Evaluate the Life History of Native Salmonids in the Malheur Subbasin

Burns Paiute Tribe, Natural Resources Department, Fisheries Program

Project 1997-019-00, Contract # 63715

For work completed 01/14-12/14

FY2014 Annual Report

Prepared for

Bonneville Power Administration

Northwest Power and Conservation Council

Background for FY2014

In FY2014 the Burns Paiute Tribe Natural Resources Department Fisheries Program (BPT) completed multiple complementary statements of work via funding through Bonneville Power Administration (BPA), Project 1997-019-00, as well as through four additional federal contracts. In this Annual Report, we summarize work completed under all contracts in the 2014 field season, since these are all related to the goals and objectives of 1997-019-00.

The BPA Statement of Work (SOW) for FY2014 included the second year of continuous electrofishing removal of brook trout in Lake Creek (Chapter 2); continuous temperature monitoring on the Logan Valley Wildlife Mitigation Property (Chapter 3), and interagency coordination to develop a long-term brook trout removal strategy for Malheur River headwaters. All FY2014 Work Elements were approved during the most recent Resident Fish Categorical Review.

Three additional federal contracts were awarded to the BPT to support the FY2014 SOW for 197-019-00. Due to these grants being obtained as cost-share to Project 1997-019-00, the results of these grants are reported here.

- Collaborative Forest Landscape Restoration Plan (CFLR) funds were awarded to the Malheur National Forest (MNF) in 2012. The BPT was granted a small amount from the U.S. Forest Service (USFS) from annual CFLR funds to bolster implementation of brook trout removal on the MNF in FY2013 and FY2014 (Chapter 1). Project 1997-019-00 was used to attract CFLR cost-share to brook trout removal in the Upper Malheur River watershed. The BPT anticipates similar funding opportunities over the next several fiscal years.
- U.S. Bureau of Reclamation (USBR), Native Affairs Program Funds, were used to support removal of brook trout in High Lake. This was the fourth and final year of this grant to mechanically remove brook trout in the geologically isolated seed source of brook trout recruitment to spawning bull trout populations in Lake Creek (Chapter 4).
- USBR, Native Affairs Program Funds, were used to further develop the use of environmental DNA (eDNA) as a proxy for traditional methodologies to determine presence. The goal of this grant is to scientifically develop this methodology into a cost-efficient strategy to evaluate the effectiveness of brook trout removal efforts conducted under 1997-019-00 (Chapter 5). FY2014 was the third year of this funding, with one contracted year remaining.

One additional federal contract is not reported on here, due to a multi-year SOW that includes future work in FY2015. U.S. Fish and Wildlife Service (USFWS), Tribal Wildlife Grant, is being utilized to support interagency planning efforts related to conducting piscicide removal of brook trout. In FY2014, these efforts included baseline survey of macroinvertebrates and amphibians present in the potential piscicide treatment area. When these efforts are complete, a report to BPA will be provided in the fiscal year of completion.

One additional federal contract was not implemented in FY2014. The BPT has a multiple year agreement with the USBR to conduct bull trout trap and haul in the tailrace of Agency Valley Dam (Beulah Reservoir) during spring spill events. There was no spill over the dam in 2014; therefore, these trap and haul activities were not conducted. The purpose of this contract is to capture entrained bull trout via angling for release in the North Fork Malheur upstream of Beulah Reservoir. The last time this contract was triggered by environmental conditions was in 2011.

Coordination efforts were central to the FY2014 SOW and comprise the majority of in kind contributions to 1997-019-00. In January 2013, at the Malheur River Bull Trout Meeting hosted annually by BPT, an interagency Malheur River Bull Trout Technical Advisory Committee (TAC) was formed. This group met several times throughout 2013 and 2014, to prioritize bull trout recovery actions in the Upper Malheur River Watershed and to identify strategies toward implementation of these actions. The 2014 TAC consisted of BPT, USFS, Oregon Department of Fish and Wildlife, USFWS, USBR, and the U.S. Bureau of Land Management. The TAC will continue to meet at minimum quarterly, with the purpose of advancing bull trout recovery actions in the Upper Malheur and North Fork Malheur River watersheds.

The TAC is integral in long-term implementation of bull trout recovery actions, and in maximizing benefit to bull trout by encouraging the coincidence of both fisheries and land management actions. The TAC formed in response to BPT advocating for basin-wide brook trout removal in the 80- 100 miles of estimated affected area in the Upper Malheur River. Accordingly, in 2014 the TAC began to prioritize action areas for implementing basin-wide removal by piscicides.

The Fisheries Program staff in FY2014 consisted of Erica Maltz (Fisheries Program Manager), Brandon Haslick (Fisheries and Wildlife Biologist), Kristopher Crowley (Fish Biologist) and Franki Gould (season Fisheries and Wildlife Technician).

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Contents

Chapter 1:

Exploratory Sampling to Identify the Downstream Extent of Brook Trout Distribution in the Upper Malheur River Watershed

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Contents

Chapter 1: Exploratory Sampling to Identify the Downstream Extent of Brook Trout Distribution in the Upper Malheur River Watershed

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1.1 Introduction

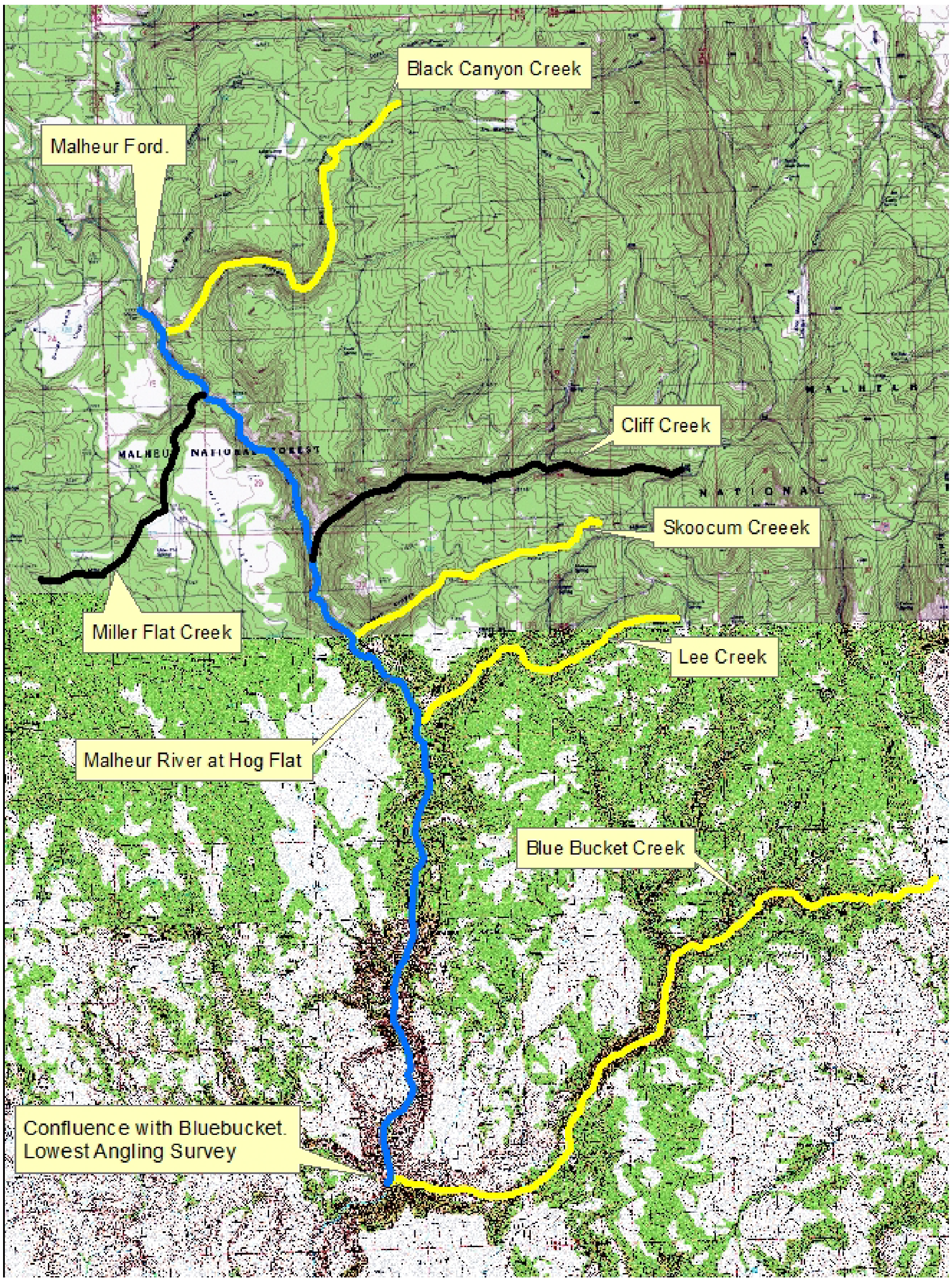
Brook trout are an invasive fish known to inhabit headwater streams in the Upper Malheur River. In many of these streams they are the dominant species present, and have been widely documented to threaten the long term viability of native trout populations (Gunckel, 2001; Dunham et al., 2002; Ratliff and Howell, 1992; DeHaan 2010). Much of the Upper Malheur River's headwater streams are currently listed as ESA Critical Habitat to bull trout (USFWS 2002). Brook trout have been shown to be the more aggressive species when present with bull trout (Gunckel et al., 2002), and have also been demonstrated to threaten the genetic purity of bull trout populations through introgressive hybridization (DeHaan et al., 2010).

Since its formation in 2013, the Burns Paiute Tribe Natural Resource Department (BPT) has coordinated the multi-agency Malheur River Bull Trout Technical Advisory Committee (TAC), developed to guide and implement recovery actions and to collaboratively monitor the status of bull trout in the Upper Malheur River, Oregon. Brook trout have been identified by both the TAC and the Draft Bull Trout Recovery Plan (USFWS, 2002) as a major threat to be managed in the basin to facilitate recovery. Therefore, in recent years there has been increasing interest to develop a basin-wide approach to brook trout eradication in the Upper Malheur River. A major component in developing this approach is empirically defining the extent of brook trout presence.

While brook trout distribution in headwater tributaries is well documented through previous surveys by Project 1997-019-00 (Fenn and Schwabe, 2003; Fenn, 2004; Fenton, 2005; Poole, 2010; Harper, 2011, 2012; Crowley, 2013), the lower extent of brook trout has yet to be formally investigated. Naturally, long term planning for control and eradication of brook trout is only likely to be effective when the population's extent is known in order to develop measures to either achieve complete eradication or to prevent repopulation from nearby streams post-treatment.

In order to address this question, BPT was contracted by the US Forrest Service (USFS) using Collaborative Forest Landscape Restoration Program (CFLR) funding to conduct formal investigation into the presence/absence of brook trout near the lower putative extent of brook trout. Surveys were completed in tributaries and the main stem of the Upper Malheur River in order to identify stream sections currently occupied by brook trout and to remove any individuals captured. Additionally, surveys provided a necessary biotic component to Level II Stream Survey data collected by the USFS in 2014. The findings of the BPT surveys will help the TAC define the extent of necessary treatments in development of a basin-wise approach to brook trout eradication.

Figure 1.1 Areas surveyed by angling (blue; mainstem Upper Malheur River; Spring) and Electrofishing (yellow; tributaries; Fall). Miller Flat Creek and Cliff Creek (black) were initially included in the study area, but were dry when sampling occurred.



1.2 Methods

Survey Area and Timing

The study area for sampling in the spring and fall consisted of the mainstem of the Upper Malheur River and its tributaries from Malheur Ford (upstream) to the confluence of the Malheur River with Bluebucket Creek (downstream; Figure 1.1). Angling surveys were selected during spring flows when mainstem temperatures were conducive to brook trout. High water from snowmelt during this time also makes angling the preferred sampling method due to large water volume.

Tributaries in the area were investigated in the fall based on temperature regimes likely causing brook trout to move out of the mainstem during the summer months to seek cool water refugia in the upper reaches of small streams. The timing of this sampling would also coincide closely with hypothetical piscicide treatment. Brook trout presence in these tributaries would prompt inclusion of the entire study area for hypothetical piscicide treatment, even in the event that no brook trout were discovered in the mainstem.

Angling-Spring Sampling

In May, BPT conducted angling surveys in the main stem of the Upper Malheur River near the lower putative terminus of brook trout distribution, as estimated by TAC professional judgment (Malheur Ford, Figure 1.1) During these surveys gear type, species captured, angler effort (hours), and location of brook trout capture was recorded. Angling occurred from May 12th-16th at Malheur Ford, Hog Flat, and at the confluence of Bluebucket Creek with the mainstem Malheur River. Spinning gear and fly gear were utilized. Specific brook trout catch locations were recorded (UTM WGS84) when satellite signal was available. Angling was selected for mainstem sampling due to logistical difficulties and safety concerns associated with electrofishing in high water volume and velocity.

Electrofishing-Fall Sampling

Presence surveys continued in Fall 2014 via backpack electrofishing, which was selected for tributary habitat due to feasibility of sampling as much of the wetted stream channel as possible and due to low water volume and velocity. From Sept 23th-30th, BPT sampled four small tributary streams from Malheur Ford to the confluence with Bluebucket Creek. The streams surveyed were (from upstream to downstream) Black Canyon Creek, Skookum Creek, Lee Creek, and Bluebucket Creek (Figure 1.1). Cliff Creek and Miller Flat Creek, although initially included in the survey area, were not sampled due to being confirmed as dry during the sampling period. Many of these streams were logistically difficult to sample due to their remote locations. Therefore, BPT contracted with Burns Llama Trailblazers to handle hauling gear and euthanized brook trout when necessary. All streams utilized llamas to assist in sampling with the exception of Bluebucket Creek. In each stream where water was present, every third pool was sampled and all fish were netted and measured. Pools were determined based on professional judgment and not on quantitative measurements. Brook trout were removed from the system and natives were released back to the pool where they were captured. If no water was present at the mouth, the dry stream bed was hiked to its origin in search of remnant pools or intermittent sections. If wetted channel was confirmed, surveying every third pool would start at the lowest pool. Sampling ended only when there were no longer fish present (i.e. impassable barrier) or the stream channel became dry. If five pools (five of every third) were sampled and no fish species were captured, sampling concluded and the last pool to yield fish was considered the upstream extent of distribution. With the exception of Bluebucket Creek, all streams were surveyed until one of the above criteria was met. Bluebucket Creek contained continuous water and pools surveyed yielded fish until the final pool sampled. Conclusion of sampling in Bluebucket Creek was dictated by time constraints rather than lack of fish or water (refer to “Recommendations” for future sampling needs). All surveys consisted of one backpack electrofisher and one hand netter.

1.3 Results

Angling

Malheur Ford

On May 12th, BPT sampling at Malheur Ford consisted of four anglers contributing approximately 8 hours of total effort. During this time, anglers spinning gear (panther martin spinners, rooster tail spinners) and fly gear (chironomid). Three brook trout were captured during sampling as well as two redband trout.

Hog Flat

On May 13th, sampling occurred at Hog Flat (approximately 5-7 miles downstream of Malheur Ford). Sampling consisted of three anglers contributing a total of 4 hours of effort. Spinning gear was used exclusively at this location due to results at Malheur Ford. Anglers captured two brook trout, one mountain whitefish, and five redband trout.

Mouth of Bluebucket Creek

The furthest downstream sampling occurred in the Malheur River at the mouth of Bluebucket Creek on May 16th. Two anglers contributed a total of four hours of sampling effort using spinning gear exclusively. Fourteen redband trout were captured. Redband trout were the only species captured during this effort.

Electrofishing

Black Canyon Creek

Sampling in Black Canyon Creek was completed September 24th beginning at the mouth and sampling every third pool. At this time of the year there was very little flow in the creek. There was a break in the stream above a 1.5' head cut after 15 pools were sampled. Stream flow above this became intermittent and every third intermittent pool was sampled. A second head cut (2') was observed after 10 more pools were sampled. Five pools were sampled above this when the stream went completely dry. Thirty one total pools were sampled in Black Canyon Creek yielding 45 redband trout and three brook trout. Of the 30 pools sampled, only eight contained no fish. Fish were found throughout the stream including above each of the head cuts and in the intermittent sections of streams. Brook trout were captured in pools where water flow was intermittent causing entrainment.

Skookum Creek

Sampling in Skookum Creek was completed on September 23rd beginning at the mouth sampling every third pool. Sampling ended after sampling nine pools. Just above the fourth pool sampled (tenth overall) was a waterfall that appeared impassable. Sampling ceased after five pools above this yielded no captures or visual encounters. A total of one redband trout was captured in Skookum Creek.

Lee Creek

Sampling in Lee Creek was completed on September 23rd beginning at the mouth sampling every third pool until no fish were captured in five consecutive (every third) pools. Five fish were captured in the 14 pools that were sampled including three redband trout and two unknown juvenile trout that were too small to positively identify in the field.

Bluebucket Creek

The furthest downstream sampling in 2014 occurred in Bluebucket Creek on September 30th beginning at the mouth and sampling every third pool. Sixty five pools were sampled. The end of sampling was dictated by time rather than a lack of water or fish. Fish were present at all but nine pools and species included: redband trout (162), speckled dace (22), sculpin (9), and brook trout (2).

1.4 Discussion

Angling surveys in May were positive for brook trout presence on two occasions (Malheur Ford and Hog Flat). At the mouth of Bluebucket Creek anglers caught no brook trout, but this does not indicate their absence in this stretch of stream. Anglers used limited gear and only 4 hours of effort. Furthermore, the presence of brook trout in Bluebucket Creek in

September increases the likelihood that brook trout utilize the mainstem of the Upper Malheur River at least seasonally.

Most brook trout that were found during the fall (low water) electrofishing efforts were in the upper reaches of streams, far from the mouth. In Black Canyon Creek, brook trout were found in pools above where stream flow was continuous. The entrainment of these fish suggests that they moved into the upper reaches of these streams during spring high water flows. Stream temperatures in the intermittent pools (BPT unpublished data) remained suitable for brook trout in the fall suggesting ground water replenishment. If this is indeed the case, brook trout in these pools may be able to survive the winter despite entrainment. This suggests the possibility of brook trout being resident to tributaries. However, it is most likely that brook trout overwinter whenever possible in the mainstem, moving into the tributaries during high water to avoid summertime mainstem temperatures.

Brook trout had never before been documented through formal sampling efforts in Bluebucket Creek, the downstream most tributary in the study area. Without knowing the lower extent of brook trout, an eradication plan cannot move forward to implementation. However, depending on the downstream extent of sampling there are potential hurdles to acquiring access from private landowners.

1.5 Recommendations

Even in small tributaries with limited brook trout presence it is unlikely to achieve eradication using mechanical methodology. While brook trout that were encountered during these surveys were removed from the system, a more comprehensive approach, such as piscicide, would be necessary to confidently rid the stream of brook trout. Upon establishing the lower extent of brook trout in the basin, BPT recommends moving forward with a comprehensive approach to effectively eradicate brook trout, alleviating the threat they pose to ESA-listed bull trout.

