FISHERY RESEARCH

Population Studies of Desert Redband Trout

Annual Progress Report for the 2002 Cooperative Study Agreement

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ABSTRACT

Radio telemetry was used to evaluate movement patterns and spawning habits of 48 desert redband trout in Big Jacks Creek from mid March to October of 2002. General spawning and spring-to-fall movement patterns were monitored using fixed-site detections, with supplemental ground tracking conducted during two periods, including the spring spawning season and during midsummer when water temperatures were highest. A total of 10 individual radio-tagged fish moved past at least one fixed receiver site during the study period, moving an average of 2,858 m from their initial tagging location. Nearly all of this movement appeared to be associated with an upstream spring spawning migration in April and May. Insufficient movement was detected past the fixed stations to document any other major trends in movement. Despite walking the entire mainstem section of the stream from Hole in the Rock to Cottonwood Creek during the spawning period (based on observation of redd building in Duncan Creek), we failed to observe a single incidence of spawning activity in mainstem Big Jacks Creek. Thus based on this study, we believe that redband trout spawning was minimal during 2002 in the mainstem of Big Jacks Creek below Cottonwood Creek. While data are limited, Cottonwood Creek and Duncan Creek do appear to function as spawning tributaries for the mainstem Big Jacks Creek population. We experienced a high and disabling rate of radio tag signal loss in this study. The proportion of tag signals lost increased from 31.3% during the spring ground survey to 52.1% during the midsummer survey and reached an inexplicable rate of 75% during the final helicopter flight in September (Table 5). Given the extreme remoteness of Big Jacks Creek Canyon, and our inability to sample sizeable portions of the drainage, it is impossible to know the cause of such high signal loss with 100% certainty. However, evidence and logic points to tag failure as the likely cause of the problem. Regardless of the cause of the signal loss, such high rates largely eliminated our ability to address the primary study objectives effectively. Further, there appeared to be a major decline in trout abundance in the Big Jacks Creek drainage in 2001 compared to mid-1990s levels when sampling was last conducted. We recommend that further life history investigation of the population using radio telemetry be discontinued, at least until the population has rebounded and the cause of high tag signal loss rates is identified.

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INTRODUCTION

Desert redband trout have been found surviving in high temperatures relative to other salmonids (Behnke 1992; Zoellick 1999) and are common in a number of south Idaho streams. Idaho Department of Fish and Game (IDFG) and Bureau of Land Management (BLM) have both identified the fish as a sensitive species. Redband trout in Idaho were proposed for listing during the mid 1990s, but the petition was not found to be warranted at that time. Recently, interior basin redband trout in Oregon were petitioned for Endangered Species Act (ESA) petition, and listing was found to be unwarranted. The original petition that involved Idaho fish did not distinguish between desert redband trout and other interior forms including steelhead. However, strong interest in the status of desert redband in Idaho remains among environmental groups, and the potential for a future petition submittal remains high.

In general, desert redband trout are probably the least studied Idaho salmonid. Population information across Idaho ranges from nonexistent to scattered inventory efforts to more intense evaluations in a few waters (Zoellick 1999). Although population inventories have been conducted in a small number of drainages (e.g., Allen et al. 1997), basic life history information is lacking for Idaho redband stocks and for the subspecies in general outside of Idaho. For example, knowledge of spawning areas, timing of spawning, or general movement patterns for desert redband trout is virtually nonexistent. Thurow (1990) conducted movement studies of rainbow/redband trout in the Big Wood River within the native range of Idaho desert redband trout using jaw tags and subsequent angler recoveries. Results suggested many of these fish moved considerable distances (5-40 km) during the spring/summer period. However, genetic analysis of these fish showed they have been substantially introgressed with coastal rainbow trout of hatchery origin (Williams and Shiozawa 1992), limiting the utility of these results for addressing movement patterns or spawning behavior of desert redband trout. Outside of Idaho, a single study addressing desert redband movement patterns has been conducted in southern Oregon using radio telemetry, but results are not being made available by the authors.

General movement patterns of desert redband trout within a drainage have implications in habitat management and estimation of extinction risk. Identification of population boundaries is important in developing estimates of population size and assessing the likelihood of various tributaries being demographically linked (Schill 2002). Identification of spawning movement patterns and actual spawning sites also has habitat management implications for the subspecies in Idaho. If most of the spawning activity occurs in limited stream segments, potential areas in need of heightened habitat management and protection may be identified. Alternatively, due to highly fluctuating water conditions and the tendency for individual streams to contain many intermittent reaches during droughts (as observed during 2001), the subspecies may have evolved a tendency for little to no movement during the spawning period. If such a life history pattern predominates, it would minimize the need for protecting any particularly important spawning reaches.

Because desert redband trout appear to inhabit streams with unusually high temperature profiles, mechanisms the subspecies employs to deal with these conditions have been the focus of several recent studies. Ebersole et al. (2001) concluded that an average of 10-40% of redband trout residing within 12 northeast Oregon stream reaches were observed within thermal refugia created by substrate upwelling during midafternoon periods of maximum stream temperatures. The same authors reported that abundance was inversely correlated with average maximum stream temperatures within 12 stream reaches. Li et al. (1994) suggested that temperature could influence overall distribution of redband trout in a watershed. However, whether individual redband trout respond to summer temperature extremes by moving sizeable distances has not been investigated.

The 2002 field season marked the second year of a cooperative project by IDFG and BLM designed to increase our understanding of desert redband trout populations and to evaluate their status in Idaho. This report documents results from that effort.

OBJECTIVES

1. To evaluate spawning movement patterns, locate principal spawning areas, and identify population boundaries for fluvial redband trout.

2. To assess redband trout movement/temperature interactions in Big Jacks Creek.

3. To continue temperature monitoring studies in various redband trout streams across their southern Idaho range.

STUDY AREA

Big Jacks Creek was selected to address focused life history work on movement patterns in desert redband trout. Big Jacks Creek flows northeasterly from the Owyhee mountains to the Snake River near the small town of Bruneau, Idaho (Figure 1). Detailed descriptions of flows, drainage area, elevation, vegetation, and channel type are available (Zoellick 1999). Segments of the stream and its tributaries lie in 20-260 m deep canyons with narrow floodplains carved through rhyolite lava (Zoellick, personal communication). Big Jacks Creek flows to the site of a U.S. Geological Survey gauging station 60% of the year at stream km 20.3, typically from January to June (Zoellick 1999). Perennial stream flow typically begins approximately 5-7 km above this site. The only direct road access to the stream occurs just above the gauging site; access to the remainder of the drainage is by foot at scattered trail locations, few of which are maintained.

We also continued temperature monitoring begun the prior year on 13 streams known or suspected to contain desert redband trout populations across their longitudinal distribution in Idaho (Figure 2). These streams varied in width from 1.2 to 8.4 m, and elevation at sampling sites ranged from 942 to 1843 m (Table 1). None of the streams are currently stocked with hatchery rainbow trout, although stocking had occurred historically at several of the sites (IDFG, unpublished data).

METHODS

Radio Telemetry

Radio Tagging

Radio telemetry was used to evaluate movement patterns of desert redband trout in Big Jacks Creek from mid March to October of 2002. Redband trout were collected from March 18 to June 6 by DC electrofishing (30-60 Hz) and anesthetized with MS-222. Fish were weighed (g) and measured (mm); sex was determined on as many fish as possible by stripping of potential males and examination of the vent for the presence of an ovipositor. Following a ventral incision, a radio tag emitting a uniquely coded identifying number was inserted just anterior to the pelvic girdle (Table 2). A modification of the shielded needle technique was used to place an external whip antenna (Ross and Kleiner 1982; Rich 1992). Antennae were trimmed at the tip of the caudal fin to reduce stress on the fish. For a more detailed description of tag implantation techniques, see Schill et al. (1994).

Two tag models weighing 2.63 g (NT6-1) and 2.0 g (NT-4-2L) manufactured by Lotek Wireless, Ontario, Canada were used. Burst rates of 10 seconds resulted in guaranteed transmitter life expectancies of 230 and 130 days for the large and smaller tags, respectively (Neil Bower, Lotek Wireless personal communication, January 16, 2002). Winter (1996) recommended limiting transmitter weights to less than 2% of the fish's weight, but more recently, Brown et al. (1999) demonstrated that transmitters weighing up to 12% did not alter swimming performance and suggested the "2% rule" had little scientific basis. Based on length-weight relationships derived from past sampling in Big Jacks Creek, we established an *a priori* minimum target length of 200 mm, which would result in a tag/fish weight ratio of 3% or less. Based on a preliminary examination of redband maturity data across Idaho (Schill unpublished data), a strong majority of those fish radio tagged (>210 mm) should be mature spawning-sized adults.

We radio tagged fish at each of four general locations throughout Big Jacks Creek in 2002 (Figure 3). Location of all tagging sites was recorded via GPS. Sites A (below Hole in the Rock) and B (Lahtinen Trail) were selected to determine if redband trout move upstream substantial distances during the spawning season and/or to escape higher summer stream temperatures known to occur in lower reaches (Zoellick 1999). To maximize the opportunity to detect spawner use of the three major tributaries, we tagged fish in the immediate vicinity of tributary streams including Wickahoney Creek, Duncan Creek, and Cottonwood Creek (Site C). Site D, near the Willies Creek confluence, was selected to determine if downstream movement in the basin occurs postspawning or during the fall/early-winter period as in Westslope cutthroat trout *Oncorhynchus clarki* (Lewynsky 1986).

Tracking

Aerial tracking was limited to a single late fall flight because of safety risks associated with low level flight in the vertical canyons and the likelihood of signal bounce among canyon walls. In addition, the remoteness of Big Jacks Canyon and lack of any road crossing or developed trail along any portion of the stream limited the potential frequency of ground tracking. Instead, to assess general spawning and spring-to-fall movement patterns, we relied on fixed-site detections with limited supplemental ground tracking (Bjornn et al. 2000). Fixed-site radio receivers (Lotek Wireless SRX400) were installed at five sites in the basin including the mouth of the three largest tributaries (Figure 3). Receiver installation dates ranged from March 18 on Wickahoney Creek to March 27 on Cottonwood Creek. Fish presence in the vicinity of or moving past these sites was recorded every 10 seconds by the fixed receivers. Receivers were housed in water resistant, grounded, security boxes designed by Aurora Power, containing a 33 amp/day battery and voltage regulator. Batteries were recharged using 21 to 55 watt Siemens solar panels.

We installed two basic types of 3-element Yagi antenna arrays (receiver site antennae manufactured by Maxrad, hand-tuned to frequency 149.380). Antenna switch boxes (Lotek Wireless ASP-8) were installed on the radio receivers to permit use of multiple antennae at each site. Three-antenna arrays were installed at tributary mouths to detect both entrance of tagged fish into tributaries or mainstem passage past them. Two-antenna arrays were constructed for the Hole in the Rock and Kittys Point sites to verify fish movement past the receiver site. As part of installation, arrays were tested and receiver gains set by passing through each antenna's field of reception with an activated radio tag attached to a stick and held underwater.

Equipment checks and receiver data downloads were initially completed biweekly at each site. Time between site visits was extended to one month once a site was consistently functioning and receiver data storage was determined not be a concern due to limited fish movement. The operational status at each receiver site was verified by the use of an activated test tag during each site visit for the entire study period.

One subobjective of this project was to identify principal spawning areas for fluvial redband trout in Big Jacks Creek. Schill (unpublished data) observed redd building and spawning activity for a single redband trout pair in Duncan Creek, a Big Jacks Creek tributary, on May 11, 2001. We conducted limited ground checks of radio-tagged fish using mobile radio receivers during late April 2002 to identify when spawning activity began. Once spawning activity was observed in May, we hiked the entire length of Big Jacks Creek known to contain radio-tagged fish based on original tagging sites and documented movements past the fixed station receivers. We sought to record GPS locations of all radio-tagged fish and document time and location of all spawning activity observed by both tagged and untagged fish.

To evaluate broadscale relationships between summer stream temperature and redband trout movement patterns, we installed Hobo Temp™ data-loggers on mainstem Big Jacks Creek and placed an additional eight in tributaries during April and May 2002 (Figure 4). Thermographs were installed upstream and downstream of tributary confluences to evaluate possible reductions in mainstem stream temperatures. Thermographs were also installed in Duncan and Cottonwood Creeks near their mouths. We sought to learn whether radio-tagged redband trout in Big Jacks Creek would use the cooler thermal plumes of tributaries during periods of heat stress as has been observed in adult steelhead trout (High 2002).

Maximum stream temperatures occur in the Big Jacks Creek mainstem from approximately 7/7 to 8/15 (B. Zoellick, BLM, unpublished data; Schill et al. 2002). We conducted ground surveys along the entire length of Big Jacks Creek during this warmwater period to locate radio-tagged fish and note the presence of untagged trout. The intent of this effort was to compare general midsummer movement patterns of individual tagged fish with temperature profiles being recorded at the various thermographs installed within the basin.

In addition to the two major ground survey efforts noted above, we flew the entire mainstem of Big Jacks Creek and Cottonwood Creek to the barrier falls in a helicopter with a mobile SRX receiver on September 26 to locate radio-tagged fish. Location of all detected signals was recorded using GPS coordinates at the site of maximum signal strength based on auditory perceptions and/or detected signal power on the Lotek Receivers.

Analysis of Movement Data

General movement and spawning migration patterns were evaluated by calculating minimum known distances moved between initial tagging site and the various fixed receiver sites at fixed time intervals (Bjornn et al. 2000). In addition, distances moved between initial tagging sites and subsequent ground observations during the spawning period were calculated from GPS coordinates. Lastly, the distance moved from the observed ground location during the spawning period to the August warmwater period for individual tagged fish was also calculated.

Rangewide Stream Temperature Evaluations

In addition to temperature evaluations conducted in Big Jacks Creek as part of the movement study, we continued monitoring stream temperatures in various redband trout streams across their range begun in 2001 (Schill et al. 2002). Thermographs recorded temperatures hourly from installation date during the spring until data were downloaded during October and November 2002. Thermographs were subsequently relaunched to allow for development of complete annual temperature profiles for a two-year period.

RESULTS

Radio Telemetry

Radio Tagging

A total of 48 redband trout were tagged in Big Jacks Creek during 2002 between March 18 and June 5 (Figure 5). There appeared to be a major decline in trout abundance in the Big Jacks Creek drainage compared to mid 1990s levels when sampling was last conducted (B. Zoellick, BLM, unpublished data). As a result, considerably more time was required to collect the fish than had been anticipated. Electrofishing was conducted on 13 different days to collect enough fish for tagging. These fish ranged in length from 191 to 320 mm and weighed 70 to 300 g (Table 2). Despite sampling just prior to the likely spawning period, we were unable to positively ascertain sex on 27 of the fish tagged. Not surprisingly, most (66.7%) of the fish we were positively able to sex were males. Tag/body weight ratios of radio-tagged fish ranged from 0.9 to 3.7%. Slightly over half (54%) of these ratios were less than 2%, and a strong majority (92%) was three percent or less. The tag/body weight ratio exceeded our original target (3%) in four fish, ranging from 3.1 to a maximum of 3.7%.

Tracking

Fixed Site Receivers—A total of 10 individual tagged fish moved past at least one fixed receiver site during the study period, moving an average of 2,858 m from their initial tagging location (Table 3). Nearly all of this movement appeared to be associated with an upstream spring spawning migration (Table 3). Fish #11 demonstrated the most upstream movement past fixed sites. This fish was radio tagged on April 18 and moved a total of 4.3 km by May 4 when it moved upstream past a fixed receiver and entered Duncan Creek. Consecutive day detections from two to four days in length were recorded for six fish at the three fixed-site receivers placed at tributary mouths (Table 3).

