Assess Current and Potential Salmonid Production in Rattlesnake Creek Associated with Restoration Efforts

US Geological Survey Reports

Annual Report
2001 - 2002

DOE/BP-00005068-1

January 2003

This Document should be cited as follows:

Connolly, Patrick, "Assess Current and Potential Salmonid Production in Rattlesnake Creek Associated with Restoration Efforts; US Geological Survey Reports", 2001-2002 Annual Report, Project No. 200102500, 87 electronic pages, (BPA Report DOE/BP-00005068-1)

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

Assess Current and Potential Salmonid Production in Rattlesnake Creek Associated with Restoration Efforts

2001 Annual Report

January 2003

Editor:
Patrick J. Connolly
Research Fishery Biologist

U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501-a Cook-Underwood Road
Cook, WA 98605

Prepared for:
Bonneville Power Administration
Division of Fish and Wildlife
COTR: John Baugher
P.O. Box 3621
Portland, OR 97208-3621

BPA Project Number: 2001-025-00
Account Number: 003882
Contract Number: 00005068

Table of Contents

Executive Summary

This project was designed to document existing habitat conditions and fish populations within the Rattlesnake Creek watershed (White Salmon River subbasin, Washington) before major habitat restoration activities are implemented and prior to the reintroduction of salmon and steelhead above Condit Dam. Returning adult salmon *Oncorhynchus* spp. and steelhead *O. mykiss* have not had access to Rattlesnake Creek since 1914. An assessment of resident trout populations should serve as a good surrogate for evaluation of factors that would limit salmon and steelhead production in the watershed.

Personnel from United States Geological Survey's Columbia River Research Laboratory (USGS-CRRL) attend to three main objectives of the Rattlesnake Creek project. The first is to characterize stream and riparian habitat conditions. This effort includes measures of water quality, water quantity, stream habitat, and riparian conditions. The second objective is to determine the status of fish populations in the Rattlesnake Creek drainage. To accomplish this, we derived estimates of salmonid population abundance, determined fish species composition, assessed distribution and life history attributes, obtained tissue samples for future genetic analysis, and assessed fish diseases in the watershed. The third objective is to use the collected habitat and fisheries information to help identify and prioritize areas in need of restoration. As this report covers the first year of a three-year study, this report is restricted to describing our work on the first two objectives only.

Large wood was low in frequency in all areas that we surveyed, and there were few quality pools. Water temperatures were regularly above the preferred range for rainbow trout throughout the summer of 2001, particularly in the section immediately above the confluence with Indian Creek.

Although fish habitat was degraded, we found a relatively robust population of rainbow trout in Rattlesnake Creek, with some large pools containing over 100 individuals. All reaches appeared to have some successful reproduction, with age-0 trout collected in every reach. The riffles in many sections were nearly dry during summer 2001, which provided little habitat for bigger fish.

The lower waterfalls on Rattlesnake Creek (3.6 m height at river kilometer 2.4) appear to be a barrier to the resident fish. Lamprey and cutthroat trout were not found above these falls. Only rainbow trout, longnose dace, and shorthead sculpin were found above and below the lower waterfall. Indian Creek had even fewer species than Rattlesnake Creek, with cutthroat trout dominating the assemblage. Another set of two falls occurs at rkm 17 that are each over 22 m in height. These upper falls are certainly fish barriers, and we have not found evidence of fish occurring above these falls to date.

Low incidence of disease was found in trout from the Rattlesnake Creek watershed in July, but we found heavy infections of diagenic trematodes and BKD in October. Longnose dace tested free from disease on both occasions. There will be additional disease samples in 2002 and 2003, so we will track the changes in disease presence and severity across time and among reaches.

During 2001, we initiated extensive PIT-tagging efforts in the Rattlesnake Creek watershed and the mainstem White Salmon River. To accomplish this, we cooperated with the U.S. Forest Service and National Marine Fisheries Service (NMFS), with each providing matching funds to enhance the effort. Over 600 PIT tags were inserted in fish in the White Salmon River and Rattlesnake Creek watersheds during 2001, with another 1,000 tags expected to be inserted in 2002. To allow us to track movement of PIT-tagged rainbow and cutthroat trout, we partnered with NMFS to install an instream PIT-tag detection system in lower Rattlesnake Creek (rkm 0.3), near its confluence with the White Salmon River. The detector became operational in August, and immediately started to detect PIT-tagged fish passing over it. Our success and lessons learned, during the first year of operation, suggest that continued use of this detection system will yield much valuable information. With additional tagging and detection efforts in 2002, we will assess patterns of habitat use and population links between the Rattlesnake Creek watershed and the White Salmon River.

Report A: Characterization of Flow, Temperature, Habitat Conditions, and Fish Populations in the Rattlesnake Creek Watershed

Prepared by:
M. Brady Allen
Fishery Biologist

Patrick J. Connolly
Research Fishery Biologist

Kyle Martens
Fishery Biologist

U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501-a Cook-Underwood Road
Cook, WA 98605

***In:* Connolly, P.J., editor. Assess Current and Potential Salmonid Production in Rattlesnake Creek Associated with Restoration Efforts**

2001 Annual Report

January 2003

Prepared for:
Bonneville Power Administration
Division of Fish and Wildlife
COTR: John Baugher
P.O. Box 3621
Portland, OR 97208-3621

BPA Project Number: 2001-025-00
Account Number: 003882
Contract Number: 00005068

List of Tables

List of Figures

List of Appendix Tables

List of Appendix Figures

Introduction

This project was designed to address a unique opportunity to document existing habitat conditions and fish populations within the Rattlesnake Creek watershed (White Salmon River subbasin, Washington) before major habitat restoration activities are implemented and prior to the reintroduction of salmon and steelhead above Condit Dam. Returning adult salmon *Oncorhynchus* spp. and steelhead *O. mykiss* have not had access to Rattlesnake Creek since 1914. An assessment of resident trout populations should serve as a good surrogate for evaluation of factors that would limit salmon and steelhead production in the watershed.

Before the construction of Condit Dam in 1913 on the mainstem White Salmon River (at river km 5.1), Rattlesnake Creek (a principal tributary of the White Salmon River at river km 13.8) was likely a productive stream for anadromous salmon, steelhead, and cutthroat trout *O. clarki* (Western Watershed Analysts 1997). With the proposed removal of Condit Dam scheduled for 2006, or at least a retrofit to provide upstream fish passage, Rattlesnake Creek has high potential to support reintroduced or naturally colonizing populations of anadromous salmon and steelhead, but not with existing habitat conditions.

As documented in several reports (Western Watershed Analysts 1997; Stampfli 1994; Rawding 2000), fish habitat has been severely degraded by a number of land-use activities in the watershed. These reports indicated fish habitat conditions in Rattlesnake Creek are compromised by high stream temperatures, low summer flows, lack of woody debris, and lack of riparian vegetation, among others.

Personnel from United States Geological Survey's Columbia River Research Laboratory (USGS-CRRL) attend to three main objectives of the Rattlesnake Creek project. The first is to characterize stream and riparian habitat conditions. This effort includes measures of water quality, water quantity, stream habitat, and riparian conditions. The second objective is to determine the status of fish populations in the Rattlesnake Creek drainage. To accomplish this, we derived estimates of salmonid population abundance, determined fish species composition, assessed distribution and life history attributes, obtained tissue samples for future genetic analysis, and assessed fish diseases in the watershed. The third objective is to use the collected habitat and fisheries information to help identify and prioritize areas in need of restoration.

As this report covers the first year of a three-year study, the data collected are partial and the results presented are preliminary. Efforts and results covered by this report include reach-scale habitat surveys (hereafter referred to as "reach surveys"), stream temperature, flow, and fish population information that we gathered at key sites within the Rattlesnake Creek subbasin. This report covers the portion of the work completed under Task 1*a* of Objective 1 (water quantity, stream habitat and riparian conditions) and Tasks 2*a*, 2*b*, and 2*c* of Objective 2 as stated in the Statement of Work submitted in May 2001 by the USGS-CRRL. This report presents data that we collected in spring 2001 through fall 2001.

We used results from habitat surveying, temperature profiling, and flow monitoring to characterize physical habitat conditions and their variation among and within streams of the watershed. Habitat characterization in concert with our report on fish population, condition, and survival will allow us to assess potential rearing conditions for salmon and steelhead within the watershed. These data should help prioritize sites in need of restoration.

Study Area

The Rattlesnake Creek watershed covers 143 km^2 and supports a third-order stream system with the largest tributary watersheds being Mill and Indian creeks, which support second-order systems (Figure 1). Rattlesnake Creek enters the White Salmon River at river kilometer 13.8, near the town of Husum. Elevations range from 114 m at the mouth of Rattlesnake Creek, which is at the watershed's western boundary, to 927 m at ridge tops near its eastern edge. The watershed's climate is temperate with 75 to 85% of the annual precipitation occurring between October and March. The average annual precipitation at the western downstream end of the watershed is about 127 cm and decreases to about 80 cm in the eastern upstream extension of the watershed (Western Watershed Analysts 1997). Due to the relatively low elevation of the watershed, precipitation in the winter is largely delivered as rain in the lower elevations and as rain or snow in the higher elevations.

There are two sets of waterfalls in Rattlesnake Creek. The lower set of falls, at rkm 2.4, has three individual drops, with the middle one being the largest (about 3.6 m total height, but with a step at 2.1 m). It is most likely a barrier to the resident fish, but may not have been a barrier to salmon and steelhead. Reiser and Peacock (1985) reported a maximum jumping height of 3.3 m for steelhead, and 2.4 m for chinook salmon. The upper falls, at rkm 17, has two separate drops of about 22 - 25 m each that is certainly a fish barrier.

Indian Creek is a tributary entering at rkm 0.8 of Rattlesnake Creek. There is a culvert approximately 0.1 rkm from the mouth of Indian Creek that may be a resident fish barrier. Mill Creek is a tributary entering at rkm 14 of Rattlesnake Creek.

We divided the drainage into four reaches (Figure 1) based on geomorphology and potential fish barriers. The lowermost reach (LRAT) starts at the mouth of Rattlesnake Creek and extends upstream about 2.4 km to the lower set of waterfalls. We had permission to sample 1100 m at the downstream end of this reach. The next reach (BRAT) is confined by canyon walls and extends from above the lower falls for about 2.5 km to the start of a much less confined area. We had permission to sample on two separate sections in this reach totaling 1800 m. The middle reach (MRAT) is a less constrained alluvial reach that extends 5.3 km between two confined reaches. We had permission to sample on the DNR (Department of Natural Resources) land totaling 580 m. The uppermost reach (URAT) starts at the base of a canyon and extends about 7 km to the base of the upper falls. We considered Indian Creek to be a separate reach with one lower section (LIND) and one middle section (MIND) that we had gained permission to sample. The section breaks were largely defined by landowner boundaries and where we had permission to access.

Methods

Habitat Surveys

To conduct reach surveys, we walked the stream channel and performed a series of measurements at 20-m intervals. At each 20-m interval, we measured stream width, took a densitometer reading, and measured stream gradient within the next 20-m interval using an Abney level. Within each 20-m interval, we counted boulders (diameter $\geq$ 0.5 m), pools, and pieces of large woody debris (LWD). We classified LWD as conifer or hardwood and tallied pieces into four size classes by length (L) and diameter (D) ($L > 5$ m with $D = 0.3$-0.6 m; $L > 5$ m with $D > 0.6$ m; L 1-5 m, with $D = 0.3$-0.6 m; and L 1-5 m with $D > 0.6$ m). We measured maximum depth in each pool and estimated percent cover for each pool. We also estimated percent spawning area and percent canopy closure within each of these 20-m intervals. Data on pool depth and cover, spawning area, and canopy closure were not analyzed at the time of this report and were not included in this report.

At 100-m intervals, we characterized riparian vegetation within a 10 x 10-m transect and assessed channel confinement. Within the transects, we described riparian vegetation. Channel confinement was assessed from estimates of distance to terraces and hill slopes. Riparian transect data have not yet been analyzed and were not included in this report.

Temperature

Personnel from the Underwood Conservation District (UCD) maintained a network of eight thermographs in the Rattlesnake Creek watershed from June 2001 through the present. Sites were chosen to provide thorough coverage of the watershed. All thermograph units deployed and maintained by UCD personnel were Optic StowAway thermograph devices from Onset Computer Corporation (OCC). Prior to deployment, the units were tested for accuracy and adequacy of response time to change in temperature as per instructions from OCC's operating manual.

Thermographs recorded temperature every two hours. Temperature data were downloaded in October 2001 and will continue to be downloaded twice a year (spring and fall). To minimize time out of water and missed readings, downloads occurred in the field with use of an OCC optic shuttle. We calculated the daily mean temperature as the mean of the 12 daily readings. We derived the daily minimum and maximum temperatures from the minimum and maximum reading of the 12 daily readings.

Flow

Personnel from CRRL established four flow-monitoring sites in the Rattlesnake Creek subbasin. The site lowest in the drainage (LRAT), along with a site in Rattlesnake Creek above the Indian Creek confluence (RAIN), Rattlesnake Creek at the middle DNR section (MRAT), and middle Indian Creek DNR land (MIND), were visited about every two weeks during June through October. Three additional sites were added for a comprehensive flow measurement on one day in June. In addition, attempts were made to measure flow at LRAT throughout the 2001–2002 winter.

Streamflow was measured following the protocol of Bain and Stevenson (1999). This protocol entailed anchoring a measuring tape perpendicular to stream flow and recording the distance at the left and right wetted edge. We measured water depth and water velocity (with a Marsh-McBirney flow meter) at a minimum of 10 (usually about 20) intervals along the measuring tape. Water velocities were measured at 60% of the depth at each interval. The flow at each interval was computed using the equation:

$$Q_n = d_n \times \left(\frac{b_{n+1} - b_{n-1}}{2} \right) \times v_n$$

Where Q_n = discharge at interval *n*, d_n = depth at interval *n*, b_n = distance along the tape measure from the left wetted edge to point *n*, and v_n = mean velocity of interval *n*. Total flow was calculated by summing the flow of each interval.

Fish

To obtain estimates of fish population, density, and biomass, we first conducted intensive habitat surveys of sampling sites during summer 2001,generally following Bisson et al. (1982). Habitat surveys were performed by measuring the length, width, average depth, and maximum depth of each habitat type (e.g., pools, glides, and riffles) from the start to the end of a fish-sampling site, usually within a few days of fish sampling. For pools, we also estimated the percent cover and types of cover (e.g., substrate, undercut bank, instream and overhead wood). In the LRAT reach, we electrofished a systematic sample of habitat units within strata of habitat types. Habitat units chosen for sampling were blocked off with nets to insure no movement into or out of the unit during sampling. A backpack electrofisher was used to conduct two or more passes under the removal-depletion methodology (Zippin 1956; Bohlin et al. 1982; White et al. 1982). The field guides of Connolly (1996) were used to insure a controlled level of precision in the population estimate (CV < 25% for age-0; CV < 12.5% for age-1 or older trout) was achieved within each sampling unit for each age group (two age groups). These methods were chosen specifically to minimize the number of units sampled by electrofishing and to minimize the number of electrofishing passes conducted. This approach serves to lessen the chance that individual fish will be exposed to potentially harmful effects of electrofishing while insuring a high degree of precision in our estimates.

In addition to the stratified systematic sampling described above, a less intensive method that we termed “index shocking” was used in other reaches sampled for fish (MIND, BRAT, MRAT). The same intensive habitat survey was conducted as described in the population estimate sampling. We then restricted our sampling to pools only. One pass was conducted (upstream and back) with no block nets in place. This method allowed us to sample a greater length of stream more quickly, while providing information on the fish population within pools and giving us the ability to measure, weigh, and insert PIT tags in fish.

Additional fish surveys were attempted by snorkeling. The water clarity during these surveys was poor, limiting the utility of this method. We will attempt to use this method again in the future to see if better results can be achieved. Results of these 2001 snorkeling efforts are not reported here.

Captured fish were anesthetized with the lightest possible dose of MS-222 before handling and were released to their approximate point of capture after handling. The exception to this protocol was when a fish died before or during handling. These mortalities were given to the U.S. Fish and Wildlife Service's Lower Columbia River Fish Health Center (LCRFHC) for disease profiling. All fish captured were measured for fork length to the nearest mm, weighed to the nearest 0.01 g, and inspected for external signs of disease. Scale samples were collected from fish measuring 70 – 100 mm and over 150 mm to estimate age classes. Because of the difficulty identifying rainbow trout from cutthroat trout when the fork length was less than 80 mm, all collected below this size were simply called "trout". All trout above this size were identified as either rainbow trout or cutthroat trout, and if the fish had hybrid characteristics, it was typically identified as a rainbow trout. In order to track movements, growth, and survival of the trout, we inserted PIT tags in most of the trout that exceeded 80 mm in fork length.

A small caudal fin clip was collected for genetic analysis from the first 50 trout and any subsequent cutthroat trout in each reach that exceeded 70 mm. These tissue samples were stored in a 1.5 ml vial with 90% ethanol. A portion of the samples was sent to Jennifer Neilson of the USGS's Alaska Science Center - Biological Science Office for genetic analysis as part of a related study by the U. S. Forest Service via Brian Bair. The results of the genetic analysis have not been received to date.

The fish provided to the LCRFHC were given a rigorous inspection for disease. Diseases screened at the LCRFHC by testing or microscopic observations included bacterial (bacterial kidney disease, coldwater disease, columnaris, emphysematous putrefactive disease, furunculosis, enteric redmouth), viral (infectious pancreatic necrosis, infectious hematopoietic necrosis, viral hemorrhagic septicemia), and parasitic agents (whirling disease, *Ceratomyxa*, digenetic trematodes, *Myxobolus kisutchi, Myxidium minteri, Hexamita, Gyrodactulus, Scyphidia, Heteropolaria*).

Results

Habitat Surveys

Reach surveys were completed on 4.1 km of stream in 2001. The locations of these reach surveys are shown in Figure 2, and described in Table 1. The majority of the rest of the creek that we gained permission to sample will be surveyed in 2002. The gradient ranged from 1.1 to 2.0% on Rattlesnake Creek and averaged 4.7% on the surveyed section of Indian Creek (Table 2). The number of pools was similar between sampled reaches (ranging from 2.2 to 2.7 pools per 100 m), however the number of boulders varied from 23 per 100 m at MRAT to 257 per 100 m at LRAT. The amount of LWD was limited (ranging from 0.1 to 0.2 pieces per 100 m for conifer LWD and 0.5 to 1.3 pieces per 100 m for hardwood LWD), with more hardwood than conifers and 0.5 per 100 m KEY pieces or less in all surveyed reaches of Rattlesnake Creek (Figure 4). The MRAT reach had the most LWD with 1.5 pieces (conifer and hardwood combined) per 100 m and 0.5 per 100 m as KEY pieces. There was mostly hardwood LWD in MIND, with a few pieces of coniferous LWD in the most upstream sampled section (Figure 5). Pieces of LWD longer than 5 m and at least 30 cm diameter were even more rare, LRAT and MRAT had similar amounts (0.7 pieces per 100 m), BRAT had the least (0.4 pieces per 100 m), and MIND had the most (0.8 pieces per 100 m).

Temperature

In the second week of June 2001, UCD placed eight thermographs throughout the Rattlesnake Creek watershed (Table 3, Figure 2). Data from these thermographs were retrieved in early October, and the thermographs will remain in place to collect temperature information year-round in future years. The analysis in this report covers data collected during June through September 2001.

The mainstem site above Indian Creek (RAIN) consistently had the highest daily maximum temperature compared with the other mainstem sites (Figure 6), and it also had the highest mean temperature of any of the mainstem sites during July (18.3 °C) and August (18.4 °C; Figure 7). The coolest mainstem site was the one located highest up the drainage (URAT). This site had the coolest mean temperatures during July (14.8 °C) and August (15.2 °C; Figure 7) and the lowest daily maximum from June through October (Figure 6). There was a period in mid-August when there was a temperature shift at the TOML site (see Figure 2 for location) compared to the other thermograph sites. During that period, it was the coolest site for about a week (Figure 6).

The rate of warming can be determined by looking at the slope of the lines in Figure 7. The mean water temperature increased at a consistent rate from URAT to MRAT in both July (0.32 °C/ km) and August (0.33 °C/ km), even with the cooling influence of Mill Creek (LMIL). However, in both months but particularly August, the monthly mean temperature at the TOML site (15.9 °C) was cooler than the upstream site (17.8 °C; MRAT). The highest rate of warming (0.52 °C/ km) was in August from TOML to the RAIN thermograph site, due to the unusually low mean temperature at

TOML (15.9 °C). The highest rate of cooling (-1.29 °C/ km) was from the RAIN site to the LRAT site, probably due to the cooling influence of Indian Creek.

