Spawning Ecology of Redband Trout in Basin Creek, Montana

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Introduction

The redband trout of the Columbia River basin ***Oncorhynchus mykiss gairdneri*** are a subspecies of the rainbow trout evolutionary line ***Oncorhynchus mykiss*** and is native to the Fraser and Columbia River drainages east of the Cascade Mountains to barrier falls on the Pend Oreille, Spokane, Snake and Kootenai rivers (Allendorf et al. 1980; Behnke 1992). A complex combination of anthropogenic influences (logging, mining, agriculture, grazing, dams), hybridization, and competition with non-native fishes have contributed to the decline of redband trout abundance, distribution and genetic diversity in the Columbia River basin (Williams et al. 1989; Behnke 1992). Consequently, many redband trout populations are restricted to headwater streams.

Redband trout in the Kootenai River drainage represent the furthest inland penetration of native rainbow trout in the Columbia River drainage. Based on genetic analysis, we have identified populations of redband trout in Callahan Creek, East Fork Yaak River and its tributaries, Yaak River (below Yaak Falls), North Fork Yaak River and tributaries to Libby Creek and Fisher River, all in the Kootenai River drainage (Allendorf et al. 1980; Leary et al. 1991; Huston 1995; Hensler et al. 1996). Results from genetic surveys indicate that redband trout may have been native to low-gradient valley-bottom streams throughout the Kootenai River drainage; currently they appear to be restricted to headwater areas. Allendorf et al. (1980) concluded that redband trout are native rainbow troutin the Kootenai River, Montana, and that "...planting of hatchery rainbow trout has created a situation of tremendous genetic divergence (hybridization) among local populations".

Montana Fish, Wildlife and Parks (MFWP) and Kootenai National Forest (KNF) raised concerns that the Kootenai River Basin redband trout population was at risk of extinction due to habitat fragmentation, stream habitat degradation, competition with non-native species and hybridization with non-native rainbow trout (Perkinson 1993; Hensler et al. 1996). In response to these concerns, state and federal agencies classified redband trout as a sensitive species or a species of special concern. In 1994, the Kootenai River redband trout population in Montana was petitioned for listing as a threatened species under the Endangered Species Act. The petition was dismissed due to lack of information to classify them as a unique or separate species.

No information exists concerning the spawning requirements of isolated populations of redband trout in the upper Columbia River Basin in Montana. Identification of the temporal and spatial distribution of redband trout during spawning will help provide watershed managers with appropriate information to develop biologically sound and effective conservation strategies. These strategies might be used to improve and protect critical habitat.

In this study, we evaluated movement, distribution and habitat selection by redband trout during spring and summer 1998. Additionally, a portion of this project is part of a larger statewide study to "...Determine the spawning life history of this strain of rainbow trout [redband trout] with emphasis on spatial and thermal requirement. Determine if this strain has either some life history attributes or WD (whirling disease) resistance which may be utilized in solutions to whirling disease in other Montana streams where rainbow trout are present" (MFWP, unpublished 1999). The objectives of this study were to (1) quantify redband trout spawning production and characterize habitat selection in Basin Creek, Montana; (2) determine the role of temperature in spawning, egg incubation and emergence for redband trout; (3) describe the movement, distribution and habitat use by post-spawned adult redband trout in Basin Creek, Montana.

Study Area

Basin Creek originates in the north slopes of the Purcell Mountains and flows south to north approximately 29.5 km to the confluence with East Fork of the Yaak River, approximately 45 km east of Yaak, Montana. This drainage includes East Fork Yaak River, Basin Creek, West Fork Basin Creek, mainstem Basin Creek and Porcupine Creek (Figure 1). The drainage mostly flows through national forest (Kootenai National Forest) and a privately owned parcel along mainstem Basin Creek. Annual precipitation ranges from 63.5 cm to 142 cm (U.S. Forest Service, Three Rivers Ranger District, Troy, MT; unpublished data). Elevation ranges from 976 m at the confluence of East Fork Yaak River to 2,095 m at the Purcell Divide.

The underlying bedrock is mostly from the Precambrian sediments of the Belt Supergroup (U.S. Forest Service, Three Rivers Ranger District, Troy, MT; unpublished data). The soil material is derived from alpine and continental glaciation, glacio-fluvial deposits, and residual material (U.S. Forest Service, Three Rivers Ranger District, Troy, MT; unpublished data). Most of this drainage supports mixed conifer stands dominated by western larch, Douglas fir, lodgepole pine and ponderosa pine. The drainage has been intensively managed for timber production.

Redband trout are the only trout species found in the Basin Creek drainage (Muhlfeld, 1999). We identified a barrier falls approximately 3.6 km upstream from the confluence with the North Fork Yaak River. We suspect this barrier is an isolating mechanism that prevents genetic exchange with other trout in the Yaak River system.

