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The Movement and Habitat Use of Fluvial Bull Trout
in the Upper Clark Fork River Drainage

by

Tim Swanberg

B.A. Whitman College, 1991

Presented in partial fulfillment of the requirements
for the degree of
Master of Science
University of Montana
1996

Approved by:


Chairman, Board of Examiners

Dean, Graduate School

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Fluvial Bull Trout Movement and Habitat Use in the Upper Clark Fork River Drainage (61 pp.)

Director: Andrew L. Sheldon

A.L.S.

The seasonal movements and habitat use of 40 fluvial bull trout *Salvelinus confluentus* in the Blackfoot River drainage were described using radiotelemetry and snorkel surveys from May, 1994 to October, 1995. Twenty-four bull trout made upriver migrations (mean distance: 63 ± 21 km), 33% of which were related to spawning. In both years fish began migrations in June, and appeared to be cued by an increase in water temperature to $17 \pm 2^\circ\text{C}$ and a $>40\%$ decrease in discharge from peak run-off. Larger fish began moving at cooler temperatures than smaller fish. Migrations occurred nocturnally and were generally rapid (mean: 4.4 ± 2.2 km/d). Daily rates of migration were correlated with maximum daily temperatures. Spawning bull trout ascended tributaries in late June to early July, 67 ± 10 d before spawning. Non-spawning fish entered the lower portions of these tributaries after spawning fish, and remained in them 28 ± 18 d before returning down-river in late August. While in Monture Creek, a major spawning tributary for the Blackfoot, adult bull trout used deep pools in greater proportion than their availability and were positively associated in habitat units with whitefish. Eighty-six percent of migrants returned downriver to within 20 m of sites they had occupied in the spring. In 1994, two non-migrating fish used cold-water confluences, while no such behavior was observed in 1995. Results suggest that water temperature influences the movement of fluvial bull trout and that tributary habitat is important for both spawning and non-spawning fish. Results also demonstrate the large spatial scale and diversity of habitats required to sustain fluvial bull trout populations.

The movements of five other bull trout were monitored by radiotelemetry after transport over Milltown Dam on the Clark Fork River. Two fish migrated 40 and 130 km to Rock Creek; one of these fish spawned. Three others moved downstream of the dam and two later attempted to re-ascend. Movements of these bull trout indicate Milltown Dam blocks migrations and that transporting fish enhances spawning populations.

Preface

The number and sizes of fluvial bull trout populations are declining. These fish are important components of their river systems because they likely maintain large-scale population connectivity and historically influenced the abundance and distribution of prey fishes. Despite their ecological importance and the declines in population sizes, little is known about fluvial bull trout.

Chapter I describes the seasonal migration and use of habitat by fluvial bull trout in the Blackfoot River drainage. Results are presented as four sections of the annual migratory circuit: upstream migration, tributary habitat use, downstream migration, and use of river habitat/winter movements. The behaviors of three categories of adult bull trout (migrating spawners, migrating non-spawners, and non-migrating fish) are compared. Results indicate the use of a wide range of habitat types and reveal differences in behavior between categories of adults.

Chapter II evaluates the effectiveness of transporting bull trout over Milltown Dam on the Clark Fork River. Bull trout populations in the Clark Fork are small; four dams on the main river have also greatly restricted movement. Based on the results of this chapter, it is suggested that transporting bull trout over dams on the Clark Fork is a cost-effective way to restore population connectivity and to enhance populations.

Most studies of bull trout have been conducted on the adfluvial and resident life-history forms. While similarities between these life-

history forms and fluvial bull trout exist (e.g., use of tributary habitat by young fluvial fish and resident fish, migrations to and from tributaries by fluvial and adfluvial adults), the use of the river environment by fluvial bull trout is unique. This research on the fluvial life-history form provides managers with information not available in studies of adfluvial and resident bull trout.

Research I conducted on the effects of transmitters on the social interaction of rainbow trout is presented in Appendix A. Results indicate that the stress of carrying a transmitter does not impair the ability of socially dominant fish to maintain their rank. It is concluded that transmitters do not alter socially determined use of microhabitat and movement patterns.

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This research was made possible by funding from Montana Power Company and by the Montana Organization for Research in Energy. Don Peters, Ron Pierce, and Dennis Workman of Montana Department of Fish, Wildlife and Parks, and Brent Mabbott of Montana Power secured summer stipends, equipment, interns and volunteers for the project. I especially thank Don Peters and Ron Pierce for their hours of advice and their amazing ability to provide a very adequate sample size of a fish that is difficult to find. Eric Krutar, David Schmetterling, and Dale Pier put in long hours of field work and together accounted for >50% of triangulated bull trout locations; it was a pleasure to share with them the excitement of discovery. I am grateful to Ralph and Toon Burchenal and Ross and Lacene Friede for providing access to the Monture Creek study area.

Chapter I

Movement and Habitat Use of Fluvial Bull Trout in the Blackfoot River

Introduction

The number and sizes of bull trout *Salvelinus confluentus* populations are declining (Rieman and McIntyre 1993); the species is presently a candidate for listing as a federally endangered species. Degradation of spawning and rearing habitat (Fraley and Shepard 1989), over-fishing (Bond 1992, Fraley and Shepard 1989), competition from non-native species (Donald and Alger 1993), hybridization with brook trout *S. fontinalis* (Leary et al. 1993), irrigation practices, and hydroelectric development (Goetz 1994) are factors causing this decline. While detrimental to all life history forms, these factors have had a particularly adverse effect on fluvial, or river-dwelling, bull trout. Rivers have received more habitat degradation from drainage-wide disturbances (Meehan 1991), channel modification (Chamberlin et al. 1991), fishing pressure (Clark and Gibbons 1991), and migration barriers than lakes or small streams.

Fluvial bull trout are important components of their river systems. They likely maintain large-scale population connectivity, enabling them to refound extirpated populations (Rieman and McIntyre 1993). This mobility is important as habitat becomes increasingly fragmented and populations of resident bull trout are isolated. As the

largest native piscivore in their range, it is also likely they historically influenced the abundance and distribution of prey fishes.

Despite their ecological importance and the decline in the number and sizes of their populations, quantitative knowledge of fluvial bull trout is lacking. For instance, the seasonal timing and causes of migration are unknown, as are uses of river and tributary habitats. My objectives were to describe these life history features using radiotelemetry, snorkel observations, and habitat surveys.

Fluvial bull trout rear in second to third-order streams and move to rivers at ages three to four (14 to 36 cm), with sexual maturation occurring at ages five to seven (40 to 50 cm; Fraley and Shepard 1989). In early summer, mature fish begin migrations to natal streams that may exceed 200 km in distance (Bjornn and Mallet 1964). Spawning occurs in clean, low-gradient streams when temperatures drop below 9°C in September or October (Fraley and Shepard 1989). Soon after spawning, fish return downstream to over-wintering sites. Fluvial bull trout can spawn more than once; both alternate-year and every-year spawning occur (Schill et al. 1994). They may live to 15 years and grow to 90 cm in length. The distribution of bull trout populations is thought to be limited by temperature above 15°C (Rieman and McIntyre 1993).

Study Area

The Blackfoot River is a tributary to the Clark Fork River in western Montana, with a drainage area of 5931 km² and an average annual discharge of 45 m³/s (Figure 1). It flows over Belt-Series geology through prairies and foothills. Riparian vegetation is mostly willow, with occasional cottonwood forests. Upland vegetation is predominantly

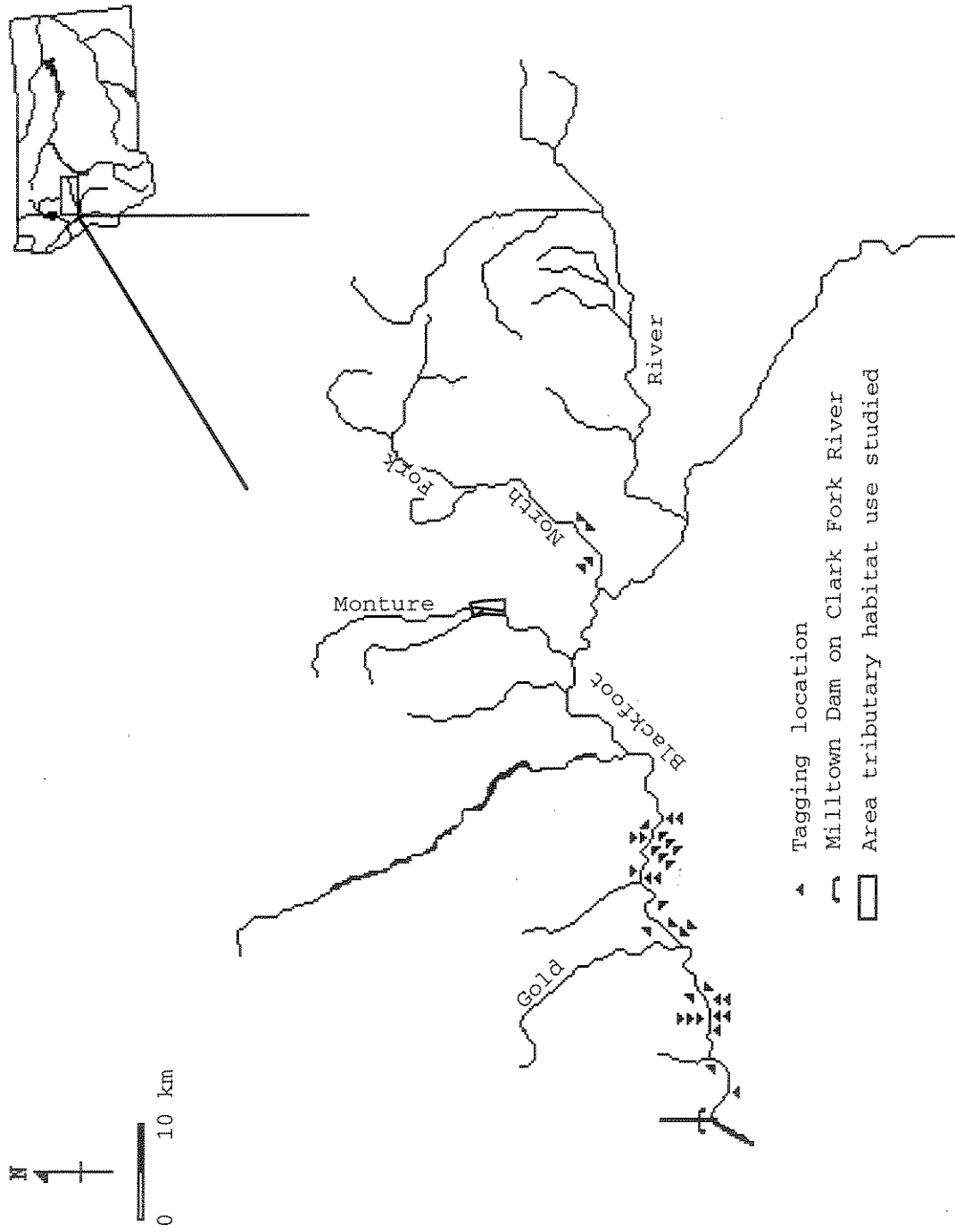


Figure 1. The Blackfoot River drainage.

ponderosa pine/Douglas fir forest mixed with areas of sagebrush.

