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Technical Report for Arrowrock Dam Biological Opinion #1009.0405 OALS #00-912 and Upper Snake River Biological Opinion # 1009.2700

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U.S. Department of the Interior
Bureau of Reclamation

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Interim Summary Report for the Arrowrock Dam Valve Replacement Project

U.S. Bureau of Reclamation, Snake River Area Office - West
230 Collins Road, Boise Idaho

by

Tammy Salow, Fishery Biologist
Lauri Hostettler, Fishery Technician

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Environmental Services Division
Water Treatment Engineering and Research Group
Denver, Colorado

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MOVEMENT AND MORTALITY PATTERNS OF ADULT ADFLUVIAL BULL TROUT (*Salvelinus confluentus)* IN THE BOISE RIVER BASIN, IDAHO

Interim summary report for the Arrowrock Dam valve replacement project

Abstract

Bull trout (*Salvelinus confluentus)* were captured using steel frame picket weir traps and tagged with radio transmitters as part of the monitoring program related to a major reservoir construction project in Southwestern Idaho. Trapping and tagging occurred between the months of August and October in years 2002 and 2003. One hundred three bull trout 327 mm to 730 mm total length were tagged with digitally encoded radio transmitters. Mortality rates were 22.0 % during the 2002 fall migration downstream to Arrowrock Reservoir and 49.0 % during the 2003 fall migration period for adult fish tagged in each year. Larger fish were selected over smaller fish by predators. Two fish (4.0 % of total tagged in 2002) did not leave the South Fork Boise River or Arrowrock Reservoir throughout the spring and summer of 2003. Twenty-four fish (48.0 % of total tagged in 2002) began moving upstream into the Middle and North Fork Boise Rivers during spring and early-summer and nine fish (18% of total tagged in 2002) entered spawning habitat. Six fish were killed or expelled tags post-spawning (12.0% of total tagged in 2002). Seventeen (34.0% of total tagged in 2002) fish overwintered in Arrowrock Reservoir or the South Fork arm of Arrowrock Reservoir and 11 (22.0% of total tagged in 2002) overwintered in the mainstem river of South Fork Boise River downstream from Anderson Ranch Dam. Entrainment through Arrowrock Dam was 4.0 % in 2002 and 11.3 % in 2003 for this group of fish.

Introduction

The Boise River is fragmented by a series of three dams designed to provide hydropower, flood control, water to numerous irrigation companies, and municipal water to the city of Boise and surrounding areas. Two of the three dams, Arrowrock Dam and Anderson Ranch Dam, are owned and operated by the U.S. Bureau of Reclamation (Reclamation). The sub-basins that feed Arrowrock and Anderson Ranch reservoirs support substantial habitat for federally listed bull trout (*Salvelinus confluentus*). Bull trout presence has been recorded throughout the Boise River Basin as well as migration documented in both Arrowrock and Anderson Ranch watersheds (Flatter 2000, Partridge 2000, Rieman and McIntyre 1995, Salow 2001). The U.S. Fish and Wildlife Service has issued two separate Biological Opinions (Opinion) to Reclamation concerning operation of the Boise, Payette, Malheur, and Powder River projects. The first was issued in 1999 and focuses on broad aspects of project operation and maintenance (USFWS 1999). There are three nondiscretionary actions that Reclamation must implement to reduce effects of the water projects on federally listed species as outlined by the 1999 Opinion:

1. Reduce incidence of bull trout entrainment due to reservoir operations
2. Ensure reservoir operations do no result in de-watering of Reclamation projects to the extent that adfluvial bull trout resident there during part of their life history are stressed or killed
3. Investigate methods to provide safe passage around Reclamation dams for bull trout.

A cooperative project between the Boise National Forest and Reclamation was initiated in 1999 to address these measures within the Boise River projects in conjunction with the need to meet forest management requirements.

The second Opinion currently issued for the affected area is related to project-specific effects of the Arrowrock Dam valve rehabilitation that began in 2001 (USFWS 2001). Reclamation proceeded with this construction project which was completed on March 2004, and the possible effects are discussed in the 2001 Final Environmental Impact Statement for the Arrowrock Dam Outlet Works Rehabilitation (USBR 2001). Reasonable and Prudent Measures (RPM) of the 2001 Opinion are specific to this construction project and include (note that RPM # 1 is the same for RPM #2 of the 1999 Opinion and RPM # 2 is the same as RPM # 3 of the 1999 Opinion specifically addressing Arrowrock Dam):

1. Ensure that reservoir operations do not result in de-watering of Arrowrock Reservoir to the extent that adfluvial bull trout present in the reservoir are stressed or killed as a result of the project
2. Investigate methods for safe fish passage around the Arrowrock Dam
3. Initiate a capture and transport program in Lucky Peak Reservoir to mitigate for entrainment that occurs at Arrowrock Dam
4. Complete a water quality monitoring plan for the construction project
5. Form a fish advisory group to advise on responsive actions and to aid in analyzing data collected throughout the project

6. Conduct population estimates prior to and following the construction project
7. Continue radiotelemetry studies in Arrowrock and Lucky Peak reservoirs
8. Continue, as directed by the Fish Advisory Group, to operate weirs on the North and Middle Forks of the Boise River.

The telemetry work described in this report is part of the monitoring effort to collect data on rates of entrainment, migration, dispersal, and impacts of environmental stresses on bull trout populations that overwinter in Arrowrock Reservoir. These data will be used to meet the requirements of the two Biological Opinions issued on the Boise River projects.

In our first year of telemetry work, we found that the duration of upstream migration, overwintering habitat use, and the departure dates from Arrowrock Reservoir varied substantially among individuals. We addressed several questions about animal condition, spawning, and overwintering habitat, especially related to reservoir overwintering habitats that can be controlled by federal operations. The questions we investigated were:

1. Can spawning patterns be predicted by the animal's condition factor or length? Northcote (1992) reviews the concept of food resources playing a major role in migration and habitat utilization and that fish in good condition can maintain themselves in marginal habitats longer than those in poor condition. Additionally, as animals mature, energy will be converted to reproductive processes over growth. Considering this, we hypothesized that older (using length as a function of age) animals in good condition would be more likely to spawn than younger animals or animals in poorer condition.
2. Does the rate of migration or time of reservoir departure depend on the animal's condition factor or length? Mobility is one of the most important characteristics of salmonids that allows them to utilize oligotrophic habitats and refound areas that may have been extirpated due to environmental extremes (Thorpe 1994). Considering that there would be a benefit of infidelity to spawning streams and a drive to investigate new habitats, we hypothesize that older animals in good condition would make a later, more rapid and directed migration while younger, poorer condition animals may be more likely to move slowly, conserving energy and/or testing new habitats as they moved.
3. Do pre-spawning, mature fish move at different rates or leave the reservoir at different times than fish that are not pre-spawning, mature animals? This question relates the first two questions to one another. The hypothesis was that older animals in good condition

(presumably pre-spawning, mature fish) would make a later, more rapid migration while younger, poorer condition animals may be more likely to move slowly, conserving energy and/or testing new habitats as they moved. Alternatively, it may be advantageous to pre-spawning, mature fish to make a later season, more rapid migration as it reduces the time that the animal is exposed to migration risks such as predation and follows peak run-off. Migration during the descending flow curve of peak run-off provides benefits of habitat that requires less energy to use compared to peak run-off yet still providing the water for sufficient habitat and increased turbidity of spring run-off that allows for reduced predation.

4. Is the occupied overwintering habitat related to animal condition, migration rates, duration of migration, or spawning patterns? The null hypothesis is that there is no difference between the habitats used to overwinter and that difference in habitat will affect animal condition, migration rates, and spawning patterns. Thorpe (1994) discusses two spawning strategies used by salmonids in marginal habitats: spring/early summer and fall. The latter infers a higher level of reliance on quality overwintering habitats for fall spawners as resources are depleted during spawning. Therefore the need for habitat that provides adequate feeding opportunity and reduced energy use is especially important to them and spawning fish should select more productive post-spawning habitat.
5. Is migration timing and the rate of migration correlated with temperature and flow? Movement in fishes has been correlated with environmental conditions that optimize both metabolic rates and energy expeditures. Movement can be driven by temperature as discussed in Brett (1971) and Bohlin et al. (1993) or energy use, which may be effected by changing flows as discussed in Whalen et al. (1999) and Jonsson et al. (2001). The null hypothesis for this question is that upstream movement will have no relationship with changing flows and temperatures. If we reject our null hypothesis, the changing conditions in temperature and flow that correspond to movement may be expected to be optimal for metabolism and expenditures of energy in bull trout.

This interim report describes the adult radio tagging project through the first eighteen months of the study. Tagging and tracking will continue at present levels through the fall period of 2005. Final reporting for this project is expected by June 2006.

Study Area

The Boise River basin is located in southwestern Idaho and is a major tributary to the Snake River. Three dams are constructed on the upper Boise River system: Arrowrock, Anderson Ranch, and Lucky Peak dams. Lucky Peak Dam, a U.S. Army Corps of Engineers project, is located at the lowest elevation in the Boise River at river kilometer (rkm) 103 with a full pool elevation of 931 meters above sea level. Arrowrock Dam, Reclamation project is 19 rkm upstream from Lucky Peak Dam on the mainstem Boise River. Arrowrock Dam has a full pool elevation of 980 meters above sea level. Anderson Ranch Dam, also a Reclamation project, is the most upstream of the three projects, located at rkm 81 of the South Fork of the Boise River with a full pool elevation of 1,272 meters above sea level. These reservoirs are operated collectively as one system for irrigation, flood control, and recreation.

The Boise River basin upstream from Arrowrock Dam covers 5,700 km^2 (2,200 $mile^2$) of the granitic rock dominated landscape with elevations ranging from 931 m (3057 ft.) to 3,231 m (10,600 ft.) above sea level. The upper Boise River includes three sub-basins: the North, Middle, and South Forks. The Boise River system is fed primarily by snowmelt run-off with highest flows occurring in April-May and lowest in September-October. Flows range from 4.25 m^3/s (150 ft^3/s) to over 339.8 m^3/s (12,000 ft^3/s) in the mainstem Boise River below the North and Middle Fork confluence. Land uses in the Boise River watershed include grazing, recreation, and both commercial and individual timber harvest. The majority of the Boise River basin lies within Forest Service or Wilderness area boundaries.

