AN EVALUATION OF THE REINTRODUCTION OF FLUVIAL ARCTIC GRAYLING INTO THE UPPER RUBY RIVER

by

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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VITA

Bradley William Liermann was born in Billings, Montana on July 10, 1975 to William R. and Nadine P. Liermann. Bradley graduated from Skyview High School in Billings, Montana in 1993 and subsequently attended the University of Montana where he pursued a degree in Wildlife Biology with an Aquatic emphasis. Bradley received this degree in 1997 and began graduate work at Montana State University in 1998.

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ABSTRACT

This study was conducted to assess the survival, movement and growth of fluvial Arctic grayling reintroduced into the upper Ruby River as part of a program to reestablish populations within their native range in Montana. Numbers and ages of fish planted were 29,808 age 0 in 1997, 9,804 age 1 in 1998, and 7,349 age 1 in 1999, distributed among three areas over a 20.2 km reach. Of the 9,804 age 1 fish planted in 1998, 3,750 were given wire tags while all age 1 fish reintroduced in 1999 were given wire tags. Wire tagging locations were varied by planting section to assess post-stocking movement. Electrofishing mark-recapture surveys were conducted at four primary sites and one pass catch-per-unit-effort (CPUE) surveys at six secondary sites in September and October each year and at three primary sites the following April. Recaptured grayling were tested for the presence of wire tags, counted, measured, and weighed, and nonnative brown and rainbow trout were counted. Movements of recaptured fish were assessed by comparing capture and release sites through wire tag recaptures, by operating a weir trap located about 13 km below the lowest planting site, and by a survey of angler catches. Habitat parameters were measured at seven of the same primary and secondary survey sites in 1998 and 1999, including length, wetted width, and average depth of pools, runs, and riffles. From these data, pool-and-run volume, pool-and-run to riffle ratio, width to depth ratio, and sinuosity were estimated for each reach. Age 0 fish planted in 1997 had no apparent survival by the following spring. Age 1 fish planted in 1998 and 1999 showed good survival for the initial three months, averaging 206 and 370 fish per km in October, in two principle monitoring sections. However, comparisons of CPUE estimates indicated reductions of about 80% between October and the following April. Downstream movement appeared low; wire tag data indicate that by three months after release, average downstream movements were 0.7 km in 1998 and 4.6 km in 1999, and only eight were captured at the weir trap each year. After the initial three months of both years, fish increased significantly ($p<0.001$) in both mean length and weight but Fulton's condition factor decreased significantly ($p<0.001$) during this period and also over the following winter. Regression analyses found only pool-and-run to riffle ratio to be a significant habitat predictor of grayling abundance. Other habitat parameters and also densities of brown and rainbow trout densities were not significantly correlated with densities of age 1 or 2 grayling. However, small sample size ($n=14$) due to a limited number of sample sections and only two years of data collection and similarity of brown trout abundance among sections substantially limited this analysis. Reintroduction of Arctic grayling into the upper Ruby River thus appeared initially successful, although future monitoring is necessary to determine the extent to which low winter survival will affect their long-term persistence in this stream and also to further monitor the natural reproduction.

INTRODUCTION

Arctic grayling (*Thymallus arcticus*) are widely distributed throughout northern latitudes, with populations found in northern Asia and North America. Although Arctic grayling populations are common in northern North America, only two glacially isolated populations were native to areas south of Alaska and Canada. One population was previously found in Michigan and the other still exists in the upper Missouri River drainage of Montana (Vincent 1962). Arctic grayling populations display two specific life history types throughout this historical distribution, fluvial and adfluvial. Populations which exhibit fluvial life histories both live and spawn in river or stream environments while adfluvial populations live in lakes or reservoirs and spawn in rivers or streams (Varley and Gresswell 1988).

In Montana, fluvial Arctic grayling were once widely distributed throughout the upper Missouri River drainage above the Great Falls (Figure 1, Kaya 1992a). Currently, many populations of Arctic grayling still exist in Montana, however most are introduced adfluvial populations (the only native adfluvial population being found in Red Rocks Lake). The only truly fluvial population still present in Montana is found in the upper Big Hole River in southwestern Montana. It is estimated that this population inhabits approximately 4% of the historical range of fluvial Arctic grayling in Montana (Kaya 1992a). This decline in fluvial Arctic grayling throughout its range in Montana has been attributed to establishment of nonnative species, habitat alteration, overharvest, and climatic change (Vincent 1962). Due to their limited range and threat of extinction, fluvial Arctic grayling in Montana are now considered a species of special concern by the

Montana Department of Fish, Wildlife and Parks (MFWP) and a candidate species under the Endangered Species Act by the U.S. Fish and Wildlife Service (Holton and Johnson 1996; USFWS 1996). The current restoration goal for fluvial Arctic grayling in Montana is to establish "at least five stable, viable populations distributed among at least three major river drainages" of the upper Missouri River (Montana Fluvial Arctic Grayling Workgroup 1995).

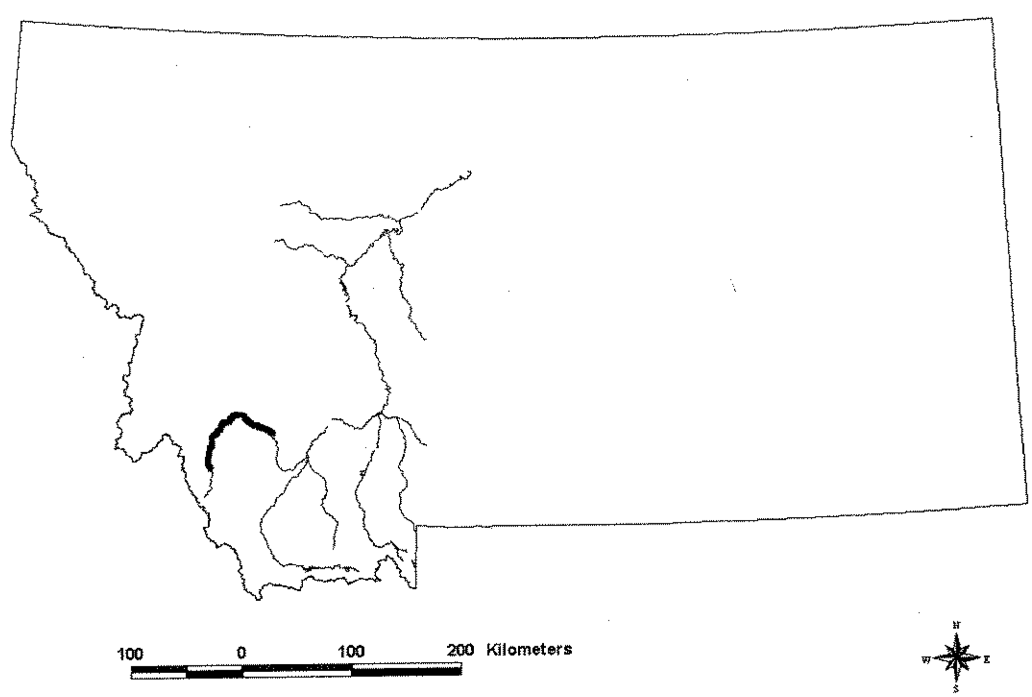

Figure 1. Historical and current distribution of fluvial Arctic grayling in Montana. The approximate historical distribution is represented by all the streams shown, while the current distribution (upper Big Hole River) is highlighted in bold. Kaya (1992a) estimates that fluvial Arctic grayling occupy approximately 4 % of their historic range in Montana

All past attempts to reestablish Arctic grayling populations within stream environments in Montana have failed (Kaya 1992b). One possible reason for the failure of these past attempts is the use of adfluvial parental stocks, such as from Red Rocks Lake, instead of more appropriately adapted fluvial parental stocks. Kaya (1990) lists many unpublished reintroduction attempts from the 1930's and 40's which used adfluvial stocks to reintroduce Arctic grayling into stream environments in Montana, all of which failed. This list includes reintroductions into the Madison, Gallatin, and Smith Rivers, all streams which historically were inhabited by Arctic grayling. Jones et al. (1977) attempted to establish Arctic grayling in Canyon Creek, Yellowstone National Park using a combination of fish from fluvial stocks and adfluvial stocks. Although a population was not established, Jones et al. (1977) observed that individuals from lacustrine stocks appeared to be absent from plant locations only weeks after the reintroduction while fluvial grayling were still present several months after. The observation that fluvial Arctic grayling seemed better adapted to holding position in stream environments than Arctic grayling from adfluvial stocks was later confirmed in both laboratory and field experiments (Kaya 1991; Kaya and Jeanes 1995).

More recently, Arctic grayling reintroductions using progeny of a fluvial population have been attempted. In 1992 and 1993, 5,400 and 10,120 yearling Arctic grayling were planted into the West Gallatin River. These Arctic grayling were progeny of the Big Hole River fluvial population (Lere 1995). Post-reintroduction monitoring, which relied primarily on angler surveys, found that reintroduced fluvial Arctic grayling dispersed large distances downstream after release with the average fish having moved 77 km downstream two months after planting. Also, angler catch rates dwindled in the subsequent years suggesting a lack of survival (Lere 1995). In 1993 and 1994, 10,000 and 10,500 Arctic grayling of fluvial ancestry were also planted into the East Gallatin River. Because of limited angler access, the East Gallatin plant was evaluated primarily by monitoring one electrofishing section. During the fall of 1993 and 1994, only 58 and 163 grayling were recaptured with only two individuals planted in 1993 recaptured in 1994 (Lere 1995). Although the East Gallatin was believed to have adequate habitat to sustain Arctic grayling, the high densities of nonnative species was cited as the main reason for the failure of this reintroduction (Kaya 1992b; Lere 1995). Similarly, a lack of adequate pool habitat and excessive stream gradient in the upper West Gallatin coupled with high densities of nonnative rainbow and brown trout in the lower West Gallatin are factors which were believed to have limited this fluvial Arctic grayling reintroduction (Kaya 1992b; Lere 1995).

As was observed in the Gallatin River reintroductions, high densities of nonnative species and a lack of suitable habitat (Kaya 1992b, Lere 1995) are two additional factors which can limit fluvial Arctic grayling reintroduction attempts. Kaya (1992a) cites the introduction of nonnative fish as perhaps the most critical factor leading to the decline of Arctic grayling throughout its range in Montana. For example, the decline of Arctic grayling in the Madison River appears to have been associated with the invasion of nonnative brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) planted in Yellowstone National Park in the late 1800's. Also, Arctic grayling densities in the Big Hole River are presently much lower below the Divide Dam where densities of rainbow and brown trout are greatest (Kaya 1992a). Lack of suitable habitat is another factor which may limit reintroduction efforts. Historically, fluvial Arctic grayling in Montana were found in larger, low gradient rivers with abundant pools (Vincent 1962) and several studies have found that lower velocity pool habitats are an important component of quality Arctic grayling habitat (Vascotto and Marrow 1973; Chislett and Stuart 1979; Liknes 1981; Hubert et al. 1985; Reynolds 1989). Thus, Arctic grayling reintroduction attempts in streams lacking these habitat characteristics may be futile. Hairig et al. (2000) report that 43% of failures in Greenback cutthroat trout reintroductions are due to unsuitable habitat in the streams in which reintroductions are attempted.

A reintroduction of Arctic grayling using fluvial progeny was also recently attempted in Cougar Creek (Madison River drainage) in Yellowstone National Park. No nonnative species were present in Cougar Creek and the habitat was believed to be suitable for fluvial Arctic grayling (Kaya 1992b). About 800 age 0 or age 1 fish were planted in each of three years: 1993, 1994 and 1995. Electrofishing surveys yielded few or no survivors in subsequent years (Kaya 2000). In 1996, biologists broadcast fertilized Arctic grayling eggs by hand onto suitable spawning gravels (J. Magee, MFWP, personal communication). Although young of the year were observed in Cougar Creek later that season, it is believed that there was no subsequent survival past the juvenile stage (D. Mahoney, U. S. National Park Service, personal communication). The small size of the stream and its low biological productivity are possible reasons for this failure (Kaya 2000).

Based on the failure of past reintroduction efforts and further knowledge of Arctic grayling ecology, several criteria are currently used to assess reintroduction sites for fluvial Arctic grayling. Streams considered for reintroductions should have: 1) relatively low densities of non-native salmonids, 2) habitat suitable for the existence of Arctic grayling which includes having an average gradient of less than 1% and abundant pool habitat, and 3) long sections of unimpeded stream (Kaya 1992b; Byorth 1997). The third criterion was selected because fluvial Arctic grayling have been found to undergo extensive seasonal migrations (Craig and Poulin 1975; Shepard and Oswald 1989; West et al. 1992; others reviewed in Armstrong 1986). Arctic grayling in the Big Hole River migrate up to 80 kilometers downstream to overwintering habitat and return upstream to spawn in the spring and over-summer in years of adequate flow (Shepard and Oswald 1989). Thus, it is believed that impassable structures such as dams or excessive dewatering which fragment a stream may reduce the possibility for a successful Arctic grayling reintroduction (Byorth 1997).

Based on the above criteria, several streams in Montana were identified as possible Arctic grayling reintroduction sites including: upper Ruby River, Firehole River above Kepler Cascades, Gibbon River upstream from Gibbon Falls, Canyon Creek (Gibbon River drainage), Cougar Creek (upper Madison River drainage), Cherry Creek (lower Madison drainage), Elk Creek (Smith River drainage), and the North and South Forks of the Sun River (Kaya 1992b). The upper Ruby River was chosen specifically among these candidate streams because it provides the largest contiguous section of river suitable for fluvial Arctic grayling (Kaya 1992a; Byorth 1997).

In addition to large sections of contiguous habitat, the upper Ruby River also meets the criteria of low densities of nonnative species and suitable habitat. In 1995 and 1996, densities of rainbow trout (including rainbow cutthroat hybrids) at the two highest monitoring sections on the upper Ruby River were estimated at less than 125 fish/km with very few brown trout captured (Byorth 1997). It has been suggested that reproduction of nonnative brown and rainbow trout may be limited by the abundance of fine sediments in this section of the upper Ruby River (Haugen 1977, cited in MFWP 1989). In sections of the Big Hole River, Arctic grayling maintain densities of 15-45 fish per km in the presence of 80-160 rainbow trout per km (Magee and Opitz 2000). Therefore, rainbow trout densities appear to be low enough to allow for the existence of Arctic grayling in this section of river. However, densities do increase to approximately 1000 (>100 mm) rainbow per km and up to 80 brown trout per km in lower sections of the upper Ruby River. Approximately 32 km of the Ruby River with low densities of nonnatives are still available as potential habitat for Arctic grayling (Byorth 1997).

The upper Ruby River also appears to have habitat suitable for sustaining a fluvial Arctic grayling population. The physical habitat of the upper Ruby River is believed to better mimic the physical habitat of the upper Big Hole River (where fluvial Arctic grayling still persist) than all other candidate streams (Kaya 1992b). The mean gradient of the upper Ruby River is estimated at 0.7% which meets the criterion of less than 1% set by Kaya (1992b), although some sections do exceed 1% (Byorth 1997). Also, the abundance of pool and run habitat appears to be suitable (Byorth 1997; Kaya 1992b). It is estimated that the upper Ruby River provides approximately 65 kilometers of unimpeded stream with suitable fluvial Arctic grayling habitat (Byorth 1997).

The goal of this study was to evaluate the reintroduction of fluvial Arctic grayling into the upper Ruby River. The following objectives were carried out to meet this goal.

1. Estimate the persistence and growth of reintroduced Arctic grayling. This objective was carried out to assess the initial success or failure of the reintroduction and to evaluate whether the upper Ruby River can sustain a fluvial Arctic grayling population.

2. Monitor dispersal and movement of stocked Arctic grayling both between study reaches and downstream of study reaches. This objective was carried out to determine if rapid downstream dispersal of reintroduced grayling occurs as observed in other reintroductions, and if seasonal movements of Arctic grayling occur as described by other studies.

3. Determine if correlations exist between physical habitat or abundance of nonnative species and Arctic grayling abundance. This objective was included to provide insight into potential reasons for the failure or success of the project as well as possible factors which may limit future reintroductions.

STUDY AREA

The headwaters of the Ruby River begin at Centennial Divide near the border of Madison and Beaverhead Counties in southwestern Montana. The upper Ruby River drainage was first settled in the late 1800's by homesteaders who utilized the land as summer range for cattle and sheep. Currently, land ownership in the upper Ruby River consists of a combination of private land holdings, federal land managed by the Beaverhead National Forest and a few sections of land owned by the State of Montana. Private lands in the upper Ruby watershed are managed primarily for agricultural purposes including hay production and pasture for domestic cattle, sheep, and bison. The 35,600 hectares of Beaverhead National Forest surrounding the upper Ruby River are managed for multiple use including recreation, wildlife habitat, and grazing allotments. Forest Service grazing allotments for cattle and sheep are issued for approximately 17,4000 hectares of this land (USFS 1992).