During June through September 2001, we recorded many daily water temperatures that exceeded 16 °C at all the mainstem Rattlesnake Creek sites and Indian Creek (Table 4). Only Mill Creek did not exceed this temperature. This 16 °C limit has been set by the Washington Department of Ecology (Washington Department of Ecology, November 18 1997, Chapter 173-201A, Water Quality Standards for the Surface Waters of the State of Washington) as an indicator of stream health. The warmest month was July, which had water temperatures above 16 °C nearly every day at all mainstem sites. The highest temperature was 23.2 °C, which was recorded at Rattlesnake Creek just above the confluence of Indian Creek (RAIN). This site also recorded temperatures higher than 20 °C for more than half of July and August. The mainstem location with the lowest maximum temperatures was in the upper canyon below the waterfalls (URAT, Table 4)

June was the month with greatest diel water temperature range measured on the hottest day at all sites (Figure 8). The water warmed 5.5 °C over the course of the day on June 21, 2001 (June's warmest day) at several sites (RAIN, BUPC, URAT). The range was less on this day at TOML and MRAT (4.3 °C and 4.6 °C). Indian Creek, with a diel range of 5.2 °C, seemed to have daily fluctuations similar to Rattlesnake Creek. Mill Creek, with a diel range of 1.2 °C, had much more stable temperatures. This trend was similar on the hottest day in July, August, and September (Figure 8).

Flow

Seven flow measurement sites were established in 2001 with four sites on Rattlesnake Creek, two on Indian Creek, and one on Mill Creek (Table 5, Figure 3). On one occasion in June, flow was measured at all sites within the watershed (Figure 9). The flow steadily increased downstream. Mill Creek (LMIL; 0.35 cfs) had nearly the same flow as upper Rattlesnake Creek (URAT; 0.39 cfs). There were few flowing tributaries between Mill Creek and Indian Creek; therefore, most of the inflow is believed to be from groundwater. Indian Creek more than doubled its flow from the middle flow site (MIND; 0.32 cfs) to the lower flow site (LIND; 0.72 cfs). There was a jump in flow from 2.75 cfs at Rattlesnake Creek above the Indian Creek confluence (RAIN) to 3.22 cfs at the lower Rattlesnake flow site (LRAT) due to the inflow of Indian Creek (0.72 cfs). However, about 0.25 cfs was added to the subsurface flow between Indian Creek and the lower flow site (LRAT, Figure 9).

From about July through October, the upper falls (rkm 17) had no surface flow at the top; however, the water flowed from the plunge pool at the bottom of the falls throughout the summer. Many of the riffles between pools had no surface flow from July through October. We recorded the base flows through the summer at four main sites (Figure 10). The lowest flows on Rattlesnake Creek, recorded July 26, 2001 were: 0.08 cfs at MRAT, 0.28 at RAIN, and 0.6 cfs at LRAT. Flows were too low to measure at MIND in July and were as low as 0.13 cfs during October (Figure 10). As expected, the flows increased over the winter, associated with rainfall. The peak flow at LRAT could not be measured due to personnel safety concerns. However, the measured flow at LRAT ranged from a low of 0.6 cfs on July 26, 2001 to a high of 160 cfs on January 14, 2002 (Figure 10).

Fish

A total of 3.2 km on Rattlesnake Creek and 0.5 km on Indian Creek were sampled for fish during the summer 2001 (Table 6, Figure 3). Thirty PIT tags were deployed in cutthroat trout in Indian Creek and 544 PIT tags were deployed in rainbow trout and cutthroat trout in Rattlesnake Creek (Table 6). We found a total of five fish species in our sampling areas in 2001 (Table 7): rainbow trout, cutthroat trout *O. clarki*, longnose dace *Rhinichthys cataractae*, shorthead sculpin *Cottus confusus*, and brook lamprey *Lampetra richardsoni*. All of these fish species were found in LRAT. Cutthroat trout and brook lamprey were not collected in reaches above the lower falls, BRAT or MRAT. Rainbow trout, lamprey, and longnose dace were all absent from the middle section of Indian Creek (MIND). The middle section of Indian Creek was above two culverts and a section of creek we lacked permission to sample.

In the LRAT reach, the habitat survey done prior to fish sampling showed over half of the wetted area was low gradient riffles (Table 8), however age-1 or older trout were at least three times more dense (number/m^2) in pools and glides than in these riffles (Table 9). In contrast, age-0 trout were mostly found in glides, next most often in shallow pools, and with low but nearly equal numbers found in low gradient riffles, high gradient riffles, and deep pools (Table 9).

Although we refrained from a formal analysis of pattern of pools and fish numbers, thinking that it would be best reserved for when more data are available, we do present this information graphically. Figure 11 shows the distribution and maximum depth of pools as well as the number and biomass of age-0 and age-1 or older trout in those pools. There appears to be little relationship between pool area and biomass but maximum depth does appear to have some influence on pool biomass.

To develop an index for our single pass shocking method, we compared the number of fish collected after the first pass to a population estimate resulting from multiple passes (Table 10, Figure 11). Although block nets were in place, the first pass should be reasonably comparable to the index shock method with no block nets. Our efficiency on the first pass ranged from 39% to 100% for both age-0 and age-1 or older trout, and averaged 64% and 71%, respectively.

The index shocking method was used in the BRAT, MRAT, and MIND reaches. Figures 12 - 14 show the distribution of pools and the number and biomass of age-0 and age-1 or older trout in those pools for each reach. There was a higher number of age-0 trout in LRAT compared with the other reaches. Sampling in future years will allow us to examine changes in the fish distribution within and among these reaches.

The maximum length recorded for an age-0 trout was 92 mm, in the BRAT reach in October (Table 11). The minimum length of an age-1 fish on Rattlesnake Creek was 78 mm in the LRAT reach in August. Indian Creek had smaller fish with the maximum age-0 fish measuring 55 mm. Ages were determined with length-frequency analysis (Figures 15-16) and by aging scales from those fish near the estimated fork-length limits for each age. We did not estimate the maximum length of age-0 cutthroat trout in LRAT because of the difficulty differentiating between rainbow and cutthroat trout that are smaller than 80 mm. Actual and predicted weights are plotted in Appendix Figures 1-6;

these figures were used to calculate length-weight regressions and to estimate fish weights when there was missing data (2% of total fish captured).

Fish were submitted to the LCRFHC for disease assessments from two separate sampling dates in 2001. On 31 July 2001, 30 rainbow trout and 25 longnose dace were submitted, and on 9 October 2001, 14 rainbow trout and 18 longnose dace were submitted. On both sampling dates, the longnose dace appeared to be in good health with only the suspected presence of bacterial kidney disease (BKD), *Renibacterium salmoninarum*. The rainbow trout sampled in July appeared relatively healthy with suspect cases of BKD and low levels of *Scyphidia* on the skin and low levels of *Nanophyetus* in the hind-gut. However, the rainbow trout sampled in October had confirmed BKD, heavy levels of *Neascus* (black spot) and *Nanophyetus* on the skin, and heavy levels of *Nanophyetus* and diagenic trematodes in the hind-gut (Appendix Table 1).

Discussion

Large wood was low in frequency throughout the system and there were few quality pools. Similar to what others have concluded (Western Watershed Analysts 1997; Stampfli 1994; Rawding 2000), these factors indicate degraded fish habitat conditions in Rattlesnake Creek in 2001. Our reach surveys showed that the MRAT and LRAT reaches had the highest amount of LWD with 0.7 pieces per 100 m that were at least 0.3 m diameter and 5 m long. The minimum amount of LWD recommended for a stream to be described as "properly functioning" is 1.24 pieces per 100 m (NMFS 1996).

However, NMFS defined LWD as pieces with a 0.3 m diameter and 10.4 m length. Therefore, Rattlesnake Creek had about half of the recommended minimum using our more liberal classification of LWD. There were fewer pools in the drainage than the recommended minimum, and the typical pool quality was poor. For a creek of its size, the recommended minimum is 3.5 pools per 100 m (Overton et al. 1997; Platts et al. 1983). At best, the reaches of Rattlesnake Creek that we surveyed had 60% of this pools standard.

Water temperatures in Rattlesnake Creek are a concern because they were regularly above the preferred range for rainbow trout throughout the summer of 2001, particularly in the section above the confluence with Indian Creek. These high temperatures combined with low base flows could make summer a stressful and potentially lethal time for trout in Rattlesnake Creek. Water from the plateau above the upper waterfall was warm upon entering the fish bearing sections of Rattlesnake Creek. Water in the upper canyon had daily maximum temperatures that were above 16 °C in over half of the days in July and August. These warm temperatures coincided with very low flows (<1 cfs at LRAT). Optimum feeding temperature for rainbow trout is between 13 °C and 16 °C (Kaya 1977; Cherry et al. 1975). At temperatures above 20 °C, rainbow trout can experience high metabolic demands and stress, which can lead to suppressed growth and early mortality (Nielsen et al. 1994; Hokanson 1977). At temperatures above 24 °C, some researchers report high mortalities (Cherry et al. 1975), with the upper incipient lethal temperature reported as 25.6 °C (Hokanson 1977; Bidgood and Berst 1969).

The water in Mill Creek was a beneficial addition (rkm 14) as it was substantially cooler than Rattlesnake Creek or Indian Creek (rkm 0.8). Mill Creek also had very little diel variation. Stream temperatures can be affected by characteristics like ambient air temperature, water velocity, flow, depth, riparian canopy cover, and groundwater inflow. Although Mill Creek and Indian Creek have similar amounts of shading, Mill Creek has a higher elevation (at mouths, 360 m vs. 128 m), which may be the primary explanatory factor.

Water temperatures at the TOML site were particularly interesting because this site was cooler than the sites either upstream or downstream. This may be due to groundwater inflow. This thermograph site was at the downstream end of a 5-km long alluvial reach and upstream from the more confined BRAT reach. Bounded alluvial valley segments have been associated with increased groundwater inflow (Baxter 1999; Stanford and Ward 1993). If this pattern persists in 2002, we hope to have UCD personnel (who has landowner permission) attempt to determine the presence of and/or extent of this groundwater influence. In streams with higher than optimal temperatures, salmonids have been shown to use thermal refugia such as coldwater patches created by groundwater seeps, springs, and thermal stratification within stream channels (Nielsen et al. 1994).

The thermograph site above the confluence with Indian Creek (RAIN) was the warmest throughout the summer of 2001. There were many long shallow glides that were exposed to the sun in the BRAT reach and LRAT reach, between the TOML and RAIN thermograph sites. However, the temperatures were reduced below the Indian

Creek confluence (LRAT), possibly due to the surface and hyporheic inflow from Indian Creek.

The lower waterfalls on Rattlesnake Creek appear to be a barrier to the resident fish. Lamprey and cutthroat trout were not found above these falls. Only rainbow trout, longnose dace, and sculpin were found above and below the lower waterfall. Analysis of PIT tag recaptures and the genetic samples may help us assess whether the fish above and below this barrier are distinct populations. Indian Creek had even fewer species than Rattlesnake Creek, with cutthroat trout dominating the assemblage. Possible explanations are: barriers on Indian Creek below the sampling site, poor habitat, flow patterns, or unsuitable temperatures for the absent species.

Although fish habitat was degraded, we found a relatively robust population of rainbow trout in Rattlesnake Creek, with some large pools containing over 100 individuals. All reaches seemed to have some successful reproduction, with age-0 trout collected in every reach. There was a higher proportion of age-1 or older trout compared to age-0 trout in pools in the LRAT reach. The riffles in many sections were nearly dry and did not provide much habitat for bigger fish.

Over 600 PIT tags were inserted in fish from the mainstem White Salmon River and the Rattlesnake Creek watershed during 2001. We will have opportunities to look at growth, movement, and life history attributes of individual fish when some of these PIT-tagged fish are recaptured in future sampling years. We will continue to monitor the remote PIT tag reader at the mouth of Rattlesnake Creek (see report B), and the fish will be queried for any detections downstream in the Columbia River. Being the first year of this study, there have been few recaptures.

Results from disease profiling indicate that longnose dace were healthy on both occasions. Trout were healthy in July but had heavy infections of diagenic trematodes and BKD in October. There are a variety of chemical, physical, biological, and ecological parameters that influence a fish population's ability to withstand disease (Snieszko, 1974). The elevated parasitic infections of these fish may be due to increased stress during times of high temperature and low flow. Disease can directly influence success of reproduction, performance, susceptibility to predation, and other critical factors required for the survival of a species (Hedrick, 1998). There will be additional disease samples in 2002 and 2003 so we will track the changes in disease presence and severity across time and among reaches.

Acknowledgements

We would like to thank many people who assisted us with this project. Jim Petersen served as the Project Leader and helped with the administration and planning of the project. We thank Ian Jezorek as a crew leader, and Jodi Charrier, Gene Holiman, Joel Quenette, Sarah Rose, and Chris Schafer for performing the data collection and entry. Thanks to many CRRL employees who helped with our fish sampling. Steve Stampfli and Roz Plumb of Underwood Conservation District provided the thermograph data reported here. Ken Lujan and Susan Gutenberger of the USFWS's Lower Columbia River Fish Health Center provided the fish health profiles. Many private landowners granted us permission to sample on their property. Without their help, this project would not be possible. Thanks to John Baugher, our BPA Contracting Officer.

References

Bain, M. B., and N. J. Stevenson. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Baxter, C. V., C. A. Frissell, and F. R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: implications for management and conservation. Transactions of the American Fisheries Society 128:854-867.

Bidgood, B. F., and A. H. Berst. 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of the Fisheries Research Board of Canada 26:456-459.

Bisson, P. A., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 *in* N.B. Armantrout. 1982. Acquisition and utilization of aquatic habitat inventory information symposium. American Fisheries Society, Western Division, Bethesda, MD.

Bohlin, T. 1982. The validity of the removal method for small populations -- consequences for electrofishing practice. Institute of Freshwater Research Drottningholm Report 60:15-18.

Cherry, D. S., K. L. Dickson, and J. Cairns, Jr. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. Journal of the Fisheries Research Board of Canada 32:485-491.

Connolly, P. J. 1996. Resident cutthroat trout in the central Coast Range of Oregon: logging effects, habitat associations, and sampling protocols. Doctoral dissertation. Oregon State University, Corvallis.

Hedrick, R. P. 1998. Relationships of the host, pathogen, and environment: implications for diseases of cultured and wild fish populations. Journal of Aquatic Animal Health 10:107-111.

Hokanson, K. E., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. Journal of Fisheries Research Board of Canada. 34:639-648.

Kaya, C. M., L. R. Kaeding, and D. E. Burkhalter. 1977. Use of a cold-water refuge by rainbow and brown trout in a geothermally heated stream. Progressive Fish-Culturist 39:37-39.

Nielsen, J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society 123:613-626.

NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual of grouped actions at the watershed scale. The National Marine Fisheries Service Environmental and Technical Services Division, Habitat Conservation Branch, Seattle, WA.

Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) fish and fish habitat standard inventory procedures handbook. USDA Forest Service General Technical Report INT-GTR-345, Ogden, UT.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report INT-138, Ogden, UT.

Rawding, D. 2000. White Salmon River subbasin summary. Draft. June 30, 2000. Prepared for: Northwest Power Planning Council, Portland, OR.

Reiser, D. W., and R. T. Peacock. 1985. A technique for assessing upstream fish passage problems at small-scale hydropower developments. Pages 423-432 *in* F. W. Olson, R. G. White, and R. H. Hamre, editors. Symposium of small hydropower and fisheries. American Fisheries Society, Western Division, Bethesda, Maryland.

Rosgen, D. L. 1994. A classification of natural rivers. Elsevier Science, B. V. Amsterdam. Catena 22:169-199.

Snieszko, S. F. 1974. The effects of environmental stress on outbreaks of infectious diseases of fishes. Journal of Fish Biology 6:197-208.

Stampfli, S. M. 1994. White Salmon River Basin assessment and watershed enhancement project- basin water quality investigation report. Underwood Conservation District, White Salmon, WA.

Stanford, J. A., and J. V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. Journal of the North American Benthological Society 12:48-62.

Western Watershed Analysts. 1997. Panakanic Watershed Analysis. Champion Pacific Timberlands, Inc.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. No. LA-8787-NERP, UC-11. Los Alamos National Laboratory, Los Alamos, New Mexico.

Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. Biometrics 12:163-189.

Table 1. Locations of reach surveys conducted within the Rattlesnake Creek watershed in 2001. Coordinates were obtained from a hand-held Global Positioning System using North American Datum 1927. Sites are listed from upstream to downstream. For additional information on reach survey locations see Figure 2.

Watershed Site	Start point distance from mouth (km)	Length of reach (km)	Coordinates at start point		Coordinates at end point	
			Northing	Easting	Northing	Easting
Rattlesnake Creek						
MRAT – DNR [a]	7.2	0.6	5076347	622077	5076668	622403
BRAT – upper	3.4	1.0	RNO[b]		5074390	620640
BRAT – lower	2.5	0.5	5073738	619276	5074077	619658
LRAT – Stampfli [c]	0.1	1.1	5072424	617997	RNO	
Indian Creek						
MIND - DNR [a]	2.2	0.9	5071551	620085	5071699	620025

[a] DNR = Land owned by Department of Natural Resources.
[b] RNO = Reading not obtainable because of topography of basin.
[c] Stampfli = Land owned by Steve Stampfli.

Table 2. Reach survey data for streams within the Rattlesnake Creek watershed. Sites are listed from upstream to downstream within a watershed.

Watershed Reach	Rosgen (1994) channel type	Accessible length (m)	Surveyed length (m)		Mean width (m)	Survey date (mm/yy)	Number per 100 m in reach length[a]					Stream gradient (%)
			Start –End	Length			Pools	Boulders	CLW	HLW	KEY	
Rattlesnake Creek												
MRAT	C	580	7200 - 7780	580	6.7	06/01	2.2	23	0.2	1.3	0.5	1.1
BRAT[b]	B, A	1900	2500 - 4400	1500	5.3	08/01	2.6	70	0.1	0.5	0.1	1.4
LRAT	C, B	1100	100 - 1200	1100	6.5	07/01	2.4	257	0.2	0.5	0.2	2.0
Indian Creek												
MIND	B	880	2200 - 3080	880	2.0	07/01	2.7	101	0.2	1.1	0.3	4.7

[a] CLW = Conifer large woody debris ≥1 m length and ≥ 0.3 m diameter; HLW = Hardwood large woody debris ≥ 1 m length and ≥ 0.3 m diameter; KEY = "Key pieces" conifer and hardwood large woody debris ≥ 5 m length and ≥ 0.6 m diameter.

[b] 400-m section of SDS land between the two sections of Bramhill land were not surveyed due to lack of landowner permission during the 2001 field season.

Table 3. Locations of thermographs deployed and maintained by Underwood Conservation District within the Rattlesnake Creek watershed. Sites are listed from upstream to downstream. Coordinates were obtained from a hand-held Global Positioning System using North American Datum 1927. For additional information on thermograph locations see Figure 2.

Watershed Subwatershed	Code	Coordinates Northing	 Easting	Elevation (m)	Distance upstream from mouth (km)	Date Start dd/mm/yy	 End dd/mm/yy
Upper Rattlesnake Creek	URAT	5081213	628410	457	16.9	06/07/01	10/04/01
Mill Creek	LMIL	5079549	626619	396	0.2	06/08/01	10/04/01
Upper Rattlesnake Creek below canyon	BUPC	5078753	624011	292	11.3	06/08/01	10/04/01
Middle Rattlesnake Creek	MRAT	5076576	622218	250	7.7	06/08/01	10/04/01
Tomlin property	TOML	5074768	620819	226	5.6	06/07/01	10/04/01
Lower Rattlesnake above Indian Creek	RAIN	5072747	618418	131	0.8	06/07/01	10/05/01
Indian Creek	LIND	5072689	618451	131	0.1	06/07/01	10/05/01
Lower Rattlesnake Creek	LRAT	5072419	617933	122	0.1	06/07/01	10/05/01

Table 4. Number of days per month when maximum water temperature exceeded 16, 18, and 20 °C and the monthly maximum water temperature recorded at locations in the Rattlesnake Creek watershed. Thermographs began recording data on 7 June or 8 June 2001 (depending on the site). Locations are listed from upstream to downstream. Refer to Table 3 and Figure 2 for additional site information.

Site	RKM	Number of days ≥ 16°C				Number of days ≥ 18°C				Number of days ≥ 20°C				Maximum (°C)			
		Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
Mainstem																	
URAT	16.9	4	23	20	0	0	6	9	0	0	0	0	0	17.6	18.9	19.5	15.7
BUPC	11.3	6	30	31	14	2	24	22	0	0	10	6	0	19.1	21.4	21.1	17.9
MRAT	7.7	14	31	31	11	3	25	23	0	0	11	0	0	19.2	21.7	19.9	17.9
TOML	5.6	13	29	27	9	4	17	2	0	0	0	0	0	18.9	19.5	18.7	17.3
RAIN	0.8	18	31	31	23	7	28	30	7	1	19	18	0	21.2	23.2	22.4	18.8
LRAT	0.1	18	31	31	17	6	26	23	2	1	9	0	0	20.3	21.1	20.0	18.0
Tributaries																	
LMIL	0.1	0	0	0	0	0	0	0	0	0	0	0	0	12.1	14.4	15.7	14.0
LIND	0.0	7	29	31	18	1	18	22	0	0	2	7	0	18.4	20.5	20.8	17.6

Table 5. Locations of flow measurements taken within the Rattlesnake Creek watershed, 2001[a]. Coordinates were obtained from a hand-held Global Positioning System using North American Datum 1927. Sites are listed from upstream to downstream. Flows were taken approximately two times a month, from June through October, unless otherwise noted. For additional information on flow measurement locations see Figure 3.

