U.S. Fish & Wildlife Service

Survey of Fish Populations in Railroad Creek, Lake Chelan Basin, Washington, 2003

U. S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
7501 Icicle Road
Leavenworth, WA 98826

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Final Report

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Abstract.--Railroad Creek, a tributary to Lake Chelan, was surveyed in August 2003 to determine bull trout *Salvelinus confluentus* presence and describe the distribution and relative abundance of other fish species. Railroad Creek was surveyed from river kilometer (rkm) 0 to a barrier falls at rkm 2.2 and from rkm 8.0 to rkm 22.0. Sample units were surveyed using a combination of night snorkeling (56%), day snorkeling (34%) and electrofishing (10%). Thirty-four sample units were surveyed for a total length of 1,970 m which was 12.2% of the area surveyed. Bull trout were not found. A total of 650 trout, including 464 westslope cutthroat trout *Oncorhynchus lewisi clarki*, 154 rainbow trout *O. mykiss*, 31 cutthroat trout *x* rainbow trout hybrids, and 3 unknown *Oncorhynchus* species were observed during the survey. Using the Peterson bull trout detection protocol method, the probabilities of detecting bull trout for the reach surveyed (rkm 0-2.2 and rkm 8.0-22.2) was calculated to be 84% and for the area accessible from the lake (rkm 0 to rkm 2.2) was 31%. Railroad Creek was larger than streams used by Peterson in his model of probabilities of bull trout detection, thus the probabilities of detection calculated for Railroad Creek are likely biased high.

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Introduction

The U.S. Fish and Wildlife Service determined the status for bull trout *Salvelinus confluentus* in the Columbia Basin as threatened in 1998 (Federal Register/Vol 63, No. 111/June 10, 1998). Bull trout in the Chelan basin are considered to be of unknown occupancy. While the Chelan basin historically supported a robust bull trout population, several factors probably contributed to their decline, and the last verified catch or observation of a bull trout in Lake Chelan was in 1957 (Brown 1984). Railroad Creek, a tributary to Lake Chelan, was accessible to adfluvial bull trout downstream of barrier falls (Brown 1984), but historic distribution of resident bull trout upstream of numerous falls is considered unknown. Considering the size of the Lake Chelan basin, isolated bull trout populations may still persist as resident populations in the lake's tributaries or as adfluvial populations (Halupka et al. 2002; USFWS 2002).

The Holden Mine which is located on Railroad Creek was one of the largest copper mines in the United States during its productive life, from 1938 to 1957. The mine and mill produced concentrated copper, gold, silver, and zinc ore. Intalco, the current owners of the mine and the oversight agencies (U.S. Forest Service, U.S. Environmental Protection Agency and Washington Department of Ecology) have been working since 1997 to characterize contamination and other impacts at the site and evaluate cleanup and restoration alternatives. Because cleanup and restoration activities have been proposed for Railroad Creek, efforts to determine bull trout presence were needed. Objectives of this survey were to (1) use statistically based survey protocols to determine bull trout presence in Railroad Creek; and (2) describe the distribution and relative abundance of fish by species.

Study area

Description of Railroad Creek

Railroad Creek is a fourth order stream and the second largest tributary to the 88 km (54.6 mi) long Lake Chelan. Railroad Creek originates near Lyman Glacier at an elevation of 1,981 m (6500 ft) and flows 35.1 km (21.8 mi) to its mouth on the western side of Lake Chelan at km 73.8 (mi 45.8), elevation 335 m (1,100 ft). The Chelan River flows 6.9 km from Lake Chelan to the Columbia River, but a natural falls on the river prevents upstream migration of fish. The Chelan basin is near the town of Chelan, Washington, on the eastern slopes of the Cascade mountains.

The Railroad Creek watershed is 14,386 ha (35,522 acres) in size, and approximately 75% of the watershed is in the Glacier Peak Wilderness area. Railroad Creek has at least 14 perennial tributaries and at least 24 intermittent tributaries. Discharge varies from summer lows typically of 850 to 1700 L/s (30-60 cfs) to annual high flows typically of 14,000 L/s to 85,000 L/s (500 to 3,000 cfs). The valley bottom ranges from narrow and canyon-like to broad and flat-floored.

The Holden Mine located near river kilometer (rkm) 17 (rivermile (rm) 10.5) has had a significant impact to Railroad Creek. About 7,700 kg (8.5 million tons) of mill tailings were placed on National Forest System lands near Railroad Creek, covering approximately 36 ha (90 acres). Tailings are located from approximately rkm 15.8 (river mile (rm) 9.8) to rkm 17.2 (rm

10.7) (Johnson et al. 1997). The stream adjacent to the tailings has been straightened and is not vegetated on the tailings side. The tailings have provided a source of fine sediments to the stream. An orange-yellow "goethite" coating on mineral grains is found in all areas downstream of the mine with the greater amounts of mine tailing material closer to the tailings (Huntamer 1997). Mine drainage and seeps from the tailing piles are known sources of acid waste and metal input to the creek (Johnson et al. 1997).

The Railroad Creek watershed is remote and accessible via boat, floatplane, helicopter, or hiking trails. There is an 18 km (11 mi) road from Lake Chelan to Holden Village. A vehicle bridge crosses the stream near Lake Chelan and two vehicle bridges cross the creek at the lower and upper end of the mine site. The Holden Village (near rkm 16.7), which is where some of the miners lived, has been operated since 1962 as a retreat center.

Description of Lake Chelan Fish Community

In the late 1800's Lake Chelan had a robust bull trout population that supported a popular sport fishery as well as a commercial fishery that also focused on westslope cutthroat trout *Oncorhynchus lewisi clarki* and burbot *Lota lota* (Brown 1984). These fisheries were unregulated and may have reduced bull trout numbers. Brown (1984) suggests that severe floods in spring 1948 and fall 1949 caused the further decline of the bull trout. These floods were followed by a die off in 1951, when large numbers of sick and dying bull trout covered with a grey fungus were observed near Stehekin (Brown 1984). The cause of the fungus and die-off remains unknown. The effect to the population from the die off and the floods appears to have been significant since according to local fishing sources after 1951relatively few bull trout were caught (Brown 1984). Again in 1955 a flood event occurred in the fall when the eggs would have been in the gravel and are vulnerable to flooding and scouring during their incubation (Rieman and McIntyre 1993). Taken together these events would have affected several age classes of bull trout and decreased quantity and quality of spawning areas.

Other factors that possibly contributed to the decline of bull trout include the Lake Chelan Dam, contaminants, and introduced fish species. The dam at the outlet was built in 1928 and raised the lake level 7.3 m (24 ft). The dam has resulted in annual lake level fluctuations, flooding of some spawning areas, and limited access into some tributaries (Brown 1984; DES 2000). The effects of contaminants from mining, DDT, and PCBs, sedimentation from roads, logging, and lakeside development on bull trout in Lake Chelan is unknown. Bull trout in Railroad Creek would probably have been affected by the Holden Mine which operated from 1938 to 1957. Runoff from the mine site contained iron, cadmium, copper, lead, zinc, and arsenic (Johnson et al. 1997). In some months iron, zinc, copper, and cadmium levels in Railroad Creek have exceeded EPA water quality criteria (Johnson et al. 1997). Lake Chelan is currently on the 303(d) list for DDE (a derivative of DDT which was used from the early 1940's until banned in 1972) and PCB for excursions beyond the criterion of edible fish tissue (WDOE 1998). Bull trout are an apex predator and could have bioaccumulated these chemicals.

The role of fish introductions in the decline of bull trout is not understood. Kokanee *Oncorhynchus nerka* and rainbow trout *O. mykiss* were introduced in 1917 and may have competed with bull trout (Mullan et al. 1992; Rieman and McIntyre 1993), but also would have provided another food source (Brown 1984). Eastern brook trout *Salvelinus fontinalis* were introduced in 1933. Brook trout threaten bull trout through hybridization, competition, and possibly predation (Leary et al. 1993; Rieman and McIntyre 1993; MBTSG 1996). However brook trout are not numerous in the Chelan basin and are found primarily in the lower Stehekin basin and in Twenty-five Mile Creek (Hillman et al. 2000; Archibald 2002). Lake trout *Salvelinus namaycush* were first stocked in 1980 which was after the decline of bull trout. Lake trout and bull trout have substantial niche overlap, and in lacustrine populations bull trout usually cannot be maintained if lake trout are introduced (Donald and Alger 1993; Donald and Stelfox 1997; Fredenberg 2002). See Appendix A Table 6 for a list of native and introduced fish species in Lake Chelan.