Milltown Dam, located at the confluence of the Blackfoot and Clark Fork Rivers, is a barrier to upstream passage.

The North Fork of the Blackfoot River, Monture Creek and Gold Creek are tributaries to the Blackfoot that contribute 54%, 16%, and 14% to Blackfoot discharge, respectively (Figure 1). The North Fork of the Blackfoot drains 590 km². Its lower 12 km flow in an unconfined floodplain with sections that may dry in drought years. The upper 30 km flow in a confined floodplain. Summer temperatures are <15°C. In 1988, a portion of the middle drainage burned, leaving many snags in the riparian zone; little woody debris exists in the channel. Large boulders and turbulence are the dominant habitat features. Monture Creek drains 363 km². It flows over gravel substrate in an unconfined floodplain. Riparian vegetation is mostly Engelmann spruce and willow. Woody debris is abundant in the channel, causing the stream to meander frequently. Summer temperatures remain <12°C. Gold Creek drains 36 km². Summer temperatures in it may exceed 18°C. The lower reaches of the North Fork and Monture are impacted by grazing, but middle reaches (where spawning occurs) have received little human-caused disturbance. Most of the Gold Creek drainage has been clear-cut and is heavily roaded.

Redd counts in Monture and the North Fork have averaged 21 and 33, respectively, over the last 8 years (Montana Department of Fish, Wildlife and Parks, unpublished data). Fluvial bull trout historically spawned in Gold Creek in large numbers; a 1994 survey detected 12 redds. Other native fish in the Blackfoot River drainage are westslope cutthroat trout *Oncorhynchus clarki lewesi* (mainly restricted to

headwaters), mountain whitefish *Prosopium williamsoni*, largescale sucker *Catostomus macrocheilus*, northern squawfish *Ptychocheilus oregonensis*, longnose dace *Rhinichthys cataractae*, and slimy sculpin *Cottus cognatus*. Introduced brown trout *Salmo trutta*, rainbow trout *O. mykiss*, and brook trout *Salvelinus fontinalis* are the most abundant salmonids.

Methods

Transmitter Implanting and Fish Tracking

Bull trout receiving transmitters were captured in the lower 40 km of the Blackfoot and in the North Fork of the Blackfoot (Figure 1). Captures were made with a Coffelt Model VVP-15 electroshocker mounted on a 3.5-m aluminum jet boat. The shocker was operated in DC mode, with an output of 1,000 watts and 200-300 volts. Surgeries were performed within 10 minutes of capture.

Before surgery bull trout were anesthetized (150 mg/L tricane methanosulphate, MS-222), and length and weight noted. To implant a transmitter, a fish was placed on its dorsum on a V-shaped operating table. A 3 cm incision was made on the mid-line of the ventral surface immediately anterior of the pelvic girdle. A hollow needle was then used to puncture a small hole immediately posterior of the pelvic girdle; internal organs were protected from the needle by a metal shield held from the incision (Ross and Kleiner 1982). The end of the antenna was placed in the hollow needle and the needle withdrawn, threading the antenna through the hole. The transmitter was then placed in the coelom on the pelvic girdle. Four to six non-absorbable, independent sutures (Ethicon 3/0) closed the incision. Surgeries lasted 6 minutes (range: 3 - 14), during which time gills were bathed with diluted MS-222 to

maintain unconsciousness. After surgery fish were held in river water until equilibrium was recovered, then released. Transmitters emitted signals at 150 MHz, were active for 258 ± 156 d (range: 40 - 586 d), weighed 5.1 to 16.3 g, and did not exceed 2% of fish weight (Winter 1983).

Locations of bull trout were determined from the ground using radial truck-top and 3-element Yagi antennas. During upriver migration, weekly plane flights were conducted 100-200 m above the river at 100 km/h with a 3-element Yagi antenna attached to a wing strut. Fixed receiver stations were also placed on the river bank during this period to monitor the diel timing of movements. Fish were contacted at least three times/week immediately prior to and during migrations, once/week while holding in tributaries, and once/month during winter. Triangulations I made were accurate to within 2 m when distances between the receiver and transmitter were <20 m. Accuracies decreased to 18 m with distances >35 m (unpublished data).

Description of Migration Patterns

Bull trout were grouped into migratory or non-migratory categories based on observed movements. Migrations were partitioned into three time intervals: upstream migration, upriver holding (including spawning), and downstream migration. Within the migratory group, fish were further divided into spawning or non-spawning categories. Fish were considered to have spawned if they were seen near a redd or if they were in a known spawning area during spawning time. Locations of bull trout were placed on digital aerial imagery (1 pixel = 1 m²). These locations were later transferred to a hydrography layer in GIS to

facilitate calculating distances moved between contacts. The date of an event, such as a migration start or stop, was estimated by the mean date of the two contacts surrounding the event.

Hourly water temperatures were recorded at 10 stations in the drainage with Stowaway™ data loggers. To evaluate the effect of temperature on migration rate, a mean daily migration rate was calculated for the interval between contacts and correlated to the maximum hourly temperature at the nearest station for that interval. Daily discharge of the Blackfoot River was obtained from a USGS gauging station at Rkm 13.

Use of Tributary Habitat

I surveyed habitat in a 6 km section of Monture Creek on July 7-13, 1994 (Figure 1). This section was selected because of its high concentration of pre-spawning fluvial bull trout (>400 mm TL). I categorized the section into habitat units (pool, riffle, or glide), then within each habitat unit estimated area and depth (Hankin and Reeves 1988), and counted the number of wood pieces (woody debris >3 m in length). Units were then snorkeled to determine use by adult bull trout and whitefish. With each observation of a bull trout, cover type used (Table 1), activity level (Table 2), and focal point distance from substrate were recorded. Snorkel surveys were conducted July 18 to 22, August 15 to 16, and September 25 in 1994 and July 20 to 21 and August 28 to September 1 in 1995. In 1994, few bull trout were observed in riffles or glides, so only pools were snorkeled in 1995.

Table 1. Cover categories used in habitat use surveys (from Dolloff and Reeves 1990).

Cover category	Description
Cobble	Rocks 100 - 300 mm diameter on streambed
Boulder	Rocks > cobble with space underneath for hiding
Undercut bank	Overhanging earth bank carved by water current
Overhead vegetation	Vegetation extending over the water surface
Log	Wood debris 10 cm - 1 m in diameter
Branches	Wood debris < 10 cm anchored to streambed
Fine debris	Loose collection of wood and other debris
Debris with undercut bank	Branches extending from an earth bank
Debris with overhead vegetation	Streambank vegetation intertwined with branches
Aquatic vegetation	Algal mats or emergent plants
Overhead vegetation with undercut bank	Vegetation and earth bank
Turbulence	Heavily aerated water created by drop in elevation
Aquatic vegetation on log	Filamentous algae supported by woody debris
Depth	Water depth > 1.0 m

Table 2. Activity categories for bull trout used for habitat use surveys.

Activity	Description
Resting	Holding on substrate with no movement
Passively holding	Occasionally finning to maintain focal point
Actively holding	Actively finning, maintaining focal point in current
Feeding	Capturing food item
Swimming	No focal point maintained
Spooked	Disturbed by observer

Analysis of Data

Both study years were grouped to analyze differences between migration categories in fish length and migration distance. Due to the small sample size in 1994, only 1995 data were used to analyze the effect of temperature on migration rate. Most data were not normal (Shapiro-Wilkes, $P < 0.05$). I used the Mann-Whitney U test to compare means and Spearman rank correlation (r_s) to test association. Locations of bull trout before migrations occurred were counted in four equal-length sections of the lower Blackfoot. A Kruskal-Wallis test then evaluated the hypothesis that fish from these sections of river began their migrations on the same date. Bull trout observed in Monture Creek were often in groups and most pools used in 1994 surveys were also used in 1995. To avoid pseudoreplication, data for each pool were used once in calculating means for used pool depth, wood pieces/pool and whitefish density/pool. A one-sample Chi-square was used to test for use of habitat types in proportion to their availability and also to test for an equal distribution of activity levels.

Results

Radio transmitters were inserted in 40 bull trout (12 in 1994 and 28 in 1995). Fish were tracked from May 30, 1994 to October 15, 1995, during which time 37 ± 19 (mean \pm SD) contacts were made for each fish. Three fish expelled transmitters within one month of receiving them; at least one of these fish died. Over the course of the study, three more transmitters became inoperable: the antenna of one was clipped by an angler, another was found on the bank, and a fish carrying a third was poached. Transmitters did not noticeably affect behavior. I am aware

of seven bull trout with transmitters being caught and released by anglers, indicating fish were feeding. Two bull trout were observed near redds with mates nearby, indicating that transmitters had not interfered with spawning. Finally, three bull trout were recaptured 4, 10 and 12 months after receiving their transmitters; incisions had left scars, but healed completely.

Twenty-four bull trout migrated upriver (3 in 1994, 21 in 1995). These fish were significantly larger than the non-migrating fish (575 ± 92 mm v 473 ± 84 mm; $P = 0.0021$). Eight (33%) of these migrating fish spawned. Spawning bull trout were significantly larger than migrating, non-spawning fish (663 ± 90 mm v 539 ± 67 mm; $P = 0.0031$; Figure 2).

Upriver Migrations

The hydrograph and thermal regime of the Blackfoot River differed greatly between study years. Peak run-off in 1994 came nearly a month earlier than in 1995 (Figure 3). Additionally, discharge during the summer of 1994 was 40% of the 40-year average and, as a result, river temperatures warmed early and were abnormally high (often $>20^{\circ}\text{C}$). In contrast, discharge during the summer of 1995 was 90% of normal, weather was frequently cool, and water temperatures rarely exceeded 20°C . Temperature was correlated to discharge in 1995 ($r_s = -0.791$, $P < 0.0001$).

