USFWS Mid-Columbia River Fishery Resource Office

Subadult Bull Trout Migrations in Lower Icicle Creek As Revealed by Genetic Stock Identification And PIT Tag Techniques 2005 - 2013

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***On the cover**: A subadult migratory bull trout (223 mm TL) entrained in the water intake system at Leavenworth National Fish Hatchery on Icicle Creek. It was PIT-tagged with code 384.3B239A8B16 and released into Icicle Creek on August 6, 2013. Genetic stock identification assigned this fish to the Chiwawa River local population. USFWS photograph by Matt Hall.*

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SUBADULT BULL TROUT MIGRATIONS IN LOWER ICICLE CREEK AS REVEALED BY GENETIC STOCK IDENTIFICATION AND PIT TAG TECHNIQUES 2005 - 2013

Mark C. Nelson and Patrick DeHaan

Abstract- Bull trout *Salvelinus confluentus* use of lower Icicle Creek has been identified as a high priority research need to inform recovery and management actions. Previous studies used radio-telemetry to gather information on large adults but techniques such as passive integrated transponder (PIT) tags and genetic stock identification (GSI) may be more suitable for subadults. Our objectives in this ongoing study are to: 1) analyze bull trout genetic samples collected from Icicle Creek and use GSI to assign the population of origin; 2) monitor PIT-tagged bull trout to investigate subadult movements and timing; and 3) use the GSI and PIT information to determine whether subadult bull trout are able to access foraging, migrating, and overwintering (FMO) habitat upstream of the Leavenworth National Fish Hatchery (LNFH). A total of 115 putative bull trout were captured and tissue sampled in Icicle Creek from 2005 to 2013 during angling for telemetry studies, entrainment in the LNFH water intake system, or trapped in the LNFH brood stock collection facility. Genetic analysis identified a total of 105 bull trout, three hybrid bull trout x brook trout *S. confluentus x fontinalis*, one brook trout *S. fontinalis*, and six samples did not amplify. Using the baseline genetic profiles developed for the upper Mid-Columbia Recovery Unit, GSI assigned the bull trout to eight distinct populations from three core areas: Chiwaukum, Chiwawa, Icicle, Nason, Etienne, and Ingalls creeks of the Wenatchee Core Area; upper Entiat River of the Entiat Core Area; and Gold Creek of the Methow Core Area. Overall, 85% of the bull trout were less than 450 mm and categorized as subadults. Subadult bull trout that migrated from six populations were identified by GSI upstream of the LNFH intake diversion dam, demonstrating that all hatchery structures were passable under currently undefined streamflow conditions or seasonal windows created by adaptive management and consultation actions at the hatchery. Both GSI and PIT-tagging techniques document the migratory connectivity of lower Icicle Creek with other local bull trout populations and core areas. Movement patterns of Icicle population bull trout differed from those from non-Icicle populations. A total of eighteen bull trout were PIT-tagged in lower Icicle Creek and nine were assigned to the Icicle population. Only one was an adult and it was detected over two years as it entered Icicle Creek in mid or late June and exited in February and November; this timing is consistent with spawning migrations. Only two of the nine tagged bull trout (22%) assigned to the Icicle population were detected moving out of Icicle Creek but at least seven of nine non-Icicle population tagged bull trout (78%) were detected leaving the creek. Fourteen subadult bull trout PIT-tagged at other locations outside of Icicle Creek were detected entering Icicle Creek primarily during two periods: early July to late August or in November. Twenty post-spawning adults tagged at other locations outside of Icicle Creek were detected entering primarily from September through November and in February. Subadult bull trout out-migrating from the Icicle population were entrained in the LNFH water system throughout the monitoring period from April through November, with the majority entrained and rescued in the fall. Thus migratory bull trout from the Icicle as well as other populations are likely present in the lower creek throughout the year. Lower Icicle Creek appears to be important FMO habitat for both subadult and adult bull trout from Icicle and several other local populations from all three core areas in the upper Mid-Columbia Recovery Unit. Uses of this information for fisheries management, hatchery operations, and bull trout recovery are discussed.

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Introduction

Detailed information on all life history stages of bull trout *Salvelinus confluentus* is needed to manage threats and recover them from threatened species status (USFWS 2008). Information has been collected on adult migrations between spawning, foraging, and wintering areas for many of the populations in the draft upper Mid-Columbia Recovery Unit (*see* Nelson and Christopherson 2015) but limited data are available for migratory subadult bull trout.

Bull trout use of lower Icicle Creek is a high priority research need identified in recent years by several agencies, working groups, and management plans interested in providing connectivity for migratory fishes in the watershed. In order to effectively address threats in Icicle Creek, a clear understanding of the foraging, migrating and overwintering (FMO) habitat requirements for different ages or life history stages of bull trout is needed. However, delineation of life stage for migratory bull trout may be subjective and variable across its range, so in this report, a subadult is defined as an immature bull trout that has migrated downstream from its natal area into a larger river system (Mulhfeld and Marotz 2005). Evidence is accumulating that most migratory bull trout in the upper Mid-Columbia River basin do not spawn until greater than 500 mm and thus migratory bull trout less than 450 mm may be best categorized as subadult (Kelly Ringel et al. 2014). This categorization may misclassify some individuals, but allows for investigation of possible differences in how and when FMO habitat is used by different life history stages in the upper Mid-Columbia Recovery Unit.

Radio-telemetry studies indicate lower Icicle Creek can be used year-round by large or adult migratory bull trout from other local populations, including Entiat River (Nelson and Nelle 2008; Nelson et al. 2011, 2012), Chiwaukum Creek (Nelson et al. 2009, 2011, 2012; Kelly Ringel et al. 2014), Nason Creek, and Etienne Creek (Nelson et al. 2011, 2012). As noted in those studies, however, it is difficult to use radio-telemetry techniques on smaller or subadult migratory individuals, due to limitations in battery life and transmitter size, and other techniques need to be used. Recent work in the upper Mid-Columbia River basin has validated the utility of the PIT interrogation site network for monitoring movement patterns of PIT-tagged subadult bull trout out-migrating from the Entiat River (Nelson and Nelle 2013) and genetic stock identification (GSI) for inferring movements of subadults and untagged adults in the Wenatchee River sub-basin (DeHaan and Neibauer 2013). These techniques are readily applied during other fisheries management surveys where bull trout are incidentally captured and sampled, helping reduce costs and maximize limited resources. Furthermore, recent genetic analyses documented relatively low diversity in the spawning population of bull trout in upper Icicle Creek relative to other Wenatchee River local populations (DeHaan and Neibuaer 2013; DeHaan et al. 2014). Using PIT tags and genetic stock identification to gather data on migratory connectivity between local spawning populations in upper Icicle Creek and other Wenatchee River local populations will be useful for evaluating the status of the Icicle Creek bull trout population.

Historically, the migratory fish of principal concern in Icicle Creek has not been the bull trout but rather the spring Chinook salmon *Oncorhynchus tshawytscha*. In the late 1930s, the Leavenworth National Fish Hatchery (LNFH) was built on lower Icicle Creek by the U.S. Bureau of Reclamation as mitigation for the loss of spring Chinook salmon runs caused by Grand Coulee Dam on the Columbia River (Hutton 1940). Initially designed as a low dam with

fish ladders, the later decision to build a high dam eliminated the salmon passage option and necessitated the fast-track construction of a then-modern hatchery complex. This required innovative strategies to solve several technical or environmental problems and included experimental designs in an attempt to successfully rear salmon using artificial and natural techniques (WDF 1938; BOC 1939). When the LNFH was completed in 1940, the natural channel of Icicle Creek was modified to include three large pens that functioned as holding ponds and spawning areas for spring Chinook salmon and steelhead at the hatchery (Hutton 1940). A by-pass canal and water control structure were constructed for flood control and to protect the pens from high water and ice damage. Each pen consisted of a series of diffusion dams, weirs, seining areas, fish lifts, traps, and spawning sheds. The seining areas were created by hauling pit-run gravel to the head of each pen where it was spread uniformly in the creek for ease of seining the ripe salmon as they moved up onto the gravel beds to spawn and the gametes were taken for culture in the hatchery (Hutton 1940). After the spawning season, the weirs and pickets were left in place with the headgate closed (USFWS 1954) and apparently no consideration was given to passage of other fish- perhaps because it was thought at the time that Icicle Creek did not produce significant native runs of salmon or steelhead (Craig and Suomela 1936; WDF 1938; Craig and Suomela 1941). Due to many difficult or unanticipated problems, the concept never lived up to its initial promise (Fish and Hanavan 1947; USFWS 1970; Mullan 1992) and by 1965 the pens and associated structures were disused and deteriorated (USFWS 1965). Although the water control structure was opened and operated intermittently in the 1960s and 70s during WDFW efforts to pass steelhead (USFWS 1964) and in the 1980s during fisheries studies (Mullan 1989; Mullan et al. 1992), by the late 1990s it was typically closed or mostly inoperable and upstream fish passage remained largely impaired (USFWS 2001). To improve passage, the interior diffusion dams and all the weirs were removed in 2003, leaving the water control structure (headgate) and the lowest diffusion dam (structure 5) in place (USFWS 2006) [1]. By 2005, adaptive management of these remaining structures provided more normative stream flows in the historic channel and increased opportunities for fish passage (Hall 2014). Management plans developed during ESA consultations now include actions designed to maintain and increase passage in balance with the operation and maintenance of LNFH and the tribal salmon fishery in Icicle Creek (USFWS 2011). As a result of improved conditions, variable numbers of adult salmon are observed upstream of the hatchery in most years. However, it is uncertain how migratory bull trout have responded to the increased opportunities for passage in lower Icicle Creek.

Our objectives in this study were to: 1) use genetic stock identification (GSI) to analyze bull trout genetic samples collected from various locations in Icicle Creek and assign their population of origin; 2) monitor PIT-tagged bull trout to investigate subadult bull trout migration timing; and 3) use the GSI and PIT information to describe migration patterns to investigate whether subadult bull trout are able to pass LNFH structures and access FMO habitat in Icicle Creek upstream of the hatchery.

[1] In addition to the headgate and structure 5, the pit-run gravel remains at the former head of the pens and the stream banks are not rehabilitated. Because the reach is not yet fully restored to its natural state or function, the terms "historic channel" or" historical channel" are often used to refer to this section of Icicle Creek.

Study Area

The draft Mid-Columbia Bull Trout Recovery Unit includes the Wenatchee, Entiat and Methow core areas (USDI 2010; 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 and Etienne creeks), 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 (Figure 1). Recently, fine-scale genetic analysis indicated that the Peshastin Creek population contains two genetically distinct and thus identifiable subpopulations in Etienne Creek and Ingalls Creek (DeHaan et al. 2014), but for recovery planning are currently a single local population. In this report, however, they are considered two populations.

Icicle Creek originates in Josephine Lake (elevation 1,427 meters) 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, 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 (Gage Station 12458000 Icicle Creek above Snow Creek, near Leavenworth WA; 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/sec; the minimum discharge was 44 ft^3/sec on Nov. 30, 1936 and the maximum discharge was 19,800 ft^3/sec on Nov. 29, 1995 (USGS 2014). Several natural and artificial obstructions to fish migrations occur in Icicle Creek. Among the many natural obstacles are the boulder falls upstream of Snow Creek at rkm 9.2 (Figure 3). In this study, these falls are considered the division between upper and lower Icicle Creek. A high falls upstream of Leland Creek near rkm 47 are judged 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 lower Icicle Creek include facilities associated with the operation of Leavenworth NFH: structure 5 (the last remaining diffusion dam) at rkm 4.4, the water control structure or headgate at rkm 6.1, and the intake diversion dam (shared with Cascade Orchards Irrigation Company) at rkm 7.2 (Figure 3). Management of the hatchery attempts to balance both hatchery operations and fish movements. Structure 5 is kept open except under certain limited circumstances related to the tribal salmon fishery in lower Icicle Creek (USFWS 2006; USFWS 2011). The headgate is open except during brood stock collection or when operated to control flooding and recharge groundwater wells and a fish ladder is operated at the intake diversion dam (USFWS 2006; USFWS 2011). The water intake system, which is not adequately screened at the point of diversion, consists of the diversion dam with an underground pipeline leading to a sand settling basin and then to a screen chamber where water is delivered to the hatchery ponds.

