U.S. Fish and Wildlife Service

Seasonal Movements of Adult Fluvial Bull Trout and Redd Surveys in Icicle Creek 2009 Annual Report

Mark C. Nelson, Andy Johnsen, and R.D. Nelle

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

***On the cover**: Fluvial bull trout code 95 in Icicle Creek at the East Leavenworth Road Bridge (rkm 3.5) on September 18, 2009. USFWS photograph by Mark C. Nelson.*

The correct citation for this report is:

Nelson, M.C, A. Johnsen, and R.D. Nelle. 2011. Seasonal movements of adult fluvial bull trout and redd surveys in Icicle Creek, 2009 Annual Report. U.S. Fish and Wildlife Service, Leavenworth WA.

SEASONAL MOVEMENTS OF ADULT FLUVIAL BULL TROUT AND REDD SURVEYS IN ICICLE CREEK 2009 ANNUAL REPORT

Study funded by

U.S. Fish and Wildlife Service
Fisheries Operating Needs System
FONS # 2003-011
FONS # 2001-002

conducted pursuant to

Section 10 of the Endangered Species Act of 1973
Permit TE-702631 Subpermit MCFRO-12

and authored by

Mark C. Nelson
Andy Johnsen
R.D. Nelle

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

Final
January 11, 2011

Disclaimers

Any findings and conclusions presented in this report are those of the authors and may not necessarily represent the views of the U.S. Fish and Wildlife Service.

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

SEASONAL MOVEMENTS OF ADULT FLUVIAL BULL TROUT AND REDD SURVEYS IN ICICLE CREEK 2009 ANNUAL REPORT

Mark C. Nelson, Andy Johnsen, and R.D. Nelle

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

Abstract- Relatively little is known about the life history, movement patterns, population numbers, and genetic diversity of the threatened bull trout *Salvelinus confluentus* in Icicle Creek. In 2007, the Mid-Columbia River Fishery Resource Office of the U.S. Fish and Wildlife Service began a telemetry study of adult fluvial bull trout to determine migration timing and distances, identify migration barriers and obstacles, document passage windows at natural and artificial obstacles, monitor seasonal movements, and locate spawning areas in Icicle Creek. In 2009, an additional seven adult bull trout were captured and radio-tagged in lower Icicle Creek and their movements were monitored. A hybrid bull x brook trout *S. confluentus x fontinalis* was captured and tagged in upper Icicle Creek. Tissue samples for genotypic analysis were taken from all captured bull trout, including 38 untagged juveniles. To date, none of the bull trout tagged in the lower river have attempted to move upstream past Leavenworth National Fish Hatchery or attempted to pass the boulder falls at rkm 9.2. In 2009, bull trout code 20 (tagged in 2008) wintered in the Wenatchee River at the mouth of Icicle Creek and then migrated upstream in the Wenatchee River to its spawning area in Chiwaukum Creek. Temperatures in lower Icicle Creek and the Leavenworth NFH spillway pool were cooler than the Wenatchee River and appeared to offer thermal refuge and foraging opportunities for both adult and juvenile/sub-adult bull trout during summer and early autumn. A total of three resident-sized bull trout redds were counted in French Creek during 2009. As water temperatures cooled in the autumn, radio-tagged bull trout exited Icicle Creek and moved into the Wenatchee River. Some bull trout stopped movements for extended periods and downstream migration rates between fixed telemetry stations ranged from 0.2 to 41.3 km/day in lower Icicle Creek and 0.7 to 47.6 km/day in the Wenatchee River. Downstream movements past fixed stations occurred primarily at night and overall migration distances ranged from 5.4 to 50.1 km. Two tagged bull trout over-wintered in the Wenatchee River and four over-wintered in the Columbia River. Water temperature and stream discharge appeared to be major factors influencing bull trout movement patterns in Icicle Creek and the Wenatchee River. Hybridization with brook trout is likely a significant problem for bull trout in Icicle Creek and surveys to determine population numbers and distribution of brook trout are needed. Genetic analyses may help estimate the emigration and immigration rates of bull trout in Icicle Creek and clarify the importance of this local population to the metapopulation of the Upper Columbia Recovery Unit.

Page intentionally left blank

Table of Contents

List of Tables

List of Figures

Page intentionally left blank

Introduction

Bull trout *Salvelinus confluentus* in the Columbia River basin were listed as threatened in 1998 (USDOI 1998) and recovery planning focused solely on migratory populations (USFWS 2002a). Icicle Creek bull trout were initially identified as a resident population and were not included as a local population of the Upper Columbia Recovery Unit in the draft bull trout recovery plan (USFWS 2002b). The rugged canyon and boulder falls beginning at river kilometer 9.2[1] were considered a barrier to migratory fish (WDF 1938), but in autumn of 2002, migratory sized bull trout were observed immediately upstream of the boulder falls (USFWS 2004). Therefore, Icicle Creek bull trout were added as a local migratory population in a revised version of the draft bull trout recovery plan, and the potential use of Icicle Creek by migratory bull trout and their status and interaction with the resident component were identified as research needs (USFWS 2004).

The Upper Columbia Bull Trout Recovery Unit encompasses the Wenatchee, Entiat and Methow core areas (Figure 1). Icicle Creek bull trout are one of seven local migratory populations designated in the Wenatchee Core Area. The other local bull trout populations are located in Peshastin Creek (including Ingalls Creek), Chiwaukum Creek, Nason Creek (including Mill Creek), Chiwawa River (including Chikamin, Phelps, Rock, Alpine, Buck, and James creeks), White River (including Canyon and Panther creeks), and Little Wenatchee River (USFWS 2004).

During the recovery planning process it was determined that 50 pairs of spawning bull trout, or 50 redds, constituted the recovered abundance of Icicle Creek migratory bull trout (USFWS 2004). Spawning ground surveys to enumerate bull trout redds were not conducted in Icicle Creek until 2008, when 8 migratory-sized redds were found in French Creek, a tributary of upper Icicle Creek (Nelson et al. 2009). Although other spawning areas have not been delineated, the abundance of migratory adults in the Icicle Creek local population currently appears to be below recovery levels.

Little is known about the movements, migration timing, population numbers, and genetic diversity of migratory bull trout in Icicle Creek upstream of Leavenworth National Fish Hatchery (NFH). In 2007, the U.S. Fish and Wildlife Service (USFWS) Mid-Columbia River Fishery Resource Office (MCRFRO) developed a multiyear radio-telemetry study in Icicle Creek (Nelson et al. 2009). In 2008, three adult fluvial bull trout were radio-tagged and one (tagged in the upper river at Icicle Gorge at rkm 26.2) migrated to and spawned in French Creek (Nelson et al. 2009). In 2009, the study was continued and this report details the results from January 1, 2009 to February 4, 2010.

The objectives of the study are to determine migration timing and distances, identify migration barriers and obstacles, document passage windows at natural and artificial obstacles, monitor seasonal movements, and locate spawning areas of adult migratory bull trout in Icicle Creek.

[1] Note that all river kilometer (rkm) designations in this report are approximate. See methods section.

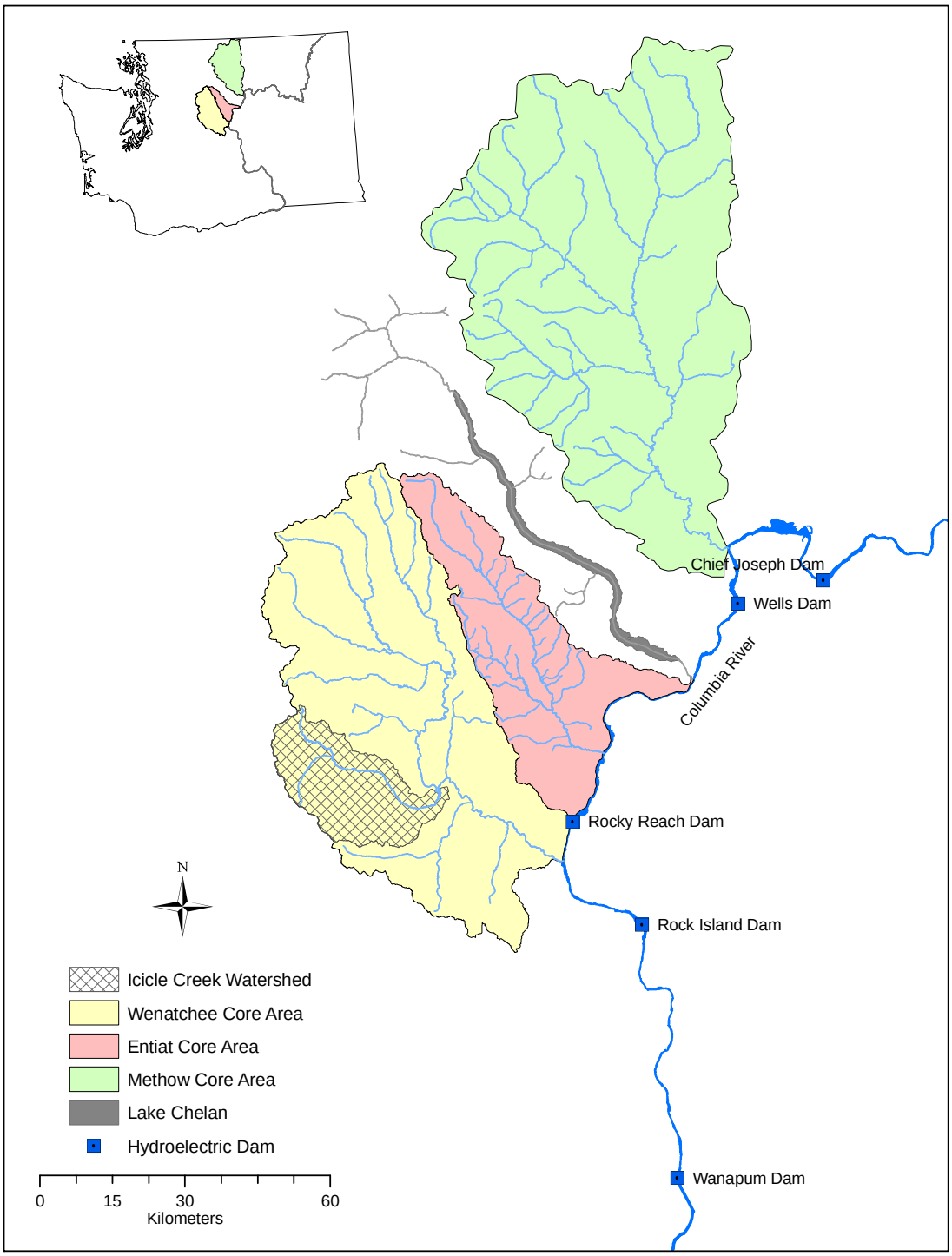

Figure 1. Map of the Upper Columbia Bull Trout Recovery Unit, showing the location of the Icicle Creek watershed within the Wenatchee Core Area.

Study Area

Icicle Creek originates in Josephine Lake (elevation 1,427 m) near the crest of the Cascade Mountains in Chelan County of north-central Washington. It flows easterly for 51.2 rkm, drains a watershed area of 555 km^2, and enters the Wenatchee River at rkm 41.2 near the town of Leavenworth (Figure 2). Eighty-seven percent of the watershed is in public ownership (74% of which is in the Alpine Lakes Wilderness Area), and 13% is in private ownership (USFS 1995).

Icicle Creek is in a narrow, steep, and glaciated valley characterized by a cascading water course that plunges downstream in a series of cataracts, riffles, and rapids. Stream discharge has been recorded by the U.S. Geological Survey (USGS) Gage Station 12458000 at rkm 9.4 from 1936 to 1971 and from 1993 to the present. The average discharge for the period of record is 614 ft^3/s and the minimum and maximum discharges are 44 ft^3/s (November 30, 1936) and 19,800 ft^3/s (November 29, 1995) (USGS 2009). Stream gradient is variable and ranges from 0.1 to 9% (Figure 3). Several natural and artificial obstructions to fish migrations occur in Icicle Creek. Among the many natural obstacles (Figure 3) are the boulder falls found both upstream of Snow Creek at rkm 9.2 and near Bridge Creek at rkm 14.3, the chute and flume falls at the Icicle Gorge (rkm 26.2), water falls at Rock Island Campground (rkm 29.1), and complex falls (step pool morphology over bedrock substrate) at rkm 34.3 and at French Creek (rkm 34.7). The high falls upstream of Leland Creek at rkm 46.8 are considered impassable to migrating fish (Bryant and Parkhurst 1950). Many of the tributaries, particularly the smaller ones, are inaccessible to migratory fish due to waterfalls and steep gradient (Mullan et al.1992).

Artificial obstructions in Icicle Creek include structures associated with the operation of Leavenworth NFH (seasonal barrier (structure 5) at rkm 4.4, headgate (structure 2) at rkm 6.1, and intake diversion dam (structure 1) at rkm 7.2) and the Icicle-Peshastin Irrigation District (IPID) diversion dam at rkm 9.3 (Figure 4). Adaptive management of Leavenworth NFH attempts to balance hatchery operations, tribal and sport fisheries, and fish movements (USFWS 2006). Structure 5 is open except when it may be operated as a seasonal barrier during the hatchery's spring Chinook salmon brood stock collection period (May 15 – July 7). The headgate is open most of the year, but exceptions may occur during brood stock collection or when operated to control flooding and recharge groundwater wells. The Leavenworth NFH intake diversion dam, shared with the Cascade Orchards Irrigation Company, has a fish ladder which is typically in operation during the migration season. The IPID irrigation diversion dam, shared by the City of Leavenworth for municipal water intake, does not have a fish ladder.

The Icicle Creek watershed sustains the heaviest recreational use of any watershed within the Wenatchee River subbasin (USFS 1995). Recreational activities include kayaking, rock climbing, hiking, backpacking, bicycling, horse riding, hunting, fishing, bird watching, sightseeing, and camping. Six of the seven U.S. Forest Service (USFS) developed campgrounds are located in the riparian zone of Icicle Creek (Figure 5) and several primitive campsites are dispersed throughout the valley. The lower 32 kilometers

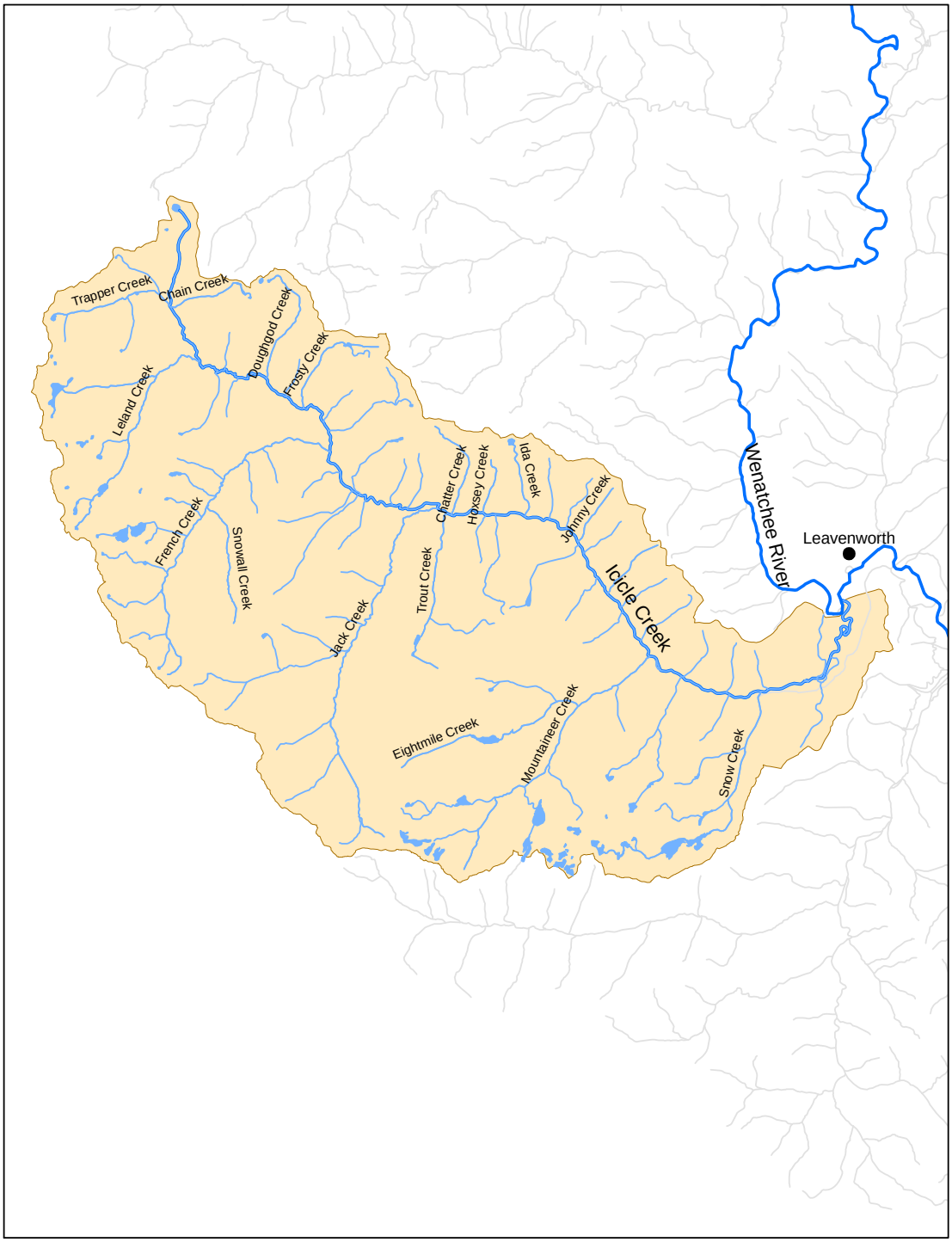

Figure 2. Map of the Icicle Creek watershed.

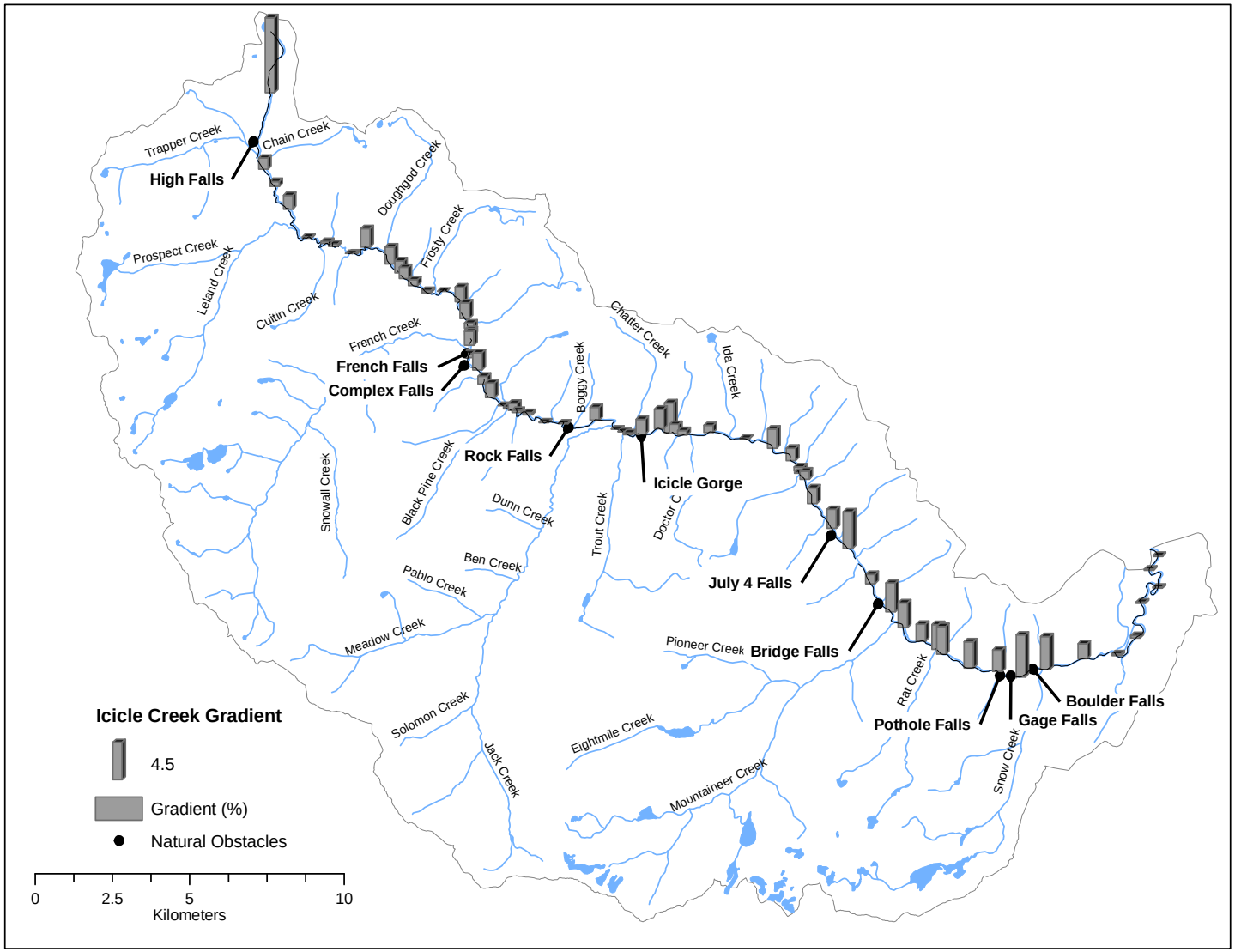

Figure 3. Map of Icicle Creek watershed, showing gradient (within stream segments as calculated in GIS) and locations of select natural obstacles.