The study area in 2014 must be expanded in future years to conduct surveys to investigate tributaries located downstream in proximity to those confirmed as brook trout-bearing in 2014. Wolf Creek and the mainstem Malheur River below Bluebucket Creek will require continuous electrofishing survey beginning in 2015 for presence/absence of brook trout, as these areas have not yet been surveyed for this purpose to date. The most downstream mainstem reaches and/or tributaries to yield no brook trout captures in 2015 will require repeat of surveys for 3-5 additional years, via electrofishing, to establish confidence in their absence and thus the true extent of lower distribution (Hurn, Pers. Comm.). If rotenone treatments are eventually planned for the main stem and tributary area below Malheur Ford, then all tributaries will need to be surveyed for water and spring distribution to ensure that treatments occur in all wetted areas. This will apply to tributaries that yielded no brook captures, but that are above the most downstream capture. BPT recommends that no assumptions should be made on whether brook trout are present in a given area if rotenone treatments must occur downstream.

1.6 Acknowledgements

BPT would like to thank the TAC and USFS for supporting a collaborative approach to bull trout recovery in the basin. This effort was supported by CFLR funds generously awarded by the USFS as cost share to Project 1997-019-00.

1.7 References

Crowley, K. 2013. Selective Removal of Brook Trout in Lake Creek, Upper Malheur River, Oregon. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2013 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

DeHaan, P. W., Schwabe, L. T., & Ardren, W. R. (2010). Spatial patterns of hybridization between bull trout, *Salvelinus confluentus*, and brook trout, *Salvelinus fontinalis* in an Oregon stream network. *Conservation Genetics*, *11*(3), 935-949.

Dunham, J.B., S.B. Adams, R.E. Schroeter, and D.C. Novinger. 2002. Alien Invasions in Aquatic Ecosystems: Toward an Understanding of Brook Trout Invasions and Potential Impacts on Inland Cutthroat Trout in Western North America. Reviews in Fish Biology and Fisheries 12:373-391.

Fenn, K and L. Schwabe. 2003. Use of a Backpack Electrofisher to Determine the Distribution of Brook Trout (*Salvelinus fontinalis*), Bull Trout (*Salvelinus confluentus*), and Potential Hybrids of Brook and Bull Trout in Lake Creek and Meadow Fork Big Creek, Oregon. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” Fiscal Year 2003 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Fenn, K. 2004. Use of a backpack electrofisher to determine changes in distribution and species composition of fish species in Meadow Fork and Lake Creek. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2004 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Fenton, J. 2005. Use of a Backpack Electroshocker to Determine the Distribution of Salmonids in Snowshoe Creek. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2005 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Gunckel, S., A. Hemmingsen, J. Li. 2002. Effect of bull trout and brook trout interactions on foraging, habitat, feeding and growth. Transactions of the American Fisheries Society. 131: 1119-1130.

Harper, D. 2011 and 2012. Selective Removal of Brook Trout Salvelinus fontinalis in Summit Creek, Malheur River Basin, Oregon. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2011 and 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Harper D. 2012. Distribution and Abundance of Redband Trout Oncorhynchus mykiss and Brook Trout Salvelinus fontinalis in Summit Creek, Malheur River Basin, Oregon. “Evaluate the

Life History of Native Salmonids in the Malheur Subbasin.” FY 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Hurn, Shannon. Ex Supervising Fish and Wildlife Biologist- Malheur District. Current Oregon Department of Fish and Wildlife. Personal Communication.

Poole, Alex. 2010. 2010 High Lake Brook Trout Suppression. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2010 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Ratliff, D.E. and P.J. Howell. 1992. The Status of Bull Trout Populations in Oregon. Pages 10-17 in P.J. Howell and D.V. Buchanon, editors. “Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society.” Corvallis, OR.

U.S. Fish and Wildlife Service. 2002. Chapter 14, Malheur Recovery Unit, Oregon. 71 P. In: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, OR.

Chapter 2:

Selective Removal of Brook Trout (*Salvelinus fontinalis*) in Lake Creek, Upper Malheur River, Oregon

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Contents

Chapter 2: Selective Removal of Brook Trout (*Salvelinus fontinalis*) in Lake Creek, Upper Malheur River, Oregon

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2.1 Introduction

Brook trout (*Salvelinus fontinalis*) have been introduced throughout the western United States. Although many of the introductions were originally intended to provide sport fishing opportunities, brook trout have been implicated in declines of native aquatic biota (Adams, 1999). Due to an apparent increased dispersal ability in the downstream direction, the stocking of mountain lakes with brook trout can be especially detrimental (Adams, 1999; Paul and Post, 2001). Though the mechanism(s) through which brook trout affect native species may be variable, predation, resource competition and hybridization are commonly cited factors (Dunham et al., 2002; Gunckel, 2001; Ratliff and Howell, 1992). In response to the identification of brook trout as a limiting factor to the recovery of ESA-listed bull trout (*Salvelinus confluentus*) in the Malheur River basin (USFWS, 2002), the Burns Paiute Tribe Natural Resources Department (BPT) began brook trout suppression efforts in 2010 (Poole and Harper, 2011).

Nonnative brook trout exist in high numbers in the Upper Malheur River basin. In the 1930's brook trout were introduced to High Lake (Bowers et al., 1993), a naturally fishless lake which serves as the headwater source of Lake Creek. Brook trout have also likely been introduced through several authorized and unauthorized stockings in the Upper Malheur basin over the last century. The reproductive success of brook trout in High Lake and tributaries of the Upper Malheur River has led to its dispersal into the majority of known suitable habitat (estimated 80-100 river miles). Three genetically distinct population segments have been documented in the Malheur basin and gene flow between them has been documented (DeHaan et al., 2010). Tribal biologists have located hot spots with high brook trout densities via annual electroshocking surveys in the basin (Schwabe et al., 2000; Schwabe et al., 2001; Fenn, 2004; BPT, unpublished data) and brook trout spawning has been observed in most tributaries known to harbor these fish (Ray Perkins, Pers. Comm.). This apparent prolific dispersal and reproduction has resulted in competition between brook trout and native fish species as well as hybridization between brook and ESA-listed bull trout.

The presence of brook trout poses serious threats to the long term viability of bull trout due to its ability to outcompete and hybridize with native species. Resource competition and high rates of introgressive hybridization between the two species has been documented in the Upper Malheur (Gunckel, 2001; DeHaan et al., 2010). Brook trout encroachment, along with other environmental and anthropogenic factors, have imperiled bull trout in the Upper Malheur and led to the population being classified as having a high risk of extinction (Buchanan et al., 1997). Recovery criteria for the Malheur Recovery Unit cite stable or increasing abundance trends in bull trout populations and the reestablishment of connectivity between the isolated populations of the North Fork and Upper Malheur as actions necessary to achieve delisting (USFWS, 2002). It has also been deemed necessary to achieve a reduction or elimination of threats from brook trout interaction in the Upper Malheur prior to restoration of passage (USFWS, 2002). Full recovery of Malheur River bull trout is therefore contingent upon minimizing the threats posed by brook trout interactions in the basin.

In 2010, the BPT began implementation of a mechanical removal project aimed at eliminating brook trout from High Lake and associated headwater portions of its outlet stream, Lake Creek. High Lake and Upper Lake Creek are high elevation sites in the Malheur National Forest of eastern Oregon. Once naturally devoid of fish, this area now hosts populations of brook trout which may serve as a source population for the Upper Malheur watershed. Suppression efforts continued in 2014 with the purpose of maximizing mechanical removal of invasive brook trout in Lake Creek. This was accomplished through a comprehensive creek electrofishing effort above Lake Creek Youth Camp and Murray Campground. Mechanical removal of brook trout in High Lake by gillnetting was also resumed in 2014 after a one year hiatus due to wildfire.

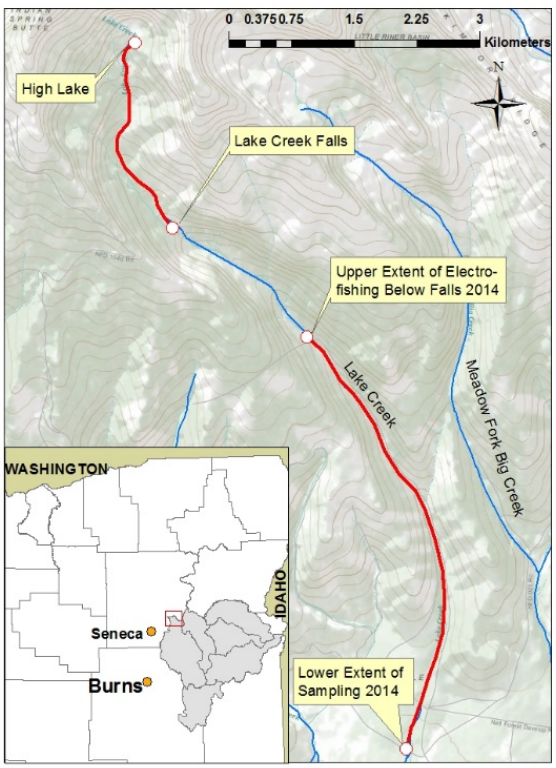


Figure 2-1: Map displaying the portion of Lake Creek electroshocked in 2014. Reaches highlighted in red were sampled (although not indicated, sites 96 and 97 of sites 81-106 above Lake Creek Falls were not sampled due to

Study Area

The study area is located on the southern flank of the Strawberry Mountains in eastern Oregon (Figure 2-1). A major headwater tributary to the Upper Malheur River, Lake Creek flows approximately 20 kilometers from its source at High Lake to its confluence with Big Creek, where the two form the Upper Malheur River. Lake Creek Falls is located near river kilometer (RK) 17 and presents a complete barrier to upstream fish passage (Figure 2-1). Much of Lake Creek upstream of Lake Creek Falls is characterized by channel widths of 1-2 meters and moderate gradients (2-5%) with intermittent steep reaches (15-20%) that may pose as barriers to upstream fish passage. Brook trout are the only fish species present above Lake Creek Falls. Below the falls, Lake Creek is characterized by moderate gradients (2-5%) and channel widths of 2-5 meters. Fish species present beside bull and brook trout include sculpin (*Cottus sp.*), redband trout (*Oncorhynchus mykiss gairdneri*), and brook trout/bull trout hybrids (Fenn, 2005).

Summer stream temperature regimes in Lake Creek appear suitable for bull trout from Lake Creek Falls downstream to Murray Campground (the lower extent of 2014 sampling; BPT, unpublished data). However, between the campground and USFS Road 16, temperatures increase dramatically and often exceed bull trout thermal tolerances in summer; essentially creating a thermal barrier to both upstream and downstream migration and isolating bull trout in the upper reaches of Lake Creek (Abel, 2010). This effectively prevents these fish from accessing the higher quality habitat present in tributaries like the nearby Big Creek system for spawning, rearing, and subsisting. Partially due to the lack of an upstream seed source, brook trout exist in much lower densities in the upper Big Creek system. Additionally, the water is generally colder, a supplementary benefit to bull trout able to migrate there.

2.2 Methods

Smith-Root models 12B and LR24 backpack electrofishers were used to conduct electrofishing for removal of brook trout in 2014. Shocker voltage was typically set at 500, pulse width at 40 Hz, and frequency at 4 ms. Settings were adjusted if necessary to optimize catch rates while minimizing harm to shocked fish. A comprehensive sampling approach was undertaken in which the entire stream was fished systematically beginning near Murray Campground (site 1) and continuing upstream. Crews intended to shock continuously to High Lake, the upper extent of Lake Creek (a total of 106 sites mapped prior to sampling, each approximately 100 meters in length). However, time constraints, spring runoff, and a need to comply with permit requirements prohibiting shocking in bull trout habitat during native trout spawning seasons prevented complete achievement of this goal (refer to Figure 2-1 for actual distance sampled). Sites 57-80 were not sampled this year. Sites 96 and 97 were also unable to be sampled as the majority of the creek flows subsurface and access is virtually impossible. The final three sites above Lake Creek Falls were shocked but featured discontinuous flow.

Individual site length was at times adjusted in the field to include favorable hydrologic structures such as pools at reach termini or entire side channels. Occasionally, sites were combined in the field if circumstances warranted. A site was typically defined as all wetted channels from the downstream beginning to the upstream terminus. However, sites with high channel complexity were sometimes broken into main stem and secondary side channel components. The amount of time captured fish were exposed to temporary holding environments was effectively reduced as a result.

All available habitats were sampled within each site with slow and deliberate anode sweeps diagonally across nearly the entire wetted width of all channels, progressing from downstream to upstream. Habitat features such as pools, undercut banks, and woody debris piles that provide cover were thoroughly shocked to improve capture rates. At least one netter, but often two or three, positioned dip nets near the anode (and cathode, if possible). Every attempt was made to capture as many fish as possible. However, stream velocity and cover such as woody debris and undercut banks naturally created obstacles to perfect capture rates. Captured native fish were deposited into aerated temporary holding buckets filled with stream water while non-native brook trout were placed into dry ‘kill’ buckets. Special attention was paid to bull trout and hybrids and any capture was efficiently processed and released in a downstream pool. At the top and bottom of each reach, crews recorded UTM locations using a handheld GPS unit. Start and finish times and temperatures were recorded for each site as well.

In previous years, shocking on Lake Creek involved the use of block nets and multiple passes for more comprehensive electrofishing results. A change in protocol came about due to time constraints, and, more substantially, the intent to reduce shocking stress and handling time on captured fish, especially bull trout. All native fish were processed in 2014 in an efficient manner for the same reasons. Fish were identified to species (except sculpins and young of year trout), enumerated, and measured (fork length). If capture rates were high, native fish were simply tallied or a subset was measured only. All native fish were released downstream. Brook trout were examined for fin clips or other markings, scanned for PIT tags, measured, weighed if a scale was available, and removed from the system. Bull trout and hybrids were processed in much the same way, removal from the system notwithstanding. With few exceptions, these fish had PIT tags implanted if not already inserted and fin clips were taken for genetic analysis. However, a small handful of fish were not tagged for reasons ranging from excessive stress and longer than usual time in the temporary holding environment to emaciated condition.

2.3 Results

Electrofishing in Lake Creek began on July 2nd and ended on September 24th. Eighty sites totaling approximately eight stream kilometers were sampled (greater than 113,503 seconds of shocking effort) with the primary goal of brook trout removal. All sites below the waterfall barrier were visited prior to August 15th to avoid harassment of bull trout during spawning season and after June 15th to prevent the same for redband trout.

Five species of fish were captured in the electrofishing effort, including brook trout (n=1241, 1231 > 60 mm fork length; n=1053, n=1046 > 60 mm fork length below the waterfall barrier), bull trout (n=12, no incidental mortality), bull/brook hybrid (n=17, 2 incidental mortalities), redband trout (n=110, 55-209 mm fork length, 6 incidental mortalities), and sculpin (n=1211, 15 incidental mortalities). All brook trout captured but one were euthanized; all other fish were released. Some trout (n=208, 4 incidental mortalities) could not be positively identified to species because of undeveloped phenotypic features. Incidental mortalities were relatively low and principally stemmed from extended time spent in a temporary holding environment to close proximity to shocking apparatus. Length-frequency histograms are provided for bull trout, brook trout, and hybrids (Appendix A).

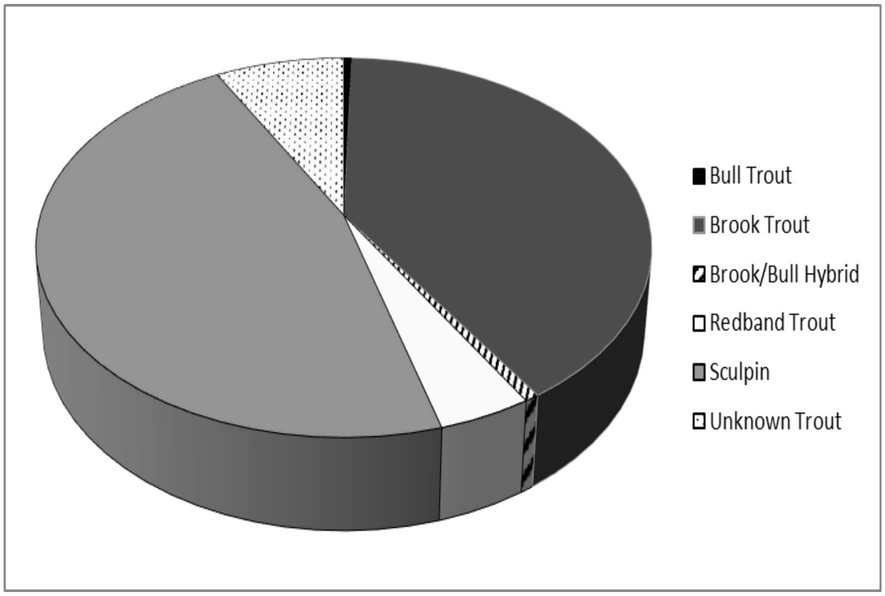


Figure 2-2: Relative abundance of all electrofishing captures below Lake Creek waterfall barrier (allopatric above).

Sculpins were the most commonly captured fish below the waterfall barrier (sites 1-56; Figure 2-2), with brook trout a close second. Unsurprisingly, brook trout were allopatric above the barrier to High Lake (sites 81-106). Brook trout captures outnumbered bull trout 88:1, hybrids 62:1, and redband trout 10:1 below the waterfall barrier. The majority of redband trout were found in the lowest 26 sites (82%). The majority of bull trout and hybrids were captured in sites 40-56 (72%).

In addition to Lake Creek main stem shocking, approximately 500 meters of Meadow Fork Big Creek were shocked (5,152 seconds of effort) in conjunction with an Oregon Department of Fish and Wildlife genetics study, the contents of which will be published elsewhere. Two brook trout (145 mm and 164 mm) twenty bull trout (ranging in size from 106 mm to 232 mm), and five hybrids (ranging from 147 mm to 162 mm) were captured. These fish are excluded from length-frequency and length-weight graphs (Appendix B) which pertain principally to Lake Creek specimens. Fish were not weighed and no individual suffered mortality or was removed from the system. Bull trout and hybrids were all fin clipped for genetic analysis and PIT tagged.

PIT Tagging

A total of eight bull trout and eleven brook/bull trout hybrids were implanted with new PIT tags in 2014 during Lake Creek electroshocking in addition to the twenty bull trout and five hybrids tagged in Meadow Fork Big Creek while assisting ODFW with genetic sampling. Four bull trout and six hybrids did not receive PIT tags for various reasons, with concerns about the health of the individual fish a primary factor. Two bull trout and one hybrid were recaptures from previous BPT efforts. Since 2011, BPT has inserted PIT tags into 40 individual bull trout, 20 brook trout, and 24 brook trout/bull trout hybrids in Lake Creek in addition to those from Big Creek.

