Effective Population Size and Connectivity of Bull Trout in the Imnaha River Subbasin

2007 Annual Report

Justin R. Cook, J. Michael Hudson, and Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
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Introduction

Bull trout (*Salvelinus confluentus*) were listed range wide as a threatened species on November 1, 1999 (USFWS 1999). Previously, the Columbia River distinct population segment (DPS) of bull trout had been listed as threatened since June 10, 1998. Factors contributing to the listing of bull trout include range wide declines in distribution, abundance and habitat quality. Land and water uses that alter or disrupt habitat requirements of bull trout can threaten the persistence of the species. Examples of such activities include: water diversions, dams, timber extraction, mining, grazing, agriculture, nonnative fish competition and/or hybridization, poaching, past fish eradication projects, and channelization of streams. These threats are prevalent throughout the Columbia River basin (USFWS 2000, 2002).

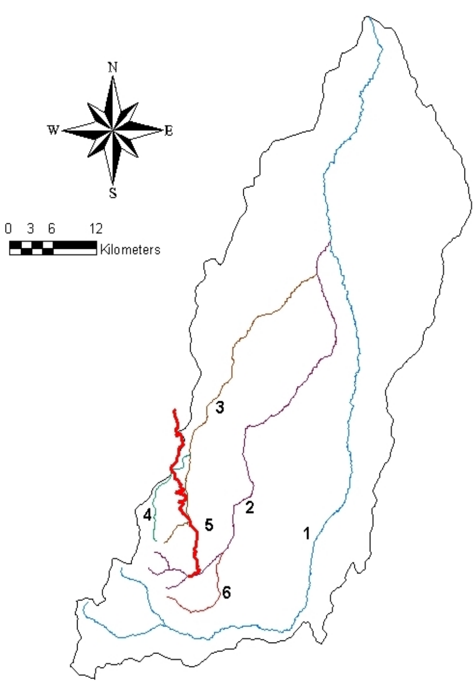

Figure 1. Study Area - 1. Imnaha River; 2. Big Sheep Creek; 3. Little Sheep Creek; 4. McCully Creek; 5. WVIC; 6. Lick Creek

Within the Columbia River DPS and Imnaha-Snake Recovery Unit, there are three core areas, one of which is the Imnaha Core Area which consists of five putative local populations (the Imnaha River above the mouth of Big Sheep Creek, upper Big Sheep Creek above the Wallowa Valley Improvement Canal (WVIC) and in the canal, lower Big Sheep Creek below the WVIC, Little Sheep Creek, and McCully Creek) (Figure 1). The resident population in Big Sheep Creek is estimated at less than 2,000 individuals, above and below the WVIC and including all tributaries (USFS 2001). The resident population in Little Sheep Creek is estimated at fewer than 500 (USFS 2003). The resident population of McCully Creek, which formerly flowed into Little Sheep Creek, is estimated at approximately 2,500 individuals (Smith and Knox as referenced in Buchanan et al. 1997). Historically, these populations could have been connected by migratory individuals and functioned as one metapopulation. However, the construction of the WVIC has potentially prevented gene flow or allowed only unidirectional movement downstream for over a century.

The WVIC is a water diversion in northeastern Oregon that has impacted bull trout and their habitat. The canal was constructed in the 1880s and diverts water from several Imnaha River subbasin streams beginning at Big Sheep Creek and continuing down past McCully Creek to Prairie Creek in the Wallowa River basin (Figure 1). The diverted water is primarily used for irrigation purposes.

During the construction of the WIVC, structures were built that create potential barriers for fish passage. Possible barriers are located at the diversion on Big Sheep Creek and within the canal at Salt Creek summit spillway (Figure 2a-2b). The construction of these structures have potentially created and isolated a population of bull trout in upper Big Sheep Creek for the past century. The canal has also diverted and isolated numerous small tributaries and streams including Salt Creek, Cabin Creek, Little Sheep Creek, Redmont Creek, Canal Creek, and Ferguson Creek. At Little Sheep Creek there is a culvert approximately 200 m above the confluence with the WVIC that could impact upstream migration of bull trout and isolate a population above (Figure 2c). The WVIC does not divert McCully Creek. Instead, the WVIC is carried over the top of McCully Creek and some water from the canal is diverted into the creek (Figure 2d). It is not likely that much, if any, immigration into McCully Creek is occurring through this diversion given the physical structure being used. In addition, McCully Creek no

a) b) c) d)

Figure 2. Potential barriers to upstream migration of bull trout in the Imnaha River subbasin: a) WVIC diversion at Big Sheep Creek; b) WVIC diversion at Salt Creek Summit; c) culverts under USFS road #130 on Little Sheep Creek, d) WVIC going over top and adding some water too McCully Creek.

longer drains into the Imnaha subbasin. The stream bed was shifted in the past (records are available but not yet analyzed) so that the creek now drains directly into the Wallowa Valley and provides another water source for irrigation. Many of the irrigation ditches in the upper Wallowa Valley ultimately connect to Prairie Creek, a tributary to the Wallowa River. Therefore, another potential source of bull trout immigration into McCully Creek may be from the Grande Ronde River subbasin. This connection seems unlikely since trout would need to navigate through a series of irrigation canals that most likely act as temperature barriers. Thus, it is reasonable to speculate that the bull trout population in McCully Creek is isolated. A more detailed physical description of the Imnaha River subbasin and the streams supporting bull trout can be found in Chapter 12 of the Draft Bull Trout Recovery Plan (USFWS 2002b).

Despite the existence of these potential isolating mechanisms, small bull trout populations persist in all of these streams above the WVIC. Genetic theory indicates that an effective population size (N_e) ≥ 50 is necessary to prevent inbreeding depression, and an $N_e \geq$ 500 is necessary for sustainability over ecological time (Franklin 1980, Soulé 1980, Allendorf and Ryman 2002). It seems reasonable that this theory holds true for bull trout, although exceptions do exist (Rieman et al. 1997, Whitesel et al. 2004). Whether bull trout exhibit departures from the 50/500 concept associated with N_e should be documented with empirical data that is robust and well described (Whitesel et al. 2004). Potential information that relates effective population size theory to absolute abundance and population genetic variability would provide information toward defining minimum viable population requirements for bull trout.

The goal of this project is to provide empirical data toward defining minimum viable population objectives that can be used for restoration and recovery of bull trout across the range. The objectives toward this end are to: 1) Determine abundance of bull trout in putative populations above WVIC; 2) Determine bull trout connectivity (movement) between populations; 3) Determine within and among population genetic variability for the five local populations of the Imnaha Core Area; 4) Determine effective population size for isolated populations above the WVIC.