Migrations began during the descending limb of the hydrograph on June 7 ± 11 d in 1994 and July 2 ± 8 d in 1995 (Figure 3). Although the mean temperature that fish began their migrations in 1995 was 17.7°C (range: 12 to 20°C), water temperature fluctuated greatly during this

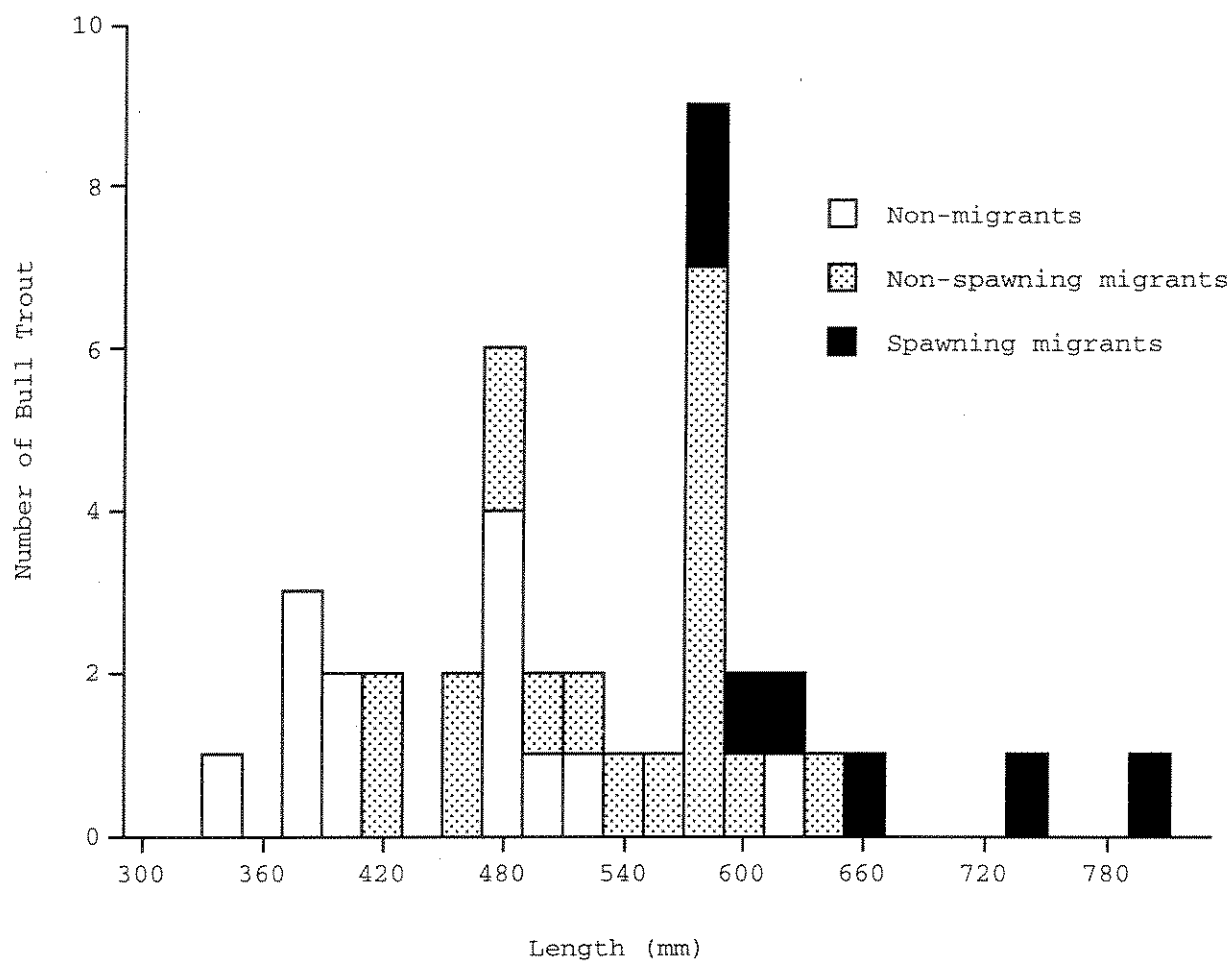


Figure 2. Length distribution of bull trout receiving transmitters.

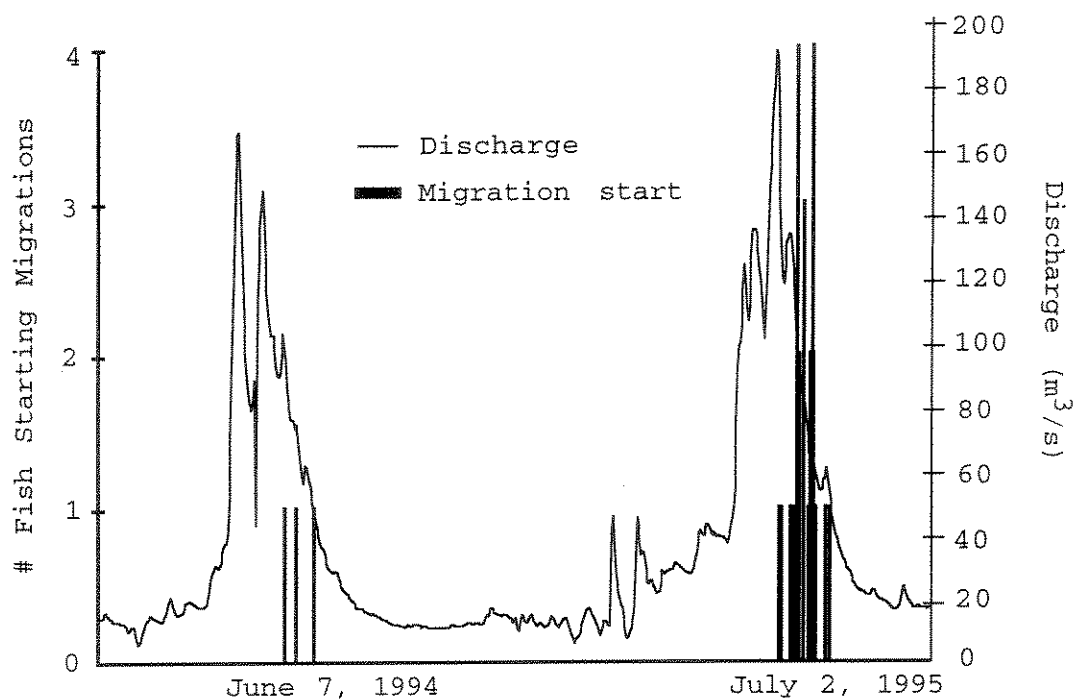


Figure 3. Relationship between discharge and the date bull trout began migrations in 1994 and 1995. Mean dates that migrations began in each year are shown below the x axis.

period. Seventy-three percent of migrations began during peaks in temperature (Figure 4). Larger fish began migrations at earlier dates ($r_s = -0.62$, $P = 0.0016$) and cooler temperatures ($r_s = -0.44$, $P = 0.04$) than smaller fish (Figure 5). There was no difference in the date fish from the four river sections began their migrations (Kruskal-Wallis: $\chi^2 = 2.07$, $df = 3$, $P = 0.56$).

Three different methods verified nocturnal movement of migrating bull trout. First, two fish that were each followed for 16 hours started and stopped moving precisely with sunset and sunrise. Second, four bull trout swam past fixed receiver stations at night, while none passed during the day. Finally, by comparing morning and afternoon locations of the same fish we detected diurnal movement in excess of 2 km on only two occasions, while on 12 other occasions no movement was detected. In contrast, upstream movement between afternoon and next morning locations was detected on 12 occasions. Once migrations began, most bull trout made some upstream movement during every diel period. However, seven non-spawning fish did pause from 2 to 13 d; these pauses appeared to be related to periods of cooling.

Migrations averaged 63 ± 21 km in distance (range: 13 to 112 km) and lasted 20 ± 10 d. The mean date migrations began was not different for fish entering Monture or the North Fork ($P = 0.45$). There was also no difference in the mean date these fish entered their tributaries ($P = 0.41$), although North Fork fish migrated farther than Monture fish (72 ± 19 km v. 54 ± 17 km; $P = 0.06$). Spawning fish entering Monture migrated total distances significantly further than non-spawning fish entering that stream ($P = 0.02$), but no such difference existed between North Fork spawning and non-spawning fish ($P = 0.30$).

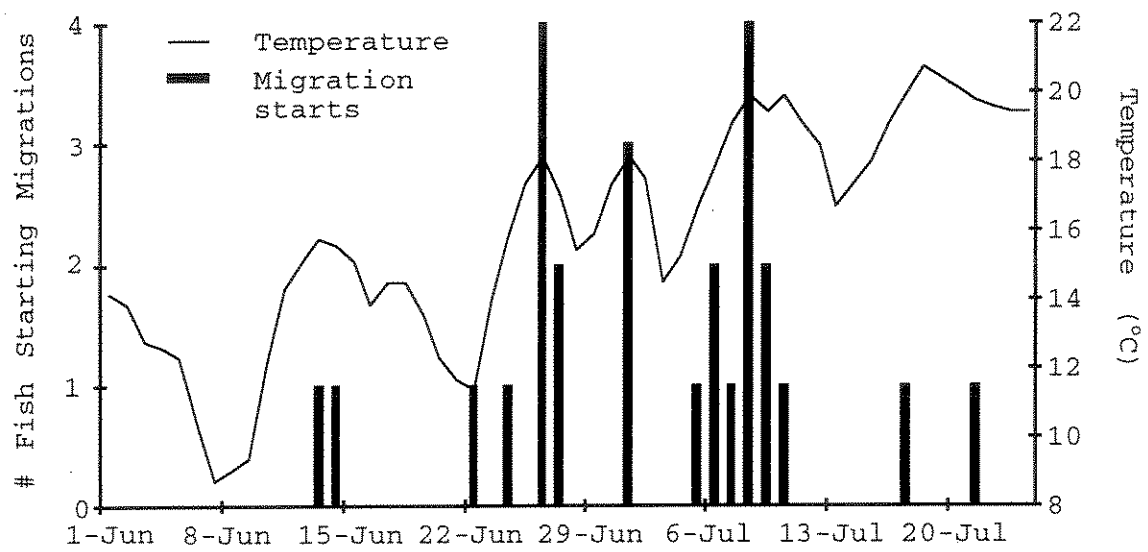


Figure 4. Relationship between temperature and the date bull trout began migrations in 1995.