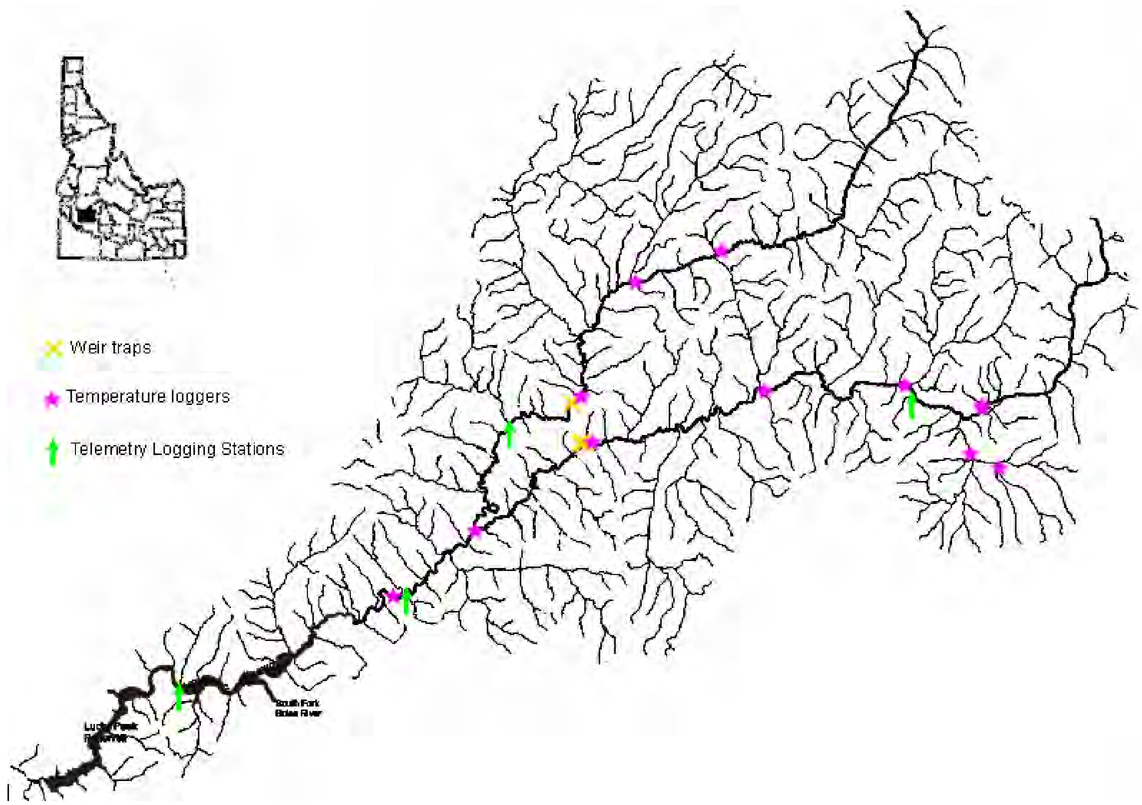

Figure 1. North and Middle Forks of the Boise River watershed with Arrowrock and Lucky Peak reservoirs. Weir traps, temperature, and telemetry monitoring stations are highlighted.

Methods

<u>Fish Capture</u>

Steel frame picket weirs were operated across the major migratory corridor in both the North and Middle Forks of the Boise River below most known spawning and rearing habitat for bull trout. A 39.50 m (130 ft.)-long x 1.53 m (5 ft.)-tall steel picket style weir with upstream and downstream traps was constructed across the full width of the North Fork Boise (at rkm 22.7 or rm 12.25) and the Middle Fork Boise River (at rkm 15.6 or rm 8.42). The traps were operated adjacent to the U.S. Forest Service Barber Flat guard station from the end of August through October during the years 2002 and 2003. The weirs were constructed of 15, 3.05-m (10 ft.) angle iron frames with steel conduit pickets spaced 1.25 cm (0.5 in.) apart (Figure 2). The traps were built following design recommendations and guidance from Russ Thurow (U.S. Forest Service, Rocky Mountain Research Station 1999). Operating time was planned during the post spawning migration of bull trout. Time and duration of the post-spawning run coincides with periods of lowest river discharge (USBR 2003, Flatter 2000). Flow information was considered and a substrate anchored trap style was chosen. The trap design had been used by other agencies to target post-spawning bull trout in a fluvial system, which fit the study goal. The trap acted as a migration barrier for all fish > 1.25 cm (0.5 in.) in width (approximately > 200 mm (3.9 in.) total length for bull trout), capturing fish in traps as they moved upstream or downstream. Traps were checked, and pickets cleaned three to four times per day. To minimize predation of small fish inside the trap boxes, a small pine tree branch was placed in one half of the box area to allow for cover (Russ Thurow, RMRS, 1999). Fish observed holding upstream of the weirs were netted at night using dipnets when possible.

Figure 2. Installation of the North Fork weir trap. Steel frames, pickets, fence posts, and sand bags used for weights, to prevent channel undercutting, and escape by digging are shown.

The traps withstood discharge exceeding 6.0 m^3/s (212 ft^3/s), but high amounts of debris or freezing led to removal each year. To add strength to the traps, the design was altered by adding 2.5-cm (1.0 in.) x 182.9-cm (72 in.) solid steel rod supports driven 30.0 cm to 40.0 cm (12 to 16 inches) into the substrate behind the supports of the trap (Figure 3). The steel rods allowed the traps to withstand higher water flows and were easier to install in rocky substrate than the steel fence posts used previously.

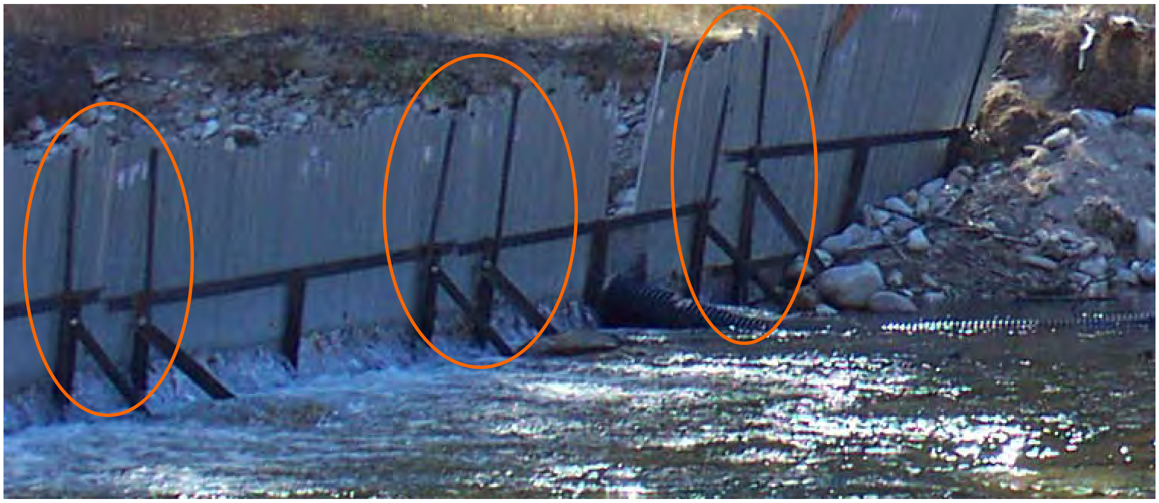

Figure 3. Downstream side of weir trap illustrating steel support rods

Fish Tagging and Handling

All fish captured were identified to species and enumerated. Total length (TL) was recorded for all game species. Captured bull trout were anesthetized using diluted tricaine methanesulfonate (MS-222) (approximately 80 mg/L). When a fish was considered anesthetized (could not right itself), its total length, fork length, and weight were recorded. A scale sample and fin clip were taken, and the fish was scanned for Passive Integrated Transponder (PIT) tags (AVID computer corporation, Norco, CA 1999). All bull trout > 100 mm TL that did not carry tags were tagged with 2.5-mm x 14.0-mm, 125 kHz PIT tags in accordance with instruction from Idaho Department of Fish and Game personnel (Russ Kiefer, IDFG 1999). Bull trout were held and monitored in live wells until fully recovered (minimum 15 minutes), and then returned to the vicinity of capture. Fish capture was recorded by date, time of trap check, and direction of migration. Groupings and pairs of fish were noted. All recaptured bull trout were measured and weighed so that data for growth over the time period for mark and recapture could be recorded.

Radio Transmitter Specifications

Six different-sized Lotek™ (Lotek Engineering, Ontario, Canada) coded radio transmitters were used for adult bull trout (Table 1). Twenty-nine fish were additionally tagged with externally attached temperature and depth archival data tags model LTD-1100 (5.0 grams in air). Radio transmitter weight (including archival tag weight when applicable) varied from 0.6 % – 3.2 % of the fish's body weight.

Transmitter Implantation

Radio transmitters were surgically implanted into the peritoneal cavity of fish meeting the minimum weight requirements for each tag model as specified in Table 1.

Table 1. Specifications of radio tags implanted in bull trout in years in 2002 and 2003

Tag Model	Dimensions	Weight (air) (g)	Fish weight needed (3% radio) (g)	Weight w/ archival (3% radio+archival)	Tag Life
MCFT-3BM	11 X 43	7.7	257	423	278
MCFT-3EM	11 X 49	8.9	297	463	399
MCFT-3FM	11 X 59	10	333	500	560
MCFT-3A	16 X 46	16	533	700	761
MCFT-3L	16 X 73	26	867	1033	1686
MCFT -3AIM	16 X 46	18	600	767	761

Bull trout were anesthetized in an 80 mg/l MS-222 solution. The gills were bathed in anesthetic solution using a bilge pump and shower system throughout the surgery. Fish were placed ventral side up in a V-shaped surgery cradle. The surgical methodology used was a modified shielded needle technique (Ross and Kleiner 1982). A small incision (1.0 cm to 2.0 cm) was made parallel to the linea alba and a sterilized transmitter was inserted into the peritoneal cavity. The antenna exit hole was created using a 12 or 14 gauge 7.6 cm (3.0 in.)-long surgical needle inserted through the body wall below the pelvic girdle onto a 1.0-cm X 7.6-cm (0.4-in. x 3.0-in) long steel spatula (Figure 4). The antenna exited the body approximately 1.5 cm to 2.0 cm (0.6 in. x 0.8 in) posterior to the pelvic girdle along the mid-ventral line. The incision was closed with Visistat™ 35 Regular or Wide disposable skin staples. In cases where staples did not provide good closure, absorbable sutures were used to close the incision. Surgical glue was then applied to the incision after sutures or staples were in place.

Figure 4. Inserting needle to create antenna exit hole during radio tag implantation surgery.

Archival temperature depth tags were attached using two different methods. In 2002, 20 gauge sterile syringe needles were used to pierce two holes through the skin and dorsal musculature 2.5 cm (1.0 in.) apart and approximately 1 cm (0.4 in.) below the insertion of the dorsal fin rays (Figure 5). Eighty pound test strength steel leader line was threaded through the needle with plastic baffles placed on one side of the animal and the tag placed on the other side. Leader line was then tied with triple surgical knots.

In 2003, the method was modified due to loss of all of the 2002 archival tags. Unmarked Peterson disks and nickel pins were used instead of the steel leader line for archival tag attachment. Nickel pins were used to pierce two holes through the skin and dorsal musculature 2.5 cm (1.0 in.) apart and approximately 1 cm (0.4 in.) below the insertion of the dorsal fin rays (Figure 6). After surgery, fish were placed in fresh water live wells to recover then released back into the river downstream from the weir during the night trap check to reduce risk of predation.

Figure 5. Attachment of 2002 archival tags using steel leader (green circle).