The study area provides a unique opportunity to test population genetic theory and provide empirical data toward bull trout recovery. There are several barriers that act as potential points of isolation and that have existed for known periods of time. These barriers lend themselves to remote monitoring via PIT tag technology. Taking this approach will provide the opportunity to confirm if and when movement is occurring between populations and if the movement is unidirectional.

Levels of genetic drift and variability should, in part, be a function of population size and the length of isolation from one another. The amount of time these populations have potentially been isolated can be determined from historical records and therefore allows for certain predictions to be made (records are available but not yet analyzed). If these small populations have been isolated without any influx of gene flow, genetic drift has likely occurred over the past century (Hartl 1988). These populations have continued to persist. However, after the construction of the WVIC, they now exist in a series of populations. Reduced effective population sizes (N_e) and continued persistence of small, isolated populations in this study area provide the opportunity to look at various levels of N_e to absolute population size ratios (N) in bull trout. These N_e:N ratios can then be compared to genetic variability present. The resulting dataset will provide guidance toward defining minimum viable population objectives. In other words, is the 50:500 required for these populations, or is there a smaller N_e under which bull trout can persist within these areas?

Recovery actions have been identified that, if implemented, will restore connectivity and opportunities for migration between these streams (Ecovista 2004, USFWS 2002a). Though desirable and beneficial to the resource, the restored connectivity will cease to present the unique situation described above, where separate populations with known isolation dates exist to test fundamental genetic theories and issues associated with population viability. Currently, small populations that are potentially isolated and have been persisting in the current state for over 100 years are presumed to exist. Therefore, the study area provides the opportunity to investigate how these populations are persisting, with respect to degrees of immigration/isolation and effective population size; investigate how well these populations are persisting, with respect to population size and genetic variability; and provide empirical data to verify theoretical models of effective population size and persistence. Understanding these relationships will provide information toward range wide restoration and recovery of bull trout populations.

Methods

Abundance

Bull trout abundance was estimated using either mark-recapture or single-pass sampling methodology. The mark-recapture approach was determined to be the most accurate and precise sampling method to estimate abundances (Cook et al. 2008). By conducting two consecutive passes the probability of capture was calculated and could therefore be applied for future single-pass estimates. It is assumed that due to the nature of these systems (temperature barriers and diversion structures blocking upstream migrations), the sampled areas of McCully Creek and Big Sheep Creek are closed to significant levels of immigration or emigration of bull trout that would influence estimates of abundance. This assumption has been supported by a lack of detecting tagged fish at PIT tag arrays within the timeframe of abundance estimate sampling.

To estimate abundance for bull trout in McCully Creek, two consecutive mark-recapture trips were completed in 2007. The first trip occurred from July 17 through July 23 and the second was from July 31 through August 5. Allowing at least seven days with no sampling between trips provided time for marked and unmarked individuals to redistribute in McCully Creek. We sampled all tributaries, springs, and side channels within the system. Within McCully Creek, the primary sampling site was an 8.45 kilometer stretch of stream beginning where the WVIC crosses and ending 0.45 kilometers above an assumed natural barrier. The McCully sampling area was then divided into 31 individual reaches measuring 250 meters each (Figure 3). One additional reach above the barrier was completed on the first trip to confirm the end of fish use. These reaches represented nothing other than a sampling segment.

To estimate bull trout abundance a single-pass was completed on upper Big Sheep Creek in 2007 (Figure 9). This work occurred August 15 through 19. Sampling efforts on Big Sheep Creek focused on the same location and approach as efforts in 2006 (Cook et al. 2008).

The sampling method consisted of backpack electrofishing upstream, using a Smith-Root model LR-24 shocker. Electrofishing was conducted using a technique to reduce potential harm to the sampled population. Specifically, only areas considered holding habitat (plunge pools, overhanging banks, eddies, large woody debris, and pocket pools within riffles) were sampled in a "stalk and shock" approach. This approach included two to three netters working with one electrofisher. The electrofisher would point out the next possible holding habitat to the netters, then quietly and quickly approach and begin shocking in one fluid motion, focusing on drawing the fish back down towards the netters. This method proved effective and allowed for the capture of fish with the use of minimal electricity and impact on the fish. Fishing effort was measured by the number of seconds the electrofisher was on (electricity in the water) and remained similar for each pass in McCully Creek. The LR-24 shocker used pulsed direct current set at a frequency of 20-24 Hz, 20-28% duty cycle, and voltage between 275 and 500 V. Settings were dependent upon fish response as well as current water conditions (i.e., water depth, conductivity, flow, and temperature).

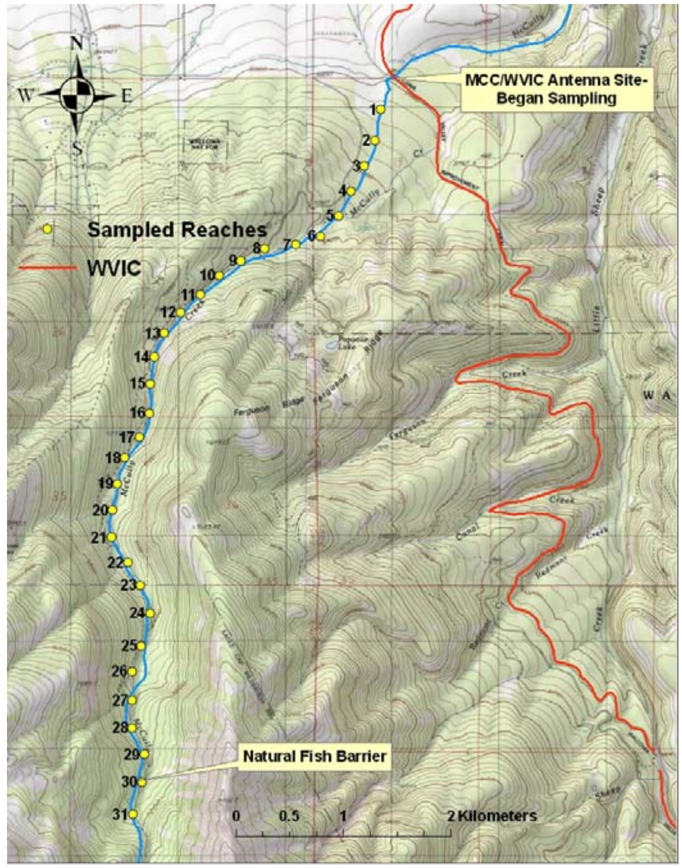

Figure 3. McCully Creek study area showing sampled reaches.