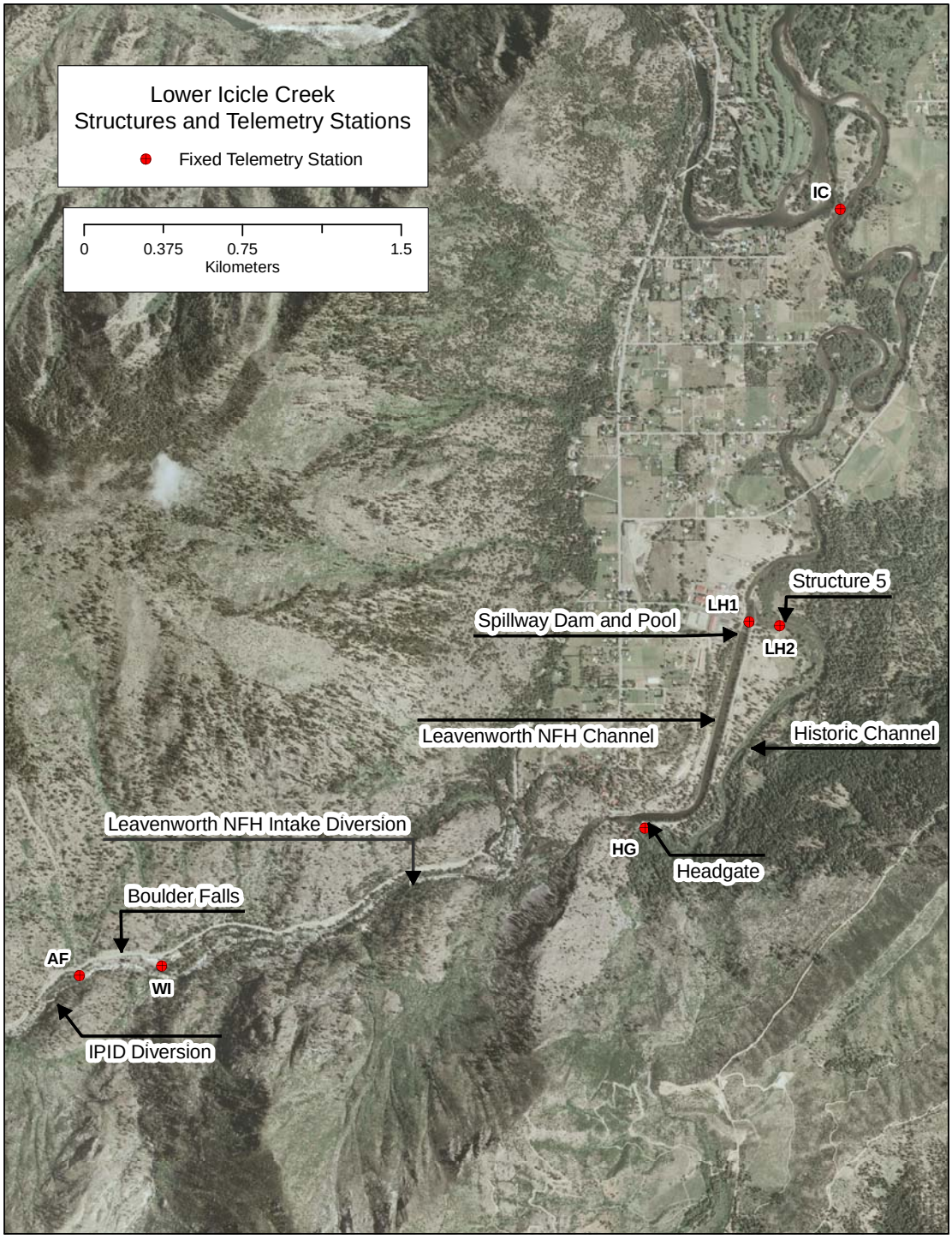

Figure 4. Aerial photograph of lower Icicle Creek, showing locations of natural and artificial obstacles and structures in the creek.

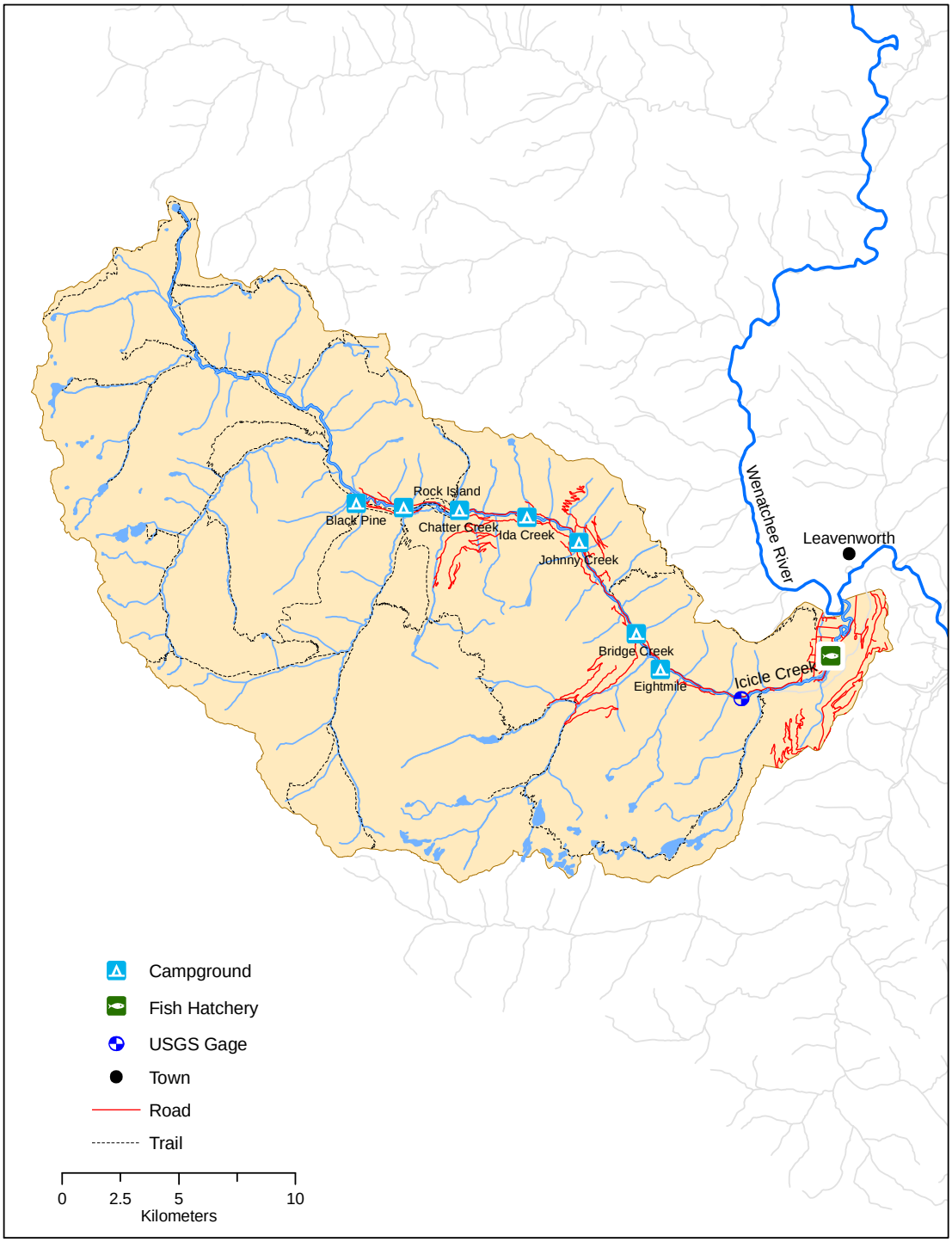

Figure 5. Locations of USFS campgrounds, Leavenworth NFH, USGS gage station, roads, and trails in the Icicle Creek watershed.

of the river are accessible by road, and the upper 19 km by trail. Forest Road 7600 closely parallels Icicle Creek for much of its route and in some locations prevents the stream from using its floodplain (USFS 1995). In 2008, a landslide near Doctor Creek (rkm 24.9) redirected Icicle Creek flows down the roadway and USFS closed FR7600 at rkm 23.5.

For descriptive purposes in this study, the boulder falls at approximately rkm 9.2 is considered the division between upper and lower Icicle Creek. Salmonines known to inhabit upper Icicle Creek are bull trout, brook trout *Salvelinus fontinalis,* hybrid bull trout x brook trout *S. confluentus x fontinalis,* westslope cutthroat trout *Oncorhynchus clarki lewisi,* rainbow trout *O. mykiss,* and redband rainbow trout *O. mykiss gairdneri*. Salmonids found only in lower Icicle Creek include steelhead *O. mykiss*, spring and summer hatchery Chinook salmon *O. tshawytscha,* hatchery coho salmon *O. kisutch,* stray hatchery sockeye salmon *O. nerka,* and mountain whitefish *Prosopium williamsoni.* Non-salmonid species in lower Icicle Creek include northern pikeminnow *Ptychocheilus oregonensis,* longnose dace *Rhinicthys cataractae,* speckled dace *Rhinicthys osculus,* redside shiner *Richardsonius balteatus,* various sculpin species *Cottus spp*., and various sucker species *Catostomus spp*.

Methods

Capture

Bull trout were captured by angling with artificial lures and single barbless hooks and landed with a knotless hand net. The locations where angling occurred in Icicle Creek during 2009 are presented in Appendix A. Sub-adult or juvenile fluvial bull trout (generally < 450 mm; see Brown 1992) were measured (± 5 mm total length) and a genetic tissue sample was taken before release at the capture location. Bull trout only greater than 450 mm were selected for tagging in order to reduce potentially negative effects of the large transmitter in the body cavity of smaller fish (Chisholm and Hubert 1985, Paukert et al. 2001). Bull trout deemed suitable for radio-tagging were placed in perforated PVC tubes and tethered in a calm area of the river while the surgery field was prepared. Each capture site was geo-referenced using a hand held global positioning system (GPS) unit (GPSMap76, Garmin Corp.). In addition to angling, a trap was operated by Leavenworth NFH at structure 5 during broodstock collection (May 19 to July 7) in an attempt to capture additional adult bull trout for tagging.

Radio transmitters and PIT tags

Radio tags implanted in the bull trout were Lotek Engineering model SR-M16-25 digitally-encoded radio transmitters using frequency 148.320 MHz. The radio tags contain a motion sensor, set to initiate a motionless code after 24 or 48 hours of inactivity. This model radio tag is 16 mm in diameter and 51 mm in length, weighs 17 g in air and has an expected battery life of 3 years at a 5 second burst rate. Each fish was also tagged with a passive integrated transponder (PIT) tag model TX1415 (3.4 x 23 mm) operating at 134.2 kHz.

Tag implantation procedure
Radio transmitters and PIT tags were surgically implanted in bull trout following the guidelines of Mulcahy (2003) and the methods described by Summerfelt and Smith (1990) and Ross and Kleiner (1982). All surgeries were performed when stream temperatures were less than 15°C.

Aseptic procedures were followed during surgery. This included triple wash and rinse of the surgeon's hands and arms with Purell® hand sanitizer (62% ethyl alcohol), use of sterile and doubled latex gloves, and an aseptic surgical field. Surgical instruments were steam sterilized using a pressure canner, and transmitters and PIT tags were gas sterilized by ethylene oxide. Seven sets of sterile surgical packs, each containing the necessary instruments and equipment for one implantation, were assembled and sterility was maintained by enclosing each pack in a series of waterproof zip lock type plastic bags. All surgeries were performed streamside at the capture location using a portable surgery kit.

Each fish was anesthetized for 8 – 10 minutes in a bath using a solution of 80 mg of tricaine methanesulfonate (MS-222) per L of H_20 and buffered with sodium bicarbonate to match the pH of the river water (Wedemeyer 1970). A battery operated bubbler was used to ensure the bull trout received adequate oxygen while in the anesthetic bath. Total and fork lengths (± 1mm), weight (± 25g), and a genetic tissue sample were collected from each bull trout. While still in the bath, anesthetized bull trout were floated onto a foam surgical cradle designed to support the weight of the fish and prevent injury to the ribs and backbone during weighing and transport to and from the surgery table. The bull trout was oriented dorsal side down in the cradle while the gills were irrigated with a buffered solution of 40 mg of MS-222/L during surgery. The ventral body surface of the bull trout was rinsed of MS-222 with river water and a 40 mm incision was made immediately anterior to the pelvic girdle and approximately 10 mm lateral of the mid-ventral line.

A sterilized syringe was used to insert the PIT tag into the body cavity without contamination. A 1cc plastic tuberculin syringe was modified by removing and discarding the detachable needle and cutting the tip off. Since the PIT tag diameter matched the inside diameter of the syringe, it was placed inside the syringe and the plunger was used to insert the tag through the incision into the body cavity.

A modification of the shielded-needle method (Ross and Kleiner 1982) was used to insert the radio-tag and thread the antenna through the body wall of the bull trout. A hollow needle was constructed from a 14 gauge x 140 mm Radiopaque FEP I.V. catheter with the plastic tubing connector cut off. The shield was constructed from a plastic coffee straw with the ends rounded by a heat gun. Using the shielded hollow needle, the lateral body wall was punctured internally posterior to the incision. The shield was removed through the incision, the wire antenna end was threaded into the hollow needle and extended through the body wall, the needle was removed and the transmitter was inserted into the abdominal cavity. A sterile surgical drape was placed over the fish to reduce contamination of the suture material while the incision was closed in an interrupted

pattern of 3 to 5 sutures tied with square surgeon knots. A FS-1 (24 mm) cutting needle and Ethicon™ absorbable ViaCryl 3-0 PDS II violet monofilament (Polydioxanone) suture material were used. Post surgery, tagged bull trout were allowed to recover from the anesthetic in a holding tube for at least 30 minutes and were released in an area of reduced water velocity and cover at the capture site, and if possible, monitored after release.

Monitoring of radio-tagged bull trout

Bull trout movements were recorded at fixed receiver telemetry stations and during mobile surveys. Telemetry receivers were programmed to also scan for radio-tagged bull trout from concurrent studies in the Upper Columbia Recovery Unit.

Fixed stations- Telemetry receivers (Lotek Wireless model SRX400 W7 or W31) equipped with antenna switching units (Lotek ASP-8 or Grant Engineering Hydra) and yagi-type antennas (Grant Engineering model 4LYVT) were used at fixed receiver telemetry stations. Solar panels (85 watt, Kyocera Solar, Inc.) equipped with charge controllers (SunSaver 10, Morningstar Corp.) were used to charge 12 V batteries at fixed stations. Small 18 amp hour batteries were used at remote fixed stations and deep cycle flooded lead acid batteries (Trojan® 24TMX) were used at easily accessible fixed stations. AC power was used to charge batteries connected to the receivers at six stations.

Fixed receiver telemetry stations were set up at key locations in Icicle Creek (Table 1, Figure 6). These locations, referenced by a two-letter code, were just upstream of the Icicle Creek confluence (IC) with the Wenatchee River, at the Leavenworth NFH spillway pool (LH), at the LNFH headgate (HG), at the City of Leavenworth water intake treatment building (WI) downstream of the boulder falls, upstream above the boulder falls (AF), at the Icicle Creek Gorge (IG) near Chatter Creek Campground, and at the road's end (RE) of the FR7609 spur road. Two antennas were used at the LH station: LH1 monitored the Leavenworth NFH spillway pool and LH2 monitored structure 5 (Figure 4).

Additional fixed receiver stations were located at other sites in the Wenatchee River basin (Table 2, Figure 6). On the Wenatchee River, the locations were Tumwater Dam (TUM), Dryden Dam (DD), and Wenatchee River County Park (WR). One station was on Chiwaukum Creek (CW) near the mouth and one station was on Peshastin Creek (PC) at the Yakama Nation Mid-Columbia Field Office.

Mobile surveys- Mobile telemetry surveys were conducted by foot and truck. For techniques used during in-stream foot surveys see Nelson (2004) and for truck surveys see Nelson (2006). Location coordinates were recorded with a GPS unit (GPSMap76, Garmin Corp.) or placed by hand on 1:24,000 USGS topographic maps. Data were recorded on daily tracking forms and in Rite-in-the-Rain field notebooks. GPS waypoints were downloaded into topographic mapping software (MapTech® Terrain Navigator 2002) and the marker files were exported into GIS (ESRI™ ArcGIS® v9.2) for creation of maps. The river mile (rm) of a location was determined in one of three ways: 1) interpolation from mile markers on USGS 1:24,000 topographic maps,

Table 1. Fixed receiver telemetry stations operated during 2009 at locations on Icicle Creek.

Station	rkm	Dates operated	Notes
IC	0.8	1/1 – 12/31	At Two Rivers Farm
LH	4.3	1/1 – 12/31	At Leavenworth NFH: 2 antennas LH1 – spillway pool, LH2 – structure 5
HG	6.3	7/20-11/25	Mounted on LNFH headgate structure Monitored pool below headgate
WI	9.1	1/1 – 12/31	Downstream of boulder falls at City of Leavenworth water intake treatment facility
AF	9.3	1/1 – 12/31	Upstream of boulder falls at City of Leavenworth intake building
IG	26.2	7/30 – 10/13	At Icicle Gorge Chatter Cr. Campground
RE	32	7/31 – 10/13	At road's end of 7609 spur off FR 7600

Table 2. Additional fixed receiver telemetry stations operated during 2009 at locations on the Wenatchee River, Chiwaukum Creek, and Peshastin Creek.

Station	rkm	Dates operated	Notes
CW	0.1	7/1 – 10/6	At mouth of Chiwaukum Creek also monitored Wenatchee R. (rkm 57.8)
TUM	52.6	1/1 – 12/31	At Tumwater Dam on Wenatchee River 1 ant. upstream; 1 ant. downstream
DD	28.3	1/1-12/31	At Dryden Dam on Wenatchee River 1 ant. upstream; 1 ant. downstream
WR	12.5	1/1 – 12/31	At Wenatchee River County Park on Wenatchee River
PC	3.4	1/1 – 12/31	At Yakama Nation Mid-Columbia Field Station on Peshastin Creek

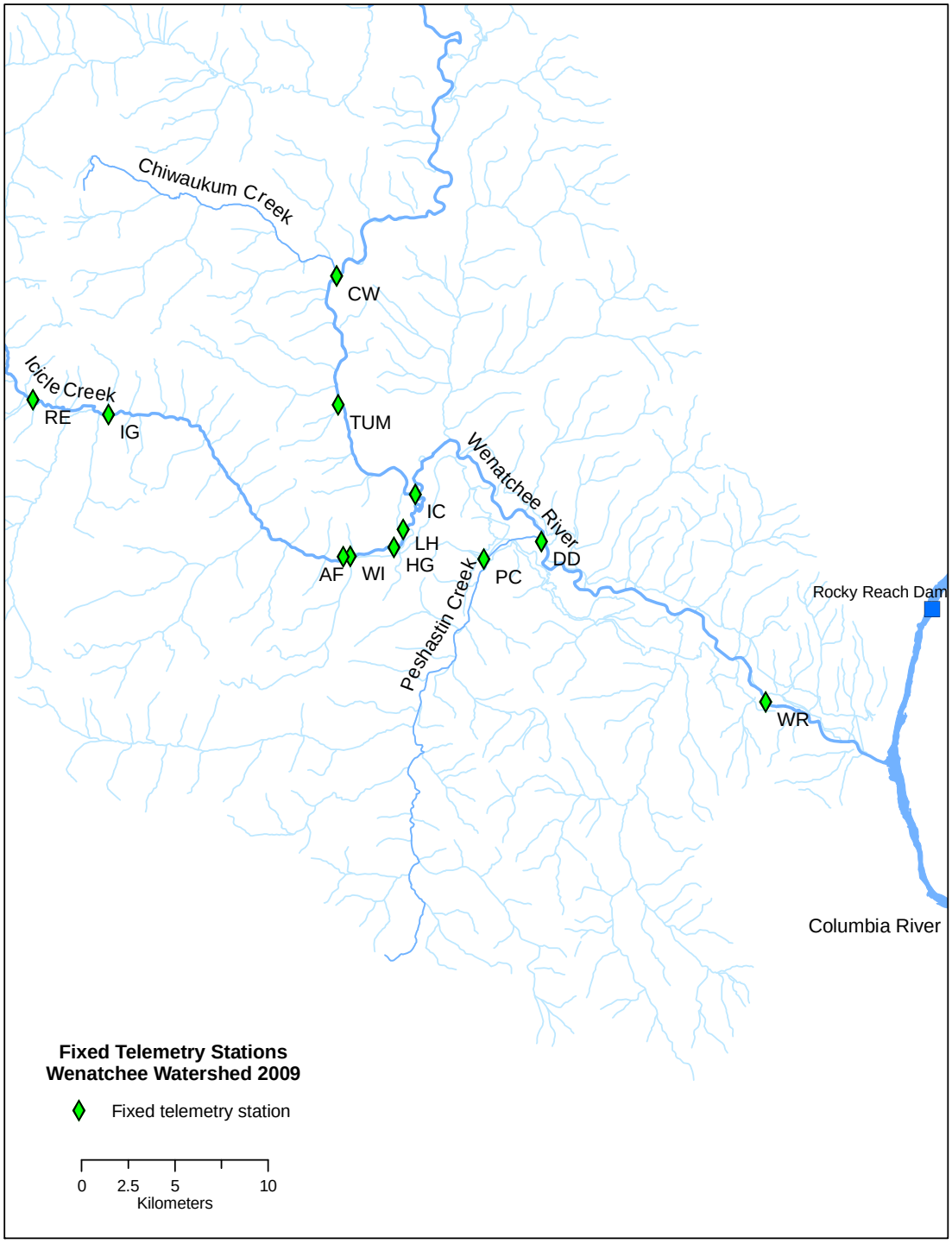

Figure 6. Map of the locations of fixed receiver telemetry stations in Icicle Creek, Wenatchee River, Chiwaukum Creek, and Peshastin Creek in 2009.

2) approximated using the linear distance tool in MapTech® Terrain Navigator, and 3) from established locations in an index (CBIACHS 1964). Therefore, the river mile designated at locations in this study may differ from those used in other documents or by other agencies. River miles were converted to river kilometers (rkm). Telemetry data were entered into a relational database (Microsoft Office Access) and paper copies archived at the Mid-Columbia River Fishery Resource Office.

Spawning ground surveys

Spawning ground surveys were conducted by experienced observers in Icicle Creek (rkm 29.1 to 34.7) and French Creek (rkm 0.0 to 7.2). The surveys in French Creek were partitioned into three reaches based on hiking distance and recognizable tributaries as definition of the reach breaks: Reach A (rkm 0 to 3.2), Reach B (rkm 3.2 to 5.6) and Reach C (rkm 5.6 to 7.2). Redds were categorized as definite, probable, or possible, with only definite and probable redds included in the final count (Bonar et al. 1997). Redd dimensions were measured with a wading staff graduated in 0.05 m increments; locations were geo-referenced with GPS units (Rino530HCx®, Garmin Corp.), and waypoints downloaded onto a digital topographic map (MapTech® Terrain Navigator 2002). Redd area (m^2) was approximated as length multiplied by width.

Discharge data

Discharge data were obtained from the USGS stream flow monitoring network for stations 12457000 Wenatchee River at Plain and 12458000 Icicle Creek above Snow Creek near Leavenworth (USGS 2009) and the Washington Department of Ecology (WDOE) stream flow monitoring network for station 45G060 Chiwaukum Creek near mouth (WDOE 2009).

Water temperature

The water temperature data in Icicle Creek were obtained from an ongoing USFWS temperature monitoring program (Kelly Ringel 2007). The water temperature data from the Wenatchee River at Tumwater Dam were recorded and provided by Washington Department of Fish and Wildlife (WDFW). Chiwaukum Creek water temperature data were recorded and provided by WDOE at station 45G060. The daily mean, minimum, maximum temperatures (T) and the running 7 day average daily maximums (7DADMax) were calculated. The largest value of the running 7DADMax indicates the maximum weekly maximum temperature (MWMT), defined as the mean of daily maximum water temperatures measured over the warmest 7 day consecutive period during a given year (Hillman and Essig 1998).

Bull trout counts at Tumwater Dam

Daily counts of bull trout passing Tumwater Dam were recorded and provided by WDFW. Daily counts of other salmonids at Tumwater Dam were downloaded from the Columbia River Data Access in Real Time website (DART 2009).