Figure 6. Attachment of archival tags in 2003 using unmarked Peterson disks (green circle) and nickel pins.

Measuring Movement and Entrainment

Bull trout implanted with radio tags were tracked using Lotek™ SRX-400 receivers with W31 Firmware. Telemetry searches were conducted weekly (weather permitting) beginning mid-September 2002 on the ground with an SRX receiver and 3-element directional YAGI antenna. In addition, fish were located weekly using either fixed wing or helicopter aircraft equipped with an SRX 400 receiver and two mounted "H" antennas (Figure 7).

Figure 7. Helicopter used for tracking with H-type antennas (green circle) mounted on each skid.

Locations of fish were taken with a hand-held GPS unit linked to the SRX-400. As each fish transmitted its code, a power and waypoint were logged with the code on the receiver automatically. These locations were then mapped on topographical maps and movement distances were calculated using TOPO!™ software. Any fish not found during ground or aerial tracking attempts were assumed to have moved from last location into an inaccessible (roadless or deep water) area prior to that tracking day.

In addition to active tracking, fixed telemetry stations were set up to record fish as they moved past. These stations consisted of a 4 element YAGI antenna connected to an SRX data receiver/logger powered by a 12-volt battery with a solar panel to recharge the battery (Figure 8). Information from these stations was downloaded to a laptop computer. To estimate entrainment and evaluate environmental conditions associated with entrainment, a remote logging station recorded data within the spilling basin at Arrowrock Dam 24 hours per day. The logging station was accessed and downloaded remotely from an analog phone line once per week. Time, discharge of the dam, and water elevation are logged for the event where any fish was entrained.

Fish were located three times per week during the construction period and fish that remained in poor habitats for over 48 hours were checked for mortality. Additionally, any fish that remained in one location for over one week were checked for mortality regardless of habitat quality. Determination of cause of the mortality was made based on the location the tag was found, time of year, condition of the animal (if found) and other clues including scat and observation of predatory animals.

Figure 8. Remote logging station located on the property at Twin Springs, Idaho.

Temperature and Flow Measurements

Water temperature was recorded every hour at eleven locations in mainstem and tributary streams across a range of elevations and stream sizes by Tidbit™ (Onset Computer Corporation, Pocasset, MA 1999) temperature loggers (sites shown in Figure 1). Additionally, data were also collected electronically from six USBR Hydromet stations. Remote access from Hydromet stations gives data for daily-accumulated precipitation, daily solar radiation, mean daily flow, and temperature, discharge from the dam, reservoir elevation and volume. The six Hydromet stations are located near Twin Springs (BTSI), Atlanta (ATLA), Arrowrock Dam (ARKD), Anderson Ranch Dam (ANDD), Big Smoky Work Station (BKSI) and Lucky Peak Dam (LUCD), Idaho (USBR 2003).

Data Analyses

Bull trout were placed into categories that described observed movement, spawning, and over-wintering patterns in order to answer questions concerning conditions, size, spawning, and movement patterns. The first category related to overwintering habitat: one group overwintered in the pool habitats of the South Fork the Boise River below Anderson Ranch Dam and the other group overwintered in the reservoir pool of Arrowrock Reservoir. The second category concerned spawning: fish were separated into spawning or non-spawning groups based on whether they were in known spawning areas during the spawning period (Swanberg 1997). The third category was related to upstream migration and reservoir departure dates: non-migrants (did not leave reservoir), early migrants (left prior to April 9), middle migrants (left between April 9 to May 12), and late migrants (left after 5/12). These dates were chosen from the patterns observed in the hydrograph and corresponding fish movement. We used four non-categorical variables in the analyses. These included fish condition calculated using length and weight from the isometric equation for growth from Everhart and Youngs (1981), total length (as an indicator of age), date the animal departed the reservoir, and duration from departure date to most upstream area that it traveled (rate of migration). Due to the limited sample size of non-normal data, Mann-Whitney U tests were used to test all categorical data sets (spawned or not, overwintering groups, reservoir departure groups). Non-categorical data sets (temperature, flow, dates of departure, solar radiation, total length) were tested with simple linear regression. Assumptions of simple linear regression were checked and if data did not fit or could not be transformed to fit the assumptions, tests results were not reported. All statistical testing was completed using SAS Version 8.0 (SAS Institute 1999).

Results

Fish Capture

We captured 323 during the trapping period in years 2002 and 2003, with 50 adult-sized (300 mm TL from Flatter 2000) bull trout receiving radio transmitters in 2002 and 53 adult-sized bull trout receiving transmitters in 2003. Most bull trout were captured during the night period from 21:00 to 06:00, and the majority of bull trout were captured moving downstream in the downstream trap box or were netted upstream of the trap frames at night.

Movement, overwintering, and spawning patterns (fish tagged in 2002)

Of the 50 radio tagged bull trout, 28 survived overwintering. Two fish were entrained into Lucky Peak and two did not move upstream during the spring migration period. Two fish remained in the South Fork Boise River over the summer of 2003. One South Fork fish overwintered in the South Fork arm of Arrowrock Reservoir, moved into the residual pool in mid-August, then returned to the South Fork Boise River below Neal Bridge in late October and again moved back to the reservoir pool again in late December. The other fish overwintered in the South Fork arm of Arrowrock Reservoir and slowly moved upstream to Reclamation Village near Anderson Ranch Dam where it spent the summer, fall, and winter. Twenty-four fish moved out of the reservoir upstream in the Middle Fork Boise River, two fish were no longer located after Memorial Day weekend (when the river fishing season starts in the Boise system), one returned to the reservoir and was killed by a raptor in late June, and a fourth was killed or expelled its tag in late May during its upstream migration near Alexander Flat. Of the remaining 20 fish, nine entered spawning tributaries, arriving to spawning areas as early as July 2, 2003 and departing no later than September 26, 2003. Eleven fish held in the mainstem river channel over the summer and never entered known spawning habitats.

Migration Habitat and Holding Areas

Several areas of the Boise River functioned as holding or refuge areas for bull trout during the upstream migration. Bull trout would use habitats for twelve hours to up to several weeks near Willow Creek campground, Haga Creek, the North Fork confluence, Roaring River confluence, Weatherby landing strip, and downstream of the Queens River confluence on the Middle Fork Boise River. Important holding areas on the North Fork Boise River included Meadow Creek confluence, Hungarian Creek confluence, Bear River confluence, McNutt Creek/Taylor Creek confluence and the pools between Lodgepole Creek and the confluence of Johnson Creek (Figure 9).

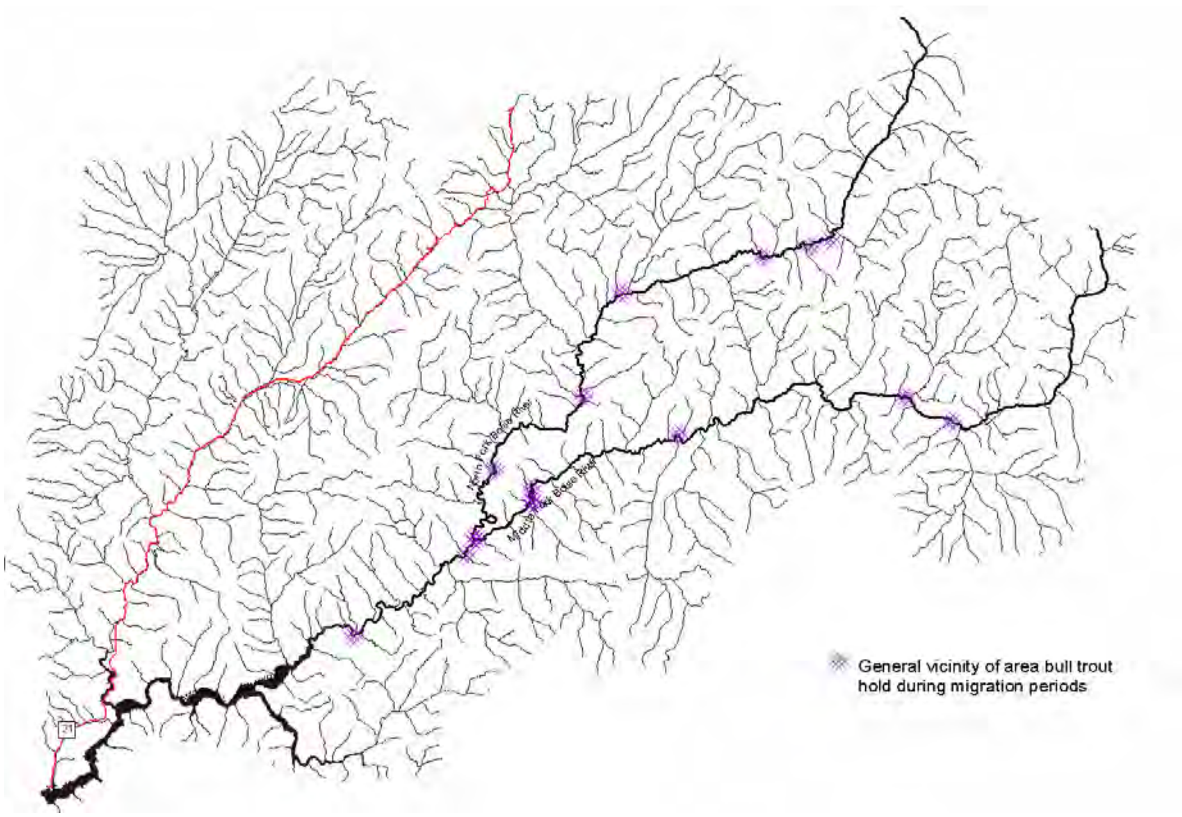

Figure 9. Areas where bull trout commonly would hold during the upstream and downstream migration periods in the North and Middle Fork Boise Rivers.

Important holding habitats in the mainstem rivers were usually characterized as large pools close to boulders, adjacent to cliffs and large rock structures. In smaller headwater streams, large bull trout were often found near debris jams or next to boulders with a bubble curtain in steep gradients, or under undercut root wads of trees.

Upstream Migration (spring)

Patterns were observed with migration timing and changes in temperature, flow, and sunlight. Figure 10 shows movement of bull trout from Willow Creek campground upstream during the spring migration period. Three groups are apparent when movement patterns are reviewed that correspond to dates where large changes in temperature, flow, or sunlight occurred. Early migrants departed the reservoir between March 3, 2003 and April 9, 2003 (mean date March 27, 2003, N = 7) with the first high-water event of the year. Mid-spring migrants departed the reservoir between April 10, 2003 and May 12, 2003 (mean date April 29, 2003, N = 2). Late spring migrants departed the reservoir after May 12, 2003 (Mean date June 10, 2003, N=15)(Figure 11). Four fish were killed or were lost during the upstream migration from the early and middle migration groups.