Since bull trout were listed as threatened in 1998, fish surveys in the Chelan basin have used the Peterson et al. (2002) and (2003) bull trout detection protocol methods. Using these methods, bull trout have not been found in surveys in the Stehekin drainage in the upper Stehekin River, Park Creek, Flat Creek (Halupka et al. 2002), South Fork of Agnes Creek (USFS 2003), and in Lake Chelan tributaries including Fish, Prince, and Safety Harbor creeks (Judy DeLaVergne, Fishery Biologist, U.S. Fish and Wildlife Service, pers. comm. 2003). Bull trout have not been found during previous surveys in the Chelan basin (Archibald 2002), however there are unconfirmed reports of anglers catching and divers sighting bull trout in Lake Chelan (T. Irish, fishing guide and resident, Stehekin, Washington, pers. comm. *in* Halupka et al. 2002; Van Ford, SCUBA instructor, Wenatchee, Washington, pers. comm. 2003). However, bull trout can be confused with lake trout and brook trout which look similar to them (Schmetterling and Long 1999).

Railroad Creek is one of 24 tributaries accessible to adfluvial trout in the Lake Chelan basin (Brown 1984). It is one of only nine tributaries with gradients less than 10% and one of only four with gradients less than 4% downstream from barriers (Hillman et al. 2000). Bull trout have not been found in Railroad Creek during snorkeling and electrofishing surveys occurring since 1966 (Crates 1966; Krcma 1967; Thorsen 1970; WDG 1982; WDG 1984; PNL 1989; PNL 1991; USFS 1992; Dames and Moore 1998, *references found in* Archibald 2002).

Westslope cutthroat trout are the only known native salmonid species in Railroad Creek upstream of the barrier falls. Fish plantings have affected the current distribution in Railroad Creek. Railroad Creek was planted in seven years from 1934 to 1947 with Twin Lakes strain westslope cutthroat trout, which originated from the Lake Chelan basin. Rainbow trout were stocked in Railroad Creek in three years from 1939 to 1947 and in Holden Lake in eight years between 1939 and 1979 (WDFW state stocking records).

Methods

Survey reaches

The stream was divided into six reaches based on natural barriers, the degree of impact due to the mine, and access (Table 1). Reach 1 was from the mouth of Railroad Creek at Lake Chelan upstream to a fish barrier falls at rkm 2.2 (rm 1.4). The USFS (1991) measured three possible fish passage barriers in this reach with heights of 3.0, 1.8, and 2.7 meters (10, 6, 9 feet). For this survey, the falls at 2.7 m at rkm 2.2 was determined to be a barrier falls to upstream migration for bull trout. Reach 2 has four possible fish barriers with heights of 4.3, 7.6, 3.7, and 6.1 meters (14, 25, 12, 20 feet) between rkm 2.2 and rkm 3.5, just upstream of Tumble Creek (USFS 1991). Reach 2 was in a gorge and was not surveyed because the field crew was not able to safely move upstream past the barrier falls and could not access the stream from the road because of steep, rocky terrain.

Reach 3 was also in the gorge but was accessible from the road by walking down steep terrain. The upper end of this reach was 5.4 km (3.3 mi) below the mine tailings. The upper end of reach 4 was at the lower end of the mine tailings. The valley was broader in this reach, and the stream was relatively easy to access from the road. Reach 5 was adjacent to the mine and tailing pile. It was impacted both from the runoff from the tailings and channelization of the stream. This reach was also relatively easy to access from the road. Reach 6 was upstream of the mine and 60 percent of the reach is located in the wilderness area. The lowest unit in the reach was accessed from the road, and other units were accessed from the hiking trail.

TABLE 1. Description of Railroad Creek stream reaches

Reach number	River kilometers	River miles	Description
1	0 – 2.2	0 – 1.4	Below barrier falls
2	2.2 – 8.0	1.4 – 5.0	Inaccessible gorge area
3	8.0 – 10.4	5.0 – 6.5	Accessible gorge area
4	10.4 – 15.8	6.5 – 9.8	Below mine, near road
5	15.8 – 17.4	9.8 – 10.8	Adjacent to mine and tailings
6	17.4 – 22.0	10.8 – 13.7	Upstream of mine

Bull trout protocol method

To assess bull trout presence, methods described in Peterson et al. (2002 and 2003) and Thurow et al. (2003) were used to select sample sites, survey for fish, and measure habitat components. The method involves randomly selecting sampling units of 50-m or 100-m within the study frame to survey using night snorkeling, day snorkeling, or electrofishing. A set of habitat measurements are collected at each survey unit. Based on habitat characteristics found at the sampling unit and utilized in the models, probabilities of detection are calculated.

To achieve an 80 to 90 percent probability of detection, 49 units were randomly selected including 9 alternate units. Alternate sites could be sampled if time allowed to increase probability of detection or to replace units that could not be sampled. Sample site selection deviated from simple random selection, to distribute sample units and because of difficulty in precisely locating sample units. A 1:24,000 scale map was used, and the entire study reach was divided into 105 200-m sections. Random number tables were used to determine which 200-m section to sample within. Then random numbers were used to determine which 50-m or 100-m unit within the 200-m section would be sampled.

Survey units were located in the field where they could be accessed directly from the road or trail based on features found on the map and often random chance of where the stream was first accessed. It was thought that these units were probably somewhere within the 200-m reach. If a unit was accessed by walking upstream, the unit was located based on map features and from estimating the distance between sample units. In addition to the randomly selected sites, high quality habitat areas were surveyed because bull trout are often found in areas associated with cover and hydraulic complexity (Pratt 1992; Rieman and McIntyre 1995). These were not included in calculations of probability of detection.

Fish Survey

Snorkeling.— Snorkeling procedures described by Thurow (1994) were followed. Two snorkelers surveyed the unit by entering downstream of the unit and snorkeling slowly upstream. Snorkelers counted the number of fish by species and estimated size classes to the nearest 100-mm size group, and counted young-of-the year fish (less than 30 mm). Snorkelers used an underwater halogen light at night.

Snorkelers measured underwater visibility using a salmonid silhouette to measure the distance the snorkeler could distinguish marks on the silhouette (Thurow et al. 2003). Crews recorded whether underwater both snorkelers together could see from bank to bank.

Electrofishing.— A Smith-Root Model 12 Electrofisher set to unpulsed direct current (DC) was used. Pulse frequency was set at 50 pulses per second (“I”), pulse width was set at 500us (“2”), and voltage was set to 900 or 1000 volts. Water conductivity was measured in each unit electrofished using a calibrated hand-held Hanna© conductivity probe.

Species identification.—To identify rainbow and cutthroat trout and their hybrids, diagnostic external features as described in Thurow (1994) were used. General distinguishing features included spotting pattern, coloration, jaw slash, and length of maxilla.

Fish genetic sample collection.—Genetic tissue samples were collected from fish captured by electrofishing. Tissue samples of at least 0.5 cm^2 were taken primarily from the caudal fin and sometimes pelvic fin. The tissue was placed in a vial with 100 percent ethanol and a label to identify the sample. Fork lengths and weights of fish were measured.

Habitat Survey

Habitat variables as described in Peterson et al. (2002) were measured in all units sampled. Water temperature was taken with a hand-held thermometer at each unit at the time it was snorkeled or electrofished. Channel dimensions were measured at three transects in each unit. At each transect the wetted width, mean depth, and maximum depth were measured. The mean depth was calculated by taking depths measured at ¼, ½, ¾ of the channel width and dividing the sum by four to account for zero depth at each bank. In each unit the number of pieces of individual wood at least 3 m long and 10 cm in diameter were counted, number of wood aggregates with more than four single pieces, and the number of rootwads were recorded. The length and width of undercut bank along each bank were measured. Undercut banks were defined as areas beneath stream banks, boulders, bedrock, or wood that were solid portions of the stream bank, and were at least 5 cm wide and within 0.5 m above or below the water surface. Stream gradient was either measured using an Abney level or an altimeter with a sensitivity of 1m (3 ft), or calculated using an 1:24,000 map in MapTech©. Channel spanning pools were counted, and their lengths estimated. The relative amount of iron flocculent by reach and other observations were noted.