Watershed Site	Coordinates		Elevation (m)	Distance upstream of mouth (km)
	Northing	Easting		
Rattlesnake Creek				
URAT – DNR [a,b]	5081436	628496	457	16.9
MRAT – DNR	5076614	622231	250	7.7
RAIN	5072742	618411	131	0.8
LRAT	5072429	617898	122	0.1
Mill Creek				
LMIL – DNR [c]	5079664	626548	396	0.1
Indian Creek				
MIND – DNR	5071671	620054	223	2.2
LIND [b]	5072687	618423	131	0.1

[a] DNR = Department of Natural Resources.
[b] Flow measured only on 06/07/01.
[c] Flow measured only on 06/08/01.

Table 6. Sites sampled for fish in the Rattlesnake Creek watershed during summer 2001. Sites and streams are listed from upstream to downstream. Coordinates were obtained from a hand-held Global Positioning System using North American Datum 1927. Fish tagged were limited to rainbow trout and cutthroat trout with fork length ≥ 80 mm. For additional information on fish sampling locations see Figure 3.

Watershed	Method	Length of stream surveyed	Start point distance from	Coordinates at start point		Coordinates at end point		Number of 134.2 kHz
Site	used	(km)	mouth (km)	Northing	Easting	Northing	Easting	PIT tags deployed
Rattlesnake Creek								
MRAT - DNR[a]	Electroshock[b]	0.6	7.2	5076154	621933	5076658	622395	36
BRAT - upper	Snorkel	1.0	3.4	5074170	620064	5074461	620696	0
BRAT - lower	Snorkel	0.5	2.5	5073735	619295	5074077	619861	0
BRAT	Electroshock[b]	1.5	2.5	5073735	619295	5074461	620696	318
LRAT - Stampfli	Electroshock	1.1	0.1	5072427	617875	5073242	618451	190
Indian Creek								
MIND - DNR[a]	Electroshock[b]	0.5	2.2	5071699	620033	5071055	620016	30
							Total	**574**

[a] DNR = Department of Natural Resources.
[b] Not a population assessment; fish collection, observation, and PIT tagging only.

Table 7. Presence and absence of the fish species found in the Rattlesnake Creek watershed by U.S. Geological Survey personnel, 2001. Sites are listed in an upstream to downstream pattern. For information on fish sampling sites, see Figure 3 and Table 6. P = present, A = absent.

Subwatershed Site	Rainbow trout	Cutthroat trout	Longnose dace	Shorthead sculpin	Brook lamprey
Rattlesnake Creek					
MRAT	P	A	P	P	A
BRAT	P	A	P	P	A
LRAT	P	P	P	P	P
Indian Creek					
MIND	A	P	A	P	A

Table 8. Population estimate of age-0 and age-1 trout by habitat type; for lower Rattlesnake Creek (LRAT, rkm 0.2-1.1). A systematic sample of habitat units within different habitat types (e.g., pool, glide, riffle) was chosen for multiple pass, removal-depletion electrofishing with blocknets. Habitat Types are: GL = glide, P1 = shallow pools (<84 cm), P2 = deep pools (≥84 cm), RH = high gradient riffles, and RL = low gradient riffles. $\hat{N}$ = estimated population size, $\hat{B}$ = biomass estimate (g), T = total, CV = coefficient of variation.

Habitat type	Total length (m) (% of total)	Total area (m^2) (% of total)	Age-0 trout				Age-1 or older trout			
			$\hat{N}_i$ (% $\hat{N}_T$)	CV_i	$\hat{B}_i$ (% $\hat{B}_T$)	CV_i	$\hat{N}_i$ (% $\hat{N}_T$)	CV_i	$\hat{B}_i$ (% $\hat{B}_T$)	CV_i
GL	111 (10)	524 (8)	72 (28)	52.4	1,376.72 (29)	47.8	142 (16)	32.9	2,857.94 (17)	32.2
P1	223 (20)	1,152 (18)	648 (25)	27.7	113.57 (24)	26.1	294 (33)	28.8	5,411.28 (31)	35.7
P2	141 (13)	778 (12)	185 (7)	5.7	351.87 (8)	5.4	165 (19)	4.4	3,820.15 (22)	4.3
RH	43 (4)	304 (5)	61 (2)	2.9	133.67 (3)	3.0	12 (1)	4.1	164.72 (1)	4.3
RL	585 (53)	3,698 (57)	94 (37)	41.0	1,673.50 (36)	43.7	277 (31)	45.4	4,969.82 (29)	48.4
Total	1,103 (100)	6,156 (100)	2,577 (100)	22.3	4,669.33 (100)	22.0	890 (100)	17.8	17,223.91 (100)	18.7

Table 9. Number and biomass (g) of age-0 and age-1 rainbow trout by habitat type for lower Rattlesnake Creek (LRAT, rkm 0.2-1.1). A systematic sample of habitat units within different habitat types (e.g., pool, glide, riffle) was chosen for multiple pass, removal-depletion electrofishing with blocknets. Habitat types are: GL = glide, P1 = shallow pools (<84 cm), P2 = deep pools (≥84 cm), RH = high gradient riffles, and RL = low gradient riffles. SE = standard error.

Habitat	Age-0 rainbow trout				Age-1 or older rainbow trout			
type[a]	no./m (SE)	no./m^2 (SE)	g/m (SE)	g/m^2 (SE)	no./m (SE)	no./m^2 (SE)	g/m (SE)	g/m^2 (SE)
GL	6.49 (3.40)	1.38 (0.72)	12.39 (5.93)	2.63 (1.26)	1.28 (0.42)	0.27 (0.09)	25.72 (8.30)	5.45 (1.76)
P1	2.90 (0.80)	0.56 (0.16)	5.07 (1.33)	0.98 (0.26)	1.31 (0.38)	0.26 (0.07)	24.18 (8.63)	4.70 (1.68)
P2	1.31 (0.07)	0.24(0.01)	2.50 (0.13)	0.45 (0.02)	1.17 (0.05)	0.21 (0.01)	27.09 (1.16)	4.91 (0.21)
RH	1.42 (0.04)	0.21 (0.01)	3.11 (0.09)	0.44 (0.01)	0.28 (0.01)	0.04 (0.00)	3.83 (0.17)	0.54 (0.02)
RL	1.61 (0.66)	0.25 (0.11)	2.86 (1.25)	0.45 (0.20)	0.47 (0.22)	0.07 (0.03)	8.49 (4.11)	1.34 (0.65)
Mean	2.19 (0.48)	0.39 (0.09)	3.99 (0.88)	0.72 (0.16)	0.76 (0.14)	0.14 (0.02)	14.69 (2.75)	2.66 (0.50)

Table 10. Comparison between the number of fish caught on the first pass and the population estimate, using multiple pass removal-depletion electrofishing with blocknets, for each pool on lower Rattlesnake Creek (LRAT, rkm 0.1-1.2).

	Age-0 trout			Age-1 or older trout		
Pool number	Pass 1	Population estimate (SE)	Percent of estimate	Pass 1	Population estimate (SE)	Percent of estimate
1	9	23 (1.8)	39	17	44 (3.4)	39
5	25	45 (8.4)	56	34	55 (6.5)	76
7	39	61 (6.4)	64	24	58 (1.3)	41
15	12	28 (0.0)	43	9	13 (0.0)	69
19	5	5 (0.0)	100	14	14 (0.0)	100
23	24	38 (5.5)	63	23	26 (0.8)	88
29	71	103 (6.3)	69	39	51 (2.7)	76
37	53	74 (2.4)	72	20	31 (2.4)	65
41	17	24 (2.8)	71	10	10 (0.0)	100
Total	255	401		190	302	
Mean	**28**	**45**	**64 (SD=16.9)**	**21**	**34**	**71 (SD=21.0)**

Table 11. Delimits of size and age classes of salmonids in Rattlesnake Creek during summer 2001. Sites are listed in an upstream to downstream pattern within the watershed. See Figure 3 and Table 6 for information on fish sampling sites. Age classes were estimated by length-frequency analysis and by aging scales.

Watershed Site	Date	Length of stream surveyed (km)	Start point distance from mouth (km)	Species	Max FL age 0	Min FL age 1 or older
Rattlesnake Creek						
MRAT	9 Oct 01	0.6	7.2	RBT	82	113
BRAT	10 Oct 01-15 Oct 01	1.5	2.5	RBT	92	95
LRAT	7 Jul 01-3 Aug 01	1.1	0.1	Trout[a]	69	--
LRAT	7 Jul 01-3 Aug 01	1.1	0.1	RBT	--	79
LRAT	7 Jul 01-3 Aug 01	1.1	0.1	CTT	--	128
LRAT	21 Aug 01	1.1	0.1	Trout[a]	69	--
LRAT	21 Aug 01	1.1	0.1	RBT	--	78
Indian Creek						
MIND	2 Nov 01	0.5	2.2	CTT	55	81

[a] Trout less than 80 mm were not identified to species.

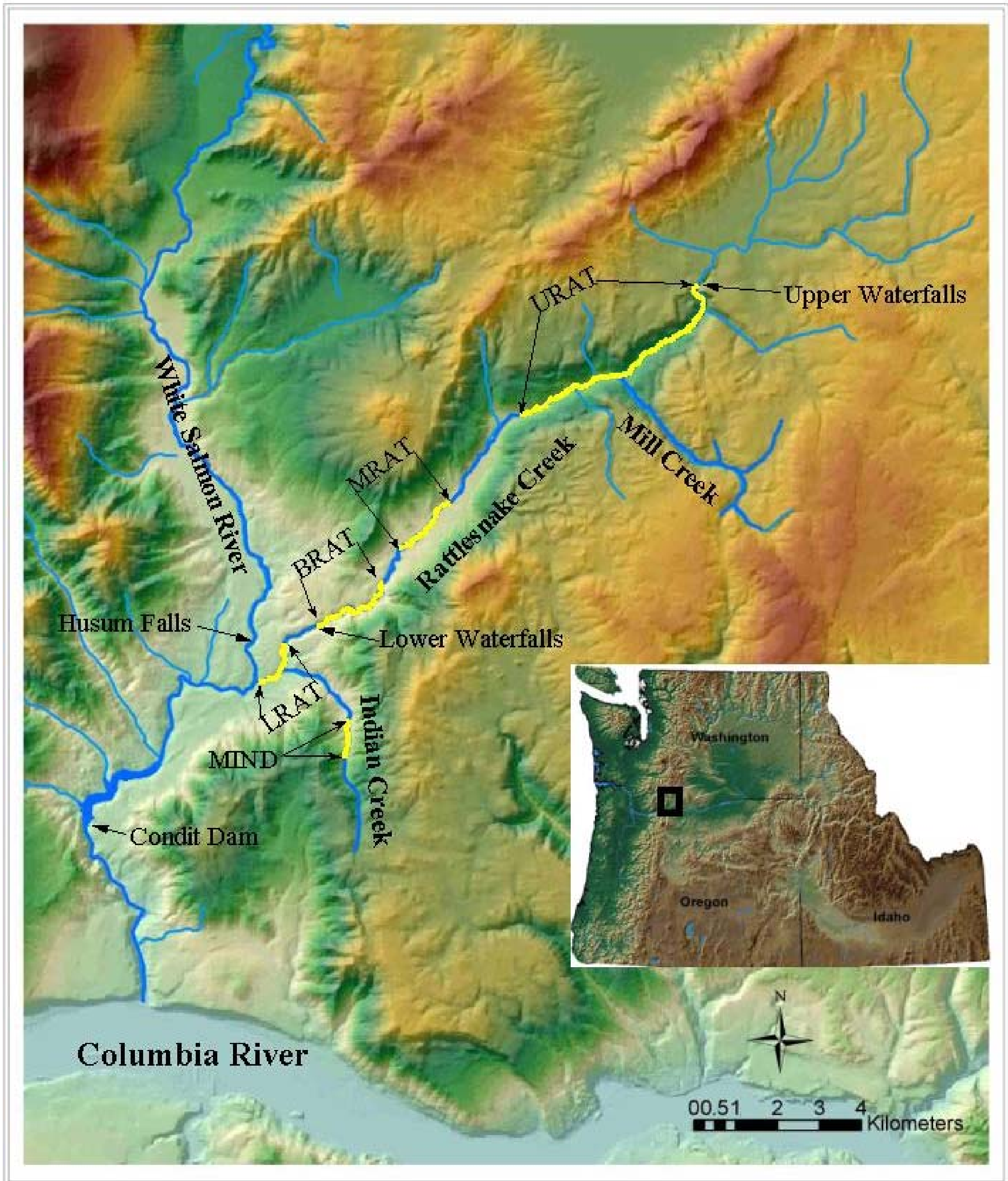


Figure 1. Location of Rattlesnake Creek, WA and study reaches within the Columbia River Gorge. Study reaches are: LRAT = lower Rattlesnake Creek below lower waterfall; BRAT = lower Rattlesnake Creek above lower waterfall; MRAT = middle Rattlesnake Creek; URAT = upper Rattlesnake Creek to upper waterfall.

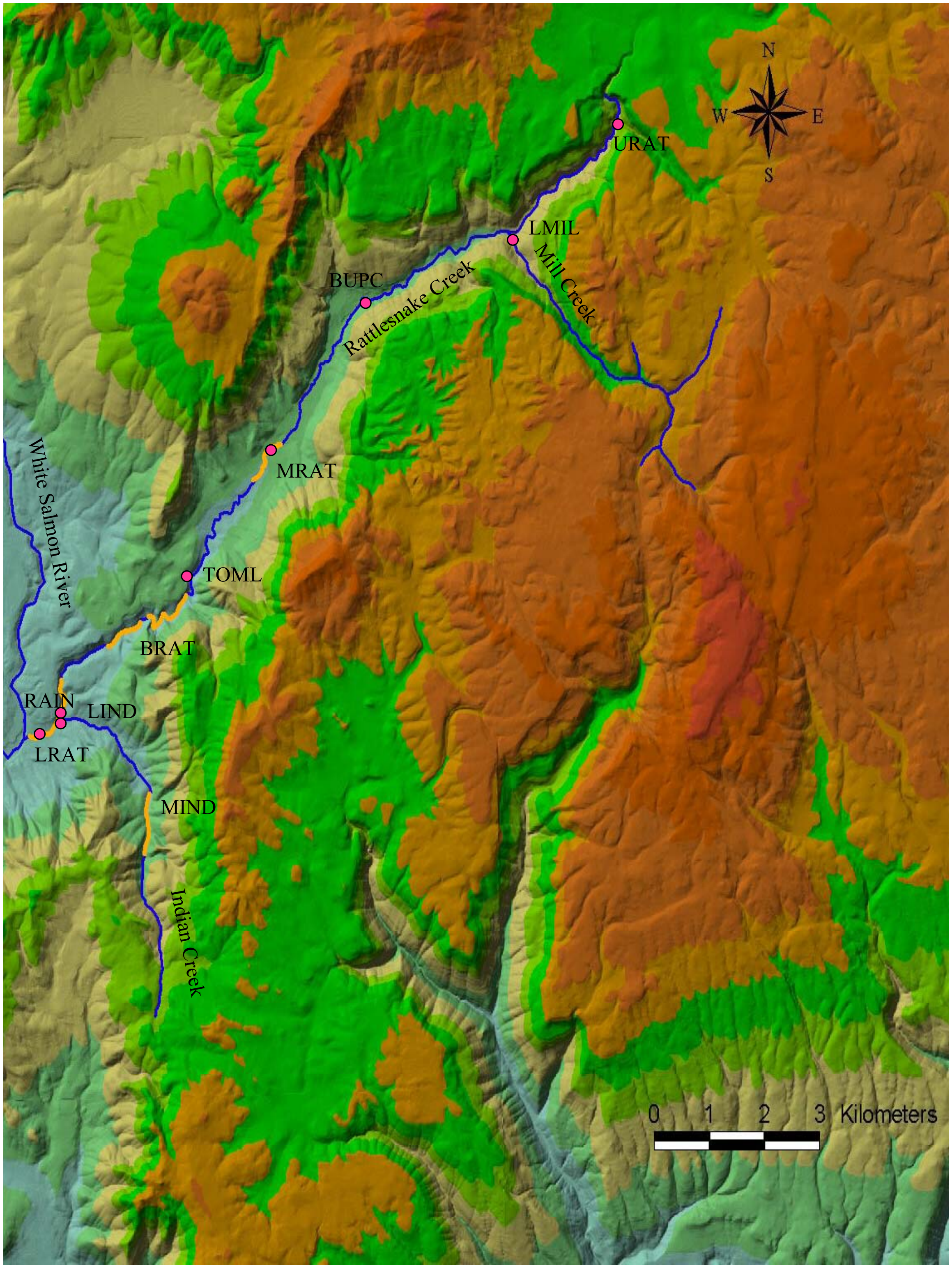


Figure 2. Locations of reach surveys and thermograph sites within the Rattlesnake Creek watershed, 2001. ▬ = Location of reach surveys. ● = Location of thermograph sites.

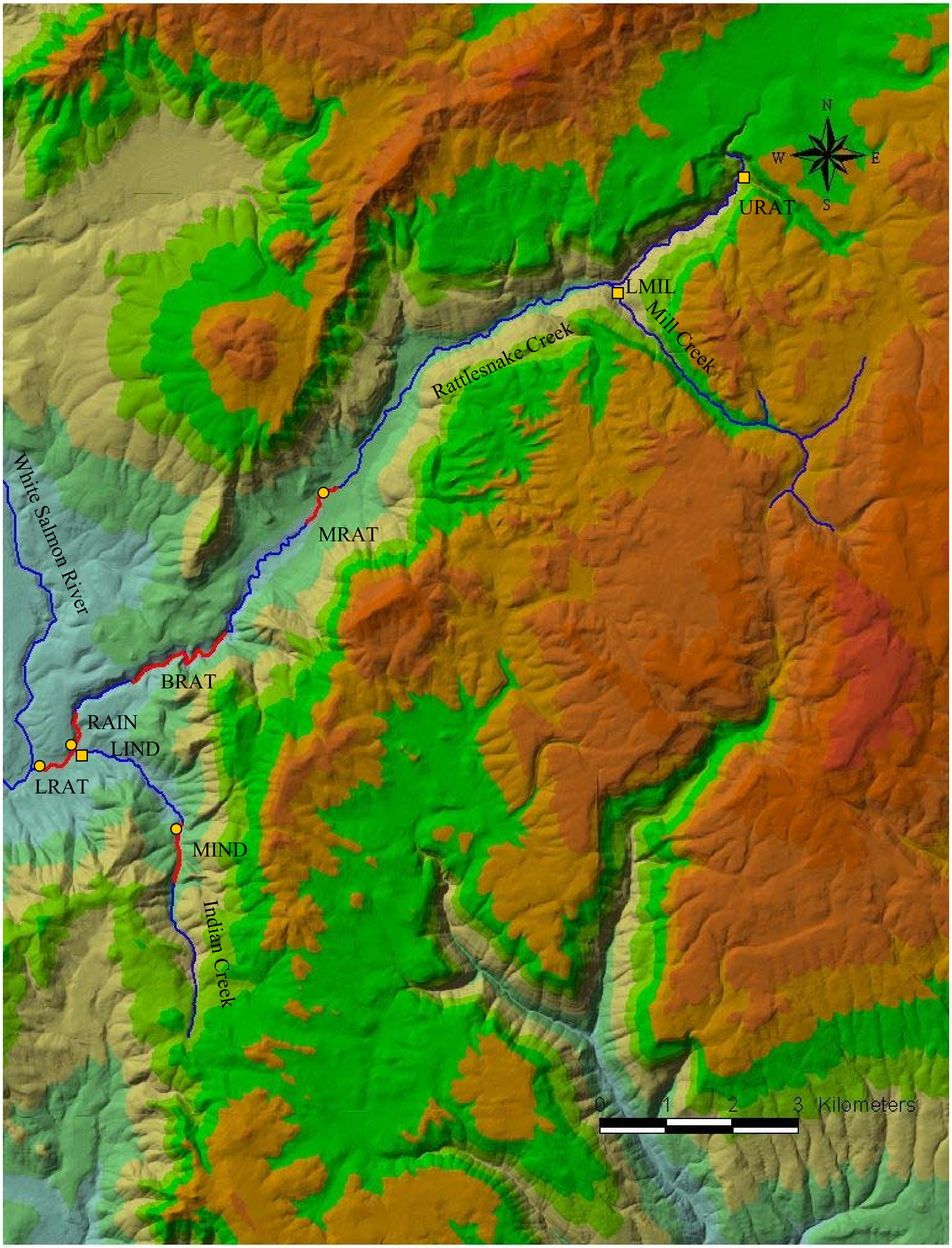


Figure 3. Locations of fish sampling and flow sites within the Rattlesnake Creek watershed, 2001. ▬ = Location of fish sampling. ○ = Flow locations taken at multiple times in 2001. □ = Flow locations taken one time in 2001.