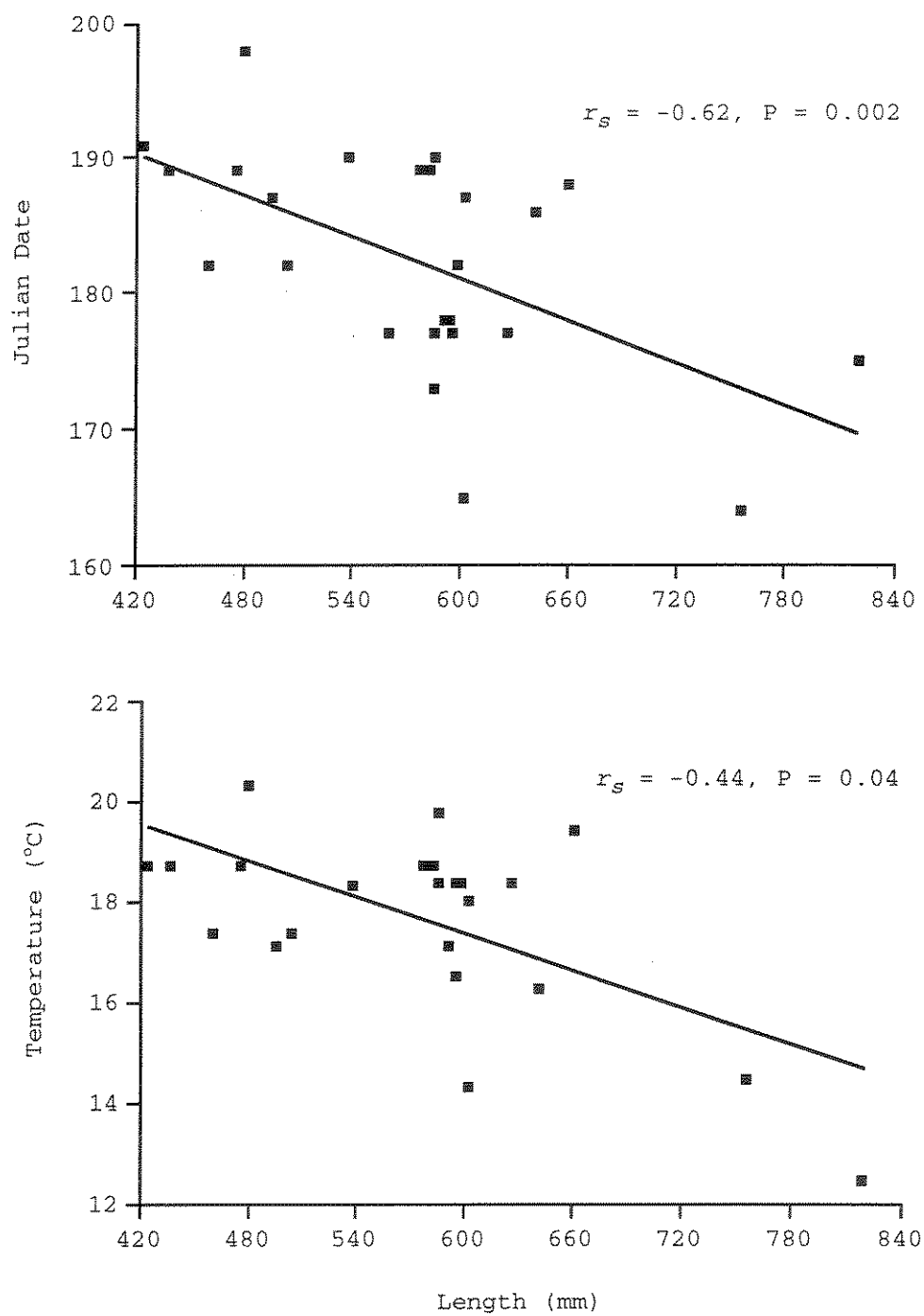


Figure 5. Relationship between fish length and the date (top) and temperature (bottom) that bull trout began migrations.

While in the Blackfoot, mean daily rates of migration for individuals ranged from 1.9 to 11.8 km/d (grand mean: 4.4 ± 2.2 km/d). Spawning fish migrated more slowly than non-spawning fish (2.7 ± 0.82 km/d v 4.1 ± 1.9 km/d; $P = 0.08$). In 1995, a non-linear relationship existed between daily rates of migration in the Blackfoot and temperature (Figure 6). This relationship was best described by a power function for spawning fish and a quadratic equation for non-spawning fish. Additionally, spawning fish generally accounted for maximum rates observed at a given temperature, while rates for non-spawning fish were scattered. Rates of migration in tributaries for all fish (1.9 ± 0.79 km/d) were slower than rates in the Blackfoot ($P < 0.0001$) and did not differ between spawning and non-spawning fish ($P = 0.66$).

Upriver Holding

Nine pre-spawning and non-spawning bull trout entered Monture (2 in 1994), 13 entered the North Fork (2 in 1994) and 1 entered Gold Creek. (Figure 7). Pre-spawning fish entered tributaries on June 20, 1994 ± 0 d ($N = 2$) and on July 7, 1995 ± 7 d ($N = 6$), 67 ± 10 d before spawning (range: 55 to 81 d). Most held with little movement within 1 km of their spawning sites, although one fish ascended 12 km to its redd site <6 d before spawning. Spawning occurred in late September in both years. One male bull trout was observed over a two day period with two mates 0.8 km apart.

Fourteen non-spawning bull trout entered tributaries July 17 ± 5 d in 1995, significantly later than spawning fish ($P = 0.001$). These fish remained in tributaries for 28 ± 14 d. None neared spawning areas, but instead held in the lower portions of tributaries (Figure 7). One

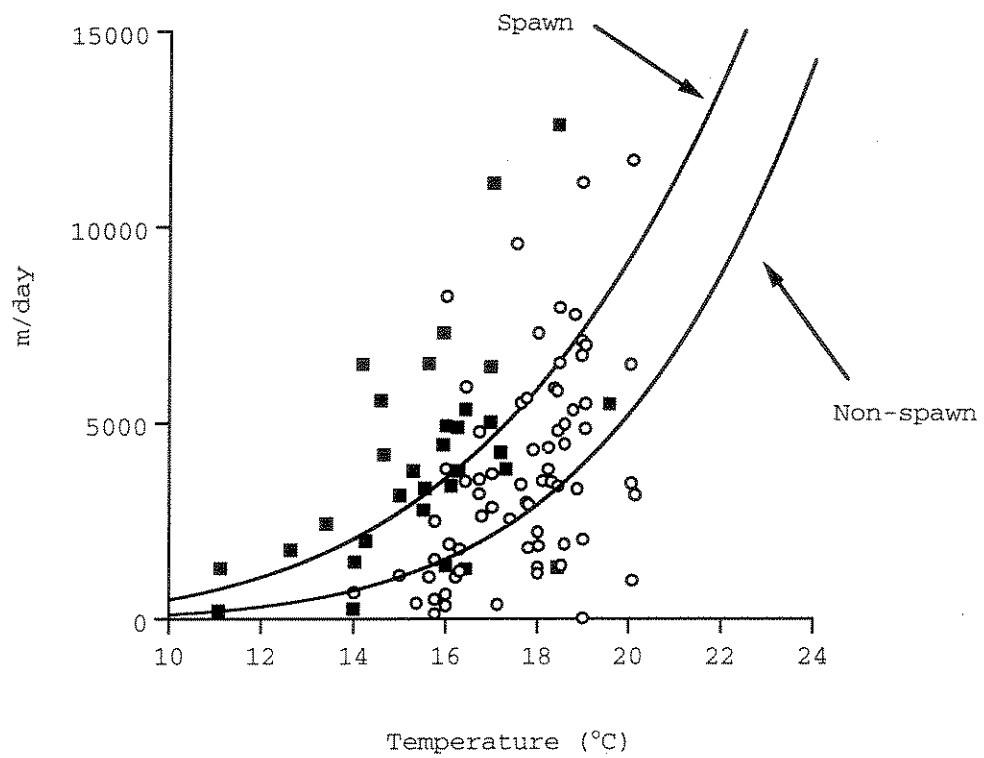


Figure 6. Relationship between temperature and daily rate of migration for spawning fish (squares) and non-spawning fish (circles).



Figure 7. Upper-most locations of spawning and non-spawning bull trout.

entered both the North Fork and Monture in 1994, staying in each for 20 d. Three other bull trout remained in the upper Blackfoot for 27 ± 18 d, two near an 8°C spring (Figure 7).

Use of Tributary Habitat

Use of tributary habitat was determined for 79 pre-spawning bull trout, 34 during the three surveys in 1994. During the surveys in 1994, fish occupied pools more frequently than glides or riffles ($\chi^2 = 19.8$, $df = 2$, $P < 0.001$). Comparing the frequency of pools used by bull trout in all surveys to the frequency available, deep pools were used in greater proportion than their availability ($P < 0.001$, Figure 8a), as were pools with high densities of whitefish ($P = 0.020$, Figure 8b). Although wood played an important role in forming pools used by bull trout, the number of pieces of wood in a pool did not seem to greatly influence use ($P = 0.34$, Figure 8c).

Activity levels of 70 observed bull trout ranged from resting to swimming without a focal point, but were predominantly resting ($\chi^2 = 40.1$, 5 df , $P < 0.001$; Figure 9). Greater than 75% of observed bull trout maintained focal points within 2.5 cm of the substrate. The most frequently used cover types were woody debris and woody debris with attached filamentous algae, which together accounted for 58% of the used cover types (Figure 10). Eighty percent of observed fish were directly beneath cover, while none were observed >3 m from cover.