Methods

Spawning and Incubation Surveys

We conducted spawning surveys in mainstem Basin Creek to quantify redband trout spawning production and characterize redd site habitat selection during May and June 1998 (Figure 1). One or two observers walked along the streambank, mapping fish locations and redd sites one to three times per week. To quantify the

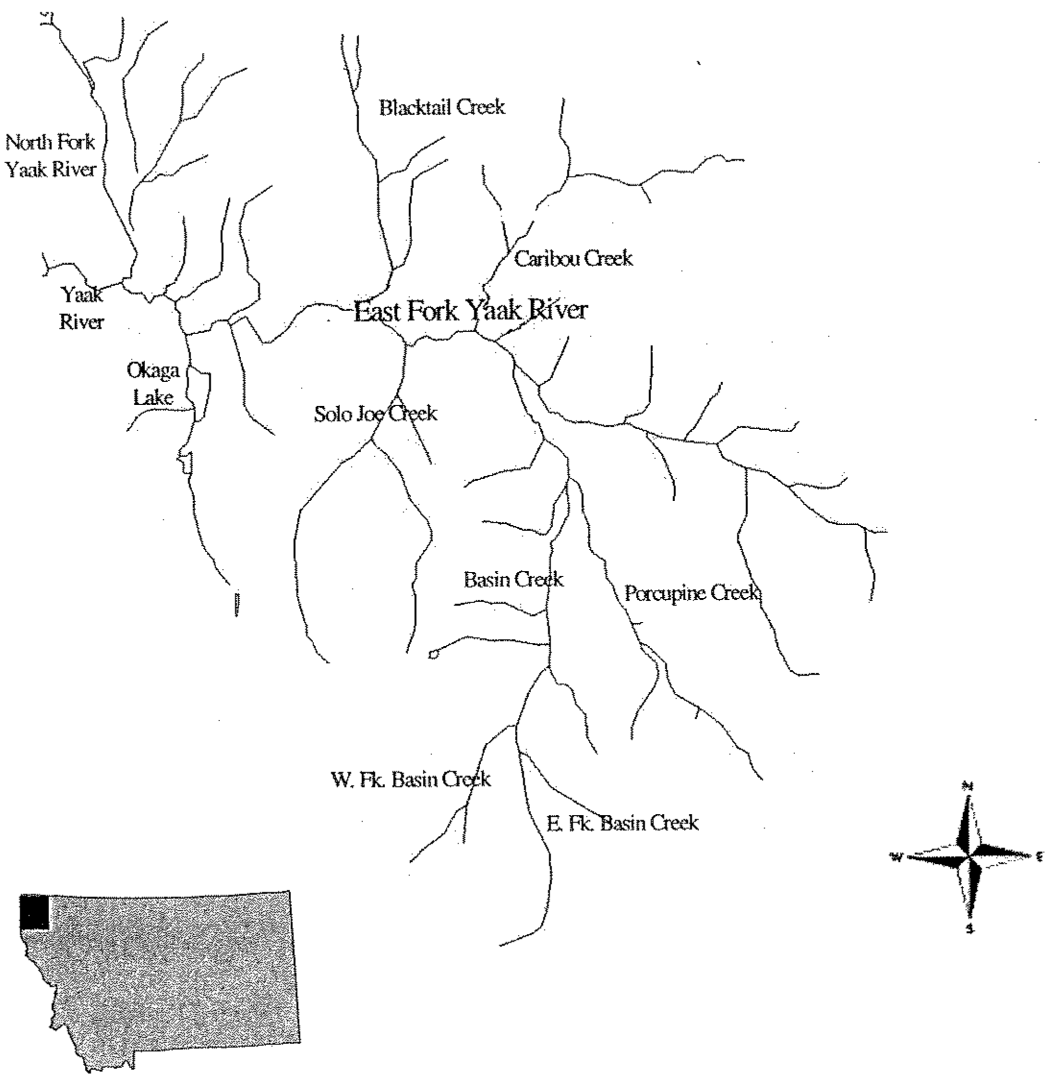

Figure 1. Study area of East Fork Yaak River drainage, Montana.

physical characteristics at each redd site we recorded the length (m), width (m), total depth (m), mean water column velocity (m/s), and substrate composition. We measured physical characteristics (length, width and depth) with a meter stick (to the nearest 0.01 m) and measured velocity with a Swoffer model 2100 electronic flowmeter attached to a wading rod. We used a modified Wentworth scale to determine a weighted substrate score for each redd (Table 1).

Table 1. Rankings for substrate types used for scoring redd material.