Insufficient movement was detected past the fixed stations to document any other major trends in movement. Taken alone, results from the fixed receivers would be an indication that movement of redband trout was very limited during the study period. However, results of ground tracking surveys (see below) suggest that a number of tag malfunctions occurred, limiting the utility of fixed-receiver findings.

Ground Tracking Surveys - Spawning Period—To begin identifying spawning locations, ground tracking of radio-tagged fish using a mobile radio receiver was conducted on a 4.9 km length of Big Jacks Creek on April 21 and April 29; no activity was observed. Due to manpower limitations, ground telemetry surveys were not conducted again until May 21. Again, no spawning activity was observed that day along Big Jacks Creek from the Holman Trail crossing to the Cottonwood Creek confluence (5.3 km) while tracking radio-tagged fish. However, on May 22, we observed 6-8 untagged redband trout actively digging redds and spawning in Duncan Creek approximately 800 m below the Buncel Ford while walking downstream to the Big Jacks Creek confluence. Additionally, two redds were observed downstream immediately below the large boulder falls (8580684E, 4712023N) and two other large redds 194 m above the Duncan Creek/Big Jacks Creek confluence (580863E, 4712529).

Once this spawning activity was observed, we immediately began hiking that length of mainstem Big Jacks Creek that could possibly contain radio-tagged fish. This work, completed between May 21 and June 5, was intended to document spawning locations in a 35.4 km segment of Big Jacks Creek between Hole in the Rock and Cottonwood Creek. However, we observed no spawning activity or redds. In addition, we visually observed no redband trout in this same stream length, including either untagged or radio-tagged individuals. Although water conditions did not permit us to observe fish in the deeper pools during this time period, visibility appeared sufficient to readily permit observation of redd building activity in pool tailouts or other suitable spawning substrate. We observed such unused habitat in numerous locations along the stream.

By the date telemetry surveys were begun in the spawning period (May 21), 32 fish had been radio tagged for periods ranging from 26 to 64 days. Of these fish, 13 (40.1%) were located and determined to be alive between May 21 and June 5 (Figure 6). Nine had moved downstream; the remaining four traveled upstream after tagging. Average distance moved since the original tagging date for these fish was 457 m (Table 4).

Of the 32 fish radio-tagged by May 21, 6 (18.8%) were recorded as known mortalities based on a complete lack of movement when wading through the stream in the immediate vicinity of the tag (Table 5). In most cases, any fish alive should have been readily observable. Although we recorded these fish as mortalities, no actual fish carcasses or tags were found in the substrate. The color of the small tags in the large basalt streambed and cloudy water made their visual location difficult. Along with actual undocumented mortality, it is possible that some of the tags were expelled based on previous studies of rainbow trout and other species.

Of more concern than mortalities/expulsions, a surprisingly high number of radio tags were not heard during the spawning period survey. Ten of the tags (31.3%) implanted 26-64 days prior to the ground tracking effort (May 21 to June 5) were not located anywhere in mainstem Big Jacks Creek within original tagging areas bounded by functioning fixed-receiver stations. Each of the three potential spawning tributary mouths were also being guarded with stationary receivers that successfully recorded the movement of a small number of tagged fish during this time period as discussed above. However, none of the missing 13 radio-tagged fish were detected passing upstream into tributaries.

Ground Tracking Surveys Mid Summer—A second ground tracking survey was completed during the warmwater summer period between July 30 and August 14. By this time, 48 fish had been radio tagged for periods ranging from 70 to 149 days. Of these fish, 13 (27.1%) were located and determined to be alive during the midsummer survey (Figure 7). Eleven of these fish (84.6%) were located downstream from their tagging location; the remaining two were located upstream (Table 4). Average distance moved since the original tagging date for these fish was 340 m. Eight tagged fish were located during both ground surveyed periods. Distances moved between the two surveys averaged 271 m (Table 4).

Of the 48 fish radio tagged, 10 (20.8%) were recorded as known mortalities, which as noted above could include both actual mortality and/or tag expulsion. Twenty-five (52.1%) of those fish radio tagged in the preceding 67-137 days were not found when hiking the Big Jacks Creek mainstem from the pipeline crossing (site of complete channel desiccation) to the headwater spring source at the falls (48.8 km). As during the earlier ground survey, the missing tagged fish had not ascended the three tributaries based on results from fixed-site receivers (Table 3).

Aerial Tracking—A large majority of radio tags released within the Big Jacks Creek drainage were not located during the September 26 helicopter flight. The aerial survey was completed prior to the life-expectancy cutoff date for 44 radio tags. Of these tags, 33 (75%) were not found; only 11 were detected (Figure 8). One of the tags located via air had not been previously detected during the two ground surveys or by the fixed station receivers. Tag #30 was located near the top of the canyon wall, well to the east of the stream channel, almost certainly carried there by a raptor. In addition to the results above for tags within the life-expectancy cutoff, one of four tags past the cutoff date was located via helicopter. This tag was operating 26 days past the guaranteed tag life date.

Rangewide Stream Temperature Evaluations

Temperature data for periods ranging from January 1 to December 31 were collected at 36 sites in 2002. Results of this temperature monitoring effort are presented in Appendix A along with associated UTM coordinates for all sites (Appendix B). Due to the timing of this report, additional information for 2003 is included for several of these streams.

In 2001, temperature data for the entire summer warmwater period were successfully recorded at all but four locations. Due to a fire and subsequent bedload movement, water flow at the Bennett Creek and Dive Creek sites effectively declined to zero during midsummer with resultant thermograph dewatering. The lower Crab Creek site was dewatered by late July (Appendix A). Due to time constraints, we were unable to download data from a single site on Duncan Creek. Vandals removed another thermograph on this stream during the 2001 deployment period.

In 2002, temperature data were successfully recorded at all but three locations. On Little Canyon Creek, dewatering of the thermograph occurred for a brief period in July based on maximum observed water temperatures (Appendix A). We also experienced thermograph malfunctions for periods of the year on Big Jacks Creek above the Cottonwood confluence and at Big Jacks Creek below the Wickahoney Creek confluence.

During 2003, a thermograph malfunction occurred on Little Canyon Creek from December 2002 until it was detected during downloading in August (Appendix A). In addition, the Duncan Creek site at Zeno Canyon was dewatered after July 2003, as was most of the nearby stream channel for several km.

DISCUSSION

Regardless of the problems noted above in successfully locating radio-tagged fish, it seems apparent that a major decline in population abundance has occurred in Big Jacks Creek. Bruce Zoellick (unpublished data) documented redband trout densities in the lower half of mainstem Big Jacks Creek from 1996 to 1998 that appear to be an order of magnitude higher than we observed during electrofishing operations in 2002. Further, 2002 electrofishing within several miles of stream near Holman Trail resulted in the capture of few fish and virtually no adult fish. During the prior year (2001) Schill (unpublished data) easily captured numerous (50+) 200-300 mm redband trout near Holman trail via angling on several occasions in July and August. Due to the apparent precipitous decline in redband trout numbers throughout mainstem Big Jacks Creek, we recommend that further life history investigation of the population using radio telemetry be discontinued, at least until the population has rebounded. It would be useful to conduct population estimates in the numerous sites sampled by Zoellick in the late 1990s to document the actual extent of population declines.

Despite walking the entire mainstem section of the stream from Hole in the Rock to Cottonwood Creek during the spawning period (based on observation of redd building in Duncan Creek), we failed to observe a single incidence of spawning activity in mainstem Big Jacks Creek. While cloudy water may have made observation of fish difficult in some of the larger pools, redd digging activities should have been visible in pool tailouts. Although it is possible that mainstem spawning occurred earlier and redds covered over with sediment, this possibility seems unlikely. The limited data provided by the fixed-site receivers shows upstream migration, presumably associated with a spawning run, was occurring commonly in mid to late May (Table 3). Based on the above results, we believe that redband trout spawning was minimal during 2002 in the mainstem of Big Jacks Creek below Cottonwood Creek.

Despite data limitations due to the high rates of tag signal loss, some limited information regarding tributary spawning of mainstem fish in Big Jacks tributaries can be gleaned from the data. Based on the fixed site receivers, we observed no tagged trout ascending Wickahoney Creek, while fish did ascend Cottonwood and Duncan Creeks during the likely spawning period. The lack of spawning trout in Wickahoney Creek was not surprising as at least the lower 5 km of the stream has been dry for most of the preceding few years (D. Schill, personal observations). In Duncan Creek, two radio-tagged fish entered and remained in the stream during the presumed spawning season—the first fish for four days (April 22-26) and the second for six days (April 28-May 4). On Cottonwood Creek, one fish first entered the stream on May 7 and exited 13 days later only to reenter the stream the following day. This fish (Tag #5) was ground tracked to a location approximately 1 km upstream in Cottonwood Creek on May 29. However, it did not return past the fixed station, assuming the tag continued to function correctly. A second fish spent five days in Cottonwood Creek from May 12-18 and a final fish spent a single day in the stream from May 28-29. Thus, while data are obviously limited and we did not actually observe spawning of radio-tagged fish, Cottonwood and Duncan Creek do appear to function as spawning tributaries for the Big Jacks Creek Population.

A summary of mortality data for radio-tagged rainbow trout suggests considerable mortality of radio-tagged fish occurred during the study period. Known mortality of tagged fish ranged from 18.8 to 22.9% from the period of marking and the two ground survey periods (Table 5). This estimate of known mortality was based on our inability to see radio-tagged fish following careful triangulation in habitats where sufficient visibility existed, or to confirm the presence of live fish by displacing and subsequently re-locating them in shallower water habitats. In some instances, radio-tagged trout were found in pools too deep to employ either of the above techniques, and such fish were classified as live. Thus, the mortality estimates above could be substantial underestimates. In retrospect, use of mortality-detecting tags would have been quite desirable for this study, although such tags often result in sizeable power loss and might not be available for such a small coding tag.

The above discussion regarding mortality detecting tags serves as a lead-in to the much more important discussion of the high and disabling number of tag signals lost in this study. The proportion of tag signals lost increased from 31.3% during the spring ground survey to 52.1% during the midsummer survey and reached an inexplicable rate of 75% during the final helicopter flight in September (Table 5). Regardless of the cause of the signal loss, such high rates largely eliminated our ability to address the primary study objectives effectively, although the small amount of movement information discussed above has some value. Due to the same high signal loss rate, we opted not to attempt correlating the limited movement data from this study with midsummer temperature information collected throughout the basin. We had hoped to examine whether summer movement patterns were influenced by high summer temperature extremes as has been suggested in other studies of redband trout (Li et al. 1994; Ebersole et al 2001). Instead, given the poor success of the radio telemetry work, we have simply opted to mesh the considerable amount of temperature data collected in Big Jacks Creek with the wider range dataset being developed for redband trout in southwest Idaho (Appendix A).

Given the extreme remoteness of Big Jacks Creek Canyon, and our inability to sample sizeable portions of the drainage, it is impossible to know the cause of such signal loss with 100% certainty. However, evidence and logic points to tag failure as the likely cause of the problem. Of the 48 radio tags inserted into redband trout in the Big Jacks Creek study, all should have been operating and locatable during the August ground surveys and 44 were within the guaranteed battery life during the September helicopter surveys (Table 5). During the September helicopter survey, those few tags located (11) were readily detected from the air at considerable distances with no apparent decline in signal strength for those tags approaching their guaranteed life expectancies.

Big Jacks Creek is somewhat unique compared to other streams where radio telemetry is often conducted, as there was no possible way for tagged fish to escape out of the study area. During the study, the desert stream disappeared completely around river km 25, approximately 5 km below the area where the lowest group of fish was radio tagged. Consequently, fish were unable to leave the bottom of the basin, and their upstream movement is blocked by a 20 m falls about 10 km below the headwaters (Figure 3). Each of the three possible spawning tributaries was “guarded” with stationary receivers, and we verified their functionality numerous times during the study via use of test tags. Further, upstream movement of redband trout in the tributaries was blocked in all three tributaries during the study period due to a culvert on Wickahoney Creek, stream desiccation on Duncan Creek near Buncel Ford, and a large barrier falls on Cottonwood Creek. We ground hiked or flew the length of all three tributary streams below these barriers to verify that no radio-tagged fish escaped by the fixed-site receivers. Based on the above observations, it becomes apparent that the tagged fish did not swim out of the study area.

Other than tag failure, the only other possible explanation for the eventual 75% tag signal loss would be removal of the tags from the entire Big Jacks basin via avian predators. Indeed, we found evidence that a single tag was transported to a high cliff above the stream. However, when conducting the helicopter flight and observing the surrounding terrain outside of the Big Jacks Creek basin, we visually assessed the possibility that 75% of the radio-tagged trout in Big Jacks Creek were transported completely outside of the huge canyon walls by avian predator/scavengers. We discounted that explanation as totally unlikely.

As noted above, after evaluating other possible explanations for the high rate of tag signal loss, the most likely explanation is tag failure. Of the original 48 tags inserted in fish, all should have been detected during the extensive midsummer ground survey and at least 44 should have been detected during the September aerial flight. A graphical summary of actual results shows this was clearly not the case (Figure 9). Assuming tag failure to be the cause of signal loss, we are left to speculate about the cause for this mishap. The small size of redband trout in Big Jacks Creek and our interest in evaluating movement over a relatively long time period necessitated our reliance on some fairly new technology. Indeed, we were among the first in the nation to employ the smaller of the two tags (the 2.0 g NT-4-2L) in a field study. Further, for both tag models used, we had the manufacturer set an unusually long burst rate of 10 seconds to extend battery life. Perhaps assumptions used in developing estimates of radio tag life using this unusually long burst rate did not actually result in the tag life projected. In summary, it is possible that reliance on new technology and employment of a relatively uncommon burst rate contributed to the high tag failure rate.

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Table 1. Redband trout streams monitored for temperature, southwest Idaho (UTM Zone 11), 2001 and 2002.

Site name	Stream width	Elevation (m)	UTM Easting	UTM Northing
Bennett Creek		1420	621328	4786796
Big Creek	1.2	1843	721455	4661460
Castle Creek	2.2	1085	546074	4749350
Crab Creek	1.5	1707	582386	4690950
Dive Creek		1419	621333	4787012
Jarbidge River, EF	8.4	1565	635122	4654588
Jump Creek	2.9	762	506380	4813950
Little Canyon Creek	1.6	1561	636402	4781260
Little Jacks Creek	3.2	1088	573257	4731076
McMullen Creek		1305	716688	4696449
Salmon Falls Creek	4.4	1113	675859	4702004
Sinker Creek	2.7	942	541490	4776243

Table 2. Summary of radio telemetry implants of redband trout tagged in Big Jacks Creek, 2002.