Results

Radio-tagging

Number tagged- Seven adult bull trout (> 450 mm) were radio- and PIT- tagged. Code 24 was captured at the head gate at rkm 6.3 and codes 94, 95, 96, 97, 98, and 99 were captured in the spillway pool at rkm 4.3 (Table 3, Figure 7).When captured and tagged downstream of Icicle Gorge at rkm 25.6, code 26 appeared to be a bull trout. However, a picture taken on August 14 showed mottling in the dorsal fin, suggesting it was a hybrid bull x brook trout (Figure 8), and subsequent genetic analysis confirmed code 26 was a F1 hybrid (P. DeHaan, pers. comm.).

Morphometrics of tagged bull trout- Lengths of tagged bull trout ranged from 455 to 605 mm and weights from 830 to 2400 g (Table 3). Condition factor ($K = (W/L^3 \times 100{,}000)$) was highest for hybrid code 26 and bull trout code 24 (Table 3). Bull trout code 99 weighed considerably less for its length than the other fish (Figure 9) and its condition factor was correspondingly very low (Table 3).

Table 3. Tagging date, location, river kilometer (rkm), weight (g), total length (mm), and condition factor (K) of bull trout and hybrid bull x brook trout (code 26) radio-tagged in Icicle Creek, 2009.

Code	Date	Location	Rkm	Weight (g)	Total length (mm)	K
24	7/20/09	Head gate	6.3	2400	605	1.084
26	*7/29/09*	*d/s Icicle Gorge*	*25.6*	*1180*	*430*	*1.484*
94	8/10/09	Spillway Pool	4.3	1280	507	0.982
95	8/11/09	Spillway Pool	4.3	830	455	0.881
96	8/11/09	Spillway Pool	4.3	1010	495	0.833
98	9/25/09	Spillway Pool	4.3	1050	475	0.980
97	9/28/09	Spillway Pool	4.3	1100	488	0.947
99	9/28/09	Spillway Pool	4.3	1390	572	0.743

Size of all captured bull trout- Bull trout captured during angling ranged from 210 to 605 mm. The majority of the bull trout were sub-adult: 39 of 46 (85%) were less than 450 mm in length (Figure 10) and therefore were not tagged. The largest bull trout was the first caught and tagged on July 20 but most fish were captured after August 5 (Figure 11). Genetic tissue samples were taken from 45 of the fish and archived at USFWS Abernathy Fish Technology Center for future analysis.

See Appendix A for specific information on angling locations, capture locations, and catch per unit effort of all bull trout during 2009.

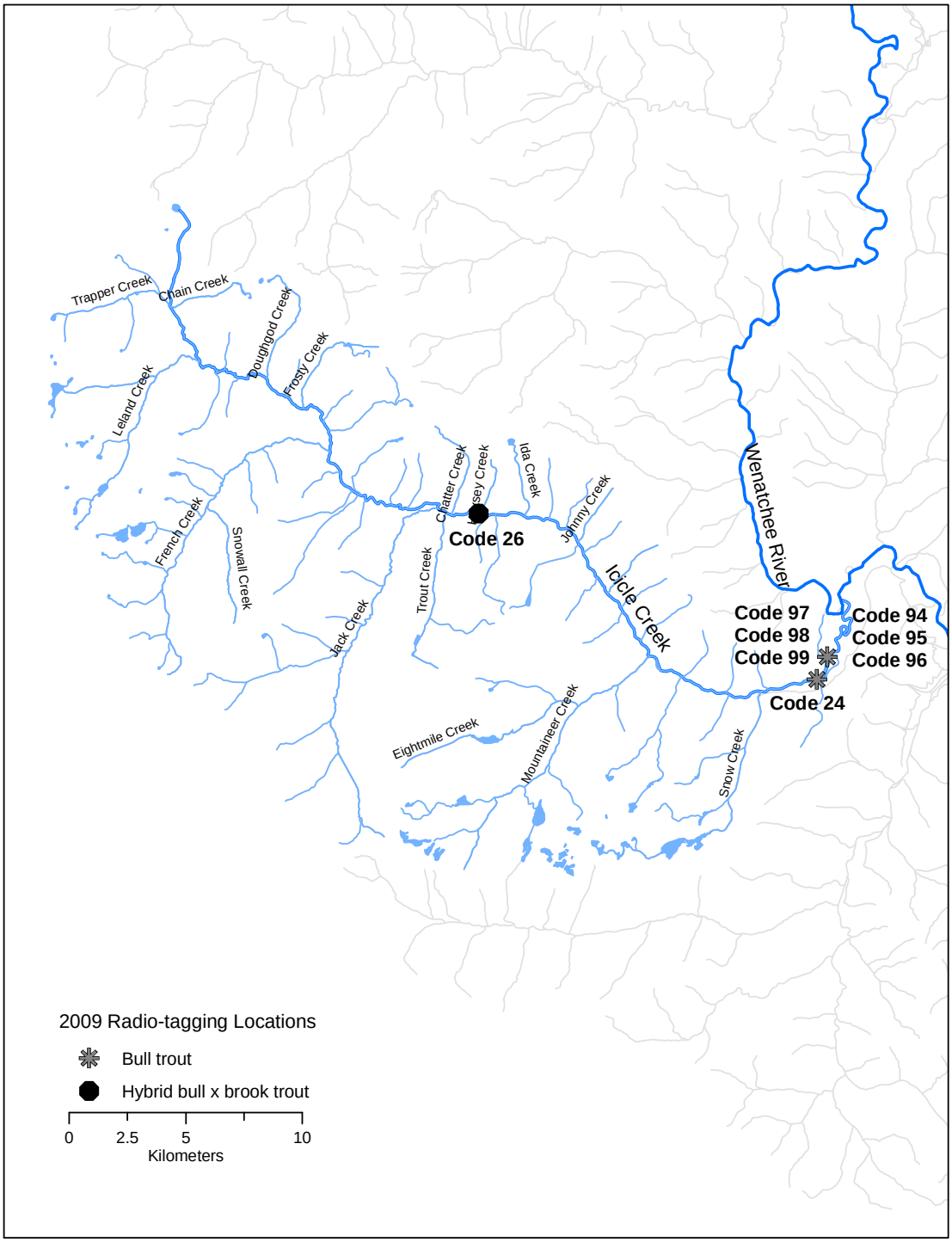

Figure 7. Capture and radio-tagging locations of adult bull trout in Icicle Creek during 2009.

Figure 8. Photograph of code 26 taken on August 14, 2009 showing dorsal fin mottling and pectoral fin coloration indicative of hybridization with brook trout.

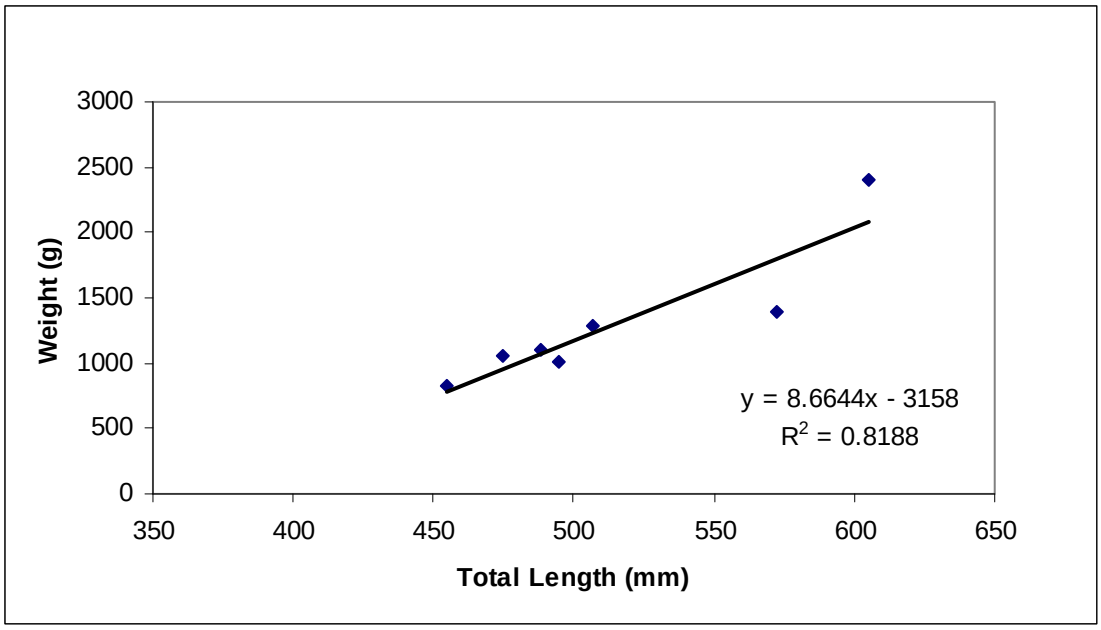

Figure 9. Weight (g) versus total length (mm) of bull trout tagged in Icicle Creek during 2009.

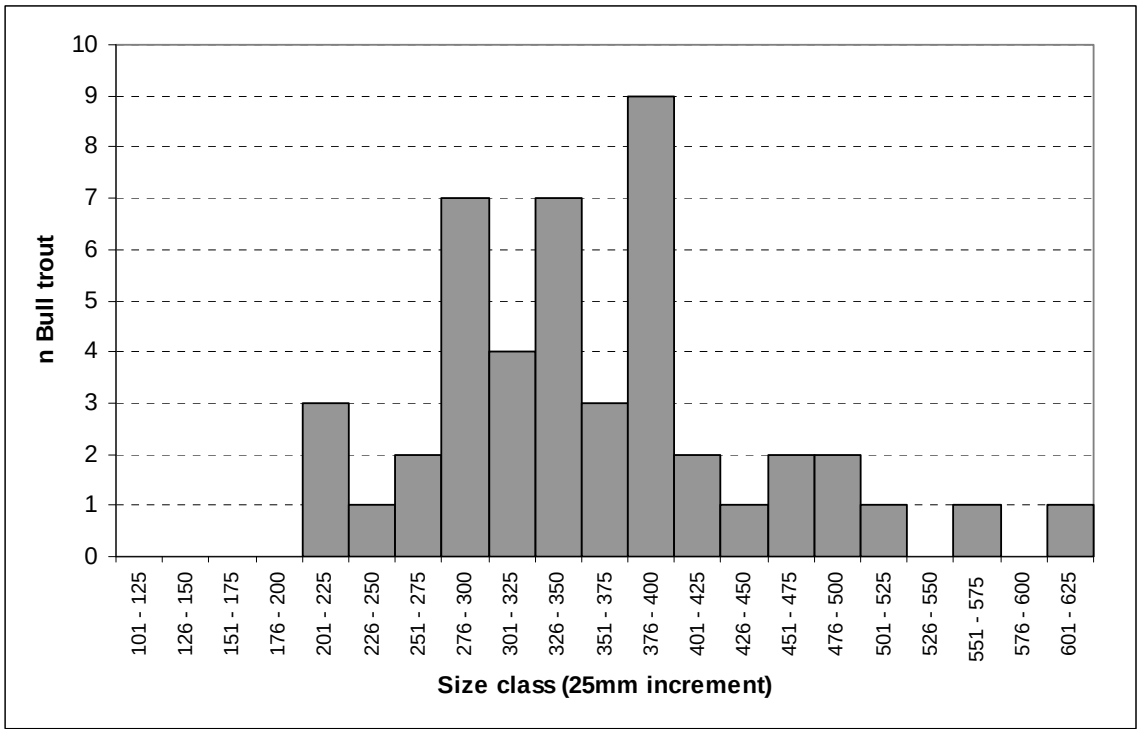

Figure 10. Sizes classes (25mm increment) of all bull trout captured while angling in Icicle Creek during 2009.

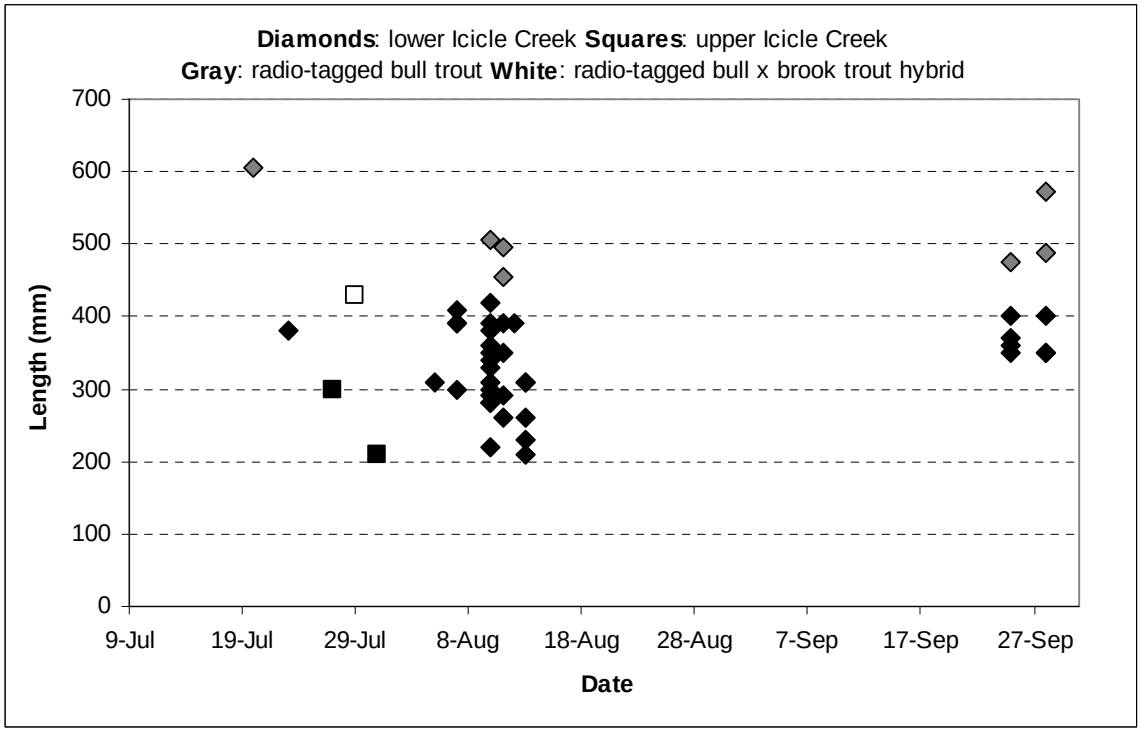

Figure 11. Bull trout lengths vs capture date during angling in lower and upper Icicle Creek in 2009.

Movements

The movements of one bull trout tagged in 2008 and eight bull trout tagged in 2009 were monitored. The movements of the individual fish are described below. Summaries of the detections of all tagged bull trout at fixed stations are presented in Appendix B.

Movements of individual bull trout

Code 20- (Figure 12). Bull trout code 20 was tagged in the Leavenworth NFH spillway pool of Icicle Creek on April 7, 2008 (see Nelson et al. 2009 for detailed description of its 2008 movements). Code 20 wintered in the Wenatchee River near rkm 41 just downstream of the confluence of Icicle Creek. It was located there until June 5, 2009, when it moved upstream in the Wenatchee River and was detected downstream of Tumwater Canyon (rkm 45) until June 26. Wenatchee River discharge had declined to 3070 ft^3/sec when code 20 entered Tumwater Canyon. During the mobile survey on June 29 code 20 was detected at rkm 49.6, downstream of the rapids below Tumwater Dam.

Code 20 was recorded by the fixed receiver telemetry station at Tumwater Dam (rkm 49.9) from June 29 to July 18 and from July 21 to 22, 2009. During foot tracking on several days from June 30 to July 21, code 20 was usually located at the dam, near or in the fish ladder entrance. However, on July 7 and 9 it was located along with 100 other salmonids in a back eddy of the rapids about 80 m downstream of the dam. On July 21 it was located 400 m downstream of the dam and was not recorded on the fixed station until July 22, when it was first detected on the downstream antenna at 07:16 hours and last detected on the upstream antenna at 14:24 hours as it passed through the fishway and moved upstream of the dam. Overall, code 20 spent 22.8 days downstream of or at Tumwater Dam before passing and the actual recorded time to move upstream through the dam was 0.3 days.

During the periods that code 20 was recorded by the telemetry station at Tumwater Dam it was also detected by the PIT array in the fishway ladder on six dates (Table 4). These PIT detections indicate code 20 moved up and down the ladder and passed the PIT antennas in weirs 15 and 18 on eight separate occasions, including two times each day on June 30 and July 12. All of the PIT detections were during daylight, and the first detection occurred about 17 hours after it arrived at the dam. It is not known how far up the fish way code 20 moved on each occasion but it appears it did not enter the fish trap above weir 20. On average code 20 spent only 39 minutes upstream of weir 18 before it moved back down the ladder.

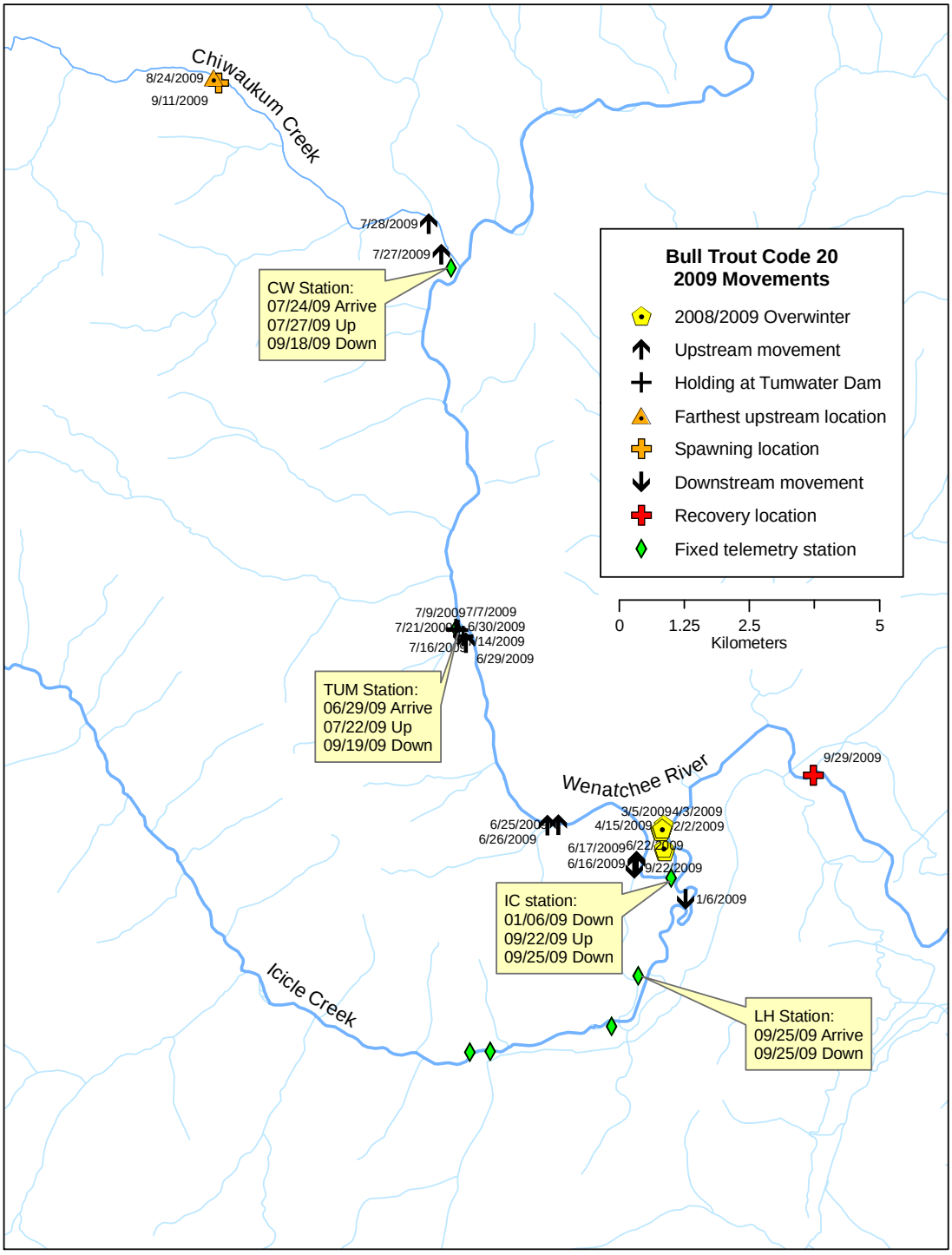

Figure 12. Map of the movements of bull trout code 20 during 2009.

Table 4. PIT detections of bull trout code 20 in the fishway at Tumwater Dam during 2009, including date and time of detections, coil and weir, and direction of travel in the ladder.

Type	Coil	Weir	Direction	Observation date/time
OBS	A2	15	up	6/30/2009 13:47
OBS	A1	18	up	6/30/2009 14:00
OBS	A1	18	down	6/30/2009 15:00
OBS	A2	15	down	6/30/2009 15:10
OBS	A2	15	up	6/30/2009 17:59
OBS	A1	18	up	6/30/2009 18:05
OBS	A1	18	down	6/30/2009 18:49
OBS	A2	15	down	6/30/2009 18:55
OBS	A2	15	up	7/02/2009 14:56
OBS	A1	18	up	7/02/2009 15:05
OBS	A1	18	down	7/02/2009 15:30
OBS	A2	15	down	7/02/2009 15:31
OBS	A2	15	up	7/06/2009 06:44
OBS	A1	18	up	7/06/2009 06:59
OBS	A1	18	down	7/06/2009 07:43
OBS	A2	15	down	7/06/2009 07:52
OBS	A2	15	up	7/10/2009 11:21
OBS	A1	18	up	7/10/2009 11:26
OBS	A1	18	holding	7/10/2009 12:08
OBS	A1	18	holding	7/10/2009 12:13
OBS	A1	18	holding	7/10/2009 12:26
OBS	A1	18	down	7/10/2009 13:03
OBS	A2	15	down	7/10/2009 13:07
OBS	A2	15	up	7/12/2009 11:06
OBS	A1	18	up	7/12/2009 11:14
OBS	A1	18	holding	7/12/2009 11:45
OBS	A1	18	down	7/12/2009 12:03
OBS	A2	15	down	7/12/2009 12:06
OBS	A2	15	up	7/12/2009 16:54
OBS	A1	18	up	7/12/2009 17:06
OBS	A1	18	down	7/12/2009 17:56
OBS	A2	15	down	7/12/2009 17:57
OBS	A2	15	up	7/22/2009 11:53
OBS	A1	18	up	7/22/2009 11:53
OBS	A1	18	down	7/22/2009 12:16
OBS	A2	15	holding	7/22/2009 12:16
OBS	A1	18	up	7/22/2009 12:36

Twenty-seven untagged bull trout were counted passing the fishway during the period code 20 was detected at the dam (Figure 13). Wenatchee River discharge had declined to less than 3000 ft^3/s before the majority of bull trout migrated through Tumwater Dam during 2009 and flow was 1500 ft^3/s when code 20 passed (Figure 13). During the period code 20 was present at Tumwater Dam, Wenatchee River daily mean water temperatures ranged from 12.7 to18.6 °C and the daily maximum temperature was 20.7 °C (Figure 14). The highest 7DADmax at the dam was 18.9 °C.