Rank	Substrate Diameter	Description
1	Less than 0.2 cm	Sand-silt
2	0.2 cm – 0.6 cm	Small gravel
3	0.6 cm – 7.5 cm	Large gravel
4	7.5 cm – 30.0 cm	Cobble
5	30.0 cm – 60.0 cm	Small boulder
6	Greater than 60.0 cm	Large boulder
7		Bed rock

Habitat units that spanned the entire channel width were classified either as pool, riffle, run or channel braid (Bisson et al. 1982). We recorded hourly temperatures with Orion Hobo and Tidbit temperature data loggers in mainstem Basin Creek, Porcupine Creek and East Fork Yaak River during the study period. We measured stream discharge at the USGS station on mainstem Basin Creek.

To quantify habitat availability throughout the spawning reach, we used a systematic transect survey. We defined the spawning reach as the furthest redd site found upstream of the confluence of East Fork Yaak River and Basin Creek to the mouth of Porcupine Creek. We established transects perpendicular to the stream at 50 m intervals throughout the section of stream beginning with a random start point and measured physical characteristics (depth, mean velocity and dominant substrate type) at 10 equally spaced locations across each transect.

We used Mann-Whitney U tests to determine if physical characteristics of depth and velocity used by redband trout for redd sites were significantly different than random availability (Zar 1996). To assess if trout used substrate in proportion to its availability we used a chi-square goodness of fit test (Neu et al. 1971) and considered significance at the $P<0.05$ level for all statistical analyses.

As part of the spawning survey we noted fry emergence times in Basin Creek. We captured and manually spawned redband trout (four females, five males) from Porcupine Creek (Figure 1). From the crosses we fertilized approximately 400 eggs. We transported the eggs to the MFWP whirling disease facility in Pony, Montana. We used incubation, hatching and yolk sac absorption times in daily temperature units (equal to one degree Fahrenheit {°F} above 32 °F for a 24-hour period [Piper et al. 1982]) to estimate incubation and hatching times for trout in Basin Creek.

Telemetry Project

We used radio telemetry to monitor movement and habitat use by post-spawned redband trout in Basin Creek. We captured seven post-spawn adult fish by hook and line; 4 (mean total length = 224 mm, range 228-285 mm) on 17 June and 3 (mean total length = 253, range: 245-299 mm) between 19 June 19 and 26 June (Table 4). For the original study, we monitored redband trout movement from 22June to 24 September, 1998 and additional movement in winter and spring 1999.

We anesthetized each fish with a 400 mg/L solution of tricaine methane sulfonate (MS-222) then placed it in a padded V-shaped trough and irrigated its gills with a 200 mg/l solution of MS-222 during surgery. We made an incision immediately anterior of the pelvic girdle and to the side (3 mm) of the mid-ventral line (Young, 1995), inserted a sterilized transmitter into the body cavity and extended the whip antenna through the side of the body wall. Finally, we closed each incision with two to three sutures.

To ensure proper recovery, prior to their release we placed post-surgery fish in live traps along the stream margin for approximately 12 hours (Winter 1983). Transmitters weighed 7.0 g in air and had a predicted life expectancy of 1 year (Advanced Telemetry Systems [ATI], Isante, Minn., model 10-28). Each tag emitted a unique frequency (56 pulses/minute) in the range of 48.131- 48.260 MHZ for 112 hours (7 days on/16 hours on/8 hours off and 7 days off) to maximize the longevity of the tag.

Large redband trout ($\geq$200g) were difficult to capture during June, 1998. Consequently, some transmitters exceeded the recommended 2% transmitter to body weight ratio as suggested by Winter (1983). However, we felt that it was unlikely that swimming performance was substantially altered. Brown et al. (in-press) demonstrated that swimming performance of interperitonealy implanted juvenile rainbow trout was not significantly altered by the presence of the tag or the effects of the operation even though the transmitter comprised 6-12% of the fish's weight. The authors suggested that the 'two percent rule' could be replaced by an index that incorporates the weight of the transmitter in water and volume of the tag.

We tracked fish during the daytime with a Lotek (model SRX 400) scanning receiver equipped with an ATS loop antenna. We started at vehicle access points along the stream. Once we detected a signal we walked along the stream bank and replaced the loop antenna with a stripped coaxial cable antenna to obtain more accurate locations. We found that our accuracy was within 1 m of the transmitter. Therefore, we assumed the habitat used was within a 1 m^2 area of the identified location. Additionally, we used fixed wing aerial telemetry to survey remote and inaccessible areas throughout the East Fork Yaak River drainage.