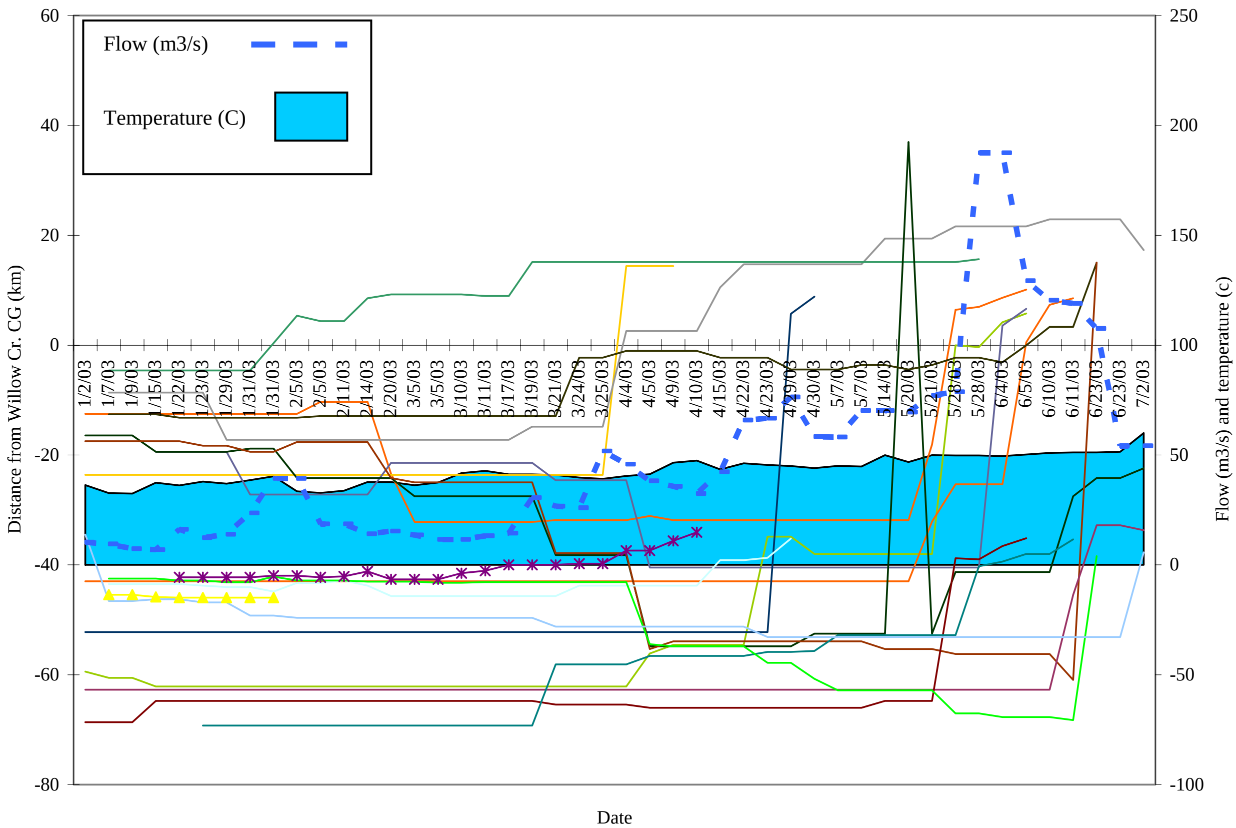

Figure 10. Pre-spawning migration distance and timing chart for radio-tagged bull trout overwintering in Arrowrock Reservoir. Single lines represent individual fish distance from Willow Creek campground (Arrowrock Reservoir full pool elevation). Negative distances are downstream distances from Willow Creek (including the South Fork Boise River).

Relationships between movement exhibited by bull trout and environmental conditions could be dependent on seasonal conditions and can be isolated by looking at downstream and upstream movement together (Figure 11). During the spring migration upstream, the largest movement of bull trout corresponded to the peak stream discharge and an early increase in sunlight (solar radiation) and temperature which then remained relatively constant. The initiation of fall migration appears to be driven by a large drop in temperature and reduction in sunlight, while stream discharge remained relatively constant.

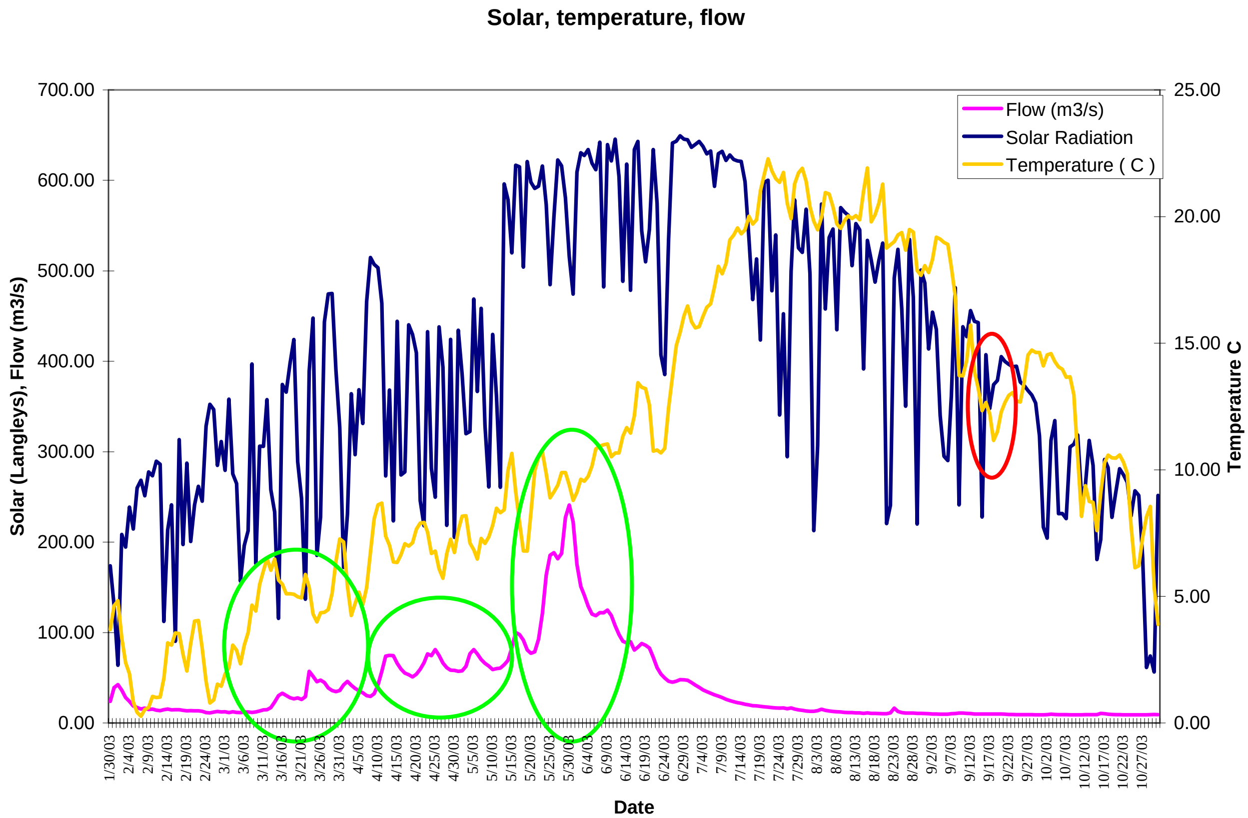

Figure 11. Temperature (gold line) and Flow (pink line) and solar radiation (blue line) of the Boise River during the migration periods. Early, middle, and late upstream migration group times are shown in green circles. Beginning of post-spawning downstream migration shown in red circle.

Downstream Migration (fall)

All of the fish that migrated upstream into the river system in the spring began the fall downstream migration within 15 days of one another (September 9 to 26, 2003). Downstream migration was relatively rapid, with fish moving from the weirs (where fish were tagged) to winter habitats in 14 to 40 days (Figure 12) while upstream migration varied 10 to 110 days from departure of Arrowrock Reservoir to summer habitat (Figure 10).

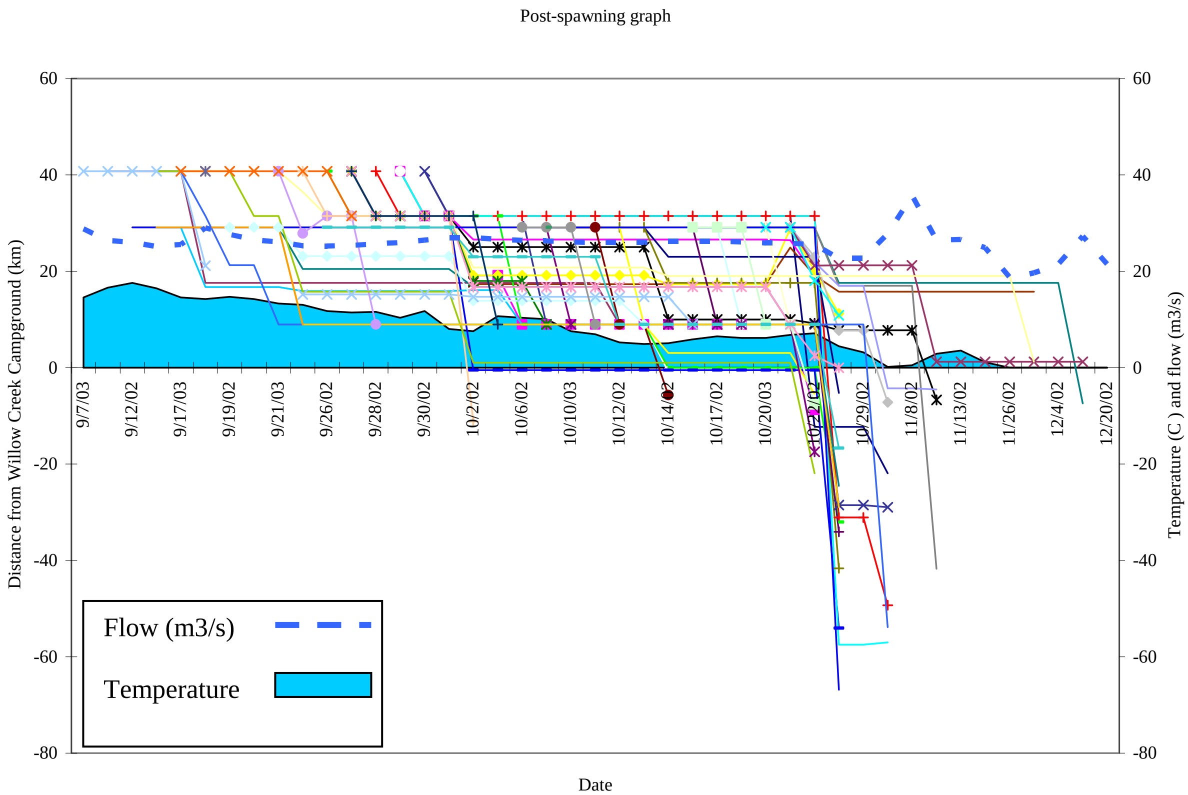

Figure 12. Post-spawning downstream migration following tagging at weir traps in 2002. Each line represents one animal's distance from Willow Creek campground (elevation of Arrowrock Reservoir full pool). Negative distances are distance downstream of Willow Creek campground.