Tagging Date	Tag #	Location tagged[a]	Length (mm)	Wt (g)	Tag size (g)[b]	Sex	Tag % of body wt.
3/18/02	20	Below Duncan	253	160	2.6	M	—
3/18/02	51	Below Duncan	274	218	2.6	—	—
3/20/02	47	Below Duncan	218	110	2.6	—	—
3/21/02	17	Bottom of Lahtinen	216	113	2.6	—	—
3/21/02	16	Bottom of Lahtinen	253	162	2.6	F	—
3/20/02	49	Above Duncan	270	206	2.6	—	—
3/21/02	48	Bottom of Lahtinen	294	248	2.6	M	—
3/21/02	50	Bottom of Lahtinen	203	87	2.6	M	—
3/21/02	46	Bottom of Lahtinen	262	172	2.6	—	—
3/22/02	15	HITR	204	70	2.6	M	—
3/22/02	14	HITR	213	78	2.6	M	—
3/22/02	2	HITR	260	166	2.6	M	—
3/27/02	42	Below Lahtinen	281	212	2.6	F	—
3/27/02	1	Below Lahtinen	248	150	2.6	—	—
3/28/02	6	Kittys Point	205	116	2.6	—	—
3/28/02	44	Kittys Point	216	128	2.6	—	—
3/28/02	45	Kittys Point	286	250	2.6	M	—
3/29/02	18	Above Holman Trail	243	176	2.6	F	—
4/17/02	3	Parker to WC	283	244	2.6	M	—
4/17/02	19	Parker to WC	320	300	2.6	M	—
4/17/02	21	Parker to WC	221	105	2.6	F	—
4/18/02	39	Parker to WC	191	74	2.0	—	—
4/18/02	11	Parker to WC	227	112	2.6	M	—
4/24/02	12	Above Holman Trail	211	93	2.6	—	—
4/24/02	4	Above Holman Trail	234	128	2.6	M	—
4/24/02	38	Above Holman Trail	202	84	2.0	F	—
4/24/02	9	Above Holman Trail	205	84	2.6	—	—
4/24/02	5	Above Holman Trail	265	198	2.6	M	—
4/25/02	8	Below Cottonwood	225	116	2.6	—	—
4/25/02	40	Below Cottonwood	200	84	2.0	F	—
4/25/02	7	Below Cottonwood	222	116	2.6	M	—
4/25/02	41	Below Cottonwood	225	106	2.0	F	—
5/30/02	33	Pipeline Tr to HITR	238	122	2.0	—	—
5/30/02	28	Pipeline Tr to HITR	224	112	2.0	—	—
5/30/02	35	Pipeline Tr to HITR	280	188	2.6	—	—
5/30/02	29	Pipeline Tr to HITR	253	128	2.0	—	—
5/30/02	31	Pipeline Tr to HITR	261	170	2.0	—	—
6/4/02	30	Pipeline Tr to HITR	233	120	2.0	—	—
6/4/02	26	Pipeline Tr to HITR	229	114	2.0	—	—
6/4/02	32	Pipeline Tr to HITR	227	104	2.0	—	—
6/4/02	27	Pipeline Tr to HITR	210	88	2.0	—	—
6/5/02	37	Willies Ck	208	87	2.0	—	—
6/5/02	24	Willies Ck	199	79	2.0	—	—
6/5/02	34	Willies Ck	237	112	2.0	—	—
6/5/02	36	Willies Ck	213	86	2.0	M	—
6/5/02	10	Willies Ck	241	144	2.0	—	—
6/5/02	22	Willies Ck	201	88	2.0	—	—
6/5/02	23	Willies Ck	218	102	2.0	—	—

[a] Site abbreviations: HITR = Hole in the Rock, WC = Wickahoney Ck
[b] Two sizes of LOTEK tags were used: NTC-6-1 = 2.6 grams, NTC-4-2L = 2.0 grams

Table 3. Summary of fish movement past five fixed-site receivers, Big Jacks Creek and tributaries, Owyhee County, Idaho, 2002.

Fish No.	Date tagged	Tagging location	Date located	Receiver site	Distance from tagging site	Direction
20	3/18	C	4/22-4/26	Duncan Ck	1294	up
51	3/18	C	4/28	Duncan Ck	992	up
			5/4-5/5	Duncan Ck		
6	3/28	C	5/8-5/12	Wickahoney Ck	3903	up
			5/13	Duncan Ck	7220	up
3	4/17	C	5/12	Kitty's Point	2531	down
11	4/18	C	5/4-5/7	Duncan Ck	4310	up
			5/7	Wickahoney Ck	997	up
			6/15	Kitty's Point	4877	down
5	4/24	D	5/7	Cottonwood Ck	1773	up
			5/20-5/21	Cottonwood Ck		
40	4/25	D	5/11	Cottonwood Ck	1264	up
			5/16	Cottonwood Ck		
38	4/25	D	5/12-5/13	Cottonwood Ck	2559	up
			5/18	Cottonwood Ck		
7	4/25	D	5/19	Cottonwood Ck	877	up
			5/28-5/31	Cottonwood Ck		
41	4/25	D	9/28	Cottonwood Ck	878	up
Average distance moved					2858	

Table 4. Summary of redband trout movement events from original tagging locations to sites observed during the spawning period (May 21 to June 4) and in midsummer (July 30 to August 14), Big Jacks Creek, 2002.

		Distance from Tagging Site				Distance between sightings	
Fish No.	Date Tagged	May /June Distance (m)	Direction	July/ Aug Distance (m)	Direction	Distance (m)	Direction
20	3/18/02	562	up	615	up	53	up
51	3/18/02	242	down	345	down	103	down
47	3/20/02	75	down	63	down	13	up
17	3/21/02	441	down	409	down	32	up
18	3/29/02	463	down	506	down	43	down
21	4/17/02	996	down	—	—	—	—
39	4/18/02	122	up	—	—	—	—
11	4/18/02	14	down	—	—	—	—
12	4/24/02	312	down	849	down	537	down
4	4/24/02	1494	up	96	down	1590	down
38	4/24/02	24	up	—	—	—	—
9	4/24/02	1021	down	977	down	44	up
41	4/25/02	180	down	157	down	23	up
28	5/30/02	—	—	98	up	—	—
31	5/30/02	—	—	120	down	—	—
27	6/5/02	—	—	61	down	—	—
34	6/5/02	—	—	124	down	—	—
Average distance moved		457		340		271	

Table 5. Eventual fate of radio tags implanted in redband trout in Big Jacks Creek, Owyhee County, Idaho, 2002.

			Tag fate (%)		
Survey type	Survey date	No. fish tagged[a]	Minimum mortality/ Expulsion[b]	Alive	Missing
Spawning season ground survey	May 21-June 5	32	6 (18.8)	16 (50.0)	10 (31.3)
Summer warm-water ground survey	July 30-Aug 14	48	10 (20.8)	13 (27.1)	25 (52.1)
Fall - Helicopter flight	Sept 26	44	[c]	[c]	33 (75)

[a] This value denotes tags released into Big Jacks creek still operating within the manufacturer's guaranteed life expectancy of 230 days for NT6-1 and 130 days for NT-4-2L.

[b] Based on streamside triangulation and lack of fish movement following wading disturbance, etc. Considered minimum mortality because some fish classed as "alive" occupied large, unwadeable pools with poor visibility.

[c] 11 tags heard but fate (mortality or alive) unknown from air.

Figure 1. Location of Big Jacks Creek and tributaries involved in movement and population delimitation studies via radio telemetry, Owyhee County, Idaho, 2002.

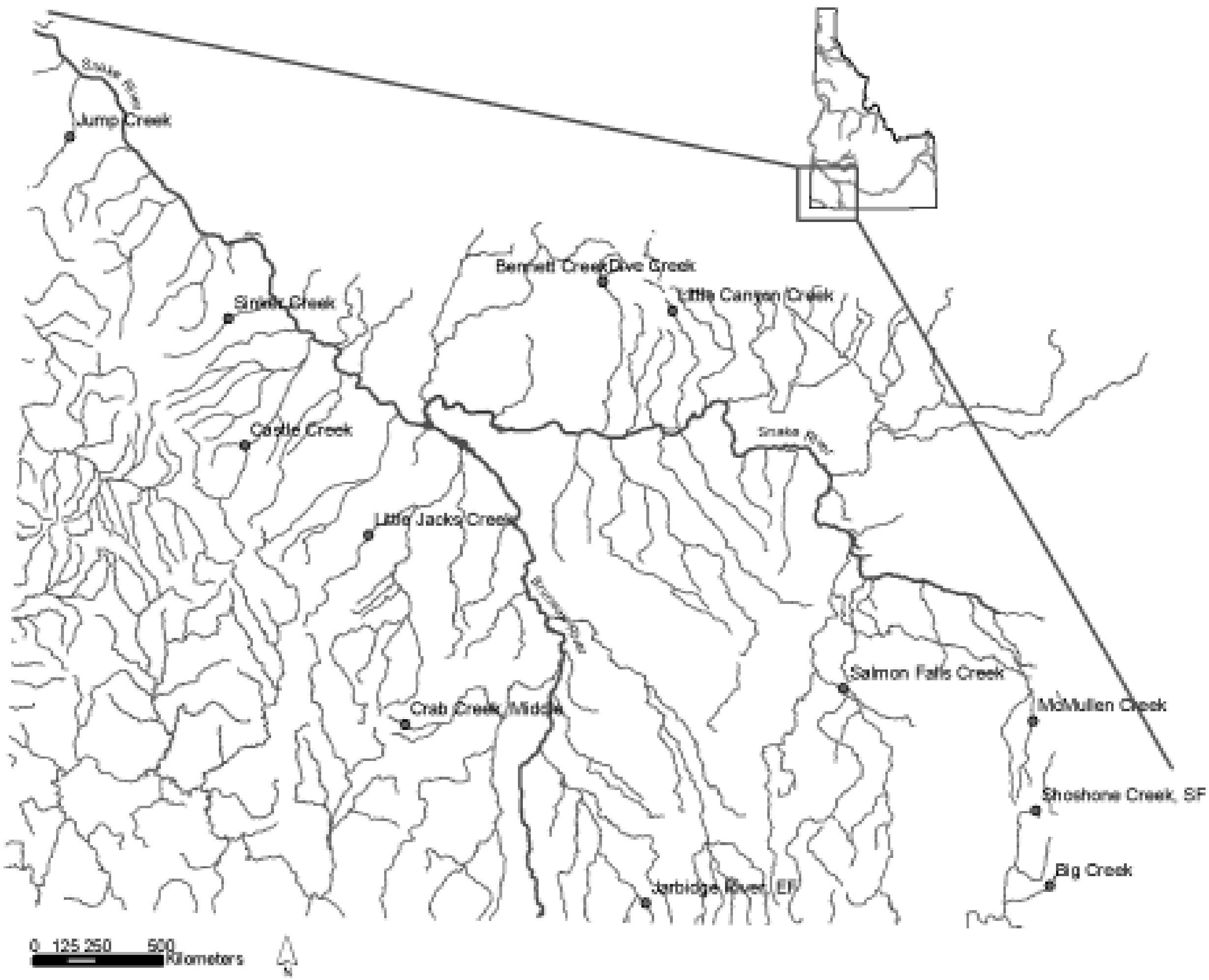


Figure 2. Location of stream temperature monitoring sites in redband trout streams originally monitored in 2001 and continued in 2002.

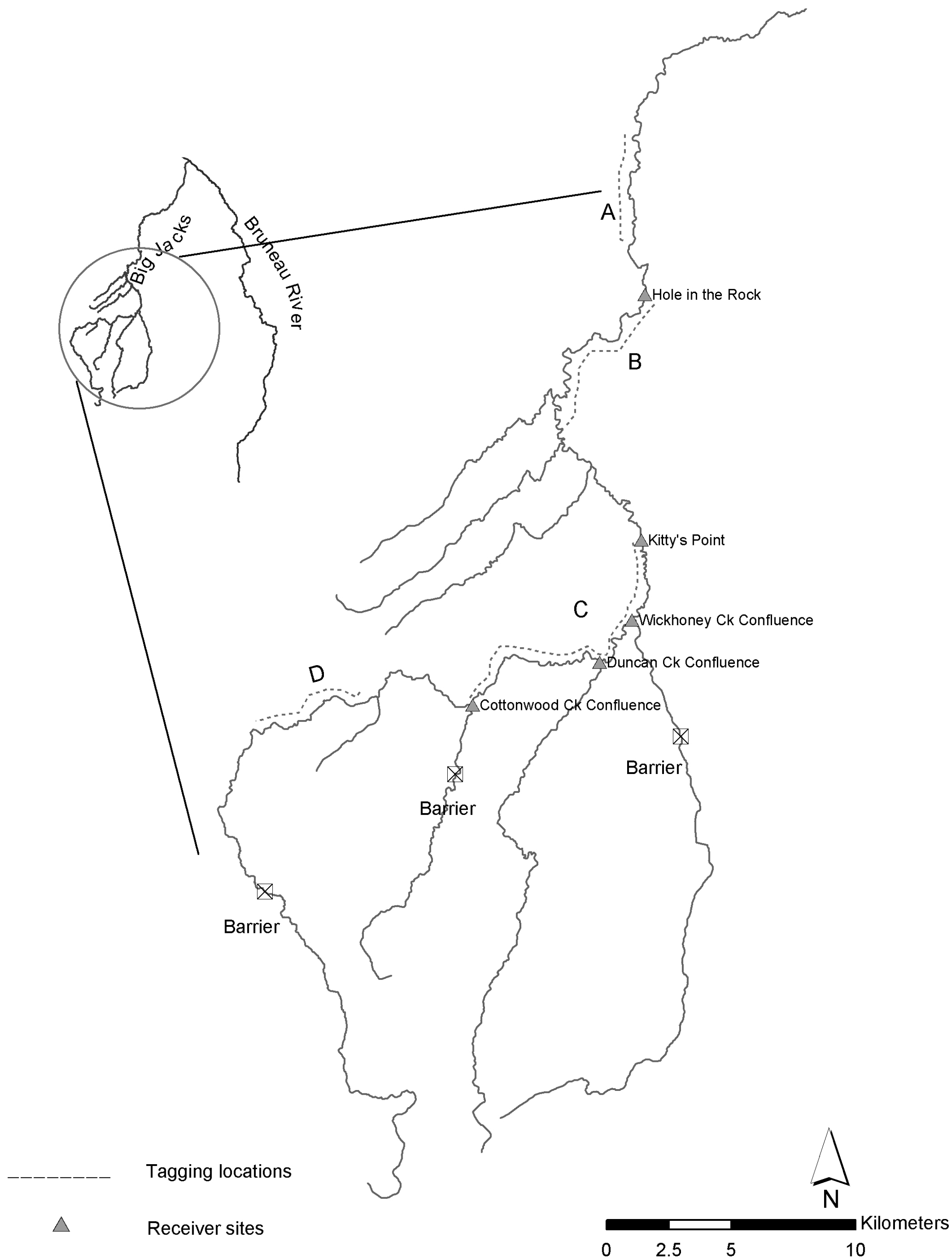


Figure 3. General radio-tagging locations and specific fixed-site receiver locations in the Big Jacks Creek drainage, Owyhee County, Idaho, 2002.