We obtained primary habitat data (i.e. habitat units which spanned the entire channel) at each fish location and classified habitat as either a pool, riffle, run, or channel braid (Bisson et al. 1982). To quantify individual fish movements we measured the distance from the previous location to the new location along the stream bank with a measuring tape or from stream survey information collected during July 1998 (Muhlfeld 1999). We determined that individual movement was the linear distance moved between locations and total movement was the sum of all movements for the duration of the study.

Results and Discussion

Spawning Surveys

Our survey in mainstem Basin Creek during May and June 1998 revealed that redband trout selected spawning sites in low-gradient reaches downstream from the mouth of Porcupine Creek to approximately 1,875 m upstream of the confluence of Basin Creek and East Fork Yaak River (Figure 1). Total length of the spawning section was approximately 1,475 m. Stream gradient ranged from 0.5 to 1.5%. Mean daily stream temperatures ranged from 37° - 46.5° F during May and June (Figure 2). Stream discharge declined from 132 ft^3/s on May 2 to 48 ft^3/s on June 27 (Figure 3). We did not collect discharge measurements from May 7 - June 1, although a flood event that exceeded bank full width occurred from May 10-12; discharge was approximately 310 ft^3/s.

Spawning behavior (e.g. pairing and redd construction) coincided with a sharp decline in spring runoff and gradual increase in water temperature (Figure 3). Fish began to pair on June 2 when average daily water temperature was 42° F (high = 44.1° F, low = 41.6° F) and stream discharge was approximately 130 ft^3/s (Figure 2). We observed redband trout building redds from June 13 through June 24 (Figure 2). During the redd construction period stream discharge generally declined and ranged between 70- 58 ft^3/s and mean water temperatures ranged from 44° F- 46° F (hi = 48.0, low = 41.6).

We identified 30 redds in Basin Creek during June 1998 (Table 2). For each of three variables (depth, velocity, substrate) we obtained 230 random habitat availability measurements (Table 2). Mean total depth (m) of redds was 0.28 (range: 0.20-0.46), mean water column velocity (m/s) at redds was 0.50 (range: 0.23-0.69) and mean substrate score was 2.1 (range: 1.95-2.25; Table 2).

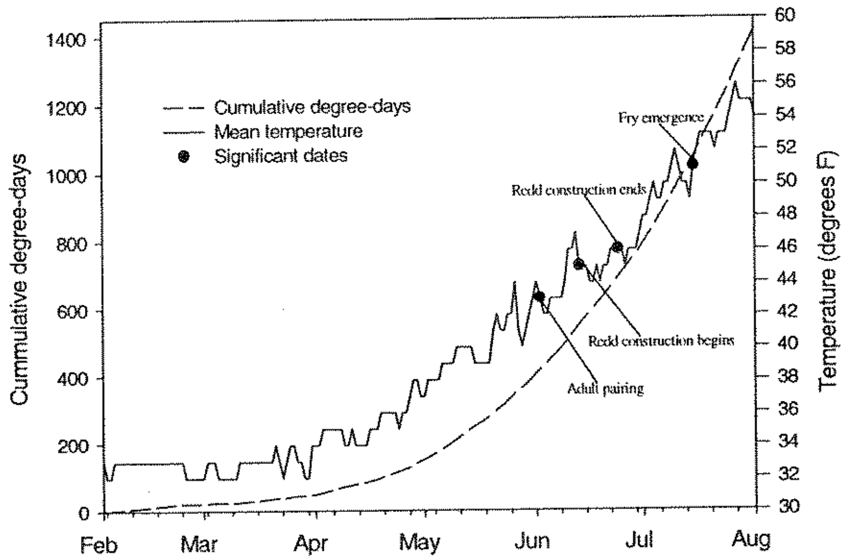

Figure 2. Cumulative degree-days and mean temperature associated with major spawning events