Relationships between fish size, condition, migration, and overwintering

We investigated five questions about the relationships that may exist among fish size, condition, migration timing, and overwintering habitat in order to develop guidelines for reservoir operations and minimum pool elevations when bull trout occupy Reclamation projects.

1. Is an animal's condition factor or length a factor in whether the animal spawns or not?

Twenty four bull trout began the upstream spawning migration in the spring of 2003. Of these, four were killed or disappeared during the upstream migration, eleven remained in the mainstem river channel and nine entered spawning and rearing habitats. Spawning fish were generally larger (Mean total length of 571 mm, s = 53 mm, range 449-610 mm for spawning fish versus mean total length was 507 mm, s = 65 mm, range 341-576 mm for non-spawning fish). Condition could not be used to significantly separate group means for spawning and non-spawning fish ($p = 0.85$). Total length, however, could be used to separate groups, but the relationship was weak and not significant ($p = 0.15$).

2. Does the rate of migration or time of reservoir departure depend on the animal's condition factor or length?

The upstream migration started with fish departing the reservoir as early as February 5 in 2003. The last bull trout left the reservoir on July 5, 2003. There was a large variation in the number of days each individual bull trout took to get to the most upstream point to which it migrated (10 to 162 days). Condition factor was not significant for predicting the rate of migration, and though length showed that a relationship may exist, it was not significant ($r^2 = 0.15$, $p = 0.09$).

3. Do fish that eventually spawn move over different durations or leave the reservoir at different times than non-spawning fish?

The mean duration of movement for fish that entered spawning habitats was significantly ($p = 0.02$) slower than for non-spawning fish (spawning fish mean movement 90.9 days, s = 38.9 days, range 38-162 days versus non-spawning fish mean movement 54.7 days, s = 23.6 days, range 10-92 days). Reservoir departure date could slightly differentiate the spawning groups, but not significantly ($p = 0.08$). Of the 24 fish that began an upstream migration from the reservoir or South Fork Boise River to a summer habitat, four fish departed in the early group, one in the middle group, 15 in the late group, two were entrained into Lucky Peak Reservoir, and two never migrated out of Arrowrock reservoir and the South Fork Boise River. Only one of the non-spawning fish was an early migrant, but it was killed by the Hot Creek fire on August 3, 2003 and may have been misclassified, the rest were late migrants. Five spawning fish were late, three were early, and one was in the middle spawning group.

4. Is the overwintering habitat related to condition factor, migration rates, duration of migration, or spawning patterns?

There were no significant relationships found among the overwintering habitats and condition factor, migration rates, duration, or whether fish spawned or not. Condition factor of the different over-wintering groups and departure dates could weakly differentiate the groups, but they were not significant ($p = 0.26$ and $p = 0.19$ respectively).

5. Are migration timing (date of reservoir departure) and the rate of migration correlated with temperature and flow?

The duration of upstream migration (number of days a fish took from the time it left the reservoir to the time it reached its most upstream point of migration) could be strongly be predicted by temperature and flow ($p = 0.005$). Migration group (early, middle, late) and date of reservoir departure were also significantly predicted by temperature ($p = 0.006$, $p = 0.0001$ respectively). Since the majority of bull trout were in the late migration group, we reviewed the mean daily water temperature as a threshold for migration rather than a trend through time. The latest any bull trout migrated from Arrowrock Reservoir was July 5 (only three bull trout left after June 15, 2003), and the mean date of departure for the latest and largest migration group was June 10, 2003. Figure 13 shows the temperature, flow, and solar radiation for the late spawning group. The mean water temperature for the period was 11.9 ^{o}C, and no bull trout left the reservoir after the mean daily water temperature exceeded 16 ^{o}C at the Twin Springs gauging station. Coincidentally, 16 ^{o}C is the temperature threshold identified in Dunham et al. (2003) for limiting distribution of bull trout. Solar radiation increased from the average of 354.2 Langleys per day to an average of 571.6 Langleys per day on May 12th (Figure 11). May 12th is when the first migrant in the late migration group which may be a response to the temperature increase corresponding to the increase in solar radiation.

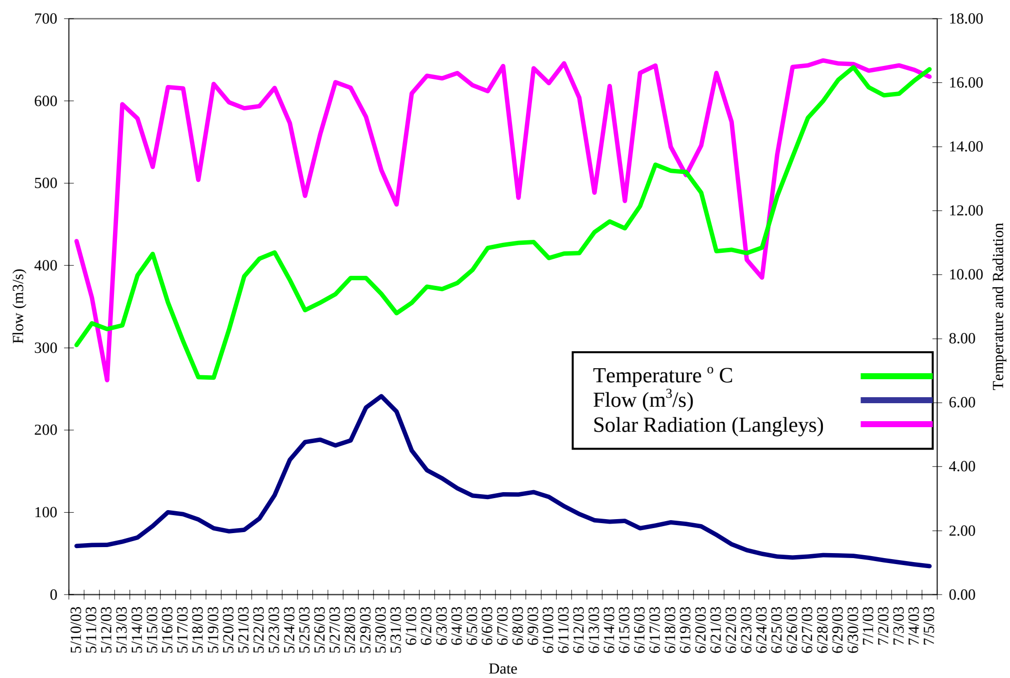

Figure 13. Mean daily water temperature, flow, and solar radiation at Twin Springs Idaho during the late spawning group reservoir departure period.

Entrainment (all radio tagged bull trout years 2002 and 2003)

Fish can become entrained at Arrowrock Dam into Lucky Peak Reservoir by three conduits: the high water spillway, an upper set of ensign valves, and a lower set of ensign valves (Figure 14).

Figure 14. Middle and lower ensign valves at Arrowrock dam. Spillway is not shown and is located on the downstream right at the surface level of Arrowrock reservoir full pool.

Two (4%) of the 50 radio-tagged fish from 2002 were entrained in 2002 or 2003. Fish code 1-81 was entrained November 2, 2003 at 01:50 hours. Reservoir elevation was 956.7 m (3139 ft.), volume 113.23 km^3 (91,789 acre-ft) and the mean discharge was 13.8 m^3/s (488 ft^3/s) with an increasing trend. This fish was entrained through the upper set of ensign valves (elevation 946.4 m, 3,105 ft.), at a depth of approximately 10.3 m below the water surface. Fish code 3-83 was entrained at 06:36 hours on July 16, 2003. Reservoir elevation was 966.8 m (3,172 ft), volume 192.89 km^3 (156,379 acre-ft), and mean discharge of 138.2 m^3/s (4,882 ft^3/s) with a declining trend. This fish was approximately at a depth of 20.4 m below the water surface. Both of these fish were entrained through the upper level gates (elevation 946.4 m, 3,105 ft) as the mid-level gates (elevation 917.8 m, 3,011 ft.) were either not operational (during the winter 2002) or were being operated sporadically (during the summer 2003) due to the construction. The upper level of valves will be retired at the end of the project.

Six fish (11.3 %) have been entrained from the 2003 adult fish sample during the construction period. All six fish were entratined when the reservoir elevation was 922.6 m (3,027 ft.) volume 2.0 km^3 (1,650 acre-ft). Fish code 1-44 was entrained at 14:30 hours on October 15, 2003. Reservoir mean discharge was 23.1 m^3/s (816 ft^3/s) with a declining trend. Fish 5-192 was entrained at 21:30 hours on October 31, 2003. The mean discharge was 23.4 m^3/s (827 ft^3/s) with a declining trend. Fish 5-187 was entrained at 14:35 hours on February 14, 2004. Reservoir mean discharge was 19.68 m^3/s (695 ft^3/s) with an increasing trend. Fish 5-164 was entrained at 4:41 hours on February 24, 2004. Reservoir mean discharge was 37.23 m^3/s (1,315 ft^3/s) with an increasing trend. Fish 5-178 was entrained at 22:20 hours on Februrary 24, 2004. Reservoir mean discharge was 40.25 m^3/s (1,432 ft^3/s) with an increasing trend. Fish 1-49 was entrained at 0:56 hours on February 27, 2004. Reservoir elevation mean discharge was 51.67 m^3/s (1,825 ft^3/s) with an increasing trend. All six fish were entrained through the mid-level gates (elevation 917.8 m, 3,011 ft) at a maximum depth of 3.0 m below the water surface. This data supports findings in Flatter (2000) that state all bull trout entrained were near the reported range of 5.8 m to 30.5 m depth from the water surface. During normal winter operations (October 1 through March 1) in years 1999 and 2000, the mean discharge from Arrowrock dam was less than 8.5 m^3/s (300 ft^3/s) (Figure 15). During construction years 2001 through 2003, mean winter discharge varied from 5.4 m^3/s (190 ft^3/s) to 24.4 m^3/s (832 ft^3/s). All six fish were entrained when mean daily discharge from the dam was greater than double that of discharge during normal winter operations (19.7 m^3/s or 695 ft^3/s).