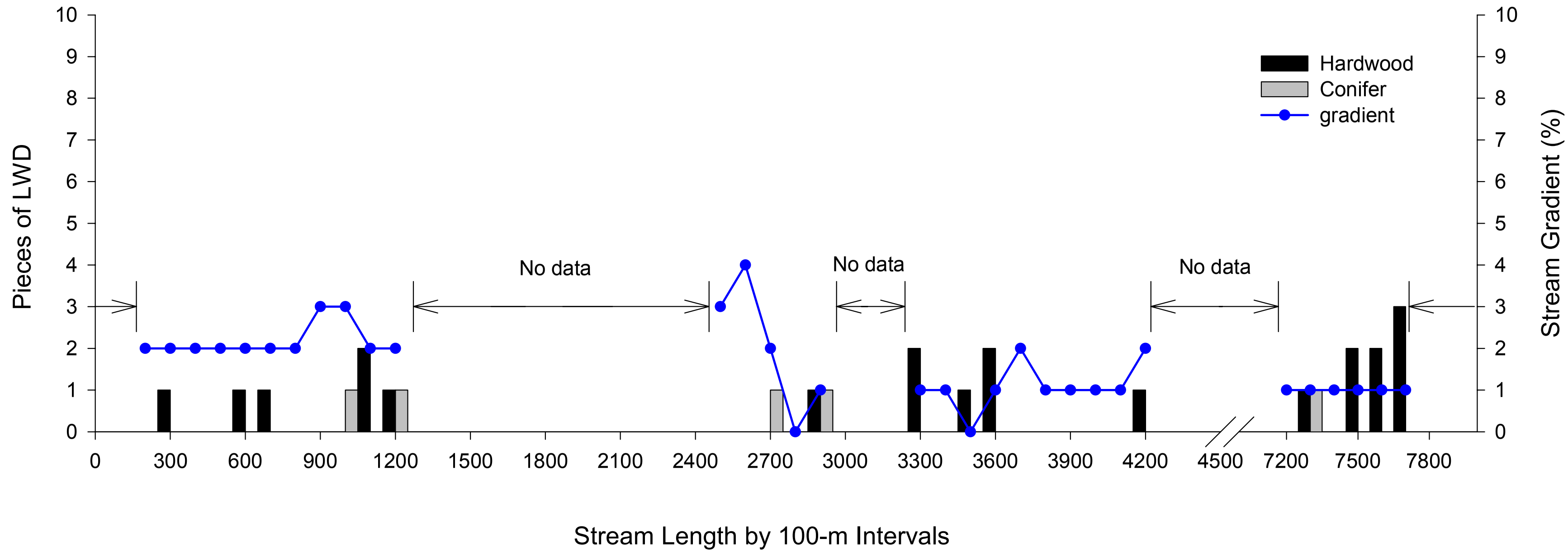


Figure 4. Reach survey data collected during 2001 from the mouth of Rattlesnake Creek to the uppermost section surveyed (LRAT, 0.1-1.2 rkm; BRAT, 2.5-4.4 rkm; MRAT, 7.2-7.8 rkm). Stream gradient (%) and counts of hardwood and coniferous large woody debris (LWD; length $1.0 m, diameter $ 0.3 m) were averaged over 100 m intervals. NS = not sampled.

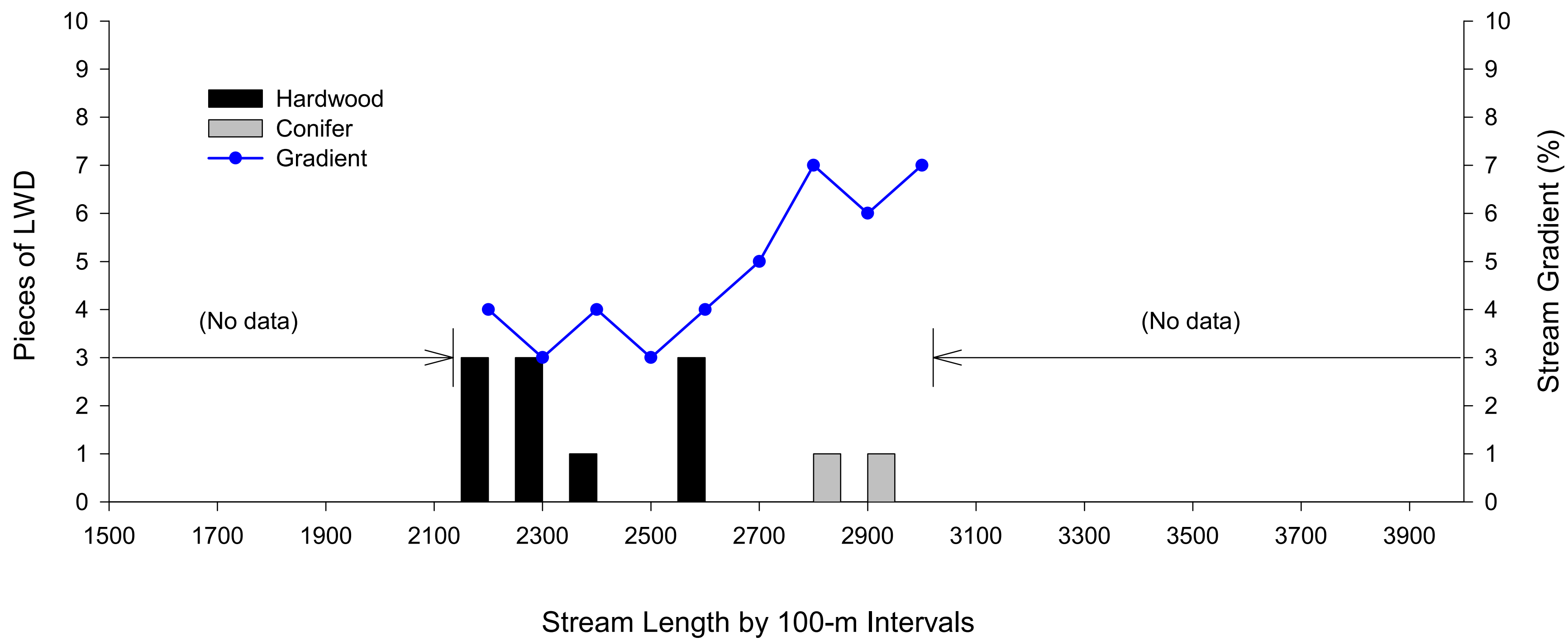


Figure 5. Reach survey data collected during 2001 from the Department of Natural Resources section of Indian Creek (MIND, 2.2-3.1 rkm). Stream gradient (%) and counts of hardwood and coniferous large woody debris (LWD; length $1.0 m, diameter $ 0.3 m) were averaged over 100 m intervals. NS = not sampled.

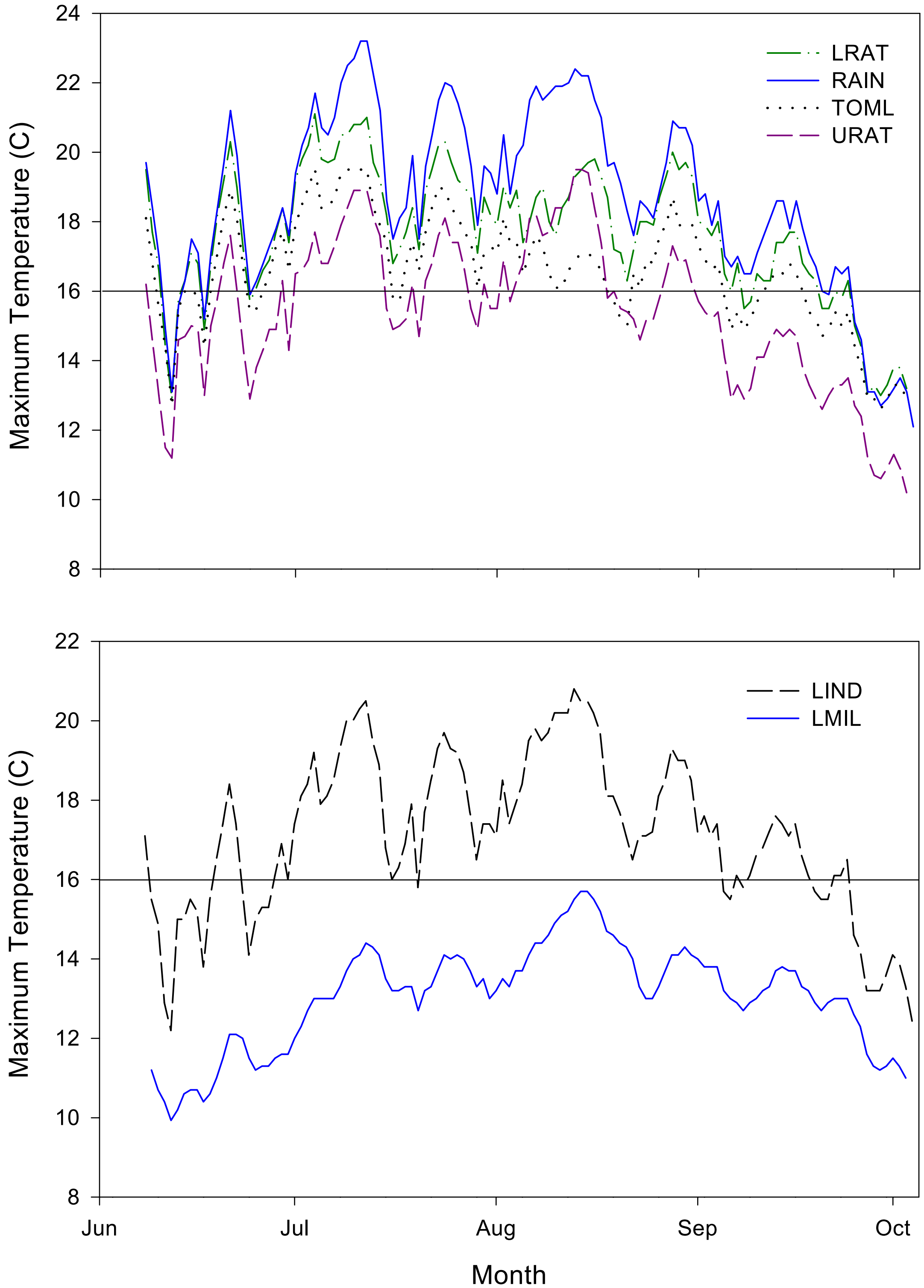


Figure 6. Daily maximum temperatures at six sites on Rattlesnake Creek from June 8 to October 4, 2001. Thermograph sites are mapped on Figure 2, and coordinates and elevation are provided in Table 3. The line at 16 °C marks the maximum surface water temperature standard set by the Washington Department of Ecology (Chapter 173-201A, November 18, 1997, Water Quality Standards for the Surface Waters of the State of Washington).

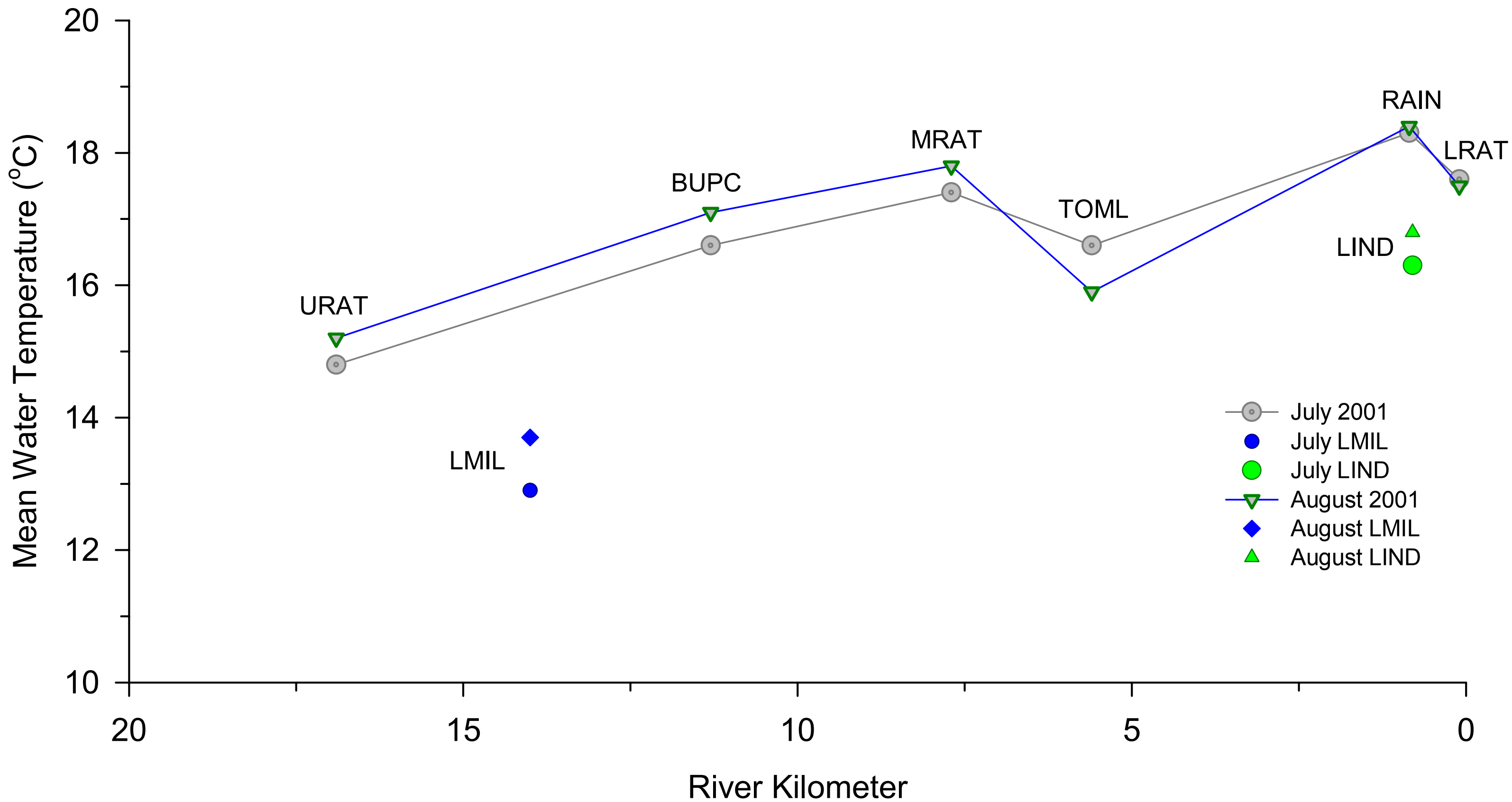


Figure 7. Mean water temperature during July and August 2001 in the mainstem Rattlesnake Creek and its tributaries. Sites, from left to right, are shown from upstream to downstream. River kilometer zero is the mouth of Rattlesnake Creek. For additional thermograph information, Figure 2 shows thermograph locations. Thermograph coordinates, elevations, and start and end dates are provided in Table 3.

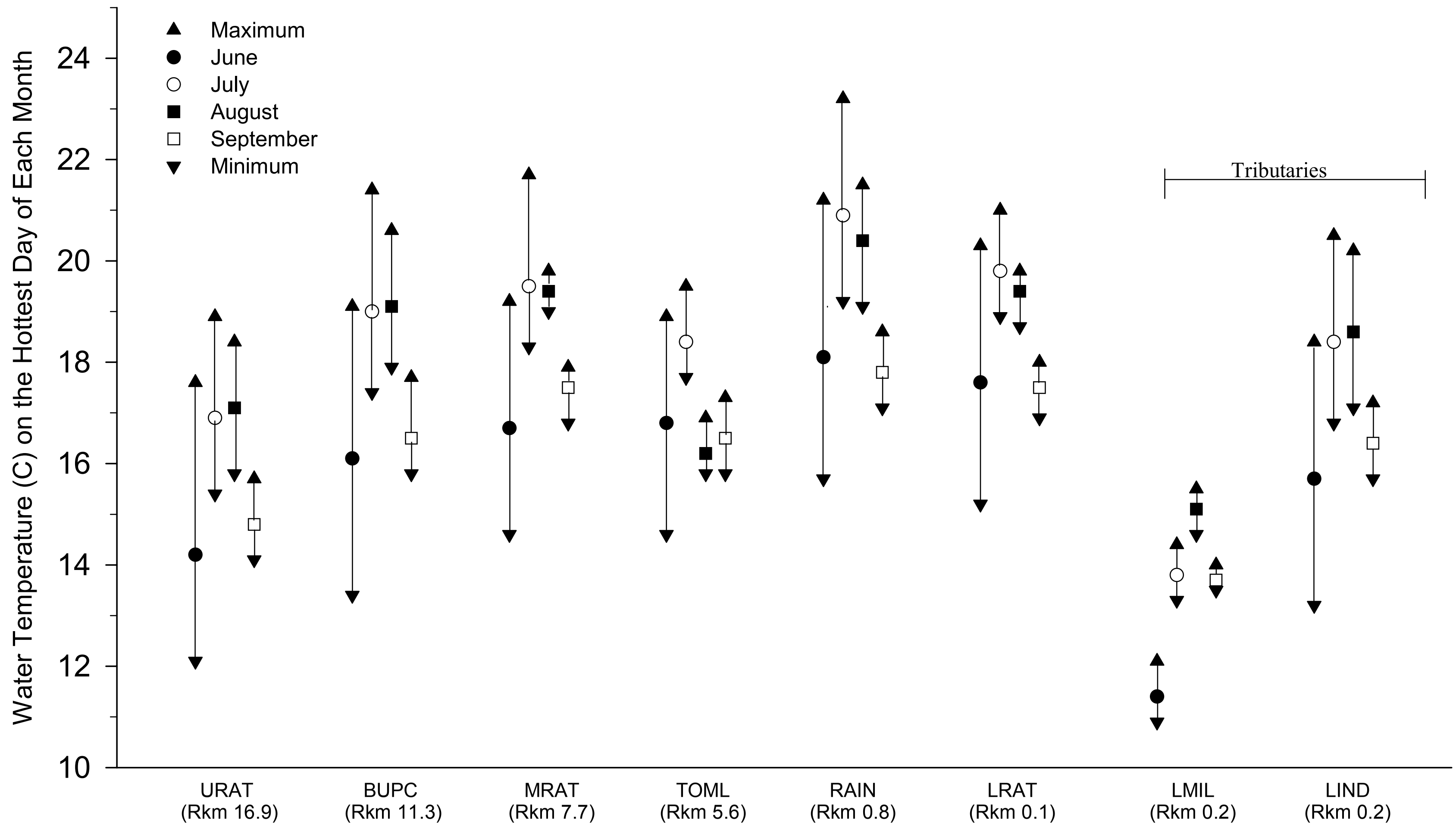


Figure 8. Dates chosen had the warmest single day water temperature for each month at most sites in 2001 (June 21, July 12, August 16, and September 1). For additional thermograph information, Figure 2 shows thermograph locations. Thermograph coordinates, elevations, start dates, and end dates are provided in Table 3. Mill Creek enters Rattlesnake Creek at rkm 14 and Indian Creek enters Rattlesnake Creek at rkm 0.8.