The primary study reach for this project was located from the upper Middle Fork Bridge to the Ruby Reservoir (Figure 2), a distance of about 65 river kilometers. The Ruby River in this section is a low gradient stream with base flows of approximately 2.5 m^3/s (Figure 3). The upper Ruby valley is subject to high natual erosion rates due to the surface geology being dominated by soft, easily erodable soils, however land uses are believed to have exacerbated this erosion (Page 1978). As a result, the upper Ruby River is primarily a highly sinuous "C" channel type (Rosgen 1994) which commonly migrates laterally and forms new channels (Page 1978). The upper Ruby River takes on the characteristics of a well-armored "B" channel in some areas (Rosgen 1994).

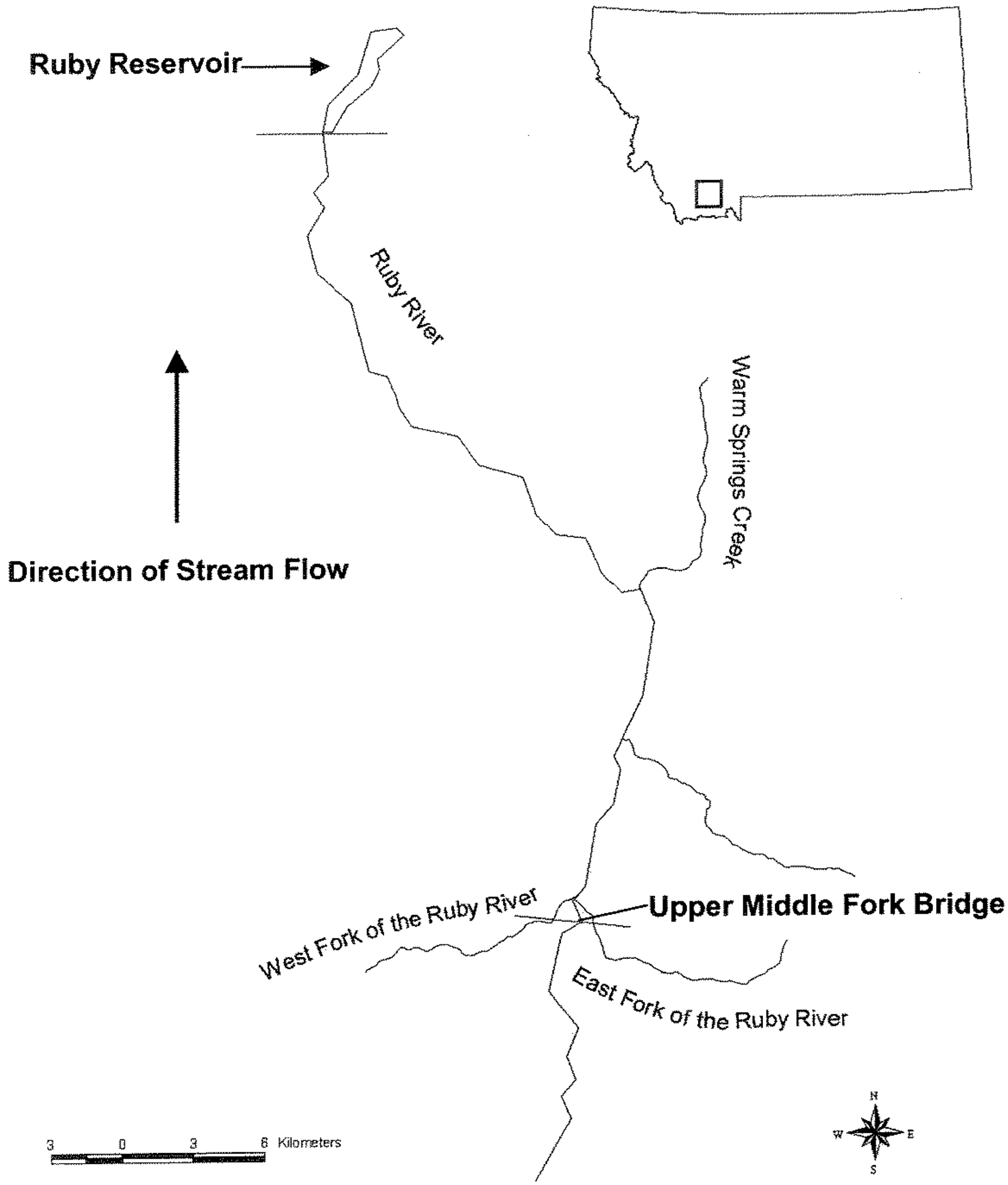

Figure 2. Study area delineation map of the upper Ruby River watershed. The study area encompasses from the Middle Fork Bridge, approximately 1 kilometer upstream of the Three Forks of the Ruby River downstream to Ruby Reservoir.

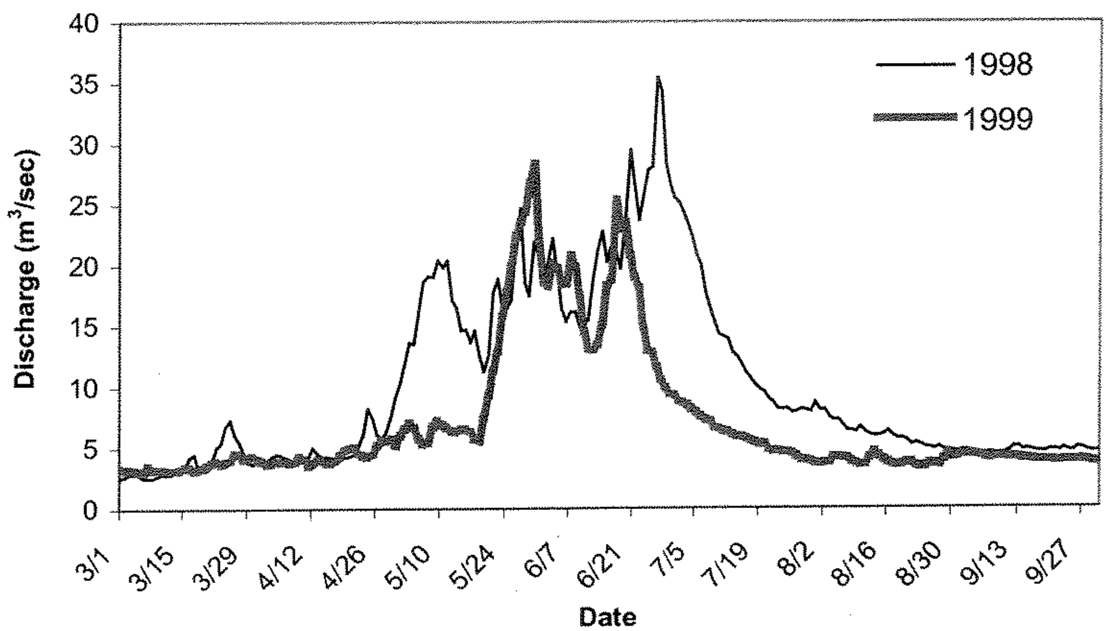

Figure 3. Discharge of the upper Ruby River at a USGS gauging station in 1998 and 1999. Discharge varied during the time of study from approximately 2.5 m^3/sec in fall 1998 to approximately 35 m^3/sec in June of 1998. Annual base flows in the upper Ruby River occurred either during early March or were similar (within 0.2 m^3/sec) to the discharges observed in early March in both years (http://www.montana.usgs.gov).

The upper Ruby River supports a depauperate fish community with only 8 species present. In addition to reintroduced Arctic grayling, fishes native to the upper Ruby River include westslope cutthroat trout (*O. clarki lewisi*), mountain whitefish (*Prosopium williamsoni*), longnose suckers (*Catostomus catostomus*), white suckers (*Catostomus commersoni)*, longnose dace (*Rhinicthys cataractae*) and mottled sculpin (*Cottus bairdi*). Nonnative species are rainbow trout and brown trout. Westslope cutthroat trout in the upper Ruby River are highly introgressed with rainbow trout due to hybridization. Due to this extensive hybridization, rainbow-cutthroat trout hybrids are managed simply as rainbow trout (Byorth 1997).

METHODS

Planting

Arctic grayling were planted into the upper Ruby River in 1997, 1998, and 1999. These fish were progeny of the fluvial Arctic grayling broodstock located at Axolotl Lake (Madison County) which are F_1 progeny of the Big Hole River population. Arctic grayling do not spawn in Axolotl Lake due to a lack of suitable habitat, thus no long term adaptation of this population to the lacustrine environment is possible (J. Magee, MFWP, personal communication). All Arctic grayling stocked in the upper Ruby River were raised at the Bluewater State Fish Hatchery near Bridger, MT.

In 1997, 29,808 age 0 Arctic grayling were planted in the upper Ruby River. These fish were planted throughout the upper portion of the study area with 7,104 being planted at Three Forks, 6,512 at Jug Creek Bridge, and 6,512 near Vigilante Bridge on September 9 (Figure 4). Age 0 plants were again conducted on September 24, with another 4,840 Arctic grayling being planted near Vigilante Bridge and 4,840 near the Broken Arrow Lodge (Figure 4). A majority of the fish were planted upstream of Warm Springs Creek due to the lower densities of nonnative rainbow and brown trout in this section.

A total of 9,804 and 7,349 age 1 Arctic grayling were planted into the upper Ruby River in 1998 and 1999 at three primary sites and three secondary sites (Figure 4). On July 13 and 15, 1998, 3,320 Arctic grayling were planted at Three Forks (river km 66 upstream from Ruby Reservoir), 3,120 at Jug Creek Bridge (river km 56) and 3,364 at Vigilante Bridge (river km 49) (Figure 4). On July 12 and 14 of 1999, 2,520 grayling

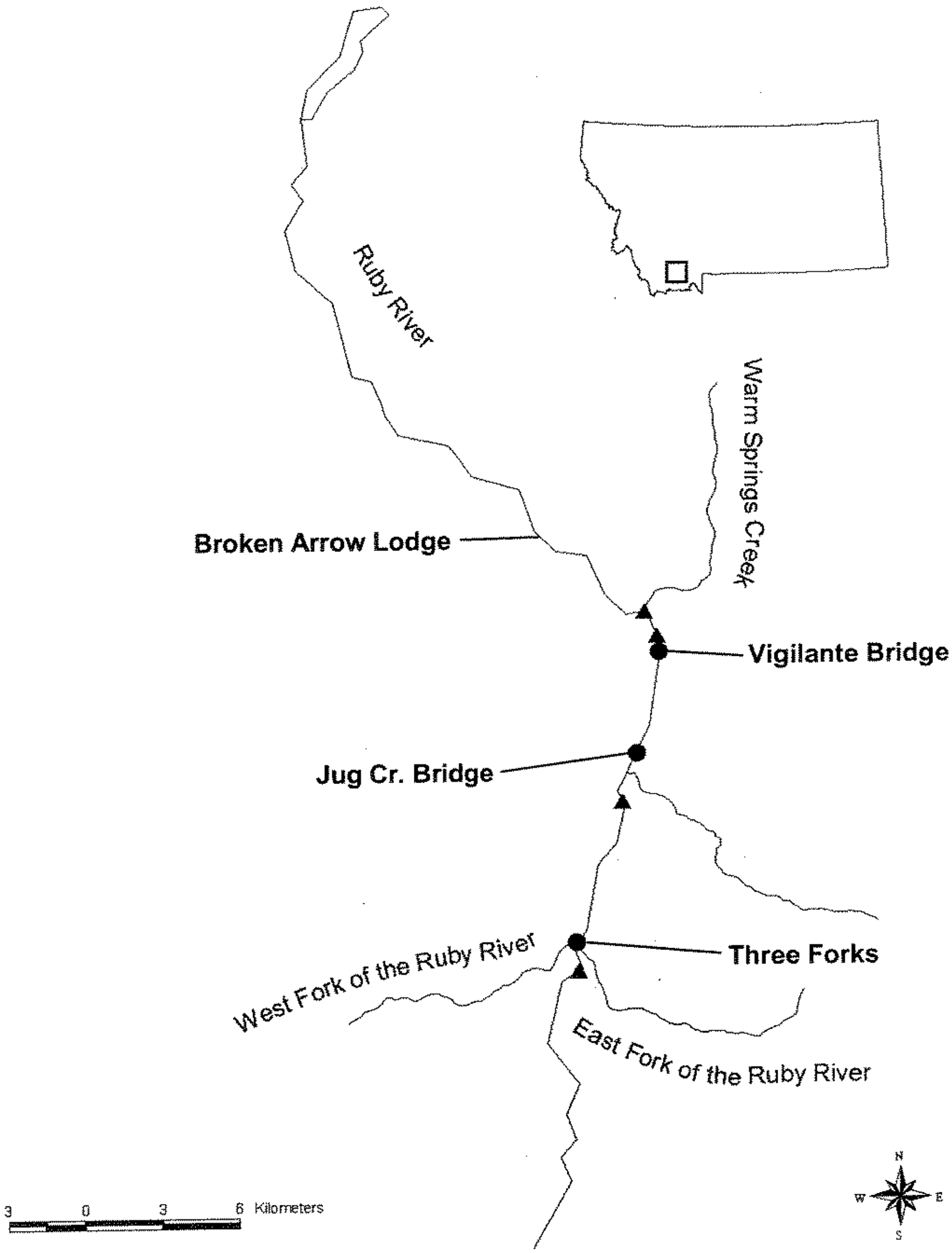

Figure 4. Locations of age 0 and age 1 plant sites for 1997-1999. Circles indicate primary plant sites and triangles indicate secondary plant sites used for age 1 Arctic grayling reintroductions in 1998 and 1999. The secondary plant site located at the mouth of Warm Springs Creek was planted only in 1998 and the triangle just north of the Vigilante Bridge site was the secondary plant site used in 1999.

were planted at Three Forks, 2,326 at Jug Creek Bridge, and 2,503 at Vigilante Bridge. During both years, approximately one third of the totals from each primary site were planted at the corresponding secondary site. These secondary sites were used to more widely distribute Arctic grayling in attempt to limit “crowding” effects. The three secondary sites included the upper Middle Fork Bridge (0.5 river km above Three Forks), the mouth of Bear Creek (2.7 river km above Jug Creek Bridge) and the mouth of Warm Springs Creek (2.4 river km below Vigilante Bridge) (Figure 4). In 1999, fish were not planted at the mouth of Warm Springs Creek and a site near Vigilante Guard Station, approximately 0.3 river kilometers downstream of Vigilante Bridge, was used as the secondary site (Figure 4).

At each primary plant site, approximately 200 age 1 Arctic grayling were kept for 3 to 7 days in holding pens to better acclimatize Arctic grayling to the upper Ruby River. Kaya and Jeanes (1995) found that age 0 fluvial Arctic grayling held in pens for 7-14 days were less likely to disperse downstream after release. Only 200 fish were held at each site due to space limitation in the holding pens.

Relative Abundance

Relative abundance of reintroduced Arctic grayling in different river segments was assessed by electrofishing. A 3000 watt generator and a rectifying unit (converting AC electricity to DC) mounted on a Coleman “crawdad” boat were used in the upper sections of the study area. In lower sections where increased discharge prevented the use of this unit, a mobile anode drift boat electrofishing unit was used. Electrofishing efforts were coordinated by MFWP biologists (J. Magee and D. Oswald).

Four MFWP monitoring sections were sampled each fall to estimate population sizes of Arctic grayling, rainbow (includes rainbow-cutthroat hybrids), and brown trout using mark-recapture estimation methods. These sections included the Three Forks, Vigilante, Section One, and Greenhorn monitoring sections (Figure 5). A more detailed description of the locations of electrofishing sections and their length is provided in Appendix A. The modified Petersen's equation and corresponding variance suggested by Chapman (1951) were used to estimate population size:

$$N = \frac{(M+1)\,(C+1)}{(R+1)} - 1$$

$$\sigma^2 = \frac{(M+1)\,(C+1)\,(M-R)\,(C-R)}{(R+1)^2\,(R+2)}$$

Where: N = estimated population size
M = number of fish marked on first (marking) pass
C = total number of fish captured on second (recapture) pass
R = number of marked fish captured on second pass

Population estimates for Arctic grayling were calculated for each 25 mm length class while population estimates for rainbow and brown trout were calculated as a combined group of all fish 200 mm and larger. The 200 mm minimum length for rainbow and brown trout estimates was selected because electrofishing efficiency based on recapture to capture ratios (R/C) tended to be similar for length classes larger than 200 mm.