Analysis of Probabilities of Bull Trout Detection

Bull trout detection models in Peterson et al. (2003) were used to calculate probabilities of detection since they include calculations for sampling without block nets. Peterson et al. (2003), is currently a draft report and may be revised (James Peterson, Fishery Researcher, University of Georgia, pers. comm. 2003). Probabilities of detection are calculated using sampling efficiencies that were field determined for the three different sampling methods under a range of habitat characteristics. Parameters used in the Peterson et al. (2003) model to determine single sample probabilities of detection for all three sample methods included survey unit length, use of blocknets, and percent of undercut banks. Other parameters used for day snorkeling were water temperature and mean depth. Electrofishing parameters included mean wetted cross-sectional area and conductivity (Appendix D, Tables 11, 12, and 13).

The general equation for the model is:

1 - [(1 – single sample detection probability) * (1 – single sample detection probability) * …..]

Results

Railroad Creek was surveyed from rkm 0 at Lake Chelan to rkm 2.2 and from rkm 8.0 to rkm 22.0 (rm 13.0) from August 11 to 15, 2003. In reach 2 (rkm 2.2 – 8.0) there were 13 randomly selected units that were not surveyed because of difficult access. Thirty-four units were surveyed, and 17 units were night snorkeled, 13 units were day snorkeled, 4 units were electrofished, and 1 pool was snorkeled as an opportunistic site (Table 2). Total stream length surveyed was 1,970 m which was 12.2% of the 16.2 km study reach. A map showing the units surveyed is in Appendix B, Figure 1.

Fish Survey

Crews observed 614 trout in the 34 units and 1 opportunistic site surveyed. No bull trout were observed. Species composition was 73% (450) cutthroat trout, 24% (145) rainbow trout, 3% (16) hybrids, and less than 1% (3) unknown (Table 3). Thirty-five of the cutthroat trout were observed in the 20-m long quality pool habitat day snorkeled in reach 3. The trout were generally small with 84% 199 mm or less (less than 8 inches) (Table 4). Four sculpins in reach 1 and 12 tailed frogs in reach 4 were observed (Appendix C, Table 7).

Cutthroat trout were the primary species (99%) in reach 3 and were also dominant in reach 5 (75%) and reach 6 (77%). In reach 1 rainbow trout were the dominant species, and cutthroat trout were mostly in the upper three units surveyed. Reach 3 had a fairly even mix of rainbow trout and cutthroat trout. Hybrids were visually identified in reaches 1, 4, and 5. Observed fish densities were highest upstream of the mine in reach 6 (68 trout/100m^2). Fish densities were lowest in reach 4 downstream of the mine (6 trout/100m^2) and in reach 5 adjacent to the mine (17 trout/100m^2) (Table 3).

TABLE 2. Number and lengths of units sampled by night snorkeling, day snorkeling, and electrofishing by reach.

Reach	River km	Night snorkel 50-m	Night snorkel 100-m	Day snorkel 50-m	Electro-fishing 50-m	Reach length (m)	Length surveyed (m)	Percent surveyed
1	0.0 – 2.2		3	3		2,200	450	20.5
2	2.2 – 8.0					5,800	0	0
3	8.0 – 10.4			5 20-m pool		2,400	270	11.3
4	10.4 – 15.8	6			4	5,400	500	9.3
5	15.8 – 17.4	5	2			1,600	450	28.1
6	17.4 – 22.0	1		5		4,600	300	6.5
Total length (m)	0.0 – 22.0	600	500	670	200	22,000	1,970	9.0

TABLE 3. Percentages of rainbow, cutthroat, and hybrid trout, total numbers, density of trout, and mean sample efficiency by reach in Railroad Creek, 2003.

Reach	Cutthroat trout	Rainbow trout	Hybrids	Unknown	Total number	Length surveyed (m)	Number trout/100m^2	Mean unit capture efficiency
1	36%	59%	5%	0%	109	450	20	0.157
3 (with 20-m pool)	99%	1%	0%	0%	150	270	33	0.104
4	50%	46%	2%	2%	42	500	6	0.142
5	75%	12%	9%	2%	99	450	17	0.178
6	77%	23%	0%	0%	214	300	68	0.119
Total (with 20-m pool)	73%	24%	3%	<1%	614	1,970	23	
Total number	450	145	17	2	614	1,970		

TABLE 4. Percentages of rainbow, cutthroat, and hybrid trout by size class and total numbers by reach in Railroad Creek, 2003.

Reach	<30 mm	30-99 mm	100-199 mm	200-299 mm	300-399 mm	Number of trout
1	18%	18%	35%	22%	7%	109
3	7%	46%	38%	9%	0%	150
4	0%	29%	57%	14%	0%	42
5	3%	24%	48%	22%	3%	99
6	11%	38%	41%	9%	1%	214
Total number	56	207	253	84	14	614

Water temperature ranged from 10.0°C to 14.5°C during surveys. Mean underwater visibility was 2.8 m in day snorkeled units and 2.3 m in night snorkeled units. Mean time to snorkel was 22 minutes for the 50-m units and 42 minutes for the 100-m units (Appendix C, Table 8).

Fish genetic sample collection.—Fish were captured for genetic samples by electrofishing in four units (units #75, #76, #86, #92) and hand-netting at night in one of those units (unit #86). Genetic samples from 38 trout were taken. Fork length ranged from 73 mm to 215 mm, mean 134 mm, SD 32, and weight ranged from 4 g to 114 g, mean 30 g, SD 23 g (Appendix C, Table 9) The field crew visually assigned 37% (14) of these fish as cutthroat trout, 24% (9) as rainbow trout, and 39% (15) as cutthroat trout *x* rainbow trout hybrids (Appendix C, Table 9). This contrasts with snorkel observations in two of those units of 71% (114) cutthroat trout, 16% (38) rainbow trout, and 13% (8) hybrids (Appendix B, Table 8). Genetic samples will be archived until funding is available for analysis.

Habitat Survey

Average stream channel dimensions in the 34 units surveyed were mean wetted width 12.7 m, mean depth 0.38 m, and mean maximum depth 0.72 m. Mean percent undercut bank was 1.9%, and mean amount of wood was 0.012 pieces per m^2. In the 34 units surveyed (not including the 20-m pool) there were 18 channel spanning pools with an average length of 7.7 m, and average pool frequency was one pool per 108 m. Pool habitat comprised 7.0% of the total length surveyed, and the remaining habitat was riffle habitat, although within this there were some pocket pools and lateral scour pools in the riffles (Table 5 and Appendix C, Table 10).

Reach 1 was typified by steep gradient and pocket pools behind boulders, but little other slow water habitat was present. This reach appeared to have relatively low concentrations of iron flocculent coating the bottom substrate. Reach 3 had moderate to low amounts of iron flocculent, and numerous macroinvertebrates were observed. The units sampled had several plunge and pocket pools. The 20-m pool that was snorkeled was the only channel spanning pool observed for this reach. Reach 4 had areas of swift water habitat with boulder and cobble substrate and only two channel spanning pools. Iron flocculent was observed on most of the stream bottom, coating and cementing the bottom substrate, and few macroinvertebrates were observed. Reach 5

TABLE 5. Habitat characteristics of units sampled in Railroad Creek by reach and [a]range of habitat characteristics of streams used to develop bull trout detection model in Peterson et al. (2003).

Reach	Number of units and (total length (m))	Gradient percent range	Water temp. °C range (mean)	Visibility (m) range (mean)	Width (m) range (mean)	Mean depth (m) range (mean)	Mean max depth (m) range (mean)	Surface area (m^2) range (mean)	Number of channel spanning pools	Length of pools (m) total	Percent undercut banks range (mean)	Number of pieces of large woody debris/ no. aggregates/ no. rootwads	Wood density (no./m^2)
1	6 (450)	1.5 – 8.0	11.0-14.0 (12.2)	1.2	10.1-14.4 (12.1)	0.46-0.52 (0.40)	0.75-1.03 (0.91)	507-1200 (906)	1	12	0	18 / 1 / 0	.004
3	5 (250)	1.5-5.5	11.0-14.0 (12.0)	3.0	12.0-18.2 (14)	0.38-0.61 (0.47)	0.65-0.95 (0.80)	565-910 (699)	0	0	0-4.5 (0.75)	2 / 1 / 2	.002
4	10 (500)	0.5-5.5	11.0-14.5 (14.3)	2.1	10.3-19.3 (13.5)	0.26-0.44 (0.37)	0.52-1.04 (0.71)	515-967 (676)	7	69	0-20.0 (3.6)	49 / 13 / 10	.021
5	7 (450)	0.5-4.0	10.0-14.0 (11.7)	2.9	9.6-17.5 (13.4)	0.21-0.48 (0.31)	0.43-0.67 (0.59)	448-1037 (851)	3	19	0-1.0 (0.2)	18 / 6 / 1	.007
6	6 (300)	1.5-3.0	11.5-14.0 (12.8)	2.9-3.6 (3.5)	7.7-13.5 (10.5)	0.25-0.37 (0.33)	0.49-0.80 (0.65)	385-675 (526)	7	38	0-22.0 (4.2)	56 / 6 / 8	.028
All	34 (1,950)	0.5-8.0	10.0-14.5 (12.8)	1.2-3.6 (2.5)	7.7-18.2 (12.7)	0.21-0.61 (0.38)	0.43-1.03 (0.72)	385-1200 (733)	18	138	0-22.0 (1.9)	143 / 27 / 21	0.00-0.10 (0.012)
[a]Peterson et al. (2003)		data not provided	5.67-12.5 (8.8)	1.10-3.88 (2.03)	2.92-7.59 (4.919)	0.07-0.23 (0.139)	0.17-0.42 (0.293)				0.14-20.55 (2.981)		0.00-0.09 (0.021)