At the completion of each reach, all captured fish were identified, measured (fork length), weighed, and scanned for passive integrated transponder (PIT) tags. Fish were anesthetized using 25 ppm clove oil. Scissors were used to collect approximately 4 mm^2 of tissue from the left pelvic fin of all bull trout upon initial capture. The samples were preserved in a vial of 100% ethyl alcohol and archived for future genetic analysis. For bull trout greater than 120 mm, a PIT tag (23 mm long, 3.84 mm diameter, 0.6 g, full duplex) was surgically implanted on the ventral side, posterior to the pectoral fins (Roussel et. al 2000). After full recovery within an aerated bucket, fish were released within their reach of capture.

Mark-recapture data was analyzed using the CAPTURE procedure (Otis et al. 1978; White et al. 1982; Rexstad and Burnham 1991) within the program MARK (White and Burnham 1999). CAPTURE was used to help determine the most appropriate estimator (*Mo* [null estimator], Jackknife *Mh*, Darroch *Mt* , Chao *Mth*, Chao *Mt* , and Chao *Mh*), but assumptions and variables associated with the choice of the most appropriate estimator were also considered. CAPTURE was used to determine confidence intervals around the abundance estimate, the coefficient of variation, and the probability of capture.

Single-pass data was analyzed using the population estimate for single catches method (Seber and Le Cren 1967):

$$\tilde{N} = C/\tilde{p},$$

where $\tilde{N}$ is the estimated abundance, C is the number of captured individuals from the single-pass, and is the estimated capture probability. Capture probability in Big Sheep Creek was estimated $\tilde{p}$ to be the same as previous capture probability that was generated from a previous mark-recapture estimate (Cook et al. 2008). Confidence intervals (95%) around the single-pass estimate were generated using the methodology of Seber and Le Cren (1967).

Movement

During the mark-recapture evaluations, movement of bull trout within streams between multiple pass sampling efforts was evaluated. The recaptured individuals that moved were analyzed, particularly with respect to size, direction, and distance. The distance of movement was estimated by calculating the sum of distances between midpoints across all reaches moved. Mean, minimum (negative indicating downstream), and maximum (positive indicating upstream) distances were estimated.

Movement between streams was determined using PIT tag technology (Zydlewski et al. 2001, 2008). Antennas were constructed as open coil inductor loops with PVC-coated multi-strand wire strung through PVC pipe, or encased within a flat panel wooden or PVC sheet design. The antennas were then connected to a Destron-Fearing reader that emits a 134.2 kHz electromagnetic energizing signal through the antenna. A field PC received serial data output from the reader at each site; detected tag identification numbers, date and time of detection were recorded. The readers, batteries and/or power supplies, and PCs were housed within a weather-proof box located outside of the immediate flood zone of the streams. Antennas located at remote sites were powered with propane thermoelectric generators.

Remote PIT tag antennae arrays were used to monitor the movement of PIT-tagged fish at three locations: the Big Sheep Creek/WVIC diversion (the canal origin), the Salt Creek summit spillway (5.9 kilometers down the canal), and the intersection of the WVIC and McCully Creek (21.2 kilometers down canal). These antennas provided data regarding fish migrations to and from the upper portions of Big Sheep Creek from areas below the canal as well as within the canal. They allowed us to assess whether bull trout left Big Sheep Creek and entered the canal, carried on down the canal past Salt Creek Summit, and continued further to McCully Creek.

Big Sheep Creek

The location and severe weather conditions prevented regular access and maintenance at this remote site during the winter months of 2006-2007. As a result, the array did not operate from November 2006 – June 2007. The winter conditions also resulted in the failure of the two lower hanging antennas on the Big Sheep Creek diversion structure (Figure 4). Operation of remaining antennas resumed on July 1, 2007. We also installed three new antennas on July 28 (Figure 5 and 6). Two flat panel antennas (A5 and A6), constructed from PVC sheeting, were installed on the structure that separates the upper and lower portions of Big Sheep Creek (Figure

6a). The third antenna (A4) was installed just downstream of the spillway structure on Big Sheep Creek. The two flat panel antennas installed on the spillway never functioned properly due to problems thought to be associated with loading interference from the diversion structure. On October 30, 2007, one of these flat panels was relocated into the canal just downstream of the Big Sheep Creek diversion structure (A3). Monitoring was maintained throughout the year on the remaining three antennas.

a)

b)

Figure 4. Antenna arrays constructed at Big Sheep Creek (a) and Salt Creek summit (b) and the subsequent damage caused by snow and ice.

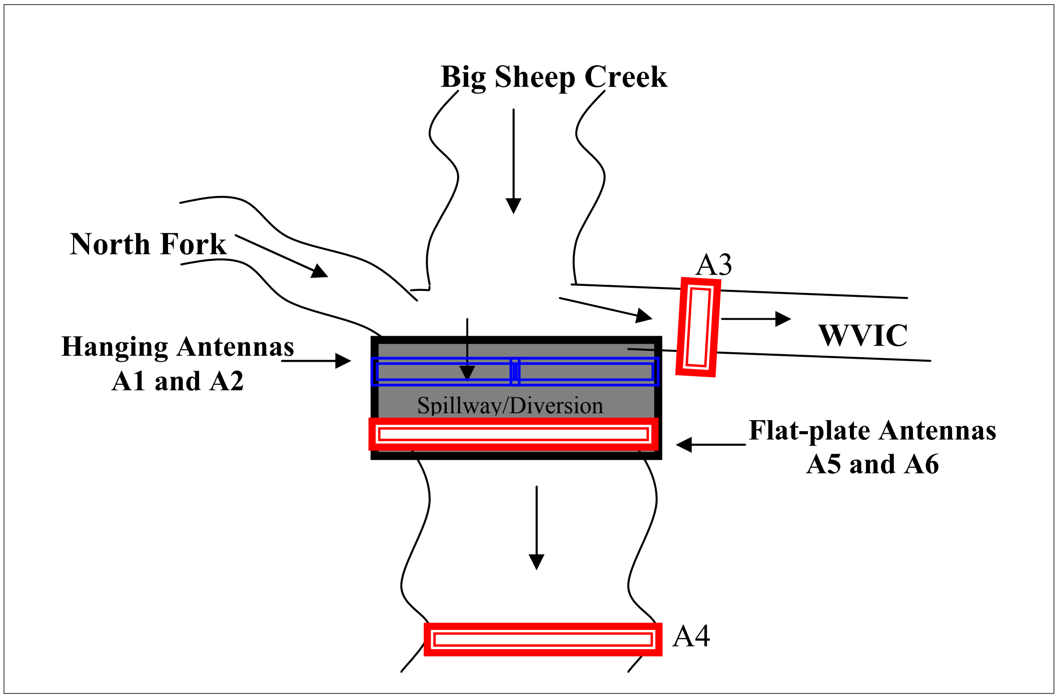

Figure 5. A diagram of the Big Sheep Creek diversion antenna site. A1 and A2 are the original hanging antennas shown in Figure 4a.

a) b) c) d)

Figure 6. Antennas installed in 2007 - a) Big Sheep Creek diversion flat panels and upper antennas; b) upstream of Salt Creek summit flat panel (wood); c) Antenna in the WVIC just below where McCully Creek goes under the canal; d) McCully Creek antennas upstream of the WVIC.