Marking runs for each of these sections were typically carried out between September 15 and October 1, with the latest marking date being October 15. Marking and recapture runs were separated by at least ten days. One pass catch per unit effort (CPUE) estimates were also attempted for the Three Forks, Vigilante, and Greenhorn

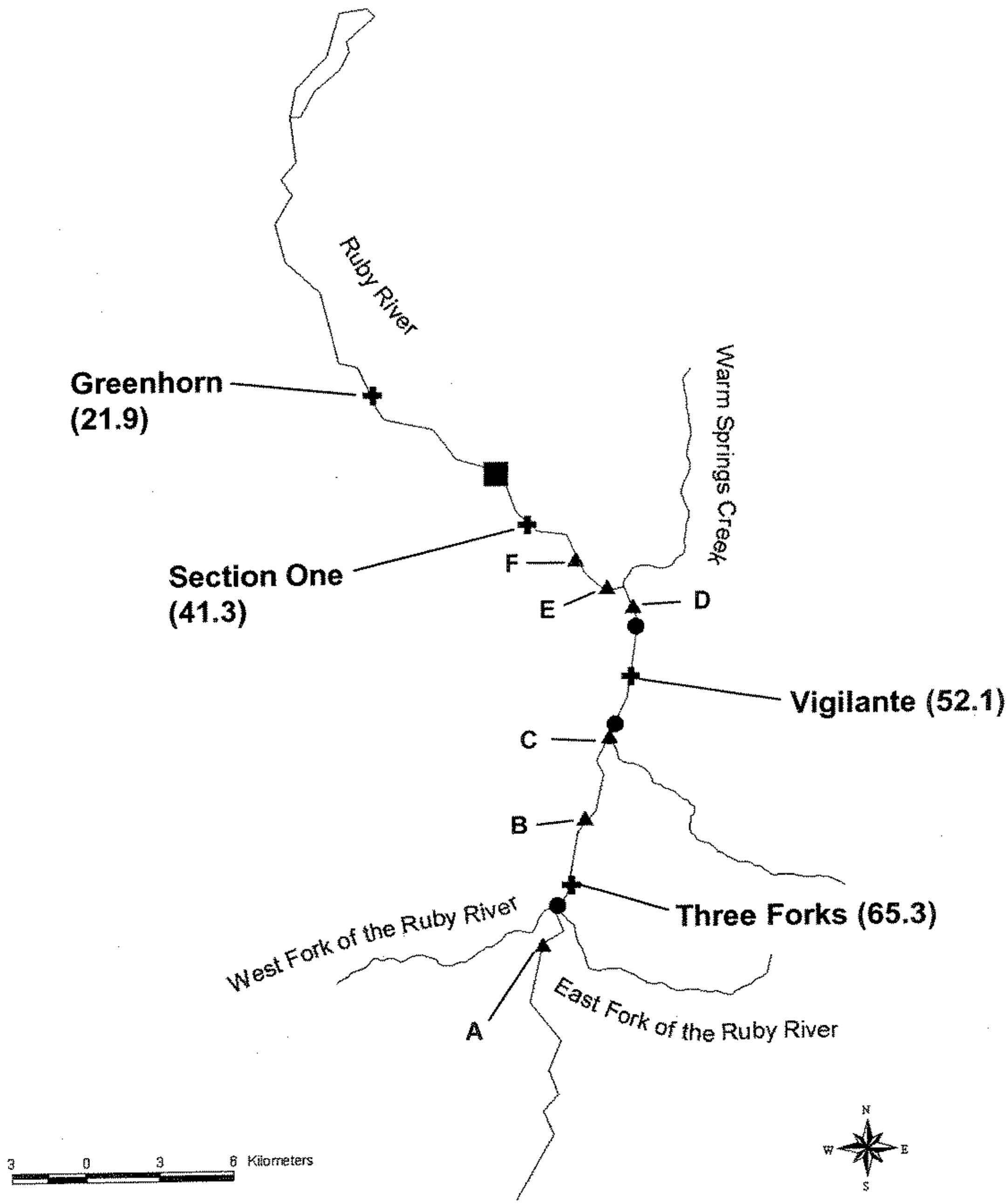

Figure 5. Locations of mark-recapture population estimate sections (represented by crosses), one-pass catch per unit effort (CPUE) estimate sections (triangles, A-F), and weir trap (square) in relation to the primary plant sites (circles) in the upper Ruby River. Values in parentheses represent river kilometers above Ruby Reservoir.

population estimate sections each spring between April 10 and April 30 to assess overwinter survival of Arctic grayling.

Six shorter (Appendix A) monitoring sections, previously established by MFWP, were also sampled with electrofishing to obtain one pass CPUE (fish captured per 100 m) estimates for Arctic grayling, rainbow, and brown trout (Figure 5). Each of these sections was sampled in the fall each year between September 15 and October 15. These sites were evenly distributed throughout the upper Ruby River (Figure 5). Mark-recapture estimates were also converted to CPUE estimates by calculating the number of fish captured per 100 m on the first pass of the estimate to allow for comparison with one pass CPUE estimates.

From July 29 through November 25, 1999, a volunteer angler creel survey was also used to assess relative abundance and dispersal through angler catch rates of reintroduced Arctic grayling. Six creel survey boxes were placed throughout the upper Ruby River in locations which both afforded heavy angler use and were evenly dispersed throughout the drainage. Forms available at each site surveyed anglers about the number of each species caught, the location of these catches, the length of time fished in each section. The forms delineated the upper Ruby River into four distinct sections: two sections between the plant sites, one upstream and one downstream of the plant sites (Figure 6). Angler catch per hour for Arctic grayling was then calculated for each section. A one-way analysis of variance (ANOVA) and a Tukey's multiple comparison test were used to test for significant differences in catch rates between sections. Statistical significance was based on an alpha value of 0.05 for all statistical tests in this

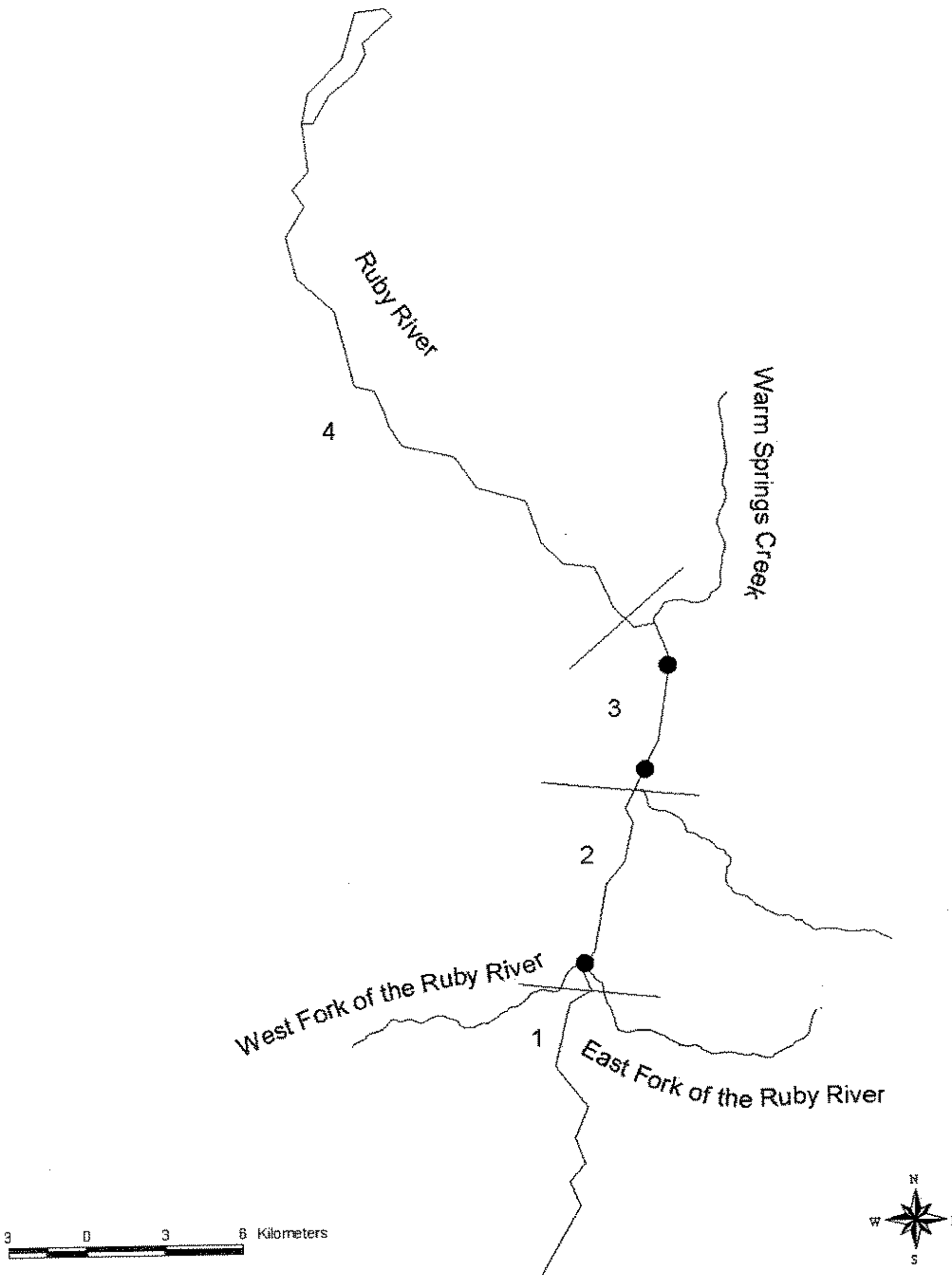

Figure 6. Delineation of the four locations outlined on the angler creel survey form in relation to the primary plant sites for age 1 Arctic grayling in the upper Ruby River.

study. For all parametric tests, the assumption of normality was tested using a normal probability plot and the assumption of homogeneity of variance was tested using a residuals versus predicted values plot.

Movement

Downstream dispersal of reintroduced Arctic grayling was assessed in 1998 and 1999 using a weir trap installed near the mouth of Ice Creek, approximately 13 river kilometers downstream of the Vigilante Bridge plant site (Figure 5). During both years, the trap was installed before planting (July 15, 1998 and July 14, 1999) and operated continuously for three weeks after planting to assess initial downstream dispersal. Thereafter, the trap was operated continuously on 5 to 10 day intervals through August. From July 15 through August in 1998 the trap was operated for a total 35 days and from July 14 through August in 1999 the trap was operated for 34 days. To assess whether large downstream fall movement occurred, fall trapping was also carried out from September 12 until November 21 in 1998 and September 1 until December 2 in 1999. During this period, the trap was typically operated for two days and nights for two out of every three weeks. The trap was operated for a total of 16 days during this fall period in 1998 and for 20 days in 1999.

The weir trap consisted of two trap boxes and a "picket fence" style weir which spanned the entire width of the Ruby River (18.9 m). The weir was constructed of 13 mm diameter aluminum electrical conduit, evenly spaced by 13 mm plastic PVC spacers and strung together with 5 mm steel cable. Several conduit panels ranging from 1.8 m to 6.1 m in length were combined to form the weir. The weir was supported by 5 mm steel cable strung across the channel from two steel fence posts located on the right and left banks. Each fence post on the bank was then cabled to two additional fence posts approximately 1 m behind the original post for additional support. Several steel fence posts were also driven into the substrate across the channel to provide additional stability for the weir.

Two trap boxes were placed in the middle of the weir. One trap box was positioned to face downstream while the other was positioned to face upstream to assess both downstream and upstream movement of Arctic grayling and to provide unimpeded movement through the reach for other species. The frame of each trap box was a cube constructed of 1.1 m sections of steel reinforcing rods welded together. Plastic mesh (8 mm square) was stretched across each side of the trap and a top door constructed of plywood provided access to trapped fish. Each trap had a 30 cm by 30 cm opening through which fish entered with an attached funnel which led fish into the main cavity of the trap. This funnel prevented fish from escaping. Each year, trap escapement was estimated by fin clipping mountain whitefish and checking the trap in the subsequent days for clipped fish. Mountain whitefish were used because they were the most abundant salmonid captured at the trap. If substantial escapement was detected, maintenance was performed on the trap and subsequent tests were conducted to confirm that repairs prevented further escapement.

Age 1 Arctic grayling were tagged prior to planting at the Bluewater State Fish Hatchery with non-coded binary wire tags (wire tags) to assess upstream and downstream movement after planting. Wire tags were implanted into one of three locations: the snout, base of the dorsal fin (referred to as dorsal tags), or the base of the anal fin (referred to as anal tags). These tag locations were used to distinguish fish released at each of the three primary and corresponding secondary planting locations. Arctic grayling planted at Three Forks were implanted with snout tags, Jug Creek Bridge fish with dorsal tags, and Vigilante Bridge fish with anal tags (Figure 4). In 1998, 3,750 of the 9,804 planted Arctic grayling were tagged, 1,250 for each planting location. Arctic grayling planted at primary and secondary were not kept separate after tagging thus, an equal portion of Arctic grayling planted at both the primary and secondary sites in 1998 had been wire tagged. In 1999, all 7,349 Arctic grayling planted were tagged. In addition to the wire tag, all fish planted in 1999 were given an adipose clip to distinguish them from fish planted in 1998.

Wire tag detectors were carried along on each electrofishing survey and the number of fish captured from each planting location recorded. The percent composition of fish from each plant site was determined for each electrofishing section and compared with other sections. Also, a total up- or downstream dispersal distance was calculated for each wire tagged Arctic grayling recaptured. From these data, a mean overall dispersal distance was calculated using all wire tagged Arctic grayling recaptured during fall surveys each year. The river km at which each fish was planted was calculated as one third the distance between the primary and secondary plant sites, based on approximately one-third of the Arctic grayling with each tag type being planted at the secondary site. Arctic grayling captured between the primary and secondary sites were considered to have moved zero km.

Retention of wire tags has been found to be exceptionally good (Tipping and Heinricher 1993; Hale and Gray 1998), however past studies have found that the limited tag loss that does occur is most prevalent relatively close to the time of injection (Blankenship 1990). Thus, wire tag retention was tested on Arctic grayling approximately 24 hours after implantation in 1998 and 1999. Wire tag retention was also tested three weeks after implantation in 1999. Tag retention three weeks after implantation could not be assessed for Arctic grayling planted in 1998 because tagged fish were mixed in with non-tagged fish.

Growth and Condition

Growth and condition factor of reintroduced Arctic grayling were also assessed. On the day of reintroduction, lengths and weights were recorded for 50 Arctic grayling randomly selected from each batch planted to provide a baseline for growth comparisons. Lengths and weights of each Arctic grayling captured during electrofishing were also recorded. Weights were taken using a HOMS brand spring scale. Mean length, weight and Fulton's condition factor were calculated for Arctic grayling for each sampling section and sampling period (spring and fall). Fulton's condition factor was calculated using the following equation (Anderson and Nuemann 1996):

$$K = (W/L^3) \times 100{,}000$$

One-way ANOVA and Tukey's multiple comparison tests were used to test for significant differences in growth indices between both the period sampled and the sections sampled.

Habitat Use

Habitat use of reintroduced Arctic grayling was assessed by correlating electrofishing CPUE estimates with physical habitat parameters measured in each section. Recent salmonid habitat studies have relied on measuring habitat use and preference at the habitat unit (pools or riffles) scale (Hankin and Reeves 1988). This technique can be effective in low order streams, however, in higher order streams such as the Ruby River (base flows of 2.5 m^3/s), the type of equipment (boat mounted mobile electrofishing unit) required to properly sample the stream does not lend itself to measuring abundance in specific habitat units. Moreover, streams this size often consist of multiple habitat units in a single channel cross-section. Arctic grayling abundance and habitat parameters were therefore measured for entire sections (CPUE monitoring sections (A-F) and mark-recapture population estimate monitoring sections). Also, habitat parameters that characterize reach scale habitat features (e.g. sinuosity, width to depth ratio) were selected to assess habitat use of Arctic grayling.

Habitat surveys were conducted in August of 1998 and 1999. Habitat surveying consisted of delineating each electrofishing section into habitat types such as pools, runs, or riffles (Bisson et al. 1982). Next, the length, wetted width, and average depth were measured for each reach, as described by Platts et al. (1983). From these data, reach scale habitat characteristics were calculated and described for each section. These included pool-and-run to riffle ratio, width to depth ratio, volume of pools and runs per 100 m, and the sinuosity of each section. Pool-and-run to riffle ratio was calculated as the length of stream classified as either a pool or a run in the entire section versus the length of stream classified as a riffle in the entire section. Width to depth ratio was simply calculated for each habitat type and averaged for the entire section. The volume of both pools or runs were calculated for each habitat unit and summed for the entire section. The volume of pools and runs for the entire section was then standardized to 100 m to allow for comparisons between sections of different lengths (Appendix A). Sinuosity was calculated by dividing the total stream length as measured through habitat surveys by the linear distance from each end of the reach as determined from USGS 1:24,000 topographic maps. Pools and runs were combined in several of these indices to make the data comparable to other studies (e.g. Liknes and Gould 1987) and because runs were much more prevalent in the upper Ruby River than pools (both of which are deep water habitats).

Simple linear regression was used to test for correlations between these habitat variables and Arctic grayling abundance. One pass CPUE estimates and mark-recapture estimates converted to CPUE data from fall 1998 and 1999 were used to estimate Arctic grayling abundance for this analysis. Converted mark-recapture estimates were used to standardize these data with one pass CPUE data. Regression analysis was performed separately on age 1 and age 2 (1999 only) Arctic grayling year classes.

<u>Effects of Nonnative Species</u>

The numbers of non-native rainbow (including rainbow-cutthroat hybrids) and brown trout were recorded in all electrofishing surveys and CPUE (fish per 100 m) estimates were used to estimate their abundance. Mark-recapture estimates were again converted to CPUE estimates to standardize these data with one pass CPUE data. Simple linear regression was used to test whether correlations exist between the CPUE of Arctic grayling and non-native salmonids. Regression analysis was performed separately on age 1 and age 2 (1999 only) Arctic grayling year classes.