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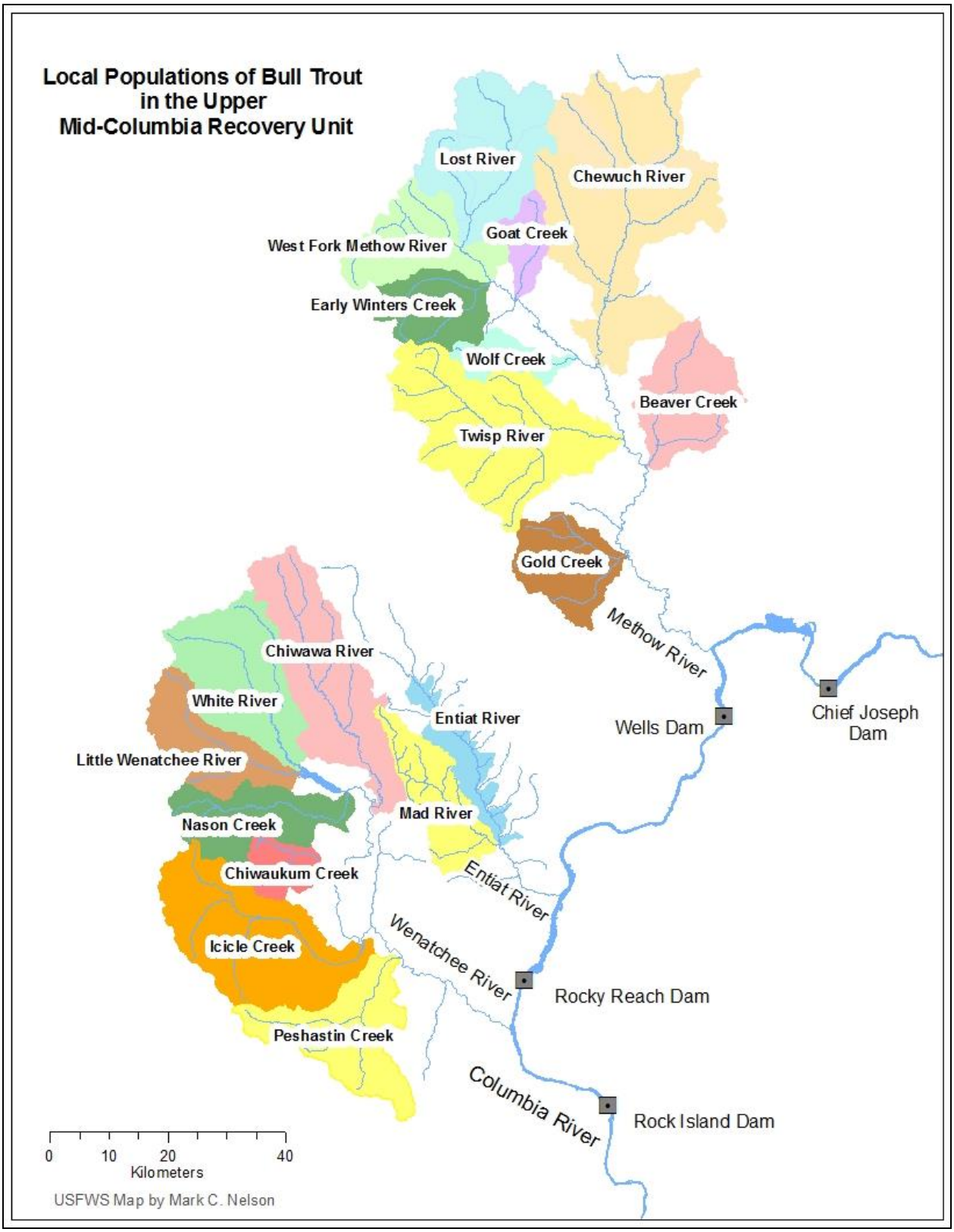

Figure 1. Map of the local populations of bull trout in the Wenatchee, Entiat, and Methow Core Areas of the draft Mid-Columbia Bull Trout Recovery Unit.

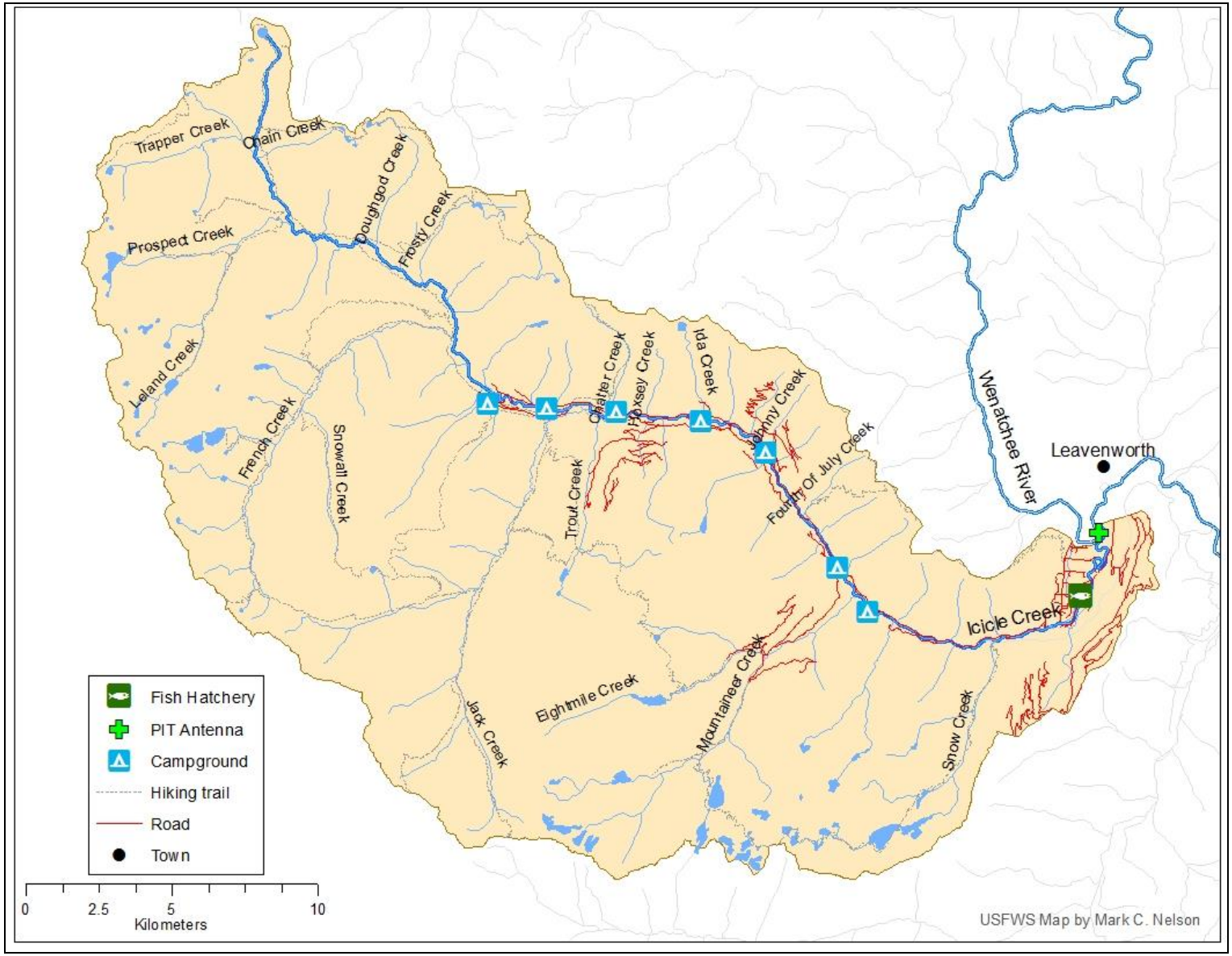

Figure 2. Map of the Icicle Creek watershed.

The Icicle Creek watershed sustains the heaviest recreational use of any watershed within the Wenatchee River subbasin (USFS 1995). Recreational activities include float tubing, 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 2) and several primitive campsites are dispersed throughout the valley. The lower 32 kilometers of the river are accessible by road, and the upper 19 km by trail (Figure 2). Forest Service Road 7600 closely parallels Icicle Creek for much of its route and in some locations prevents the stream from using its floodplain (USFS 1995).

Salmonines known to inhabit Icicle Creek are bull trout *Salvelinus confluentus,* brook trout *S. fontinalis,* westslope cutthroat trout *Oncorhynchus clarki lewisi*, rainbow trout *O. mykiss,* and redband rainbow trout *O. mykiss gairdneri*. Salmonids that have been recorded 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* (Mullan et al. 1992).

Methods

Genetic Stock Identification

From 2005 to 2013, genetic samples were collected by clipping a small piece of tissue from the caudal fin of bull trout encountered during adult and subadult PIT and radio-telemetry studies, snorkel surveys, angling, and entrainment in the LNFH water intake system. (Entrained bull trout are monitored, captured and released back into Icicle Creek per the terms and conditions of the USFWS Biological Opinion on the operations and maintenance of the hatchery (USFWS 2011).) The samples were analyzed by the USFWS Abernathy Fish Technology Center (DeHaan et al. 2014) and the local population of origin was identified using the baseline genetic profiles established for the upper Mid-Columbia Draft Recovery Unit (DeHaan and Neibauer 2013). See DeHaan et al. (2014) for a complete description of the analytical procedures used for genetic stock identification.

Icicle Creek was partitioned into five zones based on LNFH facilities and natural obstacles (Figure 3). Bull trout samples were assigned to a particular zone based on their capture locations and summarized accordingly. **Zone A** includes Icicle Creek downstream of structure 5 (including the LNFH broodstock collection facility and the spillway pool), **Zone B** is the natural or historic channel between structure 5 and the headgate, **Zone C** is between the headgate and the intake diversion dam, **Zone D** is between the intake diversion dam and the boulder falls (including the LNFH water pipeline, sand settling basin, and screen chamber). **Zone E** includes the mainstem Icicle Creek upstream of the boulder falls.

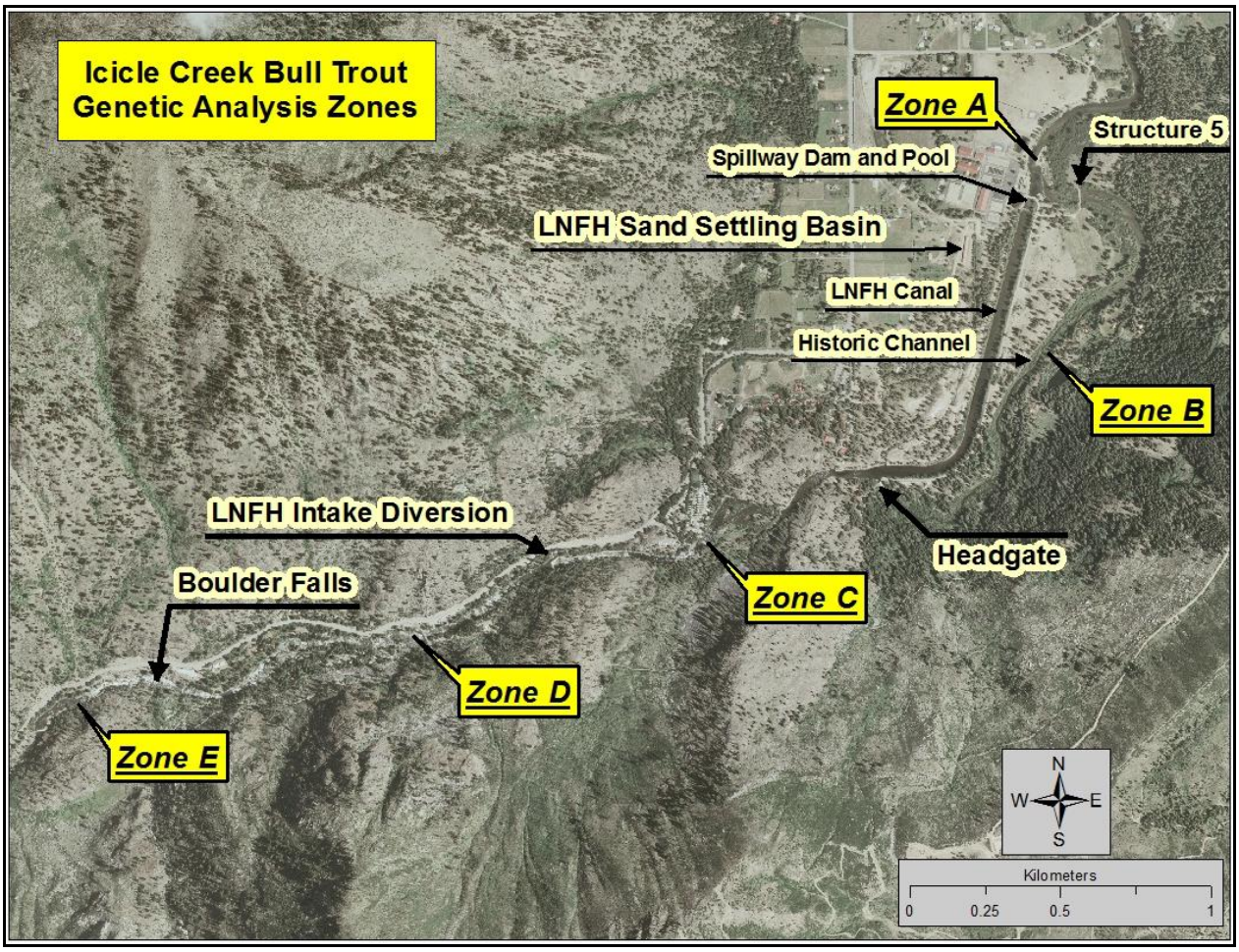

Figure 3. Aerial photograph showing Analysis Zones (A to E) used for genetic stock identification (GSI) to investigate passage of LNFH facilities by subadult bull trout in lower Icicle Creek. In this study, the boulder falls at rkm 9.2 is considered the division between lower and upper Icicle Creek.

PIT tagging

Bull trout entrained in the LNFH water intake system were PIT-tagged from 2011 to the present. Bull trout encountered during angling in 2013 were also PIT-tagged (see Kelly Ringel (2014) for details of the MCRFRO PIT-tagging procedure). Genetic tissue samples were collected from the tagged bull trout. All PIT information was entered in the PTAGIS online database. Queries are conducted on a regular and ongoing basis for incorporation into both small and large-scale movement studies undertaken by MCRFRO to inform planning for bull trout recovery. These queries also incorporated bull trout PIT-tagged at locations outside of Icicle Creek by other agencies, primarily Washington Department of Fish and Wildlife (WDFW). As directed by the PTAGIS policy on data use and ethics (Marvin and Nighbor 2009), the appropriate Tag Data Coordinators were contacted prior to the usage of their PIT data in this report.

Results

Summary of genetic stock analysis and identification

A total of 115 putative bull trout were captured in Icicle Creek from 2005 to 2013. The majority were captured during angling (68%), followed by entrainment in the LNFH water intake system (29%), or trapped in the LNFH broodstock collection facility (3%). The tissue samples were analyzed for genetic stock identification in 2013 (see DeHaan et al. 2014). A total of 105 bull trout from 8 distinct populations were identified. The results are summarized in Table 1.