2.4 Discussion

Nonnative brook trout exist in high numbers in the upper Malheur River basin and have dispersed to nearly all suitable habitat within the watershed. This dispersal has resulted in competition between brook trout and native fishes (Gunckel, 2001) and is particularly problematic for ESA listed bull trout threatened by introgressive hybridization (DeHaan et al., 2010). Brook trout suppression continued in the Lake Creek watershed in 2014 via electrofishing and gillnet operations at High Lake, the seed source. In addition to brook trout removal, Lake Creek activities supplement baseline data collection for past and future comparisons pertaining to native and exotic fish distributions, interactions, and population dynamics. Comprehensive electrofishing in Lake Creek from Murray Campground to High Lake was accomplished with the exception of the approximately 2.4-kilometer section below the waterfall barrier.

Similar to 2013, shocking efforts in 2014 focused principally on brook trout removal[1]. Captures removed totaled 1240, a substantial 54% decrease as compared with 2013. However, Lake Creek electrofishing accounted for less than half (41%) of brook trout removed from the Upper Malheur River system in 2014. Gillnetting in High Lake (described in a Chapter 4) resumed after a one year hiatus due to wildfire and accounted for the majority of fish removed. The logical assumption after a year in which mechanical removal at the seed source for Lake Creek was not completed would be higher electroshocking captures. Given that numbers decreased seemingly beyond the expected natural range of variability instead, what might account for this reduction in brook trout shocked and removed from Lake Creek this past year?

[1]2012 efforts included mark-recapture and depletion sample designs geared toward abundance estimates in addition to removal. These were intended to provide a baseline for evaluating effectiveness of this methodology in reducing spawner abundance over a five year period.

When comparing catch numbers from previous years, it is important to consider that levels of effort have not remained constant from year to year. Although shocker seconds were not recorded in 2013, linear distance shocked was and totaled approximately 10,500 meters. However, this number errs on the low side as a limited number of stations received a second pass, unaccounted for in the overall estimate. In 2014, only about 8000 meters were covered. Combining catch numbers with distance sampled yields about one brook trout removed per 3.9 meters in 2013 and about one per 6.4 meters in 2014. These adjusted numbers yield a smaller disparity between years but a substantial difference exists nonetheless. One logical conclusion that could be made is that perhaps removing such a large number of fish the previous year would create a depleted stock situation in the next. Supporting evidence for this hypothesis can be found when taking into consideration 2012's adjusted catch per meter numbers. Although considerably less stream distance was shocked in 2012, one brook trout was removed for every 2.2 meters of creek. Comparing all three years, an encouraging trend of fewer fish removed per meter of stream each consecutive year emerges. A reasonable hypothesis that brook trout densities are decreasing as a result of BPT's removal efforts can thus be ventured.

However useful it might be to attempt to draw conclusions about population status from electrofishing results, it is important to note that annual results have shown wide variability amongst other species of fish in Lake Creek, which were not removed from the system. For instance, 840 sculpin were captured in 2012 but only 571 were shocked one year later. In 2013, 178 redband trout were recorded but only 111 one year later. Eighty-two bull trout were shocked in 2013 while 2014 resulted in only 12 captures. These numbers are surprisingly disparate but do not necessarily indicate a trend one way or the other. Electroshocking in a free flowing stream can only produce a sample of total population, and oftentimes that sample can be quite small. Shocking in a dynamic system can easily produce inconsistent results year over year. Therefore, it is extremely difficult to draw conclusions about population trends and formulating a theory about brook trout population response to removal efforts should be taken in this context. However, longer datasets and additional samples will give more definition to population trends over time.

Also of note, an extenuating circumstance that might have contributed to variable brook trout capture numbers revolves around BPT's operation of a seasonal weir on Lake Creek in 2011 and 2012. Weir operation creates a physical barrier to free flow fish movement. Creating barriers to migration might prevent fish from distributing further downstream, essentially trapping them in the electroshocked reaches of Lake Creek. The net result might be that catch numbers were higher than they might have been otherwise in those two years. At any rate, the presence of a weir in 2011 and 2012 is a potentially impactful variable worth noting.

In addition to the adverse effects suffered by ESA-listed bull trout in upper Lake Creek due to a seemingly numerous invasive brook trout population despite removal efforts, bull trout are believed to be seasonally isolated in this location. Bull trout in the middle fork upper Malheur are also believed to lack access to a suitable overwintering habitat such as a reservoir or lake. This is likely due to unsuitable thermal conditions downstream caused by climate change, riparian de-vegetation, channel reconfiguration, and complex water diversions that prevent fluvial bull trout from accessing historic spawning areas during migration in the Upper Malheur Basin (Abel, 2009). This theory is supported by several years of temperature data collection (BPT unpublished data), spawning surveys (Perkins, 2012), and radio telemetry studies (Fenton, 2005). Unable to migrate from upper Lake Creek to more suitable habitat, resident bull trout become highly susceptible to hybridization and resource competition from steady brook trout immigration pressures, particularly in comparison to bull trout in other Malheur River headwater tributaries (DeHaan et al., 2010).

BPT is currently investigating several options with the potential to lower stream temperatures enough to dissipate the thermal barrier preventing fluvial bull trout migration. Ongoing negotiations with the land owner to secure the water rights and obtain ownership of the inholding between Murray Campground and Forest Road 16 have yet to be successful. However, BPT is optimistic that property acquisition remains a tenable option. Should that occur, water withdrawals would cease and shade-producing revegetation could commence in the riparian zone, similar to that which the Tribe is already engaged in on the Logan Valley Wildlife Property immediately downstream.

While electrofishing to remove brook trout may slow detrimental effects on bull trout, it is unreasonable to assume any lasting reduction in brook trout populations. The 1232 brook trout of spawning age (greater than 60 mm) removed by BPT shocking activity in Lake Creek in 2014 comprised only approximately 10.5% of the 2012 estimated 11,797 (95% confidence interval; 9,362-14,232) total population in Lake Creek above Murray Campground (Harper 2013). Based on our protocol, an estimated 42% of adult brook trout are expected to be removed from the system every season. However, the electroshocking challenges of the Lake Creek drainage (i.e. high amounts of downed wood and vegetation-choked side channels) create obstacles to netting. Regardless, even a rate of 42% might not be sufficient to achieve post-removal goals. A study in Idaho showed that electrofishing removals as high as 88% still did not have long term effects in reducing brook trout or increasing redband or bull trout populations (Meyer et al., 2006). High Lake, the upstream seed source for downstream brook trout recruitment, further reduces the effectiveness of mechanical removal of brook trout. The high ratio of sexually mature brook trout captured in Lake Creek from 2012-2014 (Harper, 2013; Crowley, 2014) alludes to the resiliency of the Lake Creek brook trout population to rebound yearly after mechanical removal. The goal of electroshocking removal efforts is simply to suppress on a yearly basis until planning is finalized and resources become available for effective eradication.

The high number of hybrid bull/brook trout detected in the upper reaches of Lake Creek highlights the urgency of setting this eradication process in motion. Introgressive hybridization poses an ever-present threat to the loss of genetically pure bull trout (DeHaan et al., 2010). Competition for resources introduces additional pressures on an already stressed bull trout population. Phenotypic overlap between pure bull trout and hybrids makes consistent identification in the field difficult, however, and determination with certainty at the present time requires genetic analysis. In addition, there exists a lack of policy clearly defining thresholds for tolerated levels of hybridization. For these reasons, hybrids are currently not removed from the system. BPT's intention is to have the genetic samples procured in 2014 analyzed in order to help prevent these issues in the future. Until then, mechanical removal of fish in the Upper Malheur Basin will continue to focus solely on brook trout.

In addition to water temperature and hybridization pressures on bull trout, competition with brook trout for available resources presents a supplementary challenge for bull trout in the upper middle fork of the Malheur River. BPT collected a substantial amount of weight information on captured salmonids in 2014, and Appendix B displays length-weight graphs from field activities in 2013 and 2014 in both Lake Creek and Big Creek. Big Creek differs from Lake Creek in that aquatic habitat, water quality, and water temperature favor bull trout, and the presence of brook trout is much reduced there. Also displayed in Appendix B is USBR bull trout length-weight information from the North Fork Malheur River, a drainage not impacted by non-native brook trout. All graphs display tight correlation between the variables of length and weight. Although imperfect, it is possible to approximate linear slope to the non-linear line of best fit. This has been calculated and added to the graphs. Based off of the length and weight correlation, slope can thus become a surrogate fitness/health metric where the higher the value, the healthier the fish (in terms of body size only). When comparing the slopes from different drainages and years, it appears as though Lake Creek hybrid and bull trout body size is surprisingly not suffering from the effects of brook trout competition. This conclusion must be taken in the context of small sample size, however, and is independent of actual population numbers, which have declined since the introduction of brook trout.

Brook trout body condition, on the other hand, appears to be suffering from the effects of limited resource pressure. Anecdotal evidence from the field and evidence from the literature support the conclusion that this is occurring, has occurred elsewhere, and might in part be a compensatory response to brook trout removal without eradication (Meyer et al., 2006; Moran and Storaasli, 2010). Brook trout presence in the upper middle fork Malheur River is primarily felt in terms of sheer numbers, which are substantial, but the length-weight relationship displayed in Appendix B indicates that these fish are not particularly healthy. Again, brook trout are non-native to this system and the conditions are not ideal for the production of brook trout with large body size. If allowed to remain in the upper middle fork of the Malheur, brook trout will continue to respond to the pressures of both intraspecific and interspecific competition, and the population will likely remain in its current condition.

North Fork Malheur River bull trout have access to Beulah Reservoir for overwintering which allows these fish to obtain large size. In order to account for this size discrepancy, two graphs were made for the North Fork. One has a cutoff of 305 mm fork length which approximates the largest size that could be expected to be captured in Lake or Big creeks. The other graph includes all North Fork fish from USBR data from the years 2011-13. The smaller bull trout in the North Fork do not appear to be as healthy based on body size as those of Lake and Big Creek. However, when the larger fish are added to the mix, the body index receives a substantial boost. What might be occurring on the North Fork is that the larger bull trout are impacting the growth of the smaller ones in much the same way that hybrids and bull trout are affecting brook trout in Big and Lake Creeks.

In addition to BPT's electroshocking program, increasing understanding of distribution and movements of fish over time in the Upper Malheur watershed is vital and can be achieved via a functional PIT tag array at the confluence of Big Creek and Lake Creek. BPT PIT-tagged 28 bull trout and 16 hybrids in 2014 to add to a growing pool of trackable fish. A PIT tag array was installed in 2013, but technical and staffing difficulties resulted in sporadic periods of operation and no detections. BPT is exploring improvement options and will contract to troubleshoot array installation and operation for the 2015 season.

2.5 Recommendations

In summary, although time intensive, the goal of removing brook trout in Lake Creek by mechanical means was successful in 2014 as 1240 brook trout were dispatched. Despite effective removal efforts, expectations are tempered for any lasting positive effects relying exclusively on mechanical methods. Bull trout in the Upper Malheur, and specifically Lake Creek, are at high risk of extinction because of invasive brook trout and isolation due to habitat loss. BPT recommends targeted piscicide treatment throughout the Upper Malheur Watershed as the best way to protect and recover existing bull trout populations. Land acquisition for restoration to mitigate thermal impediments below Murray Campground is also integral to restoring fluvial use of Lake Creek. Until eradication of brook trout in the Upper Malheur River, its tributaries, and High Lake is achievable, it is recommended that mechanical removal practices continue in order to offset present threats to native salmonids and other species. In 2015 and beyond, BPT plans to increase efficacy of its brook trout removal program in Lake Creek by targeting areas of high brook trout density. The expectation is that brook trout removal will be maximized thereby mitigating detrimental effects on bull trout most effectively.

2.6 Acknowledgements

BPT would like to thank BPA for continuing to fund brook trout removal in effort to recover bull trout in the basin.

2.7 References

Abel, C. 2010. 2009 Stream Temperature Monitoring with Implications for Bull Trout Recovery in the Upper Malheur. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin FY 2009 Annual Report.” Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Adams, S.B. 1999. Mechanisms Limiting a Vertebrate Invasion: Brook Trout in Mountain Streams of the Northwestern USA. Doctoral Dissertation. University of Montana, Missoula.

Bowers, W.L., P.A. Dupree, M.L. Hanson, R.R. Perkins. 1993. Bull Trout Population Summary Malheur River Basin. Oregon Department of Fish and Wildlife. Hines, OR. Unpublished report.

Buchanan, D.V., M.L. Hanson, and R.M. Hooton. 1997. Status of Oregon’s Bull Trout. Oregon Department of Fish and Wildlife. Portland, OR.

Crowley, K. 2014. Selective Removal of Brook Trout (*Salvelinus fontinalis*) in Lake Creek, Upper Malheur River, Oregon. Burns Paiute Tribe 2013 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur River Basin. BPA Project #199701900. Pages 2-1: 2-14. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

DeHaan, P. W., Schwabe, L. T., & Ardren, W. R. (2010). Spatial patterns of hybridization between bull trout, *Salvelinus confluentus*, and brook trout, *Salvelinus fontinalis* in an Oregon stream network. *Conservation Genetics*, *11*(3), 935-949.

Dunham, J.B., S.B. Adams, R.E. Schroeter, and D.C. Novinger. 2002. Alien Invasions in Aquatic Ecosystems: Toward an Understanding of Brook Trout Invasions and Potential Impacts on Inland Cutthroat Trout in Western North America. Reviews in Fish Biology and Fisheries 12:373-391.

Fenn, K and L. Schwabe. 2003. Use of a Backpack Electrofisher to Determine the Distribution of Brook Trout (*Salvelinus fontinalis*), Bull Trout (*Salvelinus confluentus*), and Potential Hybrids of Brook and Bull Trout in Lake Creek and Meadow Fork Big Creek, Oregon. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” Fiscal Year 2003 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Fenn, K. 2005. Use of a backpack electrofisher to determine changes in distribution and species composition of fish species in Meadow Fork and Lake Creek. “Evaluate the Life History of Native Salmonids in the Malheur Subbasin.” FY 2004 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Fenton, J. 2006. Use of Radio Telemetry to Document the Movements of Bull Trout in the Upper Malheur River, Oregon. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2005 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Gunckel, S.L. 2001. Feeding Behavior and Diet of Native Bull Trout *Salvelinus confluentus* and Introduced Brook Trout *Salvelinus fontinalis* in two Eastern Oregon Streams. Master's Thesis. Oregon State University, Corvallis.

Harper, D. 2012. Selective Removal of Brook Trout *Salvelinus fontinalis* in Lake Creek, Upper Malheur River, Oregon. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Harper, D. 2013. Selective Removal and Abundance estimation of Brook Trout *Salvelinus fontinalis* in Lake Creek, Upper Malheur River, Oregon. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Meyer, K. A., Lamansky, J. A., and Schill, D. J. (2006) Evaluation of an Unsuccessful Brook Trout Electrofishing Removal Project in a Small Rocky Mountain Stream. North American Journal of Fisheries Management. 26:849-860.

Moran, S. and Storaasli, J. 2010. Nonnative fish suppression project in the East Fork Bull River drainage, Montana: 2007-2013. Annual Progress Report 2009. Fish Passage/Native Salmonid Program, Appendix C. Prepared for Avista Corporation, Natural Resources Field Office. Doc. No. 2010-0266. 96 pages. Noxon, Montana.

Paul, A.J. and J.R. Post. 2001. Spatial Distribution of Native and Nonnative Salmonids in Streams of the Eastern Slopes of the Canadian Rocky Mountains. Transactions of the American Fisheries Society 130:417-430.

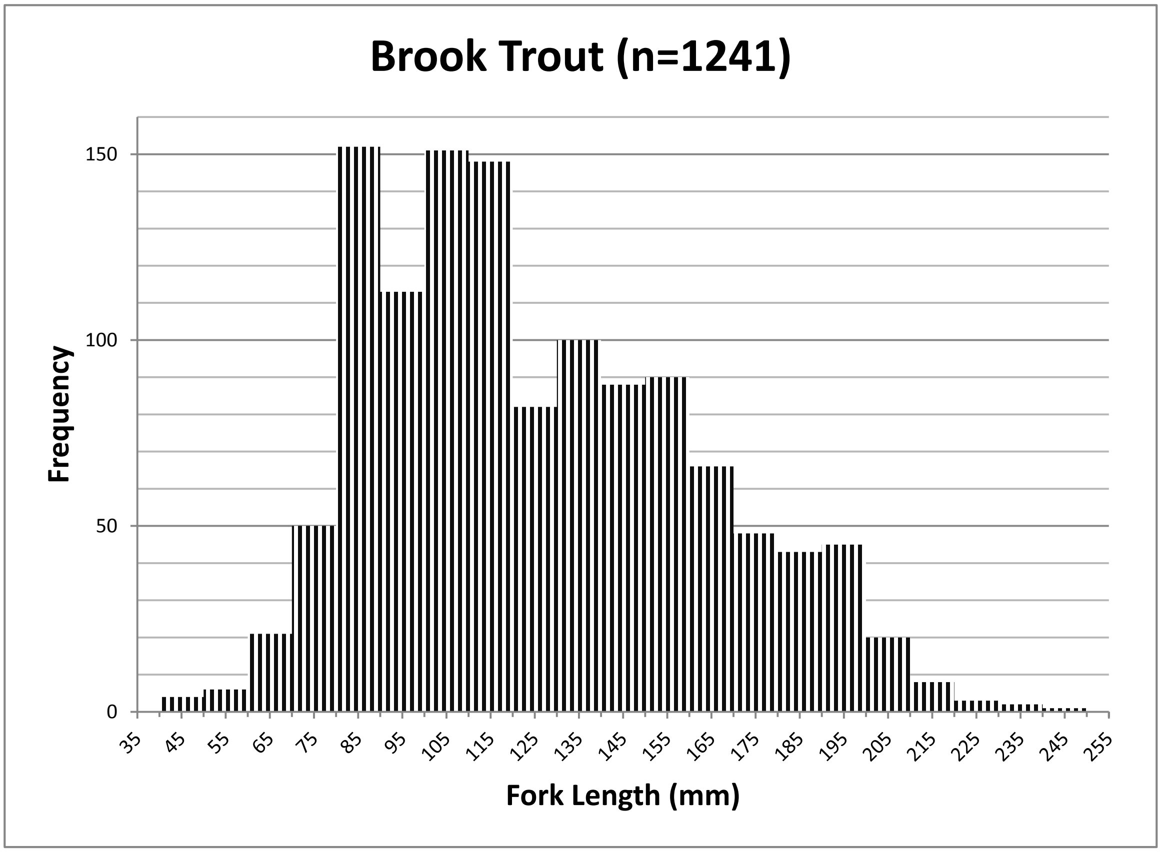
Perkins, R. 2012. 2011 Bull Trout Spawning Survey Report. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2011 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