Salt Creek Summit

From January through April 2007, the original upper hanging antennas (Cook et al. 2008) at Salt Creek Summit functioned properly (antennas 1, 2, and 3- Figure 5). The lower hanging antennas failed due to winter conditions (Figure 4). The array temporarily shut down on April 1 and two of the three upper hanging antennas were successfully turned back on April 13 when an additional wooden flat panel antenna was installed approximately 10 meters upstream from the diversion (Figure 6b and Figure 7 - A4). This antenna improved detection probabilities of fish that may have been missed by the hanging antennas. It also provided conclusive evidence of a complete passage if a fish were to be detected on the hanging antennas followed by a detection on A4. On May 3, a second flat panel antenna was installed approximately 40 meters downstream of diversion structure (A5), allowing for detections above, below, and on the spillway. All four of these antennas were maintained and kept functioning throughout the year.

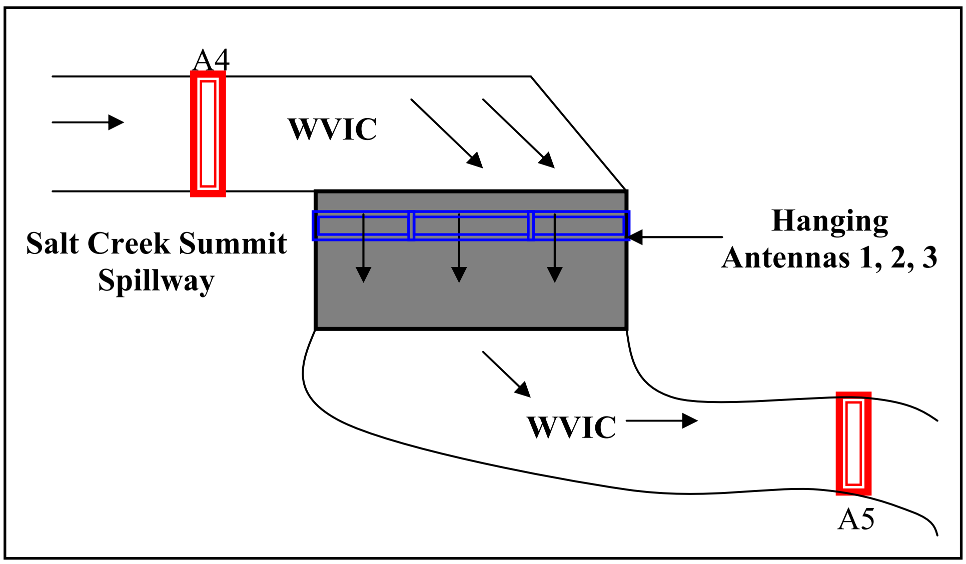

Figure 7. A diagram of the antenna array setup at the Salt Creek summit spillway. Antenna 3 did not function properly following April 1.

McCully Creek / WVIC

The antenna located on the gate (Figure 8 - A1) that diverts water out of the WVIC and into McCully Creek resumed monitoring on April 13, prior to the gate being opened. On May 4, two new antennas were installed at this site. The first was a pass-through antenna within the canal just downstream of McCully Creek (Figure 8 - A2) (Figure 6c). The second was placed in McCully Creek just upstream of the canal crossing (Figure 8 - A5). Another antenna was installed within McCully Creek, upstream of the canal (Figure 8 - A6) on June 30 to allow for the directional movement of fish to be determined (Figure 6d). These antennas were operated all year.

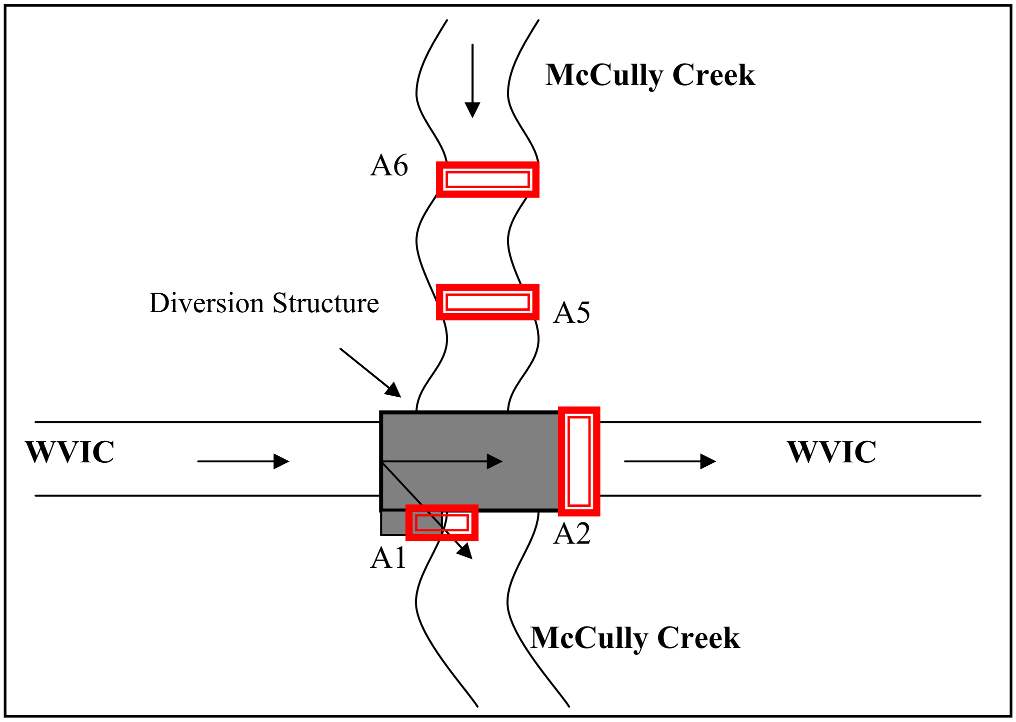

Figure 8. A diagram of the antenna array setup at the McCully Creek – WVIC junction.

Population Genetic Structure

Tissue collection was coordinated with activities being conducted to determine movement and population abundances. Samples were collected from fish within McCully Creek, Big Sheep Creek, and areas of the WVIC. Genetic variability within and among putative populations will be determined using an approach similar to Spruell et al. (2003) and Homel et al. (2008). Microsatellite markers that have been developed for bull trout molecular analysis (DeHaan and Ardren 2005) will be utilized to describe within and among population genetic variability. Genetic measures to be examined include absolute diversity, diversity and relatedness between putative populations, and observed and expected Hardy-Weinberg relationships.