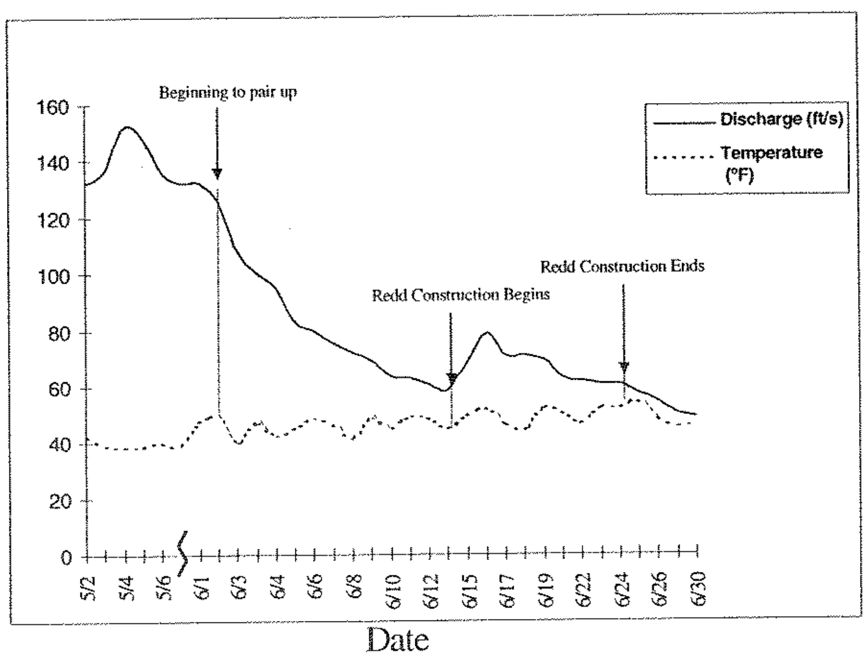

Figure 3. Temperature (°F) and stream discharge (ft^3/s) as related to the timing of spawning by redband trout during spring (May-June) in Basin Creek, Montana 1998.

Redband trout used significantly shallower water for redd sites than the mean depths available (Z= 2.89, P = 0.004). This indicated that redband trout selected spawning locations in lateral areas of the channel and pool tail-outs. We found 24 redds in pools (all in the tail-out section), four in runs (usually on a gravel bar or on the inside bend), one in a small channel braid, and one in a riffle. Redband trout used significantly different substrate than the mean available substrate (P < 0.05) and

Table 2. Descriptive statistics for spawning habitat characteristics available to and used by redband trout in Basin Creek, Montana during spring 1998.

						95% Confidence Interval for Mean					
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Min	Max	Z or X^2	P-value
Depth	*Use*	30	.2763	7.125E-02	1.301E-02	.2497	.3029	.20	.46		
	Available	230	.3788	.1968	1.297E-02	.3533	.4044	.05	1.07		
	Total	260	.3670	.1894	1.175E-02	.3439	.3901	.05	1.07	2.89	.004
Velocity	*Use*	28	.5018	.1140	2.155E-02	.4576	.5460	.23	.69		
	Available	230	.5187	.3401	2.243E-02	.4745	.5629	.00	1.65		
	Total	258	.5169	.3232	2.012E-02	.4772	.5565	.00	1.65	0.23	.819
Substrate	*Use*	30	2.0667	7.581E-02	1.384E-02	2.0384	2.0950	1.95	2.25	9.5	<0.05
	Available	230	2.6609	1.0397	6.856E-02	2.5258	2.7960	1.00	5.00		
	Total	260	2.5923	.9963	6.179E-02	2.4706	2.7140	1.00	5.00		

selected redd sites dominated by gravel substrate (Table 2; Figure 4). There was no significant difference between use of mean water column velocities and random velocities (Z = 0.23, P = 0.82). This indicates that redband trout built redds in areas where water velocity was close to the mean velocity, probably to maintain optimal positions in moderate to shallow water (0.2-0.45 m) dominated by gravel substrate.

Redd site selection in Basin Creek appears to depend on a combination of abiotic and biotic factors. Redband trout generally selected redd sites in shallow pool tail-out areas with moderate water velocities dominated by gravel substrates. Water temperature, dissolved oxygen, water velocity and gravel permeability are critical factors necessary for successful incubation of rainbow trout embryos (Raleigh et al. 1984). Redband trout selected shallow pool tail-out areas for spawning that were likely areas of upwelling. These areas of upwelling aid in embryo development by removing waste products and providing adequate dissolved oxygen.

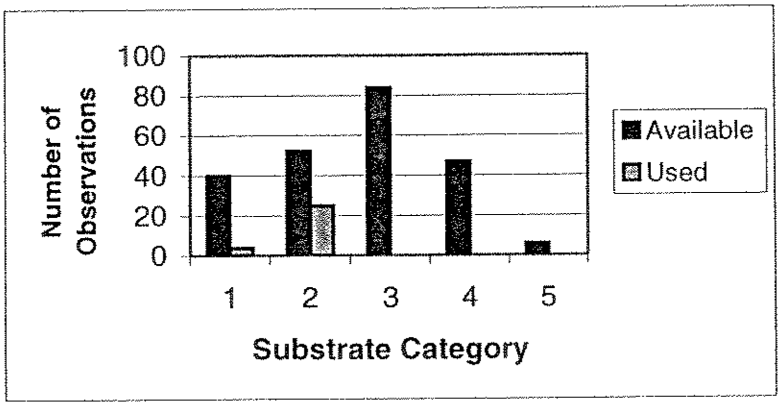

Figure 4. Number of observations in each substrate category used for redd sites and available to redband trout in the mainstem Basin Creek during June 1998.