Table 1. Summary of genetic population assignments for 115 putative bull trout collected downstream of spawning areas in the Icicle Creek watershed during 2005 - 2013.

Zone	Chiwaukum	Chiwawa	Icicle	Etienne	Ingalls	Nason	Entiat	Gold	Brook Trout	Hybrid	No amp
A	29	6	3	1	1	4	4				
B	4	3	3	1		1					
D	8	5	20		1		1	1	1	2	1
E			9							1	5
Total	**41**	**14**	**35**	**2**	**2**	**5**	**5**	**1**	**1**	**3**	**6**

Three hybrid *Salvelinus confluentus x fontinalis* and one brook trout were detected. Two hybrids were collected in Zone D (ID# 352-082: mortality collected from water intake trash rack; ID# 681-001: entrained in water intake and radio-tagged[2]) and one hybrid in Zone E (ID#355-054: angled and radio-tagged[3]). The brook trout was collected in Zone D (ID# 355-002: entrained in water intake) where it was recorded as a bull trout when encountered.

Six individuals amplified at fewer than twelve loci so were not assigned a population of origin.

Population assignment probabilities for all individuals collected in Icicle Creek were greater than 0.9 and all but four fish had assignment probabilities of 1.0. Population assignments by GSI and the associated probabilities for each individual can be found in Appendix 1.

The results for each zone are detailed in the following sections.

Zone A (Downstream of LNFH structure 5)

A total of 46 tissue samples were collected in Zone A of Icicle Creek. Forty-three bull trout were angled from the LNFH spillway pool and three voluntarily entered the LNFH fish ladder and were captured in the broodstock collection facility. Seven populations were identified by GSI, including six from the Wenatchee Core Area and one from the Entiat Core Area. The majority of bull trout were from the Chiwaukum Creek, Chiwawa River, and Nason Creek populations (Figure 4) but only a few assigned to the upper Icicle Creek population. Individuals from both subpopulations in Peshastin Creek were also identified. Eight percent of the bull trout came from the upper Entiat River population.

[2] The identification of hybrid was based on characteristics at tagging (see Appendix 1 in Nelson et al. 2009) but the loci did not amplify so genetic analysis could not confirm the identification.
[3] Nelson et al. 2011.

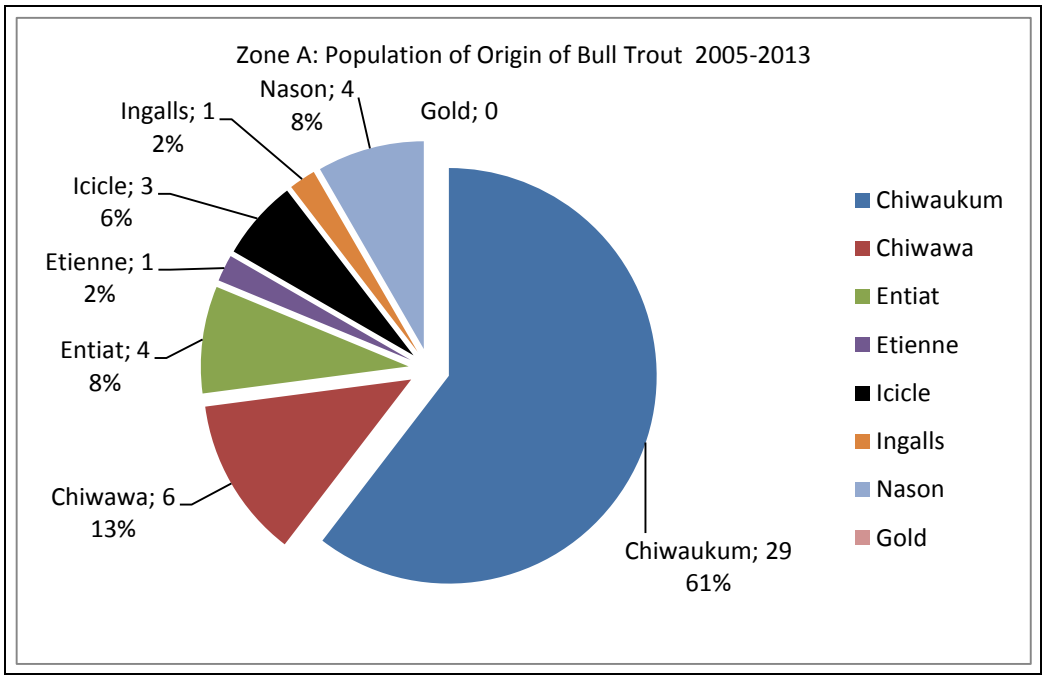

Figure 4. Population of origin as assigned by GSI for bull trout sampled in Zone A of lower Icicle Creek, 2005-2013.

Sizes of bull trout sampled in Zone A ranged from 210 to 755 mm (Figure 5). Seventy-two percent of the bull trout were subadults less than 450 mm. Only two subadults and one adult from Zone A were assigned to the Icicle Creek population (Figure 5). Three bull trout voluntarily entered the LNFH broodstock collection facility and included the largest adult bull trout that was sampled in Icicle Creek (755 mm; Figure 5). GSI assigned this adult to the Icicle local population and the two subadults (200 mm; 310 mm) to Chiwaukum (Figure 6).

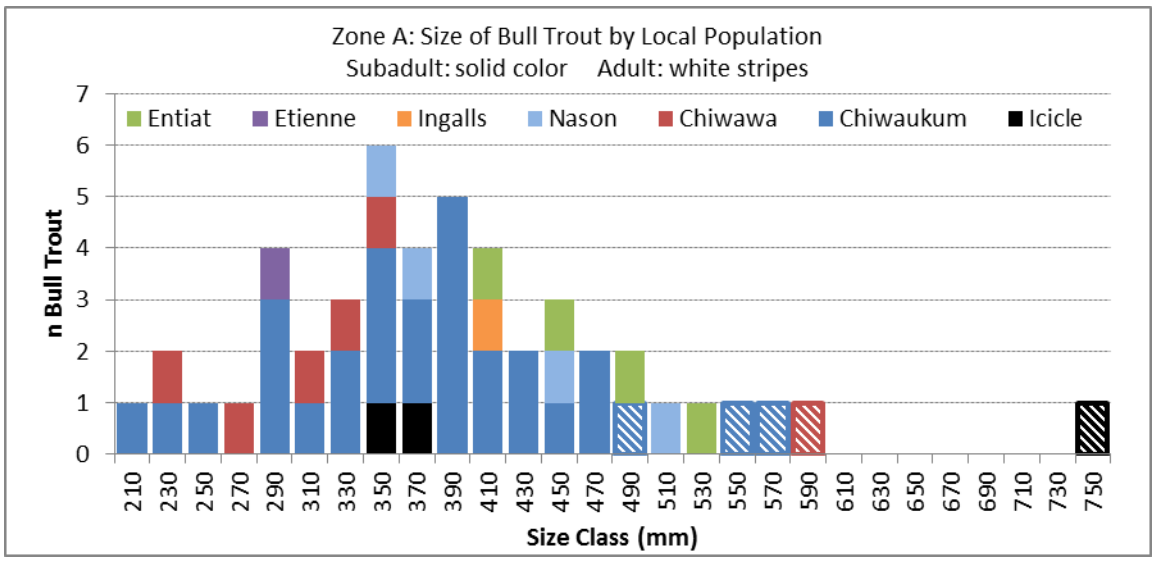

Figure 5. The sizes of bull trout (by local population) sampled in Zone A of lower Icicle Creek, 2005-2013. The white striping indicates that the bull trout was judged a mature adult.

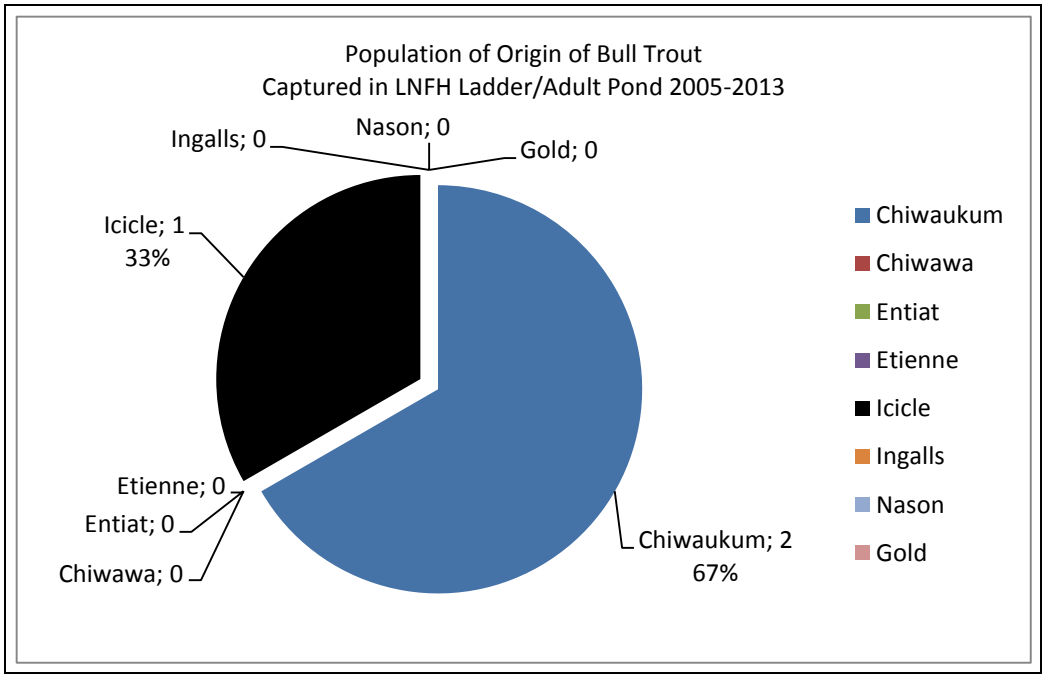

Figure 6. Population of origin as assigned by GSI for bull trout sampled in the Leavenworth NFH broodstock collection facility, 2005-2013.

Genetic assignments of radio-tagged bull trout- Twelve bull trout between 450 and 600 mm were angled in Zone A, categorized as adults, and radio-tagged during telemetry studies from 2008 to 2010 (see Nelson et al. 2009, 2011, 2012). Based on behavior, movement timing, and tracking history, only four of the twelve bull trout were judged to be mature adults at the time of tagging (Figure 5). Seven were eventually tracked to spawning reaches in Etienne Creek (1 fish- 2 spawning seasons), Chiwaukum Creek (4 fish- each 1 spawning season), Nason Creek (1 fish- 2 spawning seasons), and Entiat River (1 fish- 3 spawning seasons) (Figure 7). GSI confirmed those were also their natal populations (Appendix 1) and none of these adults returned to Icicle Creek.

One immature female that was 465 mm when radio-tagged subsequently grew to 600 mm before her first spawn in Chiwaukum Creek one and a half years later (Figure 5; see Nelson et al. 2011).

Five radio-tagged bull trout died or shed their tags before they could be tracked to a local population but GSI assigned their natal populations as Chiwaukum (2 fish), Chiwawa (1 fish), Nason (1 fish), and Entiat (1 fish). A postmortem examination of the Entiat bull trout conducted two weeks after tagging in late summer determined that it was an immature male at 530 mm TL (Figure 5).

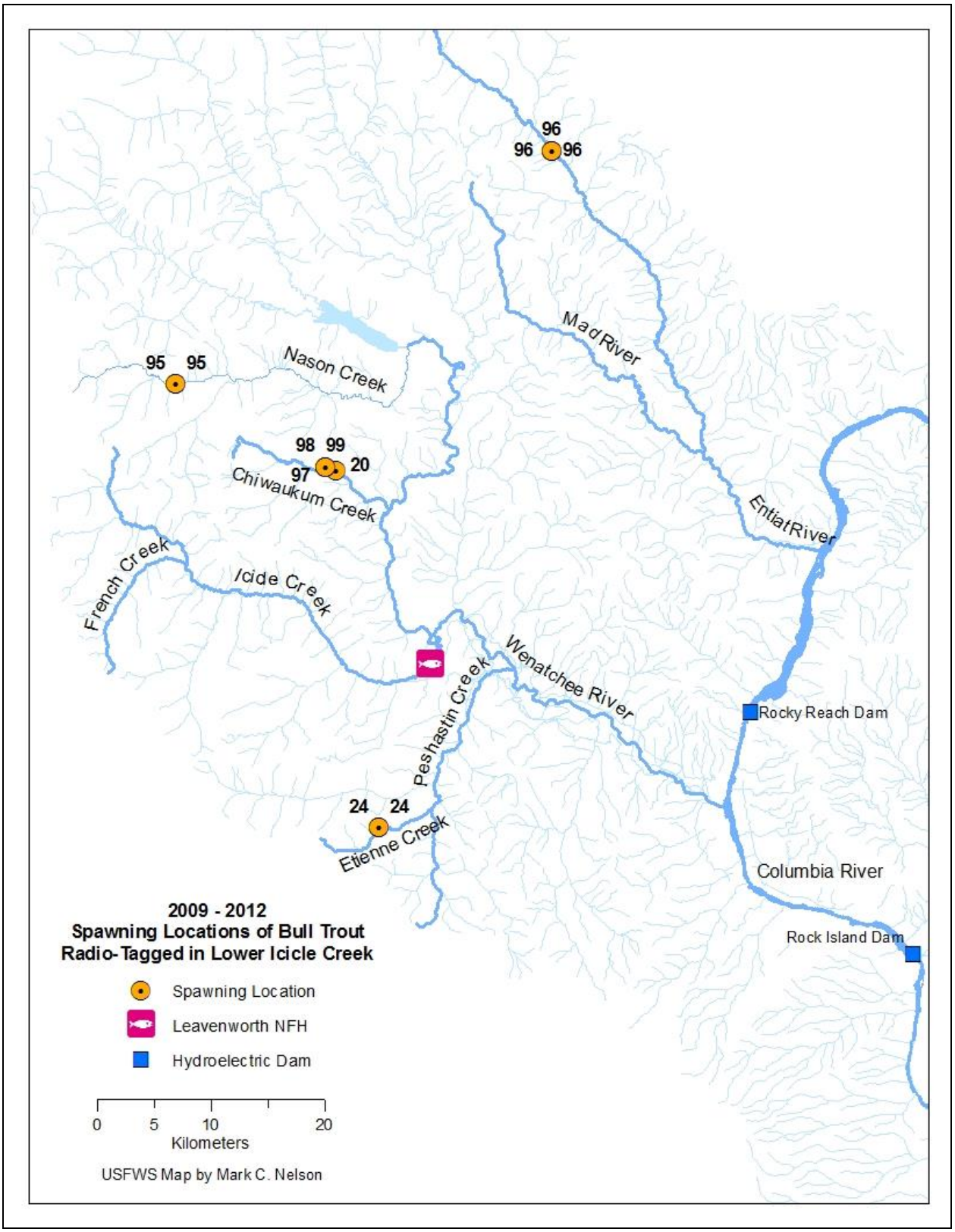

Figure 7. Spawning locations of adult migratory bull trout after radio-tagging in lower Icicle Creek, 2009 – 2012 (the numbers next to the spawning location indicate the radio code of the adult bull trout and duplicate numbers indicate successive spawning seasons for that fish).