Effective Population Size

Effective population size will be estimated using demographic and genetic approaches (Hill 1972, Nunney 1993, Nielsen 1997). The implementation of fish and tissue sampling tasks associated with this objective will be coordinated with activities being conducted to determine movement and population abundances. To date, genetic samples have been collected from several putative populations over multiple years.

Occupancy and Distribution

Temperature / Elevation Models

To further improve the understanding of water temperature characteristics in the Imnaha subbasin and areas of the WVIC, 24 individual thermographs were deployed in summer 2007 (Figure 9). These thermographs record water temperatures every 30 minutes throughout the year. They will be collected and downloaded in the summer 2008. The data gathered from these devices, when combined with the elevations at their locations, will allow for the identification of potential bull trout "patches"; or as defined by the Bull Trout Recovery and Technical Monitoring Group, "contiguous areas within a stream network where spawning and early juvenile rearing could occur and potentially support a local population" (USFWS 2008).

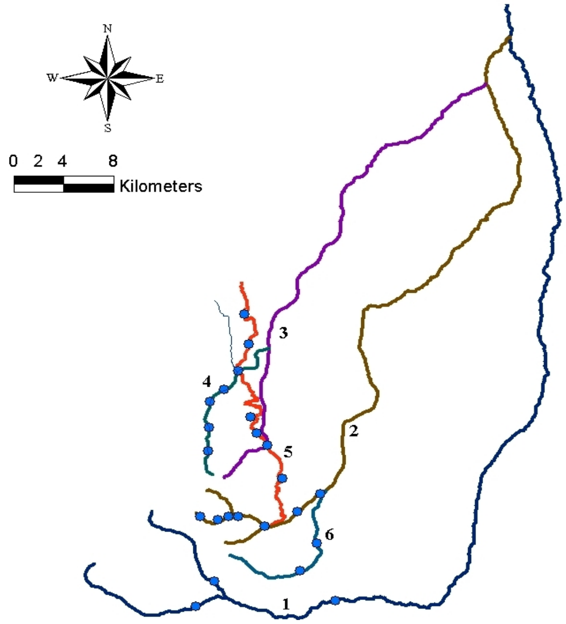

Figure 9. Thermograph locations within the Imnaha subbasin. 1. Imnaha River; 2. Big Sheep Creek; 3. Little Sheep Creek; 4. McCully Creek; 5. WVIC; 6. Lick Creek

Results

Abundance Estimates

A two pass mark-recapture abundance estimate of bull trout in McCully Creek above the WVIC was conducted in July and August. Upper reaches of McCully Creek were sampled to assess the upper distribution threshold of bull trout within the watershed. No fish were collected above an apparent barrier approximately eight kilometers upstream of the WVIC crossing (Figure 10). This barrier is likely temporary as it is constructed mostly of large woody debris. It should be noted that approximately 500 meters above this apparent barrier is a large cascading falls that creates an upstream limitation for fish migrations.


Figure10. Apparent fish barrier on McCully Creek. No fish were found above.

Over the two passes, a total of 1,655 fish ≥ 120 mm were captured in McCully Creek, 314 of which were recaptures of fish captured and marked in the previous sampling pass (Table 1). Electrofishing efforts for McCully Creek sampling totaled 6.9 hours on pass one (0.22 hours/reach) and 9.6 hours on pass two (0.31 hours/reach). Due to the unexpected high density of bull trout in McCully Creek, not all captured fish were PIT tagged. On the first pass, all bull trout ≥ 120 mm were tagged up through reach 14 (Figure 3). Following reach 14, only 10 randomly chosen bull trout were tagged per reach allowing for distribution of tagged fish throughout the entire system. All captured fish on the first pass were marked with a clip taken from the left pelvic fin. There was no tagging or marking that occurred on the second pass in

McCully Creek. The only data gathered on pass two was fork length, weight, and recapture information. Abundance estimates were generated for all bull trout ≥ 120 mm, ≥ 150 mm, and ≥ 180 mm (Table 2), as well as estimates of the number of bull trout within size classes 120-149 mm, 150-179 mm, 180-210 mm, and > 210 mm (Table 3).

Table 1. Capture results for all 2007 electrofishing efforts; 2007 recaptures are the number of unique fish captured from the prior pass (does not include duplicate recaps within a pass); Note: Not all < 120 mm bull trout are included as some were not measured and were released immediately upon capture.

Site	Pass	BT ≥ 120 mm	BT < 120 mm	Size Range (mm)	BT Tagged	2007 Recaps	2005 Unique Recaps	2006 Unique Recaps	Genetic Samples Collected
McCully Creek	1	694	131	74-262	386	0	0	0	738
	2	961	197	65-301	0	314	0	0	0
	Total	1,655	328	65-301	386	314	0	0	738
Upper Big Sheep Creek	1	749	232	81-265	96	0	17	112	96
Lower Big Sheep Creek	1	4	0	121-221	4	0	0	0	4
Lower Canal	1	5	0	179-228	3	0	1	1	3
South Fork Imnaha	1	20	66	48-210	0	0	0	0	86
North Fork Imnaha	1	14	48	47-560	0	0	0	0	62
Overall Total		2,447	674	47-560	489	314	18	113	989

Table 2. Results of estimated abundances for bull trout in McCully Creek, 2007, all bull trout ≥ 120 mm – 2 pass, ≥ 150 mm – 2 pass, and ≥ 180 mm – 2 pass.

Abundance Estimate	N	SE (±)	95% CI	Probability of Capture	Coefficient of Variation
≥ 120 mm 2 pass	2,188	76.8	2,051-2,352	.38	3.5%
≥ 150 mm 2 pass	1,368	47.6	1,285-1,472	.44	3.5%
≥ 180 mm 2 pass	573	25.1	531-630	.49	4.4%

Table 3. Estimated abundance for bull trout by size class within McCully Creek 2007 (2 pass).

Abundance Estimate	N	SE (±)	95% CI	Probability of Capture	Coefficient of Variation
120-149 mm	1,024	111.1	842-1,282	.23	10.8%
150-179 mm	808	43.5	735-906	.40	5.4%
180-209 mm	425	21.6	390-475	.49	5.1%
≥ 210 mm	147	12.6	129-179	.49	8.6%

Sampling in upper Big Sheep Creek continued in 2007 with a single electrofishing pass conducted from August 15 – 19. Sampling efforts were attempted to match those carried out in the 2006 field season, including the level of effort and the habitats sampled (Figure 11) (Cook et al. 2008). Electrofishing efforts for this pass totaled 9.0 hours and averaged 0.67 hours of fishing per reach. To keep a relatively high number of tagged individuals in Big Sheep Creek, five randomly chosen individuals (≥ 120 mm) were PIT-tagged and fin-clipped per reach for a total of 96 fish tagged. The remaining fish collected were weighed, measured for fork length, and scanned for PIT tags.