Redband trout likely selected gravel spawning substrate that was proportional to body size. Redband trout that spawned in mainstem Basin Creek were 15-30 cm in total length and strongly selected gravel dominated substrate. Raleigh et al. (1984) reported that rainbow trout <50 cm select substrate from 1.5 to 6.0 cm in diameter.

Suitable spawning habitat in mainstem Basin Creek appears to be associated with low-gradient (<1.5%) stream reaches that contain abundant pools dominated by gravel substrate. Other studies have shown a positive correlation between density of trout and abundance of spawning gravel in low-gradient streams (Lanka et al. 1987; Bozek and Rahel 1991). Muhlfeld (1999) found the highest densities of redband trout in Basin Creek and Callahan Creek, Montana were in low-gradient stream reaches with abundant pools. Low-gradient reaches with abundant pools may provide areas of extensive cover, low-velocities and complex water depths, and may also provide optimal spawning habitat for redband trout production and distribution.

We sent 400 redband trout eggs to the whirling disease testing facility in Pony, Montana to analyze egg development stages. We compared those developmental stages to egg development from strains of rainbow trout used in the MFWP hatchery system and found in the wild (Dick Vincent MFWP, unpublished 1999). The developmental stages for redband trout were considerably more advanced than the rainbow strains (Table 3). This could be important for resistance to whirling disease. Development of redband fry to at least partial ossification of cartilaginous structures might occur before *Myxobolus cerebralis* becomes infectious (Dick Vincent, personal communication). If this occurs, redband trout may be more resistant to *Myxobolus cerebralis* than rainbow trout currently in the MFWP hatchery system or wild progeny of the coastal rainbow trout heritage.

Table 3. Developmental degree-day data for several trout species/strains.

Species/Strain	Fertilization to Eye Stage	Eye stage to hatching	Hatching to Yolk Sac Absorption [3]	Total Degree-Days
DeSmet Rainbow Trout	360	280	120	760
Eagle Lake Rainbow Trout	360	280	120	760
Little Prickly Pear Creek trout	320	325	120	765
Gallatin River II Rainbow Trout	304	323	120	747
Firehole River Rainbow Trout	383	256	120	759
Hell Roaring Creek Rainbow Trout	361	249	120	730
Gallatin River III Rainbow Trout	361	249	120	730
Boulder River Rainbow Trout	323	286	120	729
Gallatin River I Rainbow Trout	302	306	120	728
Freeland Creek Rainbow Trout	305	287	120	712
Kootenai Creek Rainbow Trout	339	230	120	689
Redband trout (Lab)	306	198	120	624
Westslope Cutthroat Trout[1]		310	110-150	420-460
Redband trout (Basin Creek)				351-507 [2]

[1] From Smith et.al., 1983.
[2] We assumed yolk sac absorption and emergence occurred simultaneously.
[3] Yolk sac absorption estimated.

We first observed fry in the spawning reach on 15 July. It took 351 to 507 degree-days for fertilized eggs to develop to fry and fry to emerge from the gravel. Number of degree-days to yolk sac absorption (what we considered emergence) for redband trout eggs sent to the whirling disease station in Pony, Montana was approximately 624 degree-days. This was a considerable discrepancy but not unexpected; bull trout egg development compared between hatchery and wild conditions yielded similar results (Tom Weaver MFWP, personal communication).

Embryonic development of trout is affected by water temperature, concentrations of dissolved oxygen and type of streambed material. Fluctuating water temperatures in the wild setting may cause considerably different (apparently earlier) incubation times and emergence times than the constant temperatures typically found in labs or hatcheries. Nevertheless, the timing of egg development for redband trout was much more similar to westslope cutthroat trout than the rainbow trout strains derived from coastal stocks. Management implications include using redband trout to refound populations affected by ***Myxobolus cerebralis*** and whirling disease. Because of the dramatic differences in incubation timing between hatchery and wild trout, it is imperative that we design further research around timing of wild trout spawning and development of eggs in streams.

Telemetry Study

We tracked five of the seven radio tagged redband trout through 6 May, 1999 (Table 4). Of the seven implanted trout, we lost two to mortality by September. An angler harvested fish #161 in early September and we found fish #171 dead on the stream bank two weeks after release. We removed both fish from the analysis.

All six redband trout were quite mobile during the spring to fall study period (Table 4, Figures 5-6). Five redband trout displayed distinct downstream migrations to other habitat units (mean total movement per fish = 4199 m, range = 1502- 6330 m) and one fish displayed small upstream and downstream migrations from its release location (mean movement = 301 m, range: 5-1031 m).

Table 4. Summary of radio-tagged redband trout monitored in Basin Creek during spring 1998.