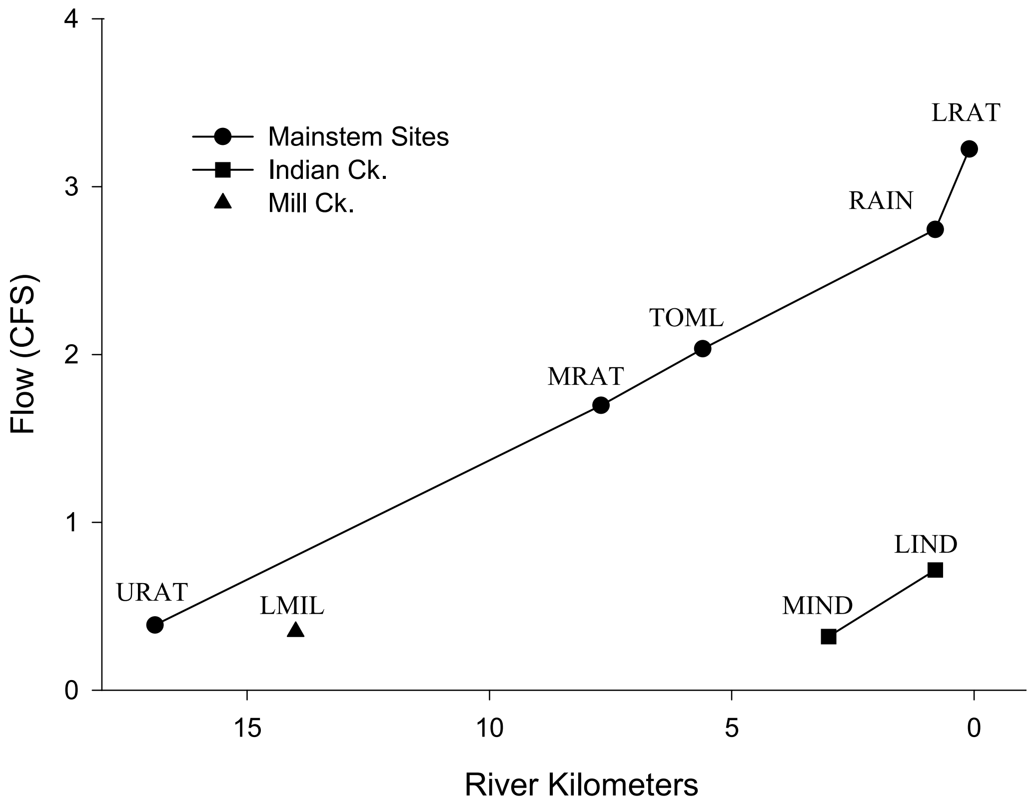


Figure 9. Flow measured in cubic feet per second (CFS) on June 7, 2001 at Rattlesnake Creek. For additional information on the locations of flow measurement sites, see Table 5 and Figure 3.

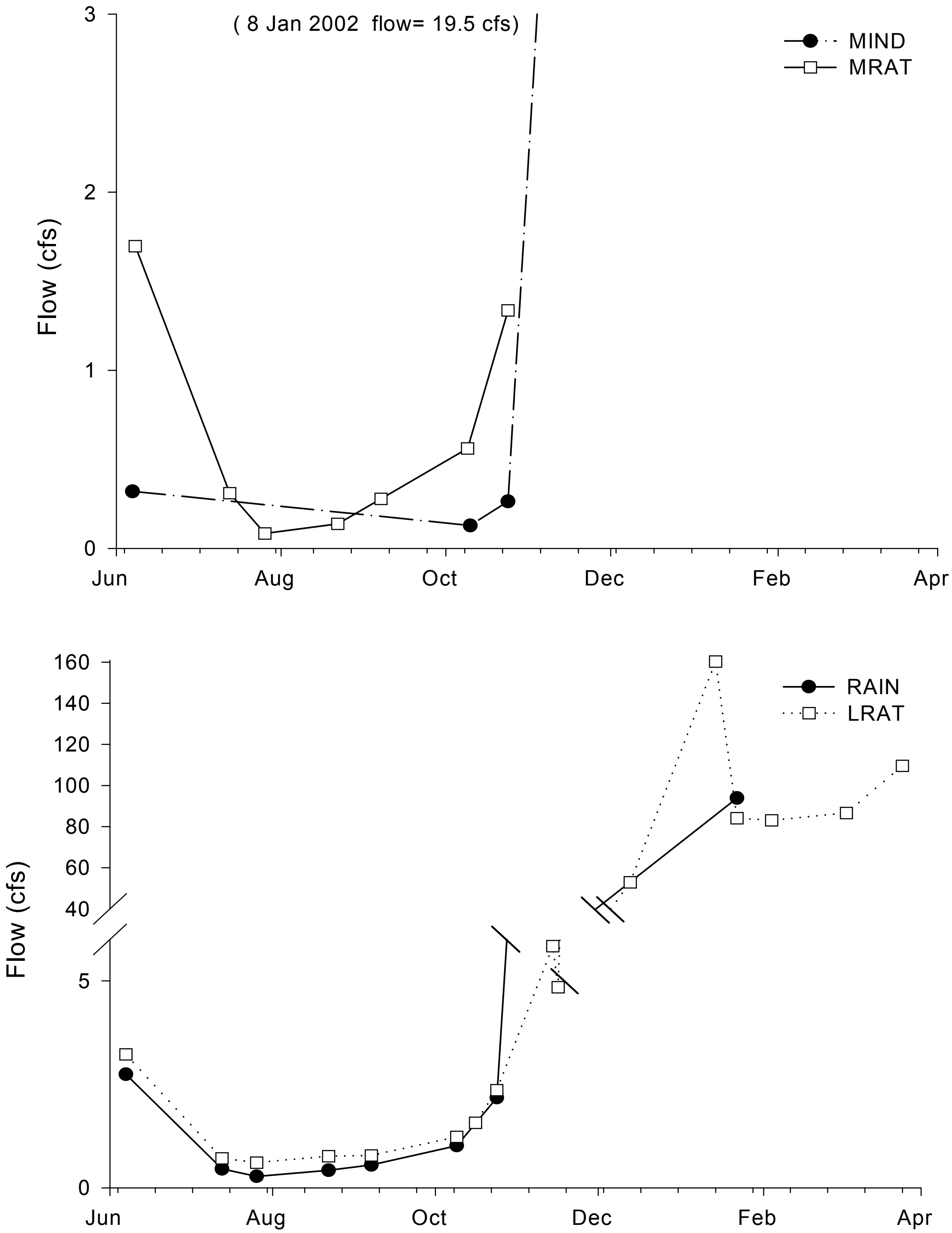


Figure 10. Flow measured at three sites on Rattlesnake Creek (LRAT, rkm 0.1; RAIN, rkm 0.8; MRAT, rkm 7.7) and one site on Indian Creek (MIND, rkm 2.2). For information on flow measurement locations, see Table 5 and Figure 3.

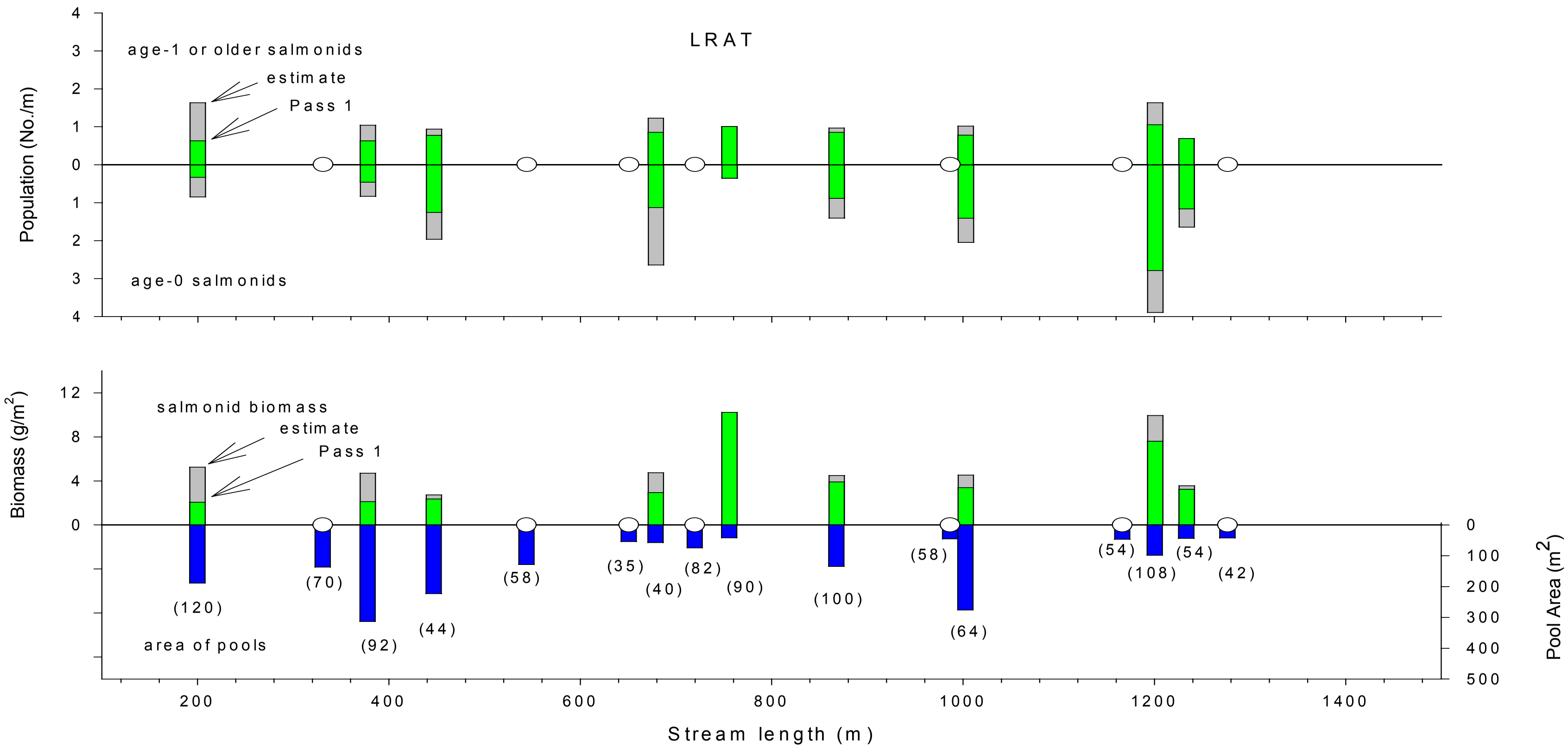


Figure 11. Comparison of salmonid population and biomass in pools (n=16) in lower Rattlesnake Creek (LRAT) (rkm 0.1-1.2). Pools were sampled using multiple pass, removal-depletion electrofishing with blocknets. The upper graph shows fish per meter of age-0 trout and age-1 or older trout after the first electrofishing pass and the estimated total population from multiple passes (2-5). The lower graph shows biomass (g/m^2) of all salmonids after the first pass and the estimated biomass (g/m^2) from multiple passes, and the area (m^2) of pools in the stream section. Maximum depth (cm) is noted in parentheses below each pool. ○ = pools not sampled for fish (n=7).

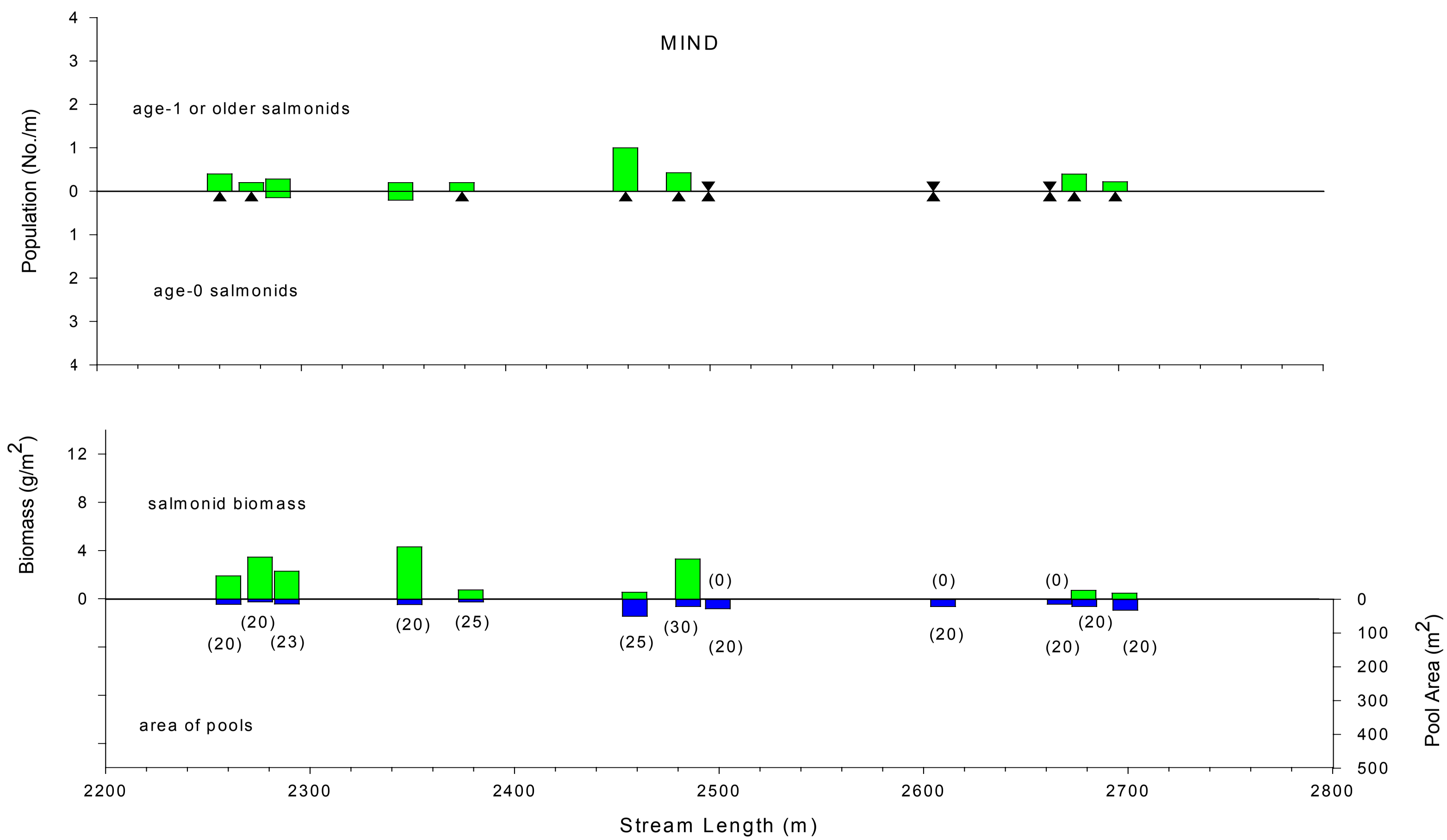


Figure 12. Comparison of cutthroat trout population and biomass in pools (n=12) in middle Indian Creek (MIND; rkm 2.2-2.7). Pools were sampled using one-pass electrofishing without blocknets. The upper graph shows fish per meter of age-0 trout and age-1 or older trout. The lower graph shows biomass (g/m^2) of all trout and area (m^2) of pools sampled. Maximum depth (cm) is noted in parentheses below each pool. ▼= No age-1 or older salmonids. ▲ = No age-0 salmonids.

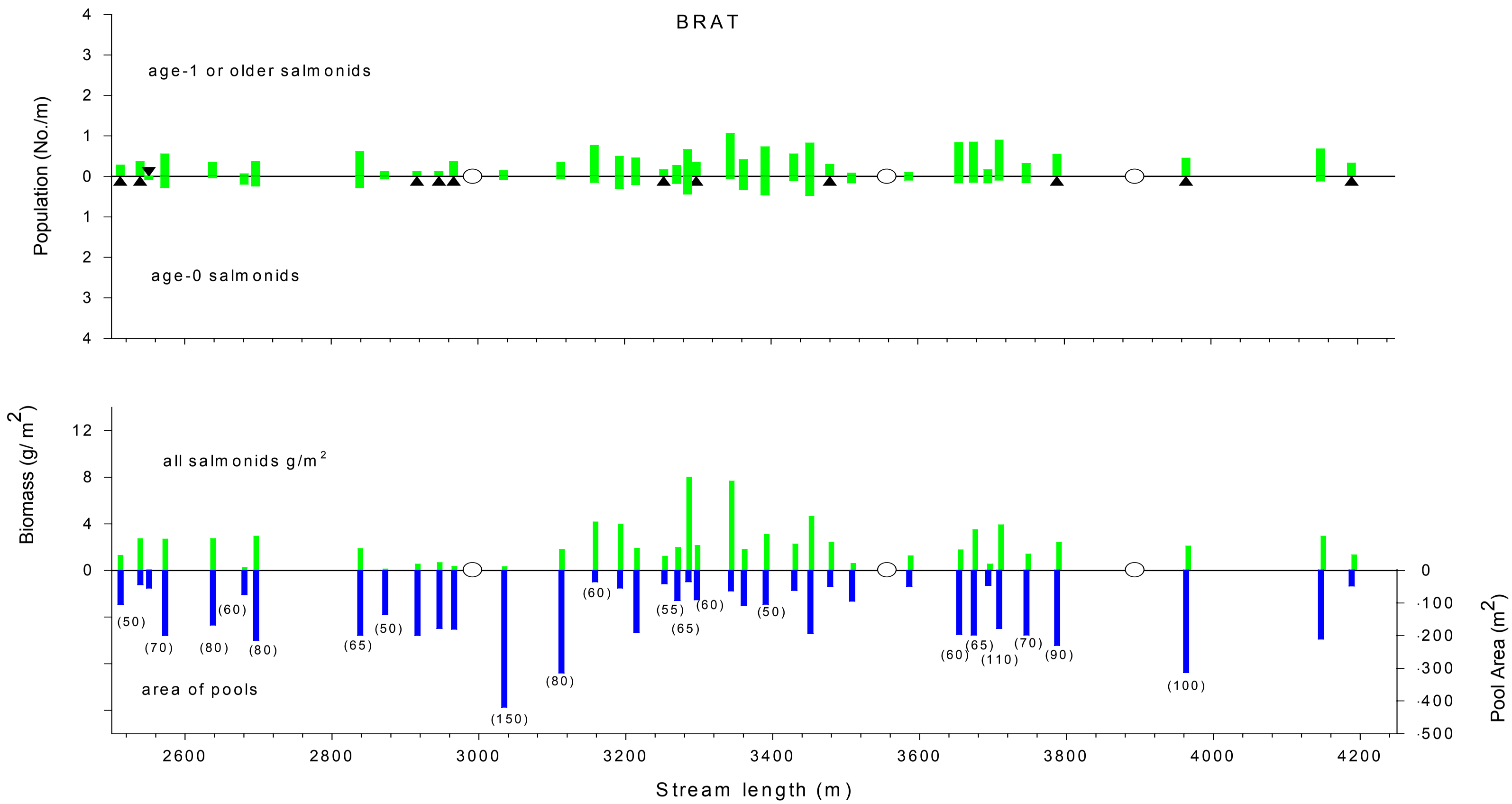


Figure 13. Comparison of salmonid population and biomass in pools (n= 38) on the BRAT reach of Rattlesnake Creek (rkm 2.5-4.3). Pools were sampled using one-pass electrofishing without blocknets. The upper graph shows fish per meter of age-0 trout and age-1 or older trout. The lower graph shows biomass (g/m^2) of all trout and area (m^2) of pools sampled. Maximum depth (cm) is noted in parentheses for pools that were at least 50 cm deep. ▼= No age-1 or older salmonids. ▲ = No age-0 salmonids. ○ = pools not sampled for trout (n= 3).

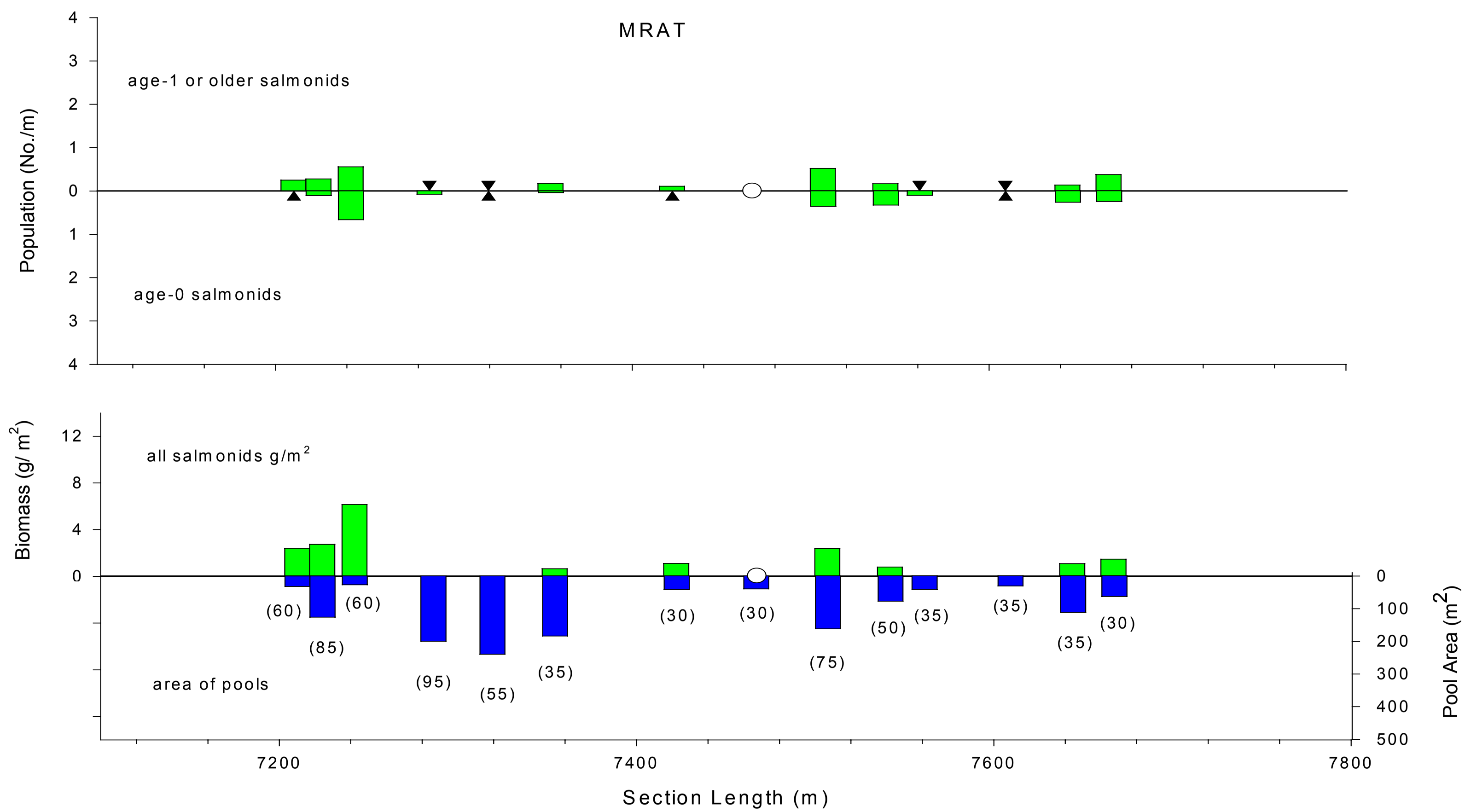


Figure 14. Comparison of salmonid population and biomass in pools (n=13) in middle Rattlesnake Creek (MRAT; rkm 7.2-7.8). Pools were sampled using one-pass electrofishing without blocknets. The upper graph shows fish per meter of age-0 trout and age-1 or older trout. The lower graph shows biomass (g/m^2) of all trout and area (m^2) of pools sampled. Maximum depth (cm) is noted in parentheses below each pool. ▼= No age-1 or older salmonids. ▲ = No age-0 salmonids. ○ = pools not sampled for fish (n=1).

