, J. C. and E. R. Vyse. 1979. Genetic variability and divergence in grayling, Thymallus arcticus. Genetics 92:263-278.

McAllister, D. E. and C. R. Harington. 1969. Pleistocene grayling, Thymallus, from Yukon, Canada. Canadian Journal of Earth Sciences 6:1185-1190.

McMichael, G. A. 1990. Distribution, relative abundance and habitat utilization of the Arctic grayling (Thymallus arcticus) in the upper Big Hole River drainage, Montana. Submitted to: Montana Natural Heritage Program, Helena, Montana.

Montana Fish, Wildlife and Parks. 1989. Application for reservation of water in the Missouri River Basin above Fort Peck Dam. Submitted to: Montana Department of Natural Resources and Conservation, Helena, MT. 3 vols.

Orians, G. H. 1986. Site characteristics favoring invasions. pp. 133-145 in H.A. Mooney & J.A. Drake editors. Ecology of biological invasions of North America and Hawaii. Springer-Verlag New York, New York, USA.

Oswald, D. 1990. Big Hole grayling field work report, fall field season 1990. Submitted to: Montana Fluvial Arctic Grayling Workgroup, Helena, Montana.

Shepard, B. B. and R. A. Oswald. 1989. Timing, location and population characteristics of spawning Montana Arctic grayling (Thymallus arcticus montanus [Milner]) in the Big Hole River drainage, 1988. Report to: Montana Fish, Wildlife and Parks; Montana Natural Heritage Program - Nature Conservancy; and U.S. Forest Service, Northern Region.

Skaar, D. 1989. Distribution, relative abundance and habitat utilization of the Arctic grayling (Thymallus arcticus) in the upper Big Hole River drainage, Montana. Submitted to: Montana Natural Heritage Program, Helena, Montana.

Streu, J. M. 1990. Select aspects of the life history and ecology of the Montana Arctic grayling (Thymallus arcticus montanus) [Milner] in the upper Big Hole River drainage, Montana. Submitted to: Montana Natural Heritage Program, Helena, Montana.

U.S. Geological Survey. 1989. Water Resources Data, Montana, Water Year 1988. U.S.G.S.,Federal Office Building, Helena, Montana.

Varley, J. F. and P. Schullery. 1983. Freshwater wilderness, Yellowstone fishes & their world. Yellowstone Library and Museum Association, Yellowstone National Park, Wyoming.

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

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J.D. Williams, M. Navarro-Mendoza, D. E. McAllister and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14:2-21.

Wipperman, A. H. 1965. Southwest Montana Fishery Study, Federal Aid Project F-9-R-8, Job No. I-A. Montana Fish, Wildlife and Parks, Helena.