Zone B (LNFH structure 5 to headgate)
Twelve bull trout were angled and sampled in Zone B of Icicle Creek. Five populations were genetically identified by GSI (Figure 8). Four bull trout assigned to the Chiwaukum population, three to Icicle and Chiwawa, and one to Nason and Etienne.

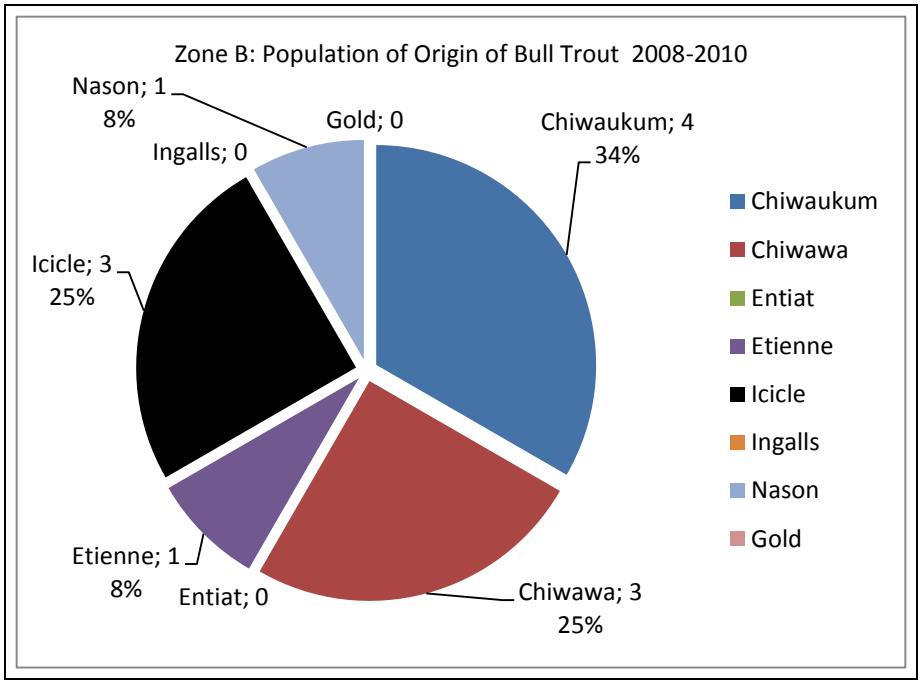

Figure 8. Population of origin as assigned by GSI for bull trout sampled in Zone B of Icicle Creek.

Eleven of the bull trout were subadults less than 450 mm (Figure 9). The adult (code 24; 605 mm when tagged) assigned to the Etienne Creek population and was detected migrating there in the following two years after it was tagged (see Nelson et al. 2011, 2012; Figure 7).

Zone C (LNFH headgate to intake diversion)
No bull trout were captured during limited angling in Zone C of Icicle Creek.

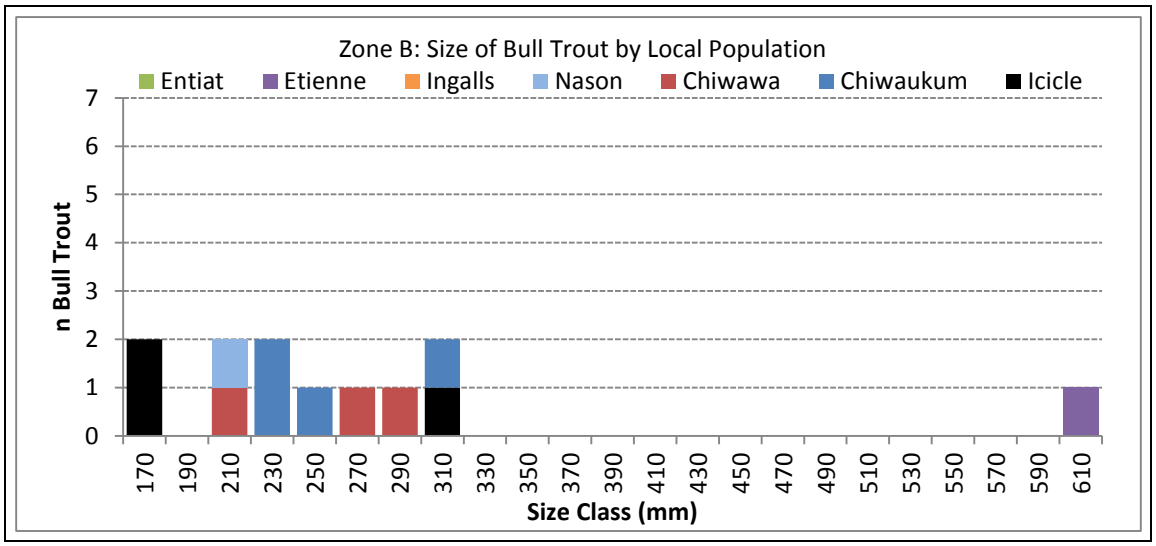

Figure 9. Size of bull trout (in 20 mm classes) from each local population sampled in Zone B of lower Icicle Creek, 2008-2010.

Zone D (Upstream of LNFH intake diversion to boulder falls)

Bull trout in Zone D were either captured by angling in the river or by entrainment into the LNFH water intake system and sand settling basin. A total of 38 tissue samples (7 angled, 31 entrained) were collected in Zone D.

Angling

Seven bull trout were captured and sampled in 2009 while angling in Zone D upstream of the LNFH diversion. Three bull trout were assigned to Chiwaukum Creek and one bull trout each to Icicle Creek, Ingalls Creek, Entiat River, and Gold Creek (Figure 10). These bull trout ranged in size from 200 to 430 mm and thus categorized as subadults (Figure 11).

Entrained

Of the 31 tissue samples collected from individuals entrained in the LNFH water intake system, 29 were typed as pure bull trout and 2 were bull trout x brook trout hybrids. Nineteen of the entrained bull trout were assigned to the Icicle Creek population (66%), five to Chiwaukum Creek (17%), and five to Chiwawa River (17%; Figure 12). Only Icicle bull trout were entrained during five years while multiple populations were entrained during the other three years of the study (Figure 13). The majority of Icicle Creek bull trout were subadults with only two fish categorized as adult (Figure 14). All non-Icicle Creek bull trout were categorized as subadults (Figure 14). Bull trout were entrained during all months of the entire monitoring period in the sand settling basin from April through November. Most Icicle population bull trout were entrained as they out-migrated during the fall but the smallest were entrained during spring and early summer (Figure 15). Bull trout from the other local populations were entrained during late summer and fall sometime after passing the headgate and intake diversion dam.

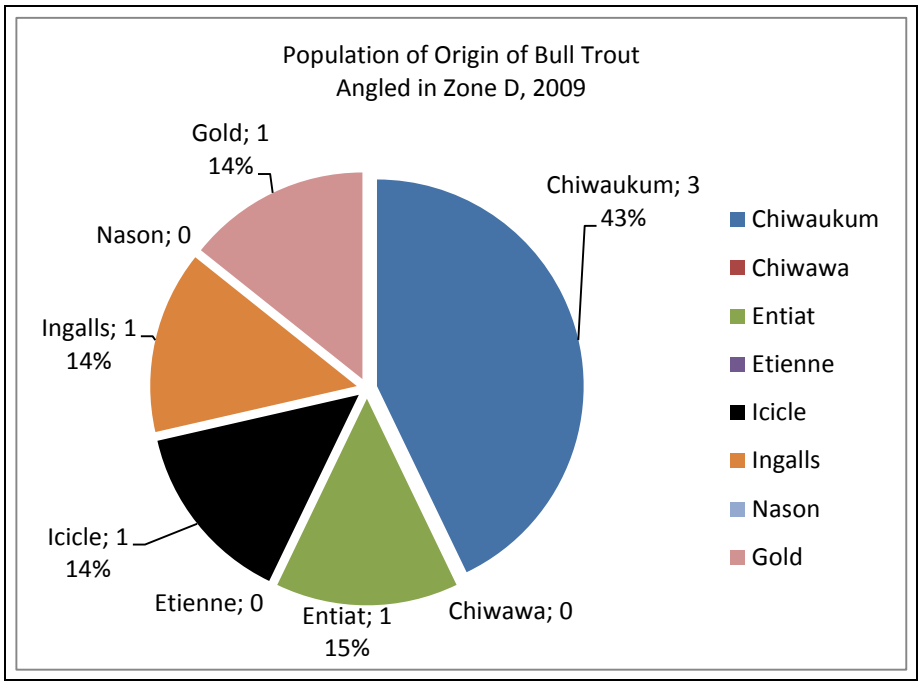

Figure 10. Population of origin as assigned by GSI for bull trout angled in Zone D of lower Icicle Creek.

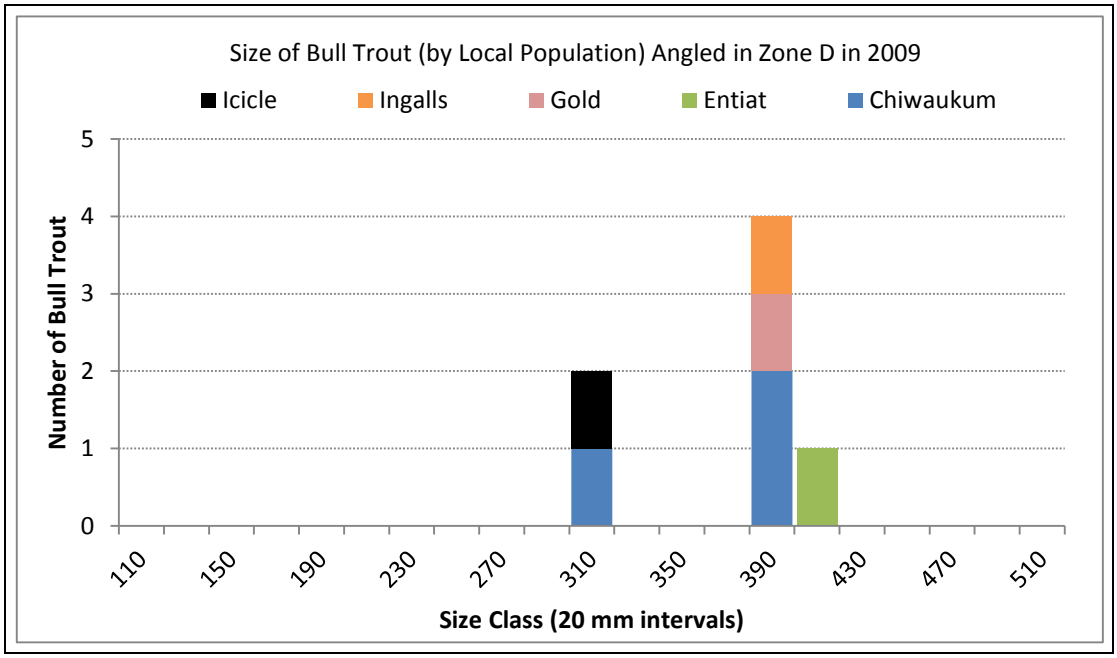

Figure 11. Size of bull trout (by population) angled in Zone D of lower Icicle Creek, 2009.