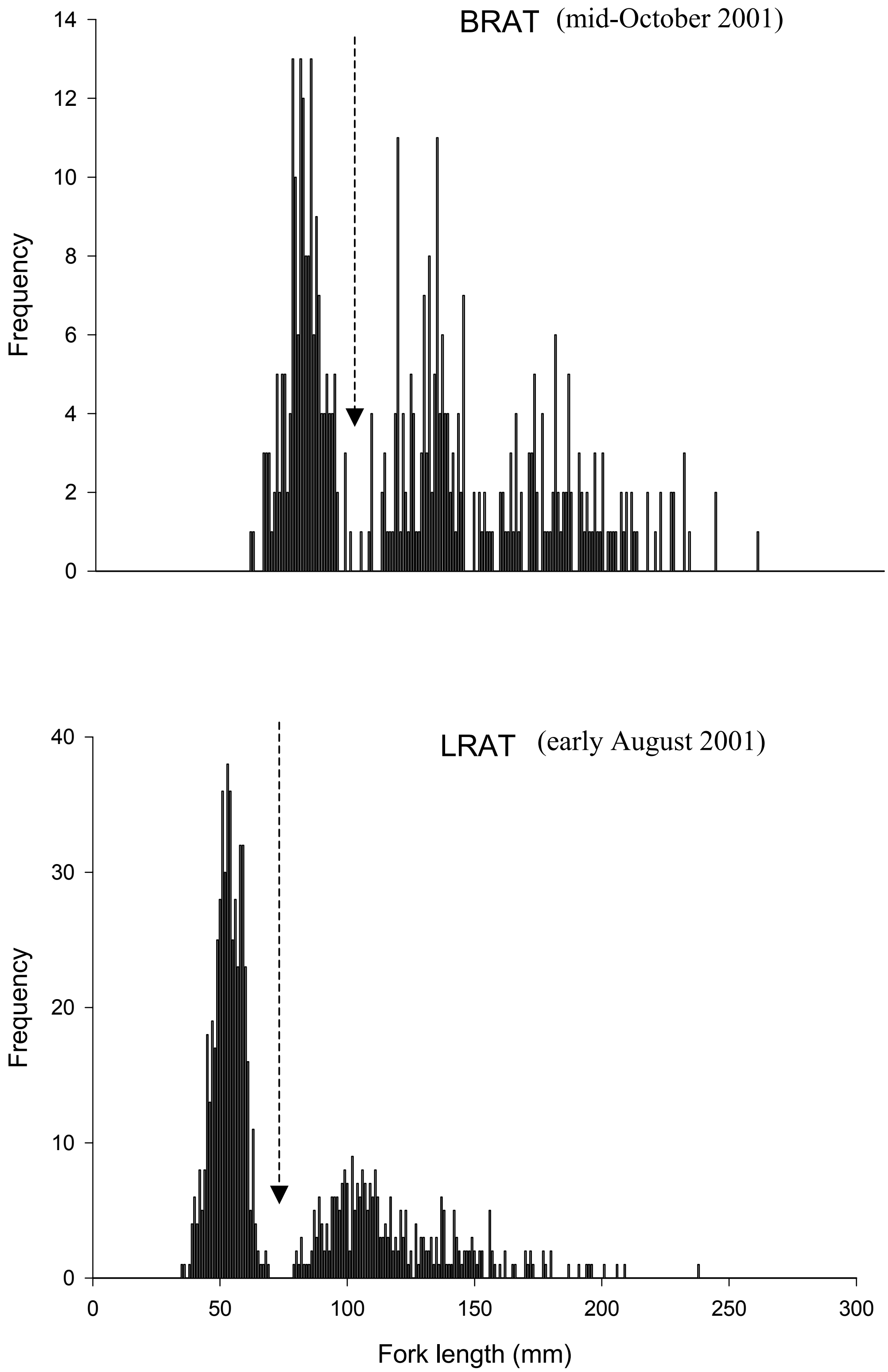


Figure 15. Length frequency in 1-mm increments of rainbow trout sampled in the BRAT reach (rkm 2.5 – 4.4) of Rattlesnake Creek, and rainbow trout and cutthroat trout sampled in the LRAT reach (rkm 0.1 – 1.2) of Rattlesnake Creek. The arrow indicates the break between age-0 and age-1. This age break was verified by aging fish scales on either side of the break.

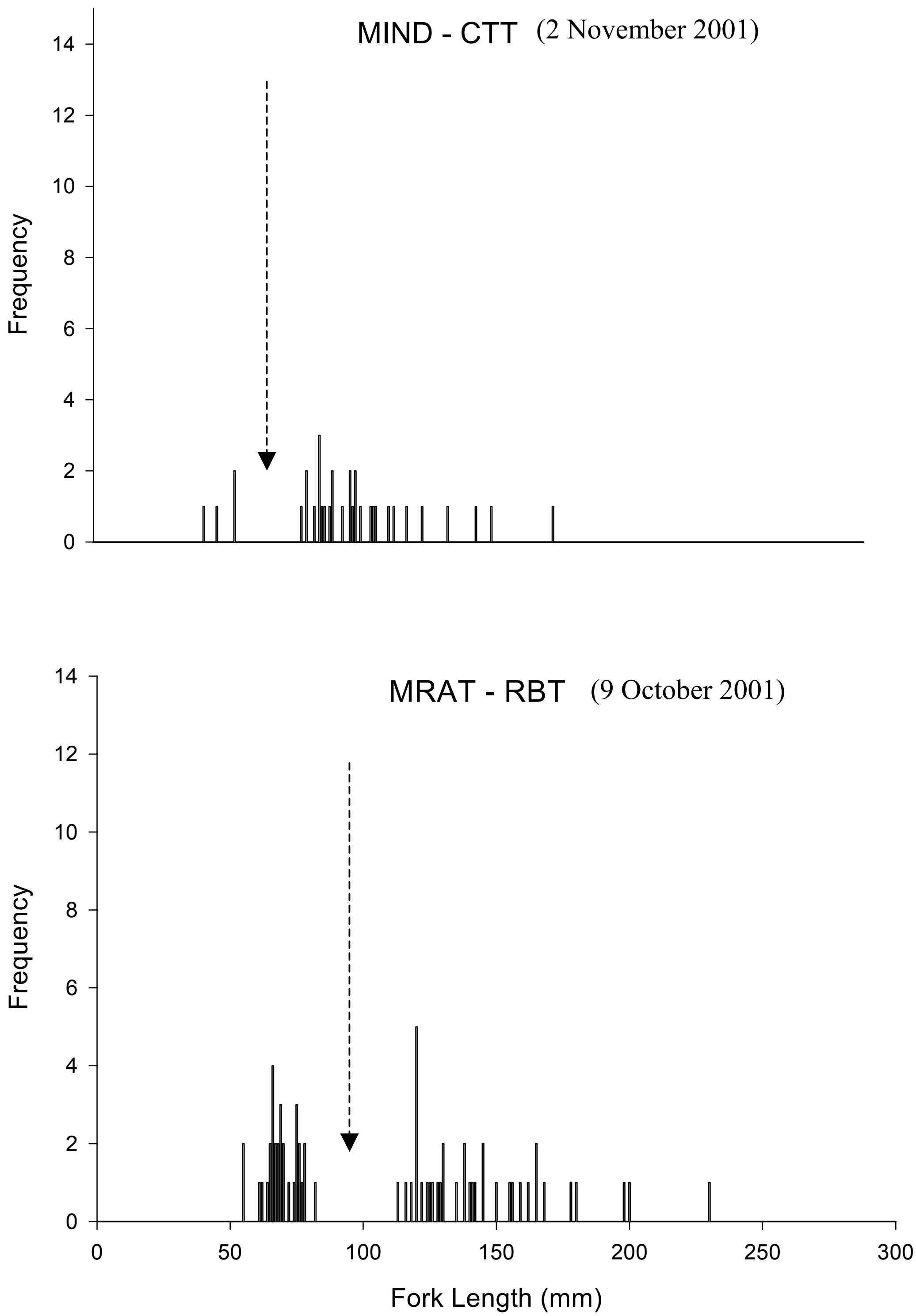


Figure 16. Length frequency in 1-mm increments of cutthroat trout (CTT) sampled in Indian Creek (MIND rkm 2.2 – 2.7), and rainbow trout (RBT) sampled in Rattlesnake Creek (MRAT rkm 7.2 – 7.8). The arrow indicates the break between age-0 and age-1. This age break was verified by aging fish scales on either side of the break.

Appendix

Appendix Table 1. Results from the U.S. Fish and Wildlife Service's Lower Columbia River Fish Health Center disease profiling for rainbow trout and longnose dace collected on Rattlesnake Creek during 31 July 2001 and 9 October 2001.

U.S. Fish & Wildlife Service
LOWER COLUMBIA RIVER FISH HEALTH CENTER
61552 S.R. 14
Underwood, WA 98651
Phone: 509-493-3156
Fax: 509-493-2748

NATIONAL WILD FISH HEALTH SURVEY REPORT

FISH SOURCE	FISH EXAMINED
Location: Rattlesnake Creek **County**: Klickitat, WA **Contact Person:** Pat Connolly **Affiliation:** USGS BRD CRRL **Phone:** (509) 538-2299	**Species:** Rainbow trout **Age:** Juvenile and adult **CHN:** 01-443 **Number of fish:** 30 **Date Sampled:** 07-31-01

DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	30	negative	Negative by EPC and CHSE-214 cells
IHNV	30	negative	Negative by EPC and CHSE-214 cells
VHS	30	negative	Negative by EPC and CHSE-214 cells
AS	24	negative	Negative by BHIA medium
YR	24	negative	Negative by BHIA medium
RS	24	suspect	+3/3 detected by ELISA, not confirmed by PCR 0/3
BCD	24	negative	Negative by TYES medium
CD	24	negative	Negative by TYES medium
ESC	24	negative	Negative by BHIA medium
WD	30	negative	Negative by Pepsin/Trypsin Digest and PCR
CS	6	negative	Negative by microscopic examination
Other			ELISA and virus pooled. Collected ½ mile upstream of 141 bridge. *Scyphidia* on the skin (low). *Nanophyetus* in the hind-gut (low).

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral Hemorrhagic Septicemia Virus, **AS** Furunculosis (*Aeromonas salmonicida)* , **YR** Enteric Redmouth (*Yersinia ruckeri),* **RS** BKD (*Renibacterium salmoninarum*), **BCD** Coldwater Disease (*Flexibacter psychrophilum)*, **CD** Columnaris (*Flexibacter columnaris)*, **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri),* **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

U.S. Fish & Wildlife Service
LOWER COLUMBIA RIVER FISH HEALTH CENTER
61552 S.R. 14
Underwood, WA 98651
Phone: 509-493-3156
Fax: 509-493-2748

NATIONAL WILD FISH HEALTH SURVEY REPORT

FISH SOURCE	FISH EXAMINED
Location: Rattlesnake Creek **County**: Klickitat, WA **Contact Person:** Pat Connolly **Affiliation:** USGS BRD CRRL **Phone:** (509) 538-2299	**Species:** Longnose dace **Age:** Juvenile and adult **CHN:** 01-444 **Number of fish:** 25 **Date Sampled:** 07-31-01

DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	25	negative	Negative by EPC and CHSE-214 cells
IHNV	25	negative	Negative by EPC and CHSE-214 cells
VHS	25	negative	Negative by EPC and CHSE-214 cells
AS	25	negative	Negative by BHIA medium
YR	25	negative	Negative by BHIA medium
RS	25	suspect	+4/4 detected by ELISA, not confirmed by PCR 0/3
BCD	25	negative	Negative by TYES medium
CD	25	negative	Negative by TYES medium
ESC	25	negative	Negative by BHIA medium
WD	25	negative	Negative by Pepsin/Trypsin Digest and PCR
CS	-	not tested	microscopic examination
Other			ELISA and virus pooled. Collected ½ mile upstream of 141 bridge.

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral Hemorrhagic Septicemia Virus, **AS** Furunculosis (*Aeromonas salmonicida)* , **YR** Enteric Redmouth (*Yersinia ruckeri),* **RS** BKD (*Renibacterium salmoninarum*), **BCD** Coldwater Disease (*Flexibacter psychrophilum)*, **CD** Columnaris (*Flexibacter columnaris)*, **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri),* **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

U.S. Fish & Wildlife Service
LOWER COLUMBIA RIVER FISH HEALTH CENTER
61552 S.R. 14
Underwood, WA 98651
Phone: 509-493-3156
Fax: 509-493-2748

NATIONAL WILD FISH HEALTH SURVEY REPORT

FISH SOURCE	FISH EXAMINED
Location: Rattlesnake Creek **County:** Klickitat **Contact Person:** Pat Connolly **Affiliation:** USGS BRD **Phone:** (509) 538-2299	**Species:** Rainbow trout **Age:** Juvenile and adults **CHN:** 02-017 **Number of fish:** 14 **Date Sampled:** 10-09-01

DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	14	negative	Negative by EPC and CHSE-214 cells
IHNV	14	negative	Negative by EPC and CHSE-214 cells
VHS	14	negative	Negative by EPC and CHSE-214 cells
AS	14	negative	Negative by BHIA medium
YR	14	negative	Negative by BHIA medium
RS	14	**positive**	+3/4 detected by ELISA, confirmed by PCR +2/3
BCD	14	negative	Negative by TYES medium
CD	14	negative	Negative by TYES medium
ESC	14	negative	Negative by BHIA medium
WD	14	negative	Negative by Pepsin/Trypsin Digest and PCR
CS	4	negative	Negative by microscopic examination
Other			ELISA and virus pooled. *Neascus* (Black spot) and *Nanophyetus* on skin (heavy levels). *Nanophyetus* on the gills and hind-gut (heavy). Diagenic trematodes in the hind-gut (heavy).

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral Hemorrhagic Septicemia Virus, **AS** Furunculosis (*Aeromonas salmonicida)* , **YR** Enteric Redmouth (*Yersinia ruckeri),* **RS** BKD (*Renibacterium salmoninarum*), **BCD** Coldwater Disease (*Flexibacter psychrophilum)*, **CD** Columnaris (*Flexibacter columnaris)*, **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri),* **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

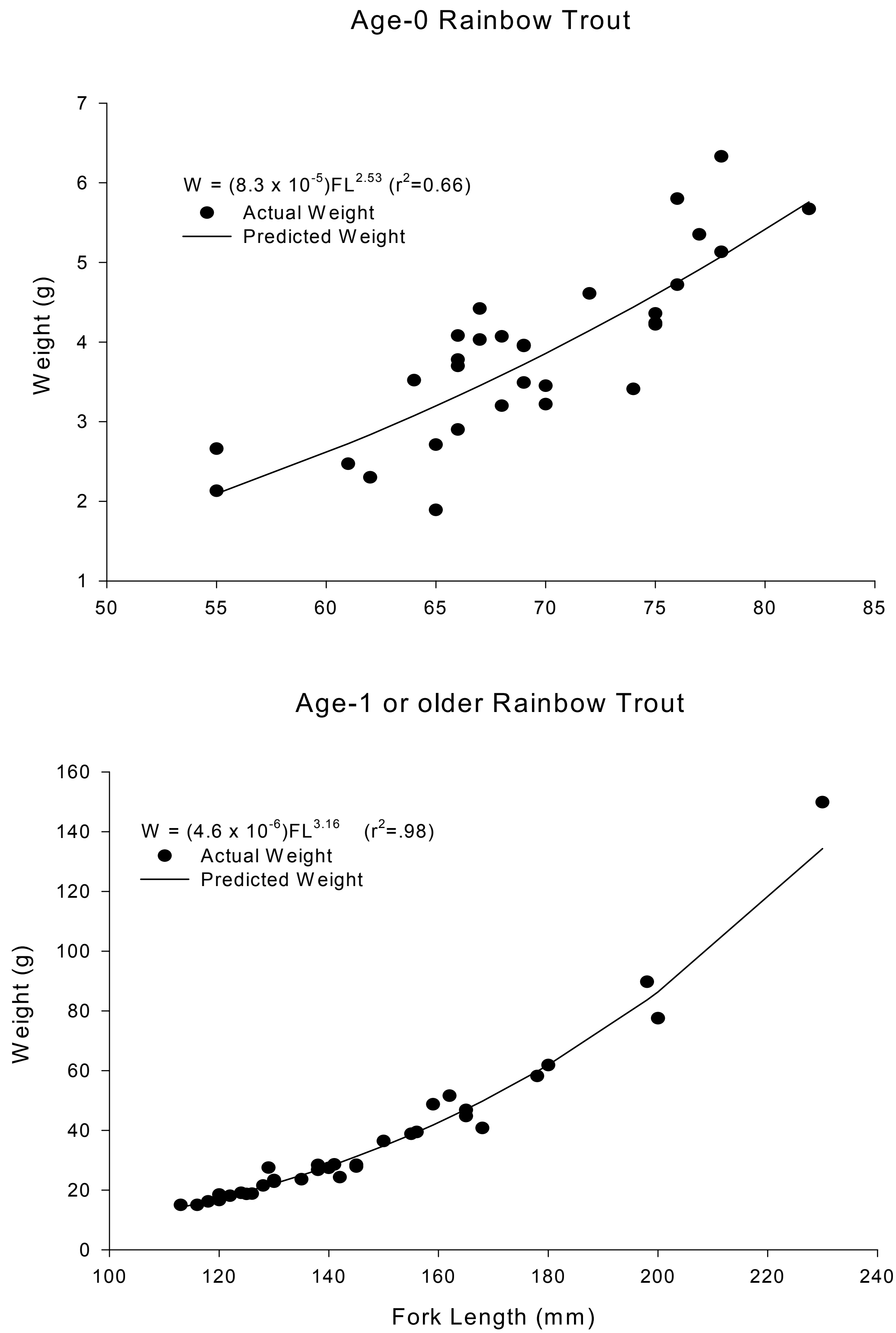
U.S. Fish & Wildlife Service
LOWER COLUMBIA RIVER FISH HEALTH CENTER
61552 S.R. 14
Underwood, WA 98651
Phone: 509-493-3156
Fax: 509-493-2748

NATIONAL WILD FISH HEALTH SURVEY REPORT

FISH SOURCE	FISH EXAMINED
Location: Rattlesnake Creek **County:** Klickitat **Contact Person:** Pat Connolly **Affiliation:** USGS BRD **Phone:** (509) 538-2299	**Species:** Longnose dace **Age:** Juvenile and adults **CHN:** 02-018 **Number of fish:** 18 **Date Sampled:** 10-09-01

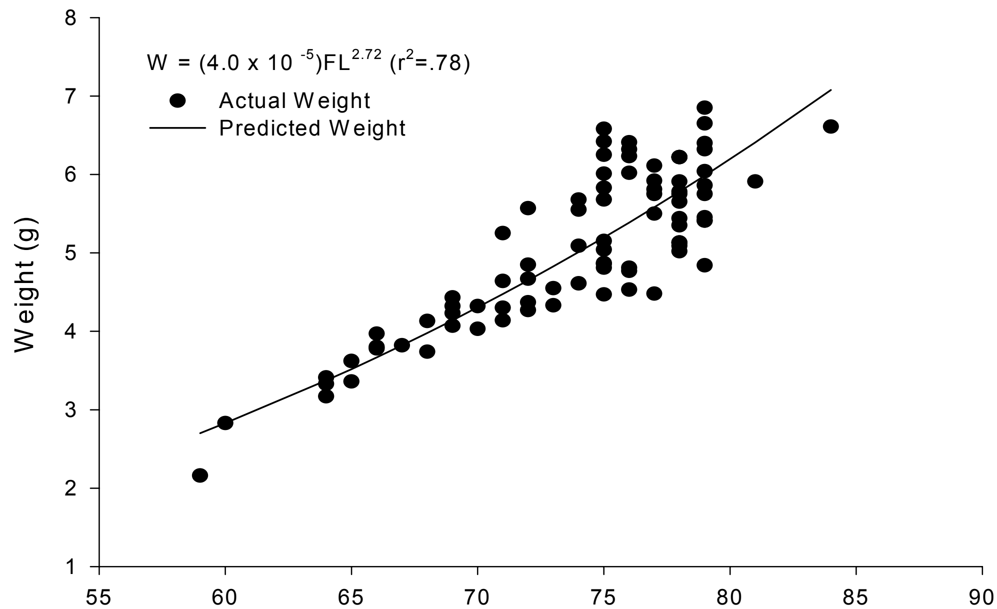
DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	18	negative	Negative by EPC and CHSE-214 cells
IHNV	18	negative	Negative by EPC and CHSE-214 cells
VHS	18	negative	Negative by EPC and CHSE-214 cells
AS	18	negative	Negative by BHIA medium
YR	18	negative	Negative by BHIA medium
RS	18	suspect	+2/2 detected by ELISA, not confirmed by PCR 0/2
BCD	18	negative	Negative by TYES medium
CD	18	negative	Negative by TYES medium
ESC	18	negative	Negative by BHIA medium
WD	18	negative	Negative by Pepsin/Trypsin Digest and PCR
CS	-	not tested	microscopic examination
Other			ELISA and virus pooled. Fish appeared to be in good health.