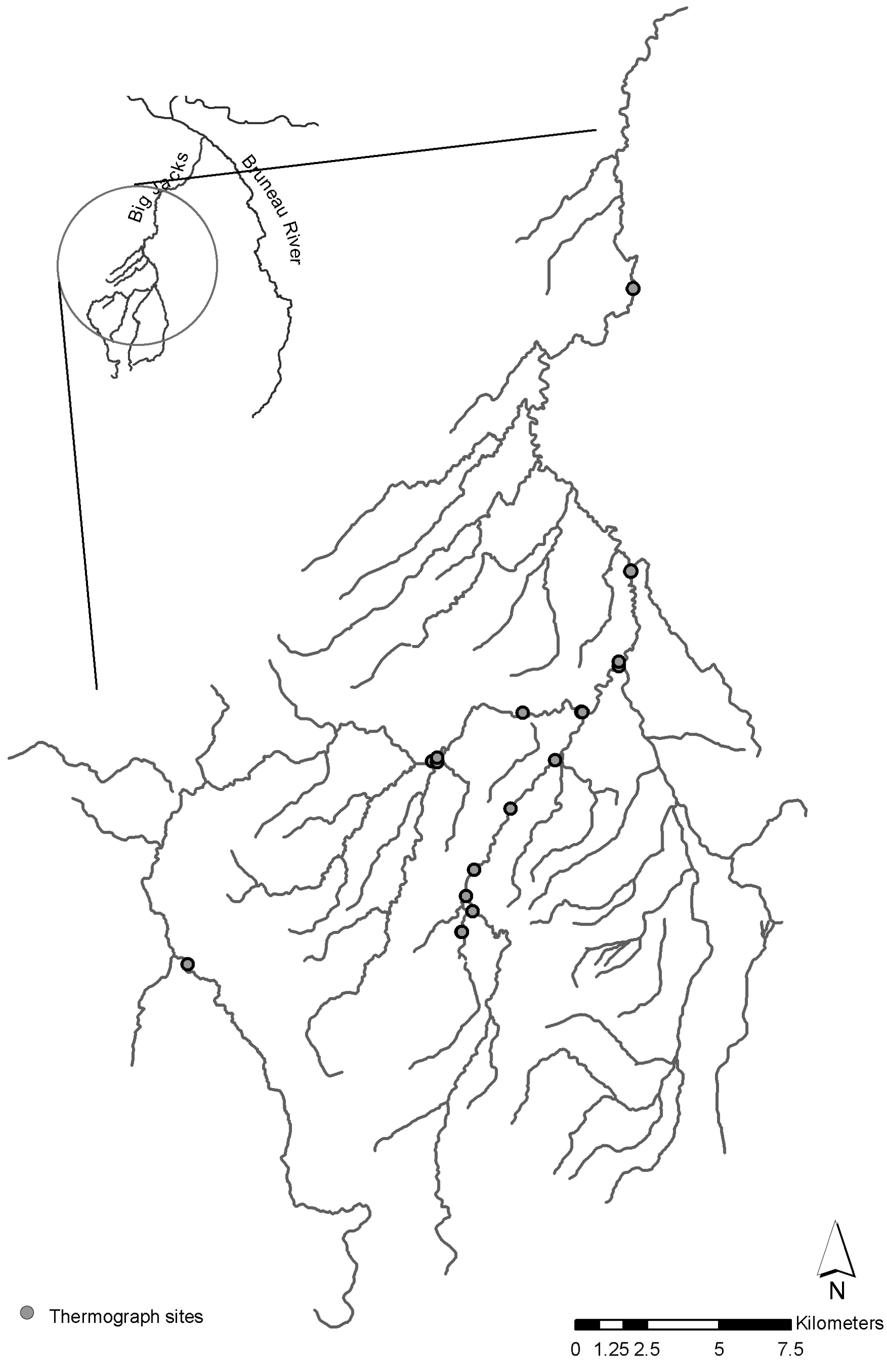


Figure 4. Location of thermographs installed to monitor hourly stream temperatures on Big Jacks Creek and tributaries, Owyhee County, Idaho, 2002.

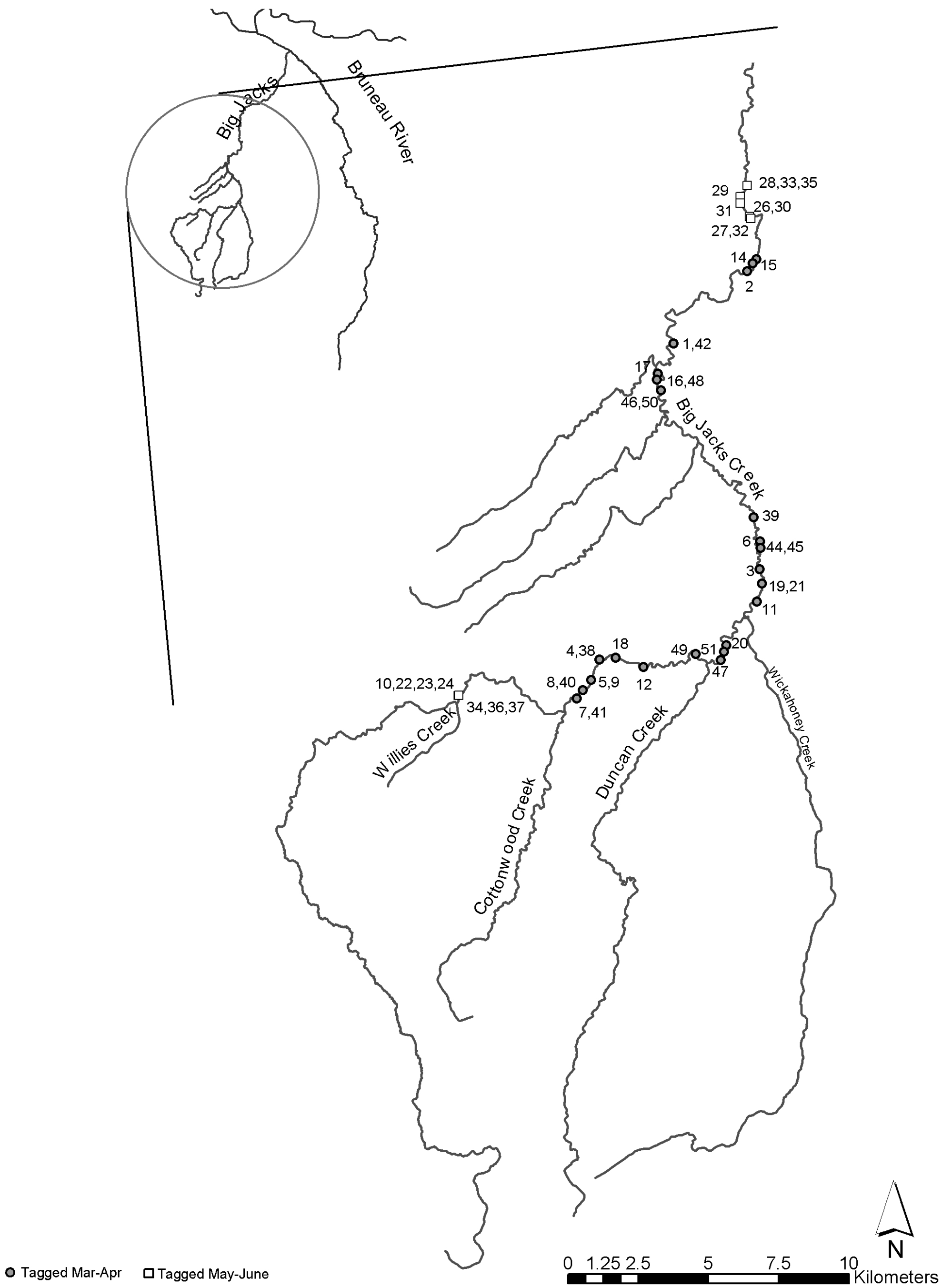


Figure 5. Tagging locations and transmitter tag numbers for 48 redband trout in Big Jacks Creek, 2002. Circles denote tagging locations for fish tagged in March and April, while boxes denote release sites for fish tagged in May and June.

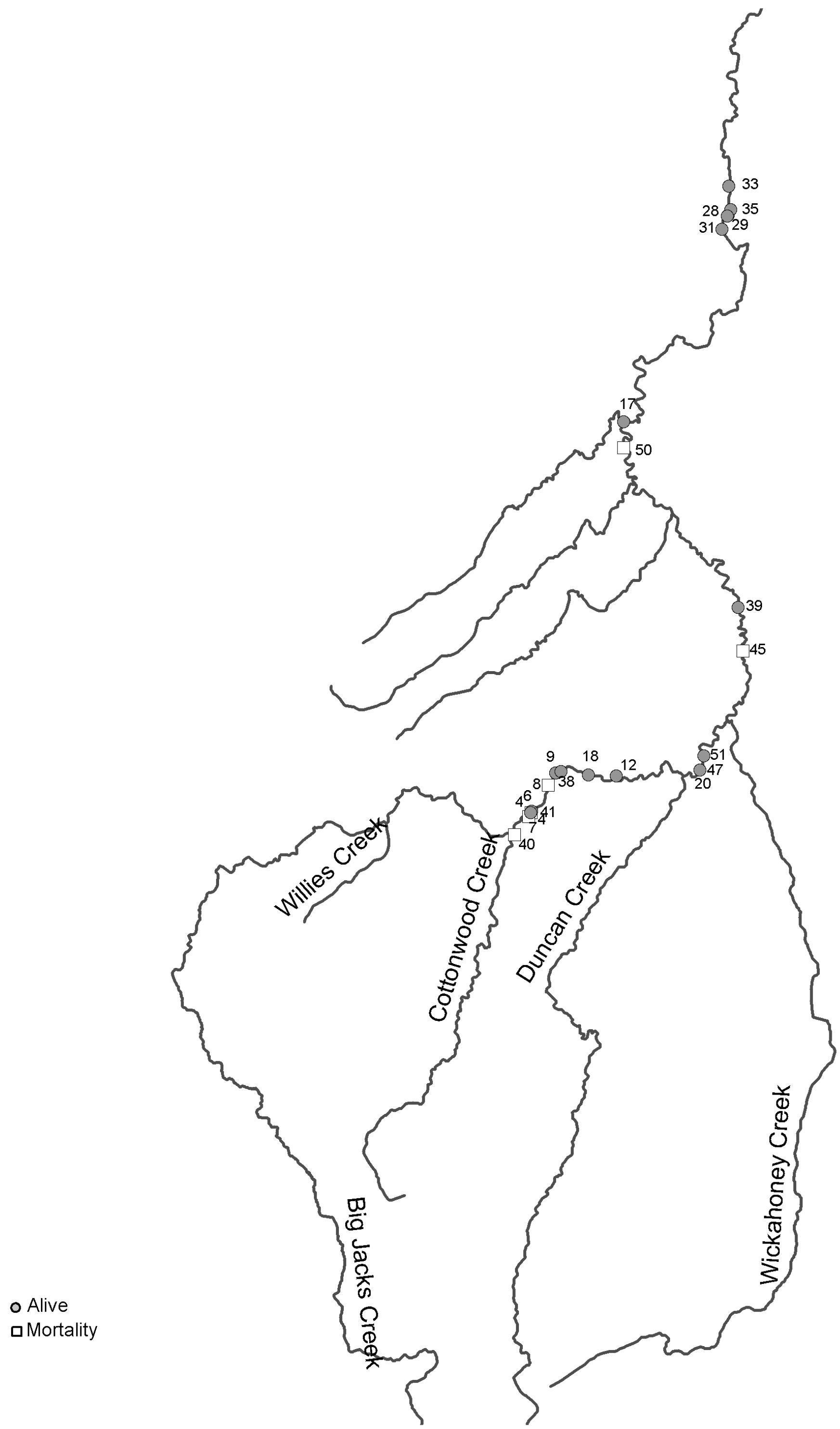


Figure 6. Results of ground radio tracking conducted during the spawning period on a 35.4 km segment of Big Jacks Creek from May 21 to June 4, 2002. Circles denote locations where fish were found alive, while boxes denote location of known mortalities. Numbers correspond to tag number of transmitter.

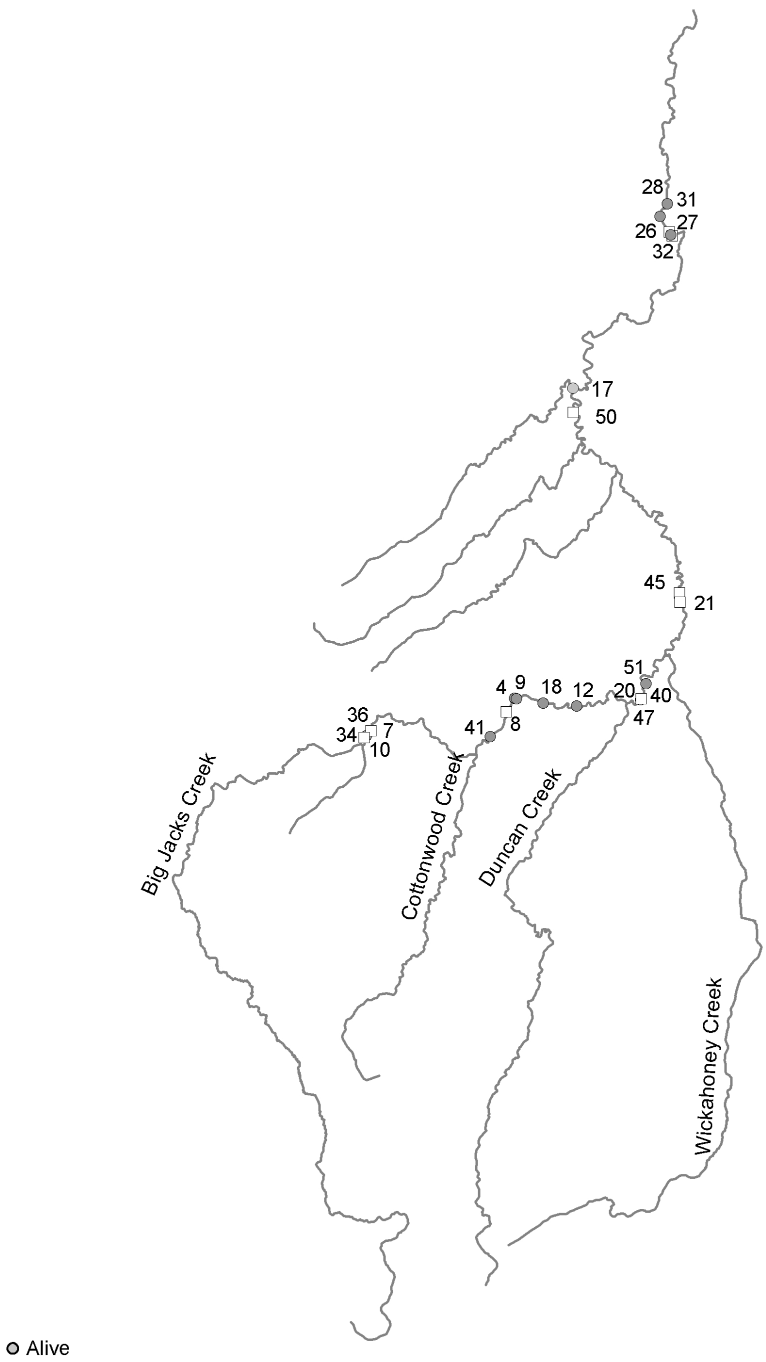


Figure 7. Results of ground radio tracking conducted during the midsummer period on a 48.8 km segment of Big Jacks Creek (site of complete stream desiccation to barrier falls) from July 30 to August 14, 2002. Circles denote locations where fish were found alive, while boxes denote location of known mortalities. Numbers correspond to tag number of transmitter.