was channelized and straightened on the bank adjacent to the mine tailings and no streambank vegetation was present. The degree of iron flocculent appeared to increase downstream along the tailings pile. The left bank (Holden Village side) had large boulders and woody debris in the channel that created pool habitat. The banks had riparian vegetation consisting of large mature trees and scrubs. Reach 6 is upstream of the mine site. No iron flocculent was observed and riparian vegetation was intact.

Analysis of Bull Trout Presence

No bull trout were observed in Railroad Creek after sampling 1,970 m (12.2% of the stream study area) from rkm 0-2.2 and rkm 8.0-22.0. Railroad Creek stream dimensions were larger than stream dimensions used to develop the model to determine bull trout detection probabilities in Peterson et al. (2003). The probability of detecting bull trout with sampling without blocknets (Peterson et al. 2003) in Railroad Creek calculated at 84% is probably high, but the degree of bias is unknown.

$$1 - [(1-0.077)^5 * (1-0.067)^3 * (1-0.058)^9 * (1-0.044)^{12} * (1-0.040)^2 * (1-.0.028) * (1-0.018)^2] = 0.84$$

This would be interpreted as there was a probability of 84% of detecting bull trout if they were present at minimum densities. The Peterson et al. (2003) model was developed using data from streams with mean wetted width up to 7.59 m, mean depth up to 0.23 m, and mean maximum depth up to 0.42 m. In all units sampled in Railroad Creek the stream size exceeded one or more of these parameters. Average stream size values in Railroad Creek were mean wetted width 12.7 m, mean depth 0.38 m, and mean maximum depth 0.72 m (Table 5 and Appendix C, Table 10). Mean capture efficiencies used in the model for Railroad Creek survey units ranged from 4.4% to 19.5%, mean 14.1%, based on sampling method and conditions. These efficiencies were determined based on field studies in smaller streams (Peterson et al. 2002 and 2003). The probabilities of detection cannot be applied to the reach from rkm 2.2 to rkm 8.0 that was not surveyed.

The probability of detecting bull trout below the falls was calculated separately since this is the only area accessible to adfluvial bull trout. Using Peterson et al. (2003), the probability of detection was 31%, which because Railroad Creek is larger is probably high but the degree of bias is unknown. This would be interpreted as there was a 31% probability of detecting bull trout if they were present at minimum densities. Mean capture efficiencies in reach 1 based on sampling method and conditions were 11.5% and 19.5%. These efficiencies were determined based on field studies in smaller streams (Peterson et al. 2002 and 2003).

$$1 - [(1-0.077)^3 * (1-0.044)^3] = 0.31$$

Discussion

Bull Trout

Confidence in whether bull trout were present or absent can be assessed by evaluating historical knowledge of presence, sampling intensity and the number of other trout observed, as well as detection probabilities. Bull trout were not found in this survey of Railroad Creek. Bull trout may never have been able to access and persist in upper Railroad Creek because of the numerous barrier falls. There are no known historic records of bull trout upstream of the falls in Railroad Creek, and none were found in this study or previous studies.

Although bull trout were not found downstream of the barrier falls in the lower 2.2 km of Railroad Creek, adfluvial bull trout from Lake Chelan could access this reach. Brown (1984) and DES (2000) identified Railroad Creek below the barrier falls as accessible to adfluvial fish from the lake. Other than the Stehekin River and Twenty-five Mile Creek, Lake Chelan tributaries tend to be steep gradient and only accessible to adfluvial fish for short reaches (Hillman et al. 2000). Railroad Creek probably ranks as the fourth best tributary to Lake Chelan in terms of amount of lower elevation stream accessible from the lake (Hillman et al. 2000). However, mining pollution was probably detrimental to any bull trout populations in Railroad Creek during the mine's operation and may limit present use by adfluvial fish.

Substrate in Reach 1 is primarily boulder and cobble (USFS 1991; DES 2000). The USFS (1991) found areas with gravel suitable for spawning at pool tailouts and downstream of boulders and log jams. Temperatures in reach 1 during the survey were 11.0^{o}C to14.0^{o}C which is below 15^{o}C, the temperature that is thought to restrict the range of bull trout (Fraley and Shepard 1989; Rieman and McIntyre 1995; Dunham et al. 2003). Additional temperature information would be needed to determine year-round suitability for rearing of juvenile bull trout.

If adfluvial bull trout are currently present in Lake Chelan, spawning adults may have entered Railroad Creek by the time of this mid-August survey. Bull trout in other watersheds in the mid-Columbia region generally spawn in September and October (Brown 1994) but enter spawning streams as early as mid May. Juvenile bull trout would probably have been in Railroad Creek if spawning was occurring there. Adfluvial juvenile bull trout generally stay in their natal stream until age 2, with smaller numbers emigrating at age 1 and 3 (Pratt 1992).

This survey was designed using bull trout protocol methods from Peterson et al. (2003) which is considered the best current model to describe the probability of bull trout presence. However, there are some problems with the model. A key assumption of the protocol is that bull trout are randomly distributed throughout the sampling frame. Bull trout distribution is affected by stream characteristics, temperature, and cover (Rieman and McIntyre 1995; Watson and Hillman 1997; Dunham et al. 2003), and these have been considered in other sampling approaches (Rieman and McIntyre 1995; Peterson and Dunham 2003). The model is limited by the stream dimension characteristics used to develop the model. Railroad Creek stream dimensions were larger than those used to develop the model to determine bull trout detection. The probabilities of detecting bull trout calculated at 84% for the entire study reach (rkm 0 to 22.2 rkm) and at 31% for the area accessible from the lake (rkm 0 to rkm 2.2) are probably inflated high. Sampling in this survey was primarily by night snorkeling which is generally the most efficient method to detect bull trout (Thurow and Schill 1996; Peterson et al. 2003; Thurow et al. 2003). Sampling efficiencies in Peterson et al. (2002 and 2003) were determined based on field sampling which improved upon earlier models which assumed 100% efficiency (Hillman and Platts 1995) and 25% minimum sampling efficiency (Rieman and McIntyre 1995; Bonar et al. 1997). The Peterson et al. (2002 and 2003) efficiencies are generally less than 25%. The previous models were applied to streams of all sizes, and like the Peterson et al. (2002 and 2003) models are based on presence assuming some minimum fish density. More data needs to be gathered to estimate with greater precision single sample probabilities of detection for larger streams.

Cutthroat Trout

Westslope cutthroat trout are native to Railroad Creek. Previous plantings of non-native rainbow trout in Lake Chelan, Railroad Creek, and some headwater lakes in the Railroad Creek basin have established this species in the Railroad Creek basin. In this survey westslope cutthroat trout, rainbow trout, and hybridized cutthroat trout *x* rainbow trout were found. Where native rainbow trout and cutthroat trout coexist, the cutthroat trout tend to be found in the upper reaches of the streams. In Railroad Creek cutthroat trout were dominant in reach 3, where 99% of the fish observed were cutthroat trout, and also in reaches 5 and 6. This distribution may in part have resulted because the rainbow trout were introduced into lakes in the upper watershed and have had to move downstream to expand their distribution.