Downriver Migration

The four bull trout that received their transmitters in the lower North Fork in September 1994 immediately began moving downriver, and

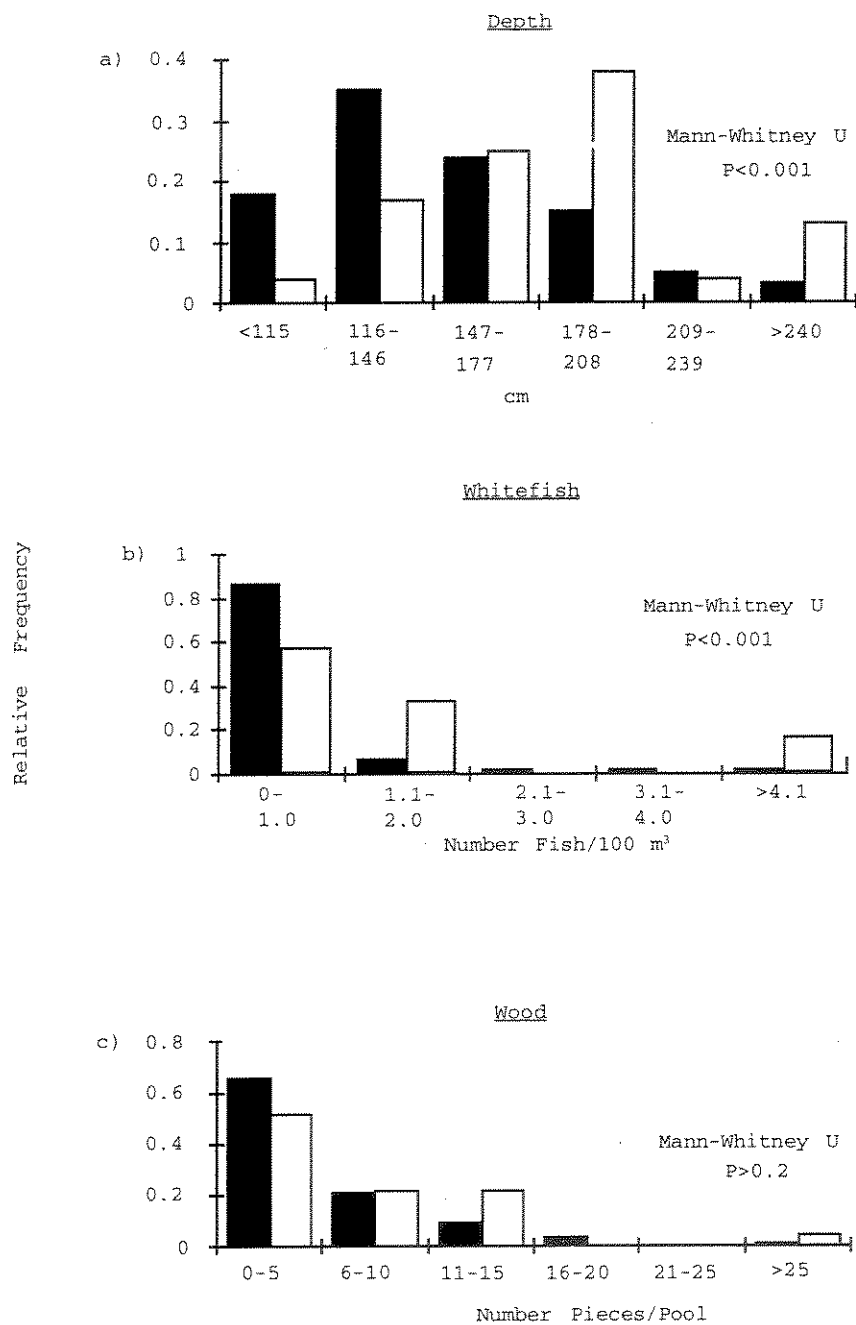


Figure 8. Comparisons between the relative frequency of used (white) and available (black) pool depths (a), whitefish densities (b), and amounts of woody debris (c).

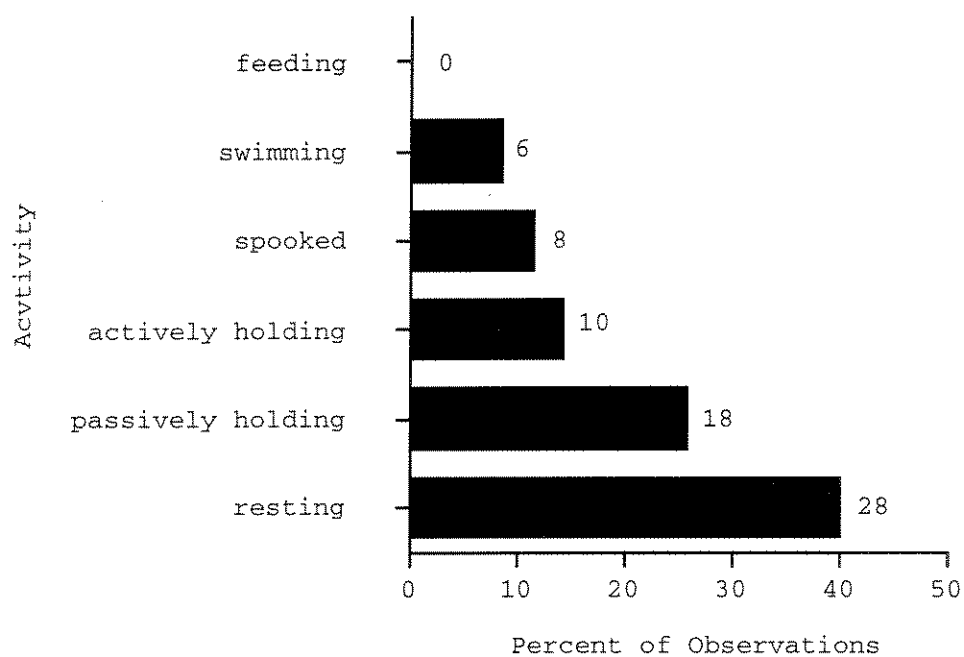


Figure 9. Observed activity levels for pre-spawning bull trout. Activity levels are defined in Table 2. Numbers to the right of bars indicate the number of fish observed for that activity level.

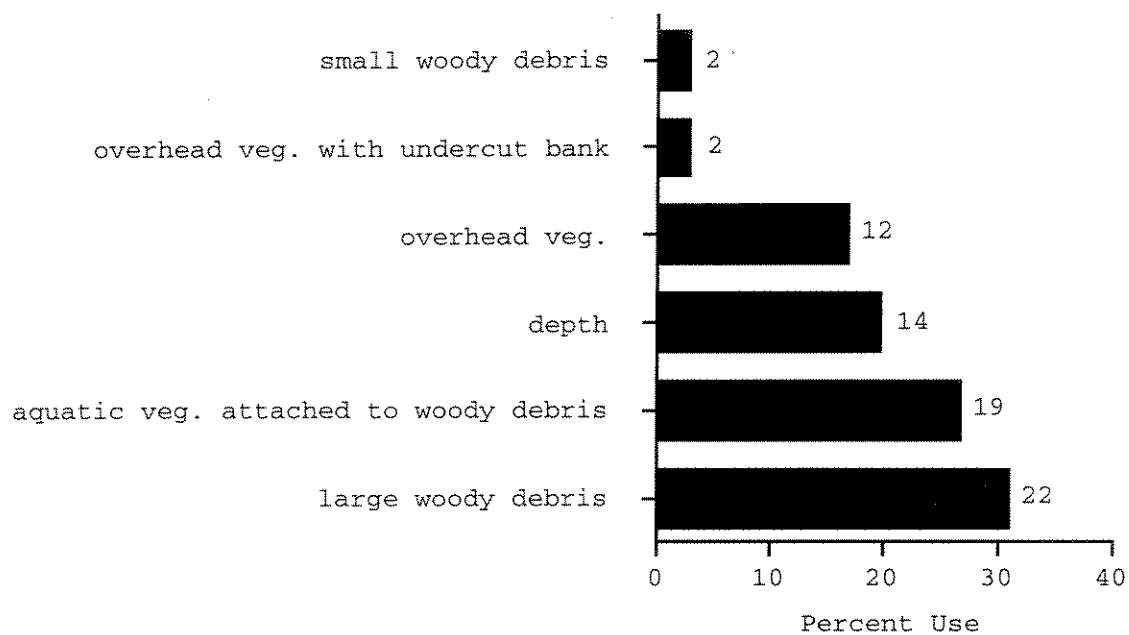


Figure 10. Cover types used by pre-spawning bull trout. Cover types are defined in Table 1. Numbers to the right of bars indicate the number of fish observed using that cover type.

continued to do so throughout the winter. Non-spawning fish, which had migrated upriver in June and July, made downriver migrations in late August during a drop in Blackfoot temperature from 18 to 12°C. Most spawning bull trout moved downriver soon after redds were complete, with the exception of two males. One of these fish left Monture three weeks after spawning, but the second remained in Monture through winter before emigrating in early spring. A third bull trout entered an irrigation ditch after leaving the spawning area; I captured and returned it to the Blackfoot. Downriver migrations averaged 13 ± 9 d in duration (range: 4-22 d); one fish traveled 90 km in <4 days. Eighty-six percent (19 of 22) of these fish returned to within 20 m of locations they occupied in the spring.

Use of River Habitat and Winter Movement

Although low sample size precluded a statistical test, it appeared that bull trout returning downstream from Monture and the North Fork distributed themselves randomly among river sections. Movements during winter were very local, never exceeding 300 m. Fish were often associated with shelf ice. During a three day warming period, I followed a fish seeking new ice shelves as the ones it had used were carried downriver. Individual use of habitat was varied; approximately half the bull trout I tracked used pool habitat.