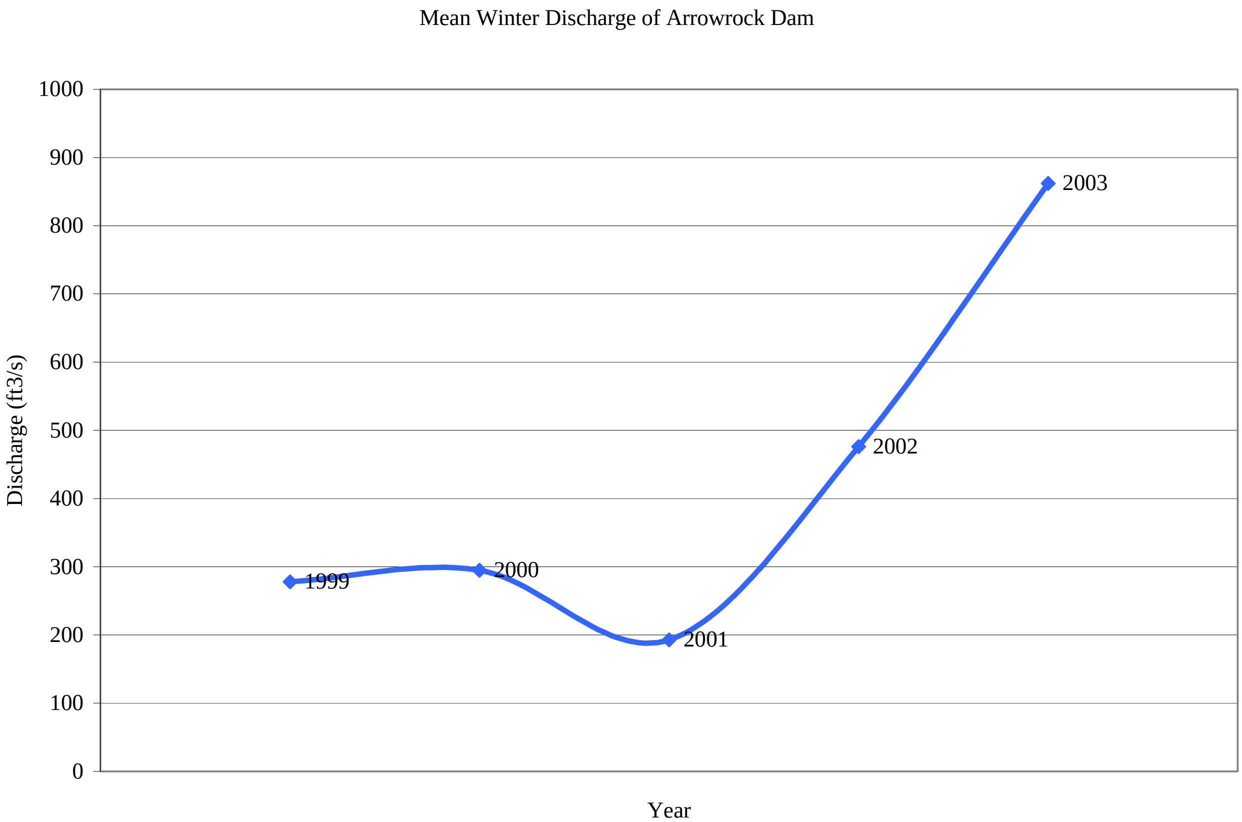

Figure 15. Mean winter discharge from Arrowrock dam (October 1 through March 1). Years 2001 through 2003 represent atypical operations due to construction.

<u>Mortality</u>

<u>Fish tagged in 2002</u>

Mortality rates for the first 18 months post-tagging were high in radio-tagged adult fish tagged in 2002, especially due to raptor predation (Table 2).

Table 2. Number of radio-tags and probable cause of tag loss for 2002 radio-tagged bull trout.

Cause of Tag Loss	**Number of Fish**
Post spawn	6
Predation, raptor	15
Predation, mammal	5
Tag expulsion/battery expired	5
Suffocation, Bank sloughing –Arrowrock	1
Injury due to angling	9
Fire and flooding	2
Missing	2
Total	**45**

Six fish that entered headwater tributaries to spawn either expelled their tags (tag found entangled in debris) or were killed (body parts visible). Fifteen of the fifty radio tags (34 %) were found near raptor nesting sites, on hill sides or ridges well out of the water. Five tags were found under banks, in log jams, or buried along the shore with mammal scat nearby. The batteries expired on two tags, one while the fish was still active and the other after the tag had been recovered. Three tags had been expelled; one fish was recaptured after the tag was expelled (Figure 16). One fish was found buried beneath more than 20 cm of sediment near the sloughing banks of Arrowrock Reservoir. The body of the animal was in good condition, with no apparent injuries. Nine tags were recovered immediately downstream from high angling use areas or within campfires or at campgrounds. Two fish were killed during the Hot Creek Fire on the Middle Fork Boise River and the subsequent mudslides and two fish disappeared during the spring spawning migration from the mainstem Boise River, inferring tag failure or that the animals may have been poached.

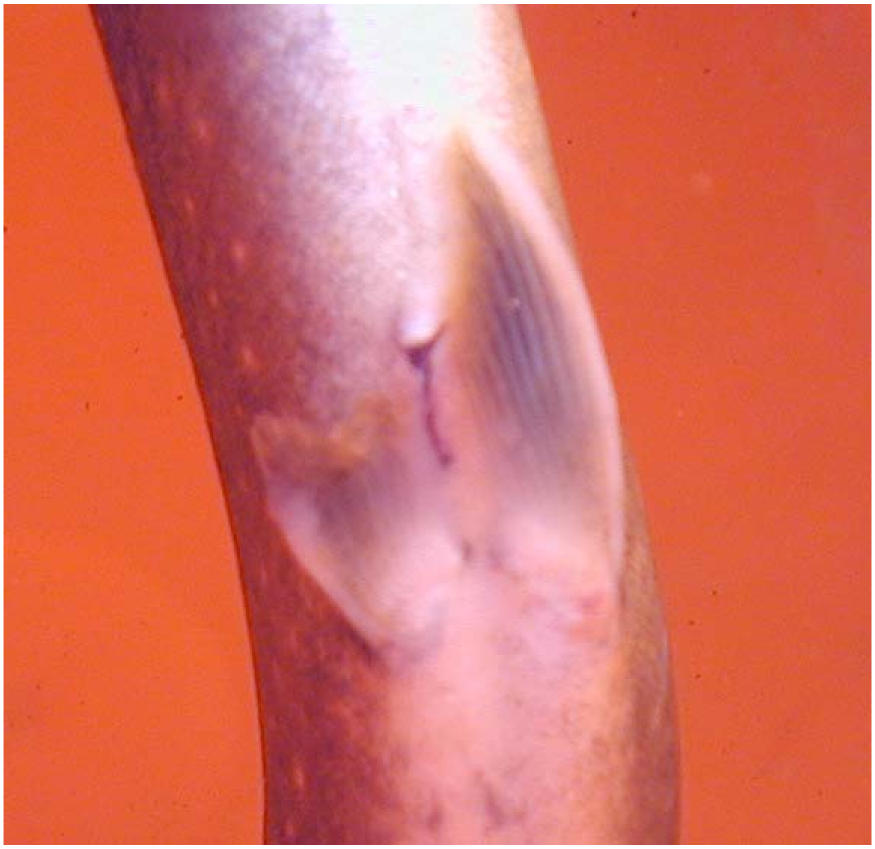

Figure 16. Hole in abdomen of fish code 3-88 when recaptured at the Boise River weir trap. The tag was retrieved from Bear River on the North Fork Boise River.

Five of the fifty radio-tagged fish survived, did not expel their tags or have their batteries expire over one year (10% of total). Condition in post-spawning fish recaptured at the weir traps was very poor and injuries were common (Figure 17).

Figure 17. Fish code 3-88 recaptured post spawning.

Fish Tagged in 2003

Mortality rates were higher in radio tagged fish during the fall 2003 downstream migration than in 2002, especially due to predation. Of the 53 bull trout tagged, 26 were killed or went missing in the post-spawning migration (49.0 %, Table 3).

Table 3. Number of radio tags and probable cause of tag loss for 2003 radio-tagged bull trout

Cause of Tag Loss	**Number of Fish**
Predation, raptor	9
Predation, mammal	6
Predation, unclear	2
Suffocation, Bank sloughing -Arrowrock	3
Injury due to angling	2
Infection or stress from tagging	2
Missing possibly poached	2
Total	**26**

Nine of the fifty-three radiotags (17.0% of total tagged) were found near raptor nesting sites, on hillsides or ridges well out of the water. Six tags were found either with teeth marks, under banks, in log jams, or buried along the shore with mammal scat nearby. Two fish were found near the shoreline with fish parts; however, the type of predator was unclear. Predation appears to be size selective, so we tested the hypothesis that the total lengths were different between killed and live fish that made the migration into either the residual pool or the South Fork Boise River. Total length was significantly different between the two groups ($p = 0.0001$) and killed fish were 526 mm mean TL, $s = 62$ mm and fish that survived were 443 mm mean TL, $s = 83$ mm. Three fish were found buried beneath more than 20 cm of sediment near the sloughing banks of Arrowrock Reservoir. The bodies of the animals were in good condition, with no apparent injuries (Figure 18).

Figure 18. Fish 1-171 found buried in sediment. The animal was unearthed and sediment has been moved away so that its condition could be illustrated. Green arrow indicates archival tag attachment

We retrieved temperature/depth archival tags from two of the buried fish. The complete loss of diel temperature fluctuations for one day supports the observation that these animals were buried and probably suffocated (Figure 19). Two tags were recovered immediately downstream from high angling use areas or within campfires or at campgrounds. One fish was found immediately downstream from the tagging site, with tagging incision appearing inflamed and another fish ceased movement three days after it was tagged in a roadless reach of river. Both fish most likely died from infection and stress due to tagging. One fish disappeared immediately after tagging and another fish disappeared from the South Fork Boise River in November 2003 inferring tag failure or that the animal may have been poached.

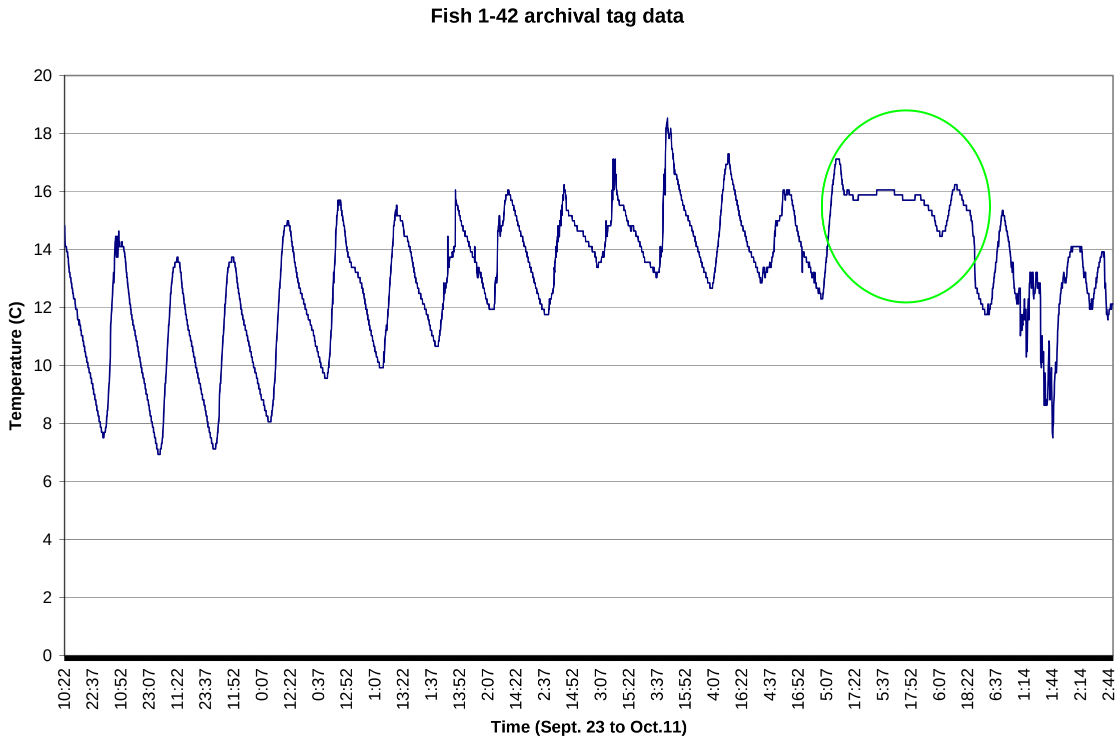

Figure 19. Archival tag data from fish 1-42. Green circle shows where fish was possibly buried.