RESULTS

Relative Abundance

Survival of the 29,808 age 0 Arctic grayling stocked in September 1997 was very low. In electrofishing surveys conducted in October, only 16 were captured in the one pass CPUE sections including three in section A and 13 in section D. Similarly, only 31 age 0 fish were captured in the Three Forks section in two passes and none were captured in the Vigilante and Section One monitoring sections in two passes during October. A mark-recapture estimate could not be obtained in the Three Forks section because no age 0 Arctic grayling were recaptured on the second pass of the estimate. While electrofishing efficiency is typically better for larger fish (Reynolds 1996), the low numbers of age 0 Arctic grayling captured is likely not a product of low electrofishing efficiency. Electrofishing efficiency was high enough in the Three Forks and Vigilante estimate sections to attain estimates for rainbow trout of slightly larger size than age 0 Arctic grayling (mean length, 63 mm; Table 1).

Table 1. Mark-recapture estimates for 100 and 125 mm rainbow trout length classes to demonstrate electrofishing efficiencies for small salmonid size classes in the Three Forks and Vigilante estimate sections.

		Mark-Recapture Estimate Statistics				
	Length Class	Marks	Captures	Recaptures	Estimate	Standard Deviation
Three Forks	100-124 mm	7	7	4	6	1.41
	125-149 mm	12	11	1	40	27.2
Vigilante	100-124 mm	7	2	1	3	1.9
	125-149 mm	20	8	6	8	2.0

In spring of 1998, electrofishing surveys were only attempted on sections A and B due to early high water conditions. No age 0 grayling were captured in either of these sections. This age 0 year class could not be monitored beyond the spring of 1998 because if these fish grew at rates similar to the Big Hole River population, their size would make them indistinguishable from the age 1 Arctic grayling reintroduced in July of 1998 (Magee 1999). However, fall and limited spring sampling suggested that few remained or survived in the study area.

Despite poor survival of age 0 Arctic grayling, mark-recapture estimates obtained in fall (October) 1998 suggest that age 1 Arctic grayling stocked in July 1998 demonstrated much better short-term survival (Table 2). Arctic grayling densities were

Table 2. Mark-recapture estimates for Arctic grayling (AG), rainbow trout (RB), and brown trout (BT) in the upper Ruby River during fall (October) 1998. Each estimate and corresponding standard deviation is based on number per km. N/a indicates sections where estimates could not be obtained due to low numbers of fish. Estimates for rainbow and brown trout include all fish 200 mm and larger.

	Mark-Recapture Estimate Statistics					
Section	Species	Marks	Captures	Recaptures	Estimate	Standard Deviation
Three Forks	AG	360	299	223	252	6.2
	RB	73	51	23	83	13.9
Vigilante	AG	166	56	3	485	259.1
	RB	101	67	15	128	45.9
Section One	AG	1	3	0	n/a	
	RB	84	120	17	454	95.8
	BT	7	15	1	50	26.7
Greenhorn	AG	0	2	0	n/a	
	RB	50	96	14	93	33.9
	BT	73	156	17	182	64.4

estimated at 252 fish per km in the Three Forks section and 485 fish per km in the Vigilante section in fall 1998 (Table 2). Estimates of Arctic grayling densities were not obtained in Section One and the Greenhorn section due to a lack of recaptures. These results were due to very few Arctic grayling being present within estimate sections rather than low electrofishing efficiency. This is supported by the fact that electrofishing efficiency was high enough to obtain estimates on rainbow and brown trout in both of these sections (Table 2).

Similar to 1998, relatively high densities of age 1 Arctic grayling stocked in July 1999 were present in fall 1999 with estimates of 161 fish per km in the Three Forks section and 255 fish per km in the Vigilante section (Table 3). Also similar to 1998, densities of age 1 Arctic grayling were much lower in Section One and the Greenhorn section with only of 12 grayling per km present in Section One and too few grayling present in the Greenhorn section to estimate abundance (Table 3).

Fall 1999 population estimates also confirmed the presence of moderate densities of age 2 Arctic grayling with estimates of 22 and 16 age 2 fish per km in the Three Forks and Vigilante sections (Table 3). However, during the second pass of the 1999 population estimate in the Three Forks section, the age of recaptured individuals was not recorded due to miscommunication with staff assisting with sampling. Therefore, the number of recaptured age 1 and age 2 fish had to be estimated. Since the number of age1 and age 2 fish captured on the first pass and the number of non-marked age 1 and age 2 fish caught on the second pass were known, only the number of recaptured fish from both

Table 3. Mark-recapture estimates for age 1 and age 2 Arctic grayling (AG), rainbow trout (RB) and brown trout (BT) in the upper Ruby River during fall (October) 1999 electrofishing surveys. Each estimate and corresponding standard deviation is based on number per km. Statistics which were estimated are denoted by an *. N/a stands for sections where estimates could not be obtained due to low Arctic grayling abundance. Estimates for rainbow and brown trout include all fish 200 mm and larger which includes several age classes (all).

	Mark-Recapture Estimate Statistics						
Section	Species	Age	Marks	Captures	Recaptures	Estimate	Standard Deviation
Three Forks	AG	1	184	161	95*	161	10.1
	AG	2	25	41	24*	22	0.8
	RB	all	93	33	9	165	55.1
Vigilante	AG	1	212	181	44	255	53.2
	AG	2	20	7	2	16	11.2
	RB	all	192	128	46	156	28.8
Section One	AG	1	3	8	1	12	3.3
	AG	2	0	0	0	n/a	
	RB	all	278	299	103	640	44.9
	BT	all	21	23	9	41	8.0
Greenhorn	AG	1	3	4	0	n/a	
	AG	2	0	0	0	n/a	
	RB	all	73	98	14	138	53.4
	BT	all	153	172	21	342	116.1

age classes had to be estimated to attain a separate estimate for each age class. This was accomplished by calculating the ratio of marked to unmarked fish for both age classes combined and extrapolating this ratio to the age 1 and age 2 year classes separately. This extrapolation assumes that there was equal sampling efficiency during electrofishing surveys for both age classes. A comparison of lengths between the two age classes of fish showed no significant difference (P=0.20, t-test), suggesting that variation in length would not have affected the electrofishing efficiency.

Mark-recapture estimates in the upper Ruby River varied markedly between sections and years. The Three Forks and Vigilante sections had estimates of between 183 and 485 grayling per km during fall 1998 and 1999. Section One and the Greenhorn section, on the other hand, had very low densities of Arctic grayling during fall surveys in both years. These results are likely due to the Three Forks and Vigilante sections being located between the primary plant sites while Section One and the Greenhorn sections are located well downstream of these sites (Figure 5). Similar results were obtained for one pass CPUE electrofishing data collected in 1998 and 1999 (Figure 7). Sections B, C, and D, located between primary plant sites, provided consistently higher CPUE estimates than sections A, E, and F (Figure 7), which are located either upstream or downstream primary plant sites (Figure 5).

While Arctic grayling densities were relatively high three months after the reintroduction in both years (from 183-485 per km), the densities of age 2 Arctic grayling in the fall of 1999 suggest a substantial decline in this cohort over a one year period. Densities of age 1 Arctic grayling averaged 369 per km in the fall of 1998 (Table 2) between the Three Forks and Vigilante population estimate sections in comparison to an average of 19 age 2 Arctic grayling per km in fall of 1999 (Table 3), approximately a year and three months after their reintroduction. This is a 94.9% reduction from the fall of 1998 to the fall of 1999, although low efficiency in the 1998 Vigilante section estimate may have overestimated this reduction (Table 2). Similar reductions were observed between fall 1998 and fall 1999 surveys in the one pass CPUE monitoring sections with

CPUE dropping from an average of 16.4 fish per 100 m in the fall of 1998 to 0.2 fish per 100 m in the fall of 1999, a reduction of approximately 98.8% (Figure 7).

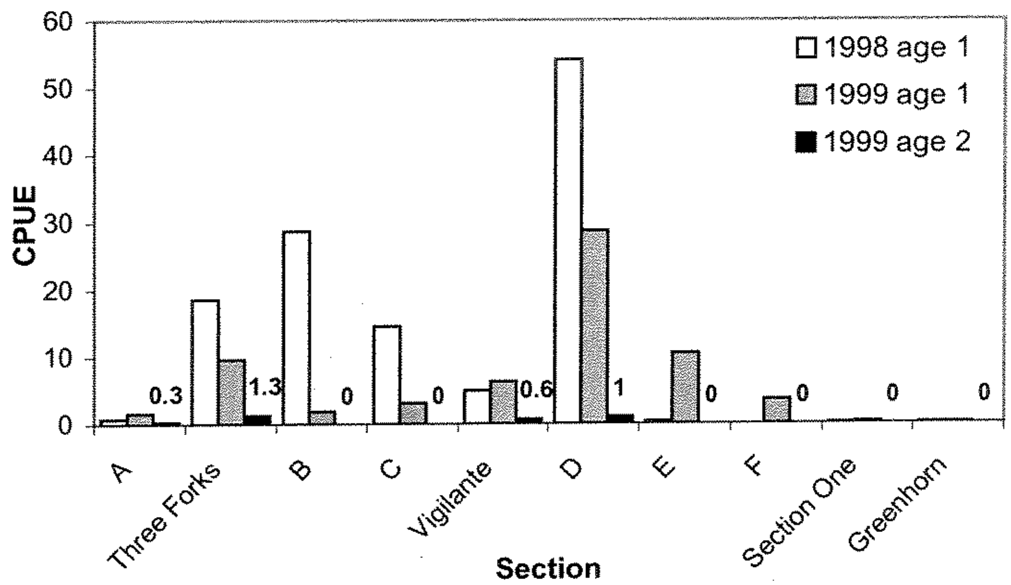

Figure 7. Comparison of catch per unit effort (CPUE, grayling per 100 m) for mark-recapture and one pass CPUE electrofishing estimate sections for fall 1998 and 1999. Electrofishing sections are listed in order from upstream to downstream. Data labels indicate CPUE of age 2 Arctic grayling in the fall of 1999.

One pass CPUE estimates obtained in the spring of 1999 and 2000 suggest that these declines in the age 2 year class may be occurring during the winter months. A comparison of the number of fish captured on the first pass of the 1998 and 1999 fall electrofishing population estimates and the spring 1999 and 2000 one pass CPUE estimates for the Three Forks and Vigilante estimate sections show a clear downward trend from fall to spring (Figure 8). This was an 84.6% reduction in CPUE for Arctic grayling. However, the single pass CPUE estimate for the Three Forks section during the spring of 2000 likely underestimated Arctic grayling abundance because high water

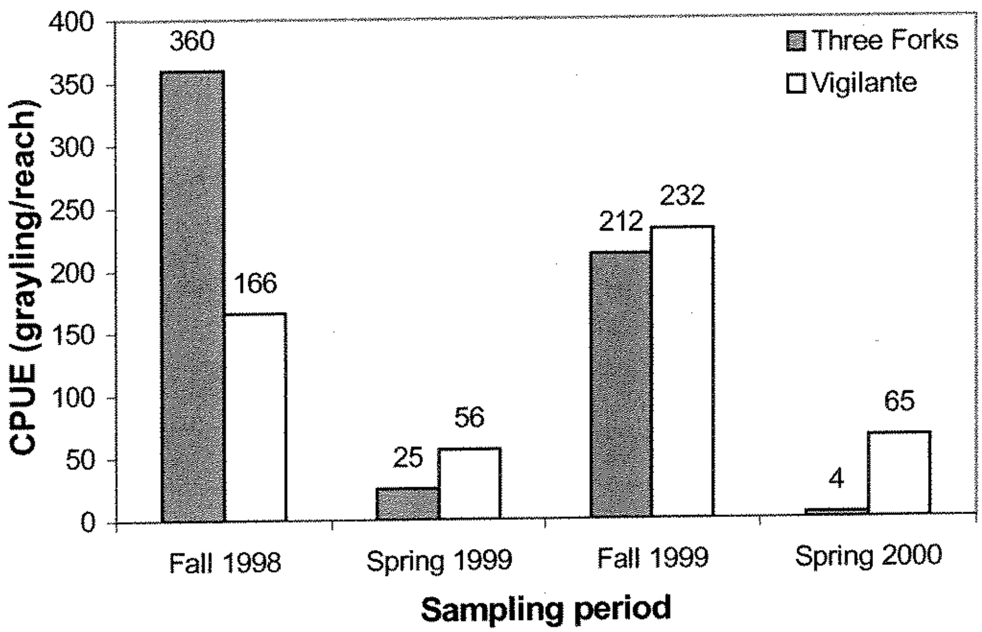

Figure 8. Comparison of Arctic grayling densities for fall (1998 and 1999) and spring (1999 and 2000) one pass electrofishing surveys in the Three Forks and Vigilante estimate sections. Arctic grayling densities were likely highly underestimated in the Three Forks section in spring of 2000 due to high water conditions during sampling.

conditions lowered electrofishing effectiveness. Nonetheless, if the Three Forks section data from spring 1999 to fall 2000 is discounted from the analysis, CPUE of Arctic grayling still declined by 80.1% from fall to spring. A comparison of CPUE for age 2 fish from fall 1999 to spring 2000 reveals that CPUE declined by only 61.0% in the Vigilante section. Again, the Three Forks section could not be compared due to high water conditions during spring 2000 sampling.

Angler Catch

A total of 176 complete survey forms were returned by anglers for the voluntary creel survey conducted from July 29 through November 25 in 1999. Complete survey forms were returned for all four stream sections used to delineate angler location for the survey (Figure 6). Mean catch rates of Arctic grayling varied throughout the upper Ruby River from a low of 1.6 fish per hour in section 4 to a high of 5.5 fish per hour in section 3 (Table 4). Catch rates among sections were significantly different ($P<0.001$, ANOVA)

Table 4. Catch rates of Arctic grayling in the upper Ruby River from a voluntary angler creel survey conducted from late July through November 1999. Letters in parentheses indicate the results of a Tukey's multiple comparison test with any sections sharing a letter having catch rates which were not significantly different.

	Survey Sections			
Catch statistics	1	2	3	4
Fish caught per hour	2.4 (zy)	4.4 (yx)	5.5 (xx)	1.6 (zz)
Standard Deviation	4.9	3.3	4.4	3.5
Surveys returned	36	67	44	29

with catch rates in section 1 being significantly lower than section 3 and catch rates in section 4 being significantly lower than both sections 2 and 3 (Table 4). Again, sections 2 and 3 in the angler creel survey encompass the stream section adjacent to and downstream of the primary Arctic grayling plant sites while sections 1 and 4 are located upstream and downstream of these plant sites. Thus, similar to the mark-recapture and CPUE electrofishing estimates, the creel survey suggests that grayling abundance was highest near the primary plant sites.

Movement

During 1998, 660 fish representing six species were captured moving downstream at the weir trap (Table 5), of which eight were Arctic grayling. From July through late September, the trap boxes were stationed in a section of lower velocity water near the stream margin of the channel cross-section. Decreased flows in the fall resulted in the incomplete submergence of the entrance to the box traps, limiting the ability of fish to enter the trap. Thus, on September 25, the box traps were shifted to the thalweg of the channel where there was adequate depth. The catch per unit effort subsequently increased from 4.0 fish per trap day to 5.1 fish per trap day for all salmonids and from 0.05 fish per trap day to 1.7 fish per trap day for rainbow and brown trout.

Table 5. Number captured and catch per unit effort (fish caught per trap day) for all species captured in a weir trap on the upper Ruby River located approximately 13 river km downstream of the Vigilante Bridge plant site.

	1998		1999	
Species	# Captured	CPUE	# Captured	CPUE
Arctic grayling	8	0.14	8	0.15
Rainbow trout	8	0.16	16	0.30
Brown trout	18	0.35	35	0.65
Mountain whitefish	166	3.25	467	8.65
Longnose sucker	455	8.92	280	5.19
White sucker	6	0.12	6	0.11

In 1999, the weir trap was installed at the same location as 1998, however the box traps were installed in the thalweg of the channel based on the increase in catch rates observed after its placement there in 1998. During 1999, 812 fish representing the same six species were captured moving downstream, of which eight were Arctic grayling (Table 5). A comparison of the 1998 and 1999 catch per unit effort data shows a substantial increase in CPUE for all salmonids and a decline in CPUE for longnose suckers in 1999.

Escapement from the box traps was found to be minimal in both years. On July 21, 1998, a trap escapement test was conducted on the box trap which measured downstream movement using 16 mountain whitefish. The next day, 13 (81%) mountain whitefish were recovered from the trap, suggesting some escapement. Maintenance was performed on the trap and another test using 10 mountain whitefish found no further escapement. In 1999, one test using 20 mountain whitefish was conducted and all fish were recovered the following day suggesting no escapement from the trap.

Captures at the weir indicate minimal downstream dispersal of reintroduced Arctic grayling in both 1998 and 1999. Eight Arctic grayling were captured in the trap in both 1998 and 1999, although at somewhat different time periods (Table 6). Catch per

Table 6. Number captured and catch per unit effort (fish caught per trap day) at the weir during each trapping month for Arctic grayling reintroduced into the upper Ruby River.