Transmitter Frequency	Length (mm)	Weight (g)	Release Date	Date of last location	Total Distance Moved (m)	Number of Relocations	Number of Movements	Final Location
48.131	285	198	6/17/98	5/6/99	1507	8	4	Basin Creek
48.161	230	100	6/17/98	7/21/98	2029	4	4	Harvested. 9/1
48.171	234	100	6/17/98	7/1/98	18	3	1	Found dead 7/21
48.181	228	90	6/17/98	5/6/99	1502	7	3	Basin Creek
48.260	245	112	6/19/98	5/6/99	5110	7	3	East Fork Yaak
48.151	255	124	6/21/98	5/6/99	6025	7	6	East Fork Yaak
48.111	299	180	6/26/98	5/6/99	6330	4	3	East Fork Yaak

Results from the radio-tracking portion of the study indicate that there is a migratory component to the population of redband trout in the upper East Fork Yaak River and Basin Creek drainages (Figure 5). Three of the five downstream migrants displayed long migrations (mean total movement per fish = 5,822 m, range = 5110- 6330 m) from Basin Creek to East Fork Yaak River (above the barrier falls) in early July after spawning was completed and remained through May 5, 1999 (Figure 5). Two fish did not leave Basin Creek, but migrated downstream to lower Basin Creek near the confluence of Basin Creek and East Fork Yaak River (Figure 6).

Our telemetry-based results suggest that redband trout in Basin Creek and East Fork Yaak River (above the barrier falls) may represent a metapopulation of redband trout that includes both resident and fluvial life history forms. Fluvial stocks are known to occupy larger rivers (i.e. East Fork Yaak R.) and spawn in smaller tributaries (i.e. Basin Creek). However, differentiation of redband trout life history forms (anadromous, adfluvial, fluvial, and resident) is difficult using meristic characteristics, coloration patterns, and genetic markers (Behnke 1992).

Prior to this project we could not use morphologic or genetic characteristics to identify life history forms of Columbia River redband trout. We had to delineate distribution of redband trout only to streams that were free of introgressing species. For example, genetic surveys indicate that the Basin Creek contains no

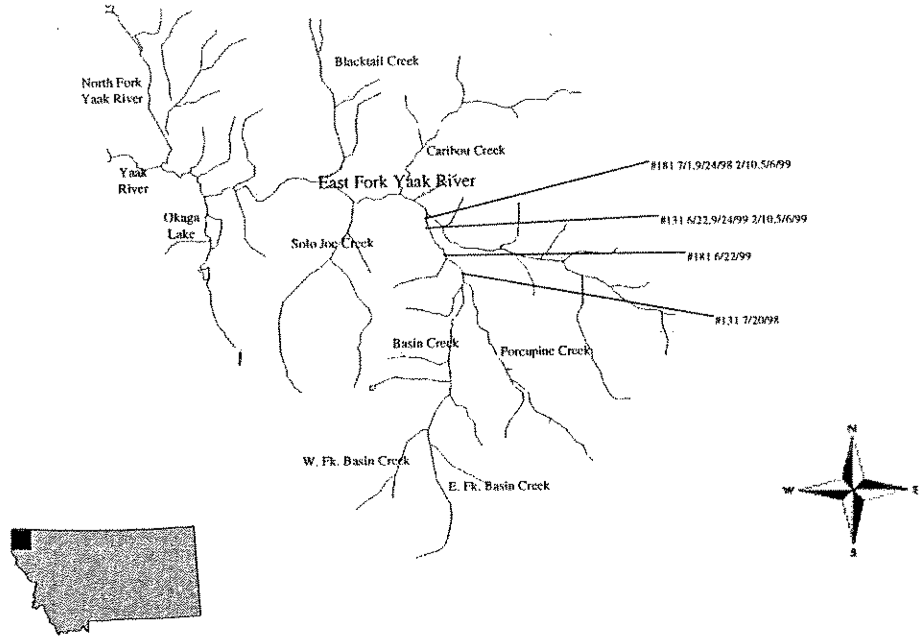

Figure 6. Locations and relocation dates for 2 radio tagged inland rainbow trout in Basin Creek, Montana, 1998-1999.