Introgressive hybridization with exotic species of trout has been identified as the greatest threat to populations of native westslope cutthroat trout (Allendorf and Leary 1988). The most hybrids were found in reach 5 (adjacent to the mine) while no hybrids were identified in reach 3 (the gorge) and reach 6 (upstream of the mine). However hybrids can be difficult to identify because of variation in the phenotypes displayed in hybrids and pure westslope cutthroat trout (Campbell et al. 2002; Weigel et al. 2002). Because of difficulty in correctly identifying cutthroat trout and hybrids based on phenotypic characteristics alone (Campbell et al. 2002; Weigel et al. 2002), there may be some error in the field identification of species in Railroad Creek. Analysis of fish genetic samples collected throughout Railroad Creek could help determine the distribution, purity, and degree of hybridization of the cutthroat trout.

A secondary threat to native cutthroat trout is interspecific competition. Typically other trout species outcompete cutthroat trout (Griffith 1988). Cutthroat trout are generalist that evolved in the presence of few other species (Behnke 1992). In the presence of other species, cutthroat trout populations tend to persist most often in high gradient areas at the heads of streams (MacPhee 1966; Griffith 1988). Reach 3 had some characteristics of a headwater, steeper gradient and in a narrow valley. The upper reaches surveyed also had higher percentages of cutthroat trout. This survey did not extend up into the headwaters of Railroad Creek. At times when space and food are minimal such as late summer, interspecific competition between cutthroat trout and other salmonids can be most intense (Griffith 1988). In reach 4 and 5 reduced cover and food availability due to effects from the mine could intensify competition between the cutthroat trout and rainbow trout. Johnson et al. (1997) found macroinvertebrate counts were significantly decreased in number and taxa richness downstream of the mine site compared to upstream. This decrease downstream of the mine was attributed to the effect from the iron flocculent in the stream (Johnson et al. 1997). Another factor that may be limiting the cutthroat trout population is recreational fishing which currently allows harvest of two trout of any species, minimum size 8 inches. Cutthroat trout can be particularly vulnerable to angling (Schill et al. 1986).

Habitat

Stream habitat in Railroad Creek has been affected by the Holden mine in the reaches adjacent to and downstream of the mine tailings. In the immediate vicinity of the mine tailings the stream has been channelized, vegetation removed, and iron flocculent was embedded in the substrate.

Sediments from mine tailings are thought to degrade the stream habitat by decreasing interstitial spaces, invertebrate production, spawning gravel quality, and likely directly affect the fish through the degradation of the water quality (Johnson et al. 1997). Fish densities were lowest in the reach immediately downstream of the mine and adjacent to mine and are likely a result of degraded stream conditions. The proposed restoration activities in Railroad Creek include reductions in runoff from the tailings to reduce the amount of iron flocculent and other chemicals that enter the stream. Channel restoration efforts have the potential to greatly enhance the fish population in Railroad Creek, specifically adjacent and downstream of the mining activities.

Conclusions and Recommendations

1. Bull trout were not found in Railroad Creek and likely were never present upstream of the series of barrier falls at rkm 2.2. Downstream of the barrier falls at rkm 2.2 is accessible to adfluvial fish from Lake Chelan, however no bull trout were observed in this survey.
2. Westslope cutthroat trout and rainbow trout were found in all reaches, and rainbow trout *x* cutthroat trout hybrids were visually identified in some reaches. Genetic analysis should be completed for fish in Railroad Creek to determine genetic purity of cutthroat trout and identify areas of hybridization. Fish management in Railroad Creek should focus on native cutthroat trout.
3. The mine and tailings have impacted Railroad Creek from channelization and effects from tailings runoff including the iron flocculent that has embedded the substrate downstream of the mine tailings. The proposed restoration activities in Railroad Creek including reductions in tailings runoff and channel restoration have the potential to greatly enhance the fish population in Railroad Creek through improved water quality and stream habitat.

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Appendix A.

TABLE 6. Native and introduced fish and aquatic species found in Lake Chelan[a].

Species common name	Scientific name	Native or introduced	Year of introduction
bull trout	*Salvelinus confluentus*	native	
westslope cutthroat trout	*Oncorhynchus clarki lewisi*	native	
mountain whitefish	*Prosopium williamsoni*	native	
pygmy whitefish	*Prosopium coulteri*	native	*Status unknown*
northern pike-minnow	*Ptychocheilus oregonensis*	native	
burbot	*Lota lota*	native	
bridgelip sucker	*Catostomus columbianus*	native	
largescale sucker	*Catostomus macrocheilus*	native	
longnose sucker	*Catostomus catostomas*	native	
peamouth chub	*Mylocheilus caurinus*	native	
redside shiner	*Richardsonius balteatus*	native	
three-spine stickleback	*Gasterostius aculeatus*	native	
mottled sculpin	*Cottus bairdi*	native	
sculpin	*Cottus* spp.	native	
dace	*Rhynichthys* spp.	native	
chiselmouth	*Acrocheilus alutaceus*	native	
rainbow trout	*Oncorhynchus mykiss*	introduced	1917
kokanee	*Oncorhynchus nerka*	introduced	1917 (or 1916)
Chinook salmon	*Oncorhynchus tshawytscha*	introduced	1974
lake trout	*Salvelinus namaycush*	introduced	1980
smallmouth bass	*Micropterus dolomieu*	introduced	1993
mysid shrimp (zooplankton spp)	*Mysis relicta*	introduced	1968

[a]Sources: Evermann 1899 (*in* Hillman et al. 2000); Brown 1984; Murphy 1995; DES 2000; Viola and Foster 2002.

Appendix B. Maps

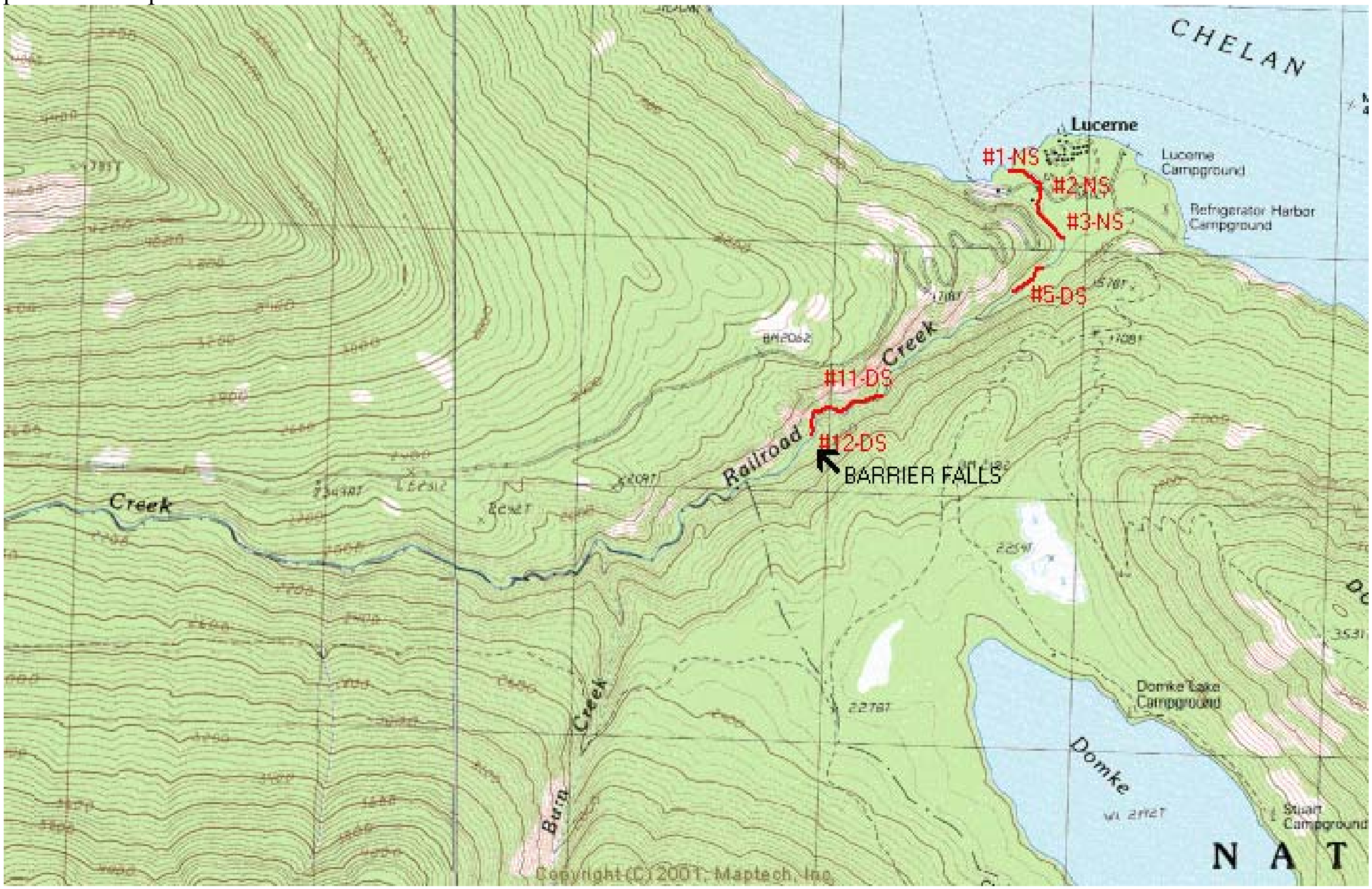

FIGURE 1. Maps of Railroad Creek with locations of units surveyed and survey method.
Key: DS =day snorkeling; NS = night snorkeling; EF = electrofishing