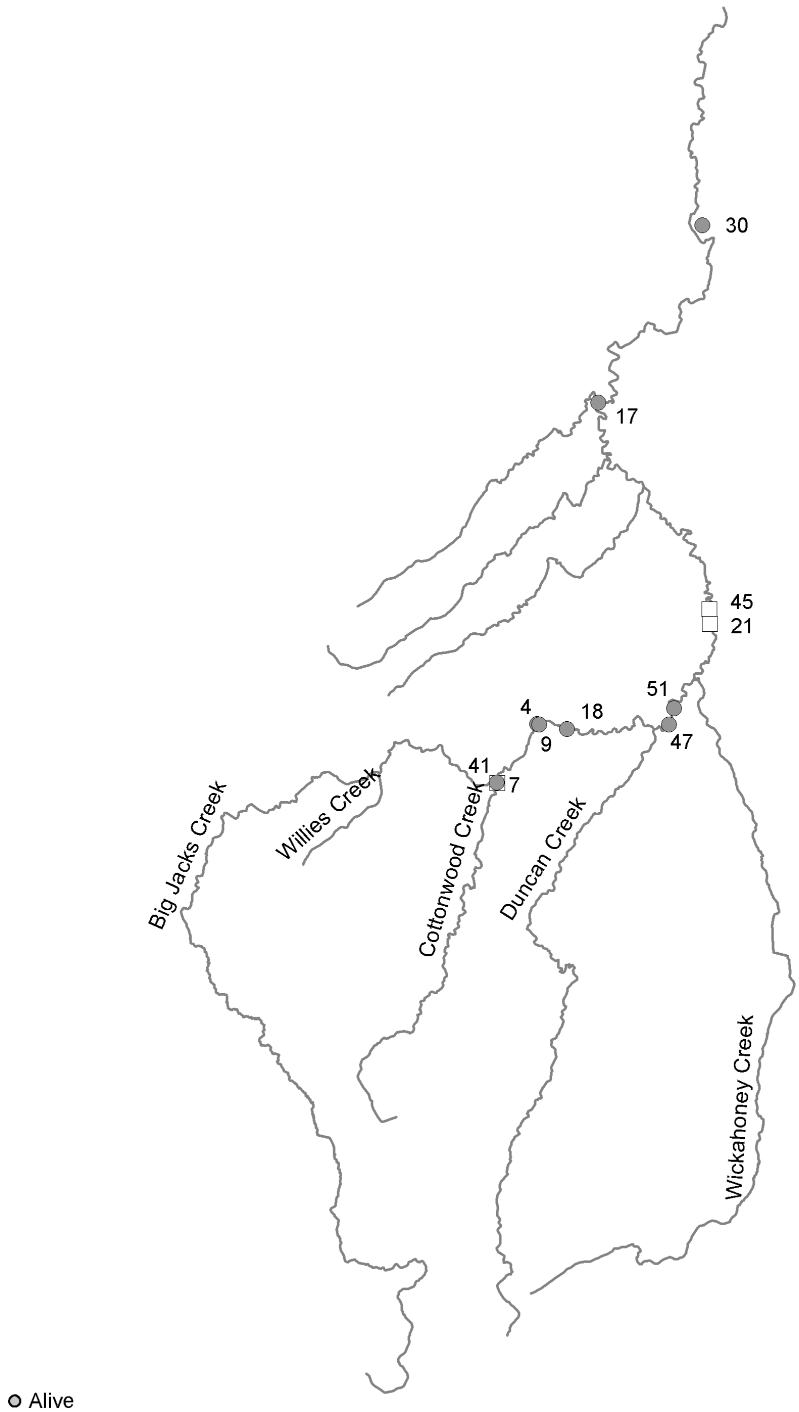


Figure 8. Results of helicopter radio tracking conducted on a 48.8 km segment of Big Jacks Creek (site of complete stream desiccation to barrier falls) and on Cottonwood Creek below the barrier falls, September 9, 2002. Numbers correspond to tag number of transmitter.

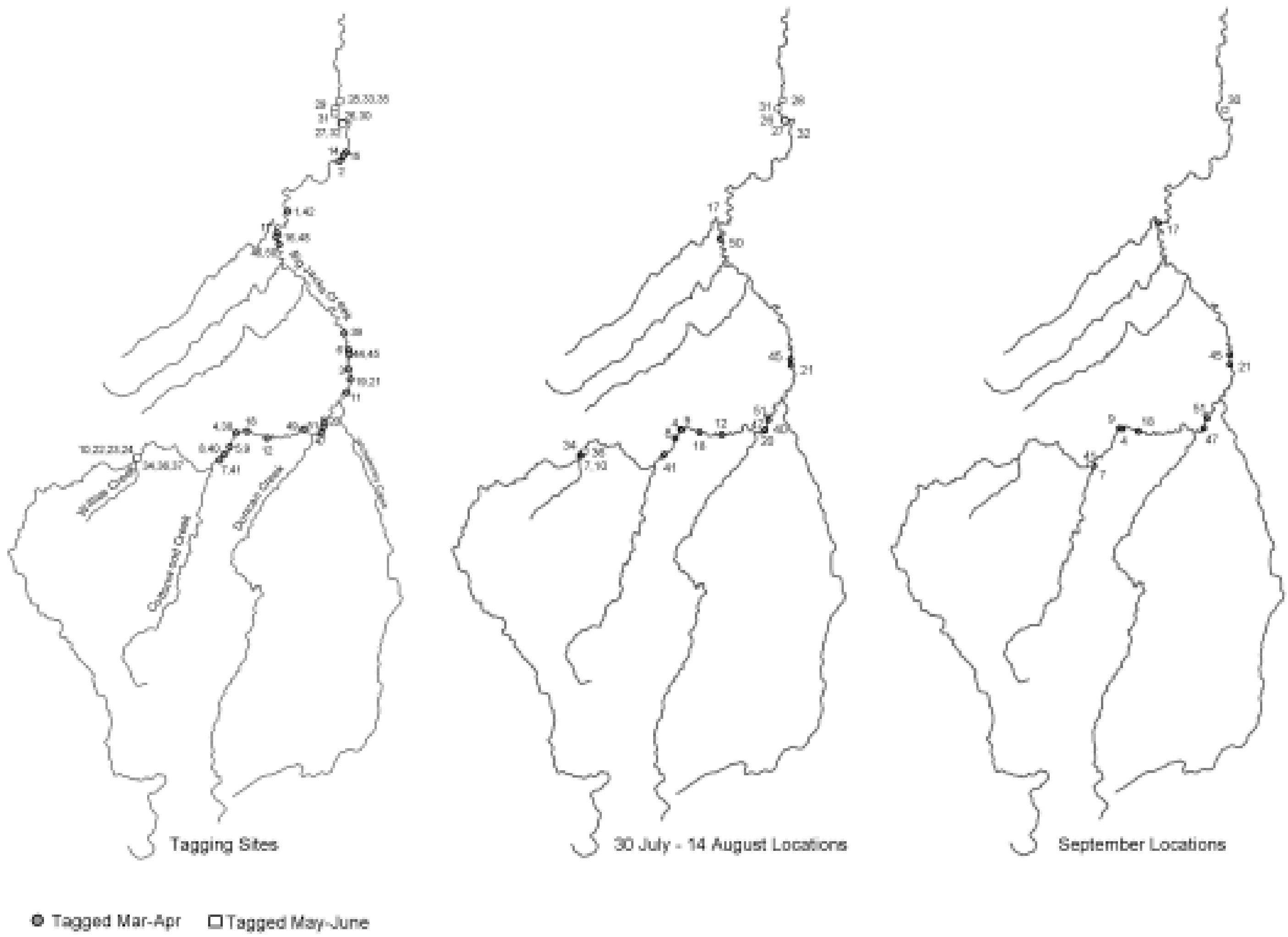
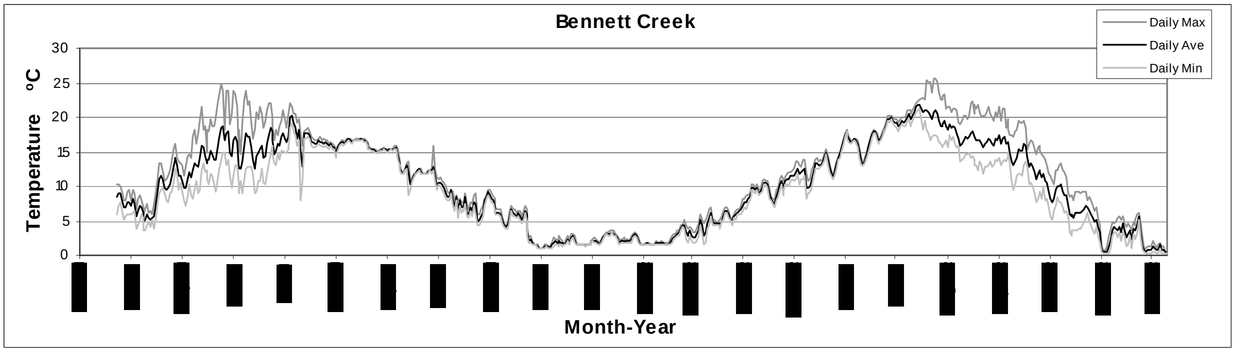
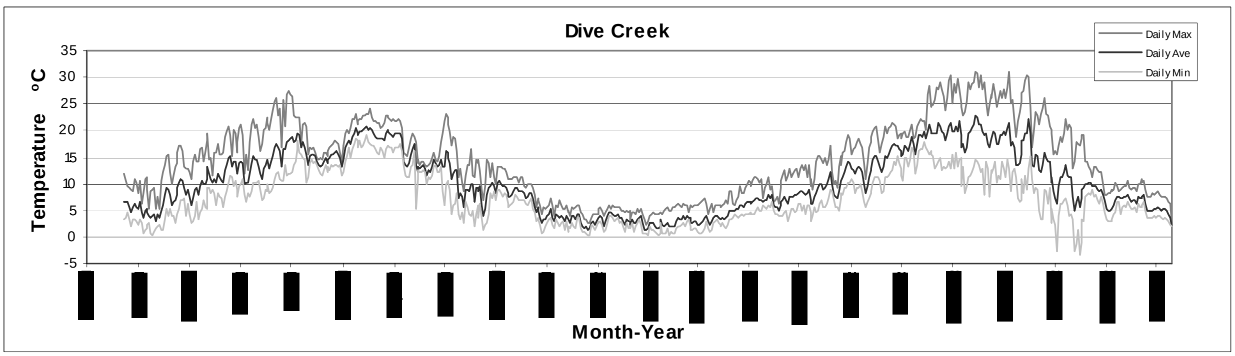


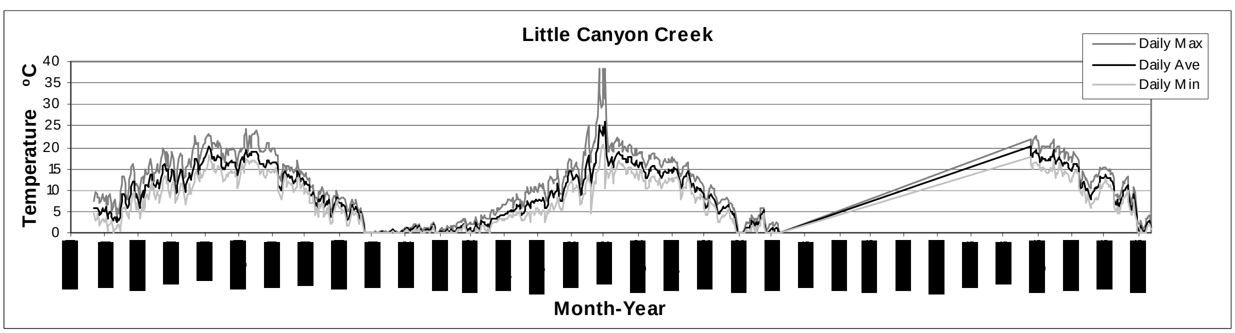
Figure 9. Original radio-tagging locations for 48 redband trout in Big Jacks Creek and subsequent detection of tags during midsummer ground tracking and a fall helicopter survey, 2002. Numbers correspond to tag number of transmitter.

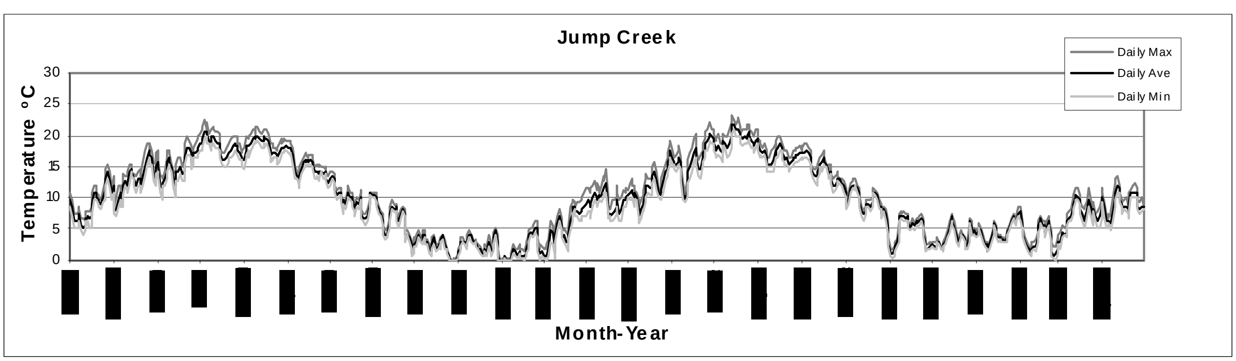
APPENDICES

Appendix A. Daily mean, maximum, and minimum water temperatures recorded by thermographs at 36 sites across Idaho desert redband trout range, March 2001 to November 2003.









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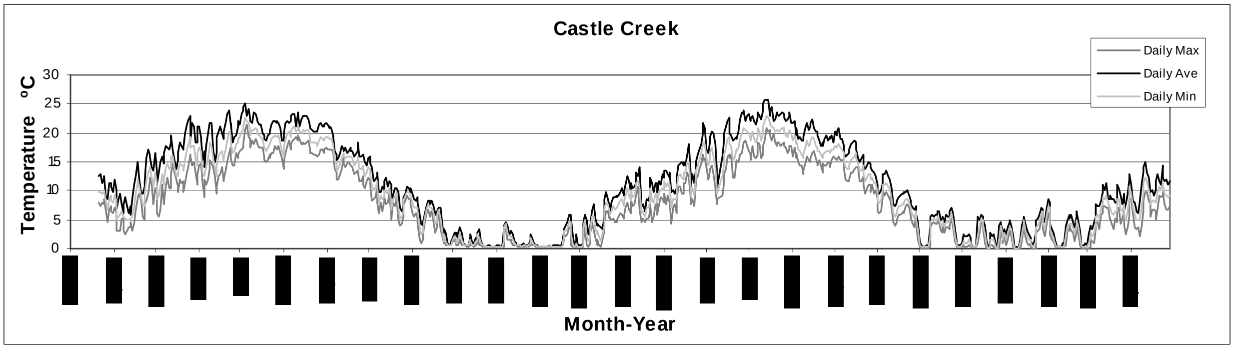