	Sampling Month					
Year	July	August	September	October	November	December
1998	5 (0.31)	2 (0.11)	0 (0)	0 (0)	1 (0.25)	N/A
1999	4 (0.24)	1 (0.06)	0 (0)	3 (0.43)	0 (0)	0 (0)

unit effort was highest for reintroduced Arctic grayling in July of 1998, directly after the reintroduction. In 1999 however, CPUE for grayling was highest in October followed by July (Table 6). All grayling captured at the trap in 1999 were age 1 fish planted in July of 1999.

All Arctic grayling captured at the weir trap were either dead or in poor condition. Only two Arctic grayling were captured alive in 1998 and both were found on or holding in front of the lead of the trap rather than in the box trap. Both fish were released downstream of the trap, but were presumed to have died based on their poor condition including missing scales and lethargic behavior. The six remaining Arctic grayling captured in 1998 were found dead on the leads of the trap. Similar results were observed during 1999 with six of the eight Arctic grayling captured being found dead, one of which was found in the box trap and the remainder on the trap leads. Two Arctic grayling were captured alive at the trap, one in the box trap and the other holding in front of the trap lead, although, these were again in quite poor condition including missing scales and lethargic behavior. Almost all other 1,456 fish of other species sampled at the trap were captured in the box traps and most appeared to be in good condition. Thus, it is believed that grayling found on the leads were fish which had died upstream of the trap and were intercepted by the trap when floating downstream. An Arctic grayling which had been implanted with a radio transmitter and subsequently died, floated approximately 10 km downstream overnight before being intercepted by a lead on the weir trap.

Similar to the weir trapping and electrofishing results, movement of wire tagged individuals was found to be minimal for reintroduced Arctic grayling within the initial three months after reintroduction. During fall electrofishing surveys in 1998, 245 Arctic grayling with wire tags were recaptured, with only 6 recaptured individuals having dispersed more than 3 km downstream (Figure 9). Smaller downstream dispersal (1-3

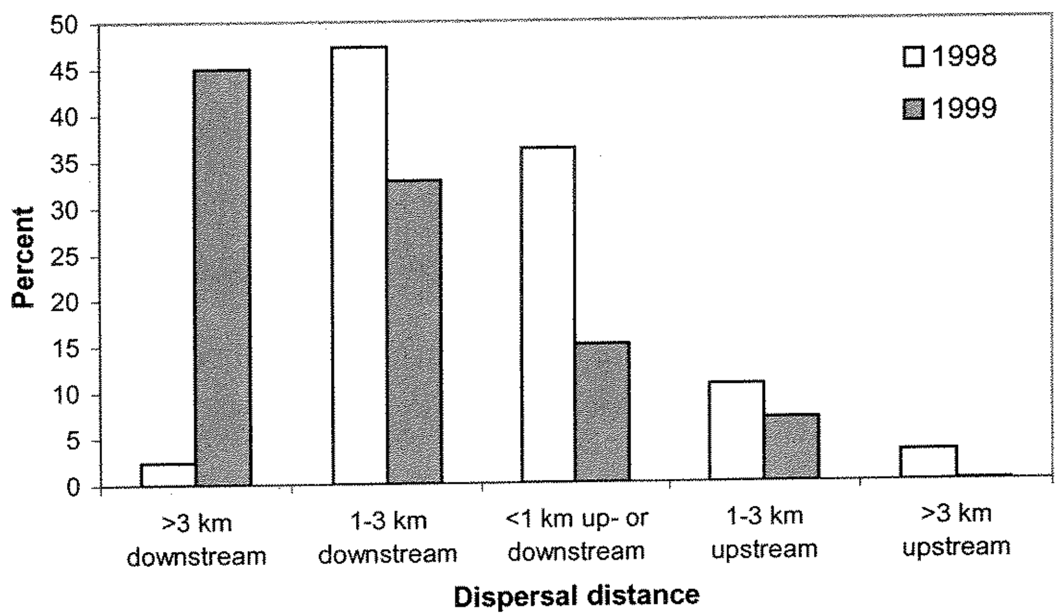

Figure 9. Dispersal distances by categories for age 1 Arctic grayling during fall (October) electrofishing surveys, approximately three months after stocking in 1998 and 1999. Data represent the percent of the total recaptured fish which had dispersed a given distance. Recaptured Arctic grayling which had moved 0 km from plant sites were included in the <1 kilometer category which includes any fish captured between primary and secondary plant sites.

km) was more common leading to an estimated mean dispersal of 0.7 (SD 1.8) km downstream by the fall of 1998, three months after the reintroduction. Some upstream dispersal also occurred in 1998 with 10.6% of the recaptured fish having moved 1-3 km upstream and 3.3% having moved over 3 km upstream (Figure 9). Increased downstream dispersal appears to have occurred between fall of 1998 and spring of 1999 with five of the 20 (25%) recaptured tagged individuals having moved greater than 3 km downstream. A mean dispersal rate could not be calculated for these fish because the one pass CPUE sections were not sampled during the spring and estimation of fish movement based on tag recaptures in only a few sections can underestimate movement (Gowan et al. 1994).

A total of 726 Arctic grayling with wire tags were recaptured in the fall of 1999, compared to the 245 recaptured in the fall of 1998. This difference was due mainly to the number of Arctic grayling tagged each year (see methods). As in 1998, downstream dispersal of age 1 Arctic grayling appeared to be minimal, with recaptured fish having moved an average of 4.6 (SD 5.9) km downstream within three months after reintroduction. Despite this minimal observed downstream dispersal, Arctic grayling reintroduced in 1999 dispersed significantly farther downstream than Arctic grayling reintroduced in 1998 ($P<0.001$, Mann-Whitney U-test). The Mann-Whitney U-test procedure was used to test for this difference due to a violation of the normality assumption of a parametric t-test. In 1999, 45% of the tagged Arctic grayling recaptured had dispersed over 3 km downstream versus 2.4% in 1998 (Figure 9). This increase in downstream dispersal is also evident when comparing the tag composition of Arctic grayling recaptured in electrofishing sections (Table 7). Less upstream dispersal of Arctic grayling reintroduced in 1999 also caused this decline in the mean dispersal value with only 6.9% of the tagged grayling moving 1-3 km upstream in 1999 versus 10.6% in 1998 and only 0.1% moving over 3 km upstream in 1999 versus 3.3% in 1998 (Figure 9).

Table 7. Number and percentage of age 1 Arctic grayling with each wire tag type recaptured in electrofishing sections in the upper Ruby River during the fall of 1998 and 1999. Electrofishing sections are listed in order of location with the sites farthest upstream listed first. Underlined values indicate recaptures of tagged fish in sections located between primary and secondary plant sites planted with that specific tag type.

		Wire Tag Recaptures		
Year	Section	Snout Tags (Percent)	Dorsal Tags (Percent)	Anal Tags (Percent)
1998	Section A	0 (0)	0 (0)	0 (0)
	Three Forks	111 (100)	0 (0)	0 (0)
	Section B	0 (0)	<u>12 (100)</u>	0 (0)
	Section C	0 (0)	<u>22 (100)</u>	0 (0)
	Vigilante	0 (0)	1 (5)	20 (95)
	Section D	0 (0)	3 (5)	<u>55 (95)</u>
	Section One	0 (0)	0 (0)	1 (100)
1999	Section A	6 (100)	0 (0)	0 (0)
	Three Forks	242 (100)	0 (0)	0 (0)
	Section B	1 (17)	<u>5 (83)</u>	0 (0)
	Section C	4 (22)	<u>13 (72)</u>	1 (6)
	Vigilante	75 (23)	157 (48)	93 (29)
	Section D	19 (23)	24 (29)	41 (49)
	Section E	5 (12)	6 (15)	30 (73)
	Section F	2 (22)	3 (33)	4 (45)
	Section One	1 (13)	3 (38)	4 (50)
	Greenhorn	1 (25)	0 (0)	3 (75)

Retention of wire tags was excellent for all three tagging locations during both years. This effectively minimized any bias in estimated distance moved caused by differential tag loss. Tag retention 24 hours after implantation was estimated at 98% for snout tags, 96% for dorsal tags, and 97.5% for anal tags in 1998 from a random sample of 200 fish with each tag type. Similarly, 24 hour tag retention was estimated at 98.4%, 97.4%, and 99.5% for the respective tag locations from 200 randomly sampled fish with each tag type in 1999. In 1999, all reintroduced Arctic grayling were wire tagged, allowing for the estimation of tag retention three weeks after implantation. It was found that tag retention 3 weeks after implantation was similar to 24 hour retention with 94.5% of Arctic grayling tagged with snout tags, 97.6% tagged with dorsal tags, and 98.9% tagged with anal tags (n=50 for each tag type) still possessing their tag. Slight increases in tag retention from 24 hours to 3 weeks for grayling tagged at the base of the dorsal fin in 1999 is due to random variation in samples taken.

Growth and Condition

Arctic grayling recaptured in the Three Forks and Vigilante sections after the 1998 and 1999 reintroductions increased in length and weight in both years (Tables 8 and 9). Arctic grayling stocked in 1998 increased significantly in length by 14 mm and weight by 15 g from July stocking until fall sampling (Table 8). Growth rates declined for age 1

Table 8. Comparison of growth and condition indices for age 1 Arctic grayling reintroduced into the upper Ruby River in 1998. Mean values (standard deviations) are given for Arctic grayling when planted and at indicated sampling periods in the Three Forks and Vigilante sections. P-values indicate results of the one-way ANOVA comparing means from each sampling period. Within a given row (e.g. total length), values sharing a letter (x, y, or z) are not significantly different (Tukey's multiple comparison test).

Growth Index	Plant (n = 150)	Fall 1998 (n = 655)	Spring 1999 (n = 81)	Fall 1999 (n = 64)	Spring 2000 (n = 7)	P-value
Total Length (mm)	236 (16.9) z	250 (18.9) y	255 (17.3) y	269 (15.1) x	282 (10.6) x	<0.001
Weight (g)	113 (25.9) z	128 (28.9) y	121 (23.1) y	164 (29.7) x	174 (27.9) x	<0.001
Condition Factor	0.85 (0.085) z	0.81 (0.096) y	0.72 (0.074) x	0.83 (0.078) w	0.77 (0.072) w	<0.001

fish through the 1998-99 winter with average length increasing by only 5 mm and weight decreasing by 7 g (Table 8). Similar results were observed for this cohort the next year with their average length and weight increasing significantly by 14 mm and 43 g from spring 1999 to fall 1999 (Table 8). Unlike the first winter, growth rates of Arctic grayling did not decline through the winter of 1999-2000, with the average length increasing by 13 mm and weight increasing by 10 g. However, these results were based on a small sample size for spring 2000 sampling and subsequently were not statistically significant (Table 8).

Despite the increases in length and weight of reintroduced Arctic grayling, comparisons of Fulton's condition factor indicated that their condition initially declined after planting (Table 8). Despite this initial decline, condition factor did increase significantly by the following fall. Condition factor declined again over the 1999-2000 winter, however this decline was not significant.

Similar to the 1998 results, Arctic grayling stocked in 1999 increased significantly in length by 15 mm and weight by 21 g from July stocking until fall sampling (Table 9). Also similar was the decline in the rate of increase in length and the significant decline in weight from fall to spring sampling. Condition factor of Arctic grayling stocked in 1999 again declined significantly throughout all periods, with the largest decline occurring between the fall 1999 and spring 2000 sampling periods (Table 9). Age 1 Arctic grayling stocked in 1999 were on average larger than age 1 Arctic grayling stocked in 1998 (Tables 8 and 9). However, due to growth after stocking, age 2 Arctic grayling were on

Table 9. Comparison of growth and condition indices for age 1 Arctic grayling reintroduced into the upper Ruby River in 1999. Mean values (standard deviations) are given for Arctic grayling when planted and at indicated sampling periods in the Three Forks and Vigilante sections. Within a given row (e.g. total length), values sharing a letter (x, y, or z) are not significantly different (Tukey's multiple comparison test).

	Growth Indices Comparison			
Growth Index	Plant (n = 150)	Fall (n = 478)	Spring (n = 62)	P-value
Total Length (mm)	250 (19.9) z	265 (18.3) y	266 (17.0) y	<0.001
Weight (g)	137 (36.5) z	158 (31.7) y	143 (25.2) z	<0.001
Condition Factor	0.86 (0.069) z	0.84 (0.073) y	0.75 (0.072) x	<0.001

average larger during 1999 sampling than age 1 fish stocked that year (Figure 10), although not significantly (P=0.20, t-test).

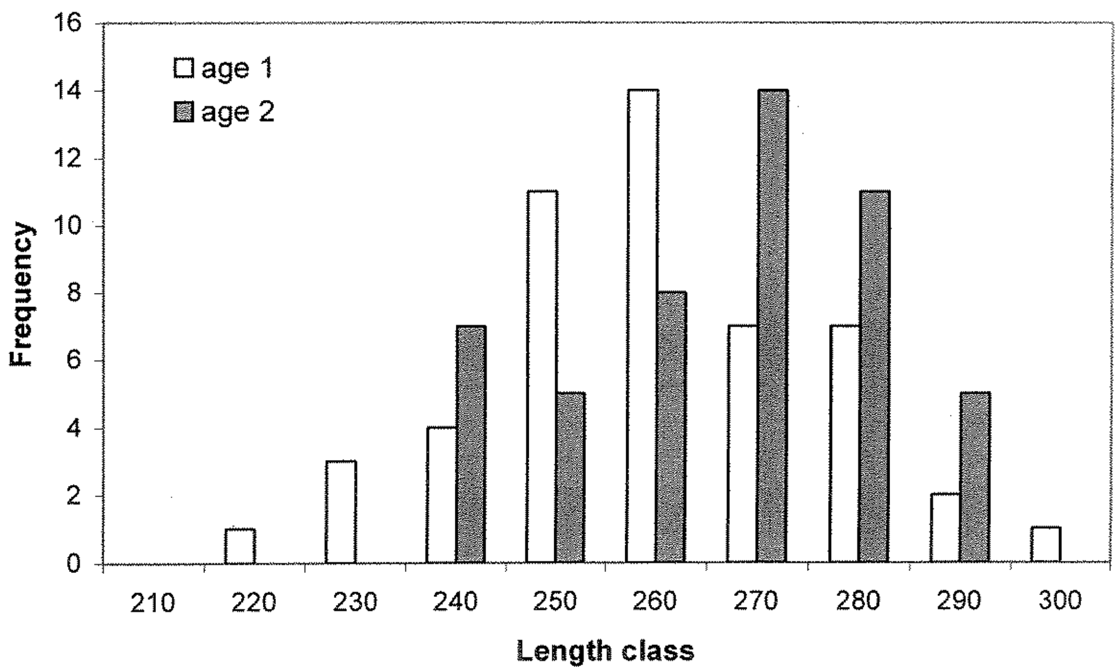

Figure 10. Length frequency histogram of a random sample of 50 age 1 and age 2 Arctic grayling captured during fall 1999 electrofishing surveys.

Comparisons of the above growth indices between monitoring sections for Arctic grayling captured during fall 1998 electrofishing surveys found one significant difference (P=0.02, ANOVA) in length, no significant differences in weight (P=0.07, ANOVA) and several significant differences in Fulton's condition factor (P<0.001, ANOVA) (Table 10). The only significant difference in length between sections was detected for the

Table 10. Comparison of growth and condition indices between monitoring sections for age 1 Arctic grayling captured in fall 1998 and 1999. The mean (standard deviation) is given for all sections except those in which fewer than five grayling were captured which are represented by n/a (not available).

	1998			1999		
	Length (mm)	Weight (g)	Condition (K)	Length (mm)	Weight (g)	Condition (K)
A	n/a	n/a	n/a	269 (17.8)	163 (25.8)	0.83 (0.06)
Three Forks	248 (18.5)	127 (28.4)	0.81 (0.10)	267 (16.0)	159 (29.9)	0.83 (0.07)
B	251 (18.2)	130 (25.5)	0.82 (0.07)	265 (9.2)	142 (11.4)	0.76 (0.05)
C	250 (16.0)	125 (24.7)	0.79 (0.05)	262 (19.7)	159 (31.8)	0.87 (0.12)
Vigilante	253 (19.5)	131 (29.6)	0.79 (0.08)	264 (18.6)	157 (33.0)	0.84 (0.07)
D	252 (15.6)	123 (23.0)	0.76 (0.07)	262 (16.6)	149 (27.7)	0.82 (0.06)
E	n/a	n/a	n/a	270 (19.6)	144 (30.5)	0.72 (0.06)
F	n/a	n/a	n/a	248 (17.0)	120 (15.7)	0.80 (0.06)
Section One	242 (16.3)	113 (22.2)	0.80 (0.13)	262 (13.7)	129 (29.5)	0.71 (0.11)

Three Forks and Vigilante population estimate sections. This significance of a difference of only 4 mm is likely related to the large sample sizes (n = 436 and 219). Unlike length and weight, significant differences in Fulton's condition factor were detected between several sections. In 1998, Arctic grayling in section D had an average condition factor of

0.76 (SD 0.07) which was found to be significantly lower than the average condition factor for Arctic grayling captured in section B, the Three Forks, and the Vigilante population estimate sections.