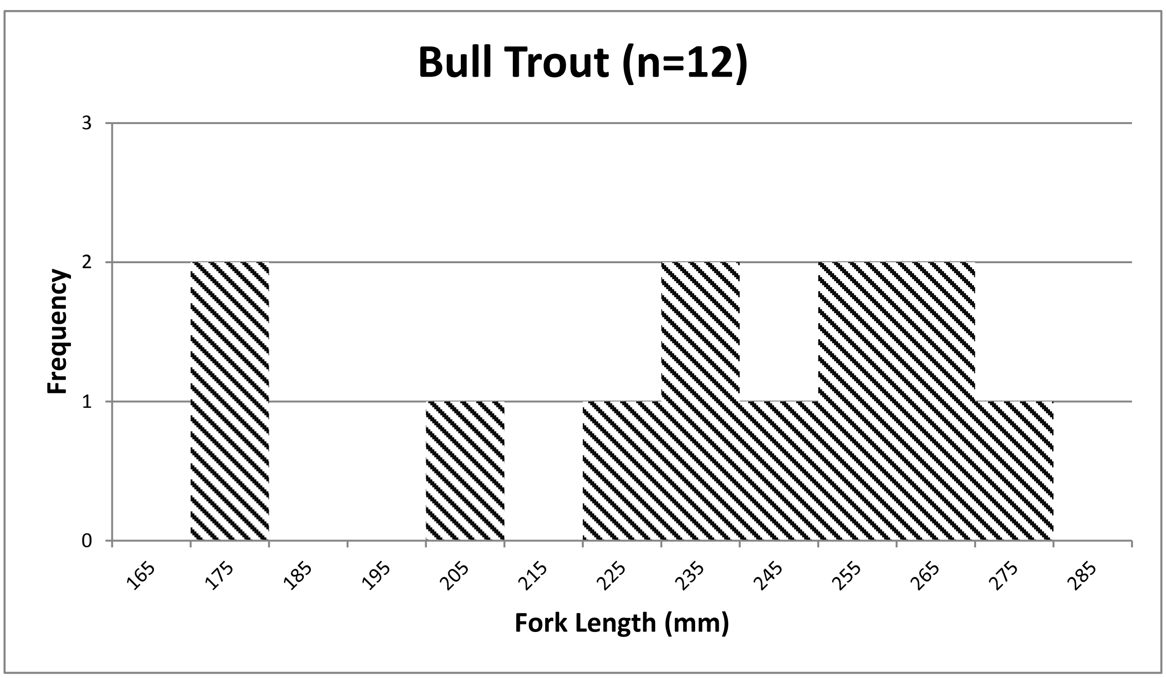
Poole, A. and D. Harper. 2011. 2010 High Lake Brook Trout Suppression. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2010 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

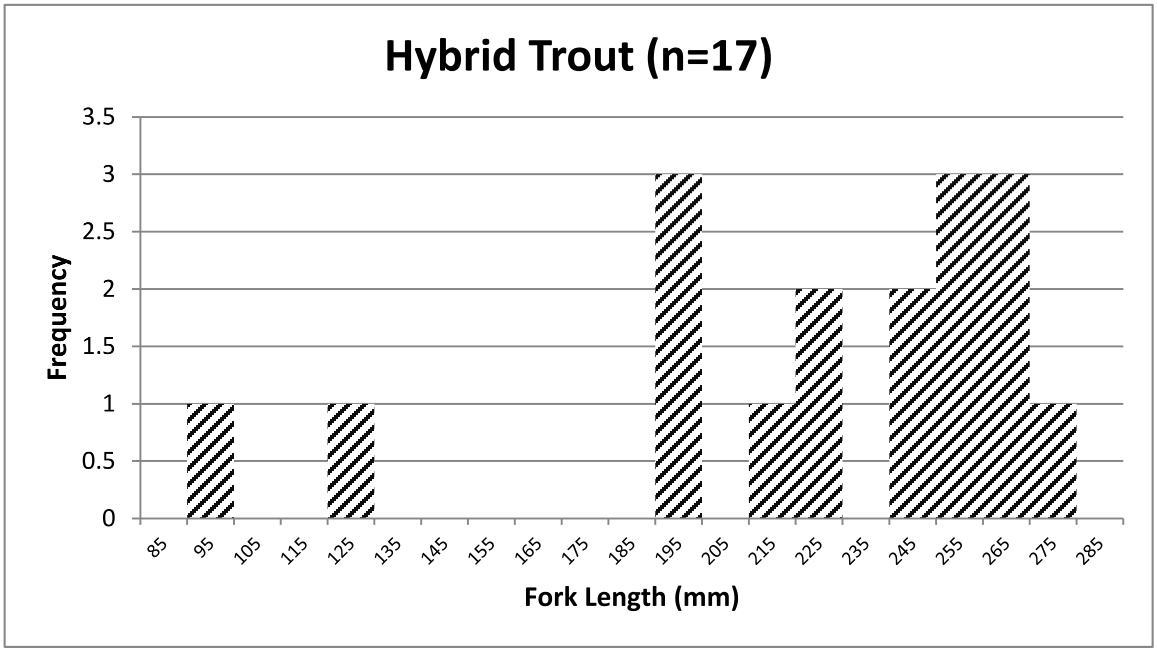
Ratliff, D.E. and P.J. Howell. 1992. The Status of Bull Trout Populations in Oregon. Pages 10-17 in P.J. Howell and D.V. Buchanon, editors. "Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society." Corvallis, OR.

U.S. Fish and Wildlife Service. 2002. Chapter 14, Malheur Recovery Unit, Oregon. 71 P. In: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, OR.

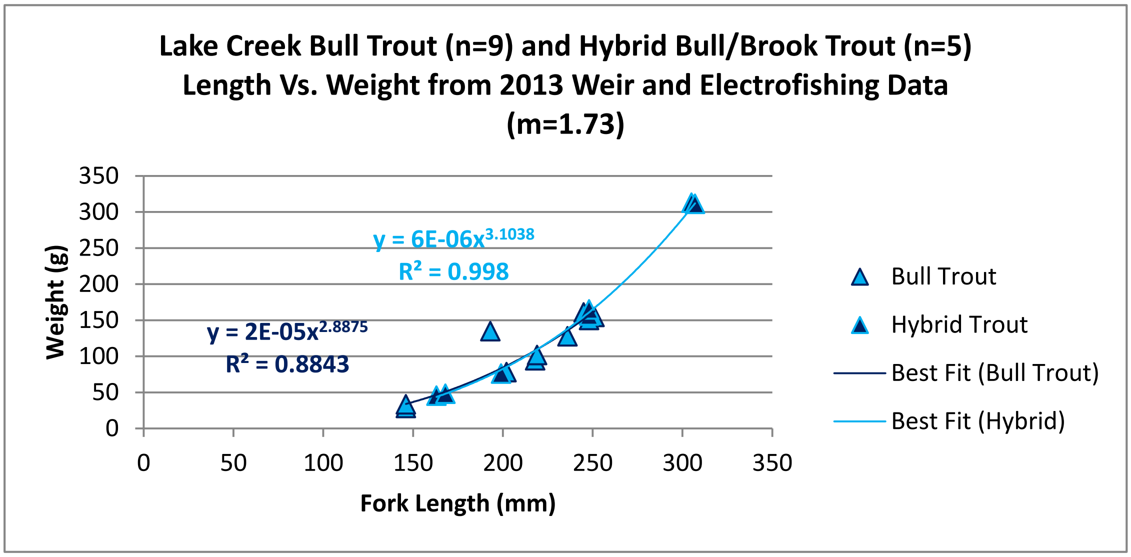
Appendix A: Length-frequency histograms for brook trout, bull trout, and hybrids from 2014 electrofishing data.

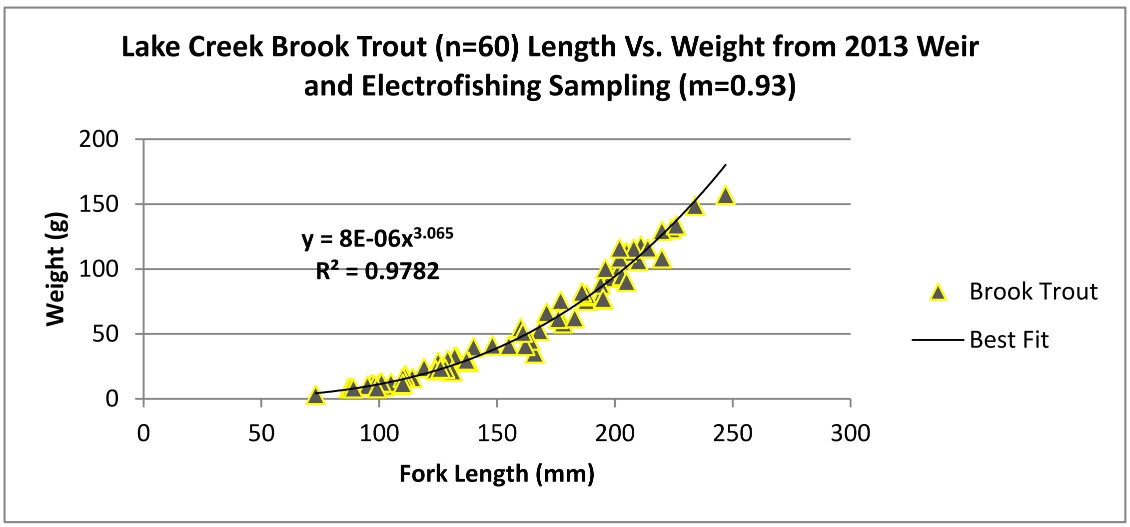


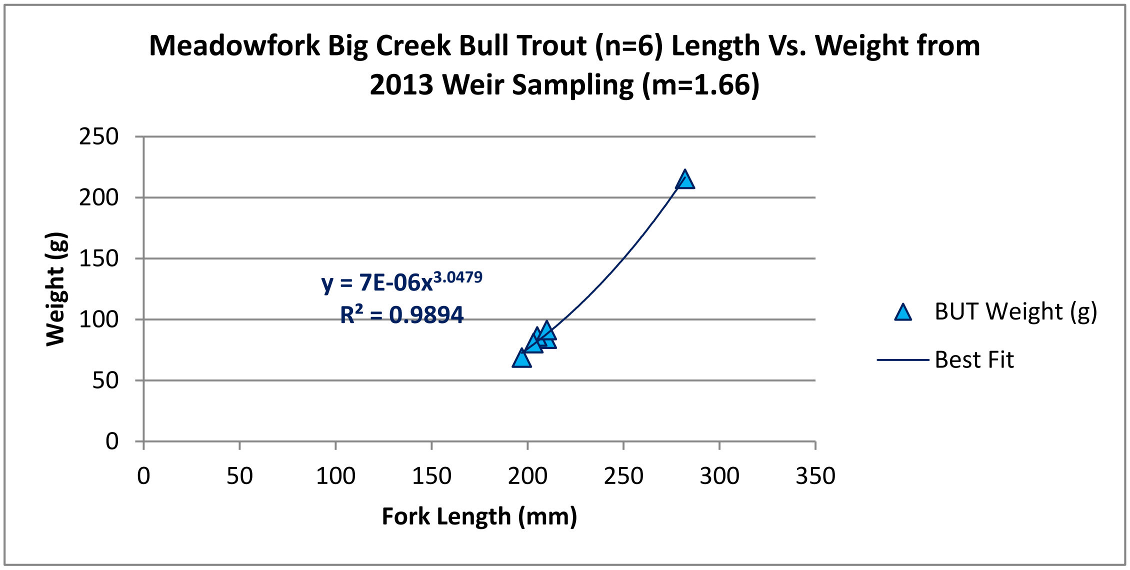


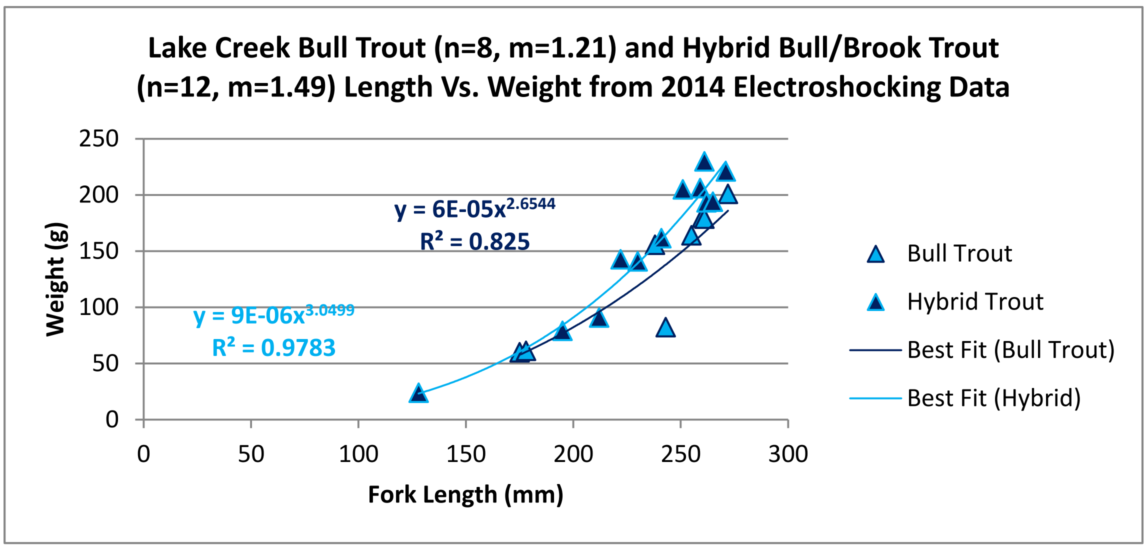

Hybrid Trout (n=17)
Frequency
3.5
3
2.5
2
1.5
1
0.5
0
85
95
105
115
125
135
145
155
165
175
185
195
205
215
225
235
245
255
265
275
285
Fork Length (mm)

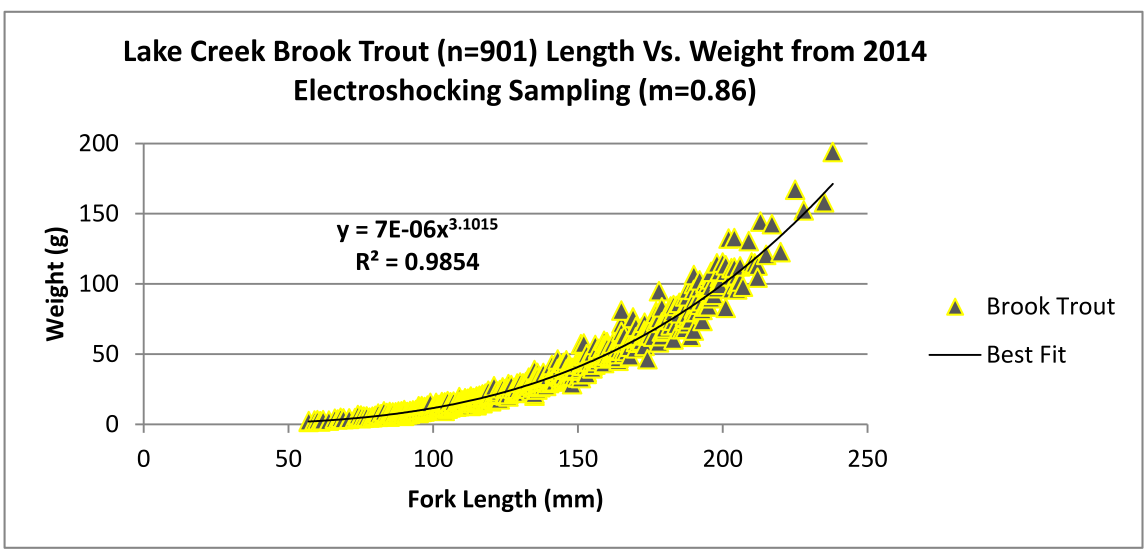
Appendix B: Length-weight relationships for bull trout, brook, trout, and hybrids from various years and drainages

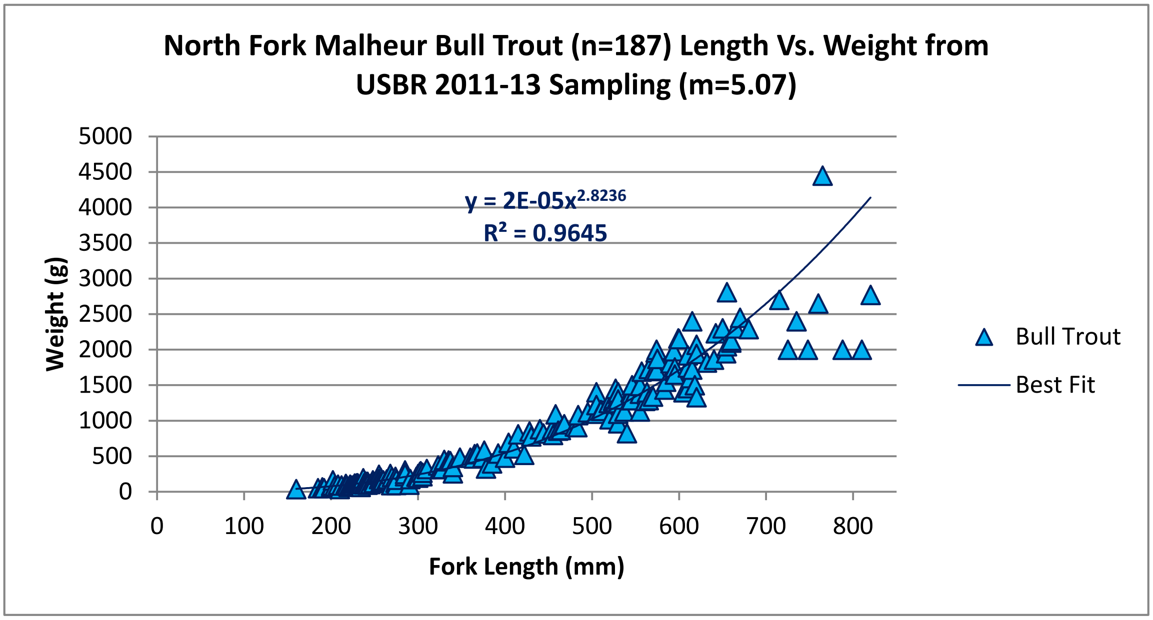


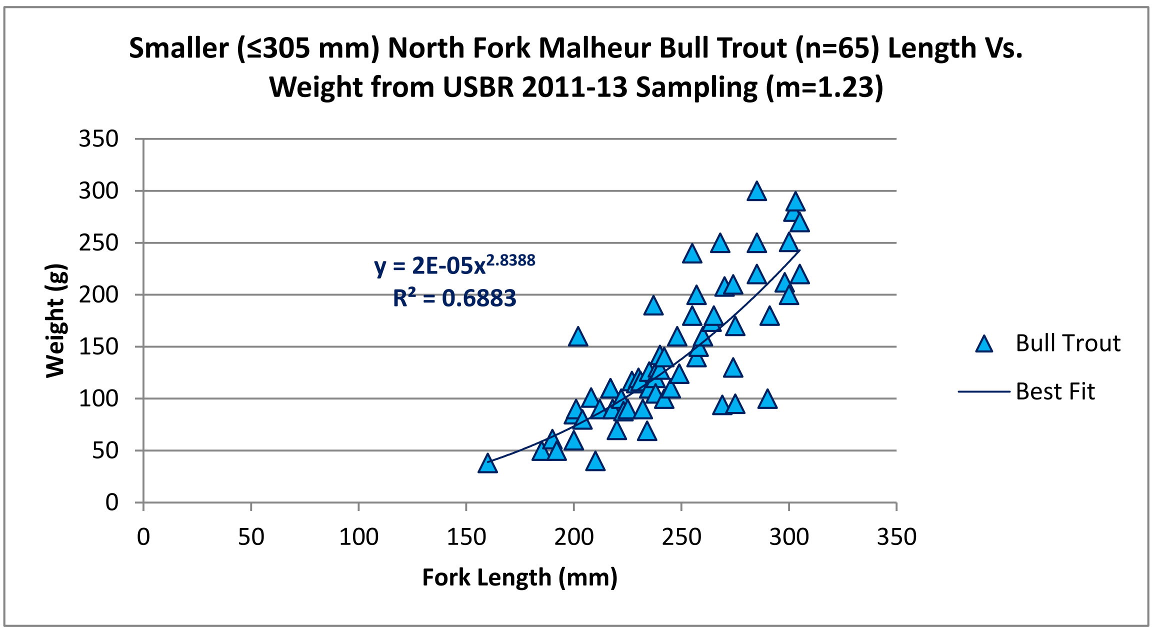



Meadowfork Big Creek Bull Trout (n=6) Length Vs. Weight from 2013 Weir Sampling (m=1.66)
Weight (g)
Fork Length (mm)
y = 7E-06x^3.0479
R² = 0.9894
BUT Weight (g)
Best Fit