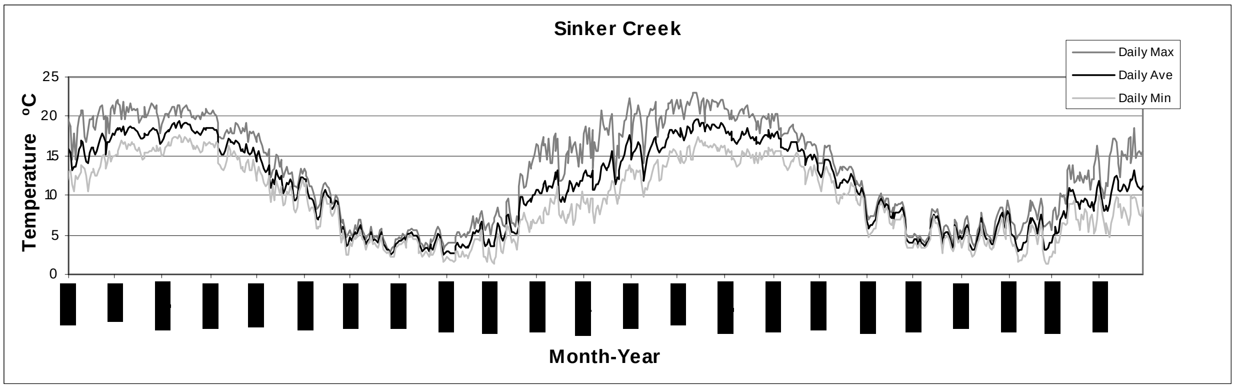

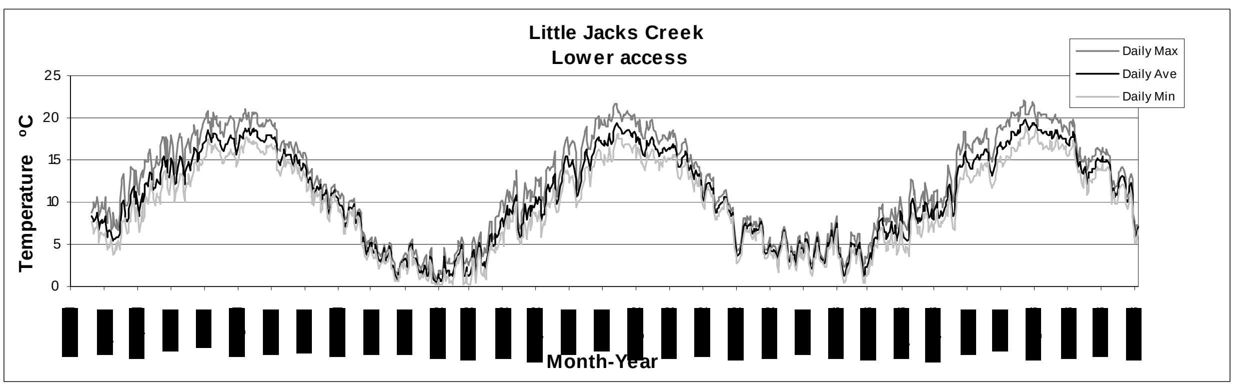

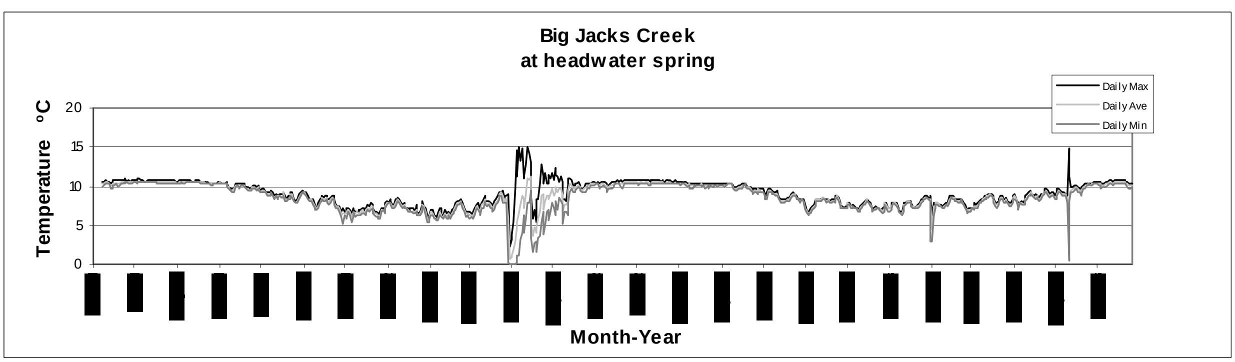

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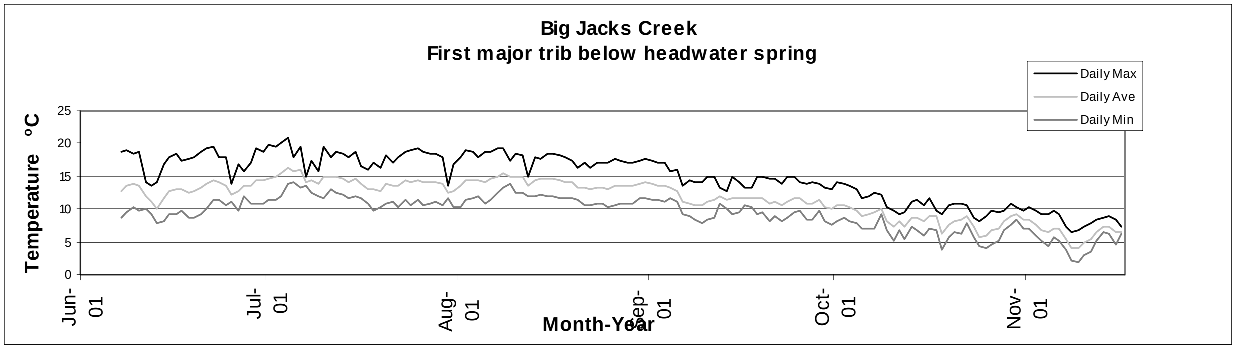

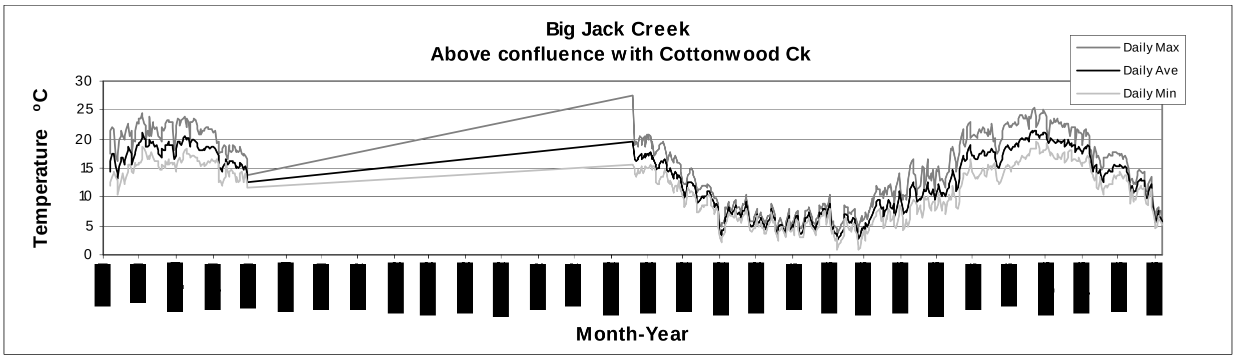

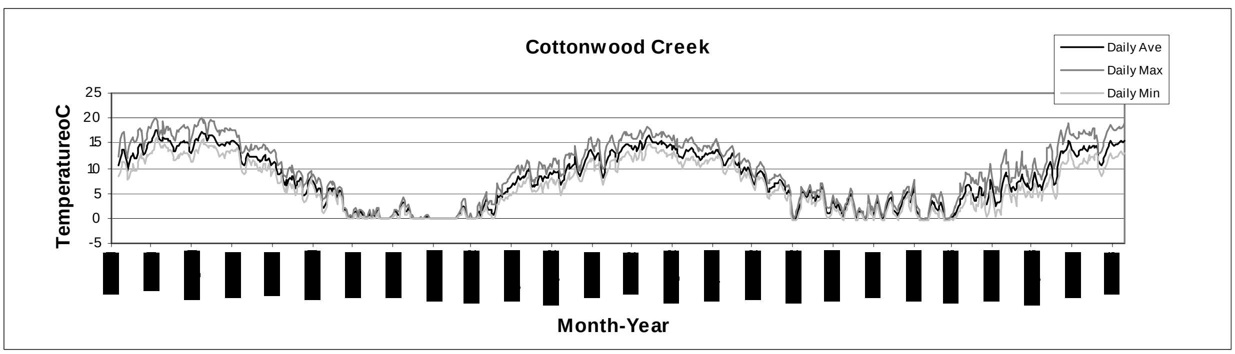

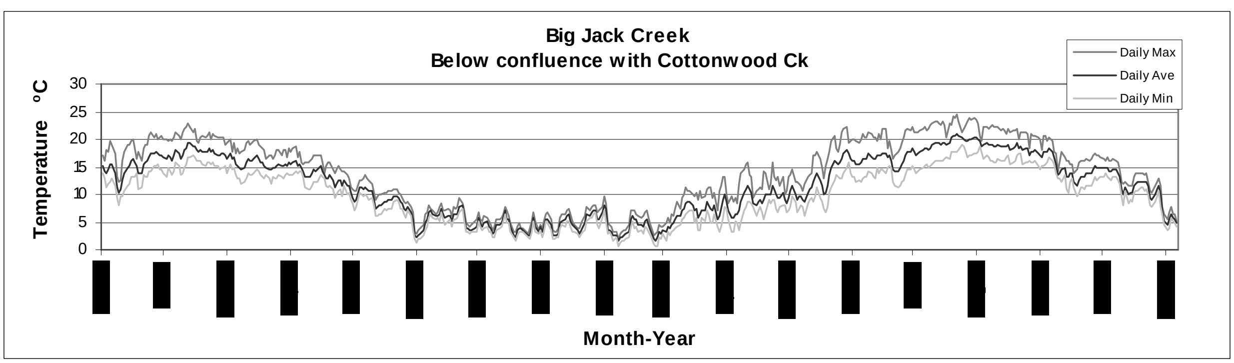

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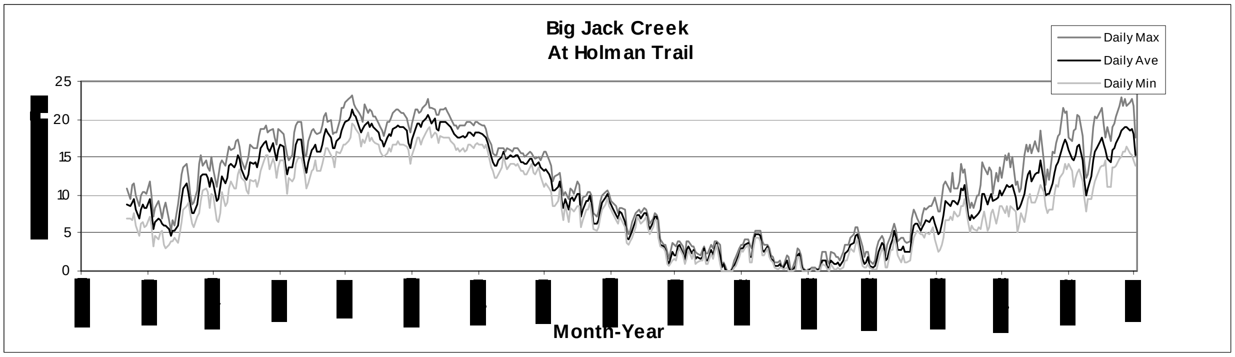

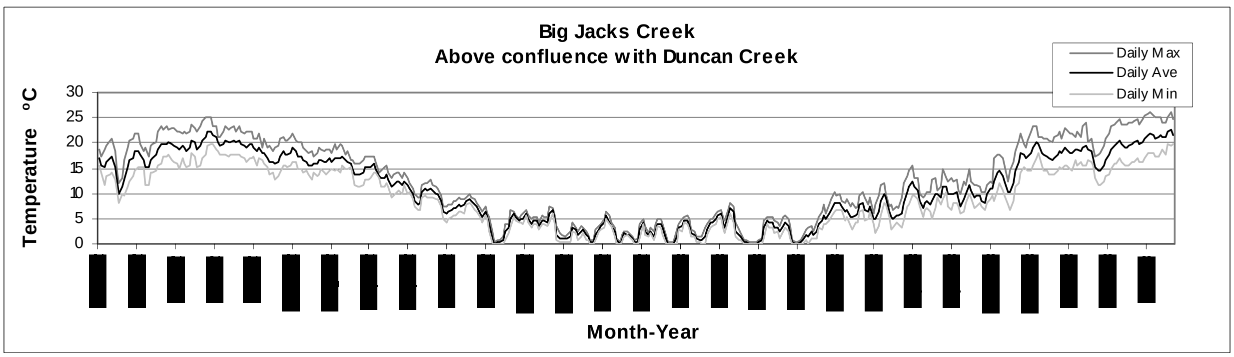

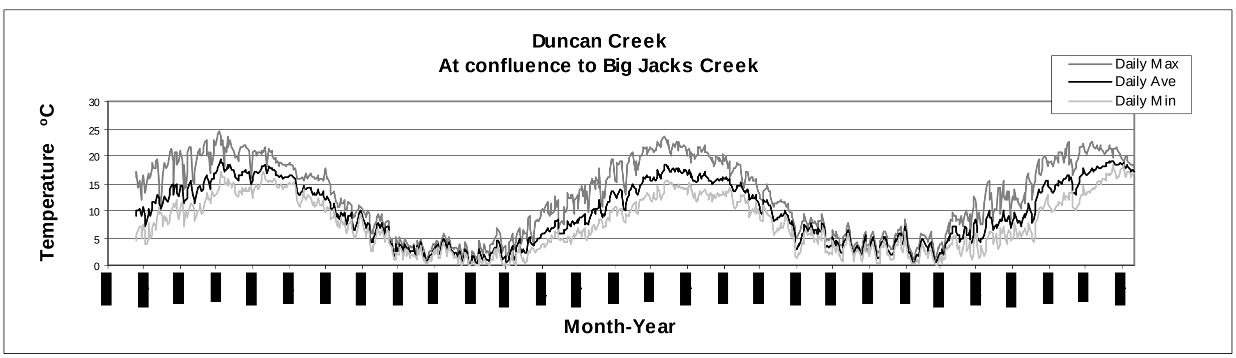

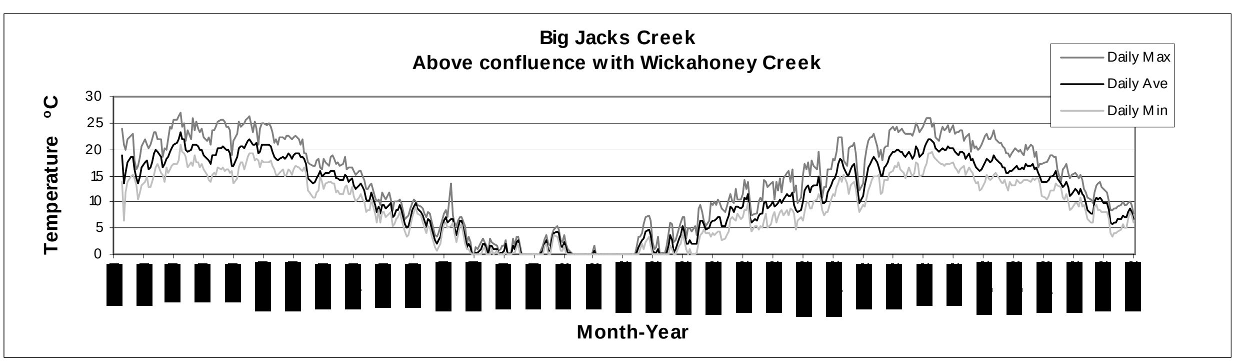

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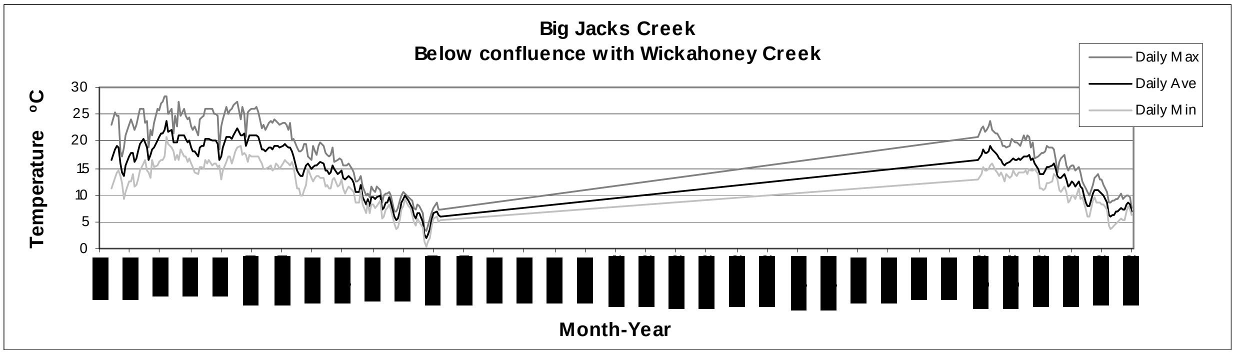