Non-migrating bull trout

Eleven bull trout did not migrate to upriver locations. Movement made by most of these fish was infrequent and not greater than 10 km. However, the three largest fish (Figure 11) made downriver movements

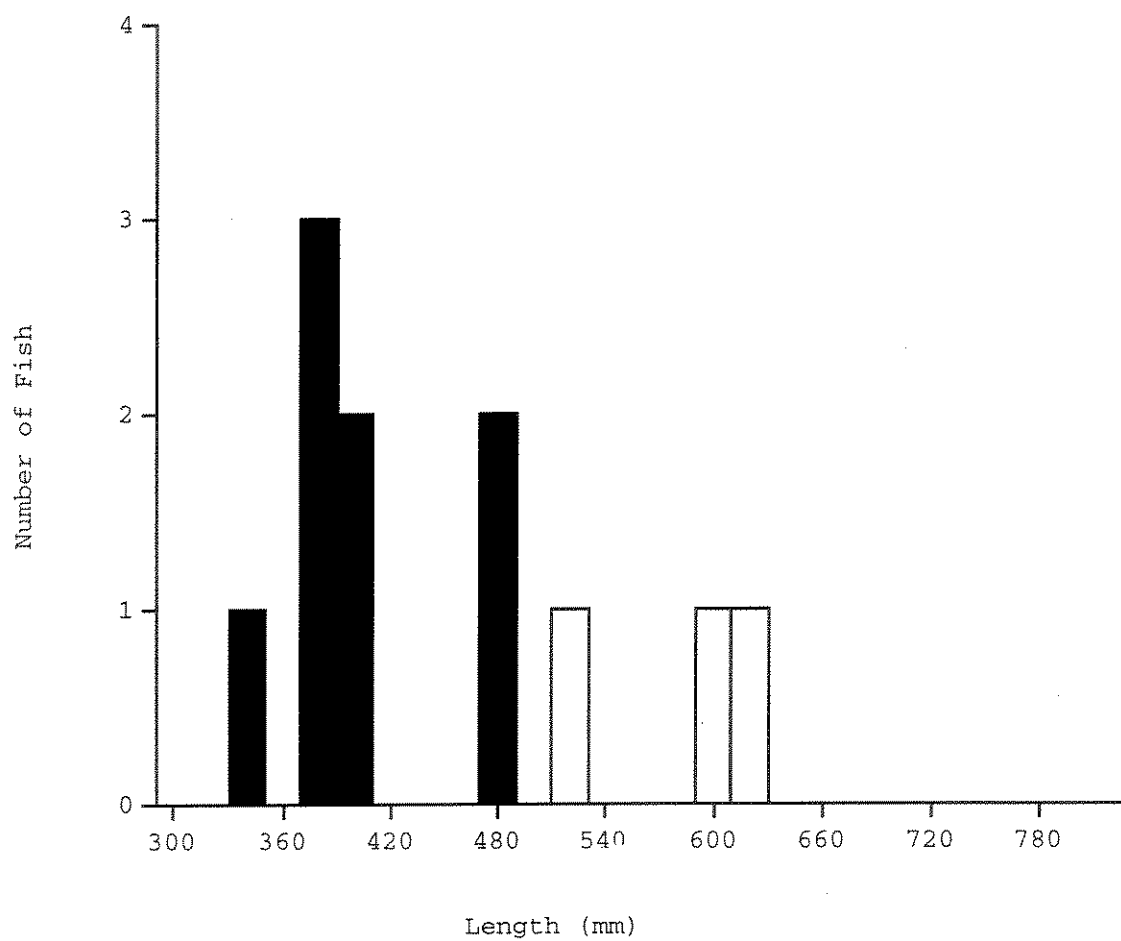


Figure 11. Length distribution of non-migrating bull trout. Unshaded bars indicate fish that passed downstream of Milltown Dam.

during summer 1995; all moved downstream of Milltown Dam. Two of these fish had left locations within 15 km upstream of the dam, but a third fish had moved down the Blackfoot 40 km. One had been tracked to the North Fork the previous year.

Blackfoot temperatures during July and August 1994 were commonly $>20^{\circ}\text{C}$. During this time, two bull trout appeared to continuously occupy a confluence with a small, 12°C tributary. In August 1994 I also observed a group of nine other bull trout at this location. All of these fish were 30-35 cm. Similar behavior was not observed during summer, 1995.

Two-summer Transmitters

Four bull trout carried transmitters for two summers. Two of these fish migrated upstream both summers; one of these, a male, spawned in both years. In 1994 the redd of this fish was below a temporary beaver dam, but in 1995 the dam had broken and its redd was located 3 km upstream. This fish over-wintered in its spawning tributary in 1994, but emigrated soon after spawning in 1995. The other fish to migrate both summers, a female, spawned the first fall but not the second. A third fish migrated upstream in 1994, but not in 1995. In both years, all three of these fish returned downstream to the same locations they had occupied before migrations. The fourth fish carrying a transmitter through two summers was likely immature. It never moved >12 km while it was tracked.

Discussion

Upstream Migration

A large change in temperature and discharge appeared to cue the beginning of upstream migration during both years of my study. I was not able to distinguish which of these variables is the main seasonal cue because they covaried. However in 1995, most bull trout began migrations during spikes in a fluctuating temperature regime, suggesting a primary response to temperature.

The mean temperature at which fish began their migrations (17.7°C) was much higher than reported elsewhere. For example, Elle (1995) and McPhail and Murray (1979) found migrations to peak at $10-12^{\circ}\text{C}$. This discrepancy may be attributed to the fact that the rivers where these data were collected never warm to the extent that the Blackfoot does. Rieman and McIntyre (1993) suggest 15°C as limiting the distribution of bull trout; Blackfoot River bull trout are an exception this statement.

I found most fish to migrate at night. This timing has been frequently observed among salmonids (Smith 1985, Jonsson 1991), and has been noted previously for bull trout (Block 1955, McPhail and Murray 1979, Shepard et al. 1984, Oliver 1985) and lake trout *S. namaycush* (Loftus 1958). The precise correspondence of movement to the absence of light that we noted suggests darkness, rather than cooling temperature, is the diel cue to which bull trout responded.

Bull trout are known to make migrations >200 km (Bjornn and Mallet 1964, Shepard et al. 1984). The maximum distances bull trout migrated in my study were a reflection of the space available to them, as several fish began their migrations within 1 km of Milltown Dam. Bull trout historically moved throughout the Clark Fork drainage (Montana Bull

Trout Scientific Committee 1994). The three fish that moved downstream of Milltown Dam indicate the downstream component of this movement still exists.

Schill et al. (1994) and McLeod and Clayton (1994) documented average migration rates of 1 km/d; rates of migration observed in my study were generally more rapid. The positive association we observed between migration rate and temperature has been noted for other migratory salmonids (Jensen et al. 1986). This relationship likely has a physiological basis; Beamish (1980) noted the critical swimming speed of char increased with increasing temperature in the laboratory. This explanation may also account for the difference in migration rates between pre-spawning and non-spawning fish: by starting migrations at earlier dates, pre-spawning fish swam in colder water than non-spawning fish. Although migration rates of pre-spawning and non-spawning fish generally increased with temperature, the latter group showed greater variability in rate at a given temperature.

Holding in Tributaries

Larger bull trout began migrations earlier and entered tributaries sooner than smaller fish. Bull trout in the Rapid River, Idaho show a similar pattern of migration (Idaho Department of Fish and Game, unpublished data). This pattern has also been noted for Dolly Varden *S. malma* (Armstrong 1974), as well as for other salmonids (Davies and Sloane 1987, Jonsson et al. 1990, Näslund 1990). Although no clear explanation for this behavior exists, Jonsson et al. (1990) suggested that circannual changes (such as habitat switching) may occur at earlier times of the year with increasing age.

The date that pre-spawning bull trout enter tributaries appears to vary greatly among populations. Shepard et al. (1984) reported bull trout staging for two months at the mouth of tributaries before ascending in late August. Other researchers have noted entries from June to July (Oliver 1979, Marotz 1989, Schill et al. 1994). Pre-spawning bull trout in the Blackfoot entered tributaries in June; however, interannual variation existed that may be explained by differences in temperature between study years. Although these fish ultimately entered tributaries to spawn, their seemingly early arrival indicates a more proximal cause existed. Monture and North Fork summer temperatures are $<15^{\circ}\text{C}$ and are typically at least 5°C cooler than the Blackfoot. As a result, the metabolic rate of bull trout in these tributaries is much less than that possible in the Blackfoot River. Berman and Quinn (1991) calculated that pre-spawning chinook salmon *O. tshawytscha* inhabiting coldwater refugia near spawning areas in the Yakima River, WA reduced their metabolic rate by 12 to 20% from that possible in ambient river temperatures only 2.5°C warmer. Similarly, use of tributaries by pre-spawning bull trout during warm summer months must conserve energy, which then can be used to reproduce.

The majority of bull trout that migrated did not spawn, but instead held less than a month in tributaries or the upper Blackfoot before returning downriver. Similar behavior has been observed for non-spawning bull trout in Idaho (Elle et al. 1995) and Dolly Varden in Alaska (Armstrong 1974). The primary purpose of the migrations we observed was unlikely to be feeding because prey fish densities in tributaries are lower than the Blackfoot. This behavior may have evolved as a strategy to avoid seasonally unfavorable conditions in the

Blackfoot (Northcote 1978), where ambient summer temperatures often exceed 20°C. In support of this hypothesis, non-spawning fish entered tributaries as temperatures warmed, but returned to the Blackfoot soon after cooling. Clapp et al. (1990) and Garrett and Bennett (1995) used similar explanations for the seasonal movements of brown trout.

Use of Tributary Habitat

Pre-spawning bull trout were mostly observed resting at the bottom of deep pools. This behavior has been noted by other workers (Block 1955, Shepard et al. 1984, Sexauer and James 1993). Elliot (1986) noted the positive association between Dolly Varden densities and amount of woody debris. While we found no significant difference between used and available amounts of wood in pools, most bull trout we observed used wood for cover. Additionally, wood was an important structural feature of many pools in the study section.

Although not observed, pre-spawning bull trout probably ate whitefish while in Monture Creek. This is supported by the facts that bull trout selected pools with higher densities of whitefish than were available and were often observed among whitefish schools. Contrary to this, Block (1955) reported that adult bull trout in North Fork of the Flathead tributaries did not feed, perhaps because these fish spent less than three weeks in tributaries.

Downriver Migration

Although fidelity of migrants returning to natal streams is frequently noted for salmonids (Quinn and Tallmon 1987), recognition of fidelity to river locations is less common. The return of most bull

trout to the exact locations used prior to upstream migration indicates a precise homing mechanism. Although olfaction has been noted as a homing mechanism for fish in small streams (Gunning 1959), it is unlikely to operate with precision in a river. Olfaction may, however, allow bull trout to recognize general locations of home sites. Because in some cases fish positioned themselves near the same boulders before and after migration, it is possible that visual recognition of familiar river features operates at a finer scale. Fish may benefit from site fidelity with intimate knowledge of feeding and hiding places (Smith 1985).

In contrast to the migrations of fish originating from the lower Blackfoot, the four bull trout that received transmitters in the North Fork during September 1994 slowly moved downstream throughout winter. Additionally, after migrations stopped, all but one moved less than 10 km for the remainder of the study. These fish were probably first-time outmigrants, as their lengths (460 mm) were similar to those in other systems (Fraley and Shepard 1989, Elle 1995).

Non-migrating Bull Trout

With the exception of those that moved downstream of Milltown Dam, bull trout that did not migrate were probably immature. Fraley and Shepard (1989) and Elle (1995) reported that immature fish spend one to two years in rivers before returning to natal tributaries. My results are consistent with these observations; additionally, my results suggest immature fish move little during this period.