Lake Creek Bull Trout (n=8, m=1.21) and Hybrid Bull/Brook Trout (n=12, m=1.49) Length Vs. Weight from 2014 Electroshocking Data
Weight (g)
Fork Length (mm)
y = 6E-05x^2.6544
R² = 0.825
y = 9E-06x^3.0499
R² = 0.9783
Bull Trout
Hybrid Trout
Best Fit (Bull Trout)
Best Fit (Hybrid)


Lake Creek Brook Trout (n=901) Length Vs. Weight from 2014 Electroshocking Sampling (m=0.86)
Weight (g)
Fork Length (mm)
y = 7E-06x^3.1015
R² = 0.9854
Brook Trout
Best Fit


North Fork Malheur Bull Trout (n=187) Length Vs. Weight from USBR 2011-13 Sampling (m=5.07)
$y = 2E\text{-}05x^{2.8236}$
$R^2 = 0.9645$
Weight (g)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
Fork Length (mm)
Bull Trout
Best Fit


Smaller (≤305 mm) North Fork Malheur Bull Trout (n=65) Length Vs. Weight from USBR 2011-13 Sampling (m=1.23)
$y = 2E\text{-}05x^{2.8388}$
$R^2 = 0.6883$
Weight (g)
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
Fork Length (mm)
Bull Trout
Best Fit

Chapter 3:

2014 Stream Temperature Monitoring in the Upper Malheur, Logan Valley Wildlife Mitigation Property

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Burns Paiute Tribe Natural Resources Department
Burns, Oregon

Contents

Chapter 3: 2014 Stream Temperature Monitoring in the Upper Malheur River, Logan Valley Wildlife Mitigation Property

Brandon Haslick, Fish and Wildlife Biologist
Burns Paiute Tribe Natural Resources Department, Fisheries Program

3.1 Introduction

The Burns Paiute Tribe Natural Resources Department (BPT) has been monitoring stream temperatures in the headwaters of the Upper Malheur since acquiring the Logan Valley Wildlife Mitigation Property in April 2000. BPT collects stream temperature data on the property in order to evaluate long-term effectiveness of aquatic habitat improvement projects, such as ongoing riparian plantings and fencing. In select years, BPT has also collected stream temperature data elsewhere to evaluate suitability of various habitat types to life history stages of both extant and extirpated native fish species, and to identify areas that may benefit from restorative or protective measures. With the ongoing regional efforts to model climate change scenarios based on local empirical datasets, BPT continues to collect stream temperature data to aid in the improvement of these models. Long-term datasets may function to refine model predictions over time and provide understanding of habitat change and loss due to climate change.

3.2 Methods

Study Area

The Logan Valley Wildlife Mitigation Property is located south of the Strawberry Mountain Wilderness in Grant County, OR. The parcel consists of 1760 deeded acres in which Lake Creek, Big Creek, Crooked Creek and McCoy Creek combine to form the Upper Malheur River. BPT has maintained five temperature sites on the Upper Malheur since acquiring the property in April 2000 (Namitz, 2000; Schwabe, 2001; Schwabe, 2002; Schwabe, 2003; Schwabe, 2004; Fenton and Schwabe, 2005; Fenton, 2006; Schwabe, 2007; Abel, 2008; Abel, 2009; Brown, 2010; Brown, 2011; Brown, 2012; Haslick, 2013). Of these five original sites, two are stationed on Lake Creek (one below the confluence with McCoy Creek and the other below the confluence with Crooked Creek), two on Big Creek, and one where Big and Lake Creeks join to form the middle fork of the Malheur River. In 2007 two more sites, with a focus on the Lake Creek drainage, were selected for monitoring (Schwabe, 2007). Another site, near the tribe’s cabin bridge, was added to Lake Creek in 2008 (Abel, 2008). For the 2009 field season, two additional monitoring sites were added, one on McCoy Creek and the other on a branch of Lake Creek (Abel, 2009). Site locations are mapped in Figure 1 and described in Table 1.

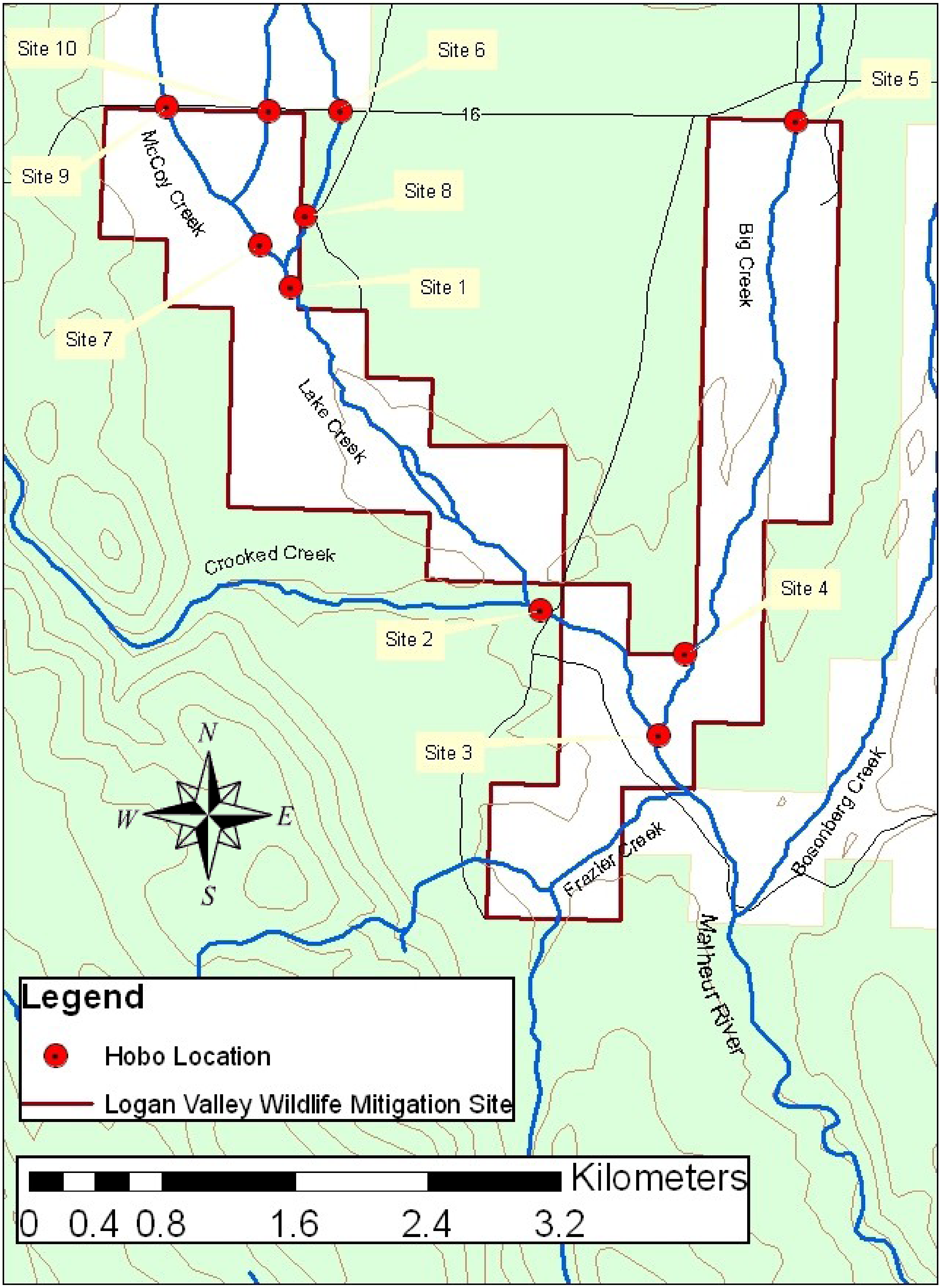


Figure 1: BPT Annual Stream Temperature Monitoring Site Locations in Logan Valley

Table 1: BPT Logan Valley Annual Stream Temperature Monitoring Site Descriptions

Site	Location	Year Initiated
1	Lake Creek below McCoy Creek	2000
2	Lake Creek below Crooked Creek	2000
3	Malheur River below Big and Lake Creek	2000
4	Big Creek one mile below Forest Service 16 Road	2000
5	Big Creek below Forest Service 16 Road	2000
6	Lake Creek below Forest Service 16 Road	2007
7	McCoy Creek above Lake Creek	2007
8	Lake Creek at Cabin Bridge	2008
9	McCoy Creek below Forest Service 16 Road	2009
10	Lake Creek Ditch below Forest Service 16 Road	2009

Field Techniques

In 2014, Tidbit v2 Temperature Loggers (hobos) manufactured by Onset Computer Corporation were deployed on the 15th and 28th of May and retrieved on the 1st and 2nd of October. Hobos were subjected to accuracy checks pre- and post-deployment using methods recommended by the Oregon Water Quality Monitoring Technical Guidebook (OPSW v2.0 2001). Standards dictate that hobo readings cannot vary from actual by more than ±0.5 °C. All hobos deployed in the 2014 field season were within accuracy parameters.

Eight pound anchors were used to secure the hobos on the bottoms of streams. The anchors were in turn cabled to a stable attachment point along the bank. In order to account for as many physical variables as possible, all hobos were set in the deep and swift water of the thalweg and shaded from the sun when possible under vegetation and undercut banks. Timing of deployment has varied slightly from year to year, usually as a result of seasonal weather conditions limiting access to sites. Hobo deployment in Logan Valley by the 31st of May was the objective in 2014. Deployment by the 25th of May will be the goal for 2015 as an extra week will allow a more complete mean weekly maximum temperature dataset over the summer interval.

Data Analysis

Temperature data is summarized by the rolling daily maximum temperature averaged over a seven day period. This is referred to as the Mean Weekly Maximum Temperature (MWMT). This unit of measurement is also known as the Seven Day Average Daily Maximum or 7DADM, and is synonymous with the maximum rolling temperature calculations utilized in previous reports by BPT. Figures 1-10A in Appendix A plot the 2014 MWMT at each monitoring site against DEQ stream temperature standards. Figures 6A and 8A illustrate the periods that the respective streambeds were dewatered, necessitating the exclusion of data from those sites during that time. Figures 4 and 5 depict the substantial daily temperature fluctuations that occurred at those sites, providing evidence of this air exposure. Also of note, the temperature loggers for Lake Creek Ditch site 10 and Lake Creek site 6 were both set on the 28th of May, thirteen days after all other sites were set. As a consequence, in Appendix A and elsewhere in this report, MWMT could not be calculated until June 4th. All other site's MWMT datasets begin June 1st.

In addition to Appendix A, Daily Average Temperature (DAT) at each site in 2014 was calculated and charted in Appendix B (Figures 1-10B). Tables 2 and 3 illustrate absolute high temperatures and the amount of time each site spent above the temperature thresholds described below. Tables 4 and 5 present color-coded depictions of initial MWMT threshold obtainment at a subset of five sites across the monitoring zone. Table 4 references 2014 data while Table 5 displays average dates over the years 2000-13. For purposes of comparison, the summer monitoring period for these tables is defined as June 7th-September 30th, a range in which a full set of MWMT data is available for all five sites in all years. Finally, Figures 2 and 3 present average temperatures and average daily maximums for the time period July 15th-August 15th for all sites for the years 2000-14. Again, the years 2000-13 are combined to allow for comparisons to 2014.

The DEQ Stream Temperature Standard is 12 °C MWMT for bull trout migration and juvenile rearing and 16 °C MWMT for salmonid core rearing areas (i.e., an area of moderate to high density use) (OAR 340-041-0028 2004). Sixteen centigrade has been cited as an important benchmark in relation to the thermal tolerance of bull trout as well. Research conducted in a controlled setting indicates that bull trout food consumption declined significantly at temperatures greater than 16 °C (Selong et al., 2001). The same study identified 20.9 °C as the Incipient Lethal Temperature for bull trout (ILT). Temperatures listed above are thus important monitoring benchmarks utilized for comparative analysis throughout this report.

3.3 Results

The timeframe July 15th-August 15th was outlined by the Oregon Department of Fish and Wildlife (ODFW) as the critical period for high stream temperatures in the Malheur watershed

(Perkins 1999). Although highest stream temperatures fluctuate in temporal occurrence from year to year, it is not unreasonable to expect them to occur within or near this date range. This timeframe has been used in previous BPT reports as an index for comparing stream temperature data between years (Namitz, 2000; Schwabe, 2001; Schwabe, 2002; Schwabe, 2003; Schwabe, 2004; Fenton and Schwabe, 2005; Fenton, 2006; Schwabe, 2007; Abel, 2008; Abel, 2009; Brown, 2010; Brown, 2011; Brown, 2012; Haslick, 2013). In 2014, highest stream temperatures for each site were identified to determine whether dates occurred within the 32-day critical period (Table 2). Table 3 represents the number of days and percent total days in 2014 that MWMT eclipsed critical temperature benchmarks during the monitoring period.

In 2014, the dates of absolute maximum temperatures occurred during the critical stream temperature period (July 15th-August 15th) at three out of the eight sites with a full set of usable data (Table 2). The other five registered absolute maximums on July 14th, one day

Table 2: Summary of Temperature Maximums at BPT Monitoring Sites, Summer 2014

2014 Monitoring Period: June 1st-September 30th					
Stream Name	Site Number	Highest MWMT (°C)	Date of Occurrence	Absolute Maximum (°C)	Date of Occurrence
Lake Creek	1	26.4	7/20/14	27.8	7/16/14
Lake Creek	2	26.3	7/20/14	27.8	7/14/14
Malheur River	3	22.4	7/18/14	23.7	7/14/14
Big Creek	4	21.4	7/18/14	22.4	7/14/14
Big Creek	5	18.5	7/18/14	19.3	7/14/14
Lake Creek	6*	-	-	-	-
McCoy Creek	7	25.3	7/20/14	26.6	7/16/14
Lake Creek	8*	-	-	-	-
McCoy Creek	9	27.6	7/20/14	29.1	7/16/14
Lake Ditch	10**	24.3	7/20/14	25.3	7/14/14

*Dewatered for a substantial portion of the summer season rendering data unusable

**Temperature logger set too late in the season to capture the first three days of June MWMT

Table 3: Number of Days and Percent Total Days at Stations MWMT Exceeded Temperature Benchmarks, Summer 2014

Site Name and Number	Days > 12 °C	Days > 16 °C	Days > 20.9 °C
#1 Lake Creek below McCoy Creek	122 (100%)	108 (89%)	43 (35%)
#2 Lake Creek below Crooked Creek	122 (100%)	114 (93%)	43 (35%)
#3 Malheur River below Big and Lake Creek	122 (100%)	88 (72%)	17 (14%)
#4 Big Creek one mile below NF-16 Road	119 (98%)	70 (57%)	5 (4%)
#5 Big Creek below NF-16 Road	111 (91%)	38 (31%)	0 (0%)
#6 Lake Creek below NF-16 Road*	-	-	-
#7 McCoy Creek above Lake Creek	122 (100%)	98 (80%)	41 (34%)
#8 Lake Creek at Cabin Bridge*	-	-	-
#9 McCoy Creek below NF-16 Road	122 (100%)	119 (98%)	51 (42%)
#10 Lake Creek Ditch below NF-16 Road**	119 (100%)	91 (76%)	38 (32%)

*Incomplete data (dewatered a substantial portion of the monitoring season)

**Temperature logger set too late in the season to capture the first three days of June MWMT

prior to the critical period. All eight sites experienced highest MWMT within the critical stream temperature interval.

As Table 3 illustrates, in the summer of 2014 Logan Valley streams regularly exceeded average weekly temperature maximums based on DEQ standards for bull trout migration and juvenile rearing habitat (12 °C), as well as standards for salmonid core rearing habitat (16 °C; OAR 340-041-0028 2004). Each site with a complete data set on the Lake Creek drainage spent the vast majority (over 90%) of the summer monitoring period (defined as the months of June, July, August, and September) with MWMT exceeding 12 °C. Furthermore, only sites on Big Creek and Lake Creek site 6 experienced any time at all below 12°C. Five of the eight sites (Lake Creek sites 1 and 2, McCoy Creek sites 7 and 9, and Lake Creek Ditch site 10) spent over 90 days in excess of 16 °C. In the cooler water of Big Creek, site 4 MWMT exceeded 16 °C for 70 days, and site 5 (upstream) exceeded that threshold for 38 days. The ILT for bull trout was surpassed at all sites except site 5 in 2014. MWMT was above 20.9 °C at site 9 for 42% of the total days monitored, about one third at sites 1, 2, 7, and 10, and 14% at Malheur River site 3. Site 4 surpassed the ILT of 20.9 °C for five days in 2014, the implications of which will be discussed below. All sites on average spent 25% of the summer period above the ILT for bull trout.

When comparing this year to last, all sites in 2014 spent a slightly greater percentage of time above 12 °C MWMT except Big Creek sites 4 and 5. Conversely, all sites spent a lower percentage of time above 20.9 °C this year as opposed to last except those same sites. Overall MWMT highs and absolute highs for the summer were greater in 2014 than 2013 at all sites except Malheur River site 3, Big Creek site 5, and McCoy Creek site 9. Temperatures rose in early summer and tailed off late season more gradually than in 2013 and the overall highs were achieved later. Both years, however, produced temperatures unfavorable to threatened bull trout.