Mortality rates: comparison of mortality during post-spawning time period in 2002 and 2003

The residual pool of Arrowrock Reservoir in 2003 was held relatively constant at 922.6 m in 2003 during the construction project at Arrowrock Dam. In 2002, the lowest reservoir elevation was 942.5 m during this time period. During 2003, the construction project required the reservoir to be held at 922.6 m, 1.9 km^3 (1600 AF) volume, which is less than one percent of its full pool volume and 3.6 percent of the smallest volume held in 2002. The effect of the low water was a much smaller reservoir pool and new dewatered sections of the reservoir that had to be used as migratory habitat (Figure 20).

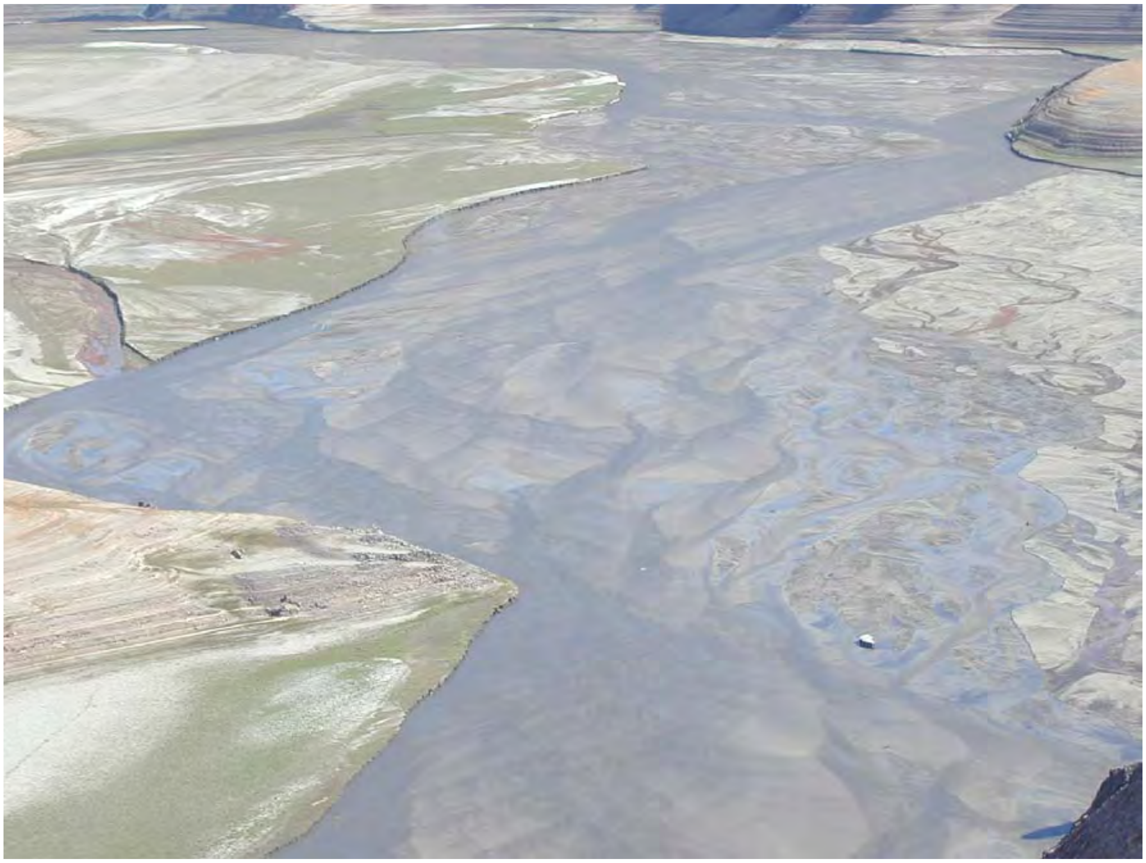

Figure 20. Aerial view of Arrowrock Reservoir, Cottonwood Creek confluence near Irish Creek Campground.

This migratory area consisted of a wide meandering channel with no cover as it is normally inundated by the reservoir pool. Predators, particularly migratory bald eagles, keyed into these areas where the large fish were conspicuous and consequentially predation rates were extremely high in the areas dewatered due to the construction project (11 of 53 fish tagged in 2003 were killed in this area in 2003, 3 of 50 fish tagged in 2002 were killed in this area of the reservoir in 2002).

To examine possible take associated with the reservoir drawdown in 2003, we examined the mortality rates for the post-spawning time period each year (September 1 through December). Reservoir elevation levels are shown in Figure 21 for each year. Table 4 lists causes of mortality and percent of total fish tagged that were lost to each cause. Locations of fish found within the reservoir pool during that time period for each year are shown in Figure 22.

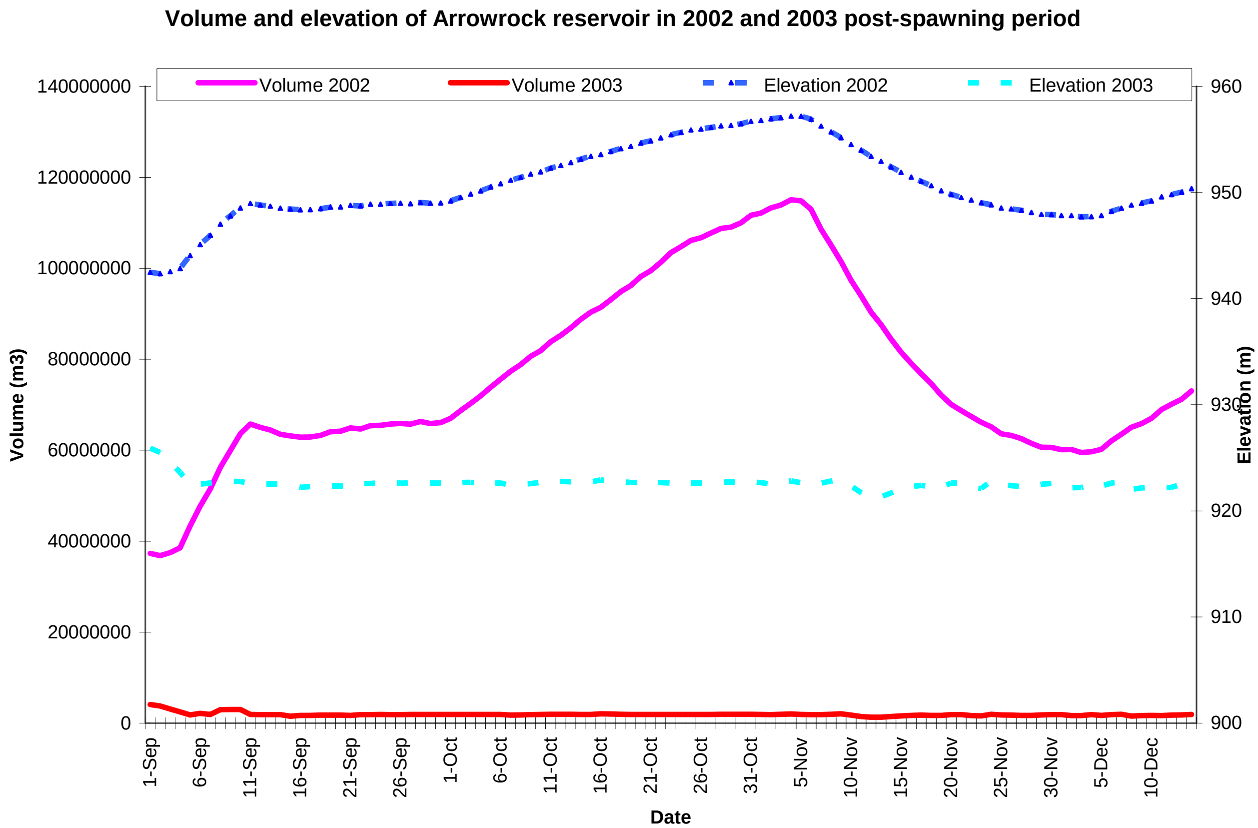

Figure 21. Arrowrock Reservoir volume and elevation during September through mid-December in 2002 and 2003.

Table 4. Comparison of mortality and causes of mortality in the downstream migration period (September 1 to December 31) in years 2002 and 2003. Mortality for each year is shown for fish tagged in that year and for the total tagged fish migrating in 2003 (includes remaining live fish from the 2002 sample).

Cause of tag loss during the post-spawning migration period	**2002 Mortality, N = 50 (percent of total)**	**2003 Mortality, N = 53 (percent of total)**	**Mortality from 2003, All fish migrating N = 68 (percent of total)**
Predation, raptor	5 (8)	9 (17)	14 (21)
Predation, mammal	2 (4)	5 (11)	8 (12)
Predation, unknown	0 (0)	2 (4)	3 (4)
Suffocation, Bank sloughing -Arrowrock	0 (0)	3 (6)	4(6)
Injury due to angling	3 (6)	3 (6)	4 (6)
Tag expulsion/battery expiration	1 (2)	0 (0)	4(6)
Infection or stress due to tagging	0 (0)	2 (2)	2 (3)
Missing	0 (0)	2 (4)	2 (3)
Total	**11 (22)**	**26 (49)**	**41 (60)**