A length/frequency histogram (Figure 12) shows the results of captured bull trout in 2006 compared with those captured in 2007 within Big Sheep Creek. A total of 749 bull trout ≥ 120 mm were captured during sampling efforts, of which 129 had been previously tagged (Table 1). 10.6% of the individuals that had been tagged in 2005 were recaptured during the 2007 efforts (17 of 161 tagged), and 27.3% of individuals that had been tagged during the 2006 season were accounted for by recaptures during 2007 (112 of 410 tagged).

Abundance estimates generated were 2,137 (2,019-2,336) for 120+ mm, 964 (893-1,097) for 150+ mm, and 451 (406-544) for 180+ mm individuals (Table 4). Estimates were also calculated for the following size classes of bull trout: 120-149 mm, 150-179 mm, 180-210 mm, and > 210 mm (Table 5).

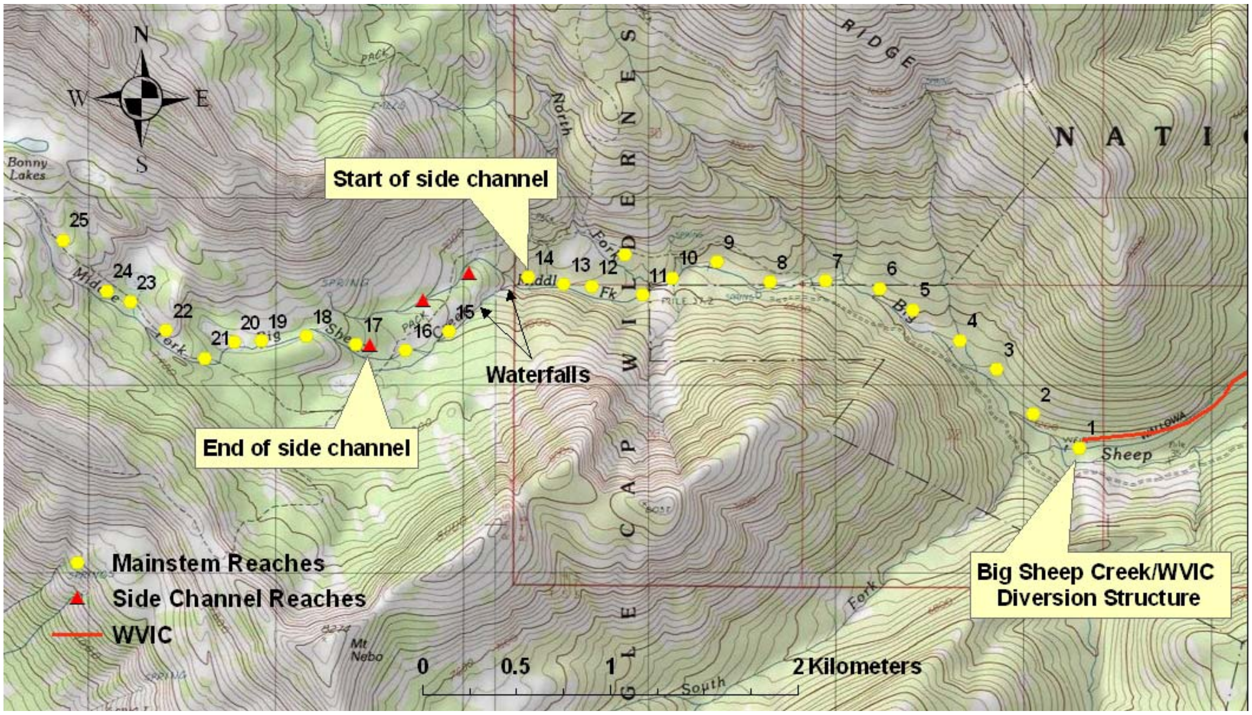

Figure 11. Sampled reaches within Big Sheep Creek, showing a side channel that bypasses two impassable waterfalls. Sampling was also conducted in the North and South forks of Big Sheep Creek.

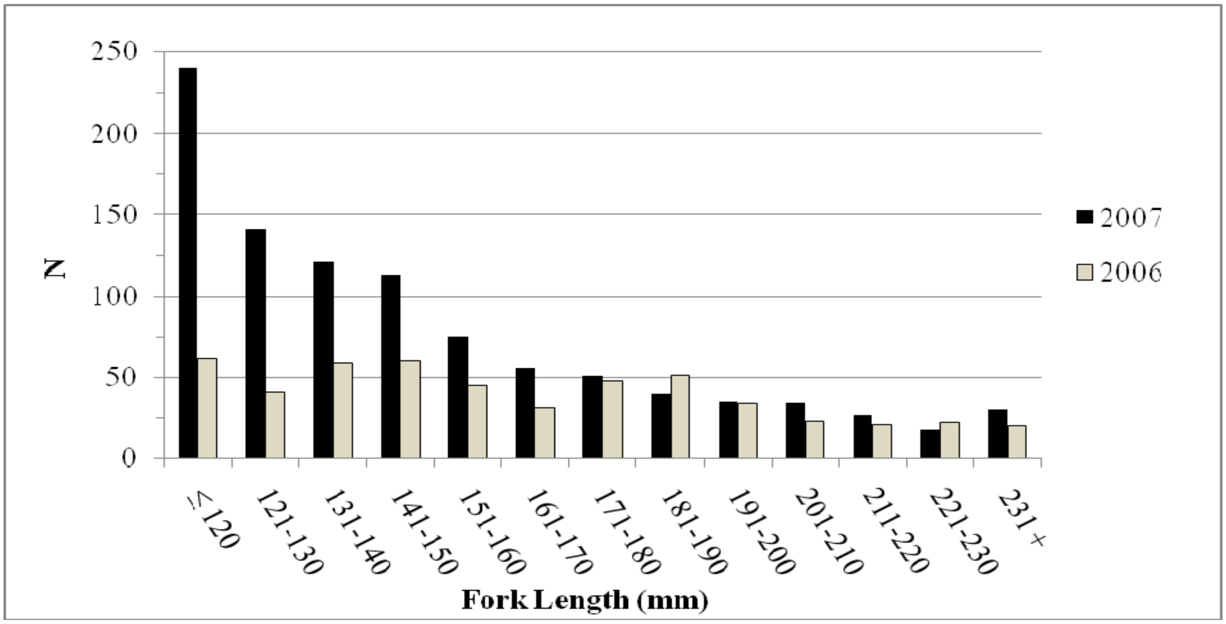

Figure 12. Upper Big Sheep Creek length – frequency comparisons of bull trout captured from 2006 and 2007 field season.