Chinook salmon and sockeye salmon also migrated upstream during the period bull trout code 20 was at Tumwater Dam (Figure 15). On July 22, when code 20 passed upstream through the fishway, the sockeye salmon count peaked at 1700 fish and over 200 adult Chinook salmon were tallied. The majority of jack Chinook salmon had already passed.

After passing Tumwater Dam, code 20 continued upstream and entered Chiwaukum Creek (rkm 57.8) on July 24, when discharge in the creek declined to 100 ft^3/s. The water temperature was several degrees warmer in the Wenatchee River (mean 17.9 °C and max 19.5 °C) than in Chiwaukum Creek (mean 12.3 °C and max 13.0 °C) when it entered the tributary (Figure 14). It was detected at the CW station near the mouth until July 27 when it moved upstream. During mobile surveys on July 27 and 28 it was detected in Chiwaukum Creek between rkm 0.3 – 0.5. During a foot survey on August 24, code 20 was located at rkm 6.8, and on September 11 it was observed there in close proximity to a bull trout redd, when water temperature was 9 °C.

After spawning, code 20 exited Chiwaukum Creek on September 18 when mean water temperature was 11.1 °C at the mouth (Figure 14) and discharge was 18 ft^3/s. It migrated downstream in the Wenatchee River, and on September 19, it quickly passed Tumwater Dam (elapsed time 8 min) when the mean water temperature was 15.5 °C and maximum was 16 °C (Figure 16). It entered Icicle Creek on September 22 and was detected in the spillway pool on September 25. It then left the spillway pool and exited Icicle Creek, passing the IC station on September 25. The water temperature in the Wenatchee River during September 22 to 25 was on average 2.7 °C warmer than Icicle Creek and 3.7 °C warmer than the spillway pool (Figure 16).

During a mobile survey on September 28, the motionless signal was detected in the Wenatchee River, and on September 29 code 20 was recovered from a deep pool at rkm 36.2. The carcass appeared in good shape, and showed no wounds, marks or obvious signs of death. The incision site was healed but one suture was still present and the antenna fistula was raw. The autopsy revealed code 20 was a female and a few remaining ripe eggs indicated she successfully spawned. The PIT tag was not found and apparently was expelled during egg deposition. The stomach was empty and very little fat was observed in the pyloric cecae and viscera. When code 20 was tagged on April 7, 2008 its total length was 465 mm. On September 29, 2009 it measured 605 mm, for a growth rate 0.26 mm/day.

Code 20 migrated 23.6 kilometers upstream to its spawning location in Chiwaukum Creek. During the post-spawn migration, code 20 traveled 37 kilometers before it died.

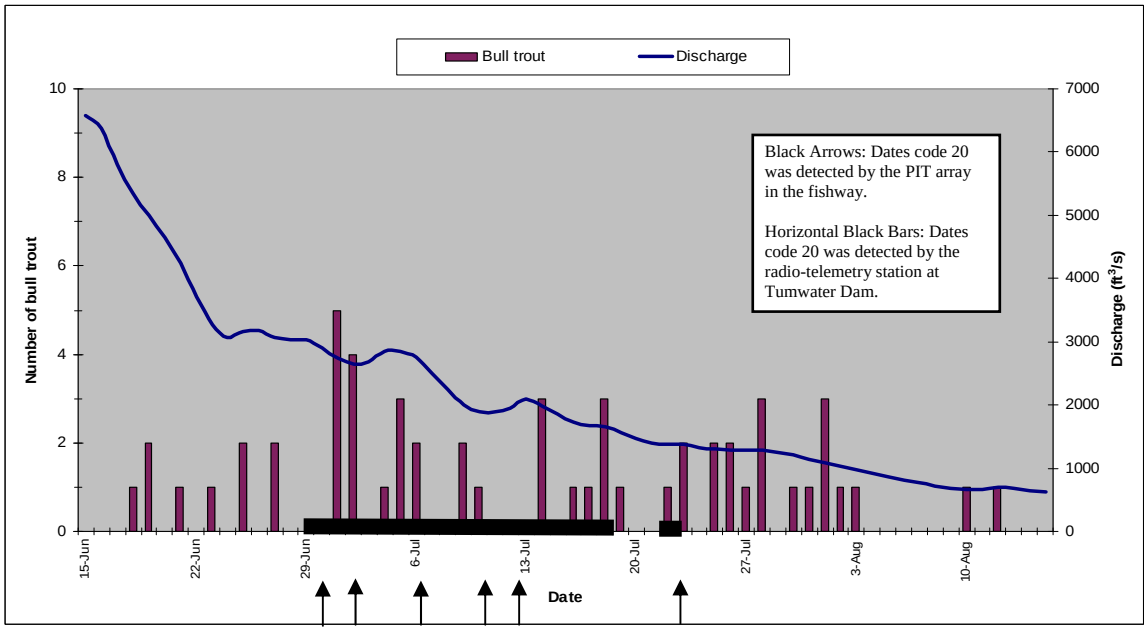

Figure 13. Wenatchee River discharge and counts of bull trout at Tumwater Dam during the dates that bull trout code 20 was detected by the radiotelemetry and PIT arrays during 2009.

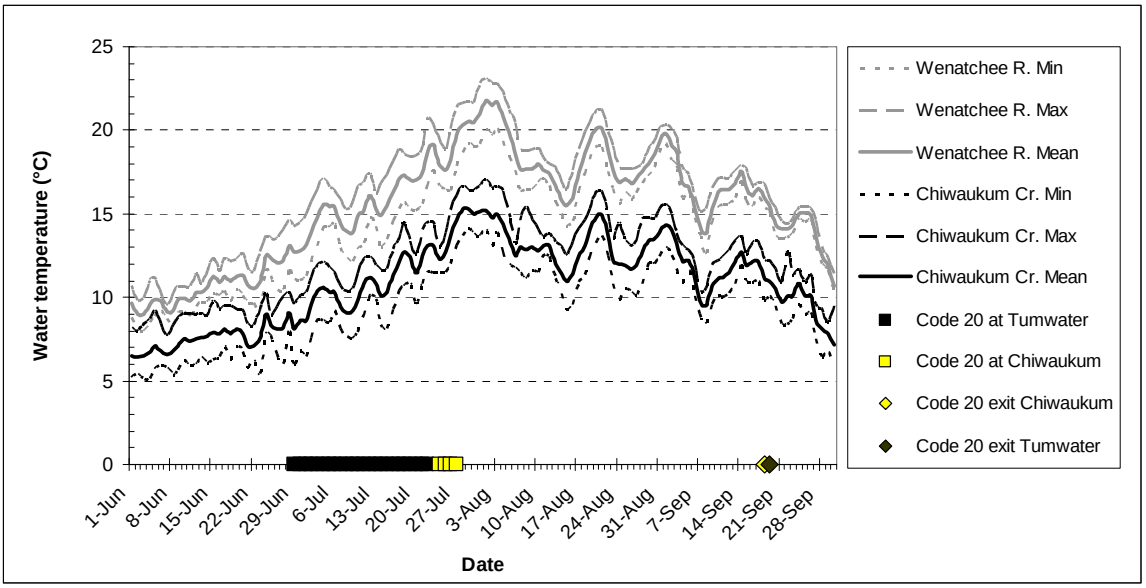

Figure 14. Mean, minimum, and maximum daily water temperatures of the Wenatchee River (at Tumwater Dam) and Chiwaukum Creek (at the mouth) during upstream and downstream migrations of bull trout code 20 at these locations during 2009.

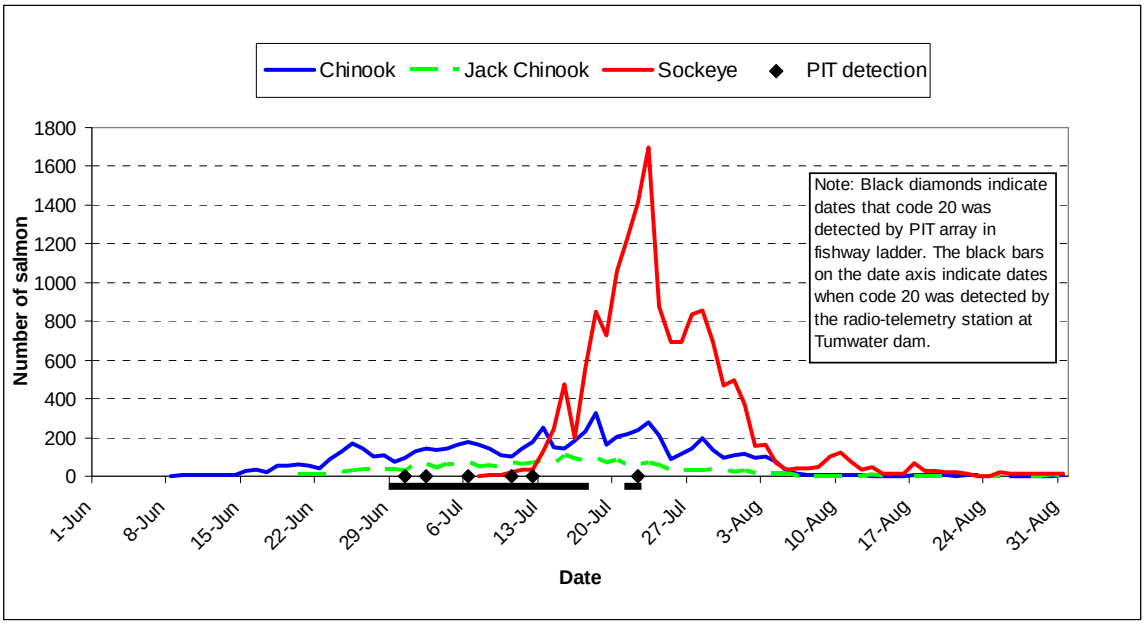

Figure 15. Counts of Chinook salmon and sockeye salmon during the dates that bull trout code 20 was detected by the radiotelemetry and PIT arrays at Tumwater Dam during 2009.

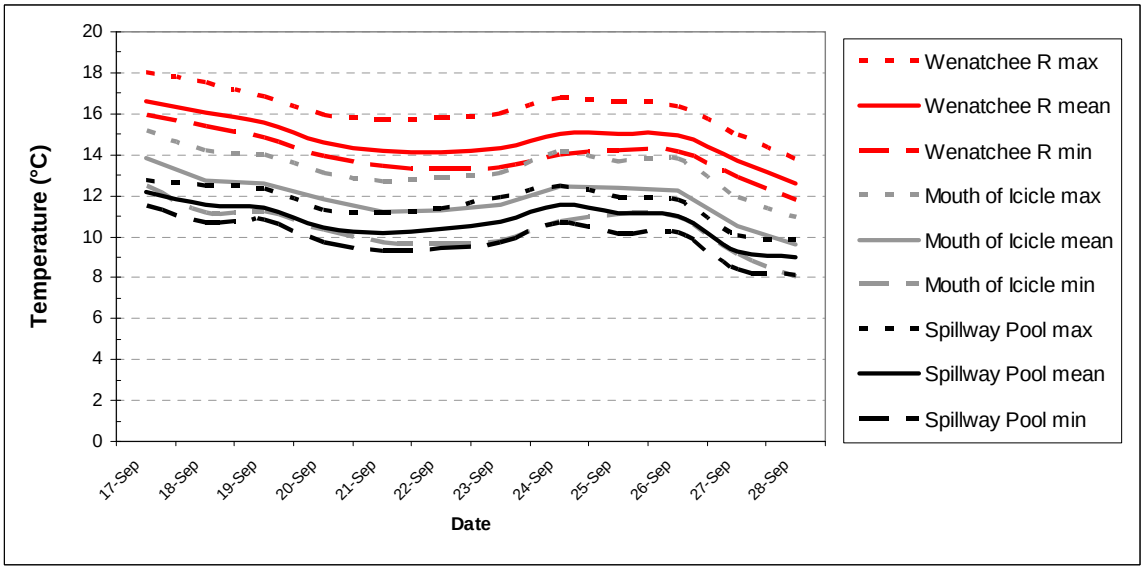

Figure 16. Maximum, mean, and minimum daily water temperatures in the Wenatchee River (rkm 41.5), Icicle Creek (rkm 0.8), and the LNFH spillway pool (rkm 4.3), September 17 to 28, 2009.

Code 24 (Figure 17)- Bull trout code 24 was captured and tagged in Icicle Creek at the Leavenworth NFH headgate pool (rkm 6.1) on July 20, 2009. On July 22, it moved downstream and exited Icicle Creek (mean temperature (T): Icicle Cr. = 17.5 °C, Wenatchee R. = 19.5 °C). It continued downstream in the Wenatchee River and passed the DD station (rkm 28.3) on July 22 and the WR station (rkm 12.5) on July 23. Code 24 was then in the Columbia River at unknown locations until it re-entered the Wenatchee River and moved upstream past the WR station on August 12 and the DD station on August 22. On August 24, it moved back into Icicle Creek (mean T: Wenatchee R. = 17.1 °C, Icicle Cr. = 14.1 °C) and was detected in the spillway pool (mean T at hatchery outfall = 12.2 °C). Code 24 remained in the spillway pool until September 29, when it moved downstream and exited Icicle Creek (mean T: spillway pool = 8.6 °C, Icicle Cr. = 9.6 °C, Wenatchee R. = 12 °C). It slowly moved downstream in the Wenatchee River and was detected upstream of Dryden Dam where it recorded on the telemetry station from October 6 to 24. It migrated downstream past the WR station on October 27 and entered the Columbia River. During a boat survey on February 4, 2010 it was located in the Columbia River at rkm 750.

Code 26 (Figure 18)- Code 26 was captured and tagged in upper Icicle Creek at rkm 25.6 on July 26, 2009. It appeared to be a normal bull trout when tagged but when observed on August 14, markings indicated hybridization with a brook trout (see Figure 8) and subsequent genetic analysis confirmed it was a F1 hybrid (P. DeHaan, pers. comm.). Code 26 remained at its tagging location until September 17, when the motionless signal was detected. The transmitter was recovered in the water at the tail out of the tagging pool. (No carcass or clues were discovered, suggesting the tag was shed.)

Code 94 (Figure 19)- Bull trout code 94 was captured and tagged in the spillway pool (rkm 4.3) on August 10, 2009. It remained in or near the spillway pool until September 5 when it moved downstream and exited Icicle Creek (mean T: spillway pool = 12.4 °C, Icicle Cr. = 13.2 °C, Wenatchee R. = 16.7 °C). During a mobile survey on September 9 it was located in the Wenatchee River at rkm 39.3. On September 14, the motionless signal was detected at rkm 37.8 and the tag was recovered from the stream bottom in a boulder area. (No carcass was found and circumstances suggest the transmitter was shed.)

Code 95 (Figure 20)- Bull trout code 95 was captured and tagged in the spillway pool on August 11, 2009. It was detected in the spillway pool from August 11 to 19 (mean T on August 19 = 14.6 °C), then moved upstream in Icicle Creek and passed structure 5 on August 19 (mean T at structure 5 = 16.2 °C). During a mobile survey on August 20, code 95 was detected in the historic channel at rkm 5.6, before it moved back downstream and exited Icicle Creek later that day (mean T: Icicle Cr. = 17.3 °C, Wenatchee R. = 20.3 °C). It re-entered Icicle Creek (mean T: Wenatchee R. = 18 °C, Icicle Cr. = 15.1 °C) and passed the IC station on August 23 and was detected in the spillway pool from August 31 (mean T at hatchery outfall = 14 °C) to September 7 (mean T = 10.2 °C). It moved downstream and during mobile surveys was located near the East Leavenworth Road Bridge (rkm 3.5) from September 9 to 24 (see cover photo). Code 95 moved downstream, exited Icicle Creek on September 28, and was detected in the Wenatchee River near the Icicle Creek confluence until October 13. It moved downstream and was located in the

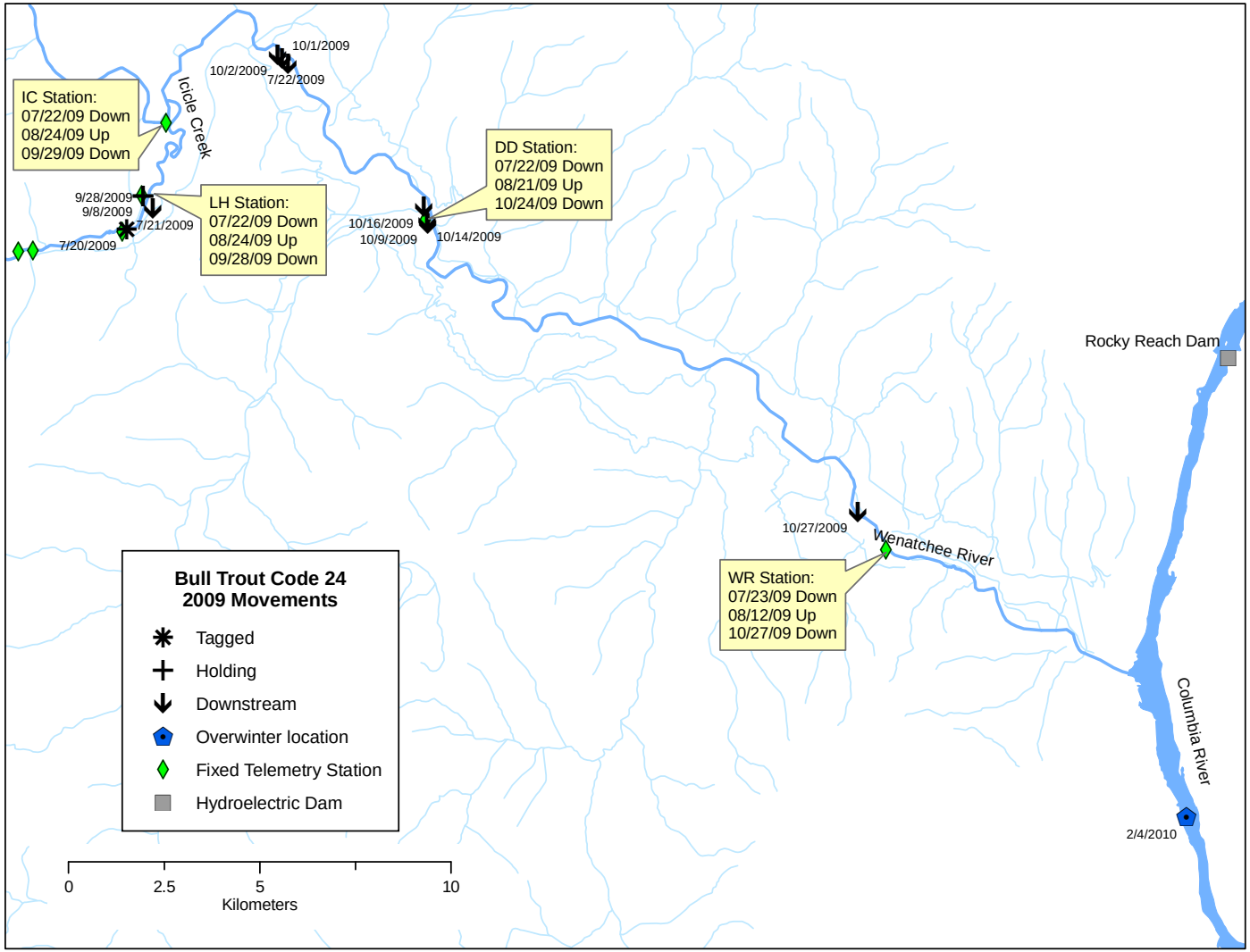

Figure 17. Map of the movements of bull trout code 24 during 2009.

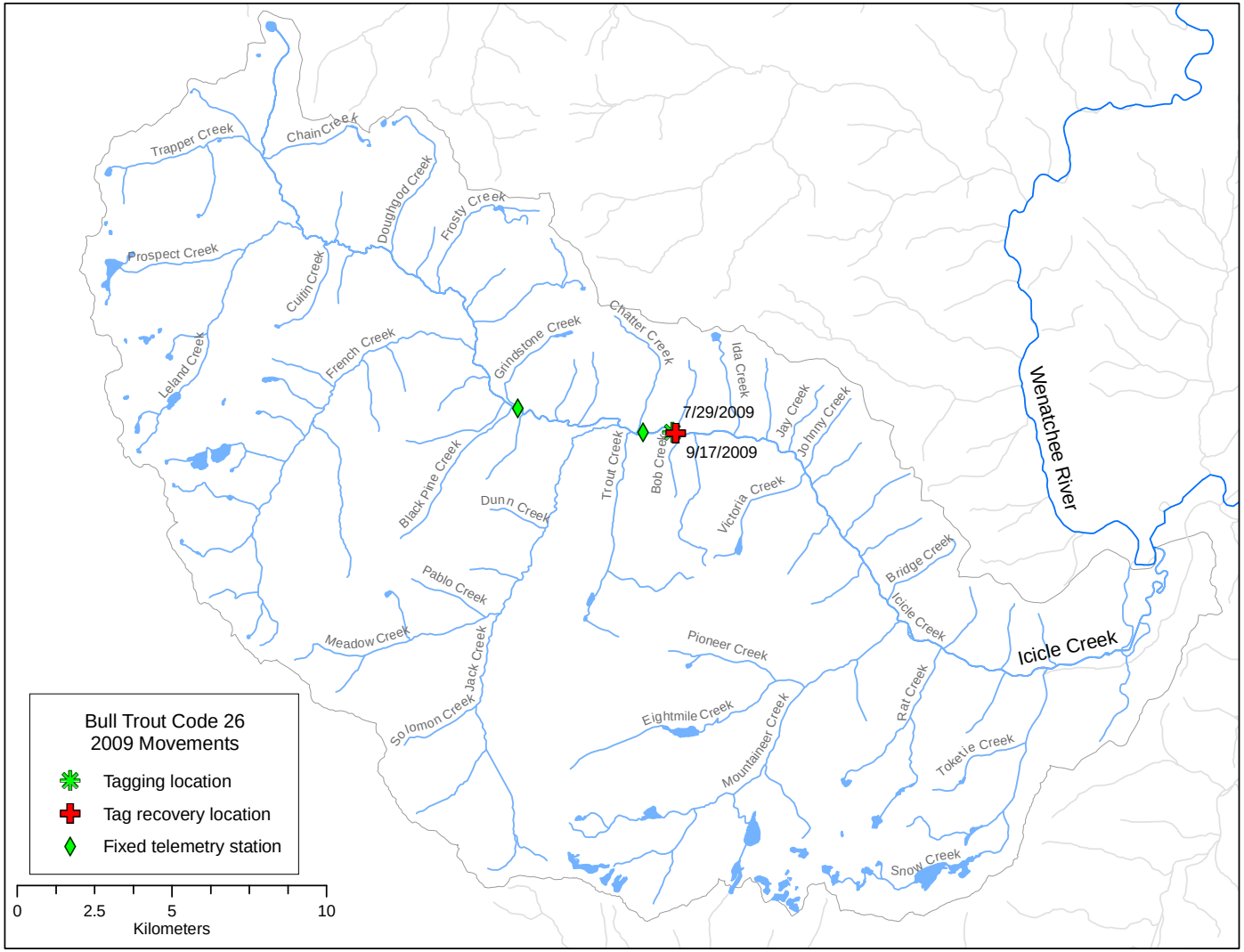

Figure 18. Map of the movements of hybrid bull x brook trout code 26 during 2009.