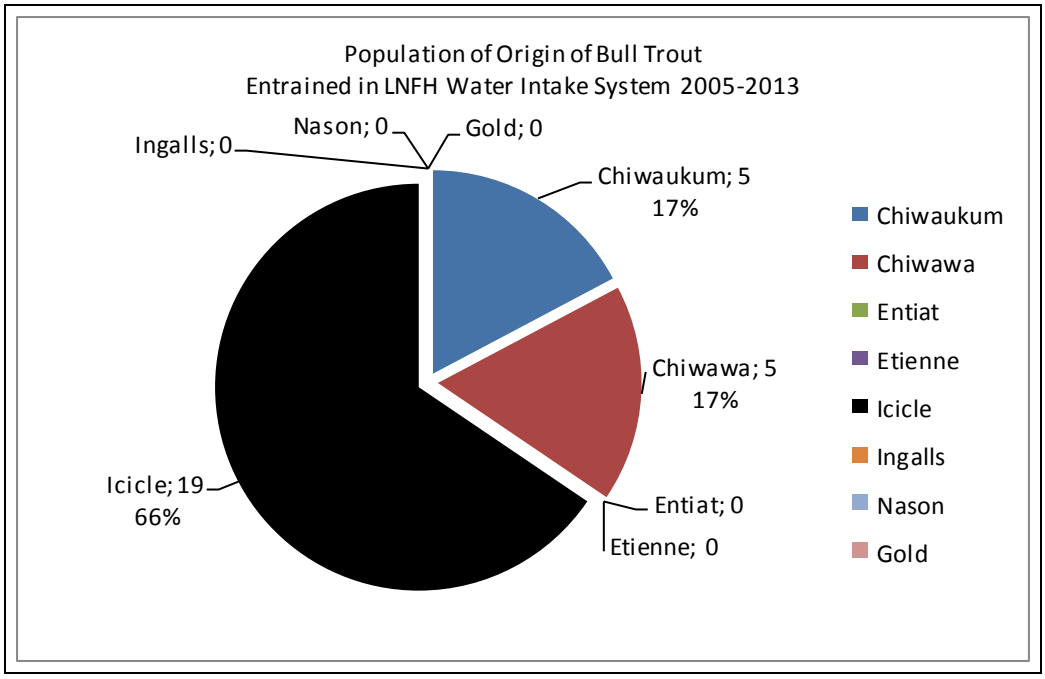

Figure 12. Population of origin as assigned by GSI for 29 bull trout entrained in the Leavenworth NFH water intake system in Zone D of lower Icicle Creek, 2005-2013.

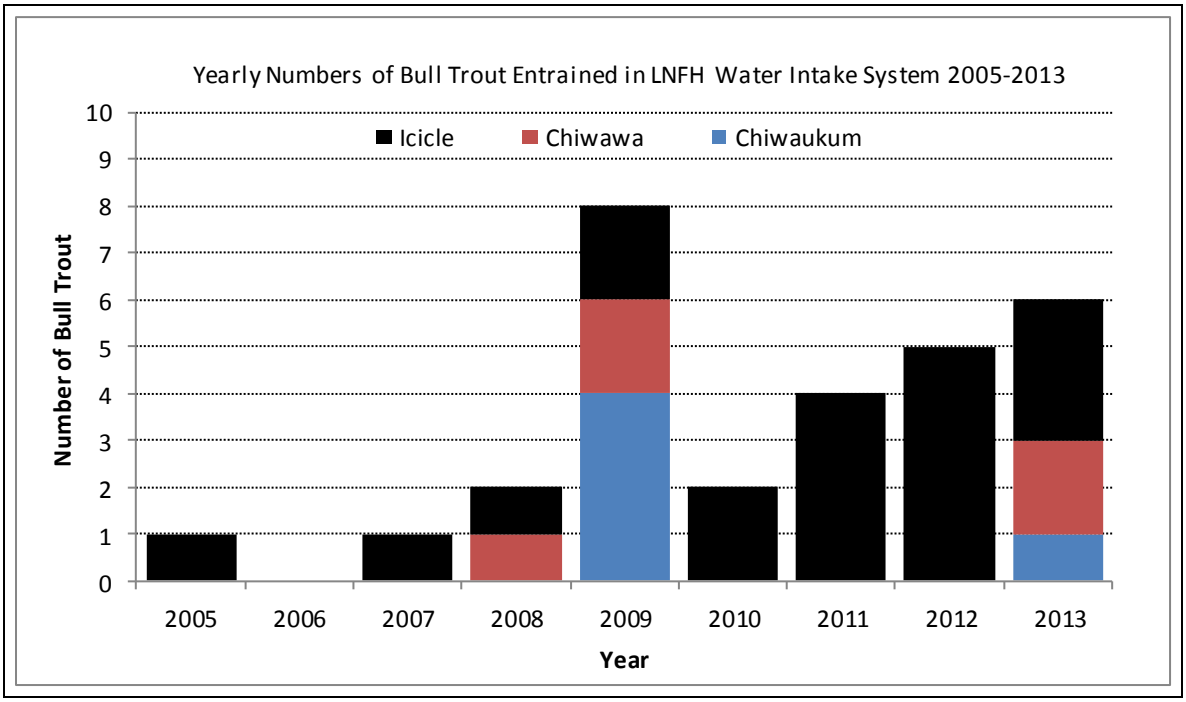

Figure 13. Yearly numbers of bull trout from each population entrained in LNFH water intake system, 2005 - 2013.

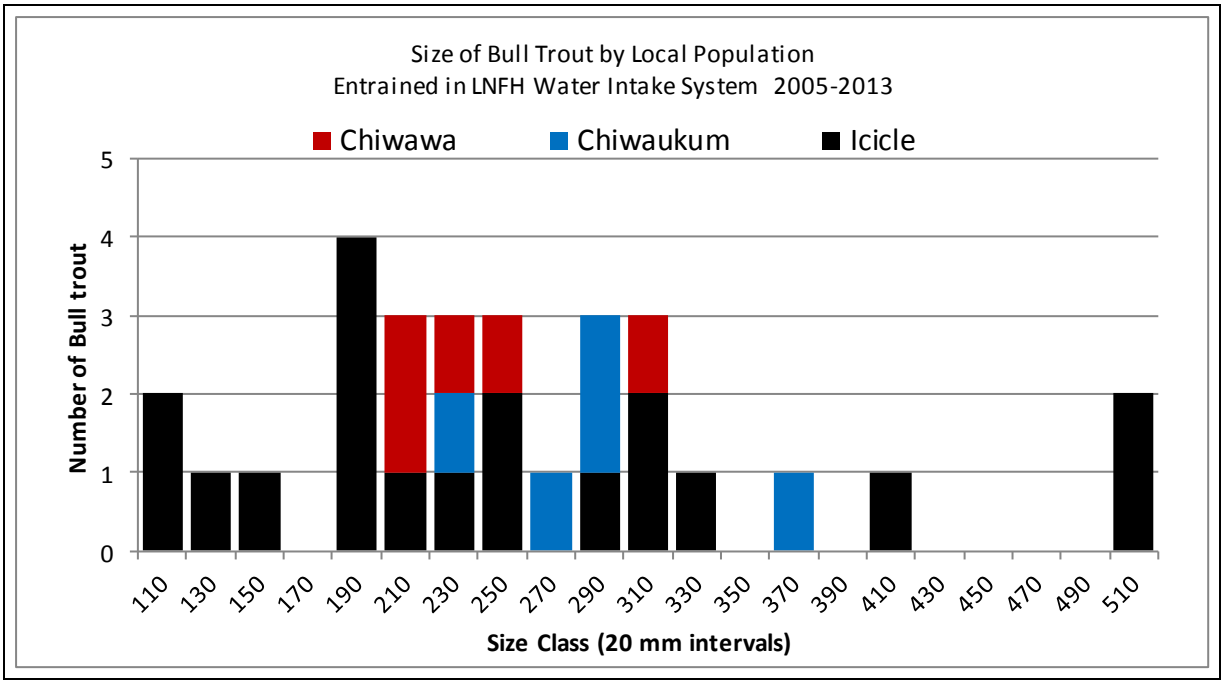

Figure 14. Size of bull trout from each local population entrained in the Leavenworth NFH water intake system in Zone D of lower Icicle Creek, 2005-2013.

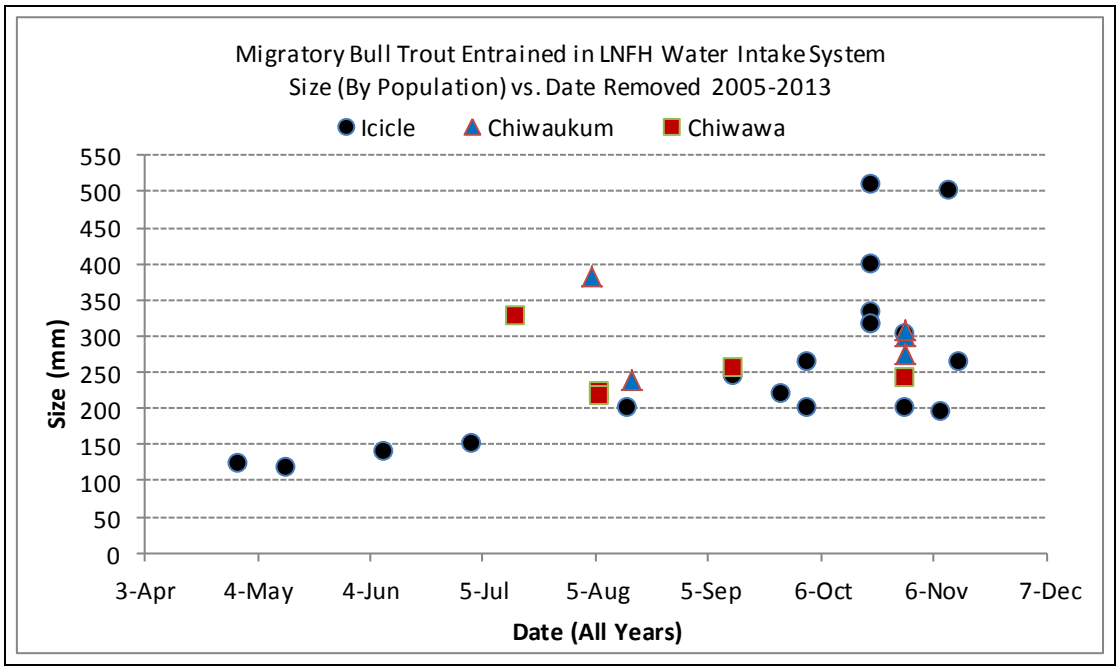

Figure 15. Size of migratory bull trout from the Icicle, Chiwaukum, and Chiwawa populations versus the date removed from the Leavenworth NFH water intake system, 2005-2013.

Zone E (Upstream of boulder falls)

A total of 15 tissue samples were collected and analyzed from mainstem upper Icicle Creek in Zone E upstream of the boulder falls and downstream of known spawning areas. GSI assigned nine samples to the Icicle population, one was a F1 generation hybrid *S. confluentus x fontinalis* (ID#355-054: radio-tagged; see Nelson et al. 2010), and five samples could not be assigned to a population as the loci did not amplify (Figure 16). Eight of the nine Icicle Creek bull trout were subadults ranging in size from 210 to 390 mm TL (Figure 17). One adult (475 mm; ID#681-016) was radio-tagged and spawned in lower French Creek (see Nelson et al. 2009).

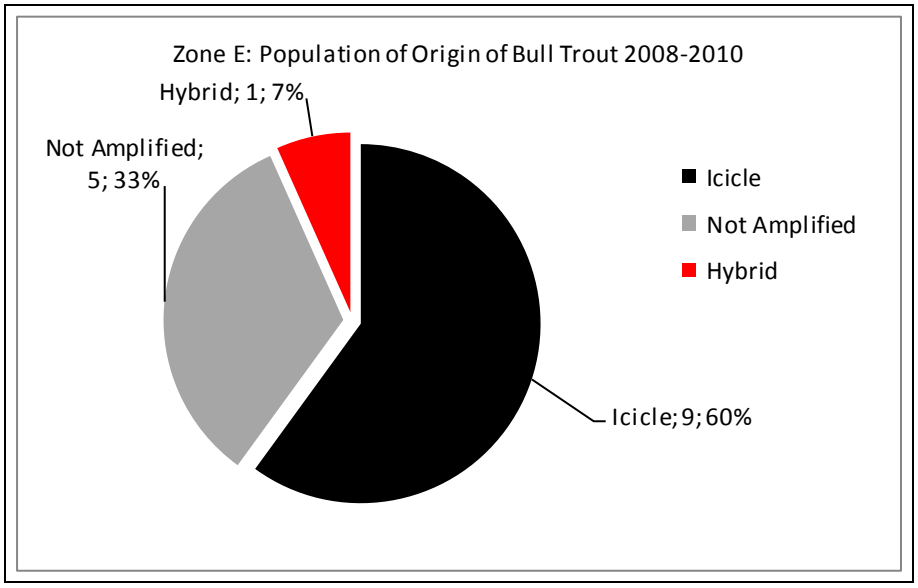

Figure 16. Population of origin as assigned by GSI for bull trout sampled upstream of the boulder falls and downstream of known spawning areas in Zone E of upper Icicle Creek, 2008-2010.

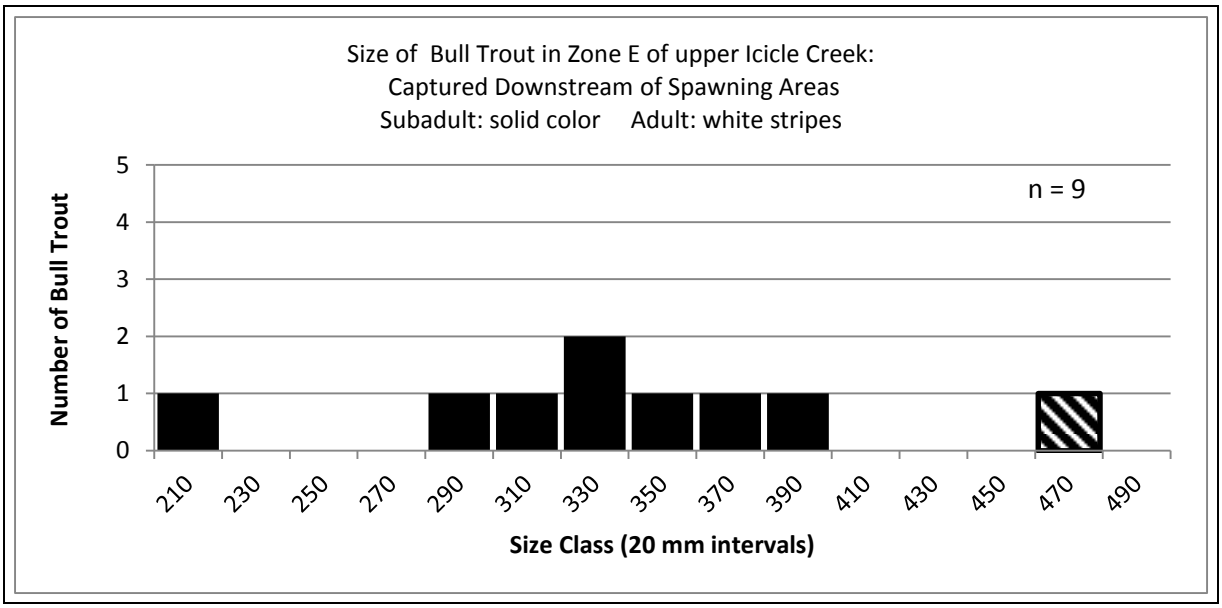

Figure 17. Size of bull trout from the Icicle population sampled downstream of spawning areas in Zone E of upper Icicle Creek.