Significant differences in length (P=0.01, ANOVA), weight (P<0.001, ANOVA), and condition factor (P<0.001, ANOVA) were observed for Arctic grayling stocked in 1999 (Table 10). Arctic grayling captured in section F were significantly shorter in length than fish captured in the Three Forks population estimate section and section D. Arctic grayling captured in section F also weighed significantly less than Arctic grayling captured in the Three Forks and Vigilante population estimate sections. Arctic grayling captured in section E and Section One were in significantly poorer condition than Arctic grayling captured in all sections located upstream of Warm Springs Creek except section B. Arctic grayling captured in section F were also in relatively poor condition in comparison to Arctic grayling captured upstream of Warm Springs Creek (Table 10), however these differences were not significant.

<u>Habitat Use and Effects of Nonnative Species</u>

Habitat parameters were estimated throughout the upper Ruby River in 1998 and 1999. All measured habitat variables varied between the reported sections, suggesting heterogeneity in physical habitat in this section of the upper Ruby River (Table 11). Because earlier results had indicated minimal downstream dispersal of Arctic grayling from the original plant sites, electrofishing sections greater than 3 km up- or downstream of plant sites were excluded from this analysis to limit the bias of "under-seeding". Three km was selected as the threshold because it is the average of the mean dispersal distances observed in 1998 and 1999 based on wire tag recaptures. Excluded sections include Section F, Section One and the Greenhorn section. Thus, habitat parameters and the densities of nonnative species in these sections are not reported (Table 11, Figures 11 and 12).

Table 11. Habitat parameters estimated for electrofishing mark-recapture estimate sections and one pass CPUE estimate sections (lettered sections) in the upper Ruby River.

	Estimated Habitat Parameters				
Section	Total length (m)	Pool-and-run to riffle ratio	Sinuosity	Volume (m^3) of pools and runs per 100 m	Width to depth ratio
Section A	363	0.97	1.44	160.4	36.9
Three Forks	1930	0.68	2.15	89.3	37.0
Section B	334	0.76	2.14	254.3	25.4
Section C	588	0.71	1.53	117.9	33.2
Vigilante	3380	1.25	1.70	213.8	54.1
Section D	304	1.74	1.41	290.7	51.4
Section E	401	0.97	1.28	320.7	31.3

Densities of nonnative rainbow trout were also somewhat heterogeneous within this section of the upper Ruby River watershed (Figures 11 and 12). Rainbow trout (including rainbow-cutthroat hybrids) were found throughout the mainstem of this section of the upper Ruby River, however densities tended to increase in the lower sections. This increase was particularly apparent downstream from the mouth of Warm Springs which is located at the beginning of section E (Figures 11 and 12). Densities of brown trout, on the other hand, were relatively low throughout all sections included in this analysis with brown trout being nearly absent upstream of the mouth of Warm Springs Creek (Figures 11 and 12).

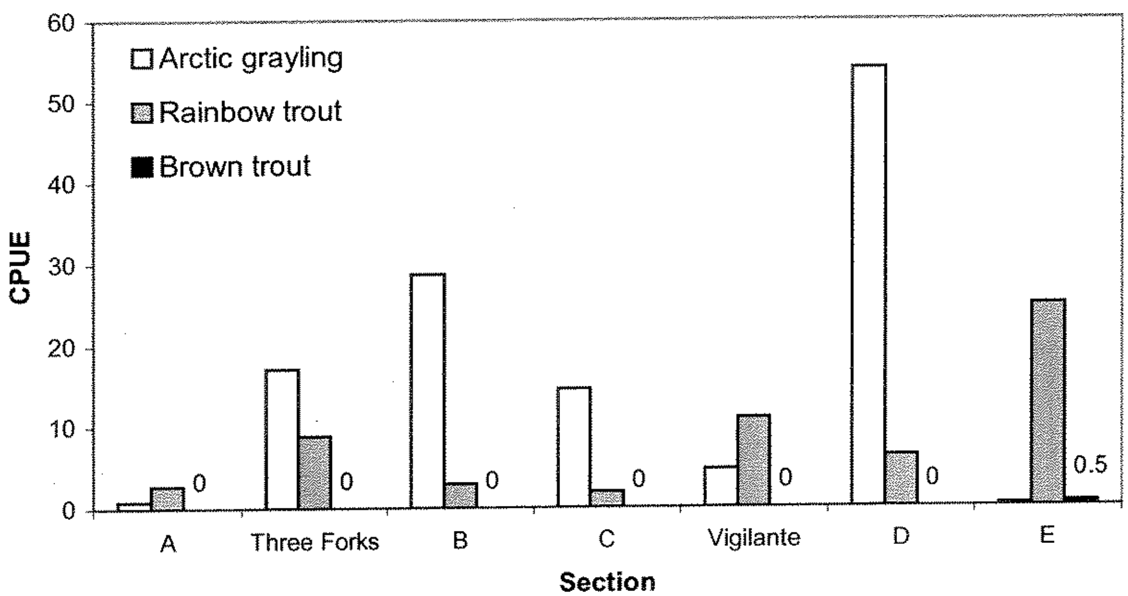

Figure 11. CPUE of Arctic grayling and nonnative rainbow and brown trout during fall 1998 sampling in sections located within 3 km of an Arctic grayling plant site. CPUE estimates were calculated as fish caught per 100 m. Data labels indicate CPUE for brown trout.

One pass CPUE estimates for rainbow and brown trout also varied between years (Figures 11 and 12). Rainbow trout densities increased substantially in section E and the Three Forks monitoring section from fall 1998 to fall 1999. However, rainbow trout densities based on CPUE in the remaining sections appeared static between the two years. Densities of brown trout also increased from 1998 to 1999, although this increase was not substantial (Figures 11 and 12).

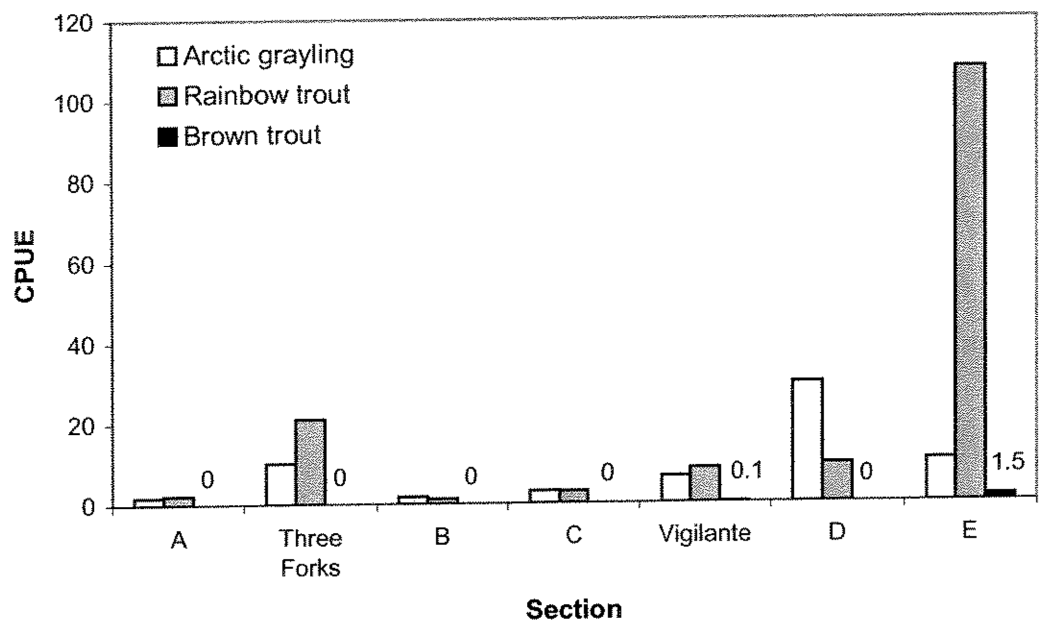

Figure 12. CPUE of Arctic grayling and nonnative rainbow and brown trout during fall 1999 sampling in sections located within 3 km of an Arctic grayling plant site. CPUE estimates were calculated as fish caught per 100 m. Data labels indicate CPUE estimates for brown trout.

Overall, one pass CPUE estimates tended to underestimate population size for Arctic grayling and rainbow trout. A comparison of mark-recapture estimates with one pass CPUE estimates show that on average, 80.4% and 36.9% of the estimated Arctic grayling population was captured on the first pass of the mark-recapture estimate (which was used to calculate CPUE) in the Three Forks and Vigilante estimate sections, respectively, in 1998 and 1999. Similarly, 38.0% and 29.9% of the estimated rainbow trout population in the Three Forks and Vigilante sections, respectively, were captured on the first pass of the mark-recapture estimates in 1998 and 1999. However, it appears that the relationship between estimated population size and one pass CPUE was somewhat uniform across species and sections, except for Arctic grayling in the Three Forks section which were sampled much more efficiently on the first pass. These similarities in efficiencies for both species and sections allows for the comparison of one pass CPUE estimates without substantial bias, except for the Three Forks section in which Arctic grayling densities will likely be overestimated in one pass CPUE estimates due to high electrofishing efficiencies.

Simple linear regression was used to test for correlations between age 1 Arctic grayling abundance during fall electrofishing surveys and both the measured habitat variables and nonnative rainbow and brown trout densities (Table 12). Again, sections

Table 12. Regression analysis testing for correlations between age 1 Arctic grayling abundance per 100 m and both habitat parameters and non-native salmonid abundances in the upper Ruby River three months after reintroduction in 1998 and 1999. Electrofishing sections farther than 3 km upstream or downstream of Arctic grayling plant sites were excluded from analysis to limit bias due to "under-seeding".

Predictors	Relationship	P-value	r^2
Pool-and-run to riffle Ratio	Positive	0.035	0.32
Sinuosity	Positive	0.976	0
Pool and run volume per 100m	Positive	0.301	0.09
Width to depth ratio	Positive	0.277	0.10
Rainbow trout per 100m	Negative	0.868	0
Brown trout per 100m	Negative	0.664	0.02

greater than 3 km downstream were excluded from the analysis to limit the effects of "underseeding". Regression analysis found pool-and-run to riffle ratio to be the only significant habitat variable, explaining approximately 32% of the variation in Arctic grayling abundance (Table 12). This relationship was positive suggesting that sections of the Ruby River with higher frequencies of pools and runs supported higher densities of Arctic grayling. Regression analysis revealed negative relationships between Arctic grayling abundance and the abundance of nonnative rainbow and brown trout, however neither of these relationships were significant (Table 12).

Simple linear regression was again used to test for correlations between age 2 Arctic grayling abundance and both habitat variables and densities of nonnative rainbow and brown trout (Table 13). Again, "underseeding" was believed to be a factor due to

Table 13. Regression analysis testing for correlations between age 2 Arctic grayling abundance per 100 m and both habitat parameters and non-native salmonid abundances in the upper Ruby River.

Predictors	Relationship	P-value	r^2
Pool-and-run to riffle ratio	Positive	0.374	0.16
Sinuosity	Positive	0.570	0.07
Pool and run volume per 100m	Negative	0.301	0.09
Width to depth ratio	Positive	0.139	0.38
Rainbow trout per 100m	Negative	0.470	0.11
Brown trout per 100m	Negative	0.396	0.15

the lack of age 2 Arctic grayling recaptured in lower electrofishing sections, thus sections greater than 3 km up- or downstream of plant sites were again excluded from analysis. Because age 2 Arctic grayling were only present during 1999, only one year of electrofishing data could be used in this analysis, substantially reducing sample size (n=7).

No habitat variables were found to be significant predictors of age 2 Arctic grayling densities. Again, regression analysis found a negative relationship between age 2 Arctic grayling abundance and the abundance of nonnative rainbow and brown trout, however neither were significant (Table 13). The best predictor of Arctic grayling densities was width to depth ratio which explained approximately 38% of the variation in age 2 Arctic grayling densities, however this relationship was not significant (Table 13). Similar to regression analysis for age 1 Arctic grayling, pool-and-run to riffle ratio was again positively related to Arctic grayling densities, although this relationship was again not significant (Table 13). However, when observing this relationship graphically, it becomes apparent that there is an outlier in the data which skews this relationship (Figure 9). This outlier is the CPUE estimate in the Three Forks population estimate section. After removing this outlier, pool-and-run to riffle ratio explains 93% of the variation in age 2 Arctic grayling abundance and is highly significant (P=0.008). High electrofishing efficiencies (based on the ratio of fish captured on the first pass to the estimated population size) in the Three Forks section in comparison to other sections, as discussed earlier, may have lead to over-estimation of CPUE causing the Three Forks section to be an outlier in the data set.

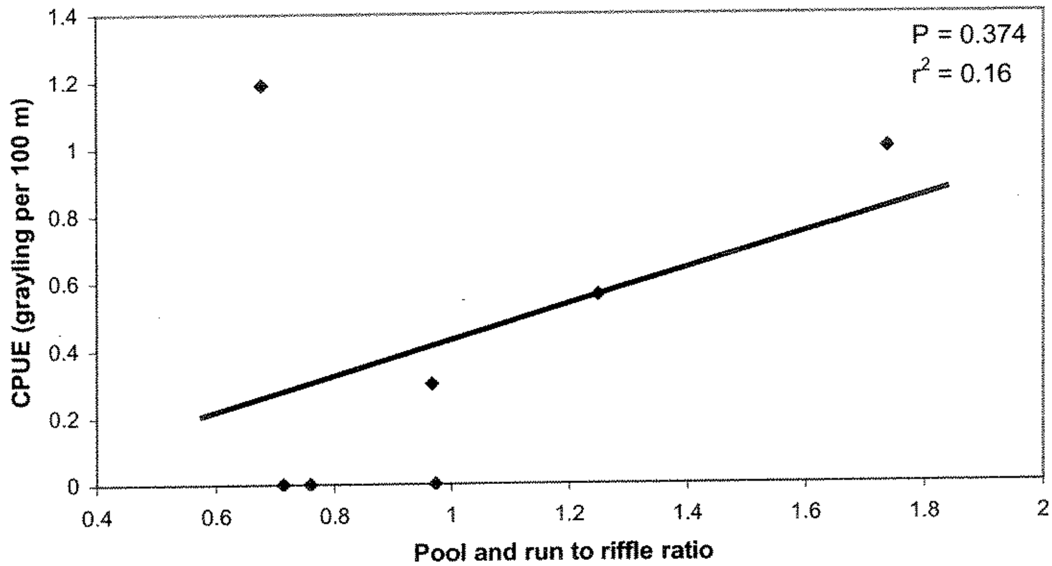

Figure 13. Relationship between pool-and-run to riffle ratio and age 2 Arctic grayling CPUE estimates for fall 1999. The outlier in this data set is the Three Forks monitoring section and removal of this data point makes this relationship highly significant ($P=0.008$) and the model provides a much better fit ($r^2=0.93$).

DISCUSSION

Despite numerous attempts in the past 70 years to reintroduce Arctic grayling into fluvial environments in Montana, none have met with success. Probable reasons for these failures include the use of inappropriate adfluvial stocks, inadequate habitat, and high densities of nonnative species (Kaya 1990). The reintroduction of Arctic grayling into the upper Ruby River was another attempt to reestablish a fluvial population, but with the use of a fluvial stock of Arctic grayling and into a stream identified as having suitable habitat and low densities of nonnative species (Kaya 1992b). In this study, abundance, dispersal, and growth indices were quantified for reintroduced Arctic grayling 1-2 years after reintroduction to evaluate its effectiveness. Correlations between Arctic grayling abundance and both physical habitat parameters and nonnative species abundance were also examined to determine possible reasons for its success or failure so as to better guide future reintroductions of this now-rare species.

Electrofishing surveys carried out in fall 1997 and spring 1998 suggested extremely poor survival of the 29,808 age 0 Arctic grayling planted in the upper Ruby River in September 1997. However, this cohort could not be effectively monitored after the spring of 1998 due to overlap in size with the age 1 grayling planted in July 1998. Although the apparent failure of the age 0 reintroductions is unfortunate, it has been documented that stocking of age 0 Arctic grayling into a fluvial environment is often unsuccessful (Kalb and Peckham 1975; Pearse et al. 1976; Kaya 1990). In the past, age 0 Arctic grayling were commonly planted in Montana because hatcheries had difficulty raising Arctic grayling to older age classes. Kaya (1990) provides an extensive list of these reintroduction attempts in Montana, many of which were attempted within the historical range of fluvial Arctic grayling. Although very few of these projects were monitored, all have been deemed unsuccessful based on the subsequent lack of Arctic grayling in the streams (Kaya 1990). Similar results were obtained for age 0 Arctic grayling stocking in the Delta Clearwater River, Alaska where 100,000 age 0 Arctic grayling were planted and none were recovered three months to one year after stocking (Kalb and Peckham 1975; Pearse and Peckham 1976). Evaluations of stocking other salmonid species into streams as age 0 fish have shown similar low survival (Flick and Webster 1964; Wentworth and LaBar 1984; Hume and Parkinson 1988; Berg and Jorgensen 1991; McMenemy 1995), although typically better than observed for Arctic grayling. These results suggest that future Arctic grayling reintroductions should not rely solely on stocking age 0 fish. Downstream dispersal of age 0 Arctic grayling after planting should also be investigated to determine if this is the factor leading to the failure of past attempts.