Table 4. Results of estimated abundances for bull trout in Big Sheep Creek, 2007, ≥ 120 mm – 1 pass, ≥ 150 mm – 1 pass, and ≥ 180 mm – 1 pass.

Abundance Estimate	N	SE (±)	95% CI	Probability of Capture	Coefficient of Variation
≥ 120 mm 1 pass	2,137	80.8	2,019-2,336	.35	3.8%
≥ 150 mm 1 pass	964	52.1	893-1,097	.39	5.4%
≥ 180 mm 1 pass	451	35.3	406-544	.41	7.8%

Table 5. Estimated abundance for bull trout by size classes within Big Sheep Creek 2007 (1 pass).

Abundance Estimate	N	SE (±)	95% CI	Probability of Capture	Coefficient of Variation
120-149 mm	1,484	78.7	1,360-1,669	.25	5.3%
150-179 mm	530	40.3	475-633	.36	7.6%
180-209 mm	311	31.6	269-393	.35	10.1%
≥210 mm	144	19.1	124-199	.52	13.3%

Movement

Movement of recaptured individuals (that had been PIT-tagged) between the first and second pass of McCully Creek did not suggest a relationship between bull trout length and distance traveled (Figure 13). Of the recaptured bull trout, 50.3% (81/161) remained within the same reach as the previous pass and 36.6% (59/161) had traveled no more than 300 meters upstream. Movement between these passes varied from an estimated 1,224 meters upstream to 515 meters downstream with an average traveling distance of 134 m ± 18.3.

Eight antennas were constructed in 2007 at three separate locations (Big Sheep Creek diversion, Salt Creek summit, and McCully Creek). These antennas were constructed to improve coverage, stability, and reliability of existing arrays installed in 2006. Since the installation of the first antenna in April 2006 through December of 2007, we have detected 49 individual fish among all locations.

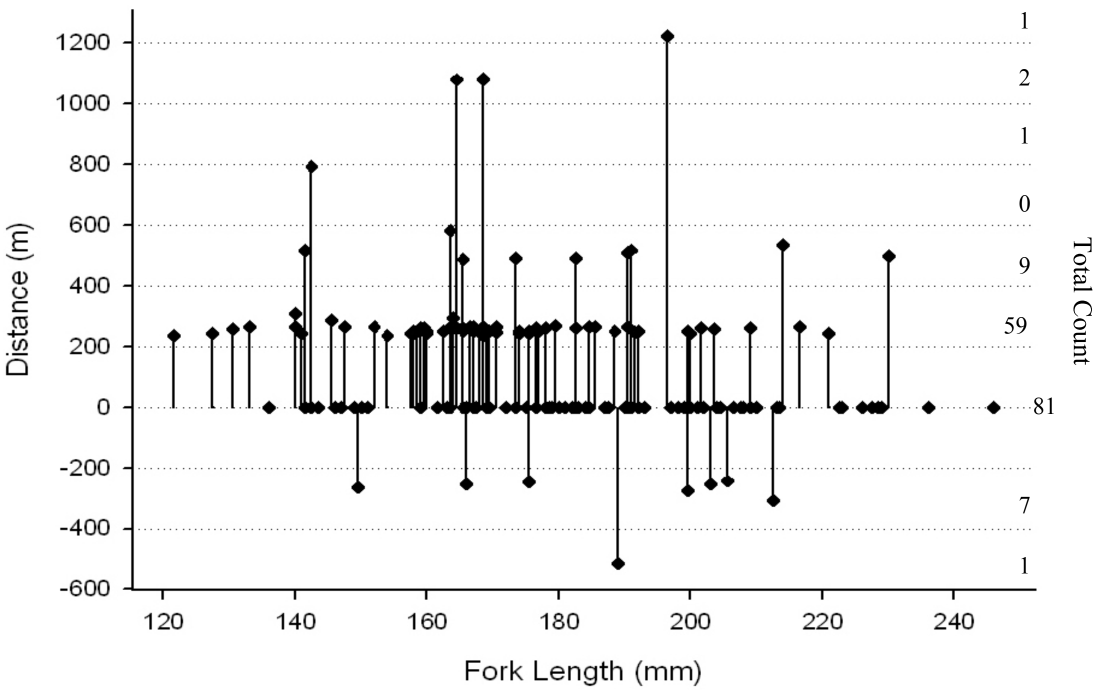

Figure 13. Movement of recaptured PIT-tagged bull trout between passes on McCully Creek.

Big Sheep Creek

Emigration detected from upper Big Sheep Creek to lower Big Sheep Creek (below the WVIC diversion structure) totaled ten individuals (Figure 14). Further emigration out of Big Sheep Creek was documented with detections at Salt Creek summit and McCully Creek. No upstream passage over the Big Sheep Creek diversion was detected.

Salt Creek Summit

A total of 15 fish were detected leaving Big Sheep Creek via the Salt Creek summit spillway. Three individuals came from upper Big Sheep Creek and were only detected on the upper antennas on the Salt Creek summit spillway (Figure 7 – antennas 1, 2, and 3).

On June 1, 2007, a 179 mm bull trout was captured, tagged, and released below the spillway at Salt Creek summit. The next day this fish was detected by the upper hanging antennas on the spillway (Figure 6 – A1) and then by the flat panel antenna below the spillway (A5). Throughout June and July this fish was detected below the spillway. On September 2, this fish was again detected on the upper hanging antennas and then one minute later picked up on the flat panel antenna upstream of the Salt Creek summit diversion structure (A4) indicating that upstream passage occurred.

In August 2006, a 134 mm bull trout was tagged in the second reach of the side channel within Big Sheep Creek (Figure 11). On August 24, 2007 this fish was detected by the lower Salt Creek summit flat-panel antenna (9.84 kilometers from its tagging site), proving that it traveled down the side channel, into the main-stem of Big Sheep Creek, and down the WVIC and over Salt Creek summit.