PIT-Tagging

Summary- PIT tag data was available for 55 bull trout that used lower Icicle Creek (Table 2). Eighteen of the bull trout were tagged by USFWS in Icicle Creek during 2011 to 2013. In 2012, WDFW began to tag bull trout incidentally captured during salmon studies in the Wenatchee River and the number of PIT observations in Icicle Creek increased. Thirty-four bull trout tagged at WDFW traps in the Wenatchee River watershed and 3 bull trout tagged at the USFWS trap in the Entiat River were detected at the ICL array (rkm 0.4) as they entered Icicle Creek (Table 2).

Table 2. Numbers of PIT-tagged bull trout that were tagged or detected in Icicle Creek at the ICL array (rkm 0.4) during 2011 to 2014: Tagging location, capture method, tagging agency, total tags by agency and method, and the year bull trout were tagged.

Tagging River	Capture Method	Agency	Total Tags	Year Tagged:			
				2010	2011	2012	2013
Icicle	Entrained	USFWS	13	--	4	4	5
Icicle	Angled	USFWS	5	--	--	--	5
Entiat	Rotary Trap	USFWS	3	1	--	2	--
Chiwawa	Rotary Trap	WDFW	11	--	--	8	3
Wenatchee	Tumwater Trap	WDFW	22	--	--	11	11
Chiwawa	Weir	WDFW	1	--	--	1	--

Bull trout tagged in lower Icicle Creek

A total of 18 bull trout were PIT tagged in lower Icicle Creek, including 13 entrained in the LNFH water intake system or broodstock collection facility from 2011 through 2013 (Tables 2 and 3) and five bull trout captured during angling in the LNFH spillway pool in 2013 (Tables 2 and 4). GSI assigned nine of the bull trout to the Icicle, five to Chiwaukum, three to Chiwawa, and one to Entiat populations (Tables 3 and 4).

Only one of the bull trout PIT-tagged in lower Icicle Creek was categorized as an adult (Table 3). It was tagged on October 21, 2011 after entrainment and GSI assigned it to the Icicle population. It left during winter and was detected re-entering Icicle Creek in mid or late June in both 2012 and 2013 before leaving in November (Table 5). The only other Icicle-assigned bull trout that was detected leaving the creek was a subadult that left nine months after it was tagged (Table 3). Thus only two of nine Icicle bull trout (22%) were detected as they moved out of Icicle Creek. In contrast, at least seven of nine non-Icicle bull trout (78%) were detected either as they passed the ICL antennas (rkm 0.4) or another array in a different river (Tables 3, 4, and 6).

Five of the bull trout from non-Icicle populations were detected at arrays outside of Icicle Creek (Table 6). Two subadult bull trout were detected at the PES array on Peshastin Creek (rkm 3), including one Chiwaukum-assigned fish that entered and left Peshastin Creek during two consecutive years. Three of the non-Icicle subadult bull trout returned to Icicle Creek during the following summer after tagging (Table 6). Only one bull trout matured and migrated to the spawning area of its local population in the year(s) after it was tagged (Chiwaukum; Table 6).

Table 3. Bull trout entrained in the LNFH Water Intake System or Broodstock Collection Facility that were PIT-tagged by USFWS in lower Icicle Creek: tag ID, GSI population assignment, total length (TL mm), release date, and date detected at ICL array in Icicle Creek or PES array in Peshastin Creek.

PIT Tag #	GSI Population	TL (mm)	Release Date	Down ICL
3D9.1C2D98CAAB	Icicle	510	10/21/11	2/10/12
3D9.1C2D98D92A	Icicle	334	10/21/11	--
3D9.1C2D98033E	Icicle	400	10/21/11	--
3D9.1C2D943437	Icicle	235	10/21/11	--
384.3B23B1C2E3	Icicle	220	09/26/12	--
384.3B239A7FE4	Icicle	265	10/02/12	--
384.3B239A9E0D	Icicle	201	10/02/12	7/21/13
384.3B239A5E42	Icicle	195	11/09/12	--
384.3B2399ACC1	Icicle	151	07/03/13	--
384.3B239A35A7	Chiwaukum	198	07/11/13	--
384.3B239A7B41	Chiwawa	218	08/07/13	missed[a]
384.3B239A8B16	Chiwawa	223	08/07/13	8/14/13
384.3B239A1F40	Chiwaukum	238	08/16/13	8/17/13

Note: a- was detected at another array in a different river; see Table 6.

Table 4. Bull trout angled and PIT-tagged in lower Icicle Creek by USFWS in 2013: PIT tag ID, GSI population assignment, total length (TL mm), release date, and date detected moving downstream past the ICL array (rkm 0.4).

PIT Tag #	GSI Population	TL (mm)	Release Date	Down ICL
3D9.1C2C50838E	Entiat	442	9/5/13	9/10/13
3D9.1C2C4F8980	Chiwaukum	325	9/5/13	--
3D9.1C2C50A0EA	Chiwaukum	400	9/5/13	9/13/13
3D9.1C2C50F967	Chiwawa	334	9/5/13	9/8/13
3D9.1C2C5038B5	Chiwaukum	384	9/5/13	missed[a]

Note: a- was detected at another array in a different river; see Table 6.

Table 5. Detection history for the single adult bull trout that was entrained in the LNFH water supply system and PIT-tagged: PIT tag ID, GSI population assignment, total length (TL mm), release date, and dates detected during downstream and upstream movements past the ICL array in lower Icicle Creek (rkm 0.4).

PIT Tag #	GSI Population	TL (mm)	Release Date	Up ICL	Down ICL
3D9.1C2D98CAAB	Icicle	510	10/21/11		2/10/12
				6/30/12	
				6/12/13	11/19/13

Table 6. Detection histories for non-Icicle population bull trout PIT tagged in lower Icicle Creek and subsequently detected elsewhere or returned to Icicle Creek: PIT tag ID, GSI population assignment, date detected moving upstream or downstream at Rock Island Dam (RIA), Icicle Creek (ICL), Peshastin Creek (PES), Tumwater Dam (TUF), and Chiwaukum Creek (CHW).

PIT Tag #	GSI Population	Up RIA	Up ICL	Down ICL	Up PES	Down PES	Up TUF	Up CHW	Down CHW
…1F40	Chiwaukum			8/17/13	8/20/13 7/20/14	10/29/13 9/14/14			
…A0EA	Chiwaukum			9/13/13					
			3/3/14 6/28/14	6/23/14					
…38B5	Chiwaukum			missed			7/4/14	7/11/14	9/27/14
…7B41	Chiwawa			missed	8/11/13	9/6/13			
…F967	Chiwawa			9/8/13					
			7/15/14	8/6/14			8/10/14		
…838E	Entiat			9/10/13					
		6/18/14	7/15/14						

Bull trout tagged at locations outside of Icicle Creek

A total of 37 bull trout PIT tagged at locations other than Icicle Creek have been detected at the ICL array. Fourteen were subadults tagged at rotary screw traps in the Chiwawa River (n = 11) or Entiat River (n = 3) and 23 were adults tagged at Tumwater Dam (n = 22) or Chiwawa River weir (n = 1) by WDFW. (Genetic stock identification has not been conducted on these PIT-tagged bull trout so the populations of origin are not known.) During 2012 to 2014, the majority were first detected in lower Icicle Creek from July 5 to November 14 (Figure 18) with the exception of two adult bull trout that were detected at ICL during the winter on February 21 and 23, 2014.

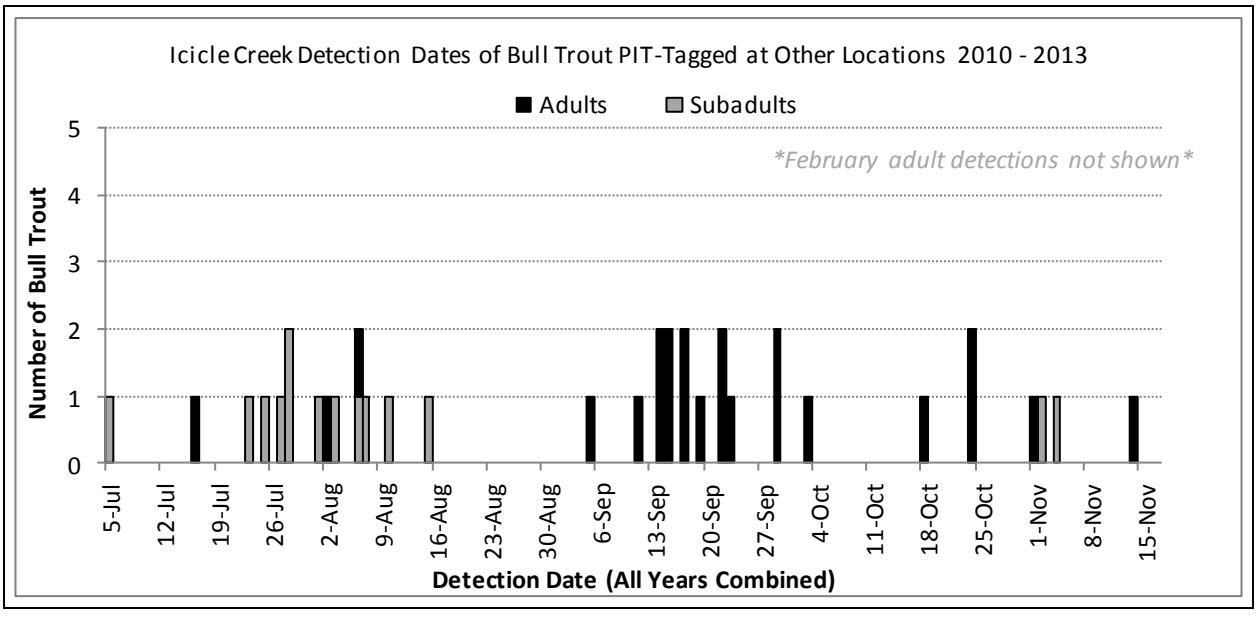

Figure 18. Icicle Creek detection dates during summer and fall of subadult and adult bull trout PIT-tagged elsewhere during 2010-2013 (does not include two adults detected in late February).

Most subadult bull trout entered Icicle Creek in July and August (Figure 18), with foraging the most likely use (Figure 19), and spent on average 87.4 days (n = 14, range 0.21 to 257 d, SD = 113.9) in lower Icicle Creek before moving back to the Wenatchee River. A few adult bull trout entered Icicle Creek for foraging in mid-summer, but the majority were detected in the fall (Figure 18) after they had spawned elsewhere, including Chiwaukum Creek or Chiwawa River and it tributaries Chikamin and Rock creeks (Figure 20).

Subadult bull trout use of FMO habitat before entering Icicle Creek appeared to be based on seasonal patterns of outmigration from rearing areas. Subadults outmigrating from their natal stream in the fall used FMO habitat in the Wenatchee River for an average of 281.5 days before entering Icicle Creek the following summer (n = 6; range 263-303 d; SD = 13.6 d). In contrast, subadults tagged in their natal stream that were then detected at ICL in same season or the next season (i.e. fall-fall, spring-summer, summer-summer) used FMO habitat in the Wenatchee River on average 59.2 days before entering Icicle Creek (n = 6; range 5-152 d; SD = 52.1). Subadults tagged in fall that then used FMO habitat elsewhere for several seasons averaged 649.5 days before detection at ICL (n = 2 (1 Chiwawa, 1 Entiat); range 646-653 d).

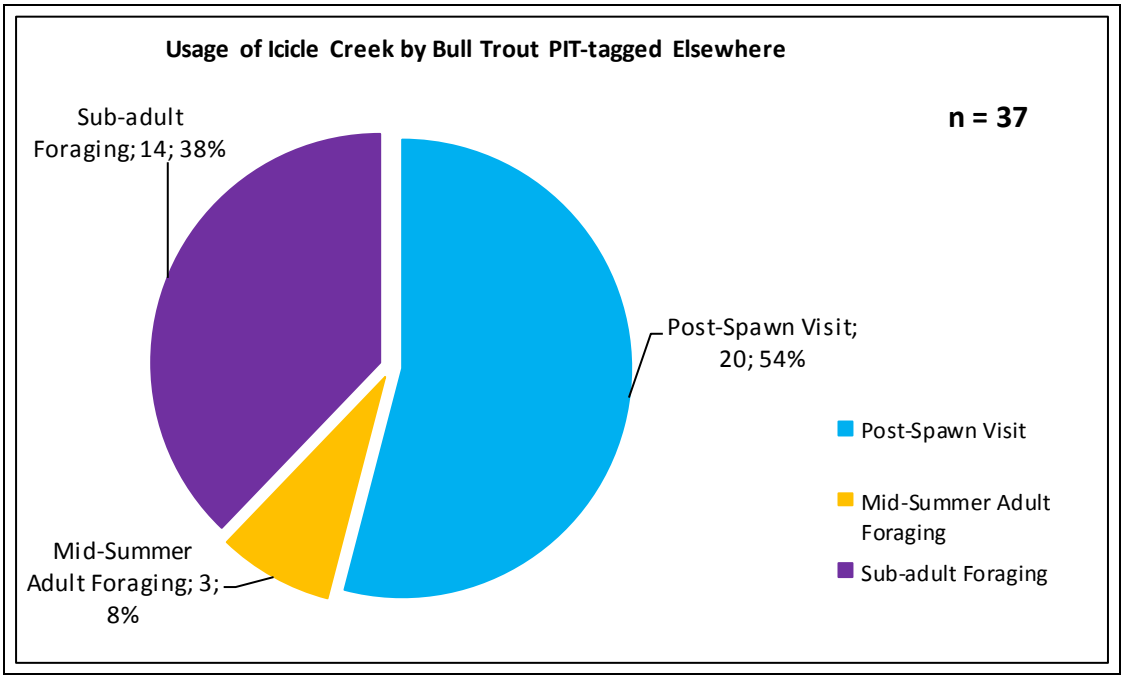

Figure 19. Icicle Creek use by bull trout PIT-tagged at locations other than Icicle Creek, 2010-2013.