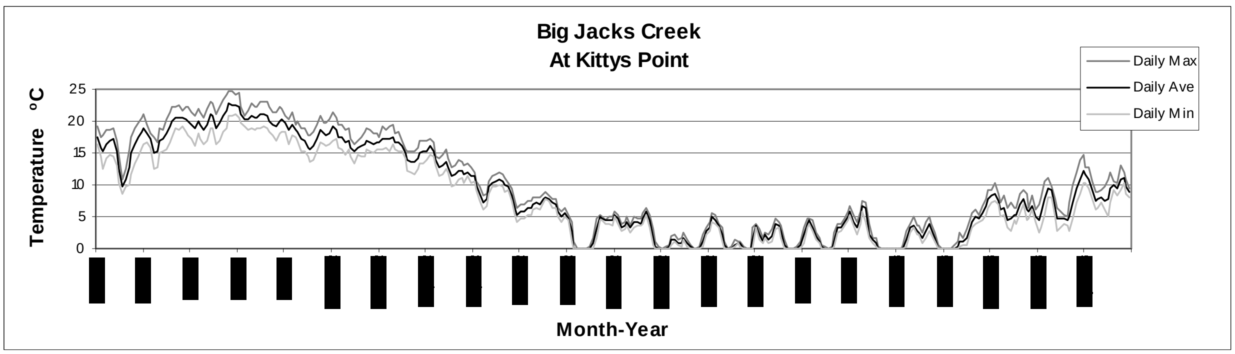

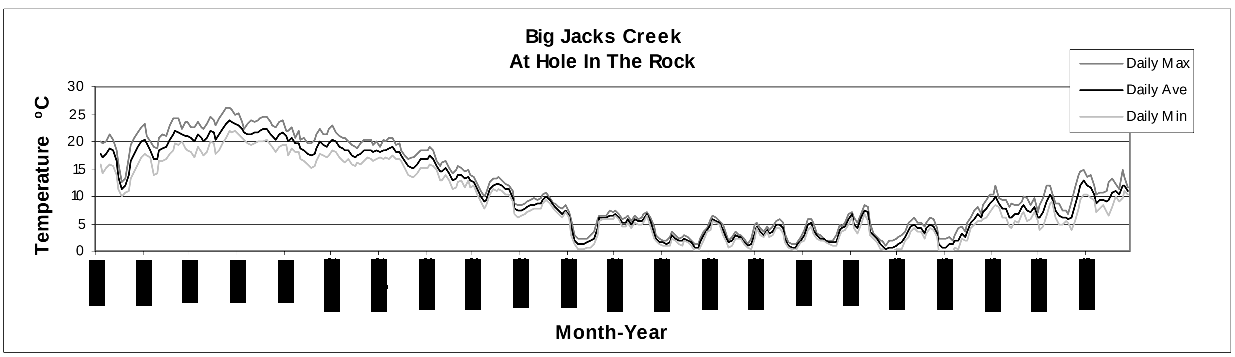

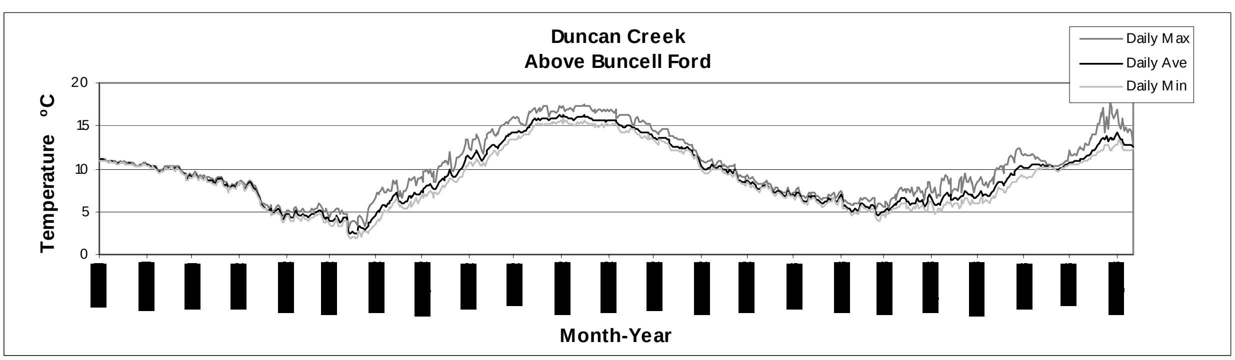

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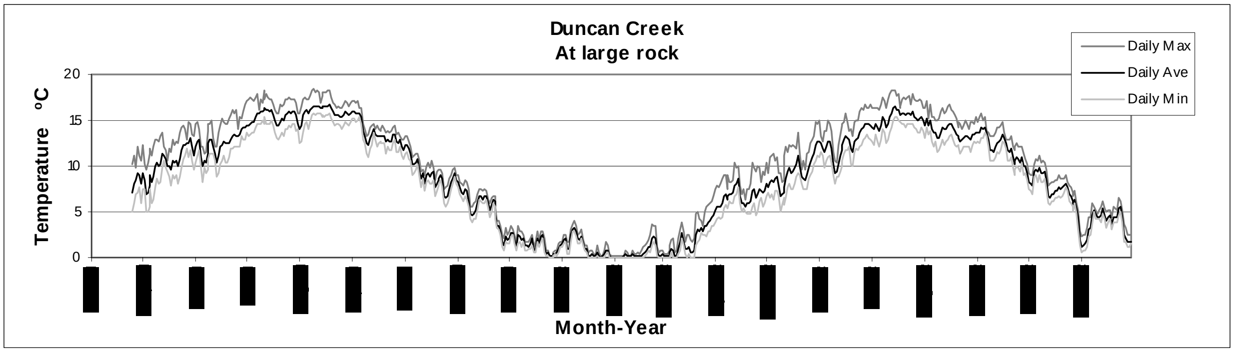

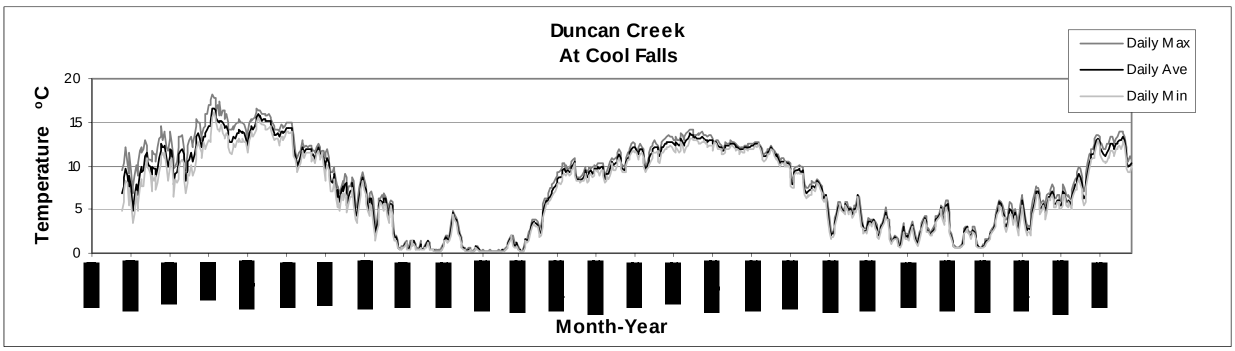

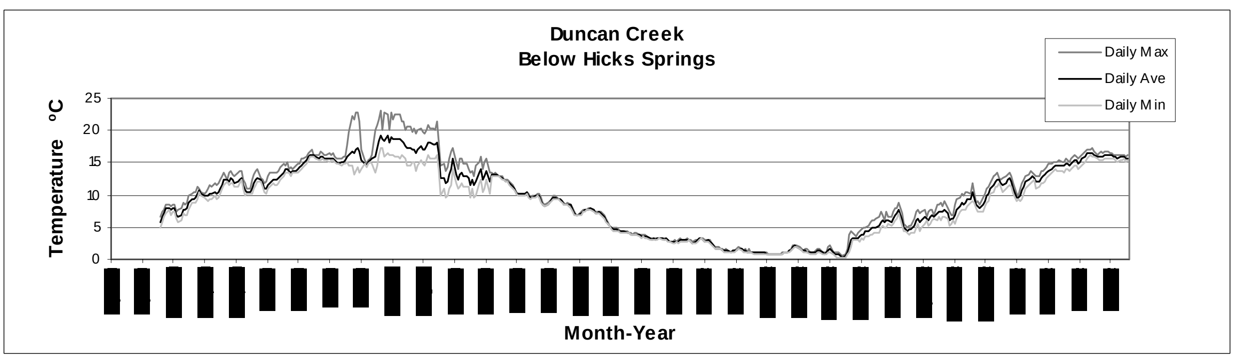

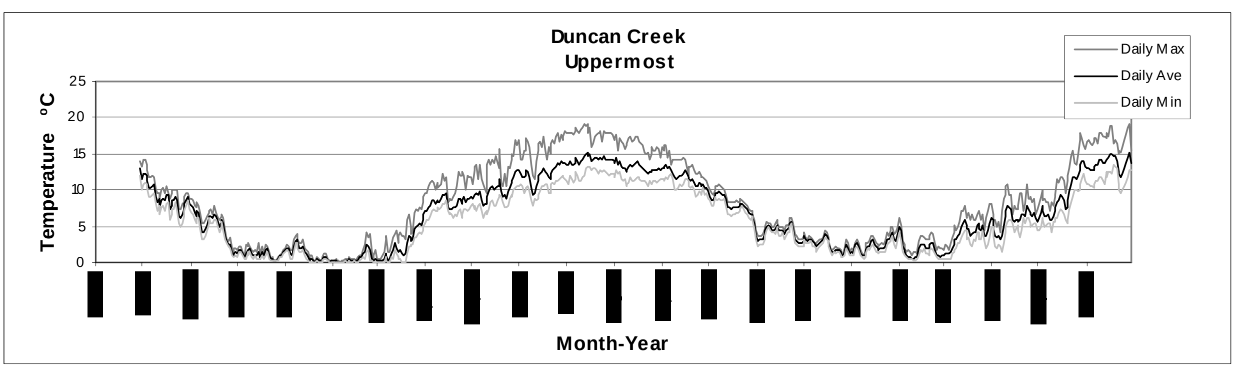

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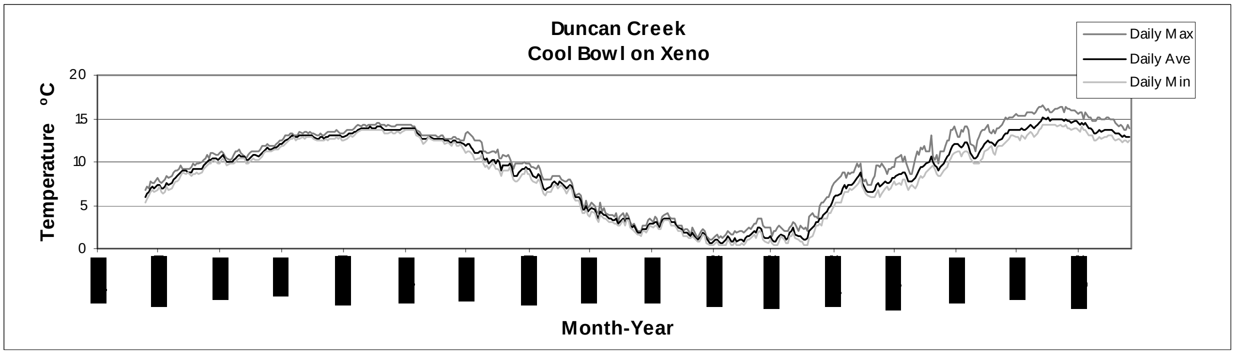