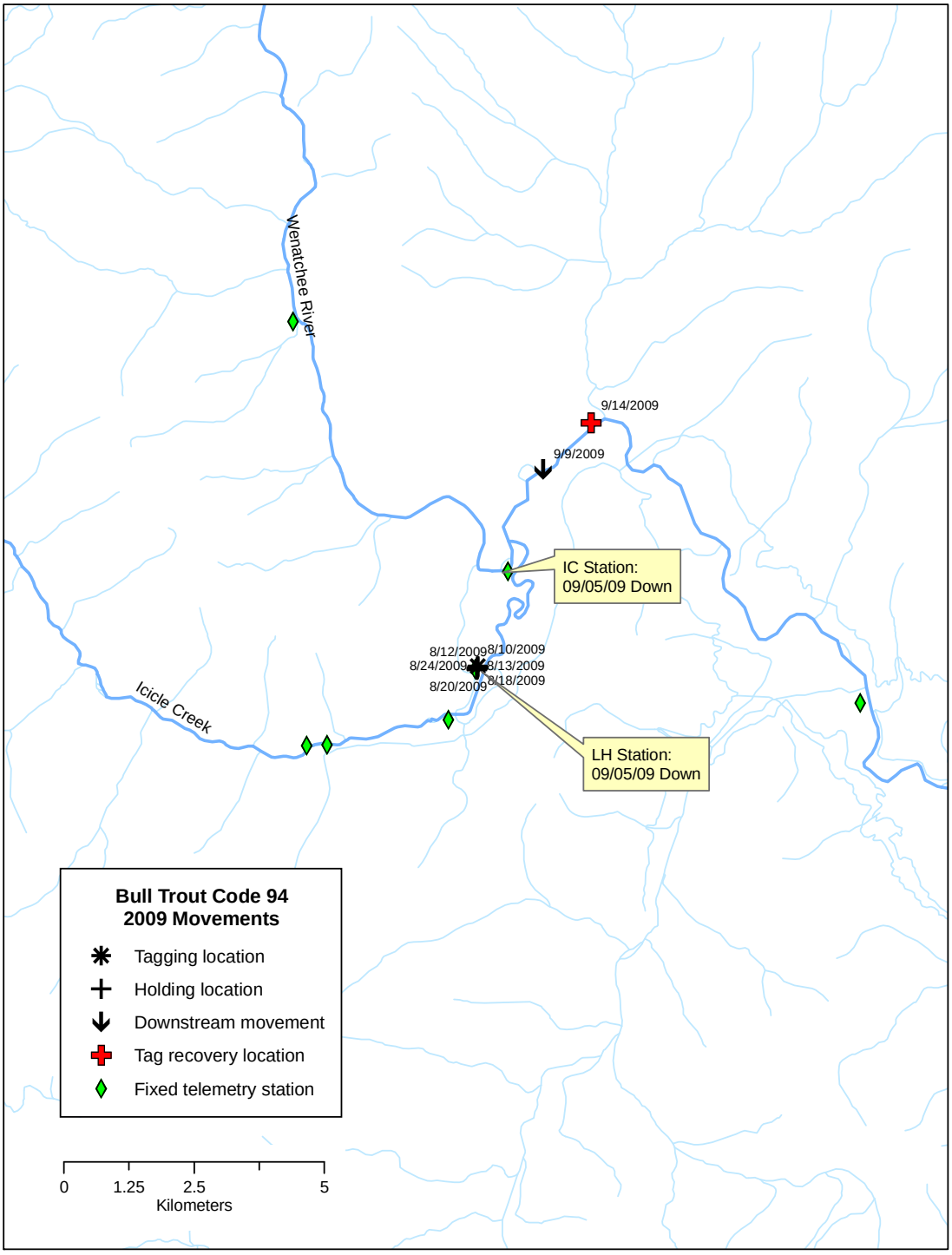

Figure 19. Map of the movements of bull trout code 94 during 2009.

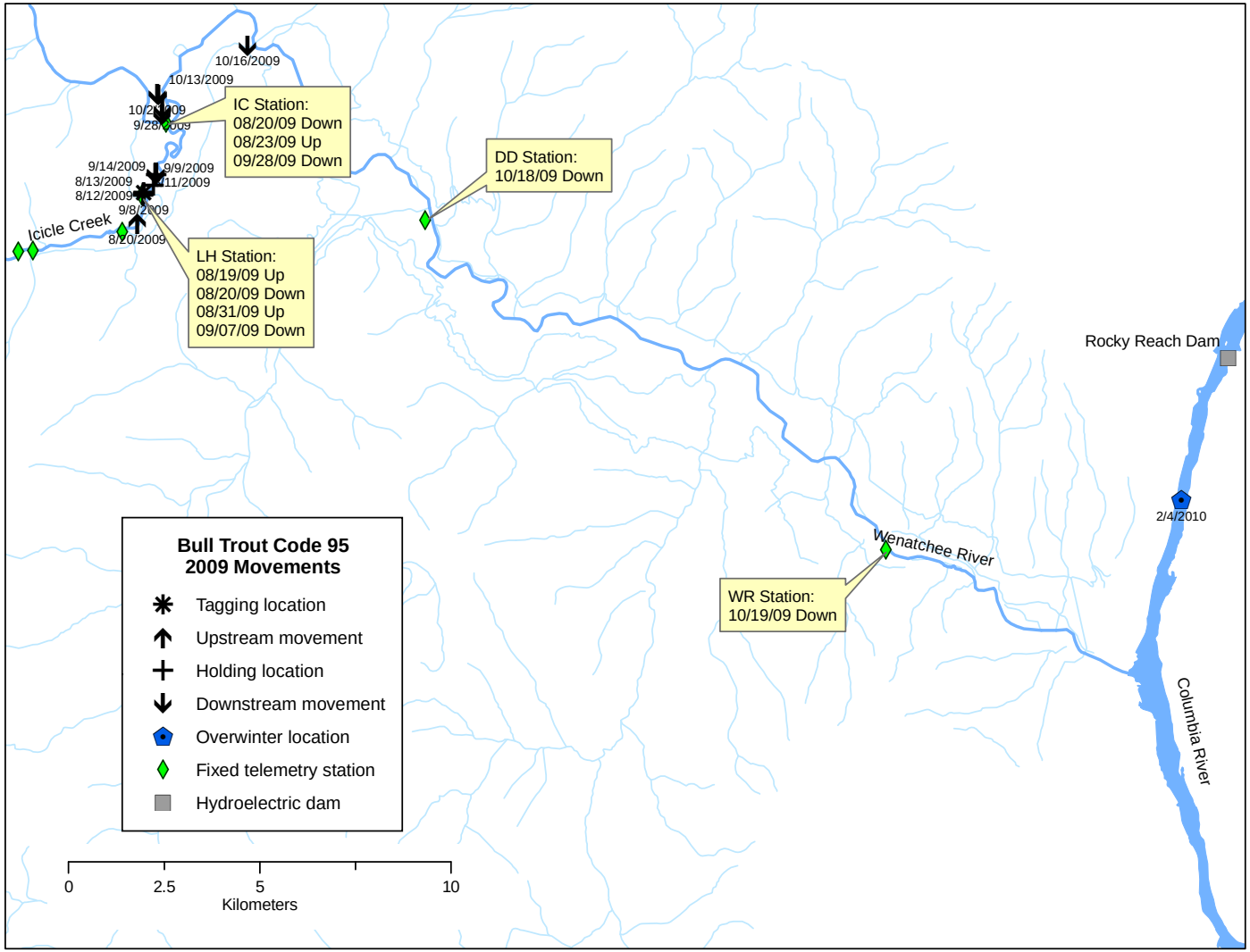

Figure 20. Map of the movements of bull trout code 95 during 2009.

Wenatchee River at rkm 36.7 during a mobile survey on October 16. Code 95 then migrated quickly downstream, passing the DD station (rkm 28.3) on October 18 and the WR station (rkm 12.5) on October 19. It entered the Columbia River and during a boat survey on February 4, 2010 was located at rkm 758.

Code 96 (Figure 21)- Bull trout code 96 was captured and tagged in Icicle Creek at the spillway pool (rkm 4.3) on August 11, 2009. It was detected in the pool until September 13, when it moved downstream. It passed the IC station (rkm 0.8) on September 14 and was detected in the Wenatchee River between rkms 36.7 and 34.3 during mobile surveys conducted from September 16 to October 2. On October 4, code 96 was detected upstream of Dryden Dam by the DD station (rkm 28.3). It remained upstream of the dam until October 16, when it migrated downstream, passed the WR station (rkm 12.5) on October 18, and entered the Columbia River. Code 96 was not detected during boat surveys and its winter location in the Columbia River was unknown.

Code 97 (Figure 22)- Bull trout code 97 was captured and tagged in Icicle Creek at the spillway pool (rkm 4.3) on September 28, 2009. It was present in or around the spillway pool from September 28 to October 18, when it moved upstream in the historic channel. It was intermittently detected on the HG station (rkm 6.1) on October 21 to 27, and analysis of the telemetry data indicated it did not move upstream into the pool below the structure or attempt to pass the headgate, which was open during this timeframe. It moved back downstream and was detected passing the LH station on October 28. During mobile surveys on October 28 and 29 it was located downstream of the spillway pool and from November 2 to 12 it was located near East Leavenworth Road Bridge (rkm 3.8). Code 97 moved slowly downstream, passed the IC station (rkm 0.8) on November 20, and exited Icicle Creek. During mobile surveys it was detected in the Wenatchee River at rkm 39.9 on November 23 and at rkm 32.5 on November 25. It passed the DD station (rkm 28.3) on November 28 and the WR station (rkm 12.5) on December 5. It was detected in the Columbia River at rkm 751 during a boat survey on February 4, 2010.

Code 98 (Figure 23)- Bull trout code 98 was captured and tagged in Icicle Creek at the spillway pool (rkm 4.3) on September 25, 2009. It was detected in the spillway pool by the LH station until October 1, when it moved a short distance downstream and was detected at rkms 3.9 – 4.2 during mobile surveys. It moved back to the spillway pool on October 9 and was detected there until October 26, when it moved downstream and exited Icicle Creek. It moved upstream in the Wenatchee River where it was detected at rkm 42.3 on October 28. It remained in this vicinity, downstream of Icicle Road Bridge, throughout the winter.

Code 99 (Figure 24)- Bull trout code 99 was captured and tagged in Icicle Creek at the spillway pool (rkm 4.3) on September 28, 2009. It moved downstream, passed the IC station (rkm 0.8) on September 29, and exited Icicle Creek. During mobile surveys it was detected in the Wenatchee River at rkm 41 on October 2, at rkm 34.6 on October 9, and at rkm 35.4 on October 14. During all subsequent mobile surveys throughout the fall and winter it was detected at several locations within the vicinity of rkm 33.8 in the Wenatchee River.

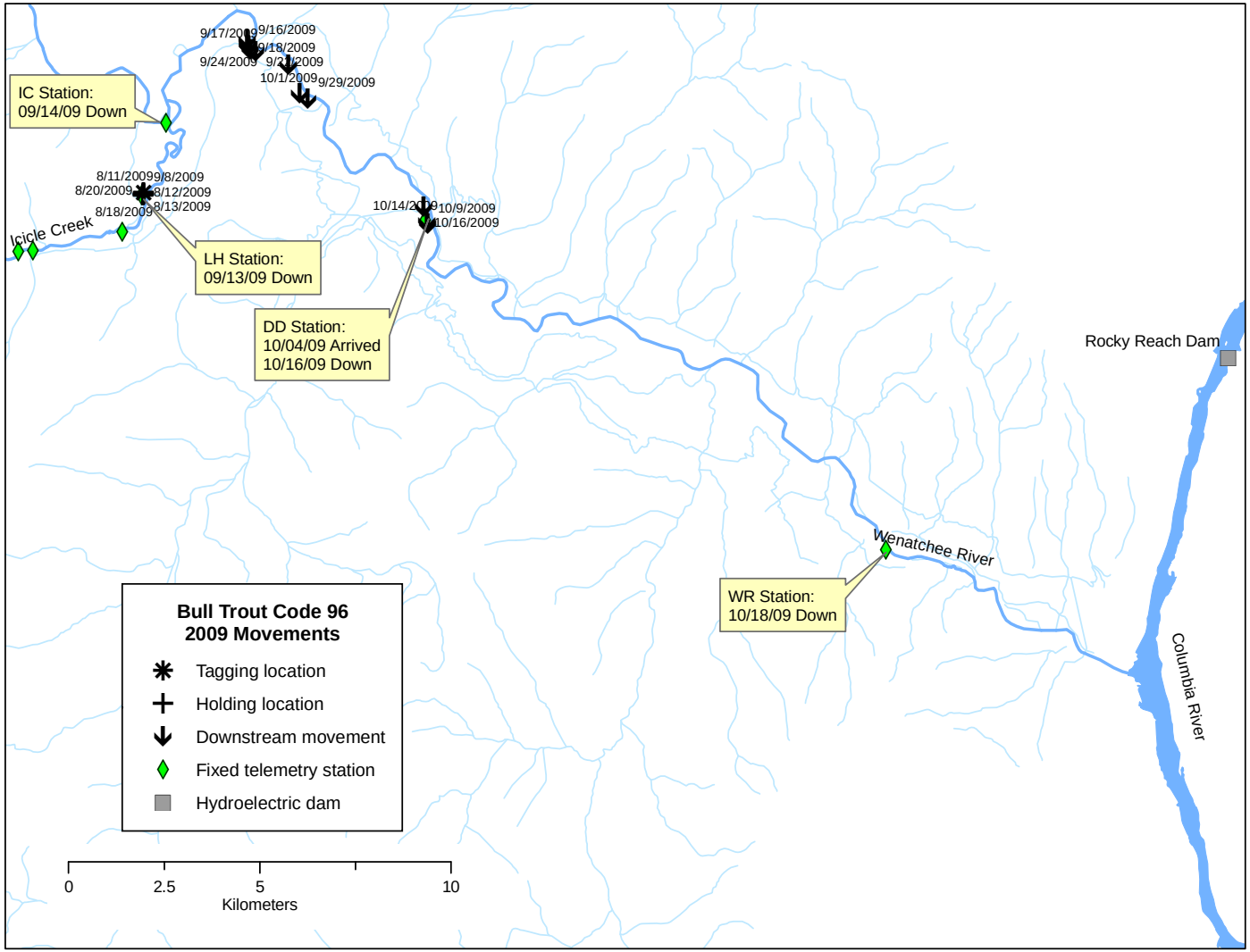

Figure 21. Map of the movements of bull trout code 96 during 2009.

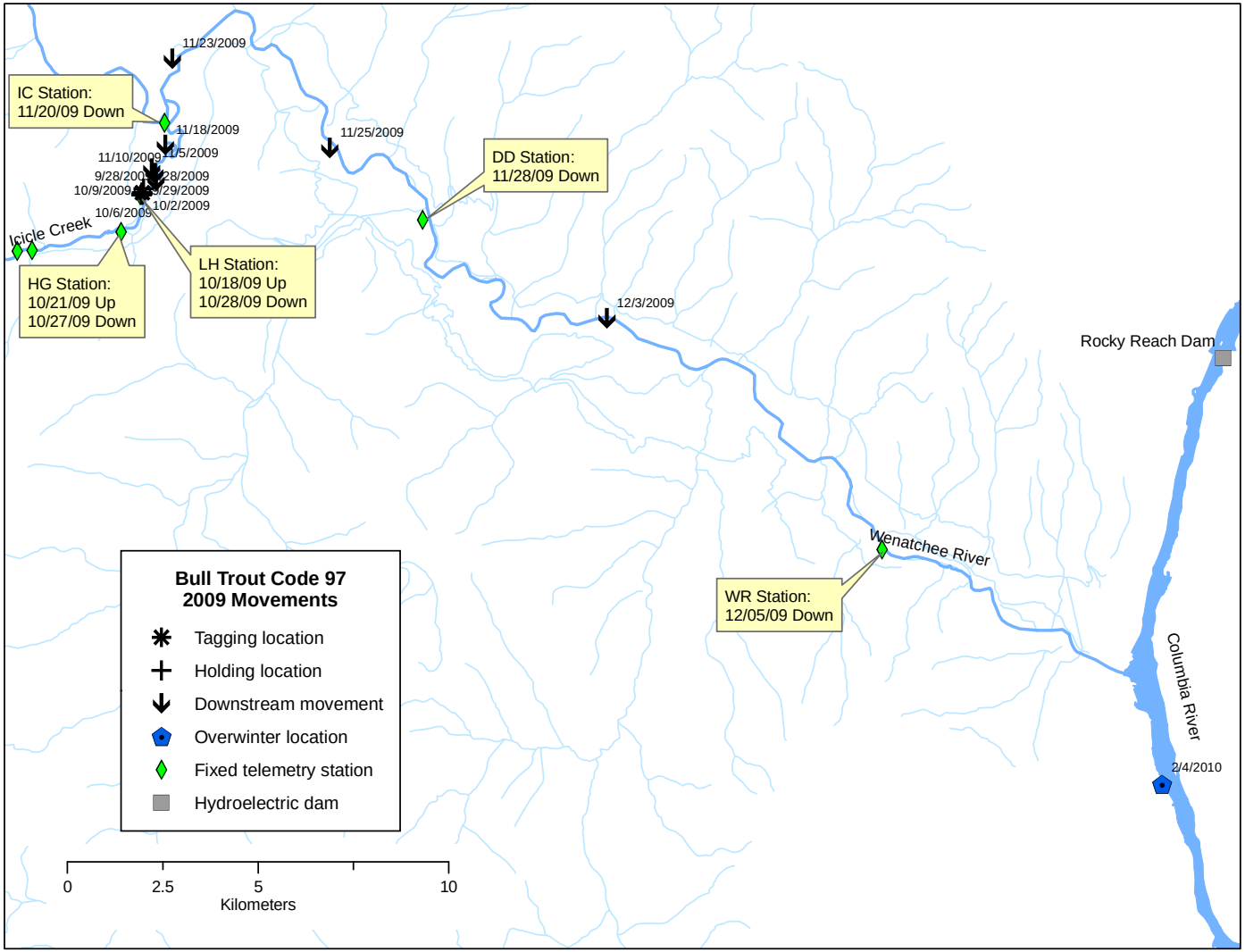

Figure 22. Map of the movements of bull trout code 97 during 2009.

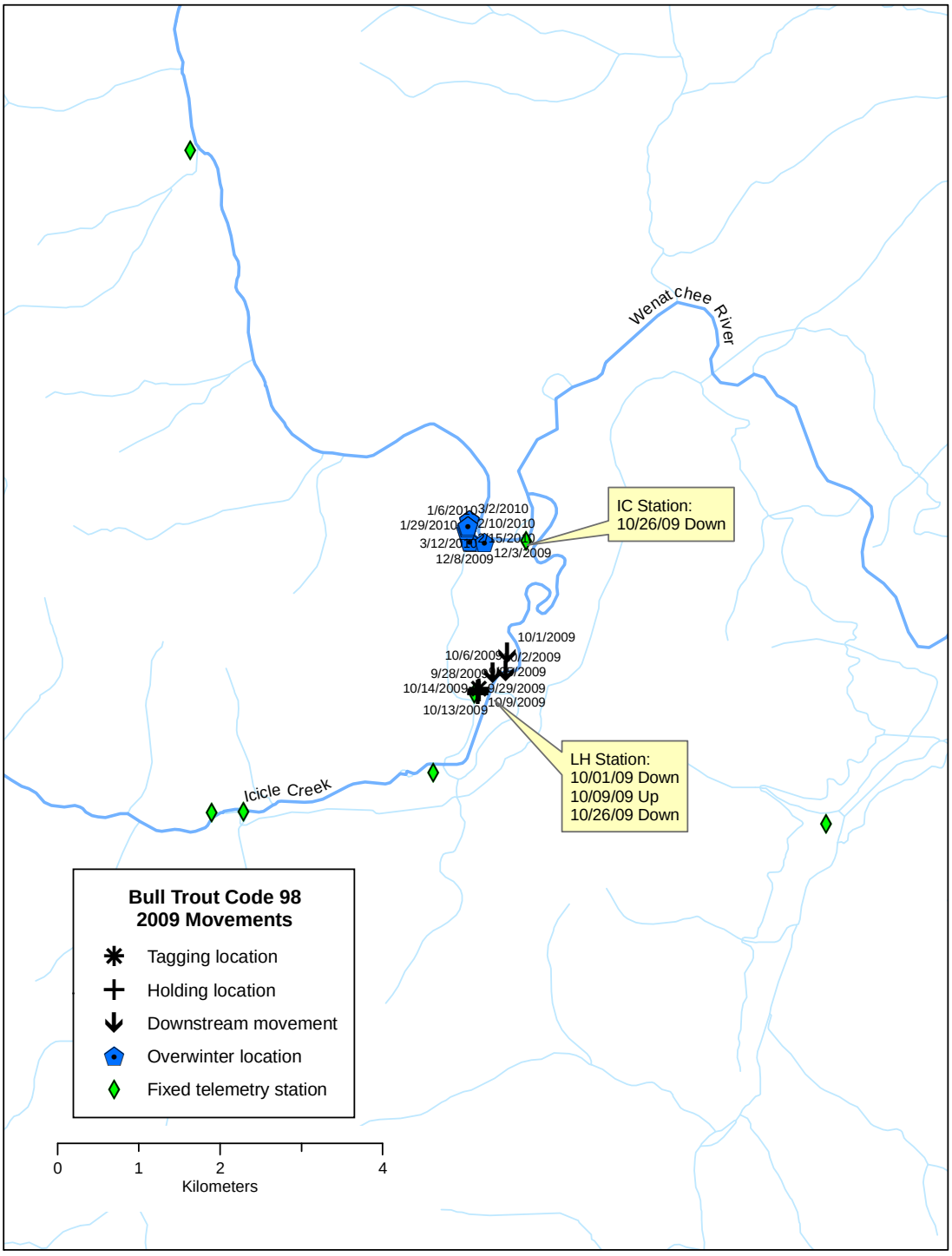

Figure 23. Map of the movements of bull trout code 98 during 2009.