Although abundant food and warm temperatures in the Blackfoot provide good growth conditions for these fish, unfavorable temperatures

may also be encountered. It appears that use of coldwater confluences during these periods may provide thermal refugia (Kaya et al. 1977). This behavior does not seem to occur annually, as fish used confluences during the warm summer of 1994 but not during the cooler summer of 1995. Similar interannual variation in the use of coldwater confluences has been observed for bull trout in northern Idaho (Rob Spangler, personal communication). Similarly, Garrett and Bennett (1995) found brown trout in a reservoir to use cool tributaries during a warm summer but not a cool one.

Management Implications

Bull trout use of the Blackfoot appears dependent on life-history stage. Mature fish use river habitat during winter and spawning areas during summer. Non-migrating bull trout continually use river habitat, but when ambient temperatures are unfavorable also appear to use coldwater confluences. Non-spawning adults, like spawners, use the river during winter; however, they use separate tributary habitat during summer. These differences in use of the river system must be considered in management plans such as those developed from the Bull Trout Round Table in Montana (Rieman and McIntyre 1993).

Migrating adults face risks while in tributaries. Poaching is easy due to the small size and remoteness of streams. Pre-spawning fish are more likely to be poached than non-spawners because they use predictable habitats, are highly visible, and remain more than a month longer in tributaries than do non-spawners. An increased presence of law enforcers from July to September along tributaries would reduce the occurrence of poaching. Loss of adults to irrigation ditches may also

impact populations. Self-cleaning screens at two headgates in the Blackfoot drainage have proved maintainable and have eliminated entrainment of fish. The placement of these screens on all headgates in the drainage would greatly reduce the loss of individuals from the population.

Bull trout in the Blackfoot River also risk moving downstream of Milltown Dam, as did 3 of the 40 (8%) fish we tracked. Because upstream passage is impossible, these fish will not spawn where they reared. For most populations, a loss of 8% is insignificant. However, it is significant in the Blackfoot River, where adult bull trout number in the hundreds. Capturing fish below Milltown Dam and transporting them upstream would greatly reduce this loss. The feasibility of this action is considered in the following chapter.

Chapter II

Movements of Bull Trout in the Clark Fork River System After Transport Above Milltown Dam

Introduction

Hydroelectric dams have a negative impact on migratory fish populations. Direct impacts include mortality from turbine entrainment, gas bubble trauma, and *Columnaris* infection (Marcey et al. 1978, Fujihara and Hungate 1971). Dams also eliminate or restrict upstream migration of adults, an impact that affects the ability of fish to reproduce in their natal environment (Gray and Haynes 1980, Cada and Sale 1993). This impact has been mitigated in many river systems with anadromous fish by passage facilities, but has largely been ignored in systems with only potadromous fish. For example, dams in western Montana are not required by the Federal Energy Regulatory Commission to provide upstream passage, although much of the river system is used by fluvial bull trout *Salvelinus confluentus*. This species is known to make migrations in excess of 200 km (Bjornn and Mallet 1964, Shepard et al. 1984).

Bull trout populations are declining (Rieman and McIntyre 1993), in part because of hydroelectric dams (Fraley et al. 1989, Rode 1990, Bond 1992, Goetz 1994). While detrimental to all life history forms, dams particularly affect fluvial bull trout. For example, bull trout

historically moved throughout the Clark Fork River system in western Montana (Montana Bull Trout Scientific Committee 1994), but with the construction of 4 dams between 1902 and 1952, upstream movement has been largely eliminated. Because fluvial bull trout populations in the Clark Fork drainage are small and uncommon (Peters 1985), transporting fish above dams may significantly enhance spawning populations. To evaluate the effectiveness of this action, bull trout were transported over a dam and radio-telemetry used to detect spawning and return movements downstream of the dam.

Study Area

Milltown Dam, constructed in 1907, is located at the confluence of the Clark Fork and Blackfoot Rivers (Figure 12). It is a five-turbine hydroelectric facility that annually produces 1399 KWH/hour. Annual discharge at the dam averages $86 \text{ m}^3/\text{s}$, approximately 50% of which is contributed by the Blackfoot River. It operates as a run-of-the-river dam, with a 6 ha storage reservoir and a vertical spillway drop of 12 m.

The fluvial bull trout transported in this study may have originated from above or below the Milltown Dam. Because other dams on the lower Clark Fork River block upstream passage, fluvial populations below the Milltown Dam could have originated only from Fish Creek or Ninemile Creek. Above the dam, populations rear in tributaries to Rock Creek and the Blackfoot River. Because origins of fish were unknown, I considered the study area to be the entire $57,740 \text{ km}^2$ Clark Fork River drainage (Figure 12). Welcome Creek, a tributary to lower Rock Creek, is a second-order stream with an estimated summer low-flow of $0.08 \text{ m}^3/\text{s}$.

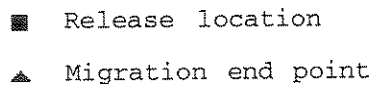


Figure 12. The upper Clark Fork River drainage, showing locations bull trout were released and destination of two fish migrating to Rock Creek.

The Middle Fork of Rock Creek is a third-order stream with an estimated summer discharge of $0.54 \text{ m}^3/\text{s}$. Summer temperatures in both streams are cold and neither stream has received much human-caused disturbance.

Methods

Five bull trout were captured in the spillway pool below Milltown Dam by hook and line or electroshocking during May 9-25, 1994. After capture, fish were anesthetized (150 mg/L tricane methanosulphate, MS-222), length and weight noted, and transmitters surgically implanted. A description of the surgical procedure is given in the appendix of this thesis. Surgeries lasted an average of 7 minutes (range: 5 - 14), during which time gills were bathed with diluted MS-222 to maintain unconsciousness. After surgery, fish were transported to the lower Blackfoot River, 200 m above Milltown Dam (Figure 12). Locations of fish were determined from the ground using radial truck-top and 3-element Yagi antennas. During periods of upriver migration, monthly flights were conducted 100-200 m above the river at 100 km/h with a 3-element Yagi antenna attached to a wing strut. Transmitters emitted signals at 150 MHz, weighed 16.1 g and did not exceed 2% of fish weight (Winter 1983). Fish were relocated at least once a month from May 9, 1994 to April 15, 1995.

Results

Bull trout receiving transmitters ranged in length from 378 to 725 mm (Table 3). Transmitters were active for $262 \pm 247 \text{ d}$ (mean \pm SD, Table 3). One transmitter was recovered from a carcass (fish a) 10 km

Table 3. Summary of bull trout sizes and telemetry data. For capture method, HL = hook-and-line and ES = electroshock.

Fish	Length (mm)	Weight (g)	Date Captured	Capture Method	Days Tracked	Number of Contacts	Destination
a	378	500	16-May	HL	30	8	Mdl Fk Rock Creek
b	505	1240	18-May	HL	146	11	Welcome Creek
c	508	1080	9-May	HL	236	15	over Milltown Dam
d	642	3015	25-May	ES	220	30	over Milltown Dam
e	725	4876	25-May	ES	680	4	over Milltown Dam

below Milltown Dam in a water diversion canal 30 d after implanting. The death of this bull trout was likely due to a deeply swallowed hook remaining in the fish from our capture effort. High temperatures in the irrigation canal may have contributed to its mortality, although it is possible the fish was dead before entering the canal.

Two bull trout (fish b and c) moved immediately after release into Rock Creek. One of these migrated 40 km in 23 d, entering Welcome Creek on approximately July 17 (Figure 12). This fish dropped its transmitter sometime after August 4, so I do not know if it spawned or died. The second bull trout migrated 130 km in 78 d, entering the Middle Fork of Rock Creek on July 26 (Figure 12). This fish was last located two weeks before spawning in a documented spawning area; it likely spawned.

The fourth bull trout (fish d), which moved downstream of Milltown Dam on June 8, descended 10 km to the Rattlesnake Creek confluence (Figure 1). After 65 d at this location, it wandered for 11 d. During this time, 5 km of the Clark Fork were ascended, descended, and 3 km of Rattlesnake Creek ascended. After <3 d in Rattlesnake Creek, 10 km of the Clark Fork were ascended to the base of Milltown Dam, where the fish remained for 38 d before again descending to the vicinity of Rattlesnake Creek on October 20.

A fifth bull trout (fish e) was contacted above Milltown Dam three times after release. After June 3, 1994 I lost contact with this fish for 2 years, although during this period much of the study area was searched from a plane. On April 10, 1996 it reappeared beneath the dam. Evidently it too moved downstream of the dam, perhaps to a deep pool

where the transmitter signal attenuated before reaching the water surface.

Discussion

Conclusions from a sample size of five must be conservative. The number of fish tracked is, unfortunately, a reflection of the population density of bull trout in the Clark Fork River. Nevertheless, implications exist for managing the passage of bull trout at dams.

Two of the five bull trout moved over Milltown Dam entered spawning tributaries, and I assume at least one spawned. Although uncertain, it is assumed these fish homed because bull trout are thought to have strong fidelity to natal streams (Goetz 1989). No fluvial bull trout have previously been observed in Welcome Creek, although they have been seen in similarly sized tributaries to Rock Creek (Don Peters, MDFWP, pers. comm.). Due to the small size of this stream, the number of bull trout in it is probably small. If the fish entering this stream spawned, it significantly contributed to the population. In contrast, the Middle Fork of Rock Creek supports the largest concentration of redds in the Rock Creek drainage (approximately 20/year; Deerlodge National Forest, unpublished data). The movements of these two bull trout indicate that transport above Milltown Dam enhances populations. Fernet and O'Neil (in press) noted similar success of bull trout moved over a newly constructed dam in Alberta, Canada.

Downstream movement of fish immediately after surgical implantation of transmitters is known to occur (Winter 1983). Because bull trout were released only 200 m above Milltown Dam, this may explain

why three returned downstream. To reduce fallback in the future, transported fish should be released further upriver from the dam. It appears the two surviving fish below the dam later attempted to re-ascend, indicating their presence there was not volitional.

Transporting fish above dams is labor intensive (Cada and Sale 1993). However, the small number of bull trout likely to be encountered in the Clark Fork River makes the effort feasible and economically the most practical alternative for fish passage. Although transport benefits above-dam populations, the recent detection of Whirling Disease below Milltown Dam complicates matters. To prevent spread of the parasite to unaffected areas, transport will no longer occur. This paradoxical situation illustrates both the beneficial and detrimental effects that dams can have on fish populations.