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral Hemorrhagic Septicemia Virus, **AS** Furunculosis (*Aeromonas salmonicida)* , **YR** Enteric Redmouth (*Yersinia ruckeri),* **RS** BKD (*Renibacterium salmoninarum*), **BCD** Coldwater Disease (*Flexibacter psychrophilum)*, **CD** Columnaris (*Flexibacter columnaris)*, **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri),* **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

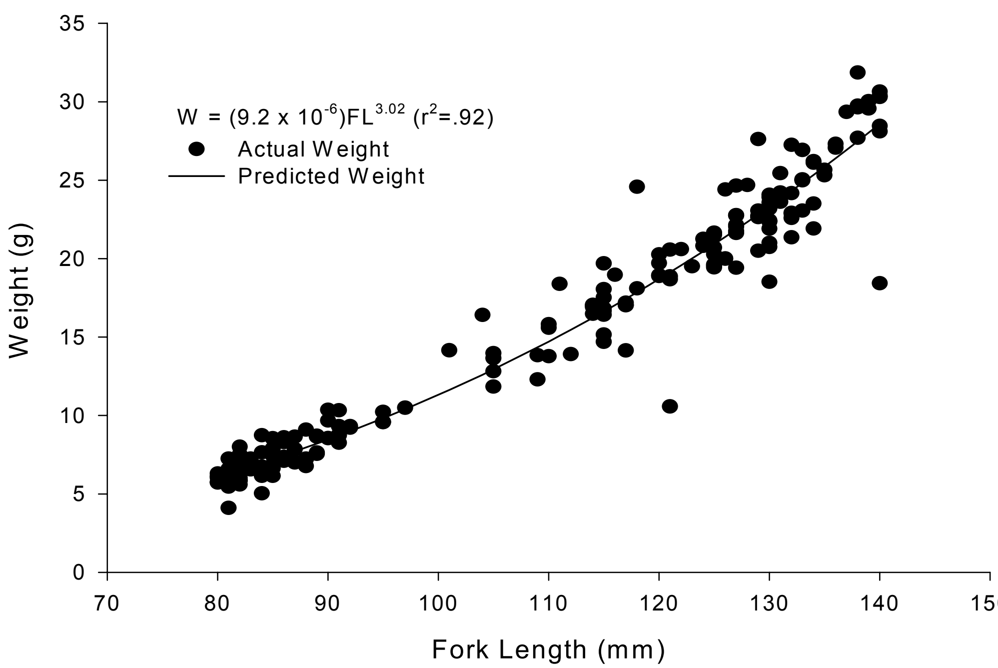


Appendix Figure 1. Actual and predicted weights of age-0 (n=31) and age-1 or older (n=37) rainbow trout sampled in middle Rattlesnake Creek (MRAT; rkm 7.2-7.8) on 9 October 2001.

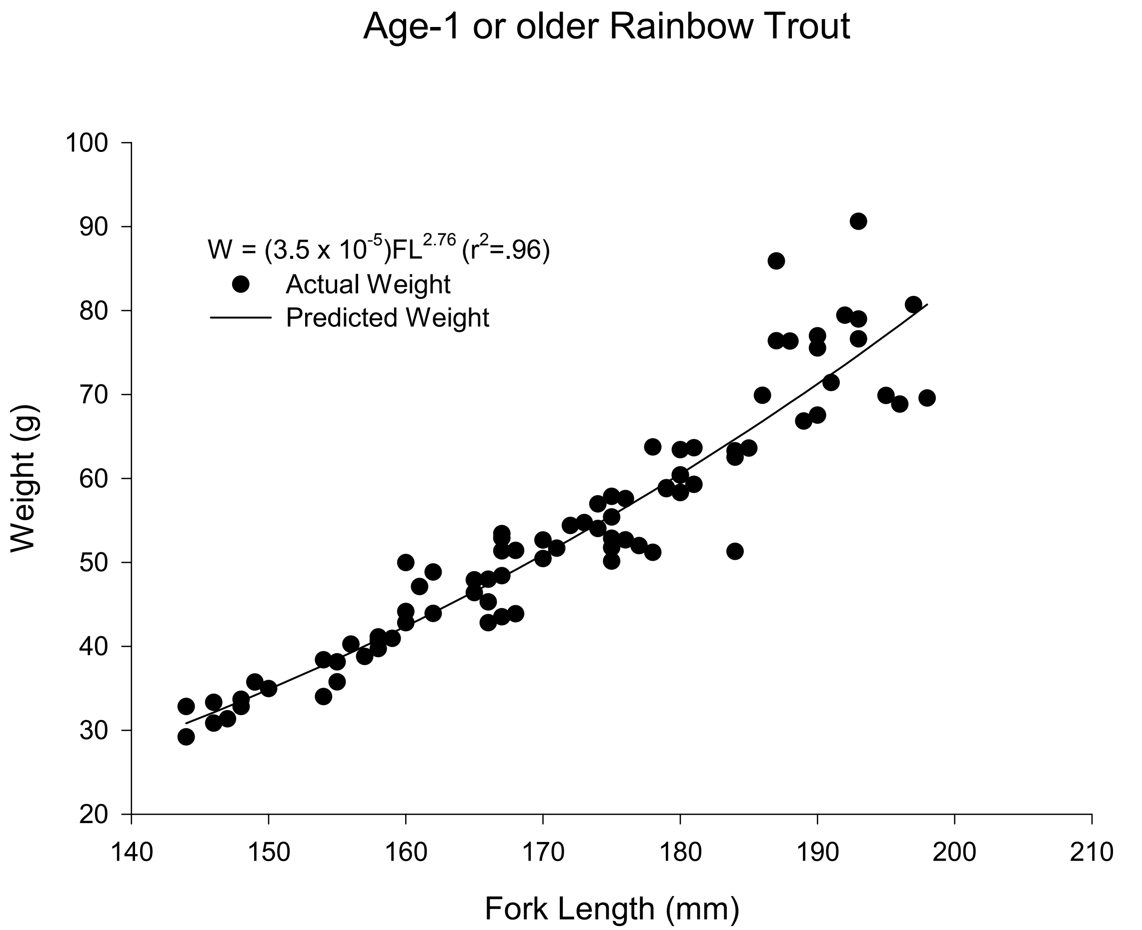
Age-0 Rainbow trout



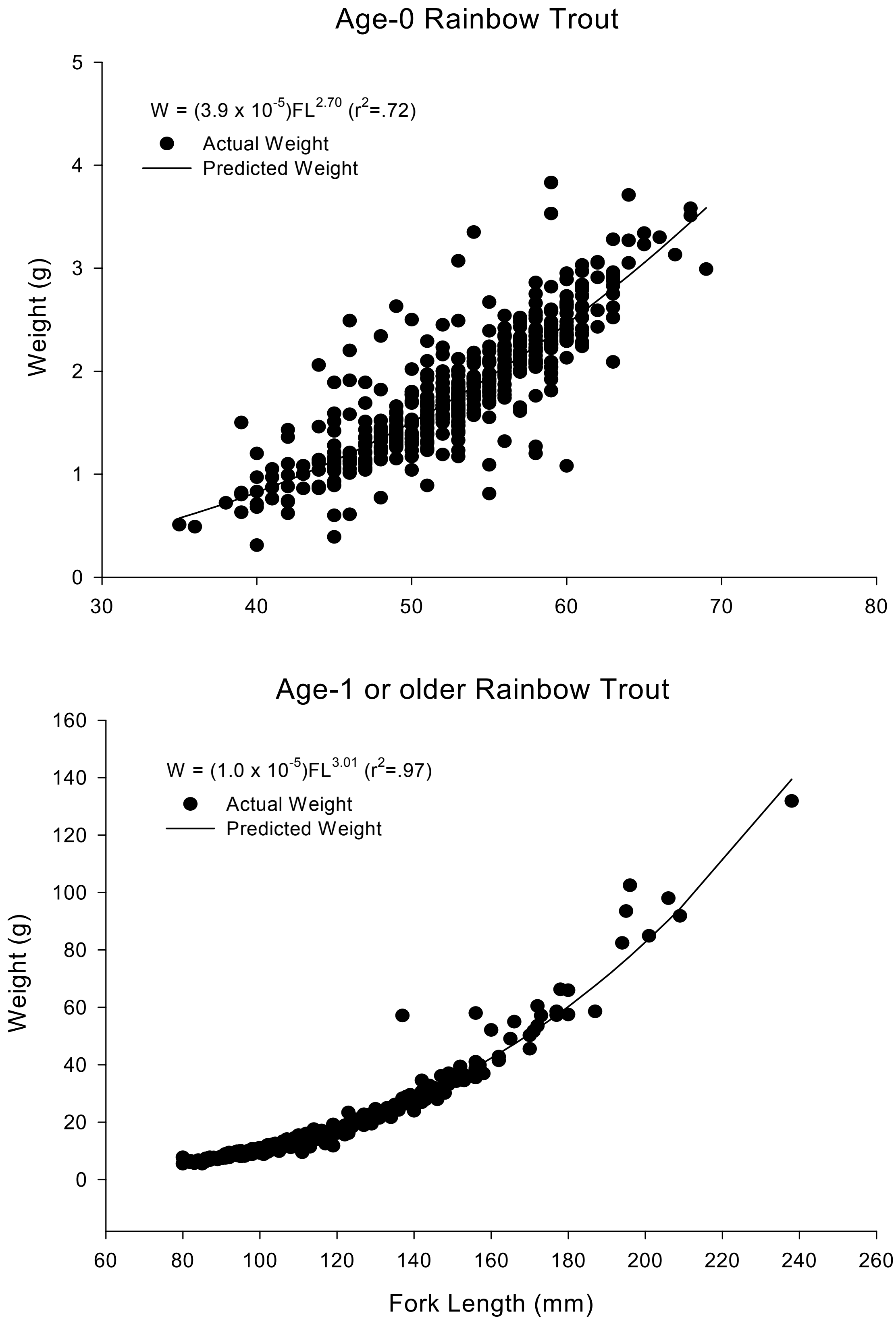
Age-1 Rainbow Trout



Appendix Figure 2. Actual and predicted weights of age0 (n=91) and age-1 or older (n=191) rainbow trout with fork lengths less than or equal to 140 mm, sampled at the BRAT reach (rkm 2.5-4.4) of Rattlesnake Creek during 10 October-15 October 2001.

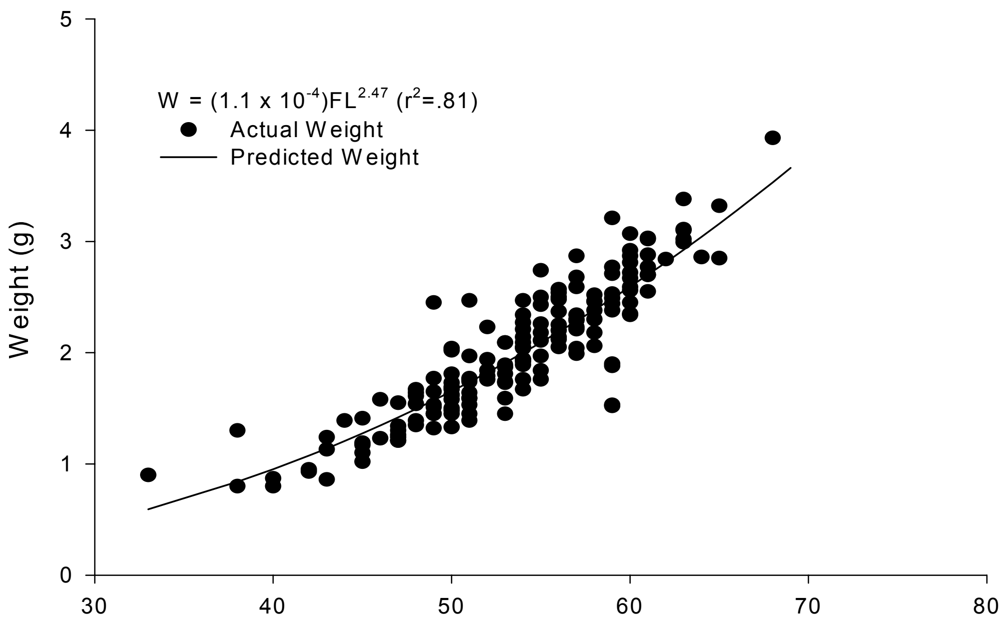


Appendix Figure 3. Actual and predicted weights of age-1 or older rainbow trout (n=84) with fork lengths greater than 140 mm, sampled at the BRAT reach (rkm 2.5-4.4) of Rattlesnake Creek during 10 October-15 October 2001.

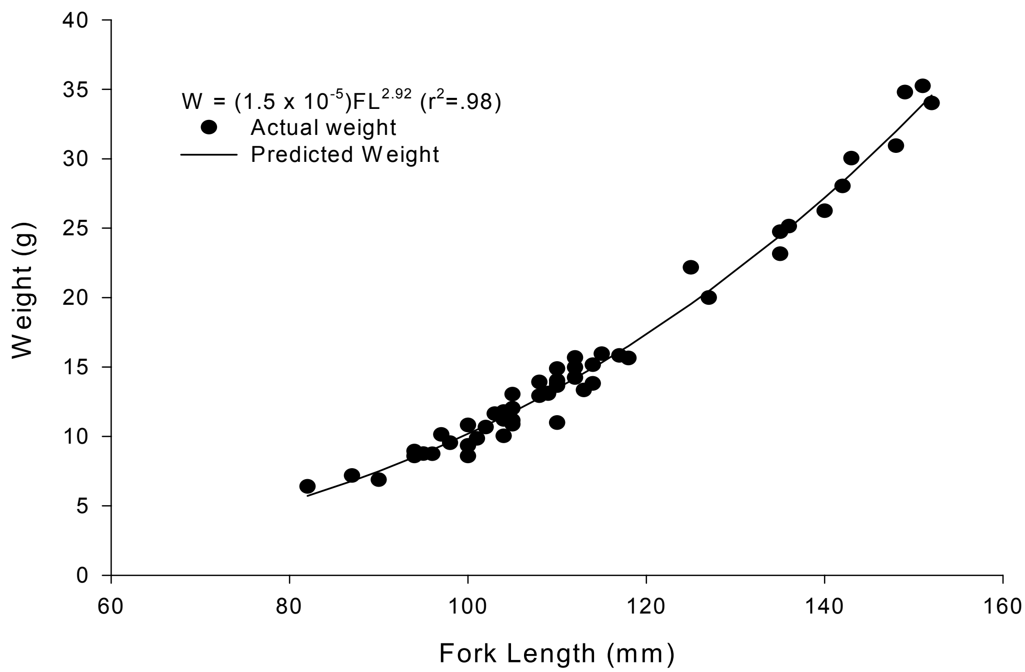


Appendix Figure 4. Actual and predicted weights of age-0 (n=500) and age-1 or older (n=293) rainbow trout sampled in lower Rattlesnake Creek (LRAT; rkm 0.1-1.2) during 31 July - 8 August 2001.

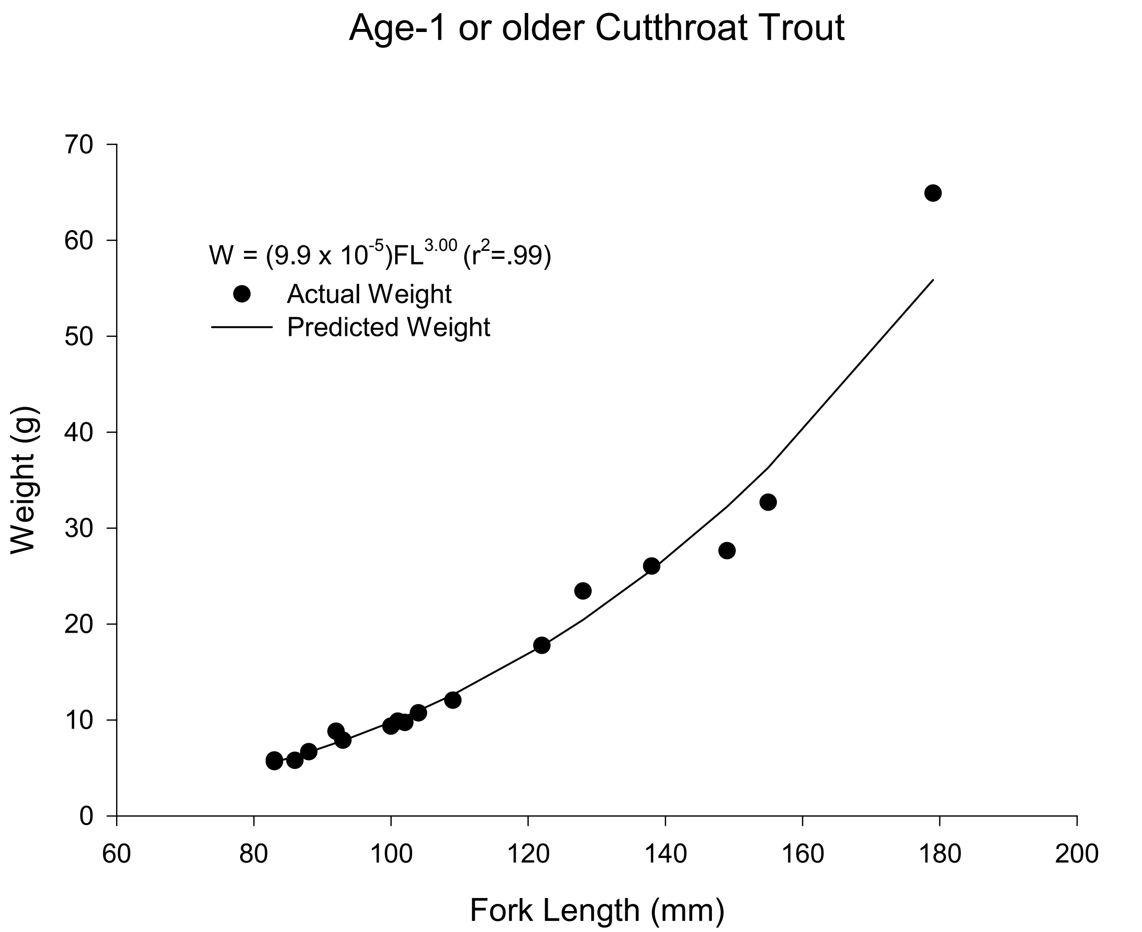
Age-0 Rainbow Trout



Age-1 or older Rainbow Trout



Appendix Figure 5. Actual and predicted weights of age-0 (n=167) and age-1 or older (n=55) rainbow trout sampled in lower Rattlesnake Creek (LRAT; rkm 0.1-1.2) on 21 August 2001.



Appendix Figure 6. Actual and predicted weights of age-1 or older cutthroat trout (n=17) sampled in middle Indian Creek (MIND; rkm 2.2-2.7) on 2 November 2001.