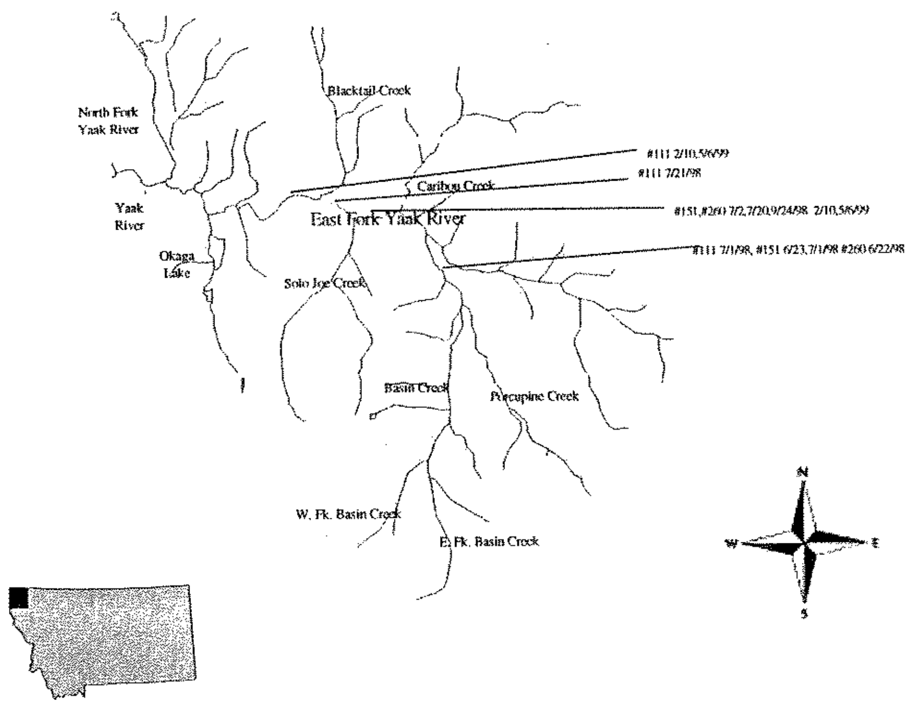

Figure 5. Locations and relocation dates for 3 radio tagged inland rainbow trout in Basin Creek, Montana, 1998-1999.

contaminating species whereas East Fork Yaak River has minor genetic introgression and may not considered an redband trout population (Leary et al. 1991). Radio tracking appears to be the only sampling strategy to identify critical adult life history components within this metapopulation framework.

Our telemetry work also suggested that redband trout used pools more than other habitat types. A total of 21 (81%) of relocations were in pools, 3 (12%) in runs, and 2 (8%) in riffles. In addition, all fish that migrated downstream to East Fork Yaak River after spawning in Basin Creek were consistently relocated (e.g. sedentary) in the same large-deep pools through September and into May, 1999. Trout are known to select pool habitats because they are relatively deep, have low water velocities and contain quality cover.

Results from the telemetry-based study should be viewed with some caution because of our small sample size (Winter 1983). Future researchers should consider increasing the number of individuals concurrently tagged to obtain a more representative sample of the population. Additionally, the life history and migration patterns of juvenile redband trout in this system needs further study. Nonetheless, our study demonstrated that there likely is a fluvial component to the East Fork Yaak River/Basin Creek population of redband trout.

Management considerations

The probability that a local population will persist over time is a function of both habitat quality and proximity to other populations of the same species (Rieman and McIntyre 1995). Maintaining stream connectivity and habitat quality in East Fork Yaak River will likely decrease the probability of a localized extirpation due to catastrophic events, stream habitat degradation, or the threat of genetic introgression. Results from this study suggest that mainstem Basin Creek is an important spawning area for redband trout from East Fork Yaak River and Basin Creek. Verification of a fluvial life-history form of redband trout has never been documented within this geographic area. A fluvial form may be the key component to the persistence of this isolated metapopulation. By determining resident times of juvenile redband trout in Basin Creek, we can more fully verify the existence of the fluvial life history.

Supplementation efforts for westslope cutthroat trout within the historic range of redband trout are being considered by MFWP. However introductions of species to any aquatic habitat requires many considerations because species interactions are complex and difficult to predict (Li and Moyle 1981). Stocking of exotic salmonids (including westslope cutthroat trout) in adjacent drainages may pose a threat to the genetic purity and population persistence of this subspecies (Allendorf et al. 1980). We need more information to determine the historic range of this species in Montana and a quality source for potential refounding of redband trout.

Redband trout in East Fork Yaak River are isolated from downstream hybridized and non-native populations. The natural barrier near Okaga Lake has kept this population free from introgression. Consequently, the East Fork Yaak population is the most likely source for refounding the historic distribution of redband trout in the Yaak River system in Montana. Conservation and management strategies that target the recovery of redband trout should consider the importance of this unique population to the persistence of this native subspecies throughout the Kootenai River drainage, Montana and potentially use it for supplementation efforts throughout the Kootenai River drainage. Additionally, the unique spawning and incubation characteristics of these redband trout may provide opportunities for more creative management in other areas of Montana where coastal rainbow trout are unsuccessful or in peril.

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