In contrast, stocking of age 1 Arctic grayling resulted in relatively good initial survival in two successive years in the Ruby River. Modified Petersen mark-recapture estimates averaged 369 age 1 Arctic grayling per km in 1998 and 208 per km in 1999 in the Three Forks and Vigilante estimate sections. These densities of Arctic grayling exceed the highest densities of grayling measured in the Big Hole River over the last decade by over 300% (Magee and Opitz 2000). Clark (1989) reported densities of Arctic grayling similar to these over several years in the Chena River, Alaska. The Chena River is a much larger system that once supported the largest Arctic grayling fishery in North

America. However, in certain years, his estimates were much higher (Clark 1989). These comparisons suggest that the upper Ruby River can support relatively high densities of Arctic grayling for at least three months after reintroduction. However, the capacity of the upper Ruby River to support older, larger fish cannot be determined by this study.

Although survival of reintroduced Arctic grayling was not directly measured for age 1 grayling in the upper Ruby River, an estimate could be obtained by extrapolating the population estimates from the Three Forks and Vigilante sections to the entire upper Ruby River. Extrapolation of this data to the upper Ruby River between Three Forks and the mouth of Warm Springs Creek would be most appropriate considering these monitoring sections nearly straddle this entire reach and that CPUE tended to be relatively similar throughout these sections and much lower outside of these sections (Figure 7). The 1999 estimate includes the reach from the mouth of Warm Springs Creek to the Section One monitoring section, because an estimate of age 1 grayling was obtained in Section One in 1999. The Section One estimate was extrapolated to this entire section because Arctic grayling CPUE tended to decline below Warm Springs Creek (Figure 7). By extrapolating this data to the entire upper Ruby River, it is estimated that a total of 7,417 grayling were present in the upper Ruby River in the fall of 1998 and 4,243 in the fall of 1999, three months after the reintroduction. Based on these estimates, short-term (three months) survival of age 1 Arctic grayling reintroduced into the upper Ruby River is estimated at 75.7% and 57.7% in 1998 and 1999, respectively.

These estimates assume that Arctic grayling densities were uniform throughout the upper Ruby River and that no dispersal out of this section of the upper Ruby River occurred. Catch per unit effort was actually substantially lower in the population estimate sections located between plant sites than the one pass CPUE sections located between plant sites, which would lead to underestimation of survival (Figure 7). Also, at least some downstream dispersal out of this reach is known to have occurred which also would make these survival estimates conservative. High variability in some of the estimates (particularly the 1998 Vigilante estimate) could also lead to over- or underestimation of survival.

While keeping the above limitations in consideration, it appears that initial survival of Arctic grayling in the upper Ruby River was similar to or higher than observed in some other salmonid stocking attempts. Survival of age 1 Arctic grayling stocked in the Chena River, Alaska was estimated at approximately 50.1% only one month after stocking (Clark 1994). Survival of age 2 cutthroat trout, which were of similar size to age 1 Arctic grayling in this study, was estimated at 15% two months after stocking in an Alberta stream (Miller 1951). Needham and Slater (1944) found similar survival to that estimated for Arctic grayling in this study for rainbow trout (49.8%) and brown trout (64.1%) approximately 3 to 4 months after stocking. However, resident wild fish were removed from these experiments which likely inflated these estimates over those observed in the presence of wild fish due to reduced competition (Needham and Slater 1944, Miller 1958). Other studies with cutthroat trout (Miller 1958) and brown trout (Weiss and Schmutz 1999) have also estimated short-term survival similar to that observed in this study. Thus, it appears from this extrapolated data that survival three months after reintroduction in both years was equivalent to or better for Arctic grayling in the upper Ruby River than reported for some other salmonid reintroductions.

Despite the apparent good initial survival of reintroduced Arctic grayling in the upper Ruby River, spring electrofishing surveys suggest that substantial mortality may have occurred during the winter months in both 1998 and 1999. A comparison of CPUE data from the fall of 1998 and 1999 to spring of 1999 and 2000 showed that Arctic grayling densities declined by approximately 80.1% in the Three Forks and Vigilante monitoring sections. This decline was caused by either overwinter mortality or the dispersal of Arctic grayling from the study section. Electrofishing and gillnetting surveys in the lower Ruby drainage suggest that overwinter survival was likely the main factor in this decline. Only two Arctic grayling were captured in 1999 and none in 2000 in the Greenhorn section during spring electrofishing surveys, suggesting that very few Arctic grayling were present in the lower sections of the upper Ruby River during this period. Also, no grayling were captured during spring gillnetting in the Ruby Reservoir in 1998 or 1999. This is despite very high gillnetting efficiencies for other salmonids during 1999 surveys due to low water conditions in the reservoir (D. Oswald, MFWP, personal communication). Therefore, it appears that this decline in Arctic grayling densities from fall to spring was due more to overwinter mortality than to dispersal.

While an 80.1% reduction in Arctic grayling densities is substantial, it is consistent with or better than overwinter mortality estimates reported in other salmonid stocking studies. Survival of age 1 Arctic grayling planted in the Chena River, Alaska was estimated at only 6% from July 1994 to July 1995 (Clark 1996). This decline was attributed primarily to poor overwinter survival. Interestingly, Clark (1996) found that after this first overwintering period, annual survival of stocked Arctic grayling was similar to annual survival of wild Arctic grayling in the same system (54%). A comparison of age 2 fish captured in the Vigilante section in fall of 1999 and spring of 2000 shows that age 2 densities were reduced by only 61% in comparison to 80.1% for age 1 Arctic grayling. Unfortunately, fall 1999 and spring 2000 data could not be compared for the Three Forks section due to high water conditions lowering electrofishing efficiency during spring 2000 sampling. Nonetheless, data from the Vigilante section suggests that similar to the results observed by Clark (1996), overwinter survival of Arctic grayling reintroduced into the upper Ruby River improved after their first winter.

Overwinter mortality of other salmonids stocked into lotic environments as age 1 or older fish has also been found to be relatively high following stocking. Overwinter mortality was estimated at 100% for age 2 and 99% for age 3 cutthroat trout in an Alberta stream (Miller 1951). Similarly, overwinter mortality of brown trout stocked into two Austrian streams was estimated at 99% and 81% (Weiss and Schmutz 1999). Several other studies have also reported high annual overwinter mortality of age 1+ salmonids stocked into lotic environments (e.g., Needham and Slater 1944; Flick and Webster 1964), although most of these studies failed to measure downstream dispersal which can greatly bias the results of survival studies (Miller 1958; Gowan et al. 1994). Nonetheless, it appears that the estimated overwinter mortality of Arctic grayling in the upper Ruby River is equal to or better than reported in other studies.

Another factor which could have contributed to mortality of reintroduced Arctic grayling is angling. Angler catch rates averaged 4.4 and 5.5 Arctic grayling per hour in sections 2 and 3 (Table 3). These catch rates are higher than those measured for cutthroat trout (MacPhee 1966; Dwyer 1990), a species commonly touted for their catchability and far surpass catch rates for rainbow and brown trout on the Madison River (McMichael and Kaya 1991), a world class trout stream. While stocked fish may be easier to catch than wild fish, these catch rates also surpass those reported for other stocked salmonids (Cooper 1952; O'Grady and Hughes 1980; Dwyer 1990). Thus, although angling pressure and total catches were not measured in this study, both the voluntary creel survey and direct casual observations indicate that many Arctic grayling were caught. All angling for Arctic grayling in the Ruby River is restricted to catch and release. However, even catch and release angling with artificial lures can result in increased mortality of salmonids, especially under summer conditions when water temperatures approach or exceed 20° C (Titus and Vanicek 1988; Schisler and Bergersen 1996). Maximum daily water temperatures did commonly exceed 20 ° C in the upper Ruby River at both Three Forks and the mouth of Warm Springs Creek during July and August in 1999 (Appendix B).

A comparison of the densities of age 1 Arctic grayling captured during fall electrofishing surveys in 1998 and 1999 suggests reduced survival of the cohort stocked in 1999. While the number of Arctic grayling stocked in 1999 was reduced by 25.0% from 1998 and densities decreased by only 27.6% in the Three Forks section, Arctic grayling densities declined by 43.5% in the Vigilante section and a combined 52.3% in the CPUE sections (A-F). However, high variability in these estimates (particularly Vigilante 1998) somewhat limits the inferences which can be drawn from this data. Nonetheless, possible reasons for this decline include variation in flow regime and the presence of age 2 Arctic grayling in the system.

A comparison of discharge data from 1998 and 1999 shows that flows were substantially lower in 1999 than 1998 (Figure 2). A positive relationship between in-stream flows and salmonid densities has been shown in several studies (Rimmer 1985; Clancy 1988; Li et al. 1994; Travnichek et al. 1995). However, this relationship has not been demonstrated for stocked fish. Nonetheless, the lower flows observed in 1999 may have limited the amount of available habitat present in the upper Ruby River for stocked Arctic grayling. Higher water temperatures characteristic of lower discharge may also have been a factor. Water temperatures in the upper Ruby River did reach nearly 24° C in 1999 (Appendix B), however this is still below the upper incipient lethal temperature of 25.0° C estimated for Big Hole River Arctic grayling (Lohr et al. 1996).

The presence of age 2 Arctic grayling in the upper Ruby River may also have affected the survival of 1999 age 1 cohort. Arctic grayling are known to be aggressive fish which actively defend feeding territories and form dominance hierarchies based on advantageous feeding positions (Vascotto and Morrow 1973; Kratt and Smith 1979; Hughes 1992). Age 2 grayling were on average larger (Figure 10), although not significantly so (P=0.20, t-test), than age 1 fish which is the primary factor in determining dominance in salmonids (Kratt and Smith 1979; Bachman 1984; Hughes 1992). Also, it has been found with Arctic grayling that prior residents have a competitive advantage over intruding individuals (Kratt and Smith 1979). Thus, age 2 Arctic grayling, which were larger and had been present in the system for a year, may have limited the ability of some age 1 fish to find and defend suitable habitat. The inability of age 1 Arctic grayling to defend suitable habitat could conceivably reduce survival. However, this relationship is only speculative because social interactions of reintroduced Arctic grayling were not observed in this study.

Movement

The dispersal of Arctic grayling after planting has not been quantified in most published examples of reintroduction attempts. Jones et al. (1977) suggested that reintroduced Arctic grayling, particularly fish from lacustrine stocks, moved downstream after their reintroduction attempt, although the amount and distance of dispersal was not quantified. Lere (1995), however, did attempt to measure dispersal through a creel survey on the Gallatin River. He found that yearling grayling of fluvial ancestry planted into the Gallatin River dispersed approximately 42 and 77 river km downstream one and two months after the reintroduction with very few angler reports in subsequent years (Lere 1995).

Because of this apparent high degree of downstream dispersal by Arctic grayling after reintroduction, a primary objective of this study was to estimate downstream dispersal of reintroduced Arctic grayling in the upper Ruby River. Unlike previous studies, downstream dispersal of reintroduced Arctic grayling in the Ruby River was found to be minimal. A weir trap installed approximately 13 river km below the Vigilante plant site captured a total of only eight Arctic grayling in 1998 and eight in

1999 with trapping being conducted from immediately after the reintroduction in July through November in each year. Of these eight fish captured each year, a majority were mortalities which likely died upstream and were simply intercepted by the trap. Thus, long-distance downstream dispersal was likely over-estimated by even the very few recovered at the weir.

As with the trapping results, movement of Arctic grayling as assessed by wire tag recaptures was also minimal. The mean dispersal distance (approximately 3 months after planting) was 0.7 km and 4.6 km in 1998 and 1999, respectively. Although this technique of measuring dispersal may have underestimated downstream dispersal because Arctic grayling caught between primary and secondary sites were considered to have moved zero km, overall dispersal was still minimal. Also, considering Arctic grayling caught between primary and secondary sites as having moved zero km also may have underestimated small upstream movement.

The lack of downstream dispersal of reintroduced Arctic grayling in the Ruby River is likely due in part to the use of a fluvial parental broodstock. It has been found that age 0 and age 1 Arctic grayling of fluvial ancestry are much more likely to hold their position in a stream environment in both field and laboratory studies (Jones et al. 1977; Kaya 1991; Kaya and Jeanes 1995). Arctic grayling reintroduced into the Ruby River were progeny of the Axototl Lake broodstock which are F_1 descendants of the Big Hole River fluvial population. Thus, these fish are likely more adapted to surviving in a fluvial environment.

However, the use of a fluvial stock is likely not the only reason for the lack of downstream dispersal observed in this study. The experimental reintroductions of Arctic grayling into the Gallatin and East Gallatin Rivers also used the Axolotl fluvial broodstock as their source for planted grayling (Lere 1995). As stated earlier, extensive downstream dispersal (average fish moving 77 km downstream two months after the reintroduction) and poor survival were observed in Lere's study. Differences in other characteristics such as physical habitat or nonnative species abundance may explain the differences in downstream dispersal observed in this study versus the dispersal measured by Lere (1995). Lere (1995) noted that reintroduced Arctic grayling appeared to be dispersing from the higher gradient, upper sections of the Gallatin River to more gradual gradient sections found in the lower river. Historically, fluvial Arctic grayling were typically found in lower gradient streams in Montana (Vincent 1962). Thus, the low gradient nature of the upper Ruby River may have fostered reduced downstream dispersal of Arctic grayling after reintroduction.

Lower densities of nonnative species in the upper Ruby River in comparison to the Gallatin River may also have led to this discrepancy in downstream dispersal. Intraspecific competition has been found to cause downstream dispersal in juvenile coho salmon *Oncorhynchus kisutch* (Chapman 1962). Interspecific competition between Arctic grayling and nonnative rainbow trout may, in a similar fashion, also regulate the amount of downstream dispersal observed for Arctic grayling after reintroduction. Arctic grayling and rainbow trout are known to compete for feeding positions in streams (Magee and Byorth 1998) and rainbow trout densities are much higher in the Gallatin River than the upper Ruby River (Kaya 1992b).

The disparity in the average distance Arctic grayling dispersed downstream within three months of stocking in 1998 (0.7 km, mean) versus 1999 (4.6 km, mean) is an interesting observation. One obvious factor which could lead to further downstream dispersal is higher stream discharge during planting, however, discharge was actually lower in 1999 than 1998 (Figure 2). Another possible explanation is the presence of age 2 Arctic grayling during the 1999 reintroduction. As stated earlier, Arctic grayling are aggressive fish which compete for advantageous feeding positions in streams (Vascotto and Marrow 1973; Kratt and Smith 1979; Hughes 1992) and it has been found that this intraspecific competition between Arctic grayling can determine the size structure of an Arctic grayling population longitudinally (Hughes and Reynolds 1994). Also, studies have found that intraspecific competition does regulate downstream dispersal in some salmonids (Chapman 1962). It has been observed that the size of a fish and prior residence both affected the outcome of dominance challenges in Arctic grayling (Kratt and Smith 1979). Age 2 grayling in the upper Ruby River were larger (Figure 10) and were likely already occupying much of the quality habitat in the upper Ruby River and thus, could have made smaller age 1 grayling disperse farther downstream upon reintroduction in search of unoccupied habitat. Again, this theory is only speculation because intraspecific interactions among Arctic grayling were not investigated.

A lack of downstream movement during fall of reintroduced Arctic grayling in both 1998 and 1999 is also interesting. Big Hole River Arctic grayling, the source population for this reintroduction, have been found to undergo extensive seasonal movements of up to 80 km downstream to overwinter in deep pools (Shepard and Oswald 1989). Similarly, Alaskan Arctic grayling commonly move long distances downstream to access overwintering habitat (Craig and Poulin 1975; West et al. 1992; others reviewed in Armstrong 1986). Weir trapping was carried out through November in 1998 and into December in 1999. In both years, only eight Arctic grayling were captured at the weir trap during both summer and fall sampling (Table 6), most of which were found dead on the lead of the trap. The weir trap was operated only two to three days a week from September through November, therefore downstream movement may have occurred while the leads of the trap were open during the fall. However, only two Arctic grayling were captured in the Greenhorn monitoring section during the spring sampling in 1999 and none during spring sampling in 2000, suggesting that Arctic grayling did not move downstream during fall when the trap was operated or even later in winter. The upper Ruby River downstream of the weir trap provides numerous large pools and runs in which grayling could overwinter. However, the upper Ruby River upstream of the weir trap (upstream to Three Forks) also has abundant pool and run habitat which also could provide adequate overwintering habitat, although these pools and runs are not as large as those found downstream of the weir trap (B. Liermann, personal observation).

Another possible explanation for this lack of fall downstream movement is Warm Springs Creek's influence on the upper Ruby River. Warm Springs Creek, as its name implies, is a groundwater fed stream with an elevated thermal regime which is large enough to substantially warm the upper Ruby River (Appendix B). This warming effect is evident when comparing temperatures for the Three Forks and mouth of Warm Springs Creek monitoring sites during late September (Appendix B). As minimum temperatures began to reach freezing at the Three Forks monitoring station in 1999, temperatures of the Ruby River downstream of Warm Springs Creek did not drop below 12° C (Appendix B). Based on this late fall and early spring temperature data, it appears that the Ruby River below the mouth of Warm Springs Creek stays much warmer over winter than other portions of the river, providing favorable overwintering conditions for salmonids. Therefore, Arctic grayling may have used this area for overwintering instead of moving farther downstream to overwinter. Arctic grayling have been found to use spring creeks and sections of river heavily influenced by groundwater as overwintering habitat in several studies (Craig and Poulin 1975; Byorth 1991; West et al. 1991; Lubinski 1995, others reviewed in Armstrong 1986, Kruger 1981, and Northcote 1995).