Appendix A

Effects of Intraperitoneal Transmitters
on Social Interaction of Rainbow Trout

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Abstract

The recent reduction in size of intraperitoneal transmitters has allowed detailed research of the movement and habitat use of small (<30 cm) salmonids. Because these aspects of behavior are in part socially determined, study methods that influence dominance contests or agonism may bias results. We studied the effect of intraperitoneal transmitters on the social interaction of rainbow trout *Oncorhynchus mykiss*. Dominant fish with dummy transmitters retained their rank and showed no difference from control fish in amounts of agonism and time interacting with subdominant fish. Based on these results we do not believe that transmitters alter socially determined use of microhabitat and movement patterns.

Introduction

Intraperitoneal transmitters have been used to study fish behavior for four decades (Trefethen 1956). An assumption of these studies is that subjects act normally (Winter 1983). For many aspects of behavior this assumption has been tested (e.g., swimming performance, McCleave and Stred 1975; buoyancy, Gallepp and Magnuson 1972; feeding and growth rates, Armstrong and Rawlings 1993; maturation, Moore et al. 1990). However, little research has been conducted on effects of transmitters on social interaction (but see Young et al. 1972, Mellas and Haynes 1985).

Stream-dwelling salmonids segregate use of habitat according to social rank, with dominant individuals occupying optimal positions (Fausch and White 1981, Nakano 1995). Subdominant fish may move more often within habitat units (Nielsen 1992) or within stream reaches (Chapman 1962). Social rank in salmonids is determined by body size and aggressiveness (Holtby et al. 1993).

With miniaturized transmitters, use of radio-telemetry to study the habitat use and movement patterns of stream-dwelling salmonids is increasing (e.g., Chisholm et al. 1987, Meyers et al. 1992, Gowan et al. 1994, Matthews 1995). Stress induced by an intraperitoneal transmitter may decrease aggression, resulting in a decreased ability to compete in a dominance hierarchy. This decrease in ability may lower rank, thereby changing use of habitat or patterns of movement, and provide biased results in telemetry studies. We tested the assumption that intraperitoneal transmitters do not affect position in a dominance

hierarchy by observing the ability of dominant rainbow trout *Oncorhynchus mykiss* to retain their rank after receiving transmitters, and by comparing the amount of agonism exhibited by dominant fish before and after inserting transmitters.

Methods

Experimental Procedures

Hatchery-reared age 1 rainbow trout (240-290 mm FL) were paired such that lengths did not differ more than 3 mm, and placed in one of four 1.5 m diameter circular tanks. Tanks were without habitat features and had flow-through water velocities <0.1 m/s. The intention of equal-sized pairings was to create contests for dominance that were not won by size, but by behavioral qualities (i.e., aggressiveness) that might be affected by transmitters. Liquid nitrogen brands (Turner et al. 1974) on the left or right flank were used to distinguish paired individuals.

The fish in each pair that nipped and chased the most was considered dominant. Agonistic interactions were defined as follows; chase: a burst of swimming greater than one body length in distance that displaced the recipient from a spot it had previously occupied; nip: a biting motion that contacted, or almost contacted, the recipient. Fish were considered to be interacting if they were separated by less than one body length.

Six trials were conducted. For each trial, two tanks were randomly chosen as controls and two as treatment. Dummy transmitters were surgically placed in anaesthetized, dominant fish of treatment tanks. Neither fish in control tanks received transmitters. To control

for effects of the anesthesia, all fish not receiving transmitters were also anaesthetized.

Trials lasted 7 days. Pairs were given 2 days to establish rank before observations began. Pre-surgery observations were made on days 3 and 4, transmitters were implanted on the afternoon of day 4 (for dominant fish in treatment groups), and post-surgery observations were made on days 5, 6, and 7. Observation periods began at 0800, with each tank being observed for 30 minutes. During observations the number of chases and nips given by each fish, and the amount of time fish interacted were recorded. Trials were conducted from October 20 to December 9, 1995. Mean water temperature during this time was $16.5 \pm 0.6^{\circ}\text{C}$.

Inserting transmitters

Anesthetized fish (60 mg/L tricane methanosulphate, MS-222) were placed on their dorsum in a V-shaped operating table. A description of the surgical procedure is provided in Chapter I of this thesis. Surgeries lasted 7 ± 4 min, during which time gills were bathed with diluted MS-222 to maintain unconsciousness. After surgery and recovery from the anesthesia, fish were returned to their tanks. Dummy transmitters weighed 2.6 g in air and did not exceed 2% of fish weight (Winter 1983).

Analysis of Data

For each pair, the mean number of nips and chases given by the dominant fish and the mean amount of time fish interacted were calculated for pre-surgery (days 3 and 4) and post-surgery (days 5, 6,

and 7) observations. The differences between pre- and post-surgery values were then averaged for control ($N = 8$ pairs) and treatment ($N = 11$ pairs) groups. The null hypotheses that mean differences in the number of nips, chases, and time spent interacting were equal for treatment and control groups were evaluated with t-tests. Data were normal (Shapiro-Wilkes test, $P > 0.05$) and homoscedastic (Levene, $P > 0.05$).

Results and Discussion

All pairs established rank within 30 minutes of placement in tanks. With one exception, only dominant fish were observed to nip or chase. We observed no treatment pairs to switch rank after transmitters were placed in the dominant fish. Lack of such an effect has been noted before. Mellas and Haynes (1985) observed rainbow trout and Young et al. (1972) observed brown trout *Salmo trutta* to maintain dominant ranks after receiving transmitters. These researchers, however, did not quantify changes in agonism shown by dominant fish after receiving transmitters.

The mean amount of agonism (nips and chases) observed in treatment tanks differed little before and after transmitters were placed in dominant fish, although the amount of time paired fish interacted decreased slightly (Table 4). Although insignificant, control tanks showed greater mean amounts of agonism for observations made on days 3 and 4 than on days 5, 6, and 7; the amount of time paired fish interacted did not change (Table 4). These decreases in agonism likely resulted from the establishment of rank over the 7 days of the trial.

Table 4. Means \pm SD of agonistic interactions and minutes interacting during 30 min pre- and post-surgery observation periods.

	Treatment (N=11)		Control (N=8)	
	Pre-	Post-	Pre-	Post-
Nips	1.14 \pm 1.60	1.27 \pm 0.947	2.50 \pm 2.55	1.94 \pm 2.77
Chases	5.77 \pm 5.91	5.67 \pm 3.88	10.8 \pm 9.59	7.29 \pm 8.03
Min Interacting	19 \pm 12	15 \pm 9	16 \pm 10	16 \pm 7

We found no difference between control and treatment groups in the change in the number of nips ($P = 0.48$), chases ($P = 0.29$), or time spent interacting ($P = 0.25$, Figure 13). The similar behavior between groups indicates that transmitters do not affect the ability of dominant fish to maintain their rank, and implies that socially determined use of microhabitat and movement patterns are unaltered. This finding partially validates studies that use precise locations of fish with implanted transmitters to describe microhabitat selection (Chisholm et al. 1987, Meyers et al. 1992, Gowan et al. 1994, Matthews 1995). It is particularly applicable to studies on small (<300 mm), stream-dwelling salmonids that aggressively form social hierarchies.

While we examined only the acute effects of intraperitoneal transmitters on social interaction, long-term effects could exist. Carrying a transmitter may slow growth rate, thereby influencing dominance contests. Lucas (1989), however, found no size difference in rainbow trout with and without transmitters held in a laboratory environment for 7 months. Atrophied fins have been observed in Arctic grayling (*Thymallus arcticus*) carrying transmitters for >1 year (Brian Lubinski, Alaska Fish and Game, pers. comm.). In a species with highly deterministic social rank (Hughes 1992), such a long-term effect may alter social interactions.

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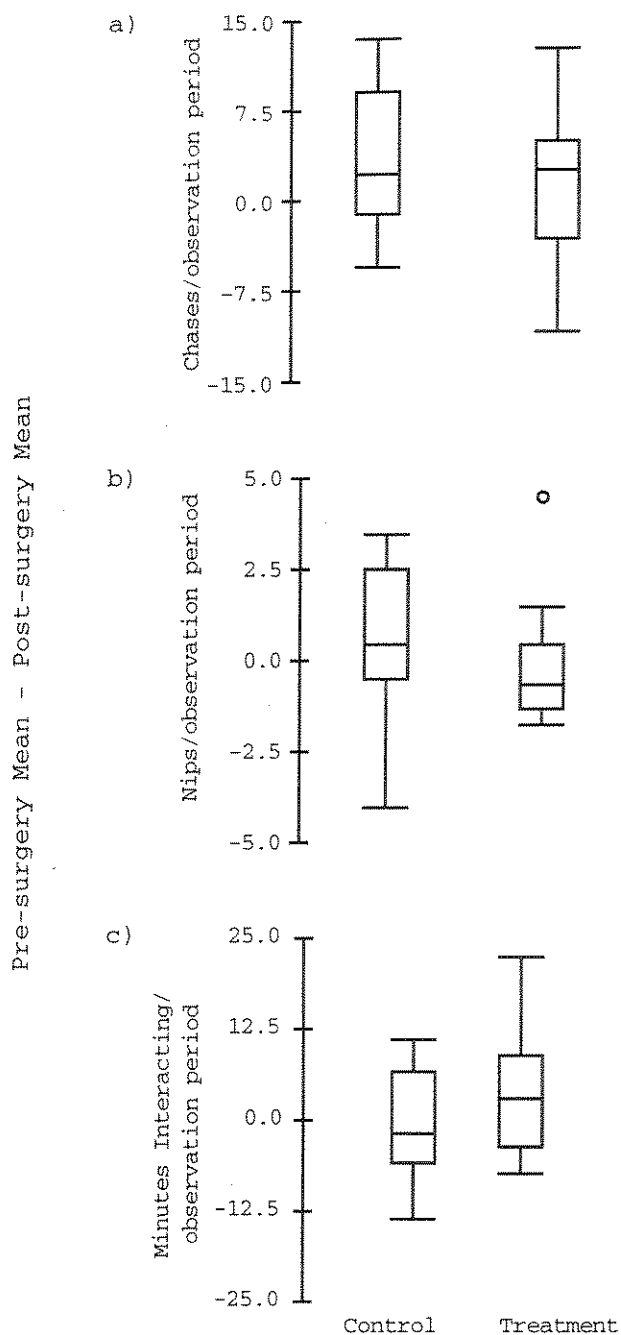


Figure 13. Mean differences (pre-surgery mean - post-surgery mean) for number of chases (a), number of nips (b), and minutes interacting (c) for control and treatment groups. Middle bars in boxes represent median values, top and bottom bars of box 75th and 25th percentiles, outer-most bars 95th and 5th percentiles, and the circle an outlying datum.

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