Taking a broader view, it becomes clear that the warm water temperature measurements recorded recently are not aberrations. Since BPT began stream temperature monitoring in Logan Valley, water temperatures have consistently surpassed the DEQ Bull Trout Temperature Standard of 12 °C MWMT for a majority of the summer period at all monitoring sites where data was collected. Taking into account the occasional inability to retrieve hobos due to loss, the original five strategically placed sites initiated in 2000 are associated with the longest datasets, thus permitting more extensively detailed comparisons. Lake Creek sites 1 and 2 have exceeded the 16 °C threshold on the very first day MWMT could be calculated (June 7th) for the years 2000-09 and 2013. The MWMT of these same sites has consistently exceeded the Incipient Lethal Temperature for bull trout, on average in late June/early July for the years 2000-08 and 2013; later in the season for the years 2009 and 2011-12.[1] At Malheur River site 3, the beginning of the summer monitoring season is typically when the MWMT has exceeded 12 °C. The mean date for the years 2000-08 when the MWMT of site 3 surpassed 16 °C was June 16th (later in June the four subsequent years and earlier in 2013). The ILT for bull trout based on MWMT has on average been obtained at site 3 in July, but this location never achieved such high temperatures in 2010 or 2011. Big Creek sites 4 and 5 typically obtain the 12 °C and 16 °C MWMT temperature thresholds later in the season. Site 5 maximum weekly average has failed to reach the salmonid temperature threshold of 16 °C MWMT only once in recent years (2011). For the years 2000-12, Big Creek sites did not eclipse the ILT based on MWMT during the summer monitoring period (Namitz 2000; Schwabe 2001; Schwabe 2002; Schwabe 2003; Schwabe 2004; Fenton and Schwabe 2005; Fenton 2006; Schwabe 2007; Abel 2008; Abel 2009, Brown 2010; Brown 2011; Brown 2012). In 2013, however, both the 12 °C and 16 °C MWMT thresholds were achieved at the beginning of the summer monitoring season on Big Creek sites

[1]Site 1 experienced one outlier year in 2010 in which it never obtained the ILT for bull trout (Brown, 2010).

and the ILT was surpassed for three days at site 4 (Haslick 2013). Refer to Table 4 for a summary of the average dates each of the five original sites have exceeded thresholds for the years 2000-13 and Table 5 to reference and compare 2014's average dates.

Table 4: Average Date of First Recorded MWMT over Cited Benchmarks for the Summer Monitoring Intervals from 2000-13

		Site 1 Lake Creek	Site 2 Lake Creek	Site 3 Malheur River	Site 4 Big Creek	Site 5 Big Creek
2000-13	> 12 °C	June 7th	June 7th	June 7th	June 10th	June 16th
	> 16 °C	June 8th	June 8th	June 18th	June 23rd	July 3rd
	> 20.9 °C	July 5th	July 3rd	July 13th	July 2nd*	no readings > 20.9 °C

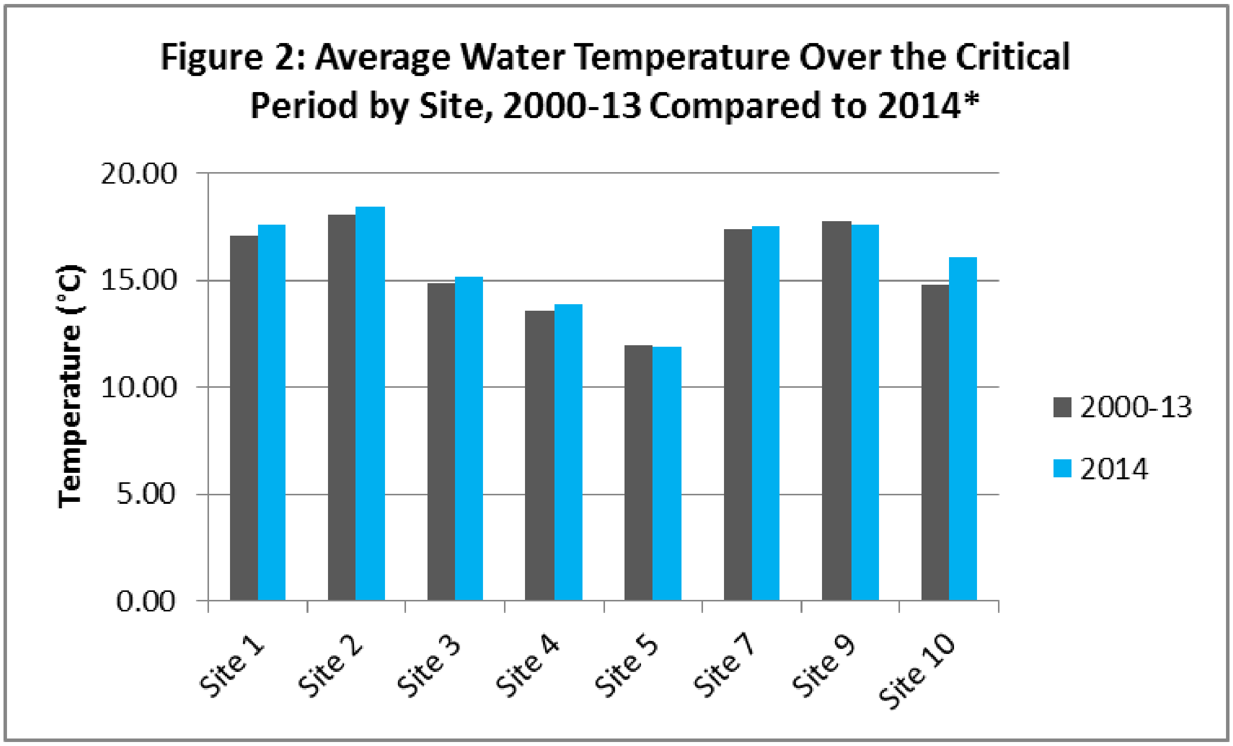
*Site 4 only obtained ILT once (2013)

Table 5: Date of First Recorded MWMT over Cited Benchmarks for the 2014 Summer Monitoring Interval

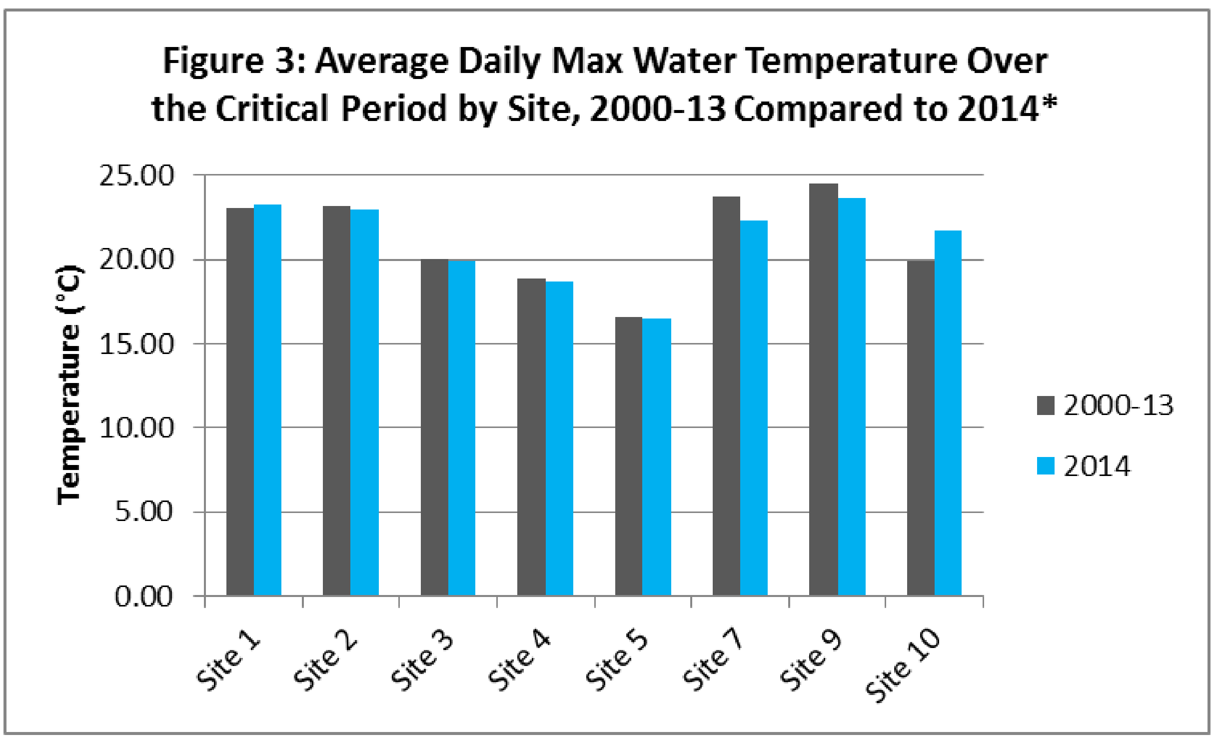
		Site 1 Lake Creek	Site 2 Lake Creek	Site 3 Malheur River	Site 4 Big Creek	Site 5 Big Creek
2014	> 12 °C	June 7th	June 7th	June 7th	June 7th	June 7th
	> 16 °C	June 7th	June 7th	June 8th	June 11th	July 4th
	> 20.9 °C	July 4th	July 3rd	July 6th	July 16th	no readings > 20.9 °C

2014 temporal temperature threshold obtainment differs from the baseline of Table 4 in several key areas. Although sites 1 and 2 recorded roughly average readings, site 3 surpassed the 16 °C MWMT threshold ten days earlier and the 20.9 °C threshold a week earlier. The 12 °C MWMT temperature threshold was bettered three days earlier at site 4 and nine days earlier at site 5 (MWMT was already surpassing the threshold on June 7th, the earliest date data is available for year by year comparisons). Site 4 broke the 16 °C MWMT mark a full twelve days earlier in 2014 while site 5 remained near the baseline. The ILT based on MWMT was obtained for the second year in a row at site 4, this time for five days in mid-July. This is notable given the first thirteen years of BPT monitoring history (2000-12) had never produced readings at this site above the ILT for bull trout (Haslick, 2013). Site 5 once again never achieved such highs (Table 5).

Because mean weekly maximum temperature measurements form the basis of the DEQ salmonid and bull trout standards, they remain the primary focus of stream temperature analysis in Logan Valley. However, higher resolution for the stream temperature trend picture can be obtained when other measurements are considered. Organized by site, Figure 2 displays average water temperatures over the critical period of July 15th-August 15th for the years 2000-13 as compared with 2014 (Figure 2). Figure 3 follows the same format, supplanting average temperatures with daily maximum average temperatures (Figure 3). All available past data was used to create the most accurate picture possible. However, some data records are incomplete and all sites were not gauged in all years. Two sites (Lake Creek sites 6 and 8) were excluded due to a history of dewatering.



*Data records could not be located or do not exist for all sites in all years. Site 7 in 2011 and sites 6 and 8 excluded due to temperature logger exposure to air.

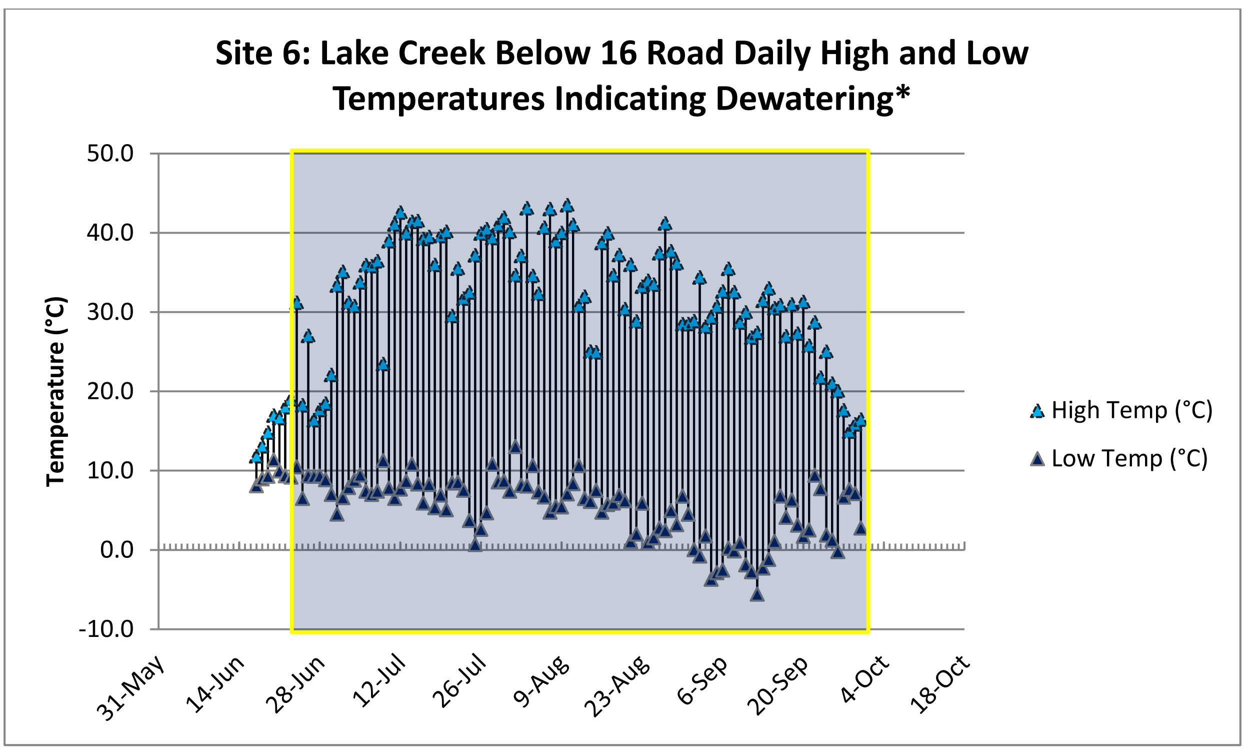


*Data records could not be located or do not exist for all sites in all years. Site 7 in 2011 and sites 6 and 8 excluded due to temperature logger exposure to air.

Based on Figures 2 and 3, average temperatures and daily maximum average temperatures in 2014 do not appear to stray from the baseline to any substantial degree for most sites. Average temperatures were generally higher in 2014 and mean maximums were generally lower. These two patterns suggest that temperatures were somewhat stable in 2014 without dramatic oscillation. The exception seems to be Lake Creek site 10. This site contained both the greatest deference from the baseline and was one of only two sites to record both higher mean maximums and daily averages. Lake Creek remains a concern due to its population of bull trout which may be isolated in the upper reaches as a result of warm summer temperatures. This site will be looked at with keen interest in the coming years to discover any discernable trends. Sites downstream of site 10 did not appear to be affected by the higher than average water temperatures from Lake Creek, however. McCoy Creek combines with Lake Creek upstream of several other monitored sites. McCoy sites registered cooler mean maximums than normal which seems to have moderated any affect Lake Creek may have had on sites downstream.

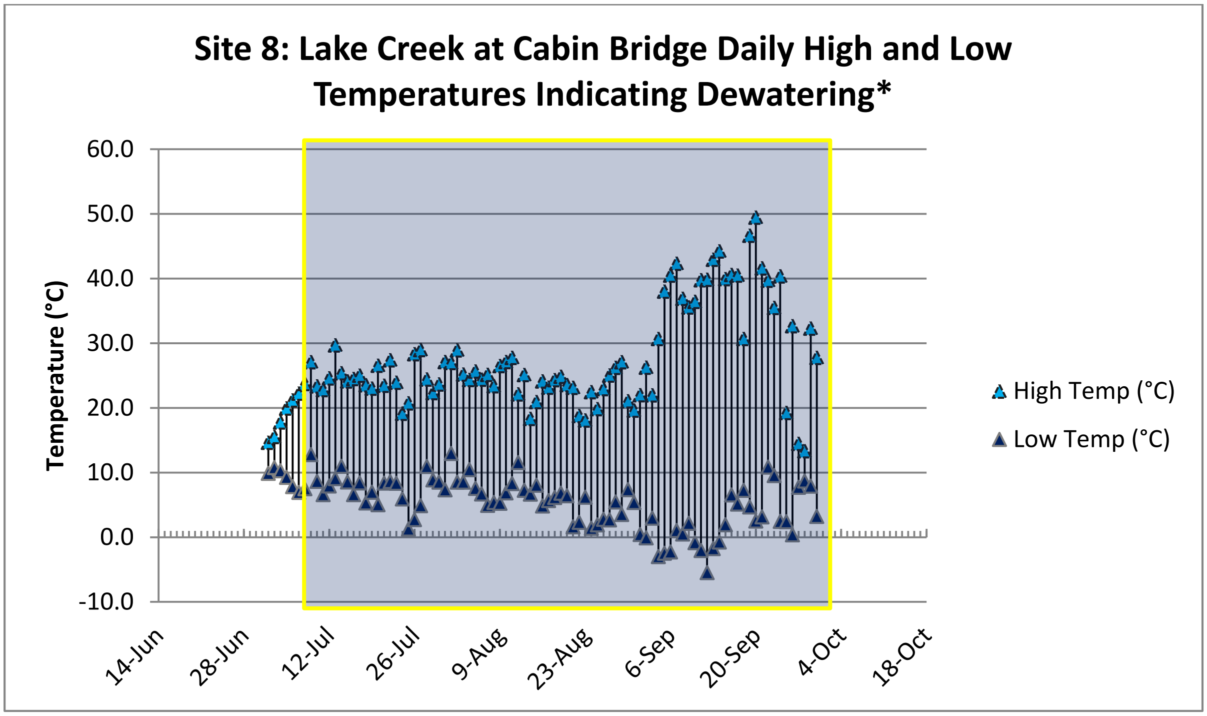
In 2014, as in previous years, Lake Creek sites 6 and 8 were dewatered to the point of hobo exposure to air. This occurred at both sites earlier in the summer monitoring period than

Figure 4: Evidence of Site 6 Hobo Air Exposure



*Dates in shaded box experienced hobo exposure to air.

Figure 5: Evidence of Site 8 Hobo Air Exposure



*Dates in shaded box experienced hobo exposure to air.

in 2013 and, unlike in 2013, neither site became rewetted after drying. Figures 2 and 3 display high fluctuations in daily temperature ranges that closely resembled the local air temperatures in Logan Valley, providing evidence of this exposure. Dates with data indicating hobo exposure to air have been excluded from temperature analysis.

3.4 Discussion

In 2000, the BPT entered into a cooperative effort with the USDA Forest Service and the Oregon Department of Fish and Wildlife to document stream temperature trends in the Upper Malheur (Namitz, 2000). The primary purpose of the monitoring effort was to utilize stream temperature data as an indicator of habitat suitability for the federally threatened bull trout (Namitz, 2000). Bull trout are stenothermal, requiring a narrow range of cold water temperature conditions to rear and reproduce (Buchanan and Gregory, 1997). In western North America, the bull trout is believed to be among the most thermally sensitive species in coldwater habitats (Buchanan and Gregory, 1997; Haas, 2001; Selong et al., 2001; Dunham et al., 2003), and maximum temperature has consistently been suggested as likely the most critical variable determining bull trout health and presence (Haas, 2001). All monitoring sites in this report occur in U.S. Fish and Wildlife Service designated bull trout Critical Habitat (75 FR 63897 2010).