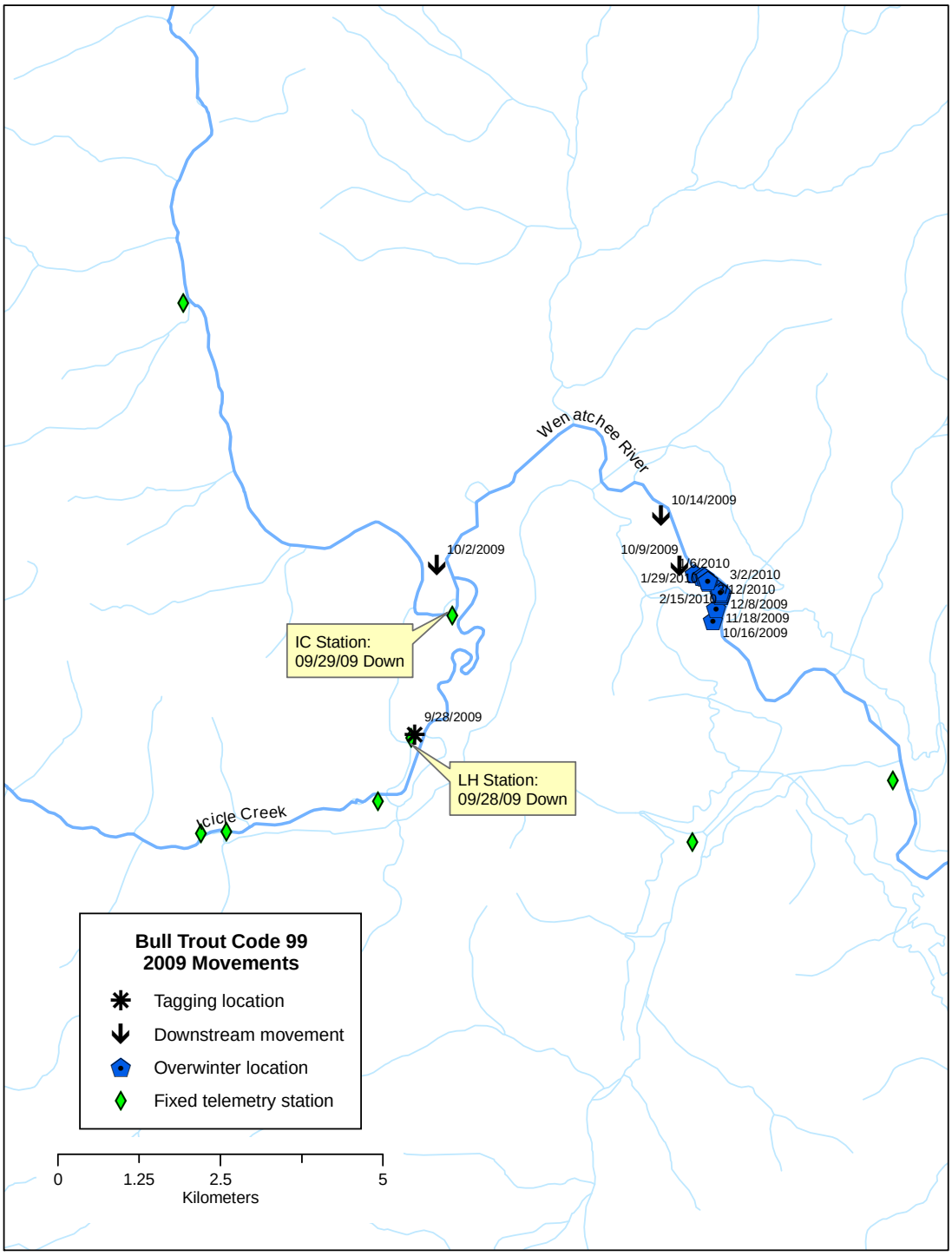

Figure 24. Map of the movements of bull trout code 99 during 2009.

Fixed Receiver Telemetry Stations

Summary of detections at fixed stations

Radio-tagged bull trout from Icicle Creek were detected at seven fixed receiver telemetry stations during 2009. No bull trout were detected at the WI, AF, IG, and RE stations in Icicle Creek or at the PC station in Peshastin Creek. No radio-tagged bull trout from concurrent studies in the Columbia River, Entiat River, and Methow River were detected at stations in the Wenatchee River basin during 2009. See Appendix B for descriptions and tables detailing the detections at fixed receiver telemetry stations.

Migration rates between fixed stations

The migration rates of tagged bull trout between fixed stations were extremely variable (Table 5, Figure 25). In Icicle Creek, rates between the LH and IC stations ranged from 0.2 to 41.3 km/day and the highest rates were attained by the earliest downstream migrants (one died and the other shed its tag). After exiting Icicle Creek, most bull trout moved slowly downstream in the Wenatchee River, particularly in the reach between the Icicle Creek confluence (IC) and Dryden Dam (DD). Mobile tracking revealed that tagged bull trout stopped for extended periods in this reach during their downstream migrations. The fastest downstream migration of a tagged bull trout was 47.6 km/day between Dryden Dam (DD) and Wenatchee River County Park (WR).

Table 5. Migration rates (km/day) between fixed stations during downstream migrations of Icicle Creek-tagged bull trout during autumn, 2009.

Code	HG – IC (km/day)	LH – IC (km/day)	IC – DD (km/day)	DD – WR (km/day)
94		41.3		
96		20.5	0.7	1.1
20		38.5		
95		0.2	0.7	47.6
24		9.4	2.0	0.7
99		8.8		
98		21.5		
97	4.2	0.2	1.7	2.1

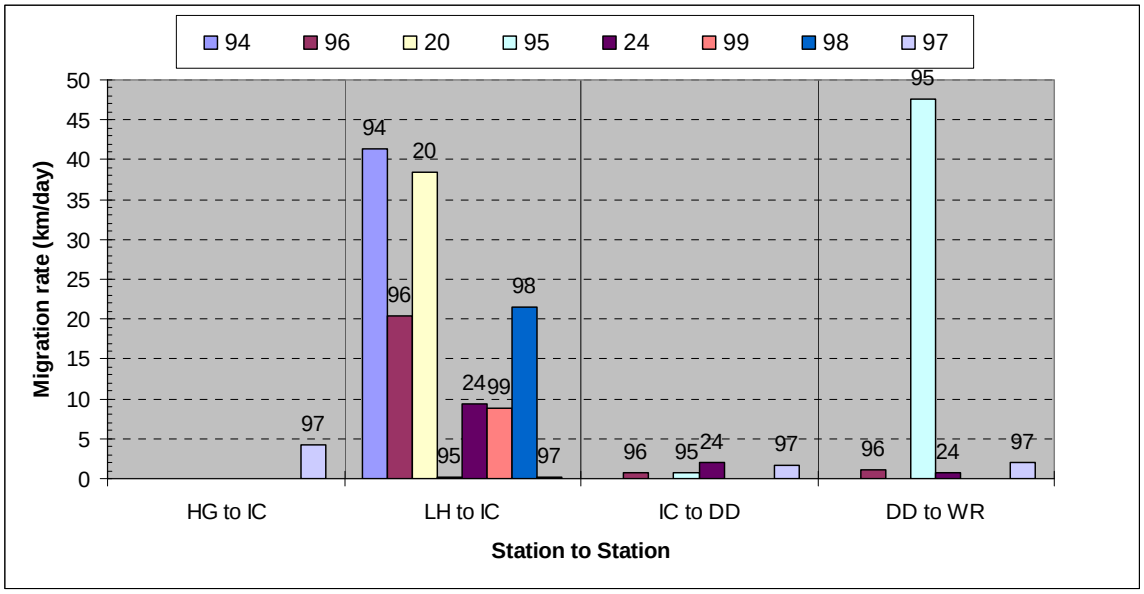

Figure 25. Migration rates of individual Icicle Creek-tagged bull trout during downstream movements between fixed stations in autumn, 2009.

Days between fixed stations

As indicated by the migration rates, the number of days that tagged bull trout spent between stations during the downstream migration was variable (Table 6). Tagged bull trout spent 0.08 to 22.9 days in Icicle Creek after leaving the spillway pool. The number of days spent in the Wenatchee River between the confluence of Icicle Creek and Dryden Dam ranged from 6.83 to 20.61 and the number of days spent in the reach between Dryden Dam and Wenatchee River County Park ranged from 0.33 to 21.36. It is not known how long it took tagged bull trout to travel from the county park to the Columbia River, so the minimum known time tagged bull trout spent in the Wenatchee basin during downstream migration to the Columbia River ranged from 34.2 to 42 days.

Table 6. Number of days that Icicle Creek-tagged bull trout spent between fixed stations during downstream migrations in autumn, 2009.

Code	CW – IC (days)	IC – LH (days)	HG – LH (days)	LH – IC (days)	IC – DD (days)	DD – WR (days)	Total (days)
94				0.08	a	-	
96				0.17	20.05	14.01	34.23
20				0.09	b	-	
95				21.05	20.61	0.33	41.99
24				0.37	6.83	21.36	28.56
99				0.40	c	-	
98				0.16	d	-	
97			0.42	22.90	8.13	7.69	39.14

Notes: a- tag recovered after exiting Icicle Creek; b- carcass recovered after exiting Icicle Creek; c- overwintered in reach between confluence of Icicle Creek and Dryden Dam; d- overwintered upstream Icicle Creek confluence.

Winter locations

Bull trout radio-tagged in Icicle Creek during 2009 overwintered in the Wenatchee River and the Columbia River (Table 7, Figure 26). In the Wenatchee River, bull trout code 98 overwintered at rkm 42.3, upstream of the Icicle Creek confluence, and code 99 overwintered at rkm 33.8. Three of the four bull trout in the Columbia River were located during boat surveys, including code 24 at rkm 750, code 95 at rkm 758, and code 97 at rkm 751. The winter location of code 96 in the Columbia River was not found.

Downstream migration distances

The distances that tagged bull trout migrated downstream in the autumn between tagging and overwintering locations ranged from 5.4 to 50.1 km (Table 7). After exiting Icicle Creek, code 98 moved 0.6 km upstream in the Wenatchee River where it spent the winter.

Table 7. Total downstream migration distances between tagging and overwinter locations of Icicle Creek bull trout in 2009.

Code	Tagging location (rkm)	Winter location (rkm)	Migration distance (km)
24	Icicle Creek (4.3)	Columbia River (750)	49.3
95	Icicle Creek (4.3)	Columbia River (758)	49.7
96	Icicle Creek (4.3)	Columbia River (unk)	45.5
97	Icicle Creek (6.1)	Columbia River (751)	50.1
98	Icicle Creek (4.3)	Wenatchee River (42.3)	5.4
99	Icicle Creek (4.3)	Wenatchee River (33.8)	11.7

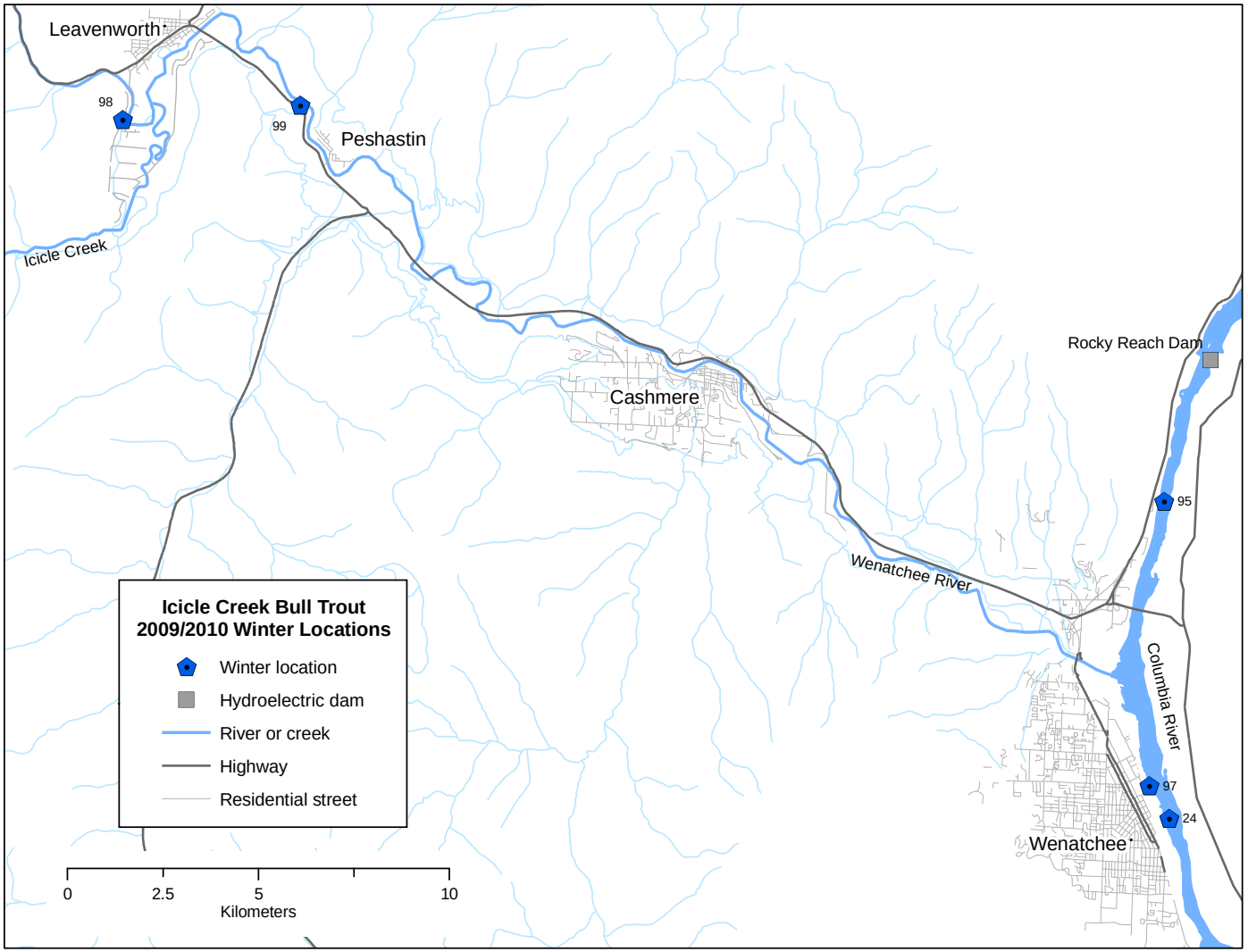

Figure 26. Map of the winter locations of adult bull trout that were radio-tagged in Icicle Creek during 2009.

Icicle Creek temperatures

The highest daily maximum stream temperatures in Icicle Creek were attained on August 1, the warmest day of the year in 2009 (Table 8). The longitudinal profile of water temperatures exhibited a general downstream warming trend, with the exception of a cooling effect at Leavenworth LNFH, due to the influence of the hatchery supplemental water from wells and Snow Lake (Table 8, Figure 27). The highest 7DADmax temperature in Icicle Creek was attained near the mouth on August 3, when it was 4.3 °C warmer than it was near Jack Creek (Table 8).

The spillway pool at Leavenworth NFH was consistently several degrees cooler than the Wenatchee River upstream of the confluence with Icicle Creek (Figure 28).

Table 8. Maximum, mean, minimum and 7DADmax water temperatures in Icicle Creek on August 1 and 3, 2009.

Temperature Logger Location (rkm)	max T °C (1-Aug-09)	mean T °C (1-Aug-09)	min T °C (1-Aug-09)	7DADmax °C (3-Aug-09)
Upstream of Jack Creek (30)	18.3	16.0	14.1	17.8
Downstream of Jack Creek (25.7)	18.0	16.1	14.2	17.6
Upstream of Snow Creek (9)	20.2	18.2	16.5	19.8
LNFH Intake (7.2)	19.8	18.1	16.6	19.6
Headgate (6.1)	19.4	18.2	17.0	19.1
Structure 5 (4.4)	20.9	18.7	16.9	20.4
Spillway Pool (4.3)	18.5	17.3	16.2	18.2
LNFH Outfall (4.3)	18.5	17.0	15.7	18.2
Downstream LNFH (4.2)	20.2	18.3	16.7	19.8
Mouth of Icicle Creek (0.8)	21.3	19.2	17.3	20.7
Wenatchee River u/s Icicle (41.5)	22.7	22.1	21.1	22.1
Air (at Leavenworth NFH)	44.3	29.0	17.0	44.1

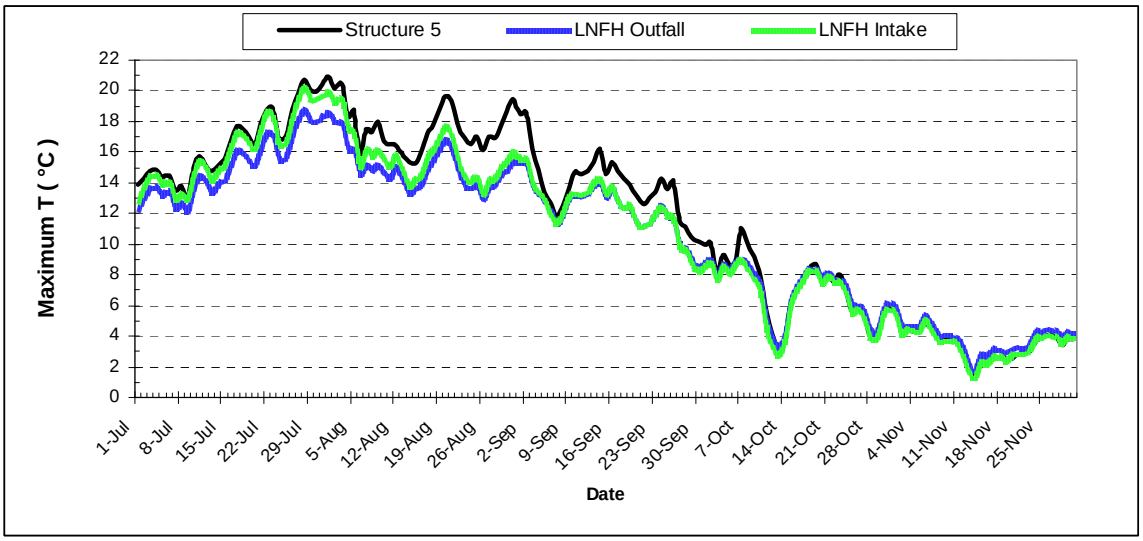

Figure 27. Maximum water temperatures recorded in Icicle Creek at the intake, outfall, and structure 5 of Leavenworth NFH, July 1 to November 30, 2009.

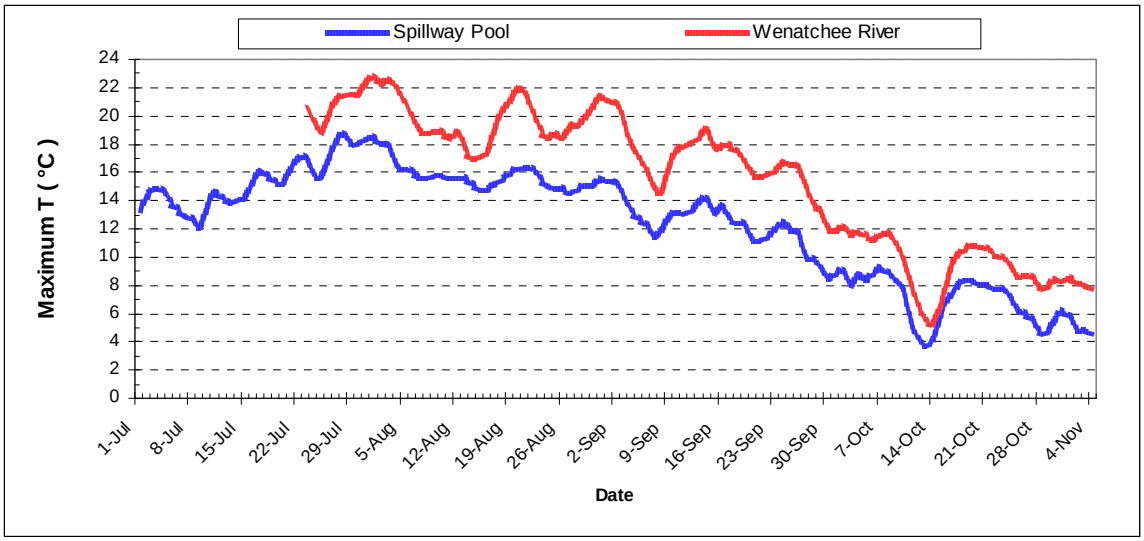

Figure 28. Maximum water temperatures recorded at the Leavenworth NFH spillway pool in Icicle Creek (rkm 4.3) and the Wenatchee River (rkm 41.5) from July 1 to November 5, 2009.

Spawning ground surveys

Bull trout spawning surveys were conducted in two areas in the Icicle Creek watershed. French Creek was surveyed three times and Icicle Creek was surveyed twice during the spawning season.

Icicle Creek (rkm 29.1 – 34.7)- Icicle Creek upstream of Rock Island Campground to French Creek was surveyed on October 7 and 19, 2009. Stream temperatures ranged from 4 to 6° C during the surveys. No redds or bull trout were observed.

French Creek (rkm 0.0 – 7.2)- Spawning ground surveys were conducted in French Creek on September 23, October 8, and October 20, 2009. Stream temperatures ranged from 7 to 9° C during the first survey and from 3 to 3.5° C on the last. Three probable bull trout redds were located in reach A (Figure 29). Redds FA01 and FA02 were recorded on September 23 and redd FA03 on October 8. A pair of bull trout (210 mm) were observed approximately 2 m downstream of redd FA03. Sizes of redds ranged from 0.15 to 0.32 m^2 and the relatively small dimensions suggest they were constructed by resident fish (Table 9).