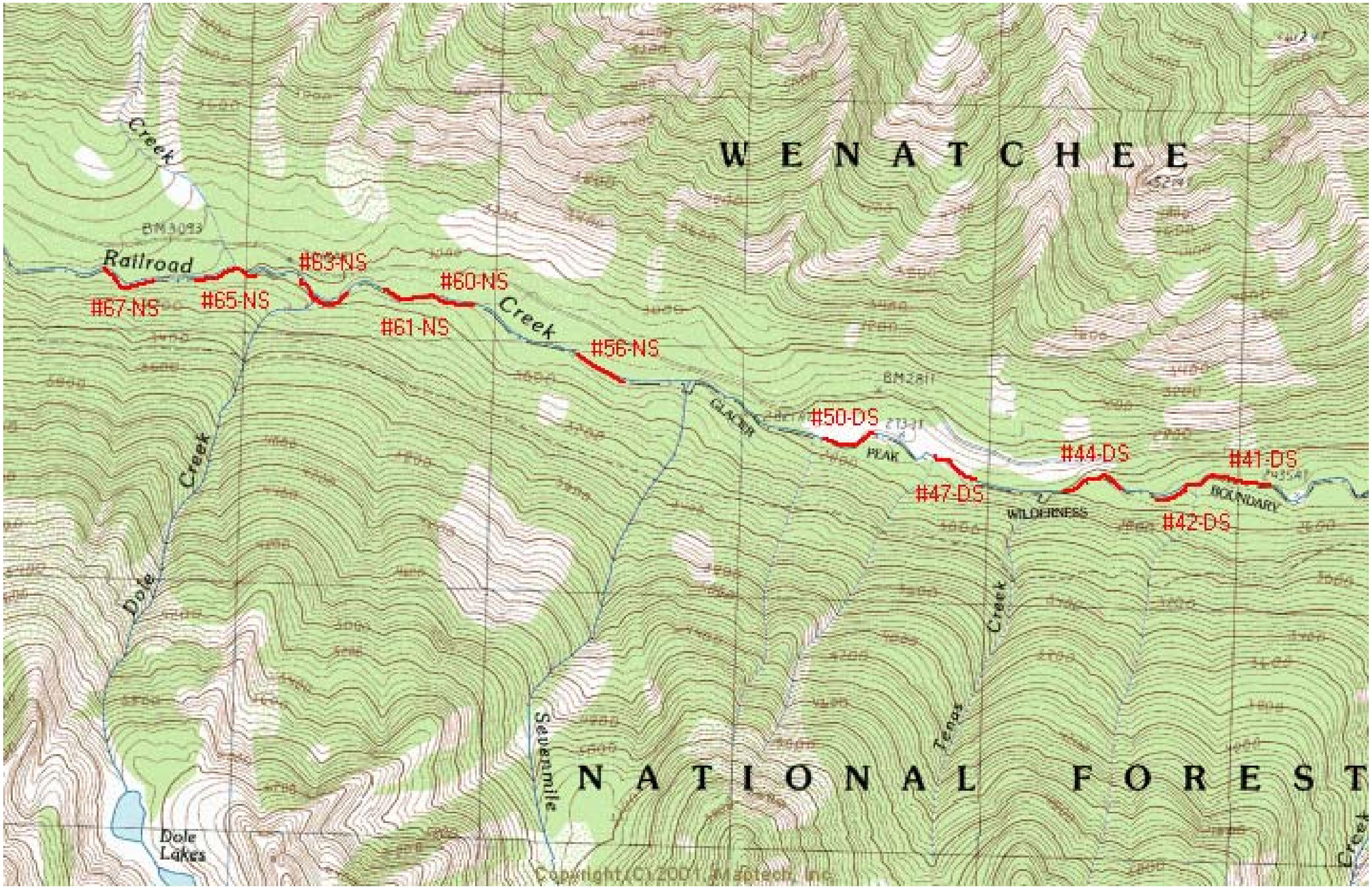

FIGURE 1. continued. Key: DS =day snorkeling; NS = night snorkeling; EF = electrofishing

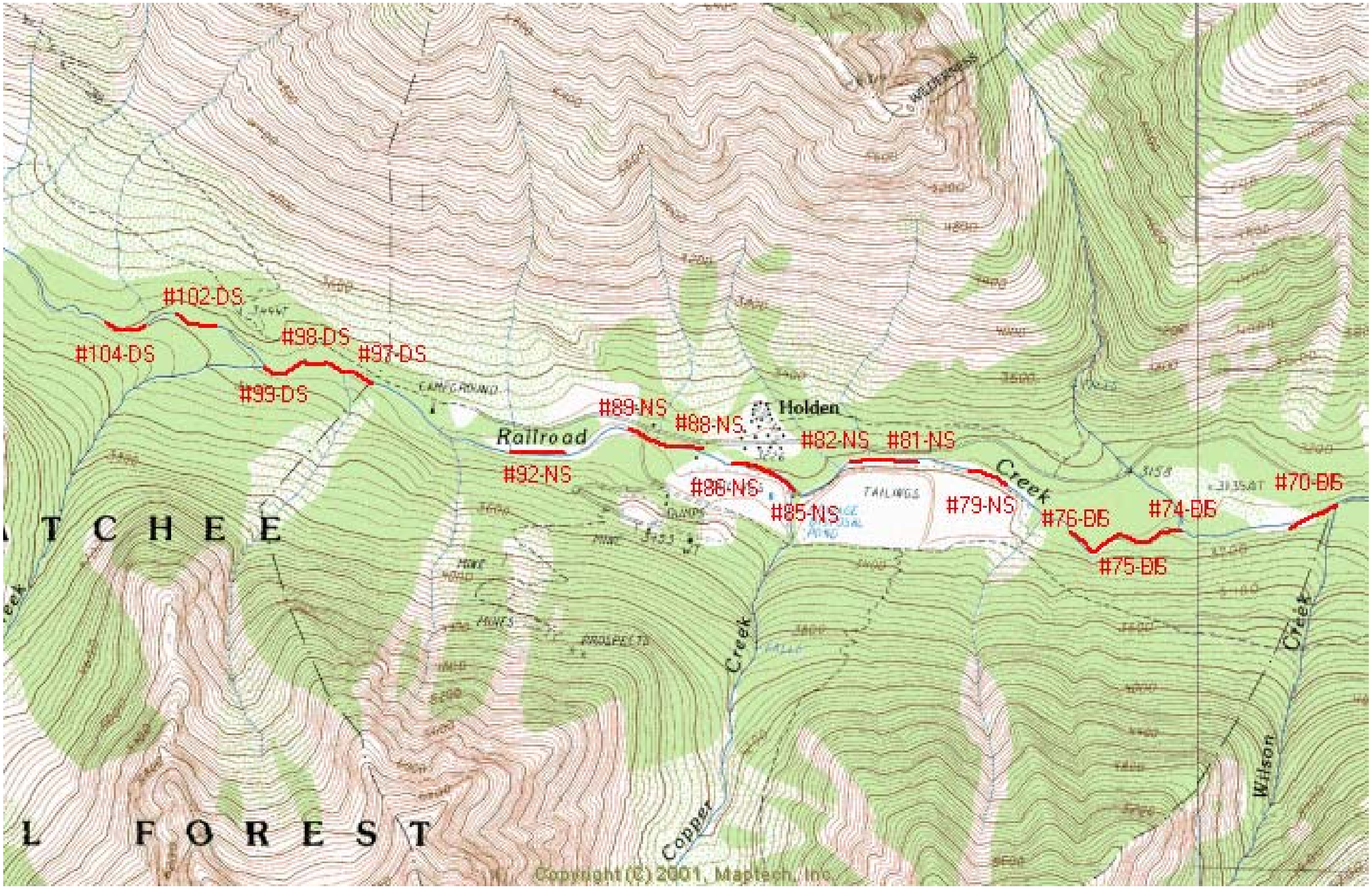

FIGURE 1. continued. Key: DS =day snorkeling; NS = night snorkeling; EF = electrofishing

Appendix C. Fish, fish genetics, and habitat data.