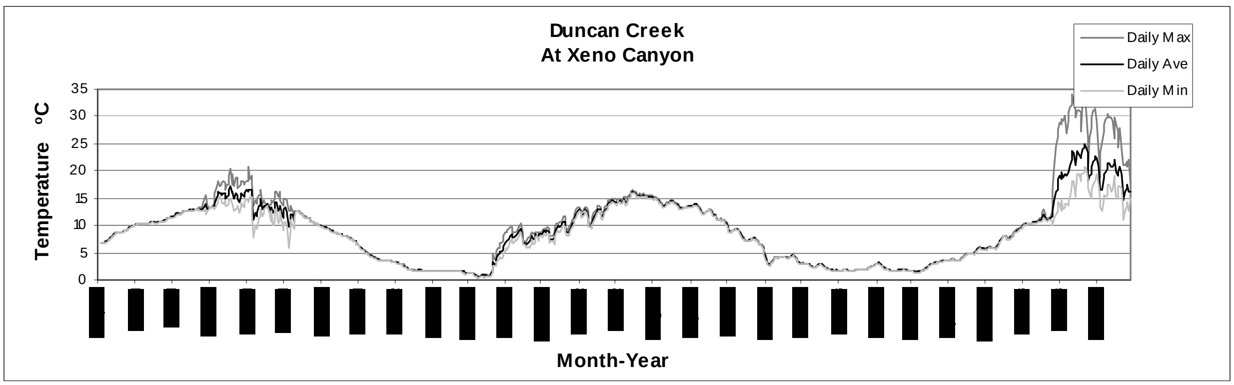

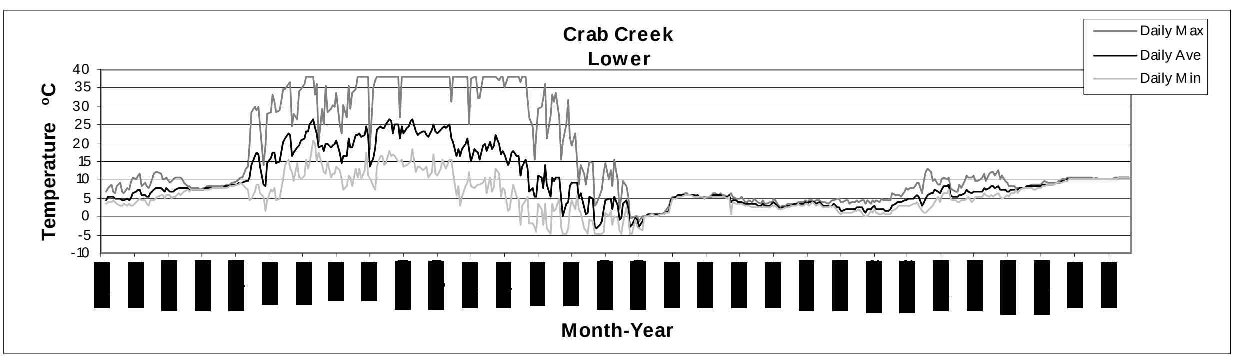

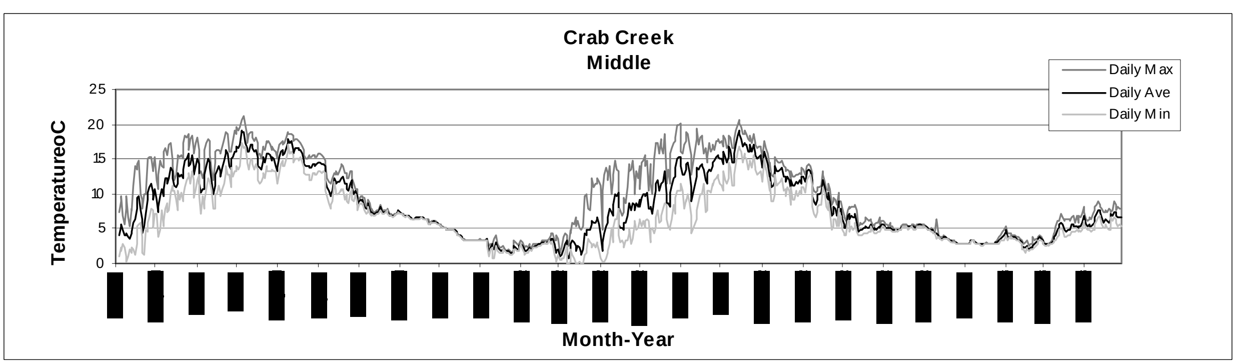

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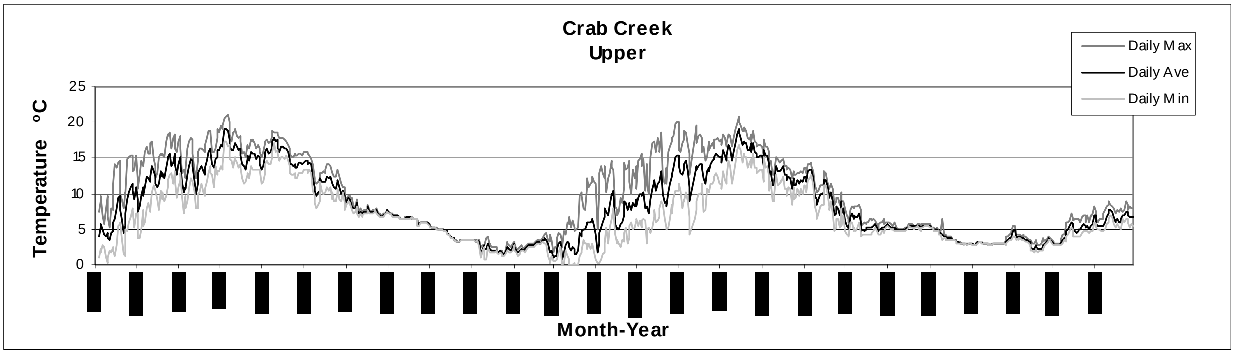
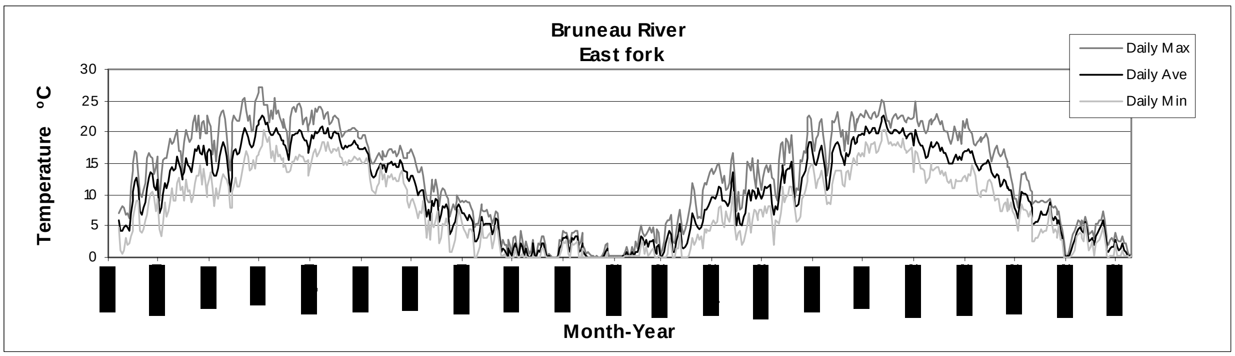
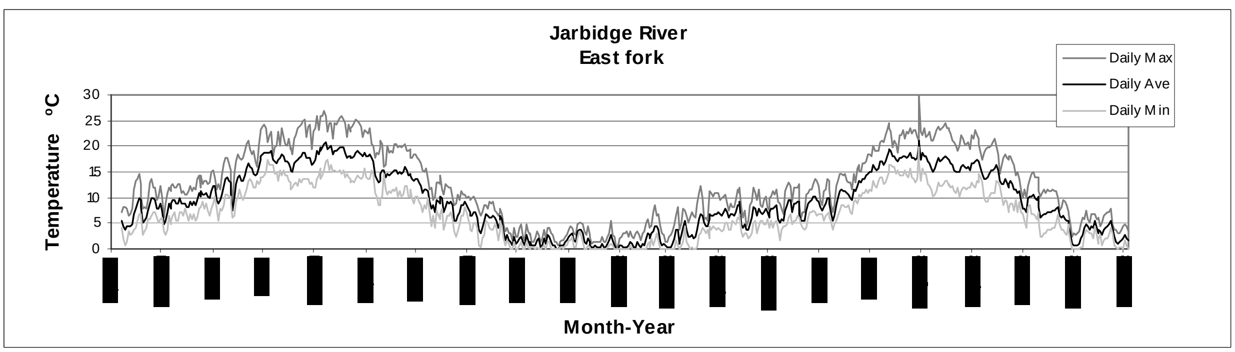
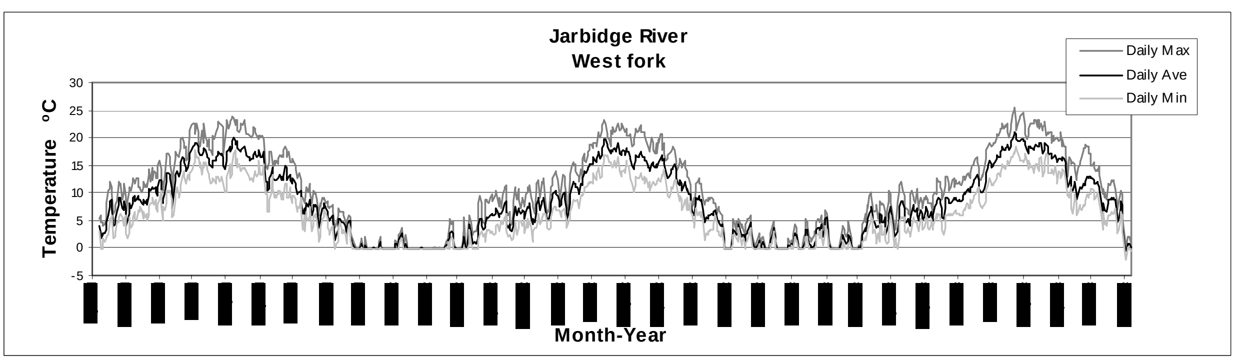
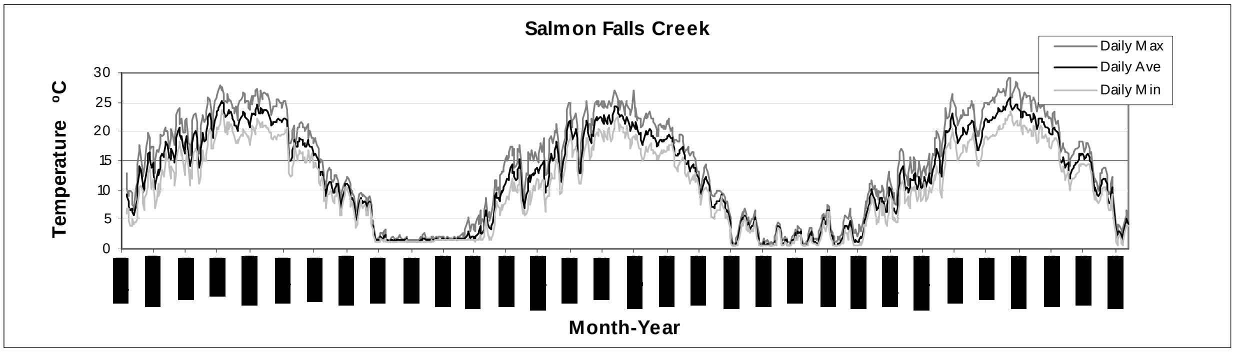


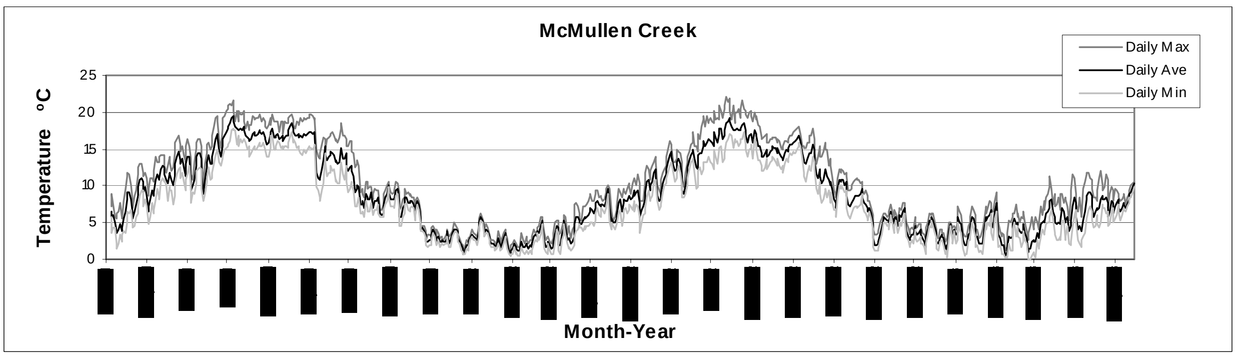


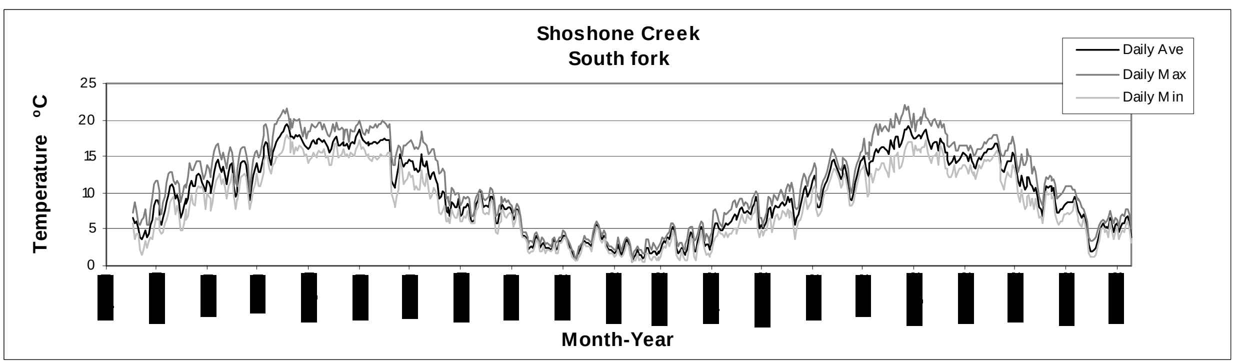


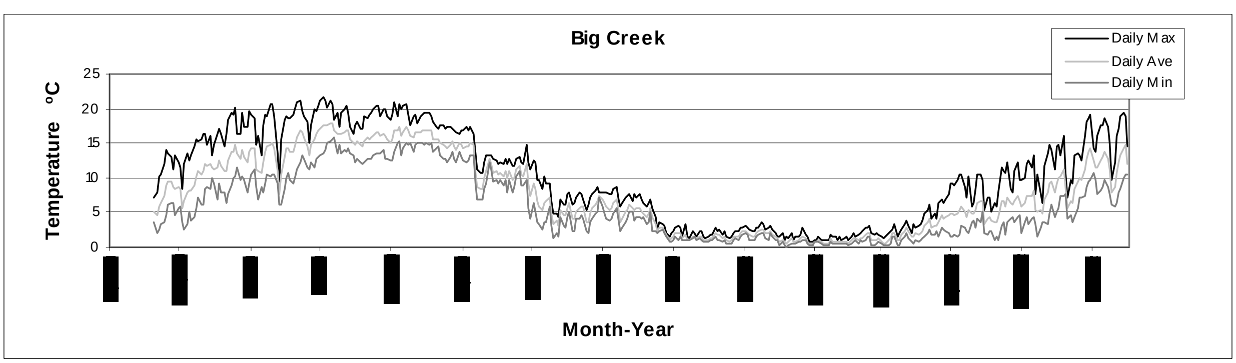


Appendix A. Continued.









Appendix B. Location of thermographs in desert redband area, 2001-2002.

Thermograph site name	Location	Elevation	Datum	Zone	UTMEast	UTMNorth
Bennett Creek	Above Dive Ck	1420	WGS 84	11	621328	4786796
Big Creek	Upper T15S R18E S34	1843	NAD27	11	721455	4661460
Big Jacks Creek	Above Wickahoney Ck	1287	NAD27	11	582085	4714467
Big Jacks Creek	1st major trib below falls	1648	NAD27	11	566827	4708709
Big Jacks Creek	Below Wickahoney Ck	1285	NAD27	11	582078	4714474
Big Jacks Creek	Above Cottonwood Ck	1415	NAD27	11	575725	4710697
Big Jacks Creek	at Holman Trail	1348	WGS 84	11	578740	4712795
Big Jacks Creek	Above Duncan Ck	1318	NAD27	11	580855	4712712
Big Jacks Creek	Below Cottonwood Ck	1401	NAD27	11	578812	4710897
Big Jacks Creek	Below Duncan Ck	1317	NAD27	11	580855	4712700
Big Jacks Creek	at Headwater Spring	1667	NAD27	11	566960	4709406
Big Jacks Creek	Kittys Point	1044	NAD27	11	582171	4727435
Big Jacks Creek	Hole in the Rock	1026	NAD27	11	582171	4727435
Bruneau River, EF	R11E T145S S31	1572	NAD27	11	647660	4669510
Castle Creek	at Alder Creek	1085	WGS 84	11	546074	4749350
Cottonwood Creek	Above confluence with Big Jacks Ck	1412	NAD27	11	575861	4710783
Crab Creek, Lower	Lower	1655	NAD27	11	584845	4690092
Crab Creek, Middle	Middle, in canyon	1707	NAD27	11	582386	4690950
Crab Creek, Upper	Upper	1761	NAD27	11	581757	4691573
Dive Creek		1419	WGS 84	11	621333	4787012
Duncan Creek	1st side canyon down from Hick Springs	1513	NAD27	11	577045	4706138
Duncan Creek	Cool bowl at fence	1494	NAD27	11	577290	4707063
Duncan Creek	by very large rock	1428	NAD27	11	578485	4709247
Duncan Creek	Cool Falls	1604	NAD27	11	576697	4705643
Duncan Creek	uppermost site, above spawning site	1599	NAD27	11	576932	4704873
Duncan Creek	Above confluence with Big Jacks Ck	1337	NAD27	11	580800	4712708
Duncan Creek	at Buncel Ford	1374	WGS 84	11	579833	4711068
Duncan Creek	Zeno Canyon	1607	NAD27	11	576946	4704875
Jarbidge River, EF	R9E T165 S25	1565	NAD27	11	635122	4654588
Jarbidge River, WF	.1 mi above EF confluence	1525	NAD27	11	633149	4656102
Jump Creek	below falls	762	NAD27	11	506380	4813950
Little Canyon Creek		1561	WGS 84	11	636402	4781260
Little Jacks Creek	Lower, at BLM crossing (fisherman's access)	1088	WGS 84	11	573257	4731076
McMullen Creek	Private property, 3 mi from main road	1310	NAD27	11	716688	4696449
Salmon Falls Creek	Lilly Grade road crossing	1113	NAD27	11	675859	4702004
Shoshone Creek, SF		1805	NAD27	11	717793	4677399
Sinker Creek	Below Hwy 78	942	NAD27	11	541490	4776243

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