There is evidence that some Arctic grayling reintroduced into the upper Ruby River accessed Warm Springs Creek for overwintering. Two Arctic grayling were captured during a hook and line survey in Warm Springs Creek in November of 1998 approximately five km upstream from its mouth. No subsequent surveys were carried out to determine the extent to which Warm Springs creek was used by Arctic grayling as overwintering habitat. On March 31, 1998, section E (which starts at the mouth of Warm Springs Creek) was electrofished and only 13 grayling were captured within 400 m, suggesting that large numbers of Arctic grayling are not using this area as overwintering habitat. However, overwintering Arctic grayling may had already moved out of this area by the time of sampling.

An important management implication of the lack of downstream dispersal after reintroduction observed in study is the selection of planting sites for future reintroductions. Primary plant sites in the upper Ruby River were on average seven river km apart. However, the average Arctic grayling dispersed an average of only 0.7 and 4.6 km downstream three months after the reintroduction in 1998 and 1999. Therefore, certain sections of the upper Ruby River may not have had enough Arctic grayling present to occupy all of the available habitat. Plant sites for further reintroductions into the upper Ruby River could be spaced at closer intervals to allow for a more even distribution of fish after reintroduction.

Growth and Condition

Growth of reintroduced Arctic grayling in the upper Ruby River was demonstrated by increases in both length and weight from the time of planting in summer to fall sampling for age 1 fish planted in both 1998 and 1999. From summer planting to fall sampling, age 1 Arctic grayling grew an average of 15 mm (from 235 to250 mm) in 1998 and an average of 13 mm (from 250 to 263 mm) in 1999. Similarly, weight increased significantly for reintroduced grayling from summer planting to fall sampling in 1998 and 1999. These increases in length and weight suggest that the upper Ruby River does provide adequate conditions for Arctic grayling to persist and grow. However, Liknes and Gould (1987) found that Arctic grayling in the Big Hole River of similar size to the age 1 grayling reintroduced to the upper Ruby River, increased in length an average of 53 mm (from 222 mm to 275 mm) and in weight and average of 73 g (from 115 g to 188 g) from age 2 to age 3. This yearly growth of Big Hole River Arctic grayling was not achieved by age 2 Arctic grayling which had increased in length by only 33 mm and 51 g from planting to fall of 1999, approximately a year and three months after reintroduction. Thus, reintroduced Arctic grayling in the Ruby River appear to grow slower than those of similar genetic stock residing in the Big Hole River.

Despite increases in length and weight for reintroduced Arctic grayling, Fulton's condition factor decreased significantly from planting in summer until fall sampling. These decreases may suggest that the upper Ruby River does not provide suitable resources for reintroduced Arctic grayling to maintain optimal condition. However, fish reared in hatchery environments expend minimal maintenance energy and are fed regularly allowing them to reach optimal condition. Thus, fish taken from a moderated hatchery environment and placed into a comparatively harsh natural environment would be expected to decrease in condition. Several studies have documented a decline in condition factor of salmonids after stocking (Miller 1951; Reimers 1963; Ersbak and Haase 1983; Weiss and Shmutz 1999). However, Miller (1951) found that after a substantial reduction in condition factor, hatchery cutthroat trout returned to their original condition by the end of summer, approximately 100 days after stocking. Arctic grayling reintroduced into the upper Ruby River in 1998, on the other hand, did not regain their original condition until the fall of 1999. Condition factor was also found to decrease significantly between fall and spring sampling each year. A reduction in condition factor for both stocked and wild salmonids is common during overwintering periods (Miller 1951; Miller 1954; Reimers 1963; Cunjak and Power 1987). Despite these reductions in condition factor during the winter period, the condition of age 2 Arctic grayling did improve significantly by the following fall.

Although very few significant differences in growth indices were found between monitoring sections located throughout the upper Ruby River, some significant differences were observed for condition factor of reintroduced Arctic grayling. In 1998, condition factor was found to be lower in section D than all other sections (not significantly lower than section C and Section One). Section D had the highest Arctic grayling densities in the upper Ruby River based on CPUE estimates (Figure 7). A negative relationship between post-stocking fish densities and condition factor due to intraspecific competition has been observed for stocked salmonids including Arctic grayling (Hume and Parkinson 1987; Byorth and Magee 1998).

Again in 1999, condition factor was found to vary between sections, however this variation was detected between different sections. Condition factor was significantly lower in section E and Section One than most electrofishing sections upstream of Warm Springs Creek. Condition factor was also lower in section F than sections located upstream of the mouth of Warm Springs Creek, although not significantly. These results suggest the Arctic grayling captured below the mouth of Warm Springs Creek were generally in poorer condition than Arctic grayling captured upstream of Warm Springs Creek. One might expect Arctic grayling to grow faster in higher average stream temperatures characteristic of the Ruby River downstream of Warm Springs Creek (for example Kaeding and Kaya 1978; Appendix B). However, this would also depend on the availability of food. A possible explanation for these results is the increase in abundance of nonnative brown and rainbow trout downstream of Warm Springs Creek. Densities of rainbow trout are nearly four times as high downstream of Warm Springs Creek as the nearest sections upstream based on mark-recapture and CPUE estimates and brown trout densities steadily increase downstream of Warm Springs Creek. It has been observed that the presence of wild fish can lead to substantial reductions in condition factor of stocked fish through competition (Miller 1958). These results were likely not detected in 1998 due to low numbers of Arctic grayling being present in these sections.

Habitat Use and Effects of Nonnative Species

Regression analysis of the relative abundance of age 1 Arctic grayling three months after the 1998 and 1999 reintroductions suggests that Arctic grayling either selected certain habitat types after reintroduction or that certain habitat types provided better survival. Due to the lack of downstream dispersal of Arctic grayling after reintroduction, as indicated by both weir trapping and wire tag recaptures, sections greater than 3 km from plant sites were restricted from the analysis to limit the effect of "underseeding." Regression analysis of the remaining sites showed that pool-and-run to riffle ratio was the only variable that was significantly associated with abundance of age 1 Arctic grayling. This analysis suggests that reintroduced Arctic grayling either selected these sites with high pool-and-run to riffle ratios, or that these sites provided better survival after reintroduction, or a combination of the two.

In contrast, pool-and-run to riffle ratio was not a significant predictor of age 2 grayling abundance. However the removal of one outlier in the data set (Three Forks monitoring section) made pool-and-run to riffle ratio a highly significant predictor

(P=0.008), which explained a majority of the variation in Arctic grayling abundance (r^2=0.93). This outlier in the data set may have been due to high electrofishing efficiency in the Three Forks section. Electrofishing efficiency in the Three Forks section, based on number of fish captured on the marking run in comparison to the estimated population size, was higher than observed in all other sections for Arctic grayling, rainbow trout, and brown trout. This higher electrofishing efficiency may have led to overestimation of densities when converting this mark-recapture estimate to a CPUE estimate, producing an outlier in the data set. Unfortunately, CPUE estimates do not account for this variability in efficiency. Also, small sample size (n=7) due to the small number of sections sampled and only one year of sampling for age 2 fish may have limited the power of this analysis to detect a significant relationship. Therefore, despite its statistical insignificance, sections of the Ruby River with high pool-and-run to riffle ratios may also have been selected for by age 2 Arctic grayling or may have provided better survival for this age class.

The importance of pools and runs as adult fluvial Arctic grayling habitat has been shown in many studies. Fluvial Arctic grayling in the Big Hole River occupy primarily pool and run habitat both during the summer and also while overwintering (Liknes and Gould 1987; Shepard and Oswald 1989; Skaar 1989; Byorth 1991). Similar to the results of this study, Liknes and Gould (1987) found that the highest densities of Arctic grayling in the Big Hole River occurred in sections with the highest pool to riffle ratio, although this relationship was not tested statistically. Their pool to riffle ratio is essentially equivalent to this study's pool-and-run to riffle ratio in that they classified pools as any habitat type with reduced velocities, smooth surfaces, and maximum depths greater than 0.5 m (Liknes and Gould 1987). These characteristics encompass what was characterized as either a pool or run in this study. The section in which Liknes and Gould (1987) found the highest densities of grayling had a pool to riffle ratio of 1.51 which is very similar to section D in the upper Ruby River which had the highest densities of Arctic grayling and a pool-and-run to riffle ratio of 1.74.

As in Montana, Arctic grayling in Canada and Alaska have also been found to prefer lower velocity pool and run habitat (Vascotto and Marrow 1973; Stuart and Chislett 1979; Hubert et al. 1985; Reynolds 1989). Age 2+ Arctic grayling were found primarily in mainstem pools during summer, fall and winter in the Sukunka Drainage (Stuart and Chislett 1979). Adult Arctic grayling in Alaska have been found to occupy pools almost exclusively (Vascotto and Morrow 1973). Thus, the fact that fluvial Arctic grayling use primarily pool and run habitat is not novel, however, this is the first study to show this relationship for stocked Arctic grayling. This relationship also suggests that having abundant pool and run habitat in systems in which reintroductions are attempted may be very important to the success of future reintroductions.

The lack of a statistically significant relationship between age 1 and age 2 Arctic grayling abundance and the abundance of non-native rainbow and brown trout after reintroduction is also an interesting observation of this study. Despite this lack of significance for the regression analysis, comparisons of CPUE estimates for Arctic grayling and rainbow trout in fall 1998 (Figure 11) suggest that age 1 Arctic grayling densities were substantially higher in sections with lower densities of rainbow trout.

However, this relationship was not as clear when comparing CPUE estimates for Arctic grayling and rainbow trout in 1999 (Figure 12).

Circumstantial evidence suggests that Arctic grayling have been negatively impacted by the introduction of non-native species. For example, the relative abundance of Arctic grayling in the upper Big Hole River is highest in sections with the lowest densities of rainbow and brown trout (Kaya 1990). Also, the decline of Arctic grayling in the Madison River coincided with the spread of introduced rainbow and brown trout from Yellowstone National Park in the early 1900's (Kaya 1990). Very few studies have demonstrated the mechanisms that may cause the replacement of Arctic grayling by non-native species. Magee and Byorth (1998) found that Arctic grayling and rainbow trout did compete for feeding positions within an experimental stream, although grayling were typically dominant over similar sized rainbow trout. It was hypothesized that Arctic grayling may over-compete with rainbow trout leading to an excessive expenditure of energy, which may lead to reduced survival (Magee and Byorth 1998).

Interactions between Arctic grayling and brown trout are even less clear. Magee and Byorth (1998) found that Arctic grayling and brown trout did not actively compete for feeding stations within an experimental stream. Brown trout predation on Arctic grayling has not been studied due to the present lack of overlap in their distribution. However, one brown trout (approximately 600 mm TL) was captured in the Section One monitoring section during the fall of 1999 with a partially digested Arctic grayling (approximately 250 mm TL) protruding from its mouth. Thus, despite the lack of a statistically significant relationship between Arctic grayling abundance and rainbow and brown trout abundance in the upper Ruby River, competition and predation between these species may be affecting grayling densities in the upper Ruby River and may hinder future reintroductions. Two substantial problems with this data set which could have prevented this analysis from detecting relationships if indeed they were occurring include: 1. a lack of statistical power (n=14) due to the low number of sample sites and only two years of sampling and 2. a lack of variation in brown trout densities throughout the sampling sections included in this analyses. Therefore, the results of this study do not discredit the theory that non-native species have deleterious effects on reintroduced Arctic grayling and further research into this topic should be conducted.

In summary, this study has demonstrated the persistence and growth of age 1 Arctic grayling in the upper Ruby River after their reintroduction in 1998 and 1999. Estimated survival three months after reintroduction and overwinter appears to have been comparable to or better than observed in other studies. Also, contrary to the results of other Arctic grayling reintroduction attempts, minimal downstream dispersal after reintroduction was observed in the upper Ruby River. Based on these criteria, this reintroduction appears to have been initially successful.

The next step in demonstrating the success of this reintroduction would be the confirmation of natural reproduction in the upper Ruby River. In the fall of 2000, MFWP crews conducted fall monitoring in the upper Ruby River. In these surveys, five age 0 Arctic grayling were captured, two in the Three Forks monitoring section and three in the Vigilante monitoring section (J. Magee, MFWP, personal communication). Because age 0 plants have not been attempted since 1997, these fish are undoubtedly progeny of Arctic grayling reintroduced into the upper Ruby River. These findings suggest that the upper Ruby River does provide at least some adequate spawning and rearing habitat for Arctic grayling. Also, the presence of these age 0 fish in both the Three Forks and Vigilante monitoring sections suggest that adequate spawning habitat may be located through the upper reaches of the study area. Natural reproduction of Arctic grayling in the upper Ruby River is an essential step towards the formation of a stable, viable population, the main goal of this reintroduction (Montana Fluvial Arctic Grayling Workgroup 1995). Further monitoring of these wild age classes should be conducted to determine their recruitment into adult age classes. If possible, all Arctic grayling reintroduced in the future should be given permanent marks (e.g. adipose clip) to distinguish stocked Arctic grayling from those which are products of natural reproduction, facilitating the monitoring of these wild age classes.

Further monitoring of this reintroduction is essential to fully evaluate the success or failure of this project. While this study provides an in depth analysis of the persistence, movement, and growth of reintroduced Arctic grayling within the first three years of the reintroduction, only further monitoring can evaluate the long term persistence of these Arctic grayling and determine whether natural reproduction of Arctic grayling continues to occur in the upper Ruby River. Both of these factors are integral in determining whether this reintroduction is ultimately successful. This monitoring will be carried out by MFWP (J. Magee, MFWP Fisheries Biologist, Dillon) and is scheduled to continue through at least the year 2004.

Summary

1. Electrofishing surveys approximately one month after the reintroduction and later the following spring indicated poor persistence of the 29,808 age 0 Arctic grayling reintroduced in August of 1997. Further monitoring of this age class was not possible due to overlap in size with age 1 grayling reintroduced in 1998. It is uncertain as to whether poor survival or downstream dispersal led to the failure of these plants.
2. The reintroduction of age 1 fluvial Arctic grayling into the upper Ruby River appeared to be initially successful. Densities of age 1 grayling in the Three Forks and Vigilante population estimate sections averaged 369 and 208 fish per km in 1998 and 1999, respectively, three months after the reintroduction. Densities of the cohort reintroduced in 1998 were substantially lower as age 2 Arctic grayling in the fall of 1999 with estimates of 22 and 16 fish per km in the Three Forks and Vigilante population estimate sections, respectively. These reductions appear related primarily to overwinter mortality.
3. Reintroduced Arctic grayling underwent minimal downstream movement after reintroduction in both years. Eight fish were captured in both 1998 and 1999 at a weir trap located 13 km downstream of the lowest plant site with a majority of the captured fish suspected to have died upstream of the trap. Dispersal was also found to be minimal based on wire tag recaptures with the average recaptured fish having moved approximately 0.7 km downstream in 1998 and 4.6 km downstream in 1999 three months after reintroduction.

4. The growth of reintroduced Arctic grayling was demonstrated by significant increases in both length and weight both three months after reintroduction and over one year after reintroduction. Fulton's condition factor declined significantly both three months after reintroduction and over winter. Condition factor did return to nearly the same value measured at planting over one year after the reintroduction for age 1 Arctic grayling.
5. Densities of age 1 Arctic grayling during fall surveys were significantly correlated with pool-and-run to riffle ratio, suggesting that Arctic grayling either selected reaches of stream with high pool-and-run to riffle ratios or that these sections provided better survival for reintroduced fish. A similar relationship was found for densities of age 2 grayling during fall 1999 electrofishing surveys, however one outlier and small sample size (n=7) precluded this variable from being significant. All other habitat variables were not significantly correlated to Arctic grayling densities. Age 1 and age 2 Arctic grayling densities were negatively correlated with densities of nonnative rainbow and brown trout densities, however these relationships were also not significant. Problems which limited this analysis include small sample size (due to a limited number of sample sites) and a lack of variation in several of the tested variables.
6. Monitoring by MDFWP in the fall of 2000 revealed the presence of age 0 Arctic grayling which were products of natural reproduction by reintroduced Arctic grayling in the upper Ruby River. Further monitoring is necessary determine

whether natural reproduction continues to occur and ultimately, whether a stable, viable population develops.

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APPENDICIES

Appendix A. Location and total length of electrofishing sections including population estimate sections and one pass CPUE estimate sections. River km calculated as km upstream of the inlet of Ruby Reservoir which is approximately 82.8 km upstream of the mouth of the Ruby River.

	Population Estimate Sections			
	Three Forks	Vigilante	Section One	Greenhorn
River km	65.3	52.1	41.3	21.9
Total length (m)	1930	3380	1255	3540

	CPUE Sections					
	A	B	C	D	E	F
River km	66.6	57.9	55.1	48.6	46.1	41.9
Total Length (m)	363	334	588	304	401	277

Appendix B. Maximum and minimum daily water temperatures near the Three Forks of the Ruby River (upper chart) and the mouth of Warm Springs Creek (lower chart) in the upper Ruby River watershed during 1999.