MWMT data plotted against temperature benchmarks in Figures 1-10A (Appendix A) coupled with site location from Figure 1 yield several observations: 1) Lake Creek sites reached much higher maximum temperatures and sustained bull trout ILT for longer durations than Big Creek sites. 2) Big Creek lowers the temperature of the Malheur River (site 3). 3) McCoy Creek (sites 7 and 9) is a major driver to the high stream temperatures noted in Lake Creek. 5) Stream temperature movement patterns at all sites except 6 and 8 show considerable similarity. 6) A lack of continuous flow throughout the summer at sites 6 and 8 present barriers to migrating fish and could potentially lead to stranding.

The patterns and observations evident in 2014, with particular emphasis on the essential bull trout corridors of Lake and Big Creeks and general trend of sites exceeding temperature thresholds, have important implications for these stenothermic fish. Given that cooler water temperatures are important surrogates for bull trout habitat utilization, the clear differences in recordings between Big and Lake Creek are concerning. However, bull trout are migratory and rates of movement have been found to correlate with rising daily maximum water temperatures (Swanberg, 1997). Thus, migratory patterns could be theorized to stay ahead of the curve of rising temperatures and trump summer temperature extremes. Previous bull trout migration studies in Logan Valley point to a mid-summer concentration of activity in Big Creek and avoidance of Lake. These studies suggest that, at least for fluvial bull trout populations, migration through the Logan Valley property occurs before the critical stream temperature period generally associated with annual temperature maximums (Schwabe, 2000; Fenton and Schwabe, 2001). It is important to note, however, that stream temperatures at all monitoring sites in those studies did not peak until late July/early August. In 2014, temperatures peaked a couple of weeks earlier, forcing bull trout to adjust migratory patterns accordingly.

Assuming bull trout are migrating ahead of lethally warm summer water temperatures, they are still likely subjected to temperatures in excess of the DEQ standard of 16 °C (Figures 4A and 5A). Thus, exploring ways to lessen exposure and maintain adequate stream temperatures to allow a longer suitable migration window could prove beneficial to success of the breeding population, especially in regard to Lake Creek. Because stream temperatures in Lake Creek during the primary migration period (June 1st-July 14th) reach critical thresholds sooner than in Big Creek (Tables 4 and 5), the result is a potential thermal barrier that prevents upstream movements of fluvial bull trout. A thermal barrier early in the primary migration period might explain why no radio-tagged bull trout were observed using the Lake Creek corridor to access upstream spawning grounds in previous tribal studies. In 2001, a tagged bull trout attempted migration up Lake Creek but retreated to join Big Creek migrants. Stream temperatures in Lake

Creek had already surpassed bull trout ILT when the Lake Creek migration attempt was made (Fenton and Schwabe 2001).

Last year's bull trout redd counts in the upper reaches of Lake Creek are about average for periods of drought, but redd count data is muddled by difficulty distinguishing between bull and invasive brook trout redds (Brown, 2012). In 2013, 17 bull trout redds were observed at Lake Creek spawning grounds (Hurn, 2014). Based on current temperature data and past tracking efforts, it is likely that the Lake Creek breeding population is comprised of an isolated resident, non-migratory population. The current status of the entire Upper Malheur bull trout metapopulation is considered to be at a high risk of extinction (Buchanan et al., 1997, USFWS, 2002). If the small Lake Creek subpopulation truly is isolated, depensatory factors and hybridization with non-native brook trout may contribute to risk status.

It is worth discussing Lake Creek sites 6 and 8 in detail, given their propensity to become dry in a typical year. Both stations lie in the historic Lake Creek main channel, a stream course that has largely been diverted and rerouted just above NF-16 (16 Road) for many years for grazing and irrigation purposes on private land. After supplying irrigation, the remaining water flows into another Lake Creek channel, referred to by BPT as Lake Creek Ditch, the location of site 10 (K.A. Heinrick and E.M. Maltz, pers. comm.). As a consequence of this diversion, hobos at both sites 6 and 8 experienced exposure to air in 2014. This is a common occurrence at both sites, with site 6 becoming dewatered five out of eight monitored years and site 8 five of seven (Schwabe, 2007; Abel, 2008; Abel, 2009; Brown, 2010; Brown, 2011; Brown, 2012; Haslick, 2013).

The consequences of water management on Lake Creek upstream of site 6 include reductions in flow, increased water temperatures, and a disjointed historic channel unsuitable for bull trout migration. Any resident fish attempting to use this channel instead of Lake Creek Ditch for migration between overwintering areas before or after spawning are exposed to temperature stress, the risk of stranding, and potential lethal take. The BPT Natural Resources Department has been in contact with the landowner to seek a solution.

3.5 Recommendations

Based on the challenges and difficulties comparing and analyzing temperature data, the following recommendations, if implemented, should permit more efficient and accurate temperature data collection. Hobos should always be accuracy checked both prior to deployment and after retrieval. Hobos that are malfunctioning, low on battery, or not within the accuracy brackets for proper recording should be replaced. If accidentally used, an entire season of temperature data could be compromised for that location. Additionally, hobo depths and station flows should be taken at a minimum upon deployment and retrieval if staff time allows. This would facilitate a greater understanding of temperature in the context of site-specific depth and discharge.

Water temperatures at BPT's Logan Valley Wildlife Mitigation Property monitoring sites were higher in 2014 than in years past; land managers should focus on strategies they can control to address this concern and its impacts to threatened bull trout. As discussed above, bull trout are a highly temperature sensitive coldwater species (Buchanan and Gregory, 1997; Haas, 2001; Selong et al,. 2001; Dunham et al., 2003). In addition, they have also been shown to be positively correlated with deep pools, undercut banks, large substrate, and riparian habitat dominated by trees and shrubs (Watson and Hillman, 1997). Recommendations to create better habitat should focus on water withdrawals, pool creation, riparian restoration, and potentially substrate alteration. Most of these activities, discussed below, would likely lower water temperature as well.

With the exception of Big Creek, stream channels through the mitigation property exist in largely open environments, a result of prior land management activities. Historically, riparian willow and sedge coverage was estimated at 40 percent and 60 percent, respectively (K.A. Heinrick, pers. comm.). Changes in composition and density of riparian vegetation have been shown to produce corresponding changes in water temperature (Rosgen, 1996). In 2009, a large scale native revegetation project was undertaken on the Logan Valley Wildlife Mitigation parcel in the riparian corridors of Lake, McCoy, and lower Big Creek. 100,000 willows were planted with only an estimated 18 percent survival rate due to subcontractor quality control issues. An additional 2,000 willows are planted annually to supplement the original mass planting (K.A. Heinrick, pers. comm.). Although it is too soon for the surviving willows to have any impact on reducing stream temperature, it is expected that the current level of willow restoration will begin to have an effect in twenty years. Establishing riparian zones that create shade is a practical and effective way to cool stream temperatures to create more suitable bull trout habitat. Therefore, it is imperative that the willow restoration in Logan Valley be continued and if possible, substantiated.

Other avenues to pursue include bank stabilization, large woody debris placement in stream corridors, or encouraging beaver activity in Logan Valley. The principle goal of these activities would be to slow water velocity enough to create deep backwaters, supplying cool water refugia to potential bull trout migrants. At the same time, large wood would increase available cover for bull trout and bank stabilization has the potential to lessen total dissolved solids, improving both water quality and fines deposition rates.

Finally, negotiations with private landowners upstream of BPT's property should continue. Grazing and water withdrawals just north of the mitigation lands have substantial negative effects on stream temperatures and quality and quantity of water downstream.

Alleviating those negative impacts through property acquisition or some other means would likely lower stream temperatures and create more suitable bull trout habitat.

3.6 Acknowledgements

The BPT thanks Bonneville Power Administration for their continued financial support of this project.

3.7 References

75 FR 63897. 2010. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States; Final Rule. U.S. Fish and Wildlife Service. Title 50, CFR part 17, Vol. 75, No. 200: 63897-64070.

Abel, C. 2008. Synopsis of 2000-2008 Stream Temperature Monitoring with Implications for Bull Trout Recovery in the Upper Malheur. Burns Paiute Tribe 2008 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 2-1: 2-24. BPT Natural Resources Dept. Fisheries Division. Burns, Oregon.

Abel, C. 2009. 2009 Stream Temperature Monitoring with Implications for Bull Trout Recovery in the Upper Malheur. Burns Paiute Tribe 2009 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 2-1: 2-20. BPT Natural Resources Dept. Fisheries Division. Burns, Oregon.

Brown, D. 2010. 2010 Stream Temperature Monitoring in the Upper Malheur. Burns Paiute Tribe 2010 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 2-1: 2-22. BPT Natural Resources Dept. Fisheries Division. Burns, Oregon.

Brown, D. 2011. 2011 Stream Temperature Monitoring in the Upper Malheur Logan Valley Wildlife Mitigation Property. Burns Paiute Tribe 2011 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 5-1: 5-22. BPT Natural Resources Dept. Fisheries Division. Burns, Oregon.

Brown, D. 2012. 2012 Stream Temperature Monitoring in the Upper Malheur Logan Valley Wildlife Mitigation Property. Burns Paiute Tribe 2012 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 3-1: 3-24. BPT Natural Resources Dept. Fisheries Program. Burns, Oregon.

Buchanan, D.V., and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pages 119-126 *in* Brewin, M.K., W.C. Mackay, and M. Monita. 1997. Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force, c/o Trout Unlimited Canada. Calgary, Alberta.

Buchanan, D.V., M.L. Hanson, and R.M. Hooton. 1997. Status of Oregon's Bull Trout. Oregon Department of Fish and Wildlife. Portland, Oregon.

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

Fenton, J., and L. Schwabe. 2001. Use of Radio Telemetry to Document Movements of Bull Trout in the Upper Malheur River, Oregon. Burns Paiute Tribe 2001 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin (Cooperative Bull Trout/Redband Trout Research Project). BPA Report DOE/BP-00006313-3. Pages 37-66. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Fenton, J., and L. Schwabe. 2005. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2005. Burns Paiute Tribe 2005 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin. BPA Report DOE/BP-00006313-6. Pages 7-1: 7-21. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Fenton, J. 2006. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2006. Burns Paiute Tribe 2006 Annual Report. Pages 5-1: 5-27. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Haas, G.R. 2001. The mediated associations and preferences of native bull trout and rainbow trout with respect to maximum water temperature, its measurement standards, and habitat. Pages 23-26 *in* Brewin, M.K., M. Monita, and A.J. Paul, editors. Bull Trout II Conference Proceedings. Trout Unlimited Canada. Calgary, Alberta.

Haslick, B.D. 2014. 2013 Stream Temperature Monitoring in the Upper Malheur Logan Valley Wildlife Mitigation Property. Burns Paiute Tribe 2013 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur River Basin. BPA Project #199701900. Pages 4-1: 4-31. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Heinrick, K.A. 2014. Informational meeting. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Heinrick, K.A., and E.M. Maltz. 2013. Informational meeting. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Hurn, S. 2014. Bull Trout Spawning Survey Report, 2013. Burns Paiute Tribe 2013 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur River Basin. BPA Project #199701900. Pages 1-1: 1-19. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Oregon Plan for Salmon and Watersheds, Version 2.0. 2001. Water Quality Monitoring Technical Guidebook.

Oregon Administrative Rule (OAR) 340-041-0028. 2004. Oregon Secretary of State. Department of Environmental Quality. Salem, Oregon.

Namitz, S. 2000. Upper Malheur River Water Quality and Bull Trout. Burns Paiute Tribe 2000 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin (Cooperative Bull Trout/Redband Trout Research Project). BPA Report DOE/BP-00006313-2. Pages 96-119. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Perkins, R. 1999. Malheur River Bull Trout Population Status Special Report. Oregon Department of Fish and Wildlife. Southeast Fisheries District.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Schwabe, L. 2000. Use of Radio Telemetry to Document Movements of Bull Trout in the Upper Malheur River, Oregon. Burns Paiute Tribe 2000 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin (Cooperative Bull Trout/Redband Trout Research Project). BPA Report DOE/BP-00006313-2. Pages 11-32. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Schwabe, L. 2001. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property. Burns Paiute Tribe 2001 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin (Cooperative Bull Trout/Redband Trout Research Project). BPA Report DOE/BP-00006313-3. Pages 105-132. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Schwabe, L. 2002. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2002. Burns Paiute Tribe 2002 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 71-82. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Schwabe, L. 2003. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2003. Burns Paiute Tribe 2003 Annual Report: Evaluation of the Life History of Native Salmonids in the Malheur River Basin (Cooperative Bull Trout/Redband Trout Research Project). BPA Report DOE/BP-00006313-5. Pages 5-1: 5-20. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Schwabe, L. 2004. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2004. Burns Paiute Tribe 2004 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 7-1: 7-9. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

Schwabe, L. 2007. Stream Temperature Monitoring on Streams Flowing through the Logan Valley Wildlife Mitigation Property, 2007. Burns Paiute Tribe 2007 Annual Report: Evaluate the Life History of Native Salmonids in the Malheur Subbasin. Pages 1-1: 1-27. BPT Natural Resources Dept. of Fish and Wildlife. Burns, Oregon.

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

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

U.S. Fish and Wildlife Service. 2002. Chapter 14: Malheur Recovery Unit, Oregon. Pages 1-71 *in*: U.S. Fish and Wildlife Service. 2002. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

Watson, G. and T.W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales. North American Journal of Fisheries Management 17: 237-252.

APPENDIX A: Stream Temperatures Expressed by MWMT

FIGURE 1A: LAKE CREEK BELOW MCCOY CREEK (SITE 1)

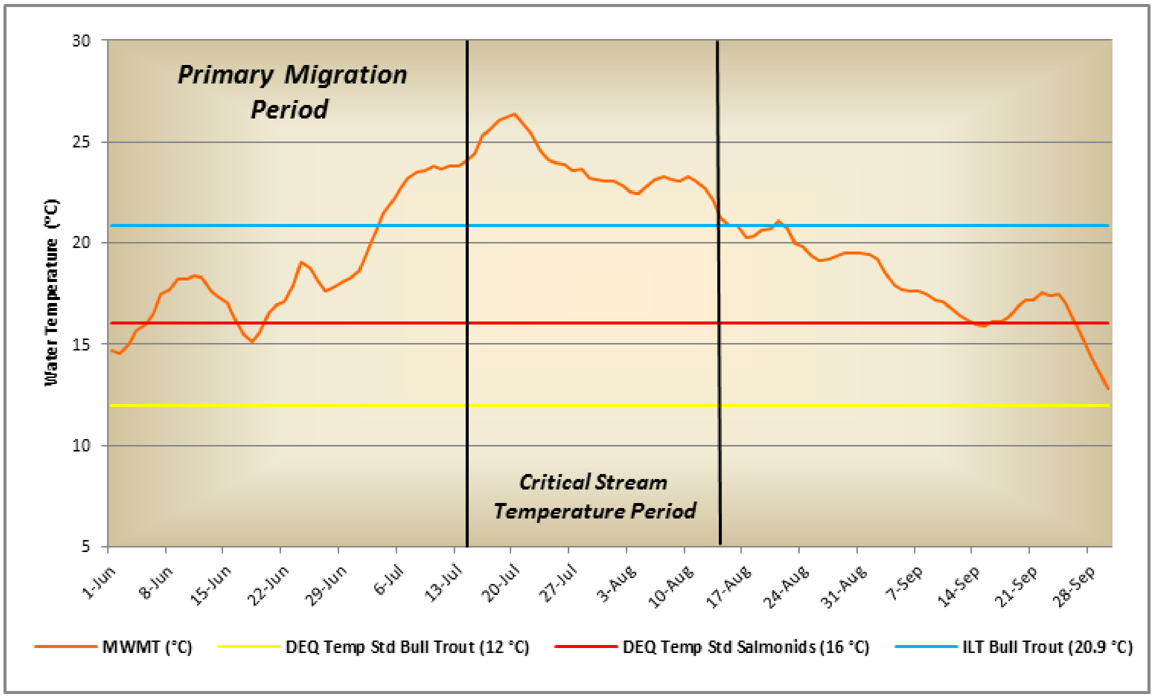


FIGURE 2A: LAKE CREEK BELOW CROOKED CREEK (SITE 2)

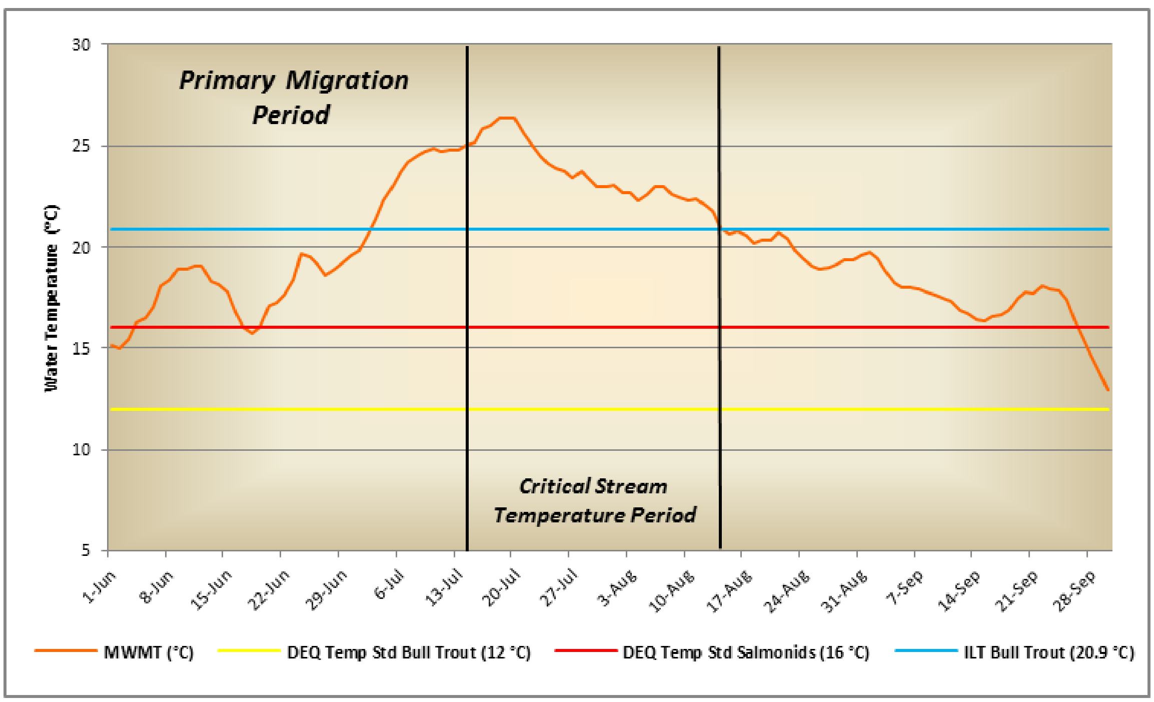


FIGURE 3A: MALHEUR RIVER BELOW BIG AND LAKE CREEK (SITE 3)