Report B: Instream PIT-Tag Detection System

Prepared by:
Ian Jezorek
Fishery Biologist

Patrick J. Connolly, Ph.D.
Research Fishery Biologist

U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501-a Cook-Underwood Road
Cook, WA 98605

***In:* Connolly, P.J., editor. Assess Current and Potential Salmonid Production in Rattlesnake Creek Associated with Restoration Efforts**

2001 Annual Report

January 2003

Prepared for:
Bonneville Power Administration
Division of Fish and Wildlife
COTR: John Baugher
P.O. Box 3621
Portland, OR 97208-3621

BPA Project Number: 2001-025-00
Account Number: 0003882
Contract Number: 00005068

Introduction

Use of Passive Integrated Transponder (PIT) tags in fish research has recently increased, particularly in the Columbia River basin of the Pacific Northwest. PIT tags have become a primary method for monitoring juvenile salmonid passage through dams and for computing survival past these dams (Prentice et al. 1986; Nunnalle et al. 1998; Skalski et al. 1998; Muir et al. 2001a). Because they have a long life, PIT tags can also provide information on returning adult anadromous fish. Much has been done to outfit fish ladders in the Columbia River Basin with detectors for adults (McCutcheon et al. 1994). Because of interest in monitoring the fate of individual fish for studies of habitat use, population structure, survival, and responses to environmental variables (Lucas 2000; Bell et al. 2001; Muir et al. 2001b), the use of PIT tags has increased substantially.

PIT tags allow tracking of individuals within a population. These tags consist of a copper coil and a circuit chip encased in glass. Those used in fish are generally 10 – 32 mm in length and 2 – 4 mm in diameter. When energized by an electromagnetic signal, the tag returns a unique alphanumeric code of 10 digits with 34×10^9 possible combinations. Because PIT tags do not rely on battery power, they have an expected life of at least 10 years. The tags are generally placed in the body cavity of a fish by injection or surgically (Prentice et al. 1990; Gries and Letcher 2002). PIT tags have not adversely affected growth or survival of fish in laboratory or field tests (Prentice et al. 1990; Achord et al. 1996; Ombredane et al. 1998; Gries and Letcher 2002). Their long life and lack of adverse affects on fish make PIT tags good tools for monitoring of individuals. PIT tags can be read at speeds over an antenna of up to 3.6 m/s (Prentice et al. 1990). Because PIT tags are passive, the range at which they can be detected is small, necessitating the need to physically capture the fish or have the fish pass very close to an antenna.

Researchers have been investigating fish life-history and physical aspects (e.g. antenna design, read range, read efficiency) of instream PIT-tag-detection studies. Greenberg et al. (2001) used instream antennas to investigate diel use of pools and riffles with differing substrates by brown trout tagged with 11-mm PIT tags. Brannas and Lundquist (1994) used 12-mm PIT tags in arctic char in an artificial stream channel with two antennas to monitor directional movement. They used video cameras to tape fish as they swam over the antennas. When fish crossed an antenna singly, read efficiencies were 100%, but when two or more fish were near an antenna, only the stronger tag would be read. They reduced this problem by removing substrate from the antenna area to make it less attractive as habitat. In an experiment with Atlantic salmon tagged with 12-mm tags, Armstrong et al. (1996) found 99% of fish movements were recorded with use of a 4-antenna system. Additionally, Armstrong reported no adverse reaction of the fish to the electromagnetic field generated by the antennas. In a separate experiment with Atlantic salmon tagged with 12-mm tags, Armstrong et al. (2001) found efficiency to be 70.5% and read range to be 2.3-cm for parr swimming into and out of a redd surrounded by an antenna. There was a difference in efficiency for parr entering and leaving the redd implying that direction of movement can influence efficiency. Fish moving in differing directions, particularly in an area of current, may travel at different depths or orientation relative to an antenna.

Some researchers have made use of larger PIT tags that have greater read ranges. Morhart et al. (2000) achieved read ranges up to 59-cm with a 32-mm tag in brown trout in an artificial stream channel. Zydlewski et al. (2001) used 23-mm tags in Atlantic salmon smolts and monitored downstream passage with two antennas anchored to a bridge covering the full 8-m width of Smith Brook, Vermont. Read range for the 23-mm tags was 45-cm from the plane of the antenna coil. She measured detection efficiencies of 93% by using captures at downstream smolt traps and drones. Additional studies are warranted to investigate both fish behavior and the emerging technology of instream detectors, particularly in streams where full coverage of the stream width or the water column is not possible.

In order to track movement of PIT-tagged rainbow trout and cutthroat trout, we cooperated with National Marine Fisheries Service's (NMFS) Manchester Research Station to develop an instream PIT-tag detection system in Rattlesnake Creek. Personnel from NMFS, under the direction of Earl Prentice, installed the system hardware and software. Personnel from USGS-CRRL inserted PIT tags in fish, handled data collection and treatment, and monitored the detection site. A private landowner agreed to allow the system installed on his property. The PIT-tag-detection system was installed at the downstream end of our study area in Rattlesnake Creek (rkm 0.3), near its confluence with the White Salmon River. The detection system was deployed to provide information on movement and habitat use of tagged salmonids at the reach and watershed scale. The objective of work by U.S. Geological Survey's Columbia River Research Laboratory (USGS-CRRL) was to characterize life-history attributes and habitat use of resident rainbow trout and cutthroat trout. This work corresponds to Task *2-b* of Objective 2 as stated in the Statement of Work submitted in May 2001.

Methods

During August 2001, NMFS personnel installed two antennas that were anchored in the stream about 15 m apart. Two antennas were used so that direction of fish movement and read efficiency could be determined. The antennas were housed in 10-cm diameter PVC pipe and are 203 cm by 81 cm. The antennas were deployed in two configurations: the downstream antenna was mounted flat against the stream bottom (pass-by design; Figure 1), and the upstream antenna was mounted upright (pass-through design; Figure 2). At base flow (as shown in Figures 1 and 2), the antennas are capable of scanning very close to 100% of the water passing them. Maximum depth at the antenna during base flow is 21-cm at the pass-by, and 23-cm at the pass-through. Because it was mounted flat on the stream bottom, the pass-by design was expected to sustain high flows and debris, but the fraction of the water column scanned was expected to decrease as flow and depth increased. The pass-through design was expected to scan a higher fraction of the water column as flow and depth increased, but because it was exposed to debris loading and strong current, it was likely to be more susceptible to blow out or damage than the pass-by design.

Each antenna was paired with a transceiver. The transceivers were model FS 1001-A 24-V units manufactured by Digital Angel (Figure 3). Power for the transceivers was from an AC source on the property. Because we found that use of direct AC power caused high interference readings on the transceivers, the AC power was converted to DC at the transceiver housing. Data on tag detection and system diagnostics were sent to a computer housed on-site. The MULTIMON program (developed by NMFS and Pacific Northwest National Laboratory) combined data from the two transceivers into daily files.

Personnel from USGS-CRRL sent the files for incorporation into Pacific States Marine Fisheries Service's PTAGIS database.

During summer 2001, personnel from USGS-CRRL deployed 544 PIT tags in rainbow trout and cutthroat trout in Rattlesnake Creek, 30 PIT tags in cutthroat trout in Indian Creek, and 59 PIT tags in rainbow trout in the White Salmon River. At sites above the hydroelectric system on the Columbia River, researchers are limited to using 12-mm tags due to the concern of larger tags "blocking" reads from other tagged fish at bypass routes at dams. All PIT tags used were 12-mm, 134.2 kHz. For all PIT tagging, we followed the procedures and guidelines outlined by Columbia Basin Fish and Wildlife Authority (1999). We PIT tagged rainbow trout or cutthroat trout that were 80-mm or greater in fork length. We PIT tagged fish in three sections of Rattlesnake Creek (Table 1): section 1 started at rkm 0.2 and was about 1000 m, section 2 started at rkm 2.5 and was about 1000 m, and section 3 started at rkm 7.1 and was about 500 m. Sections 2 and 3 were above a falls that may be an upstream barrier to resident rainbow trout and cutthroat trout. We electrofished to collect fish in Rattlesnake and Indian creeks, and we angled to collect fish in the White Salmon River.

As part of a companion study funded by the U.S. Forest Service (USFS), we radio-tagged adult rainbow trout during 2001 in the White Salmon River. Some of the radio-tagged fish also received a PIT-tag, and fish that were too small to radio-tag received a PIT tag only. We installed a radio receiver at the site of the instream PIT-tag antennas (Figure 4). We used this system of dual tagging to help us determine reader efficiencies.

Results

The instream PIT-tag detection system became operational on 23 August 2001. Both antennas immediately detected tagged fish. During the period 23 August to 31 December 2001, the antennas detected 27 individual fish. Initially, the transceivers were set to record every instance of a tag read. Several fish were using the antennas as cover, and because the transceivers can record many reads per second, this setup was generating extremely large data files. Subsequently, the transceivers were set to record individual tags only one time per minute. If two tags are in the field simultaneously, only the tag with the strongest signal will be detected (Brannas and Lundquist 1994). When fish use the antenna for cover, there is a much higher potential for missed detections if another fish passes through the field. We found that several tagged fish were using the antenna as habitat, and we subsequently removed several of these fish.

We classified PIT-tagged fish in Rattlesnake Creek into "local" or "non-local". Non-local fish were those tagged and released more than 50 m upstream of the antennas. Of 27 individual fish read by the antennas during 2001, two were non-local but both were from section 1. One of these fish passed in late October, the other in mid November. Each of the non-local fish was first read on the pass-through antenna, then on the pass-by antenna. Travel time between the two antennas was less than 1.5 minutes for both fish, indicating rapid downstream movement.

At the time of this writing, we have little data to interpret movement and habitat use by PIT-tagged rainbow trout and cutthroat trout. Continued monitoring will allow us to correlate fish movement with environmental variables such as flow and temperature.

A preliminary matching of flow and movement of fish is shown in Figure 5, but more data are needed to test the relationship.

On 14 December 2001, the pass-through antenna washed out during a high-flow event. We were unable to reset the pass-through antenna before the end of the year.

Discussion

Despite the washout of the pass-through antenna, instream PIT-tag detection operations in Rattlesnake Creek during 2001 demonstrated the feasibility and potential of such a system. We successfully detected fish from nearby habitat and from upstream. During 2002, we plan to test a pivoting antenna designed by NMFS. In the event of high flows or debris loading, a pivoting antenna would lay flat on the bottom, and at times of moderate flow, the antenna would pivot up to cover more of the water column. Pass-through type antenna designs may be most suited to very small streams that carry little debris loads, that have controlled-flow situations, or that have existing structures to which antennas can be anchored, as used by Zydlewski et al. (2001).

Although an instream PIT-tag detection system could be used for studies of unit scale habitat use (Armstrong et al. 1997; Greenberg et al. 2001), the propensity of fish to use the antennas for habitat is problematic. Our current system appears best suited to studies of fish movement at the reach and watershed scale. Researchers wishing to investigate unit-scale movement with instream PIT-tag readers should make any instream antenna undesirable to fish as habitat, yet insure that no impediment to fish movement results.

The detection of two non-local fish moving downstream during fall 2001 is an encouraging start for our studies of life-history strategies and habitat connectivity in Rattlesnake Creek and the White Salmon subbasin. Using detections by non-local migrants at the antennas, we hope to produce efficiency estimates for each antenna. With our current PIT-tagged fish in the White Salmon River, Rattlesnake Creek, and Indian Creek, and with additional tagging in 2002, we hope to establish patterns of habitat use and population links between Rattlesnake Creek and the mainstem White Salmon River. Our success and lessons learned during the first year of operation suggest that continued use of this detection system will yield much valuable information.

Acknowledgements

A number of people helped with this work. Steve Stampfli allowed use of his property for the system. Sandra Downing, Bruce Jonasson, Ed Nunnallee, and Earl Prentice of NMFS were instrumental with the hardware and software installation and with troubleshooting. Kyle Martens served as our field crew leader. Jodi Charrier, Gene Hoilman, Joel Quenette, Sarah Rose, and Chris Schafer all helped with fish collection and tagging. An acknowledgement goes to John Baugher, our BPA Contracting Officer, and to Jim Petersen, our Project Leader at CRRL.

References

Achord, S., G. M. Matthews, O. W. Johnson, and D. M. Marsh. 1996. Use of passive integrated transponder (PIT) tags to monitor migrations timing of Snake River chinook salmon smolts. North American Journal of Fisheries Management 16:302-313.

Armstrong, J. D., V. A. Braithwaite, and P. Rycroft. 1996. A flat-bed passive integrated transponder antenna array for monitoring behavior of Atlantic salmon parr and other fish. Journal of Fish Biology 48:539-541.

Armstrong, J. D., S. Einum, I.A. Fleming, and P. Rycroft. 2001. A method for tracking the behavior of mature and immature salmon parr around nests during spawning. Journal of Fish Biology 59:1023-1032.

Bell, E., W. G. Duffy, and T. D. Roelofs. 2001. fidelity and survival of juvenile coho in response to a flood. Transactions of the American Fisheries Society 130:450-458.

Brannas, E. and H. Lundqvist; E. Prentice, M. Schmitz, K. Brannas, and B. Wiklund. 1994. Use of the passive integrated transponder (PIT) in a fish identification and monitoring system for fish behavioral studies. Transactions of the American Fisheries Society 123:395-401

Columbia Basin Fish and Wildlife Authority, PIT Tag Steering Committee. 1999. PIT tag marking procedures manual. Portland, Oregon.

Greenberg, L. A., T. Steinwall, and H. Persson. 2001. Effect of depth and substrate on use of stream pools by brown trout. Transactions of the American Fisheries Society 130:699-705

Gries, G., and B. H. Letcher. 2002. Tag retention and survival of age-0 Atlantic salmon following surgical implantation with passive integrated transponder tags. North American Journal of Fisheries Management 22:219-222.

Lucas, L. C. 2000. The influence of environmental factors on movements of lowland-river fish in the Yorkshire Ouse system. The Science of the Total Environment 251/252:223-232.

McCutcheon, C. S., E. F. Prentice, and D. L. Park. 1994. Passive monitoring of migrating adult steelhead with PIT tags. North American Journal of Fisheries Management 14:220-223.

Morhardt, J. E., D. Bishir, C. I. Handlin, and S. D. Mulder. 2000. A portable system for reading large passive integrated transponder tags from wild trout. North American Journal of Fisheries Management 20:276-283.

Muir, M. D., S. G. Smith, J. G. Williams, and B. P. Sandford. 2001a. Survival of juvenile salmonids passing through bypass systems, turbines and spillways with and without flow deflectors at Snake River dams. North American Journal of Fisheries Management 21:135-146.

Muir, M. D., S. G. Smith, J. G. Williams, and E. E. Hockersmith. 2001b. Survival estimates for migrant yearling spring chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

Nunnallee, E. P., E. F. Prentice, B. F. Jonasson, and W. Patten. 1998. Evaluation of a flat-plate PIT tag interrogation system at Bonneville Dam. Aquacultural Engineering 17:261-272.

Ombredane D., J. L. Baglinière, and F. Marchand. 1998. The effects of passive integrated transponder tags on survival and growth of juvenile brown trout (*Salmo trutta* L.) and their use for studying movement in a small river. Hydrobiologia 371/372:99-106.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. American Fisheries Society Symposium 7:317-322.

Prentice, E. F., D. L. Park, T. A. Flagg, and S. McCutcheon. 1986. A study to determine the biological feasibility of a new fish tagging system, 1985-1986. Report (Contract DE-A179-83BP11982, Project 83-19) to Bonneville Power Administration, Portland, Oregon.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484-1493.

Zydlewski, G. B., A. Haro, K. G. Whalen, and S. D. McCormick. 2001. Performance of stationary and portable passive transponder detections systems for monitoring of fish movements. Journal of Fish Biology 58:1471-1475.

Table 1. Number of rainbow trout (RBT) and cutthroat trout (CTT) PIT tagged in Rattlesnake Creek, Indian Creek, and White Salmon River during 2001 and those detected at instream readers, September 2001 through December 2001. Unit PT = pass-through; Unit PB = pass-by.

			Number detected	
Location	Species	No. PIT tagged	Unit PT[a]	Unit PB
Rattlesnake Cr.				
Section 1	RBT	185	12	27
	CTT	5	0	0
Section 2	RBT	318	0	0
Section 3	RBT	36	0	0
	Total	**544**		
Indian Cr.	CTT/RBT	30	0	0
White Salmon R.	RBT	59[b]	0	0
	Grand Total	**633**		

a = PT unit was not functional from 14 December 2001 to 11 March 2002.
b = Includes 18 fish with both a PIT tag and radio tag.

Figure 1. The pass-by antenna at low flow in Rattlesnake Creek.

Figure 2. The pass-through antenna at low flow in Rattlesnake Creek.

Figure 3. Transceivers and housing at Rattlesnake Creek.

Figure 4. Fixed-site radio receiver at Rattlesnake Creek.

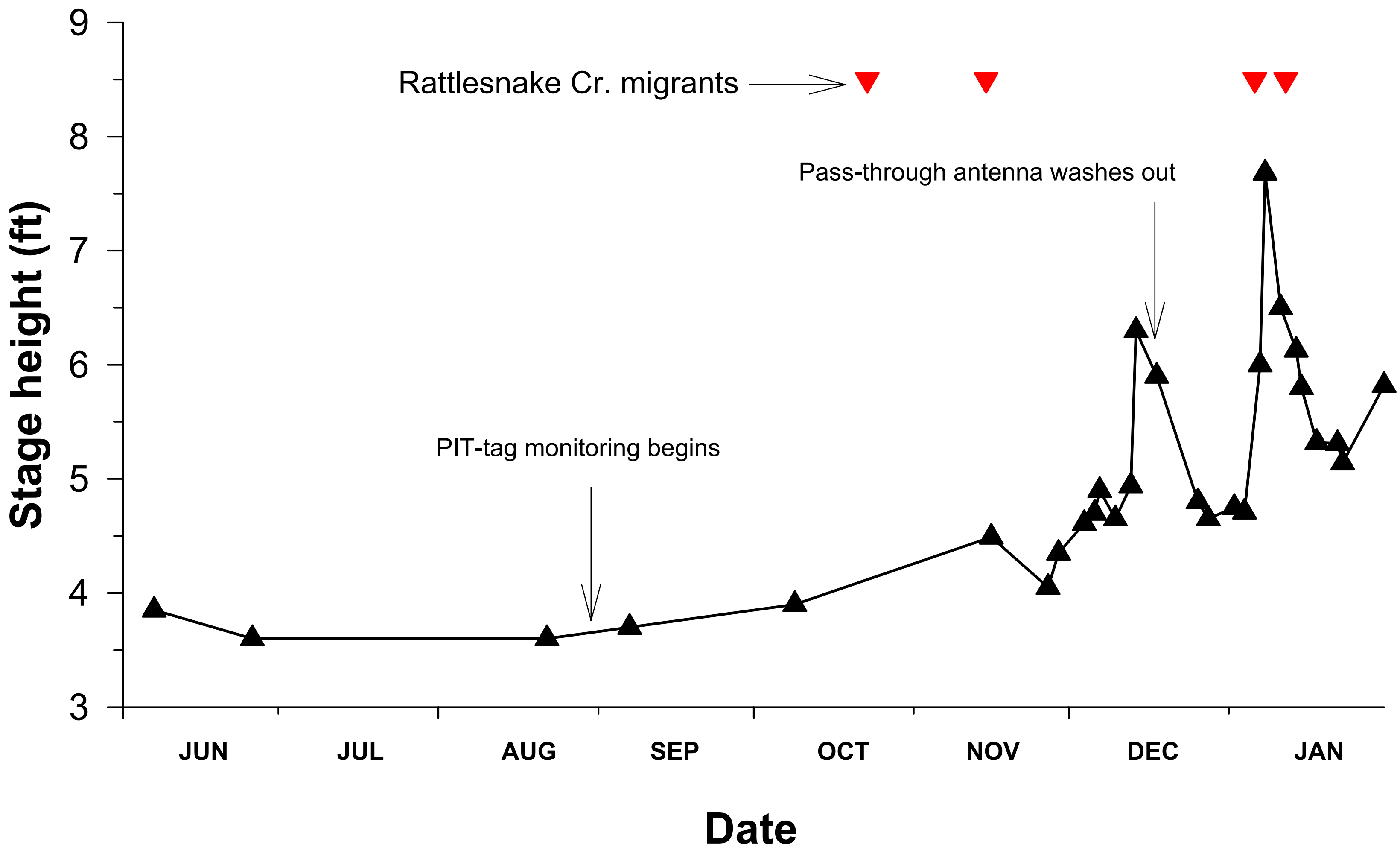


Figure 5. Stage height and passage of non-local fish at the instream PIT tag detectors on Rattlesnake Creek, June 2001 – January 2002. Non-local fish are those fish PIT tagged and released 50 m or more upstream of the antennas.