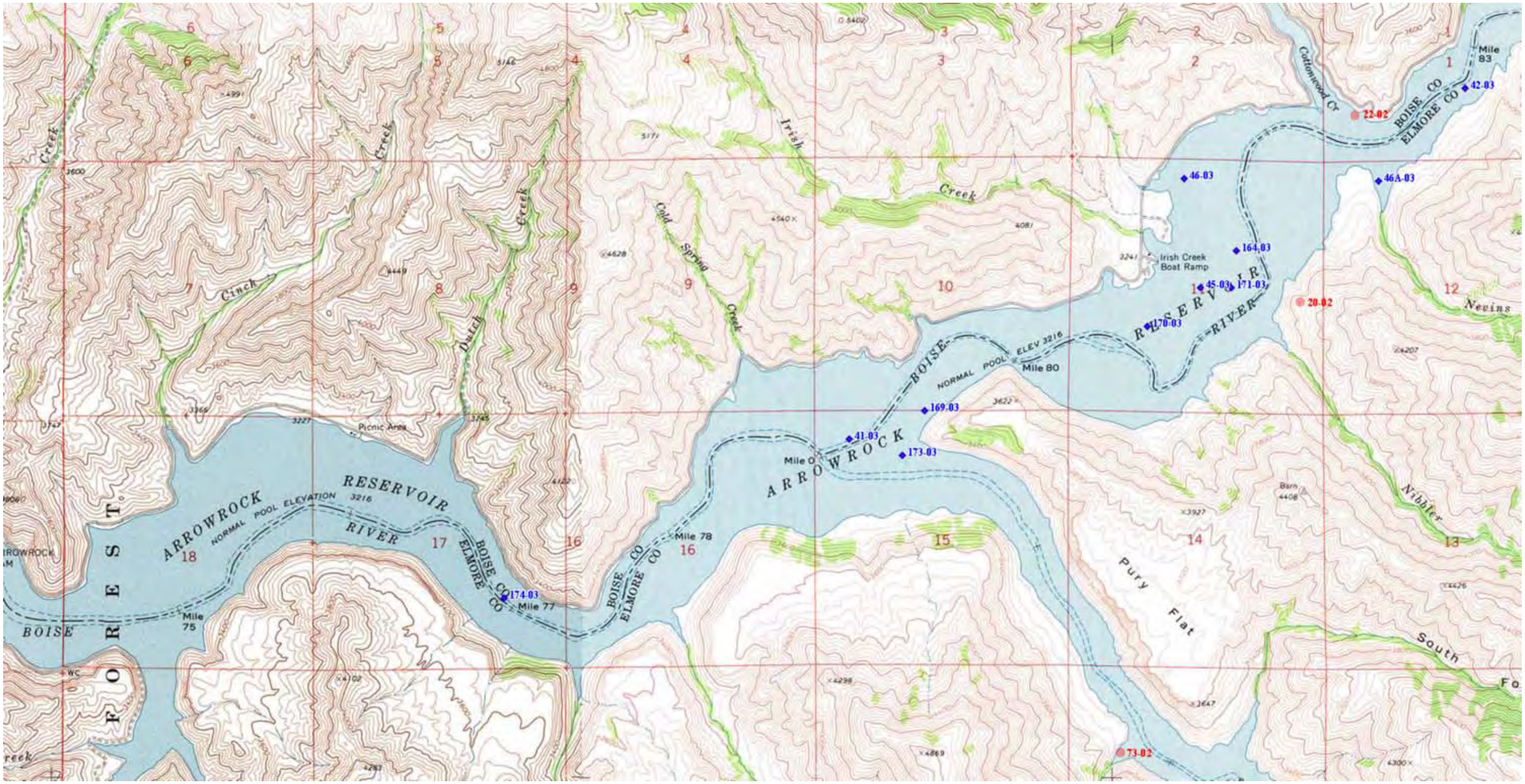

Figure 22. Location of radio tags retrieved from Arrowrock Reservoir in 2002 (red) and 2003 (blue).

Discussion

Migratory Behavior Patterns

We tested several hypotheses concerning patterns of movement and behavior that might be expected based on general life history theory for migratory salmonids. The first hypothesis was that older animals in good condition would be more likely to spawn than younger animals or those in poor condition. The mean size of spawning fish in this sample was generally larger; however, size was not significantly different between spawning and non-spawning groups. One explanation is that evidence of alternate year spawning patterns was doucmented in both weir data and our telemetry work, creating substantial variance in sizes of non-spawning fish. One fish was found 3-5 hours post-mortem in September of 2003, and though it had not spawned that year, it did carry immature eggs (Figure 23). This fish was 473 mm total length when it had been tagged in 2002.

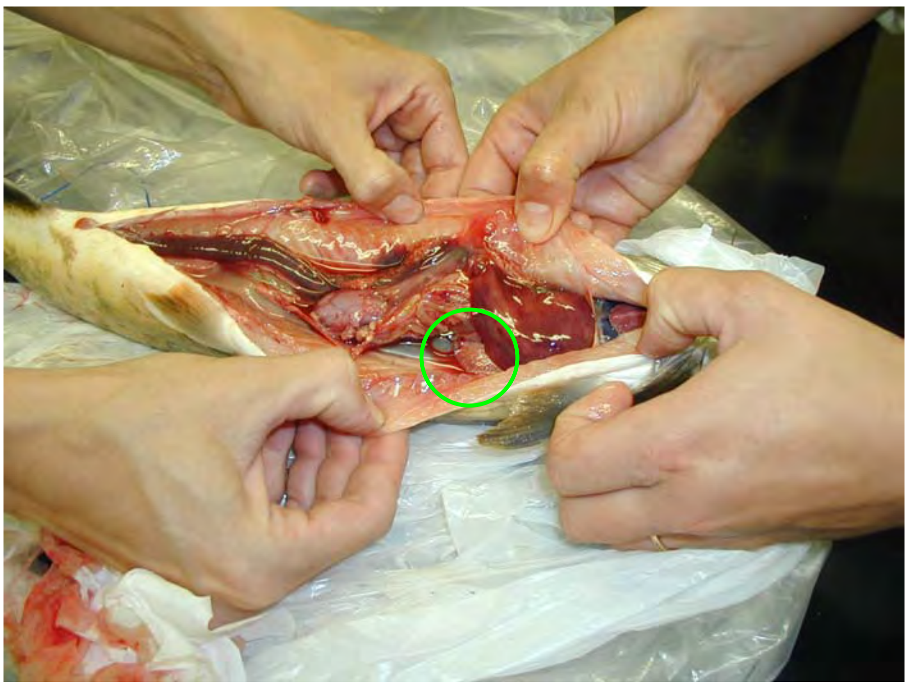

Figure 23. Post-mortem inspection of bull trout found in the Middle Fork Boise River. Immature eggs are circled in green, some eggs had been removed to show injuries.

We tested if the duration of migration or time of reservoir departure depended on the animal's condition or size but found there were no significant relationships. Additionally, there were no significant differences found between the habitats used by overwintering fish, the rate of migration, and whether the animal spawned in the following year. Condition was not a significant explanatory variable for spawning, overwintering, or migration behavior. One explanation is that the condition is calculated from weight at post-spawning capture which may change depending on the individuals overwintering patterns and feeding opportunities. Additionally, weights of the fish captured post-spawning may have not been good indicators for condition as several fish that were captured consumed some of the rainbow trout and whitefish while being held in the traps prior to processing. These fish were very heavy for their size due to the recently consumed meal; however, they may not have been in the best condition. We did not want to take stomach lavage samples due to the fact that the fish were post-spawning and already stressed from trapping and surgery.

Our third hypothesis was that older animals in good condition would make a later, more rapid and directed migration while younger, poorer condition animals may be more likely to move slowly, conserving energy and/or testing new habitats as they moved. We found evidence to the contrary, that the duration of migration for spawning fish was significantly slower than non-spawning fish. Several factors may help explain these findings. First, the rate of migration was calculated from the time the animal left the reservoir until the time it reached its most upstream location. For all spawning bull trout, this was substantially further than for non-spawning bull trout. Spawning bull trout move into small headwater streams while the non-spawning fish stayed in the mainstem rivers at lower elevations. Most non-spawning fish reached their summer habitats by July 15th, while some spawning fish did not reach those habitats until mid-August. Additionally, all but one of the non-spawning fish were in the late migrant group. All of the early and one of the mid-migrant fish were spawning fish, increasing their overall rate, which raises the question about why spawning fish would have longer migration periods. First, the early and middle migration groups leave the reservoir at peak or just prior to peak spring run-off. Movement against higher water velocities requires more energy and longer recovery periods in refuge habitats than movement against the descreasing water velocities of the late migration period. Additionally, bull trout may be following prey species (rainbow trout and whitefish) during their upstream migration in the spring and take advantage of increased prey in river habitats.

Finally, we tested if upstream movement will correspond with changing flows and temperatures that are optimal to bull trout. These tests showed a positive relationship, however, this may be due to the fact that both temperature and flow follow trends in time through spring and fall, similar to migration in bull trout. Temperature appears to be a strong explanatory variable for when fish would leave the reservoir and the rate at which they moved after leaving the reservoir. Two factors may be driving this finding. First, temperature has been found in numerous studies to be a key factor for the initiation of migration in bull trout (Swanberg 1997, Fraley and Shepherd 1994).

We did find that 16 ^{o}C appears to be a threshold temperature in that bull trout did not migrate after water reached this temperature at the Twin Springs gauging station and that most bull trout migrated when mean daily temperatures were between 9-12 ^{o}C. Secondarily, numerous other factors contribute to the changes in temperature in a system and the movement of bull trout. First, bull trout move out of the reservoir progressively in spring, with all fish departing by early-July. As the date advances, the water temperature increases, creating a positive correlation due to the natural changes of the system. Additionally, the hours of daylight per day increase with date, increasing water temperature that may also play a role in the initiation of migration upstream. Downstream migration began (when fish began moving from the farthest point moved upstream to return downstream) for all fish during the same two week (from tracking dates September 9, 2003 to September 26, 2003) period, corresponding to a significant drop in temperature and solar radiation (Figure 11) though stream flow remained the same.

Entrainment

Entrainment rates are reported for the entire year for fish tagged in 2002 and only the first six months for fish tagged in 2003 in this interim report. Some entrainment may still occur as Arrowrock Reservoir begins to refill in March 2004, fish become more active, and water releases from the dam increase. All of the fish entrained in 2003 did so when the mean winter discharge from the dam exceeded twice that of normal mean winter discharge. Since entrainment rates in 2003 were nearly three times that of 2002, high discharge from near surface elevation in 2003 is slightly more shallow than that found by Flatter (2000), but this is due to the construction project maintaining water at a specific elevation with discharge occurring through single conduit releases near the surface. Entrainment therefore may significantly be reduced when the new valves become fully operational, releasing water deeper in the water column when the reservoir held at its normal operational level. The new valves allow primary discharge from the dam to occur from the lowest elevation of gates. These new gates have the capacity to operate at a greater depth (higher pressure and flow capacities) than those currently documented for bull trout entrainment. We will continue to document levels of entrainment in 2004 and 2005 to address this question.

Mortality

Mortality rates were substantially higher during the 2003 construction period than they were during the 2002 period, primarily due to increased predation in areas that were dewatered for the construction project. Additionally, mortality rates basin-wide may have been higher due to multiple years of drought, low stream flows and consequently reduced refuge habitat for bull trout. To reduce this kind of mortality and provide protection for migratory bull trout in future years, we recommend a fall minimum pool established by September 20th (the earliest date that bull trout have been documented to enter the reservoir pool) in Arrowrock Reservoir that corresponds to year 2002. The volume for a minimum pool based on 2002 data for September 20th was 65.4 km^3 (53,000 acre-feet) and 948.6 meters (3,112 ft) above sea level. We would encourage exceeding the 2002 minimum pool recommendation during this time period when possible as it may provide additional benefits of increased refuge habitat and also provide habitat for prey species.

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