TABLE 7. Numbers of rainbow trout, cutthroat trout, hybrid rainbow x cutthroat trout and length (mm) in each sample unit surveyed.

			Rainbow trout number by length (mm)						Cutthroat trout number by length (mm)						Hybrid rainbow *x* cutthroat and unknown number by length (mm)					
Reach	Unit	Length (m)	YOY <30	30-99	100-199	200-299	300-399	Rb total	YOY <30	30-99	100-199	200-299	300-399	CT total	YOY <30	30-99	100-199	200-299	Hyb total	Trout total
1	1	100		3	5	6		14		1	2		2	5					0	19
1	2	100			5	2	4	11						0			2	4	6	17
1	3	100			2	1		3		2	2		1	5					0	8
1	5	50	10	3	4	1		18	4	4	3	1		12					0	30
1	11	50	3	2	2	2		9			8	4		12					0	21
1	12	50	3	3	1	1	1	9		1	2	2		5					0	14
	Reach 1 Total		16	11	19	13	5	64	4	8	17	7	3	39	0	0	2	4	6	109
3	41	50						0		21	12	4		37					0	37
3	42	50						0		10	7	1		18					0	18
3	opt	20						0		18	12	5		35					0	35
3	44	50						0	5	6	5	1		17					0	17
3	47	50						0	3	9	13	1		26					0	26
3	50	50			1			1	2	6	7	1		16					0	17
	Reach 3 Total		0	0	1	0	0	1	10	70	56	13	0	149	0	0	0	0	0	150
4	56	50		7	6			13		1	3			4			1unk		1unk	18
4	60	50						0			1			1					0	1
4	61	50		1	1			2			2			2					0	4
4	63	50			1			1			1	1		2		1			1	4
4	65	50			2			2		2	3	4		9					0	11
4	67	50			1			1			1			1					0	2
4	70	50						0						0					0	
4	74	50						0						0					0	
4	75	50						0				1		1					0	1
4	76	50						0			1			1					0	1
	Reach 4 Total		0	8	11	0	0	19	0	3	12	6	0	21	0	1	1	0	2	42

TABLE 7 continued. Numbers of rainbow trout, cutthroat trout, and hybrid rainbow x cutthroat trout and length (mm) in each sample unit surveyed.

			Rainbow trout number by length (mm)						Cutthroat trout number by length (mm)						Hybrid rainbow *x* cutthroat and unknown number by length (mm)					
Reach	Unit	Length (m)	YOY	30-99	100-199	200-299	300-399	Rb total	YOY	30-99	100-199	200-299	300-399	Ct total	YOY	30-99	100-199	200-299	Hyb total	Trout total
5	79	50			1			1				6		6			1unk	1unk	2unk	9
5	81	100						0			5	3	1	9					0	9
5	82	50						0		4	5	2		11					0	11
5	85	50				2		2		2	6	1		9					0	11
5	86	100		2	2		1	5	2	11	15	3	1	32		2	6		8	45
5	88	50				1		1		1	5	3		9					0	10
5	89	50	1	2				3						0			1		1	4
	Reach 5 Total		1	4	3	3	1	12	2	18	36	18	2	76	0	2	8	1	11	99
6	92	50		12	22	4		38	20	43	19			82					0	120
6	97	50		2	3			5		5	5	2		12					0	17
6	98	50		2	2	1		5						0					0	5
6	99	50						0		6	15	5	3	29					0	29
6	102	50						0	2	6	14	4		26					0	26
6	104	50		0	0	1		1	1	6	7	2		16					0	17
	Reach 6 Total		0	16	27	6		49	23	66	60	13	3	165	0	0	0	0	0	214
Grand total:		1,970	17	39	61	22	6	145	39	165	181	57	8	450	0	3	9 2unk	4 1unk	16hyb 3unk	614

TABLE 8. Sample unit characteristics for Railroad Creek including estimated sampling efficiencies and single sample probability of detections from Peterson et al. (2003) for each unit surveyed.

Reach	Unit	Length (m)	Total time (min)	Day or Night Snorkeling or EF	Visib-ility (m)	Bank to bank visibility Yes/No	Water temp ^{o}C	Percent undercut banks	Estimated sampling efficiency	Single sample probability of detection
1	1	100	70	NS	1.2	N	11.0	0	0.195	0.077
1	2	100	40	NS	1.2	N	11.0	0	0.195	0.077
1	3	100	29	NS	1.2	N	11.0	0	0.195	0.077
1	5	50	41	DS	1.2	N	13.7	0	0.119	0.044
1	11	50	35	DS	1.2	N	12.6	0	0.119	0.044
1	12	50	23	DS	1.2	N	13.9	0	0.119	0.044
3	41	50	23	DS	3.0	N	11.0	0	0.119	0.044
3	42	50	15	DS	3.0	N	11.0	0	0.119	0.044
	opt	20		DS		N	11.0			
3	44	50	17	DS	3.0	N	14.0	9	0.044	0.018
3	47	50	15	DS	3.0	N	12.0	0	0.119	0.044
3	50	50	18	DS	3.0	N	13.0	0	0.119	0.044
4	56	50	50	NS	2.1	N	13.1		0.166	0.058
4	60	50	27	NS	2.1	N	13.1	0	0.166	0.058
4	61	50	25	NS	2.1	N	13.1	0	0.166	0.058
4	63	50	14	NS	2.1	N	13.0	0	0.166	0.058
4	65	50	17	NS	2.1	N	12.0	6	0.192	0.067
4	67	50	22	NS	2.1	N	12.5		0.166	0.058
4	70	50	18	EF	I2, 1000V, 49 uohms		12.5	40	0.071	0.028
4	74	50	15	EF	J2, 1000V, 170 uohms		11.0	10	0.104	0.040
4	75	50	15	EF	I2, 1000V, 65uohms		14.0	10	0.104	0.040
4	76	50	15	EF	I2, 1000V, 38 uohms		14.5	0	0.115	0.044
5	79	50	15	NS	2.9	N	10.0	0	0.166	0.058
5	81	100	35	NS	2.9	N	12.0	0	0.195	0.077
5	82	50	16	NS	2.9	N	11.0	0	0.166	0.058
5	85	50	13	NS	2.9	Y	11.0	0	0.166	0.058
5	86	100	37	NS	2.9	Y	10.0	0	0.195	0.077
5	88	50	15	NS	2.9	N	14.0	4	0.192	0.067
5	89	50	19	NS	2.9	N	14.0	0	0.166	0.058
6	92	50	27	NS	2.9	Y	13.0	6	0.192	0.067
6	97	50	35	DS	3.6	N	11.5	0	0.119	0.044
6	98	50	33	DS	3.6	N	12.5	0	0.119	0.044
6	99	50	15	DS	3.6	N	12.5	44	0.044	0.018
6	102	50	17	DS	3.6	Y	13.0	0	0.119	0.044
6	104	50	20	DS	3.6	Y	14.0	0	0.119	0.044

TABLE 9. Trout sampled for genetics, Railroad Creek, 2003.

Unit	Approximate location (rkm)	Vial number	Species	Fork length (mm)	Weight (g)
75	14.8	1	cutthroat	215	114
76	15.1	2	cutthroat	117	18
92	18.2	3	cutthroat	124	18
92	18.2	4	rainbow	113	13
92	18.2	5	cutthroat	87	9
92	18.2	6	rainbow	75	4
92	18.2	7	hybrid	172	59
92	18.2	8	hybrid	165	48
92	18.2	9	cutthroat	153	36
92	18.2	10	hybrid	105	14
92	18.2	11	cutthroat	123	18
92	18.2	12	hybrid	172	47
92	18.2	13	hybrid	153	38
92	18.2	14	hybrid	186	73
92	18.2	15	hybrid	195	80
92	18.2	16	cutthroat	133	28
92	18.2	17	cutthroat	142	30
92	18.2	18	rainbow	119	18
92	18.2	19	rainbow	147	34
92	18.2	20	cutthroat	115	10
92	18.2	21	rainbow	145	35
92	18.2	22	rainbow	135	28
92	18.2	23	rainbow	109	15
92	18.2	24	cutthroat	135	26
92	18.2	25	rainbow	128	20
86	17.0	26	cutthroat	147	38
86	17.0	27	hybrid	139	23
86	17.0	28	cutthroat	134	24
86	17.0	29	cutthroat	108	13
86	17.0	30	cutthroat	167	52
86	17.0	31	hybrid	126	14
86	17.0	32	rainbow	105	11
86	17.0	33	hybrid	84	6
86	17.0	34	hybrid	73	4
86	17.0	35	hybrid	134	26
86	17.0	36	hybrid	137	26
86	17.0	37	hybrid	130	22
86	17.0	38	hybrid	162	47

TABLE 10. Habitat data collected for Railroad Creek, 2003.