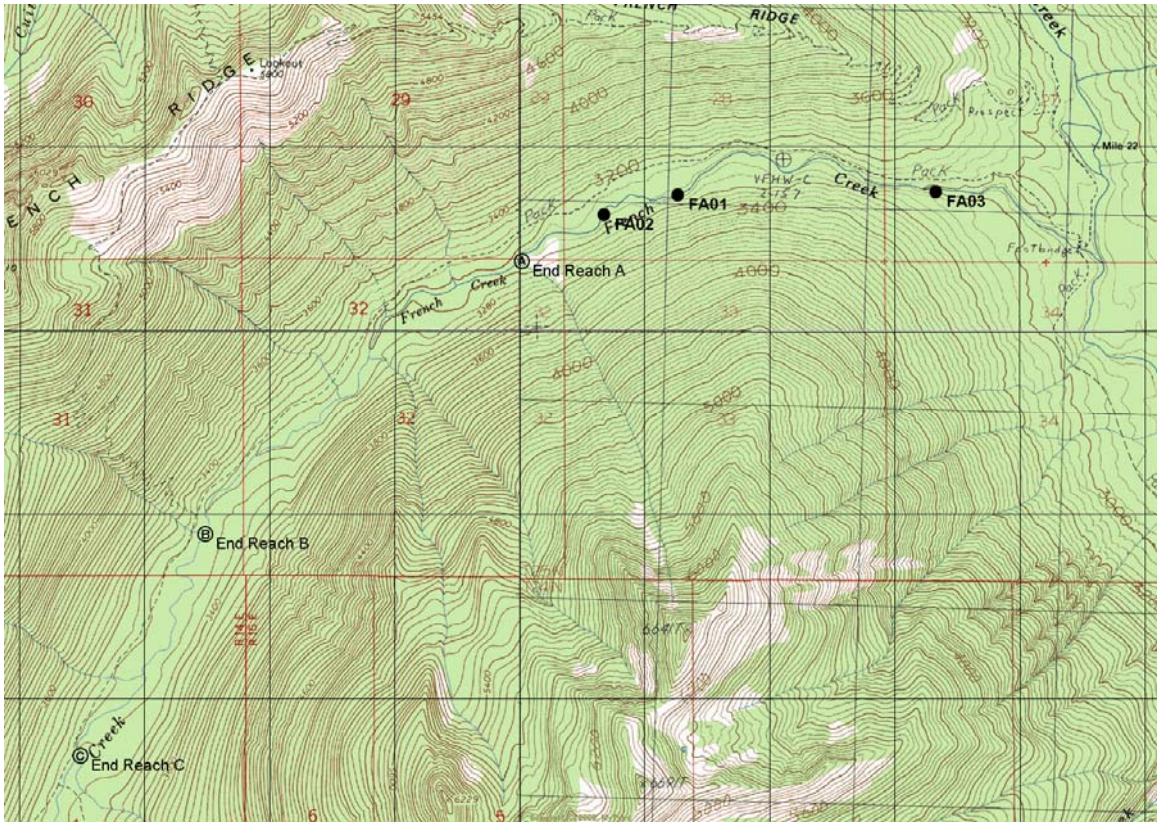

Figure 29. Locations of bull trout redds (solid black circles) observed during spawning ground surveys in French Creek during 2009.

Table 9. Dimensions of bull trout redds observed during spawning ground surveys in French Creek during 2009.

Redd	Length (m)	Width (m)	Depth of pit (m)	Depth at top of pit (m)	Redd area (m^2)	Category
FA01	0.6	0.3	0.26	0.2	0.18	Probable
FA02	0.8	0.4	0.33	0.29	0.32	Probable
FA03	0.6	0.25	0.26	0.22	0.15	Probable

Discussion

Capture of bull trout

For a variety of reasons, using telemetry to describe the timing of the upstream movements of bull trout into Icicle Creek is surprisingly difficult. To date, the only tagged bull trout that have been monitored entering Icicle Creek during the typical upstream migration period were tagged during telemetry studies in other rivers (Nelson et al. 2009). Because we increased the angling effort in Icicle Creek both seasonally and at more locations in 2009, some additional insights can be gained from the bull trout capture data (See Appendix A). No bull trout were caught during the spring, suggesting few were present or moving at that time. Angling during the summer period began on July 9, but the first bull trout (an adult) was not captured until July 20. Angling did not occur in the lower river from July 27 to August 5 due to the elevated temperatures, but bull trout were not consistently caught until after August 5, when 74 bull trout were first observed in the spillway pool during the annual snorkel survey (USFWS 2009). Thus it appears that in 2009 most bull trout arrived in the vicinity of Leavenworth NFH in late July or early August, which is somewhat later than the known movements of tagged adult bull trout that entered Icicle Creek in the past during those other telemetry studies (Nelson et al. 2009). Because the majority of bull trout in the lower river during 2009 were sub-adult (85% during angling and 90% during snorkeling), it may indicate that immature bull trout move into Icicle Creek later in the season than adults. Water temperatures vary each year and likely play a role in the timing of seasonal movements and distribution of bull trout of all age classes in Icicle Creek.

Movements of bull trout

None of the tagged bull trout in lower Icicle Creek attempted to move upstream past Leavenworth NFH during 2009, even though all were caught and tagged after broodstock collection was completed and all the structures were open. That the structures were passable is evidenced by the observation of large fluvial bull trout upstream of Leavenworth NFH during the annual USFWS snorkel survey of lower Icicle Creek on August 5 (USFWS 2009). Also during that survey, two small bull trout (190 and 300 mm) were observed just upstream of the boulder falls (rkm 9.2), but because their size was consistent with out-migrating juvenile bull trout it cannot be determined if they had ascended the boulder falls or were migrating downstream from the upper river. During surveys conducted by the Wild Fish Conservancy in 2009, two untagged large fluvial bull trout were observed in upper Icicle Creek, including one in lower French Creek (WFC 2009). Although we found only resident-sized redds in French Creek in 2009, the sightings of these large bull trout suggest migrants may have spawned without detection in the upper watershed. Bull trout are migrating in upper Icicle Creek (Nelson et al. 2009) but the passage windows at obstacles downstream of Icicle Gorge are unknown, including at the boulder falls.

The movements of bull trout tagged in lower Icicle Creek in 2009 were similar to the movements of tagged bull trout in an earlier (2000 – 2004) USFWS telemetry study in the Wenatchee Core Area. During that currently unpublished study, the movements of four bull trout tagged in the Leavenworth NFH spillway pool during 2001 and 2002 were

monitored (USFWS data from files). Two of these bull trout exhibited behavior similar to code 20, including rearing in lower Icicle Creek, over-wintering in the Wenatchee River, and migrating to Chiwaukum Creek to spawn. Structure 5 and the headgate were open during most of the summer and fall in 2001 (USFWS 2006) but it is not known if any of those tagged bull trout attempted to move upstream of the spillway pool. However, two bull trout tagged in the Columbia River during Chelan County Public Utility District telemetry studies were detected in Icicle Creek upstream of Leavenworth NFH- code 46 was detected just downstream of the boulder falls (rkm 9.2) from July 27 to August 31, 2001 (BioAnalysts 2004) and code 5 was detected in lower Snow Creek in September 2005 (MCRFRO 2005). After passing Leavenworth NFH, it is not known whether these bull trout attempted to migrate further upstream to spawn but were blocked by the boulder falls or if they were non-spawners that sought thermal refuge or foraging opportunities in Icicle Creek. To date, no tagged bull trout have passed upstream through the boulder falls in Icicle Creek.

The movements of tagged bull trout illustrate the importance of lower Icicle Creek as foraging habitat for bull trout during the summer and fall. Due to the cooling influence of Leavenworth NFH operations, the spillway pool offers a thermal refuge from elevated temperatures in the Wenatchee River during summer. The prey base in lower Icicle Creek is abundant and includes rainbow trout, cutthroat trout, wild juvenile spring and summer Chinook and coho salmon, whitefish, suckers, dace, northern pikeminnow, sculpins, and aquatic insects (MCRFRO 2004). In addition, coho and spring Chinook salmon smolts released from Leavenworth NFH provide high density forage in the spring. The relatively high quality of the foraging habitat in Icicle Creek and the Wenatchee River is indicated by the growth rate of code 20 during 2008/2009, which was more than two times the growth rate of tagged bull trout of similar size recaptured from the Methow River and the Columbia River (Nelson et al. 2011).

Tumwater Dam

During the 2000 – 2004 USFWS telemetry study in the Wenatchee Core Area the movements of radio-tagged bull trout were also monitored by a telemetry station at Tumwater Dam. Between 2001 and 2004, the upstream movements of five bull trout were recorded, and included detections during one migration for four bull trout and during two migrations for one bull trout (USFWS data from files). The time to for these fish to move upstream through the dam (defined as elapsed time from first detection on downstream antenna to last detection on upstream antenna) ranged from 0.1 to 3.4 days (mean 1.4 days). During 2009 in comparison, bull trout code 20 took much longer to pass the dam (22.8 days). However, it was detected by the PIT array in the fishway 0.7 days after it first arrived at the dam, so it appears this fish did not have much difficulty in finding the entrance and ascending the ladder. That it then descended and re-ascended the fishway several times but apparently would not enter the trap at weir 20 suggests that bull trout code 20 may have been trap-shy or that the presence of large Chinook salmon in the trap inhibited it from entering. Code 20 passed the dam on the day with the highest count of sockeye salmon, and the large number of those fish in the ladder may have influenced its behavior to move upstream.

Downstream movements of five bull trout bull trout at Tumwater Dam were also recorded during the 2000 – 2004 telemetry study and included two bull trout detected during one migration, two detected during two migrations, and one detected during three migrations (USFWS data from files). The elapsed time to move downstream past the dam (defined as elapsed time from first detection on upstream antenna to last detection on downstream antenna) ranged from 10 minutes to 11.7 days (mean 2.2 days). In 2009 for comparison, bull trout code 20 was detected for 8 minutes as it moved downstream past the dam.

Several factors appear to influence both upstream and downstream passage of bull trout at Tumwater Dam. During upstream migrations, high discharges can result in slower migration rates and can delay or temporarily halt migration (Swanberg 1997, Nelson 2008, Nelson and Nelle 2008, Nelson et al. 2011). Bull trout may slow their migration rate as they near their spawning tributary or stage nearby (Fraley and Shepard 1989), particularly if it is still relatively early in the migration period (Nelson et al. 2011); thus it may be that a Chiwaukum Creek bull trout is more likely to move slower at Tumwater Dam than a bull trout from the upper Chiwawa River or Nason Creek. High discharge can also delay or halt downstream migrations (Monnot et al. 2008, Nelson and Nelle 2008). In addition, some bull trout may naturally move slower and stop for longer periods even in free flowing reaches (Nelson and Nelle 2008). Individual bull trout may also exhibit idiosyncratic behavior such as the repeated short daily movements of code 20 in the vicinity of the spillway pool in Icicle Creek during 2008 (Nelson et al. 2009). Although environmental and biological factors may have affected the migration rate of code 20, the behavior observed in the fish ladder suggests it may be prudent to review the fish trapping procedures at Tumwater Dam. Whatever the reasons, however, the apparent delay did not prevent bull trout code 20 from reaching Chiwuakum Creek, where it successfully spawned.

Water temperatures

Cold water temperatures are associated with the distribution and habitat use of bull trout (Dunham et al. 2003). In Icicle Creek it appears that both juvenile and adult bull trout utilize the area near Leavenworth NFH as a refuge from elevated water temperatures in the Wenatchee River. The cooler temperatures in lower Icicle Creek are influenced by the water system of Leavenworth NFH, and without the supplemental cold water from deep wells, Icicle Creek may not be as effective a thermal refuge. For example, due to the hatchery outfall, water temperatures in the spillway pool are almost as cool as temperatures near Jack Creek, 25 rkm farther upstream. Water temperatures in lower Icicle Creek were relatively high before Leavenworth NFH was constructed in 1940– on August 12, 1937, the maximum temperature at rkm 4.3 (the current site of structure 5) was 19.5° C (WDF 1938). Thus, the well water from Leavenworth NFH appears to be beneficial for bull trout habitat and because individuals from other local populations are known to utilize lower Icicle Creek, maintaining the cold water discharge is especially important.

Although bull trout are a cold water species, laboratory studies indicate juveniles can survive prolonged exposures to elevated temperatures, with upper incipient lethal

temperatures of 20.9 °C for 60-d exposure and 23.5 °C for 7-d exposure (Selong et al. 2001). Recent telemetry observations indicate migratory adult bull trout can tolerate exposures to relatively high water temperatures in the Entiat River (Nelson and Nelle 2008) and the Lostine River (Howell et al. 2010), apparently without seeking thermal refuges. However, the long term effects of high water temperatures on individuals and populations are unknown. Elevated temperatures increase metabolic rate and bioenergetic costs (Wootton 1990) but because bull trout apparently do not actively feed during spawning (Bjornn 1991) and perhaps during migration (Fraley and Shepard 1989) they must rely on stored energy reserves for extended periods. Thus the additional temperature related metabolic output in combination with the energetic costs of reproductive behavior may ultimately affect the survival of spawning adults, as suggested by the thermal profile in the Wenatchee River during the migrations of bull trout code 20 and its post-spawn demise. Recent modeling indicates climate change and increased temperatures will significantly reduce the range and distribution of bull trout (Rieman et al. 2007) and the effects of warmer stream temperatures urgently require further investigation.

Genetics

Genetic profiles of local populations of bull trout in the Upper Columbia Recovery Unit are currently being analyzed by USFWS Abernathy Fish Technology Center and Central Washington Field Office[2]. Preliminary results indicate that the number of alleles, allelic richness, and heterozygosity of bull trout in French Creek of upper Icicle Creek are comparable to other local populations with a migratory life history (P. DeHaan, pers. comm.). The genetic diversity of the French Creek population shows no evidence of a bottleneck and French Creek bull trout appear to be most genetically similar to other populations within the Wenatchee Basin (P. DeHaan, pers. comm.). The genetic profile of resident bull trout from Early Winters Creek (Methow Basin) also looked very similar to fish collected from French Creek. Interestingly, the resident bull trout population in Early Winters Creek is upstream of a 6 m high barrier waterfall and all geological indications are that it has been isolated from other populations for a long time- perhaps thousands of years (J. Riedel, pers. comm.). We speculate that the resident populations in Early Winters and French Creek may represent genetic remnants of the original middle Columbia Basin population that re-colonized the upper Columbia River tributaries after the retreat of the last ice age (Hass and MacPhail 2001).

To date, over 60 genetic samples have been collected by MCRFRO from sub-adult and adult fluvial bull trout in lower Icicle Creek. When the genetic profiles for all populations of the Upper Columbia Core Area are completed, comparative analyses should provide an estimate of the emigration rate from upper Icicle Creek and immigration rates from other populations.

[2] This study is a cooperative effort and other agencies providing support and collection of tissue samples include USFWS Mid-Columbia River Fishery Resource Office, US Forest Service, USGS Cook Laboratory, Yakama Nation Mid-Columbia Field Station, Washington Department of Fish and Wildlife, Chelan County and Douglas County Public Utility Districts, and Wild Fish Conservancy.

Brook trout and hybridization

Two large bull x brook hybrid trout have now been documented in Icicle Creek and it appears brook trout present a major threat to the bull trout population. It is probable that hybridization in Icicle Creek is not just a recent phenomenon. Eastern brook trout were first introduced to eastern Washington in 1896, when 1000 adults and yearlings were planted in Fish Lake near Cheney (U.S. Commission of Fish and Fisheries 1898). During 1913, approximately 800,000 eastern brook trout fry were consigned from the Spokane State Hatchery for stocking in Chelan County and apparently at least 90,000 were placed in Icicle Creek (Anon. 1913a), including 60,000 planted near Eightmile Creek (Anon. 1913b) and 6,000 in Hart and Nada lakes (Anon. 1913c). Early plantings of fish were conducted by local game wardens and sportsmen associations and detailed stocking records do not exist prior to 1934, but it appears that for many years eastern brook trout were routinely planted in Icicle Creek. They probably now occur throughout the watershed and are found in potential bull trout spawning areas, such as upstream of Leland Creek (Kelly Ringel 1997).

Hybridization was confirmed for code 21 (tagged in 2007, *see* Nelson et al. 2009) and the initial genetic analysis indicated it may have been a backcross (P. DeHaan, pers. comm.). Hybrids are known in the Flathead River and Bitterroot River but it is thought they may have reduced fitness or are non-migratory, which may limit negative impacts on populations (Kanda et al. 2002). Both hybrids from Icicle Creek were migratory-sized, but because they either shed their radio tags or died it is not known if they would have exhibited fidelity to their spawning area or if they would disperse into other local populations. Hybrid code 21 moved 69 km after it was tagged, so it is possible hybrids could migrate considerable distances to other bull trout populations in areas without brook trout and negatively affect that population.

The usual pairing during hybridization is a female migratory bull trout with a male brook trout (Kanda et al. 2002). Because brook trout are widely spread throughout Icicle Creek, it is possible that obstacles or barriers in upper Icicle and French creeks could increase the incidence of hybridization by restricting the movements of female fluvial bull trout and preventing them from pairing with a male bull trout.

Recommendations for future study

Radio-tagged bull trout will be monitored during 2010. However, in order to minimize impacts to the relatively few migratory bull trout documented upstream of the boulder falls, tagging will not continue in upper Icicle Creek. Elevated water temperatures limit angling and tagging windows during the summer and may also increase the incidence of shed transmitters. Thus tagging in 2010 will focus on early summer in lower Icicle Creek in an attempt to deploy the remaining transmitters purchased for the study.

Completion of the genetic analyses of all local populations in the Upper Columbia Recovery Unit will allow the establishment of a genetic baseline. This baseline, in combination with a comprehensive and long term genetic tissue sampling program, may help measure gene flow and quantify emigration and immigration rates of bull trout in Icicle Creek. Additional samples from Icicle Creek bull trout should be collected

whenever possible and the larger sample size will increase the robustness of these estimates. Archived tissue samples of tagged bull trout from other studies that entered Icicle Creek should be analyzed and their local population assigned when the genetic baseline is completed.

Intensive surveys to determine the distribution and population size of brook trout in Icicle Creek are needed. Some sites in the watershed are periodically monitored during the Integrated Status and Effectiveness Monitoring Program (OWNF 2006) and that snorkeling and electrofishing database should be queried for locations and numbers of brook trout to assist with planning of additional surveys. Methods to control brook trout and reduce or eliminate hybridization with bull trout should be explored.

USFWS will continue to conduct spawning ground surveys in French Creek and Icicle Creek (downstream of French Creek). Standardized spawning ground surveys should be expanded into other likely areas in Icicle Creek such as Leland Creek or in Icicle Creek upstream of the French Creek confluence. Jack Creek was surveyed during 2008, and although it appears only limited spawning substrate is available in the lower reaches, it should periodically be checked as well. Because much of upper Icicle Creek is remote and difficult to access, coordination with other agencies and groups working in the watershed would increase efficiency of survey efforts and minimize disturbance to spawning bull trout.

Acknowledgments

A telemetry project such as this cannot be accomplished without the help of many other people. Field assistance was provided by USFWS personnel, including Christine Adelsberger, Cal Yonce, Josh Pieratt, and Matt Hall. USFWS biologists Barb Kelly Ringel and Judy Delavergne generously shared currently unpublished data from their earlier (2000 to 2004) Wenatchee River bull trout telemetry study. USWFS Fish Biologists Dave Irving, Jim Craig, Bill Gale, and Malenna Cappellini reviewed the draft manuscript and provided editorial comments that improved the report.

Thanks are due to Dr. Larry Vance, DDS, and his staff at Exceptional Smile Dental Clinic in Cashmere for sterilizing our radio transmitters and PIT tags in their ethylene oxide chamber. Chad Herring of Washington Department of Fish and Wildlife provided water temperature data from Tumwater Dam and Tyler Burks of Washington Department of Ecology provided water temperature data from Chiwaukum Creek. The Yakama Nation Mid-Columbia Field Office, Chelan County Public Utility District, and USFWS Central Washington Field Office loaned telemetry receivers and equipment.

For allowing us to place fixed telemetry stations on their property (and for those providing AC power), we thank Two Rivers Farm, City of Leavenworth, Leavenworth National Fish Hatchery, USFS Wenatchee River Ranger District, Chelan County Public Utility District, Wenatchee River County Park, and Yakama Nation Mid-Columbia Field Office.

Literature Cited

Anon. 1913a. Plant trout in Wenatchee River. The Wenatchee Daily World, Vol. VIII No. 253. May 2, 1913. Wenatchee, Washington.

Anon. 1913b. Nearby streams stocked with 200,000 brook trout. The Leavenworth Echo Vol. 10 No. 17. May 2, 1913. Leavenworth, Washington.

Anon. 1913c. Seven hours for two mile climb to stock two lakes. The Wenatchee Daily World, Vol. VIII No. 276, May 30, 1913. Wenatchee, Washington.

BioAnalysts. 2004. Movement of bull trout within the Mid-Columbia River and tributaries 2001-2004-final. Prepared by BioAnalysts, Inc., Boise Idaho, for Chelan, Douglas, and Grant PUDs. May 26, 2004.

Bjornn, T.C. 1991. Bull trout *Salvelinus confluentus.* Pages 230-235 *in* Stolz J. and J. Schnell, editors. 1991. Trout. Stackpole Books. Harrisburg, PA. 370 pp.

Bonar, S.A., M. Divens, and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout and Dolly Varden. Washington Department of Fish and Wildlife, Olympia, WA.

Brown, L. 1992. Draft management guide for the bull trout *Salvelinus confluentus* (Suckley) on the Wenatchee National Forest. March 1992. Washington Dept. of Wildlife, Wenatchee, WA.

Bryant F.G and Z.E. Parkhurst. 1950. Survey of the Columbia River and its tributaries-part IV: Area III Washington streams from the Klickitat and Snake Rivers to Grand Coulee Dam, with notes on the Columbia and its tributaries above Grand Coulee Dam. Special Scientific Report-Fisheries No. 37. Washington D.C.

CBAICHS (Columbia Basin Inter-Agency Committee, Hydrology Subcommittee). 1964. River mile index: Wenatchee River, Entiat River, Chelan River, Methow River, Columbia River Basin, Washington. Portland, OR. 24 pp.

Chisholm, I.M. and W.A. Hubert. 1985. Expulsion of dummy transmitters by rainbow trout. Transactions of the American Fisheries Society 114:766 – 767.

DART (Data Access Real Time). 2009. (http://www.cbr.washington.edu/dart/dart.html)

Dunham, J., B. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894-904.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Science 63(4):133-143.

Haas, G.R. and J.D. MacPhail. 2001. Quantitative post-Wisconsinan glacial biogeography of bull trout, and the use and importance of such analyses and information for conservation and management. Pages 237 – 240 *in* Brewin, M.K., A.J. Paul, and M. Monita, editors. Bull trout II conference proceedings. Trout Unlimited Canada, Calgary, Alberta.

Hillman, T.W. and D. Essig. 1998. Review of bull trout temperature requirements: a response to the EPA bull trout temperature rule. *Prepared for* Idaho Division of Environmental Quality *by* BioAnalysts, Inc. November 1998.

Howell, P.H., J.B. Dunham, and P.M. Sankovich. 2010. Relationships between water temperatures and upstream migration, cold water refuge use, and spawning of adult bull trout from the Lostine River, Oregon, USA. Ecology of Freshwater Fish 19:96-106.

Kanda, N., R.F. Leary, and F.W. Allendorf. 2002. Evidence of introgressive hybridization between bull trout and brook trout. Transactions of the American Fisheries Society 131:772 – 782.

Kelly Ringel, B. 2007. Progress report Icicle Creek water temperatures: November 1, 2005 – October 31, 2006. U.S. Fish and Wildlife Service, Leavenworth, WA.

MCRFRO (Mid-Columbia River Fishery Resource Office). 2004. Memorandum to files: Snorkel survey results for adult spring Chinook salmon in Icicle Creek. August 15, 2004. U.S. Fish and Wildlife Service, Leavenworth, WA.

MCRFRO (Mid-Columbia River Fishery Resource Office). 2005. Memorandum to files: Detection and recovery of bull trout radio tag code 5 in Snow Creek. Dated October 5, 2005. U.S. Fish and Wildlife Service, Leavenworth, WA.