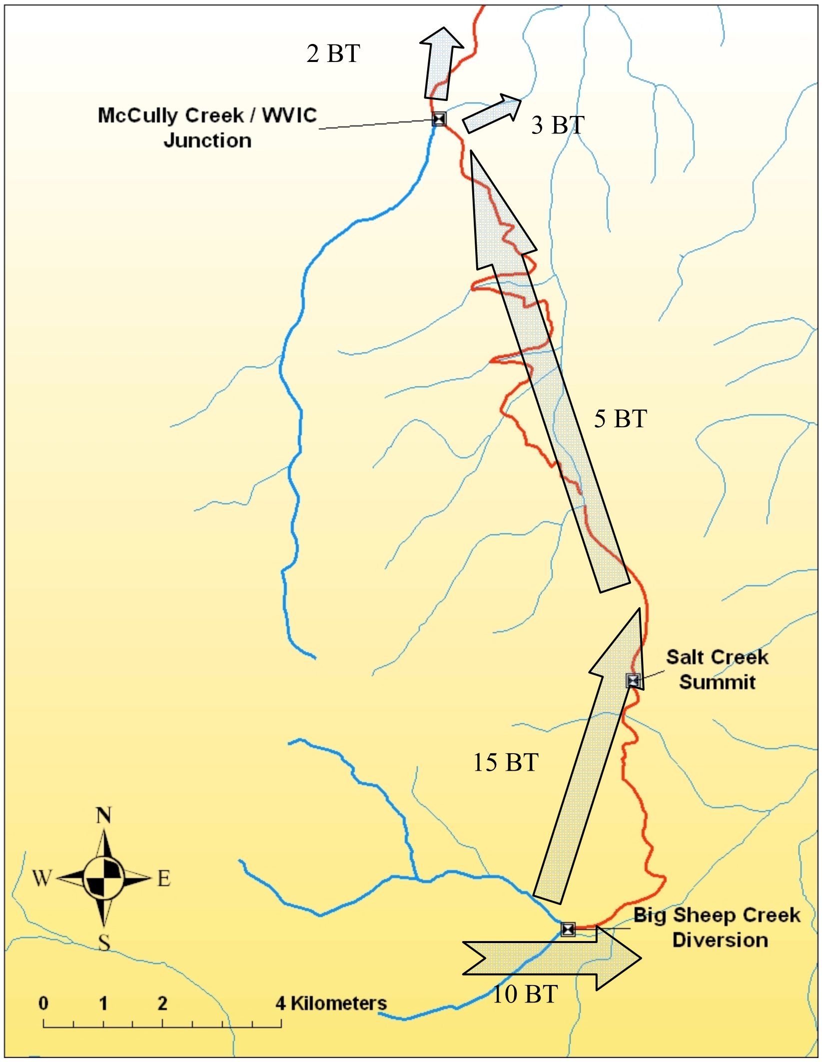

Figure 14. A map showing the number of bull trout detected emigrating from upper Big Sheep Creek to lower Big Sheep Creek, over Salt Creek summit, down the canal past McCully Creek, or into McCully Creek during 2007.

McCully Creek / WVIC

Of the 15 fish that were detected leaving Big Sheep Creek over Salt Creek summit, two were picked up continuing down the canal past McCully Creek and three individuals dropped into McCully Creek through the diversion structure (Figure 14). Following the August sampling efforts on McCully Creek, the only fish detected leaving the sample area was a 163 mm steelhead tagged on the first pass. No fish were detected entering the McCully system from below the antennas.

The longest known distance of travel still remains from 2006 data involving the 428 mm individual captured in 2006 in reach 13 of Big Sheep Creek (Figure 11) and detected 24.7 kilometers down the canal as it passed through the diversion structure into McCully Creek (Figure 7 – A1). In 2007, a bull trout was found to have travelled 24.2 kilometers from Big Sheep Creek reach 11 to the antenna within the canal at McCully Creek (Figure 7 – A2). This fish was tagged in August of 2006 (165 mm) and detected in August of 2007.

The longest distance for a fish that was both tagged and detected in 2007 was 23.5 kilometers in 87 days. This 184 mm fish was tagged on August 16 at reach 8 of Big Sheep Creek (Figure 11) and detected on November 11 passing down the canal at McCully Creek (Figure 7 – A2) and averaged 0.27 kilometers per day.

Population Genetic Structure

Tissue samples were collected from individuals in: McCully Creek (N = 738, range = 74-262 mm); Big Sheep Creek above the WVIC (N = 96, range = 121-257 mm); Big Sheep Creek below the WVIC (N = 4, range = 121-221 mm); the WVIC below Salt Creek summit (N = 3, range = 179-216 mm); the North Fork Imnaha River (N = 62, range = 47-560 mm); and the South Fork Imnaha River (N = 86, range = 48-210 mm) (Table 2). Sampling efforts in the upper reaches of the Imnaha River primarily focused on collecting genetics from a single age class of bull trout (<100 mm) that could then be compared to other populations within the Imnaha subbasin.

Findings

The abundance estimates from the 2007 return trip to Big Sheep Creek proved to be higher than the 2006 estimates. In just one pass the total number of captured bull trout ≥ 120 mm in 2007 was 749 (Table 1), compared to a three pass average of 217 individuals per trip in 2006 (Cook et al. 2008). The majority of the new fish captured in 2007 came from smaller size classes of fish (Figure 12). This finding was also significantly different from 2006 results in Big Sheep Creek (Cook et al. 2008). Interestingly, however, the 2007 Big Sheep Creek abundance estimates were similar to 2007 estimates for McCully Creek. There is not enough information to draw conclusions on what is driving population dynamics in these streams. However, given that bull trout are largely the only fish species above the WVIC in both of these streams and the change in size structure seen in Big Sheep Creek, it is possible that population levels are related in part to the occurrence of cannibalism.

The detection of a fish passing upstream over the Salt Creek summit spillway confirms connectivity between Big Sheep Creek and tributaries downstream along the canal. This may explain the presence of fluvial size individuals captured in Big Sheep Creek in the past (Cook et al. 2008). The rate of immigration is unknown. In addition, there is still no evidence of fish passing upstream from lower Big Sheep Creek to upper Big Sheep Creek over that diversion structure or of fish migrating upstream into McCully Creek.

The detection at Salt Creek summit of a 134 mm bull trout captured in the side channel of Big Sheep Creek provides evidence of that channel as passage to and from the upper reaches of Big Sheep Creek. This channel provides passage around two waterfalls (approximately 3 m and 15 m in height) and a high gradient reach between. The use of this channel also roughly doubles the amount of habitat available to bull trout in Big Sheep Creek.

2008 Tasks

- Maintain PIT tag antenna arrays year around at all sites.

- Conduct a two pass mark recapture population estimate of bull trout on Lick Creek, starting from the junction with Big Sheep Creek to the end of fish use- July/August 2008.

- Evaluate the possible isolation of bull trout above the WVIC diversion structure at Little Sheep Creek and gain more genetic samples from Little Sheep Creek- July/August 2008.

- Patch out the Imnaha River basin

- Install new PIT tag antennas at the Big Sheep diversion site above diversion and within canal and replace any non-functioning antennas at Salt Creek Summit – Spring 2008.

- Repeat one complete sampling pass of McCully Creek above the diversion structure – July/August 2008

- Intensify sampling efforts in various areas of the WVIC and in Big Sheep Creek below the diversion structure to increase sample size of PIT tagged bull trout in the watershed – July/August 2008

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