Reach	Unit	Length (m)	Unit mean width	Unit mean depth	Mean max depth	Surface area(m2)	Length of undercut bank(m)	Large woody debris count	Large woody debris aggregates	Root-wads	Gradient %	Gradient measured with	Channel spanning pools	Pool length (m)
1	1	100	12.0	0.46	0.92	1200	0		1		5.0	map	0	
1	2	100	12.0	0.46	0.92	1200	0				5.0	map	0	
1	3	100	12.0	0.46	0.92	1200	0				5.0	map	0	
1	5	50	14.5	0.48	0.75	723	0	0	0	0	5.0	Abney	0	
1	11	50	10.1	0.52	0.91	507	0	0	0	0	1.5	Abney	0	
1	12	50	12.2	0.49	1.03	608	0	18	0	0	8.0	Abney	1	12
3	41	50	11.3	0.61	0.95	565	0	1	0	1	5.5	map	0	
3	42	50	15.3	0.44	0.85	765	0	0	0	0	5.5	map	0	
3	44	50	18.2	0.38	0.65	910	4.5	1	1	1	5.5	map	0	
3	47	50	12.0	0.51	0.85	600	0	0	0	0	5.5	map	0	
3	50	50	13.1	0.38	0.70	655	0	0	0	0	4.5	map	0	
4	56	50									1.5	map	0	
4	60	50	10.6	0.41	0.65	528	0	3	0	0	0.5	Abney	0	
4	61	50	13.2	0.42	0.75	658	0	30	0	2	2.0	Abney	0	
4	63	50	12.2	0.44	0.83	608	0	1	0	0	0.5	Abney	1	10
4	65	50	17.7	0.26	0.52	887	6	5	2	1	4.0	map	1	5
4	67	50									5.5	map	1	7
4	70	50	19.3	0.35	1.04	967	20	2	7	3	2.0	altimeter	2	18
4	74	50	13.2	0.34	0.61	662	5	1	2	1	2.0	altimeter	1	20
4	75	50	10.3	0.35	0.64	515	5	5	1	1	4.0	altimeter	1	9
4	76	50	11.6	0.37	0.61	580	0	2	1	2	4.0	altimeter	0	
5	79	50	9.6	0.48	0.74	482	0	0	0	0	4.0	altimeter		
5	81	100	14.8	0.27	0.64	1483	0	5	1	0	1.0	Abney	0	
5	82	50	16.3	0.33	0.60	813	0	3	4	0	1.0	Abney	0	
5	85	50	16.3	0.28	0.67	815	0	6	0	0	1.0	Abney	1	4

TABLE 10 continued. Habitat data collected for Railroad Creek, 2003.

Reach	Unit	Length (m)	Unit mean width	Unit mean depth	Mean max depth	Surface area(m2)	Length of undercut bank(m)	Large woody debris count	Large woody debris aggregates	Root-wads	Gradient %	Gradient measured with	Channel spanning pools	Pool length (m)
5	86	100	10.4	0.30	0.51	1037	0	3	1	1	0.5	map	2	15
5	88	50	17.5	0.21	0.43	877	2	1	0	0	0.75	Abney	0	
5	89	50	9.0	0.32	0.54	448	0	0	0	0	0.75	Abney	0	
6	92	50	11.7	0.35	0.80	585	3	39	4	5	1.5	Abney	3	
6	97	50	13.5	0.25	0.49	675	0	0	0	0	3.0	Abney	0	
6	98	50	9.8	0.37	0.67	490	0	3	0	0	2.0	Abney	1	10
6	99	50	10.7	0.37	0.73	537	22	8	1	2	2.0	Abney	2	13
6	102	50	7.7	0.33	0.63	385	0	4	0	0	2.5	map	0	
6	104	50	9.7	0.33	0.60	485	0	2	1	1	2.5	map	1	15

Appendix D. Probability of detection and sample size tables from Peterson et al. (2003).

TABLE 11. *Table from* Peterson et al. (2002). Mean estimated bull trout single sample detection probabilities for single pass day snorkeling without blocknets, by habitat groups. Probabilities are averaged across fish body sizes. Required sample sizes for 80%, 90%, and 95% detection probabilities by habitat groups are given. Detection probabilities estimated assuming distribution of densities for 50-m and 100-m sample units in Peterson et al. (2002).

			Without blocknets				
Water temperature	Mean depth	Undercut banks	Mean capture efficiency	Single sample detection	80%	90%	95%
50-m sample units							
> 9.25 ^{0}C	>0.17 m	> 1.6 %	0.044	0.018	91	130	169
		≤ 1.6 %	0.119	0.044	36	52	67
	≤0.17 m	> 1.6 %	0.057	0.023	70	100	130
		≤ 1.6 %	0.148	0.053	30	42	55
≤ 9.25 ^{0}C	>0.17 m	> 1.6 %	0.029	0.012	137	196	255
		≤ 1.6 %	0.081	0.032	50	71	93
	≤0.17 m	> 1.6 %	0.039	0.016	102	147	191
		≤ 1.6 %	0.105	0.040	39	56	73
100-m sample units							
> 9.25 ^{0}C	>0.17 m	> 1.6 %	0.049	0.024	67	96	125
		≤ 1.6 %	0.131	0.057	27	39	51
	≤0.17 m	> 1.6 %	0.063	0.030	53	76	99
		≤ 1.6 %	0.163	0.068	23	32	42
≤ 9.25 ^{0}C	>0.17 m	> 1.6 %	0.032	0.016	100	144	187
		≤ 1.6 %	0.090	0.042	38	54	71
	≤0.17 m	> 1.6 %	0.043	0.021	76	109	142
		≤ 1.6 %	0.116	0.052	30	43	56

TABLE 12. *Table from* Peterson et al. (2002). Mean estimated bull trout single sample detection probabilities for single pass night snorkeling without blocknets, by habitat groups. Probabilities are averaged across fish body sizes. Required sample sizes for 80%, 90%, and 95% detection probabilities by habitat groups are given. Detection probabilities estimated assuming distribution of densities for 50-m and 100-m sample units in Peterson et al. (2002).

	Without blocknets				
Undercut banks	Mean capture efficiency	Single sample detection	80%	90%	95%
50-m sample units					
>1.6%	0.192	0.067	23	33	43
<1.6%	0.166	0.058	27	38	50
>1.6%	0.226	0.086	18	26	33
<1.6%	0.195	0.077	20	29	37

TABLE 13. *Table from* Peterson et al. (2002). Mean estimated bull trout single sample detection probabilities for single pass electrofishing without blocknets, by habitat groups. Probabilities are averaged across fish body sizes. Required sample sizes for 80%, 90%, and 95% detection probabilities by habitat groups are given. Detection probabilities estimated assuming distribution of densities for 50-m and 100-m sample units in Peterson et al. (2002).

		Without blocknets				
Stream mean wetted cross-sectional area	Conductivity	Mean capture efficiency	Single sample detection	80%	90%	95%
50-m sample units						
> 1.00 m^2	>53 μohms	0.104	0.040	40	57	74
		0.167	0.059	26	38	49
	≤53 μohms	0.071	0.028	57	82	106
		0.115	0.044	36	51	66
≤ 1.00 m^2	>53 μohms	0.139	0.051	31	44	57
		0.217	0.073	21	30	39
	≤53 μohms	0.097	0.038	42	60	78
		0.153	0.056	28	40	52
100-m sample units						
> 1.00 m^2	>53 μohms	0.112	0.049	32	46	60
		0.179	0.072	21	31	40
	≤53 μohms	0.076	0.036	44	64	83
		0.123	0.054	29	42	54
≤ 1.00 m^2	>53 μohms	0.149	0.063	25	35	46
		0.232	0.087	18	25	33
	≤53 μohms	0.104	0.046	34	49	63
		0.164	0.068	23	33	43

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