Monnot, L., J.B. Dunham, T. Hoem, and P. Koetsier. 2008. Influences of body size and environmental factors on autumn downstream migration of bull trout in the Boise River, Idaho. North American Journal of Fisheries Management 28:231 – 240.

Mulcahy, D.M. 2003. Surgical implantation of transmitters into fish. ILAR Journal 44(4):295-306.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, J.D. McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. USFWS Monographs I. Leavenworth, Washington.

Nelson, M.C. 2004. Movements, habitat use, and mortality of adult fluvial bull trout isolated by seasonal subsurface flow in the Twisp River, WA. U.S. Fish and Wildlife Service, Leavenworth, WA.

Nelson, M.C. 2006. A hitch mounted mobile telemetry system. U.S. Fish and Wildlife Service, Leavenworth, WA.

Nelson, M.C. 2008. Adult fluvial bull trout passage of Tumwater Dam on the Wenatchee River: analysis of WDFW ladder counts (1998 – 2006) with application to Icicle Creek. U.S. Fish and Wildlife Service, Leavenworth WA.

Nelson, M.C. and R.D. Nelle. 2008. Seasonal movements of adult fluvial bull trout in the Entiat River,WA 2003 – 2006. U.S. Fish and Wildlife Service, Leavenworth WA.

Nelson, M.C, A. Johnsen, D. Pearson, and R.D. Nelle. 2009. Seasonal movements of adult fluvial bull trout in Icicle Creek, WA 2008 Annual Report. U.S. Fish and Wildlife Service, Leavenworth, WA.

Nelson, M.C., A. Johnsen, and R.D. Nelle. 2011. Migration patterns of adult fluvial bull trout in the Methow and Columbia Rivers during 2007. Draft report. U.S. Fish and Wildlife Service, Leavenworth, WA. 68 pages and separate appendices.

OWNF (Okanogan Wenatchee National Forest). 2006. Fish population monitoring. Annual report for the Integrated Status and Effectiveness Monitoring Project.

Paukert, C.P, P.J. Chvala, B.L. Heikes, and M.L. Brown. 2001. Effects of transmitter size and surgery on survival, growth, and wound healing of bluegill. Transactions of the American Fisheries Society 130:975 – 980.

Rieman, B.E., D. Isaak, S. Adams, D. Horan, D. Nigel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River basin. Transactions of the American Fisheries Society 136:1552-1565.

Ross, M. J. and C. F. Kleiner. 1982. Shield-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish Culturist 44: 41-43.

Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance for fishes. Transactions of the American Fisheries Society 130:1026-1037.

Summerfelt, R.C. and L.S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-272 *in* C.S. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Swanberg, T. 1997. Movements and habitat use by fluvial bull trout in the Blackfoot River, Montana. Transactions of the American Fisheries Society 126:735-746.

U.S. Commission of Fish and Fisheries. 1898. Part XXIII. Report of the commissioner for the year ending June 30, 1897. Washington, Government Printing Office.

USDOI (United States Department of the Interior). 1998. Fish and Wildlife Service. 50 CFR Part 17. Endangered and threatened wildlife and plants; determination of threatened status for the Klamath River and Columbia River distinct population segments of bull trout. Federal Register: June 10, 1998. Volume 63(111):31647 – 31674.

USFS (United States Forest Service). 1995. Icicle Creek Watershed Assessment- Fish Habitat Module. Wenatchee National Forest, Leavenworth WA.

USFWS (United States Fish and Wildlife Service). 2002a. Chapter 1, Upper Columbia Recovery Unit, Washington. 113 p. *in* U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

USFWS. 2002b. Chapter 22, Upper Columbia Recovery Unit, Washington. 113 p. *in* U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

USFWS. 2004. Revised Chapter 22, Upper Columbia Recovery Unit, Washington. 113 p. *in* U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. June 14, 2004 version. Portland, Oregon.

USFWS. 2006. Biological assessment for operation and maintenance of Leavenworth National Fish Hatchery. U.S. Fish and Wildlife Service, Leavenworth, WA.

USFWS. 2009. Memorandum to files re: Snorkel survey results for adult spring Chinook salmon and bull trout in Icicle Creek. August 6, 2009. Mid-Columbia River Fishery Resource Office, Leavenworth, WA.

USGS (United States Geological Survey). 2009. Stream flow monitoring network (http://waterdata.usgs.gov/wa/nwis/rt)

WDF (Washington Department of Fisheries). 1938. Report of the preliminary investigations into the possible methods of preserving the Columbia River salmon and steelhead at Grand Coulee dam. *Prepared for* The United States Bureau of Reclamation *by* The State of Washington, Department of Fisheries, in cooperation with the Department of Game, and the United States Bureau of Fisheries. B.M. Brennan, Director of Fisheries. January 1938. 121 pages.

WDOE (Washington Department of Ecology). 2009. Stream flow monitoring network (https://fortress.wa.gov/ecy/wrx/wrx/flows/regions/state.asp)

Wedemeyer, G. 1970. Stress of anesthesia with MS-222 and benzocaine in rainbow trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada 27:909-914.

WFC (Wild Fish Conservancy). 2009. 2009 upper bull trout survey results. Wild Fish Conservancy Northwest, Duvall, WA.

Wootton, R.J. 1990. Ecology of teleost fishes. Chapman and Hall, London. 404 pp.

Personal Communications

DeHaan, Patrick. 2010. USWFS Abernathy Fish Technology Center. E-mails to M. Nelson. April 26, 2010 and March 9, 2010.

Reidel, Jon. 2009. NPS. North Cascades National Park. E-mail to M. Nelson. July 1, 2009.

Appendix A: Angling Effort at Locations in Icicle Creek During 2009.

Overall angling effort

Crews angled for bull trout in Icicle Creek during the spring, summer, and fall in 2009. Angling was conducted on 11 days in the spring period (April 3 to May 29), 24 days in the summer period (July 9 to August 14) and 2 days in the fall period (September 25 and 28). A total of 208.4 angling hours were expended and 46 bull trout were caught for a catch per unit effort of 0.22 bull trout per hour (Table A1). Forty-four of the bull trout were caught in lower Icicle Creek (cpue = 0.3) and two bull trout were caught in upper Icicle Creek (cpue = 0.03). Overall 30 hours of angling were required to catch each of the seven adults that were subsequently tagged. No bull trout were captured during the spring period. Incidental fish species caught included hybrid bull x brook trout, brook trout, rainbow trout, juvenile and adult spring Chinook salmon, and juvenile and adult coho salmon (Table A1).

Table 10. Angler effort, (hours), number of species captured (n), and catch per unit effort (cpue) of bull trout during angling in Icicle Creek during 2009.

angler effort (hours)	BT n (cpue)	BT x BRK n	BRK n	RBT n	SCS n	COH n
208.4	46 (0.22)	1	5	26	12	6

Note: BT = bull trout, BT x BRK = hybrid bull x brook trout, BRK = brook trout, RBT = rainbow trout, SCS = spring Chinook salmon, COH = coho salmon.

Angling effort by season and location

During 2009, no bull trout were caught during 37.5 angler hours in the spring angling period (Tables A2 and A3). Thirty six bull trout were caught during 160.4 angler hours in the summer angling period, including thirty four in lower Icicle Creek (Table A4) and two in upper Icicle Creek (Table A5). Early morning stream temperatures rose above 15° C and prevented angling in the lower river from July 27 to August 5. Angling resumed at the boulder falls on August 5 and in the spillway pool on August 10. During the fall, ten bull trout were caught in the LNFH spillway pool during 14.5 angler hours in lower Icicle Creek (Table A6). Upper Icicle Creek was not angled during the fall.

Table A2. Bull trout catch per unit effort (cpue) at each angling location in lower Icicle Creek during the spring angling period, April 3 to May 29, 2009.

Area name	rkm	Angler effort (hrs)	n Bull Trout	cpue
Corner hole	4.0	2.0	0	0
LNFH spillway pool	4.3	17.8	0	0
Headgate pool	6.1	3.5	0	0
CCC pool	6.3	1.1	0	0
Hatchery intake pool	7.4	4.5	0	0
Boulder Falls pools	9.2	1.0	0	0
Spring totals lower Icicle Creek	***4 - 9.2***	***29.9***	***0***	***0***

Table A3. Bull trout catch per unit effort (cpue) at each angling location in upper Icicle Creek during the spring angling period, April 3 to May 29, 2009.

Area name	rkm	Angler effort (hrs)	n Bull Trout	cpue
IPID pools	9.3	0.7	0	0
Bridge Creek Falls pools	14.3	5	0	0
Group camp	19.3	1.9	0	0
Spring totals upper Icicle Creek	***9.3 – 19.3***	***7.6***	***0***	***0***

Table A4. Bull trout catch per unit effort (cpue) at each angling location in lower Icicle Creek during the summer angling period, July 9 to August 14, 2009.

Area name	rkm	Angler effort (hrs)	n bull trout	cpue
Drift boat lower Icicle	0 - 4.0	5.3	0	0
LNFH spillway pool	4.3	30.9	20	0.65
Historic channel	4.6	3.2	1	0.31
Headgate pool	6.1	15.0	5	0.33
CCC pool	6.3	1.8	0	0
Cedar pool	6.9	7.0	0	0
Hatchery intake pool	7.4	7.6	0	0
Icicle Island pool	8.6	4.3	2	0.47
Boulder Falls pools	9.2	27.6	6	0.22
Summer totals lower Icicle Creek	***0 - 9.2***	***102.7***	***34***	***0.33***

Table A5. Bull trout catch per unit effort (cpue) at each angling location in upper Icicle Creek during the summer angling period, July 9 to August 14, 2009.

Area name	rkm	Angler effort (hrs)	n bull trout	cpue
IPID + Gage pools	9.3 - 9.5	2.0	0	0
Bridge Creek Falls pools	14.3	3	0	0
July 4 falls	18.3	1.5	0	0
Group camp	19.3	5.3	0	0
Debris dam pool	24.9	5	0	0
Log island pool	25	1.3	0	0
Beach pool	25.5	4.6	0	0
Icicle Gorge	26.2	22.6	1	0.04
Rock Island Camp	29.1	8.5	1	0.12
Summer totals upper Icicle Creek	***9.3 - 29.1***	***53.8***	***2***	***0.04***

Table A6. Bull trout catch per unit effort (cpue) at each angling location in lower Icicle Creek during the fall angling period, September 25 to September 28, 2009.

Area name	rkm	Angler effort (hrs)	n bull trout	cpue
LNFH spillway pool	4.3	12.7	10	0.79
Headgate pool	6.1	0.5	0	0
Icicle Island pool	8.6	1.3	0	0
Fall totals lower Icicle Creek	***4.3 - 8.6***	***14.5***	***10***	***0.69***

Icicle Creek discharge during capture dates

All bull trout captured during the summer and fall angling periods were caught when Icicle Creek flows were less than 500 ft^3/s (Figure A1).

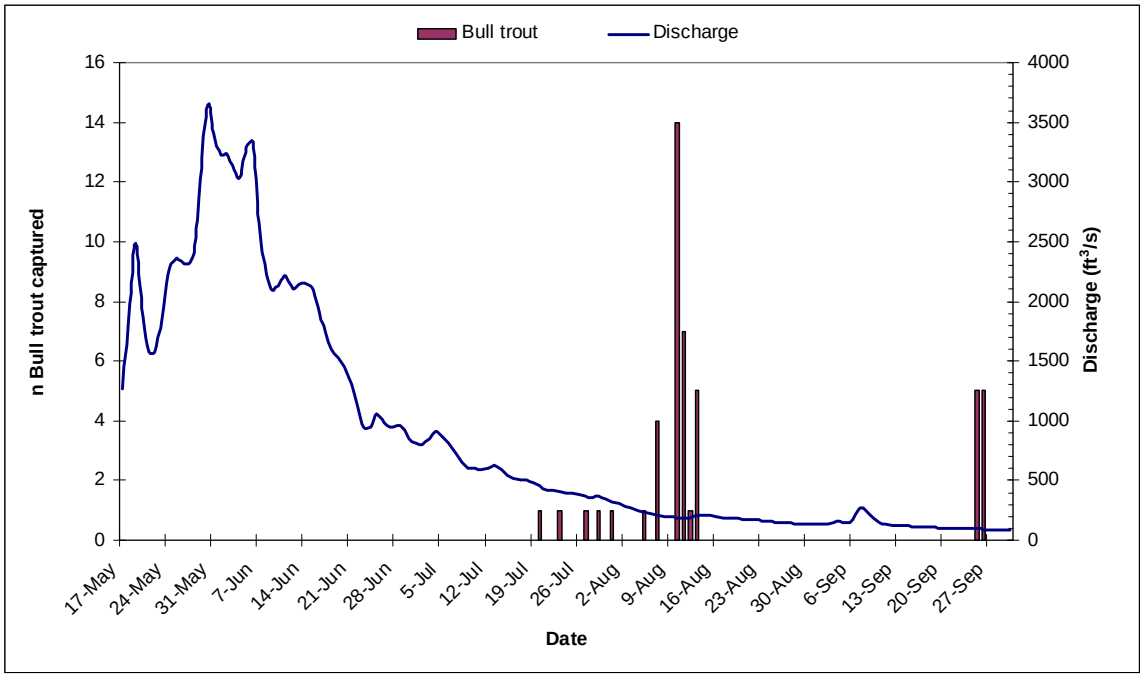

Figure A1. Icicle Creek discharge and dates bull trout were captured during angling in 2009.

Appendix B: Detections of Bull Trout at Fixed Receiver Telemetry Stations in the Wenatchee River Basin During 2009.

TUM station (Wenatchee River rkm 52.6)- Only one bull trout was detected at Tumwater Dam (Table B1). Code 20, tagged in Icicle Creek in 2008, migrated upstream and arrived at the dam on June 29, 2009 at 19:33 hours. Code 20 both arrived and passed the dam during the day. During the upstream passage event, it was detected at the dam for just over 7 hours. It was detected migrating downstream past the dam on September 19 during the night, when the total detection time recorded on the telemetry station was 8 minutes.

Table 11. TUM station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at Tumwater Dam on the Wenatchee River (rkm 52.6).

Code	Station	Direction	Date	Time	Diel period
20	TUM	arrived[a]	06/29/09	19:33	day
20	TUM	upstream	07/22/09	07:16 - 14:24[b]	day
20	TUM	downstream	09/19/09	22:58	night

Notes: a- first detection at dam then detected downstream of dam for 22.8 days; b-times are first detection on downstream antenna and last detection on upstream antenna as moved upstream.

CW station (Chiwaukum Creek rkm 0.1)- Code 20 was the only bull trout detected on this station at the mouth of Chiwaukum Creek (Table B2). It arrived at the station during the day on July 24, but it was not clear from the telemetry data whether it was in the Wenatchee River at the confluence or in Chiwaukum Creek near the station. It was detected by the station until July 27, when it moved upstream in Chiwaukum Creek before sunrise. During its post-spawn migration, code 20 passed the station and exited Chiwaukum Creek on September 18 during the night.

Table B2. CW station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at the mouth of Chiwaukum Creek (rkm 0.1).

Code	Station	Direction	Date	Time	Diel period
20	CW	arrived[a]	07/24/09	09:13	day
20	CW	upstream[b]	07/27/09	05:04	night
20	CW	downstream	09/18/09	20:17	night

Notes: a- recorded in vicinity of station for 3 days; b- last detection as moved upstream in Chiwaukum Creek.

LH station (Icicle Creek rkm 4.3)- Eight radio-tagged bull trout were detected at the LH station monitoring the spillway pool and structure 5 on Icicle Creek during 2009 (Table B3). Seventeen distinct movements were detected and fifteen of the movements occurred at night. Two of the bull trout moved upstream past LH2 at structure 5 (code 95 moved into the historic channel for 1 day and code 97 moved to headgate and held downstream of it for 10 days). The six bull trout tagged in the spillway pool were detected in the pool for 6 to 33 consecutive days before moving. Four bull trout made movements away from the pool but then returned at a later date- code 24 moved to the Columbia River after tagging but returned to the pool and held there for 35 days; code 95 made a short move upstream before moving out of Icicle Creek only to return and hold in the pool for another 8 days; code 98 moved downstream for 8 days before returning and holding for another 17 days; and after spawning in Chiwaukum Creek, code 20 briefly returned to the pool 270 days after it left.

Table B3. LH station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station monitoring the Leavenworth NFH spillway pool and structure 5 on Icicle Creek (rkm 4.3).

Code	Station	Direction	Date	Time	Diel period
24	LH	downstream	7/22/09	Not detected	
24	LH1	arrive back	8/24/09	22:52	night
24	LH	holding	8/24 – 9/28/09		
24	LH	downstream	9/28/09	19:16	night
94	LH1	holding	8/10 – 9/5/09		
94	LH1	downstream	9/5/09	20:07	night
95	LH1	holding	8/11 – 8/19/09		
95	LH2	upstream	8/19/09	22:02	night
95	LH2	downstream	8/20/09	21:10	night
95	LH1	downstream	8/20/09	22:07	night
95	LH1	arrive back	8/31/09	04:39	night
95	LH1	holding	8/31 – 9/7/09		
95	LH1	downstream	9/7/09	03:18	night
96	LH1	holding	8/11 – 9/13/09		
96	LH	downstream	9/13/09	22:59	night
97	LH	holding	9/28 – 10/18/09		
97	LH2	upstream	10/18/09	01:33	night
97	LH2	downstream	10/28/09	02:52	night
98	LH1	holding	9/25 – 10/1/09		
98	LH1	downstream	10/1/09	19:04	night
98	LH1	arrive back	10/9/09	06:37	night
98	LH1	holding	10/9 – 10/26/09		
98	LH1	downstream	10/26/09	00:58	night
99	LH1	downstream	9/28/09	18:44	day
20	LH1	arrive	9/25/09	06:05	night
20	LH1	downstream	9/25/09	17:44	day

HG station (Icicle Creek rkm 6.1)- Two bull trout were detected on the HG station at the headgate on Icicle Creek during 2009 (Table B4). Neither of these bull trout was detected moving upstream past the station and through the headgate. Code 24 was detected in the pool below the headgate for 11 hours after it was tagged on July 20 before it moved downstream during the night. Code 97 was detected from October 21, after it moved upstream in the historic channel from the spillway pool, until October 27. During this period it recorded on the station in 3 separate blocks- on October 21 (for about 14 hours), from October 24 to 26 (for about 55 hours), and on October 27 (for about 1 hour). The strength of the transmitter signal recorded during these blocks indicated code 97 remained downstream of the station and the headgate and did not attempt to pass upstream. During the first detection block, code 97 moved during the night, but during the latter two blocks it moved during the day.

Table B4. HG station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at the Leavenworth NFH headgate on Icicle Creek (rkm 6.1).

Code	Station	Direction	Date	Time	Diel period
24	HG	departed	7/20/09	21:12	night
97	HG	arrived	10/21/09	05:00	night
97	HG	downstream	10/21/09	18:42	night
97	HG	arrived	10/24/09	09:48	day
97	HG	downstream	10/26/09	17:09	day
97	HG	arrived	10/27/09	15:22	day
97	HG	downstream	10/27/09	16:40	day

IC station (Icicle Creek rkm 0.8)- Nine bull trout made 14 different movements that were detected at the IC station at Two Rivers Farm during 2009 (Table B5). All the movements past the station occurred at night. Three downstream movements were recorded before the fall migration. Code 20 exited Icicle Creek on January 6, 2009 and overwintered just downstream of the confluence. Code 24 exited Icicle Creek on July 22, 2 days after it was tagged, and traveled to the Columbia River before returning on August 24. Code 95 left Icicle Creek on August 20 and returned on August 23. After spawning in Chiwaukum Creek, code 20 entered Icicle Creek on September 22 and left again on September 25.

During the fall downstream migration period, tagged bull trout passed the IC station and exited Icicle Creek from September 5 to November 20, 2009. The total time that downstream migrating bull trout were detected at the station ranged from 2 to 38 minutes, with a mean detection time of 9 minutes.

Table B5. IC station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at Two Rivers Farms on Icicle Creek (rkm 0.8).

Code	Station	Direction	Date	Time	Diel period
20	IC	downstream	01/06/09	22:06	night
24	IC	downstream	07/22/09	00:22	night
95	IC	downstream	08/20/09	23:11	night
95	IC	upstream	08/23/09	03:52	night
24	IC	upstream	08/24/09	01:21	night
94	IC	downstream	09/05/09	22:09	night
96	IC	downstream	09/14/09	03:05	night
20	IC	upstream	09/22/09	20:30	night
20	IC	downstream	09/25/09	19:55	night
95	IC	downstream	09/28/09	04:36	night
24	IC	downstream	09/29/09	04:12	night
99	IC	downstream	09/29/09	04:17	night
98	IC	downstream	10/26/09	04:52	night
97	IC	downstream	11/20/09	00:32	night

DD station (Wenatchee River rkm 28.3)- Four bull trout tagged in Icicle Creek during 2009 were detected on the DD station at Dryden Dam (Table B6). All of the detections occurred during the night. In the summer, code 24 was detected when it moved to the Columbia River on July 22 and also when it returned upstream on August 21.

During the fall downstream migration period, detections at Dryden Dam occurred from October 4 to November 28, 2009. Before passing downstream, codes 96 and 24 were detected for 12 and 18 days upstream of the dam, and during several foot tracking sessions the two bull trout were located at the confluence of Peshastin Creek.

Table B6. DD station data: time, date, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at Dryden Dam on the Wenatchee River (rkm 28.3).

Code	Station	Direction	Date	Time	Diel period
24	DD	downstream	07/22/09	23:19	night
24	DD	upstream	08/21/09	02:41	night
96	DD	arrived	10/04/09	04:22	night
96	DD	holding	10/4 – 10/16		
96	DD	downstream	10/16/09	20:01	night
24	DD	arrived	10/06/09	00:09	night
24	DD	holding	10/6 – 10/24		
24	DD	downstream	10/24/09	18:07	night
95	DD	downstream	10/18/09	19:20	night
97	DD	downstream	11/28/09	03:41	night

WR station (Wenatchee River rkm 12.5)- Four bull trout tagged in Icicle Creek in 2009 were detected a total of six times at the WR station at Wenatchee River County Park (Table B7). Code 24 was detected three times as it moved to and returned from the Columbia River in the summer and again as it migrated back downstream in the fall. Four of the six detections occurred during the night.

During the fall downstream migration period, tagged bull trout from Icicle Creek passed the WR station from October 18 to December 5, 2009.

Table B7. WR station data: date, time, direction of travel, and diel period of movement of radio-tagged bull trout detected at the fixed telemetry station at Wenatchee River County Park on the Wenatchee River (rkm 12.5).

Code	Station	Direction	Date	Time	Diel period
24	WR	downstream	07/23/09	03:35	night
24	WR	upstream	08/12/09	12:12	day
96	WR	downstream	10/18/09	04:38	night
95	WR	downstream	10/19/09	03:18	night
24	WR	downstream	10/27/09	08:41	day
97	WR	downstream	12/05/09	20:13	night

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

January 2011