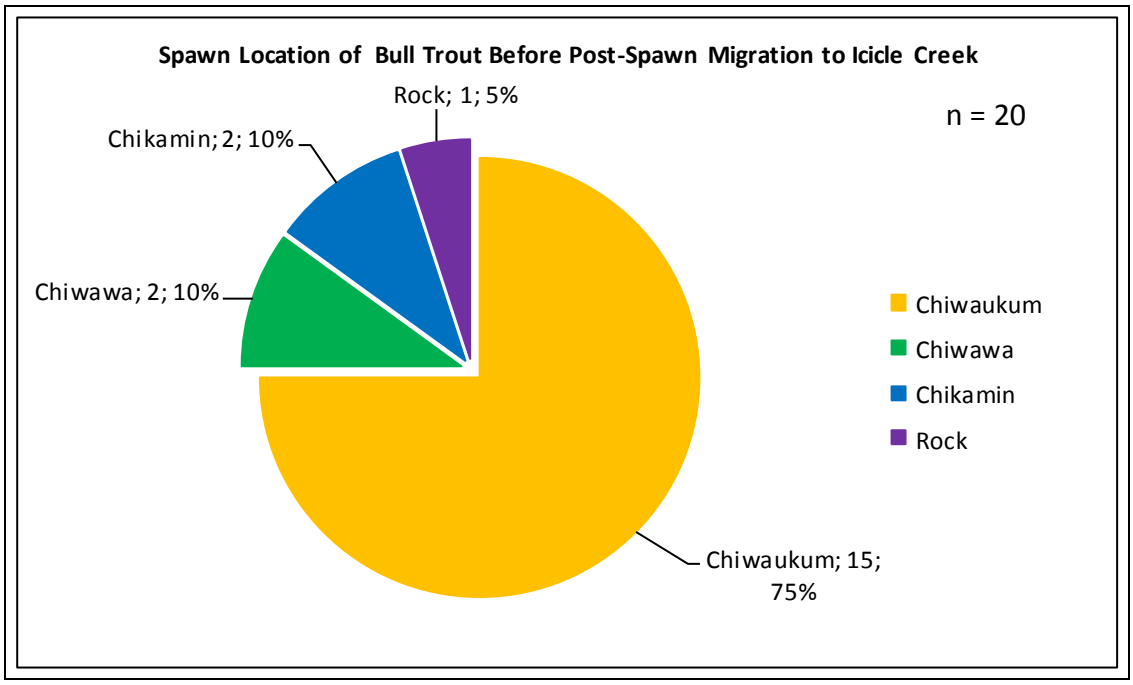

Figure 20. Spawn location of adult bull trout PIT-tagged at locations other than Icicle Creek before post-spawn migration to Icicle Creek.

Discussion

Lower Icicle Creek provides foraging, migrating, and overwintering habitat for subadult and adult bull trout from at least eight local populations and from all three core areas of the upper Mid-Columbia Recovery Unit (MCRU). There are other places in the upper MCRU where bull trout populations are known to similarly commingle but these are usually in large connecting waters such as the Columbia River, lower Methow River, lower Wenatchee River, or Lake Wenatchee (BioAnalysts 2004; Nelson and Nelle 2008; Nelson and Johnsen 2012; Nelson 2014; Kelly Ringel et al. 2014). Applying the relatively noninvasive techniques of GSI and PIT-tagging in a small focal area of Icicle Creek increased our understanding of subadult bull trout migration patterns on several scales. The complexities of bull trout use of lower Icicle Creek highlight some of the challenges inherent in threatened species recovery, ESA consultations, and fisheries management actions. Many of our perceptions about subadult bull trout migration in the upper MCRU may rely on incomplete or possibly outdated information, including from studies outside the area. It is important, therefore, to gather and use local data during recovery actions, consultation processes, and fisheries planning whenever possible. This may provide a balanced approach to develop solutions to complex fish passage issues.

By using genetic stock identification on bull trout sampled in the creek, our results document that the migration corridor in lower Icicle Creek is connected with the stream network of the upper Mid-Columbia basin. ESA consultation coupled with adaptive management of LNFH resulted in improved passage conditions at the hatchery and structure 5, the headgate, and the intake diversion dam are now all passable by subadult bull trout under some movement windows. In contrast, a modeling exercise conducted without gathering local data concluded that the LNFH headgate is completely impassable by subadult bull trout (Anglin et al. 2013), but the authors note their analysis is a mathematical concept constructed on several assumptions and their conclusion should not be interpreted that the structures are not passable in reality. The fact that bull trout from Gold Creek, Entiat River, Ingalls Creek, Chiwawa River, and Chiwaukum Creek were captured upstream of the LNFH facilities proves that the structures are negotiable by migratory bull trout of several sizes and age classes.

GSI has documented that bull trout as small as 220 mm are able to pass the LNFH structures. The sample size is small and the environmental conditions and timing that facilitate subadult bull trout passage are not specifically known. However, some general movement information on small fish was gathered during three seasons of monitoring adult Chinook salmon passage at the headgate, where a DIDSON camera recorded that fish smaller than 400 mm (n = 37) passed at flows less than 1100 ft^3/s and most (92%) passed at less than 600 ft^3/s (Hall 2014). The monitoring periods occurred only in June and July and the species could not be identified, so in addition to body size, other factors such as peak discharge, run timing, and population-specific behavior may influence passage of subadult bull trout. The PIT interrogation network in Icicle Creek was recently expanded to include antenna arrays above the hatchery and additional tagging could help define the passage windows. Additional site specific data from known local populations is vital in order to accurately monitor and manage the effects of hatchery structures on bull trout in Icicle Creek.

Genetic stock identification demonstrates some of the difficulties inherent in ESA consultations intended to minimize take of bull trout. For instance, the USFWS Biological Opinion on Operations and Maintenance of LNFH (BO) requires a reasonable and prudent measure to minimize and monitor the impacts of incidental take of the bull trout caused by impaired upstream passage conditions for migratory bull trout at structures 2 and 5 (RPM #1, USFWS 2011). To implement this measure and help increase passage opportunities, the BO mandates that the headgate remain open when feasible to minimize the period of impairment and increase passage opportunities for migratory bull trout (T&C #1, USFW 2011). This is a crucial condition, particularly for Icicle Creek bull trout, and the mandated terms demonstrably improved passage. An unintended consequence, however, was an overall fifty percent increase in entrainment through take on two other populations- Chiwaukum Creek and Chiwawa River- that may not have accessed that area without the open headgate. Because the migration corridors between most bull trout populations in the upper MCRU are connected, implementation of RPM #1 can affect not only the Icicle Creek population but potentially individuals from all populations in the upper MCRU. Given the extensive migrations of subadult and adult bull trout documented in the recovery unit to date, almost all hydro- or stream-related activities throughout the upper MCRU have similar potential. In our study, for example, the subadult bull trout from Gold Creek was exposed to multiple potential threats during its 185 km long migration as it moved downstream in the Methow River, passed downstream through two Columbia River hydroelectric dams, moved upstream in the Wenatchee River past Dryden Dam, entered Icicle Creek, and passed the LNFH headgate and diversion dam before it was caught upstream.

Effectively managing threats and the take of bull trout will require local data and adaptive actions in consultation and management plans. The results of the GSI indicate that fish screening at the LNFH intake should be a high priority as entrainment results in the highest incidental take of bull trout from several populations. Ideally, the screening should be fixed to modern compliance before additional passage actions are undertaken at other hatchery structures. Then possible improvements such as fishways at the headgate and intake diversion could be developed, with options such as a vertical slot ladder designed for salmonids; a notched pool and weir more suitable for a wider range of species; a roughened channel to mimic more natural conditions; or even removal of the headgate altogether.

The stream corridor at LNFH is passable during at least some of the migration season and our study documents that bull trout from Icicle and other local populations can reach the boulder falls at rkm 9.2. Another modeling exercise concluded that those falls are passable for adult bull trout using certain routes at low flows (Dominguez et al. 2013). Large migratory bull trout are observed upstream of the boulder falls (Nelson et al. 2009) but to date, genetic stock identification has not detected the recent signature of any outside populations in the bull trout sampled in upper Icicle Creek downstream of spawning areas or in the leave-one-out analysis of the Icicle population conducted for the population baseline (DeHaan et al. 2014). In order to maintain genetic fitness, gene flow with occasional emigrant bull trout from other populations is needed (Whitesel et al. 2004). It has been yet been confirmed whether actual passage of the boulder falls obstacle is possible, but the exploratory behavior of migratory bull trout of several size and age classes documented in the upper MCRU indicates gene flow from other populations could eventually occur. Surveys for bull trout in the upper Icicle have been expanded (Nelson and Sulak 2013; Nelson 2015) and an outside population influence may be detected by GSI or

PIT techniques. Genetic sampling should occur in combination with tagging in order to accurately document and interpret the movement patterns expressed by bull trout from known local populations.

Genetic stock identification was also useful in verifying our categorizations of the life history stage of migratory bull trout encountered downstream of spawning areas. The majority of bull trout encountered in lower Icicle Creek were categorized as subadults based on our local size criteria of 450 mm and GSI assigned most of these to non-Icicle populations. Given that most tagged bull trout in the upper MCRU exhibited fidelity and returned to spawn in their natal area (Nelson et al. 2007; Nelson and Nelle 2008; Nelson and Nelle 2013; DeHaan and Neibauer; Nelson 2014; Kelly Ringel et al. 2014), the fact that these non-Icicle bull trout were using lower Icicle Creek during the pre-spawning or spawning seasons but were not detected moving to their natal areas indicates they were immature individuals. However, the size criteria should not be considered absolute as bull trout larger than 450 mm sampled in lower Icicle Creek were confirmed as immature although we categorized them as adult, including a male (530 mm, Nelson et al. 2011) and a female (grew from 460 mm to 600 mm before first spawn, Nelson et al. 2012). Conversely, it is probable that some individuals of either sex are mature at less than 450 mm but may be more likely males (or "jacks"; see James and Sexauer 1997) as they are less dependent on large body size for reproductive success than migratory females and thus can mature across a much greater range of ages and sizes (Jonsson and Jonsson 1993, McCart 1997).

Bull trout life history metrics vary between populations and the 450 mm criteria may not apply to other geographic areas. For example, in the South Fork Walla Walla River of the lower Mid-Columbia Recovery Unit, growth rates of migrants appear lower and maximum lengths smaller than migrants in the upper Mid-Columbia Recovery Unit. The calculated asymptotic length of bull trout in the South Fork was 517 mm (95% CI: 484-557 mm; Harris et al. 2014) but during a multiyear telemetry study in the Wenatchee River watershed the average size of immature bull trout in the year(s) before first spawn was 519 mm (SD 62, range 390-650 mm) and the average size of known spawners was 580 mm (SD 59, range 490-680 mm, Kelly Ringel et al. 2014). Thus, caution should be exercised when applying data derived from one population to another: One size does not fit all. There is not a single template for recovery of bull trout but instead local information should be used locally whenever possible. This is particularly true in a large well-connected river system such as the upper Mid-Columbia River and associated sub-basins where bull trout are able to freely move long distances to locate prime FMO areas and grow large while still immature; a situation that may not be readily available in many other core areas such as the Walla Walla River.

Bull trout migration timing and use of lower Icicle Creek as revealed by PIT detections varies by age or life history stage and population. Previous limited information on the timing of seasonal movements of bull trout into Icicle Creek was derived primarily from capture dates while angling during telemetry studies. That data indicated that most subadults- the majority of which we now know are from non-Icicle populations- did not move to the vicinity of the LNFH until mid to late July as stream flows declined to 500 ft^3/s (Nelson et al. 2011), possibly for refuge from seasonally warmer water in the Wenatchee River (Nelson et al. 2011; Kelly Ringel et al. 2014; MCRFRO 2014). Data from bull trout PIT-tagged in Icicle Creek and at other locations validate the subadult timing but indicate movements may be more complex for adults. The majority of

PIT-tagged adults came from upper Wenatchee River populations and moved to Icicle Creek in the fall relatively quickly after spawning, but a few adults entered in February, indicating some bull trout may move throughout the winter rather than overwintering in one specific location. The one known Icicle adult entered Icicle Creek during two successive years in mid or late June and exited in February or November and the timing is consistent with a spawning migration (see below). Entrained bull trout out-migrating from the Icicle population were removed from the sand settling basin throughout the monitoring period from April through November, with late season captures indicating entrainment may continue into the winter. Combined with previous telemetry information (Nelson et al. 2011; Kelly Ringel et al. 2014), this indicates that seasonally variable numbers of subadult and adult bull trout from Icicle or several other populations could be actively moving in lower Icicle Creek throughout the year.

Despite the long period of impaired passage at LNFH, GSI confirmed that the migratory life history strategy is still present in the Icicle Creek population. It is uncertain how much the impairment reduced or limited the migratory expression as there very little information on bull trout before construction of the hatchery. In 1937, a by-pass trap in the IPID diversion canal was operated during May to October and captured 12 subadult bull trout ranging in size from 134 to 240 mm (Chapman and Quiztorff 1938). In comparison, recent yearly numbers of Icicle population bull trout entrained in the LNFH water intake system ranged from 1 to 5 individuals of similar or greater lengths. Although the subadult out-migration pattern appears similar between periods, long term monitoring of bull trout in upper Icicle Creek will be needed to determine if increased passage will affect the expression of the migratory life history in the population.

Bull trout populations can be polymorphic and may contain different proportions of the resident and migratory forms that vary over time (Brown 1994; McCart 1997). In the upper MCRU, for example, the Mad River population of the Entiat Core Area recently declined and then shifted from migratory to resident life history in apparent response to debris jams that prevented migratory access to most of the optimal spawning and rearing habitat (Nelson and Nelle 2008; Nelson 2014). Large debris jams recur at regular intervals in the Mad River migration corridor (Archibald and Johnson 2006) and the blockage may result in alternating periods of migratory versus resident life history strategies expressed in the population. It is not known to what extent this may occur elsewhere in the upper MCRU but indicates migration obstacles can rapidly change the dynamics of a bull trout population.

Telemetry, snorkel surveys, and spawning ground surveys in the upper tributaries of Icicle Creek indicate the populations may be primarily resident with relatively high densities in some areas and include an unknown number of migrant adults able to return to the upper watershed (Nelson 2007; Nelson et al. 2009; Nelson et al. 2011; Nelson and Sulak 2012; Nelson 2015). Several migration strategies may be present in Icicle Creek bull trout, and speculating on a small sample size, it may be that bull trout from the Icicle population do not migrate as extensively as other populations in the upper MCRU. Some bull trout may mature without leaving the lower river, as suggested by the low percentage of PIT-tagged Icicle population subadults detected leaving Icicle Creek. It is also possible some migrants can mature and grow large in the upper watershed, as can happen in the South Fork Walla Walla River (Al-Chokhachy and Budy 2008). More

robust studies with a larger number of PIT-tagged Icicle Creek bull trout are needed to examine these possibilities.

To date, only one migratory adult that GSI assigned to the Icicle Creek population has been PIT-tagged in the lower river. That individual left Icicle Creek in winter before re-entering in late June the first year and mid-June the second. During the second year the timing of its movements suggests it may have been on a spawning migration as it spent over five months in the creek before leaving in November. However, it is not known if it was able to pass the boulder falls and migrate to spawn in its natal area in upper Icicle Creek. A PIT antenna array was recently installed upstream by WDFW and additional PIT tagging may help document the movement windows for Icicle Creek bull trout at that natural obstacle.

This observational study increased our knowledge and understanding of bull trout on several scales. It is based on incidental genetic sampling and opportunistic tagging so there are limits to interpretation. Snorkel and other surveys for bull trout need to continue in the watershed. Additional PIT-tagging and genetic sampling with stock identification will assist in monitoring movement patterns to increase our knowledge of subadult and adult bull trout in both lower and upper Icicle Creek.

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Appendix 1: Bull Trout Population Assignments by Genetic Stock Identification

Appendix Table 1. Genetic stock identification population assignments of bull trout sampled in Icicle Creek: genetic identification number (Gen ID), total length (TL mm), date sample collected, location, rkm, collection zone, population assignment (Pop Assign), probability of population assignment (Prob Pop), core area assignment (Core Assign), and probability of core area assignment (Prob Core). See DeDehaan et al. (2014) for details of the GSI procedure. An asterisk next to the Gen ID number indicates it was radio-tagged for adult telemetry studies in Icicle Creek (Nelson et al. 2009, 2011, 2012).

Gen ID	TL (mm)	Date	Location	Rkm	Zone	Pop Assign	Prob Pop	Core Assign	Prob Core
355-015	380	07/23/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-022	380	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-024	350	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-026	340	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-028	280	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-029	420	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-033	330	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-034	290	08/10/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-037	350	08/11/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-038	390	08/11/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-050	370	09/25/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-052	310	11/23/09	ladder	4.3	A	Chiwaukum	1.00	Wen	1.00
355-058*	488	09/28/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-059*	475	09/25/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
355-060*	572	09/28/09	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
681-014*	465	04/07/08	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
681-018*	552	07/30/08	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-013	390	08/23/10	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-014	370	08/23/10	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-015	430	08/23/10	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-017	410	08/23/10	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-018	280	08/23/10	spilllway	4.3	A	Chiwaukum	1.00	Wen	1.00
878-019*	457	08/23/10	spilllway	4.3	A	Chiwaukum	0.98	Wen	0.98
2490-02	198	07/10/13	pond	4.3	A	Chiwaukum	1.00	Wen	1.00
2491-32	325	09/05/13	spilllway	4.7	A	Chiwaukum	1.00	Wen	1.00
2491-33	400	09/05/13	spilllway	4.7	A	Chiwaukum	1.00	Wen	1.00
2491-35	384	09/05/13	spilllway	4.7	A	Chiwaukum	1.00	Wen	1.00
355-023	220	08/10/09	spilllway	4.3	A	Chiwawa	1.00	Wen	1.00
355-025	310	08/10/09	spilllway	4.3	A	Chiwawa	1.00	Wen	1.00
355-035	260	08/11/09	spilllway	4.3	A	Chiwawa	1.00	Wen	1.00
355-045	350	09/25/09	spilllway	4.3	A	Chiwawa	1.00	Wen	1.00
878-016*	580	08/23/10	spilllway	4.3	A	Chiwawa	0.99	Wen	1.00
2491-34	334	09/05/13	spilllway	4.7	A	Chiwawa	1.00	Wen	1.00
355-049	400	09/25/09	spilllway	4.3	A	Entiat	1.00	Entiat	1.00
355-057*	495	08/11/09	spilllway	4.3	A	Entiat	1.00	Entiat	1.00
878-020*	530	08/23/10	spilllway	4.3	A	Entiat	1.00	Entiat	1.00
2491-31	442	09/05/13	spilllway	4.7	A	Entiat	1.00	Entiat	1.00
355-036	290	08/11/09	spilllway	4.3	A	Etienne	1.00	Wen	1.00
352-080	755	06/17/05	pond	4.3	A	Icicle	1.00	Wen	1.00
355-046	360	09/25/09	spilllway	4.3	A	Icicle	1.00	Wen	1.00

355-047	350	09/28/09	spilllway	4.3	A	Icicle	1.00	Wen	1.00
355-048	400	09/28/09	spilllway	4.3	A	Ingalls	1.00	Wen	1.00
355-027	360	08/10/09	spilllway	4.3	A	Nason	1.00	Wen	1.00
355-051	350	09/28/09	spilllway	4.3	A	Nason	1.00	Wen	1.00
355-055*	507	08/10/09	spilllway	4.3	A	Nason	1.00	Wen	1.00
355-056*	455	08/11/09	spilllway	4.3	A	Nason	1.00	Wen	1.00
139-098	300	08/07/08	headgate	6.1	B	Chiwaukum	1.00	Wen	1.00
355-041	230	08/13/09	S5 corner	4.6	B	Chiwaukum	1.00	Wen	1.00
878-011	220	08/27/10	headgate	6.1	B	Chiwaukum	1.00	Wen	1.00
878-012	250	08/27/10	headgate	6.1	B	Chiwaukum	1.00	Wen	1.00
355-031	280	08/10/09	headgate	6.1	B	Chiwawa	1.00	Wen	1.00
355-042	210	08/13/09	headgate	6.1	B	Chiwawa	0.93	Wen	1.00
355-043	260	08/13/09	headgate	6.1	B	Chiwawa	1.00	Wen	1.00
355-053*	605	07/20/09	headgate	6.1	B	Etienne	1.00	Wen	1.00
139-096	175	08/07/08	headgate	6.1	B	Icicle	1.00	Wen	1.00
139-097	175	08/07/08	headgate	6.1	B	Icicle	1.00	Wen	1.00
355-040	310	08/13/09	headgate	6.1	B	Icicle	1.00	Wen	1.00
139-100	200	08/07/08	headgate	6.1	B	Nason	1.00	Wen	1.00
355-002	223	10/08/07	screen	7.2	D	**Brook Tr.**	-	-	-
2490-06	238	08/15/13	s basin	7.2	D	Chiwaukum	1.00	Wen	1.00
355-007	382	08/04/09	s basin	7.2	D	Chiwaukum	1.00	Wen	1.00
355-008	300	10/29/09	s basin	7.2	D	Chiwaukum	1.00	Wen	1.00
355-010	309	10/29/09	s basin	7.2	D	Chiwaukum	1.00	Wen	1.00
355-014	274	10/29/09	s basin	7.2	D	Chiwaukum	1.00	Wen	1.00
355-018	310	08/05/09	Icicle Is.	8.6	D	Chiwaukum	1.00	Wen	1.00
355-021	390	08/07/09	Icicle Is.	8.6	D	Chiwaukum	1.00	Wen	1.00
355-030	390	08/10/09	Snow Br	8.8	D	Chiwaukum	1.00	Wen	1.00
2490-03	223	08/06/13	screen	7.2	D	Chiwawa	1.00	Wen	1.00
2490-04	218	08/06/13	screen	7.2	D	Chiwawa	1.00	Wen	1.00
355-03	255	09/12/08	s basin	7.2	D	Chiwawa	1.00	Wen	1.00
355-006	327	07/14/09	s basin	7.2	D	Chiwawa	1.00	Wen	1.00
355-011	242	10/29/09	s basin	7.2	D	Chiwawa	1.00	Wen	1.00
355-019	410	08/07/09	B. falls	9.2	D	Entiat	1.00	Entiat	1.00
355-039	390	08/12/09	Snow Br	4.3	D	Gold	1.00	Methow	1.00
352-082	u	11/10/05	intake	7.2	D	**Hybrid**	-	-	-
681-001*	440	11/07/07	s basin	7.2	D	**No Amp** [4]	-	-	-
2490-01	151	07/02/13	screen	7.2	D	Icicle	1.00	Wen	1.00
2490-05	200	08/14/13	s basin	7.2	D	Icicle	1.00	Wen	1.00
352-081	u	11/10/05	intake	7.2	D	Icicle	1.00	Wen	1.00
355-001	140	06/08/07	screen	7.2	D	Icicle	1.00	Wen	1.00
355-005	244	09/12/08	s basin	7.2	D	Icicle	1.00	Wen	1.00
355-009	201	10/29/09	s basin	7.2	D	Icicle	1.00	Wen	1.00
355-012	302	10/29/09	s basin	7.2	D	Icicle	1.00	Wen	1.00
355-044	310	08/13/09	Snow Br	8.8	D	Icicle	1.00	Wen	1.00
878-052	220	09/25/12	s basin	7.2	D	Icicle	1.00	Wen	1.00
878-053	201	10/02/12	s basin	7.2	D	Icicle	1.00	Wen	1.00
878-054	265	10/02/12	s basin	7.2	D	Icicle	1.00	Wen	1.00
878-055	195	11/08/12	s basin	7.2	D	Icicle	1.00	Wen	1.00

[4] Characteristics of this fish identify it as a hybrid (see Appendix 1 in Nelson et al. 2009).

878-056	265	11/13/12	s basin	7.2	D	Icicle	1.00	Wen	1.00
878-057	123	04/29/13	screen	7.2	D	Icicle	1.00	Wen	1.00
879-002	117	05/12/11	s basin	7.2	D	Icicle	1.00	Wen	1.00
879-003	315	10/20/10	s basin	7.2	D	Icicle	1.00	Wen	1.00
879-004	334	10/20/11	s basin	7.2	D	Icicle	1.00	Wen	1.00
879-005	510	10/20/11	s basin	7.2	D	Icicle	1.00	Wen	1.00
879-006	400	10/20/11	s basin	7.2	D	Icicle	1.00	Wen	1.00
879-001	315	10/20/10	s basin	7.2	D	Icicle	1.00	Wen	1.00
355-020	390	08/07/09	Icicle Is.	8.6	D	Ingalls	1.00	Wen	1.00
355-013	243	10/29/09	s basin	7.2	D	**No Amp**	-	-	-
355-016	300	07/27/09	gorge	26	E	Icicle	1.00	Wen	1.00
355-017	210	07/31/09	RI camp	29	E	Icicle	1.00	Wen	1.00
355-054*	430	07/29/09	d/s gorge	25	E	**Hybrid**	-	-	-
681-016*	475	07/25/08	gorge	26	E	Icicle	1.00	Wen	1.00
681-017	382	07/28/08	gorge	26	E	Icicle	1.00	Wen	1.00
878-002	325	08/24/10	gorge	26	E	Icicle	1.00	Wen	1.00
878-004	320	08/24/10	gorge	26	E	Icicle	1.00	Wen	1.00
878-007	360	08/24/10	gorge	26	E	Icicle	1.00	Wen	1.00
878-008	330	08/24/10	gorge	26	E	Icicle	1.00	Wen	1.00
878-009	350	08/24/10	gorge	26	E	Icicle	1.00	Wen	1.00
878-001	340	08/24/10	gorge	26	E	**< Loci Amp**	-	-	-
878-003	270	08/24/10	gorge	26	E	**< Loci Amp**	-	-	-
878-005	310	08/24/10	gorge	26	E	**< Loci Amp**	-	-	-
878-006	340	08/24/10	gorge	26	E	**< Loci Amp**	-	-	-
878-010	360	08/24/10	gorge	26	E	**< Loci Amp**	-	-	-

Note: An asterisk (*) next to Gen ID indicates the bull trout was radio-tagged for adult telemetry studies in Icicle Creek.

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