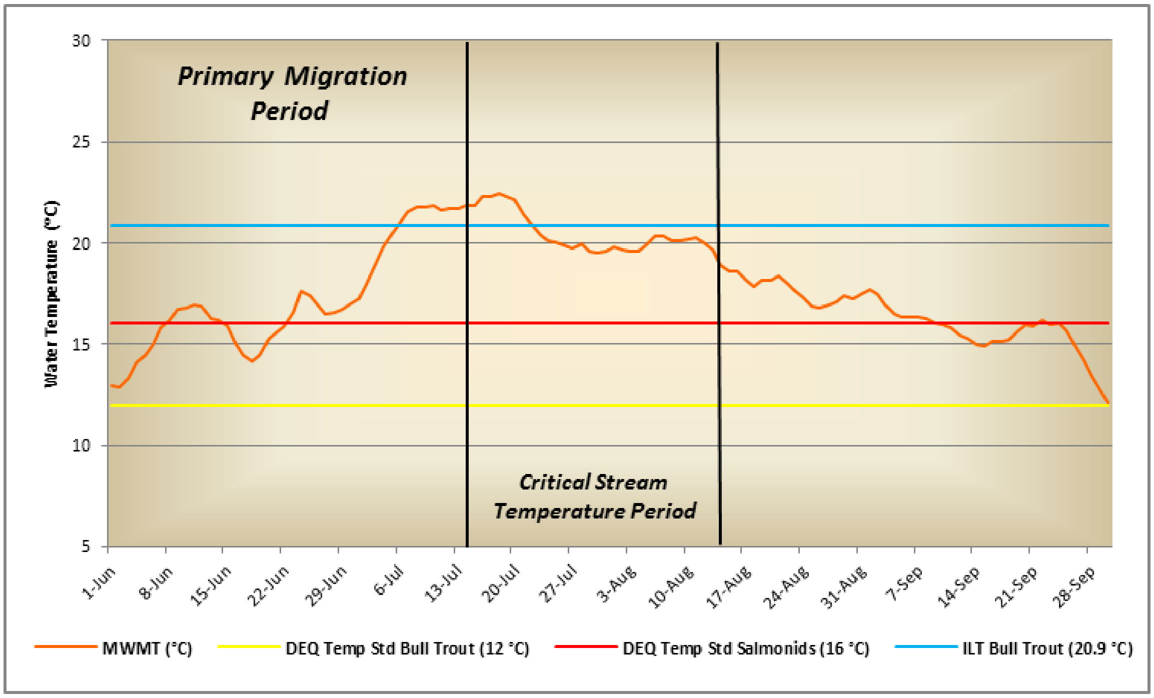


FIGURE 4A: BIG CREEK ONE MILE BELOW NF-16 ROAD (SITE 4)

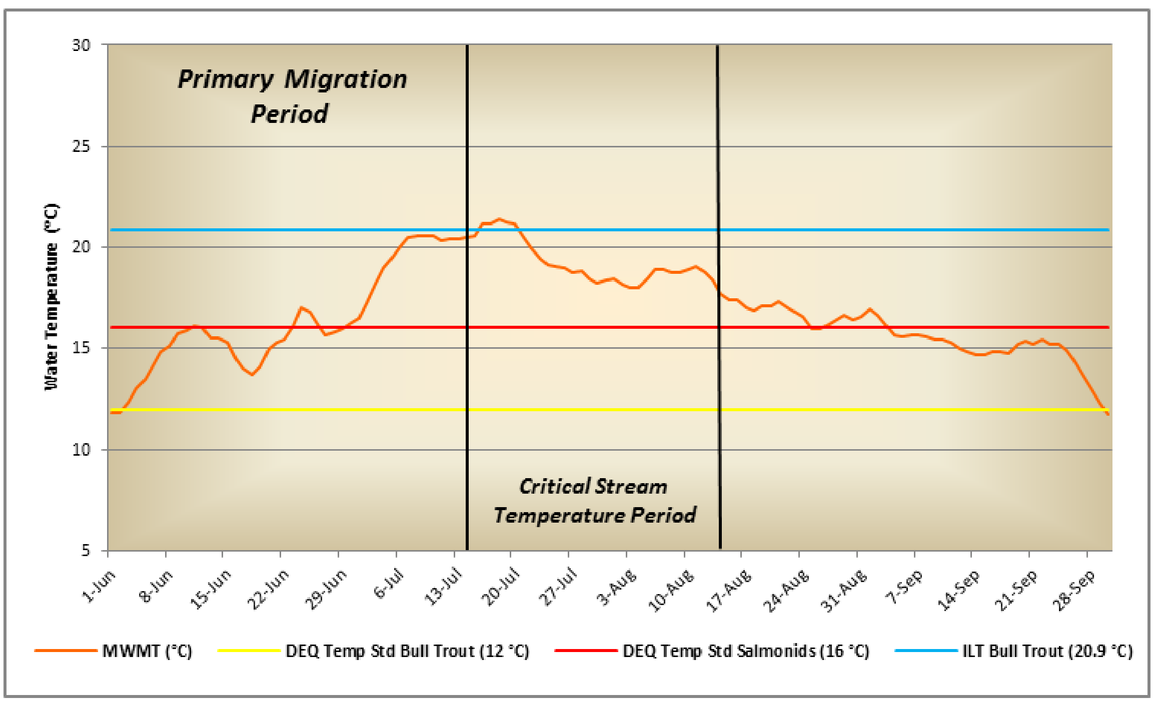


FIGURE 5A: BIG CREEK BELOW NF-16 ROAD (SITE 5)

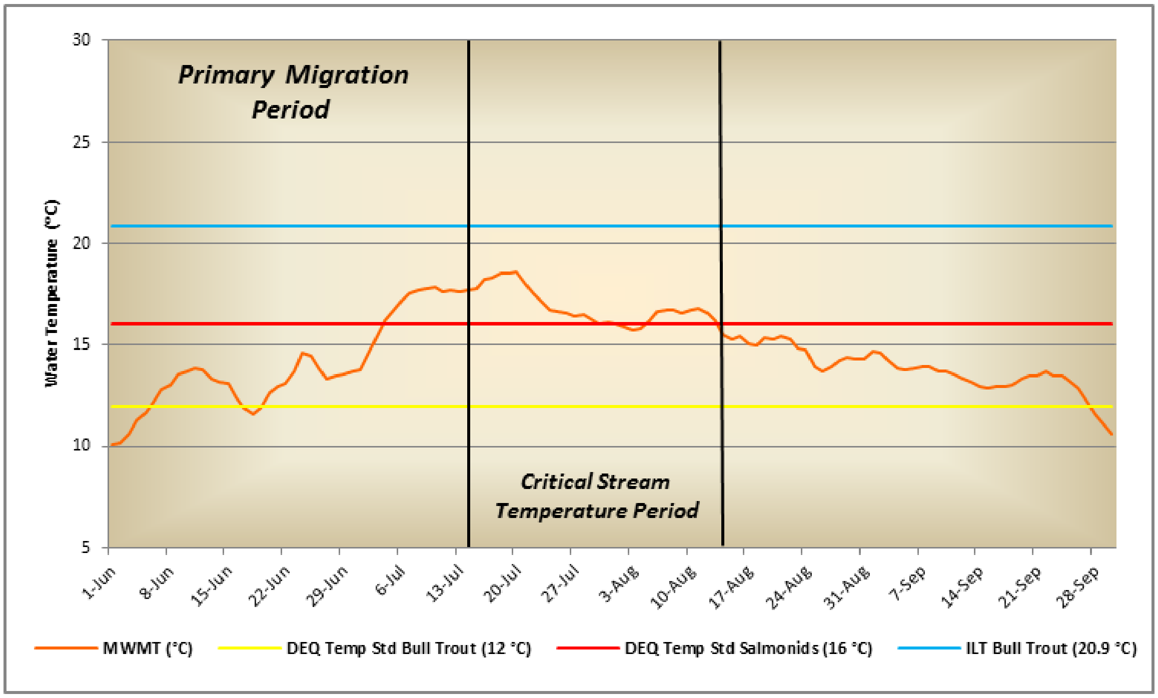
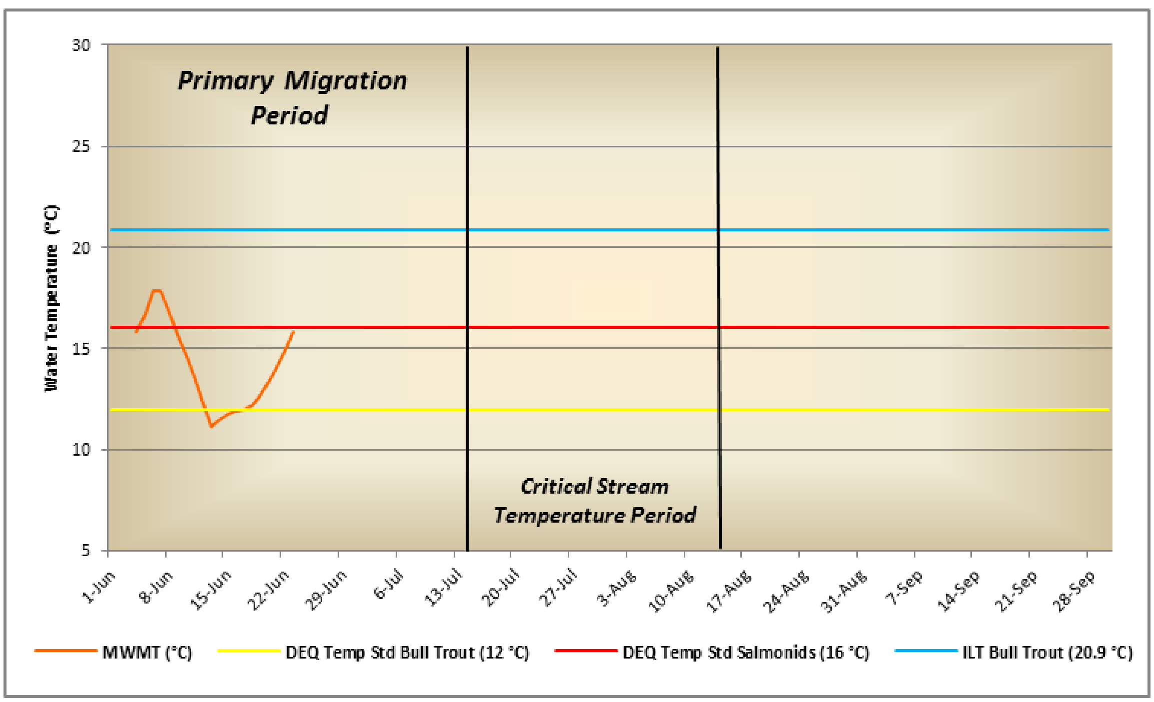


FIGURE 6A: LAKE CREEK BELOW NF-16 ROAD (SITE 6)*



*Incomplete data set due to air exposure

FIGURE 7A: MCCOY CREEK ABOVE LAKE CREEK (SITE 7)

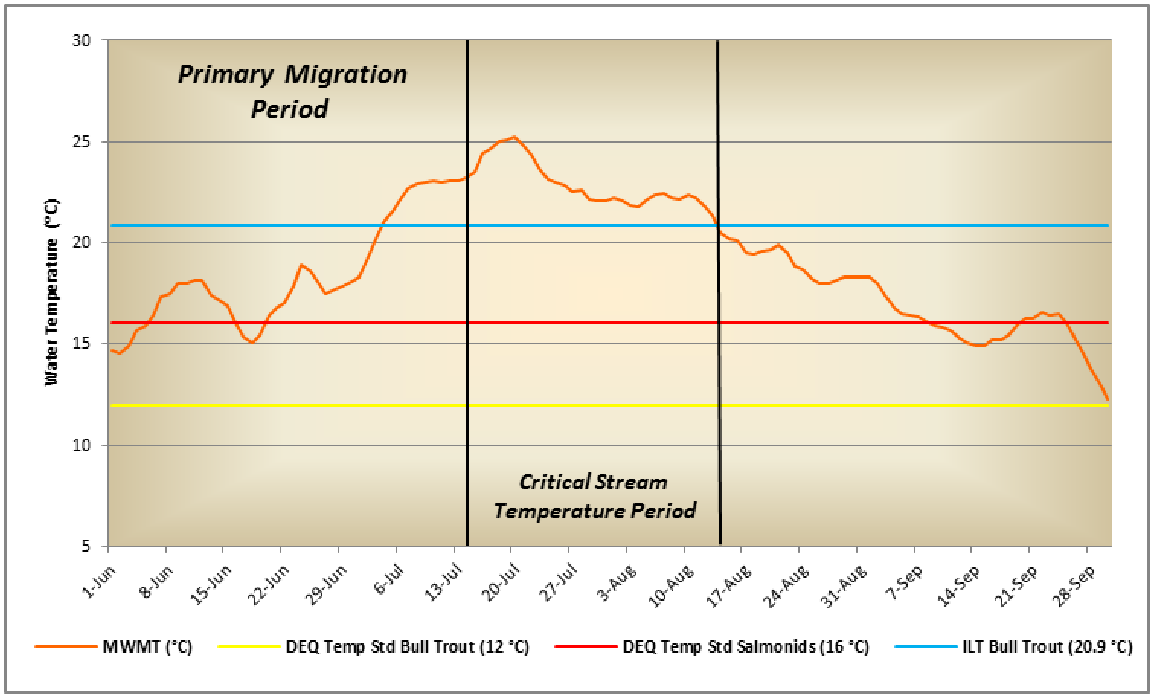
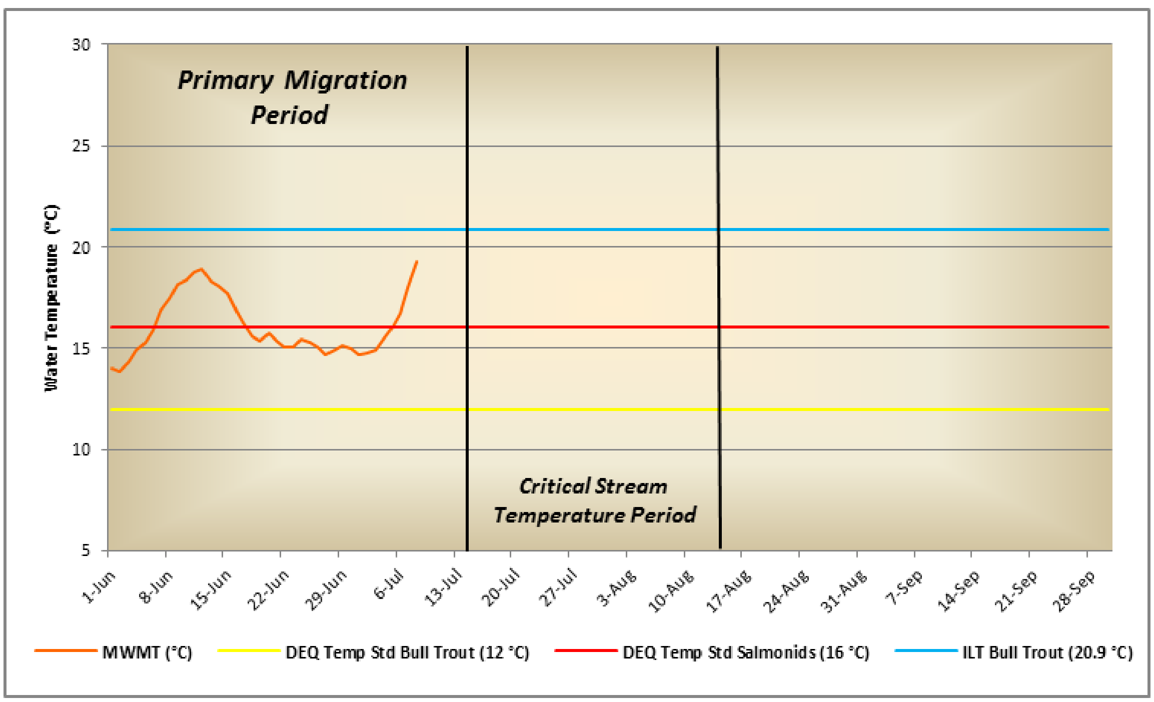


FIGURE 8A: LAKE CREEK AT CABIN BRIDGE (SITE 8)*



*Incomplete data set due to air exposure

FIGURE 9A: MCCOY CREEK BELOW NF-16 ROAD (SITE 9)

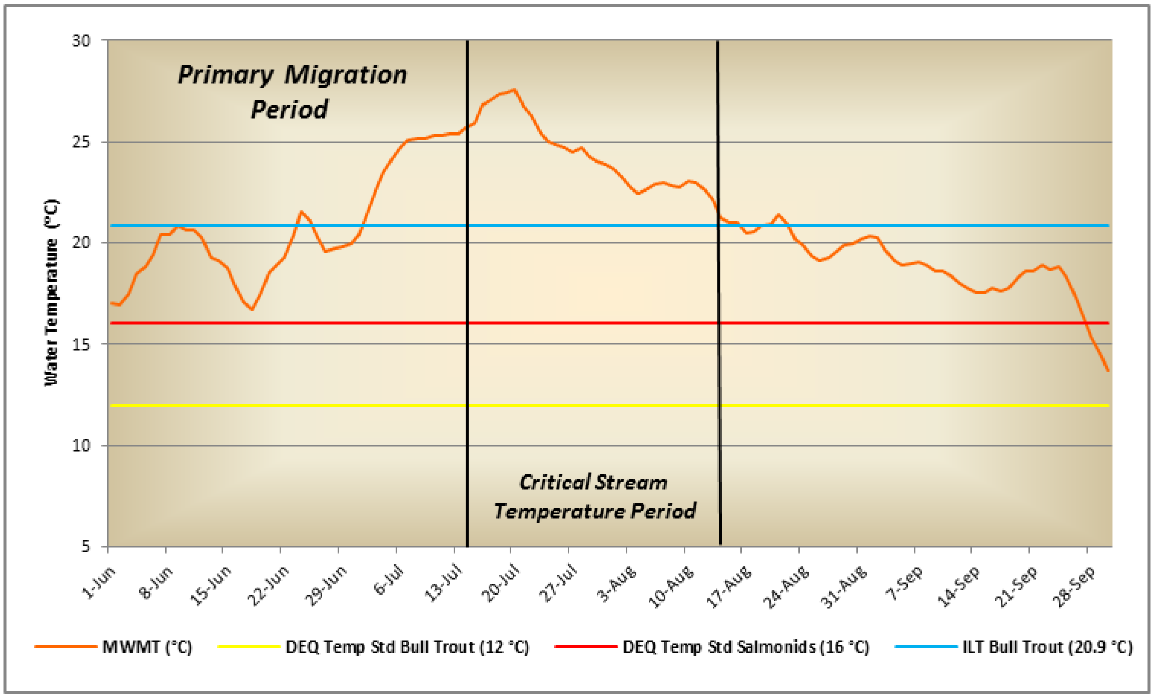
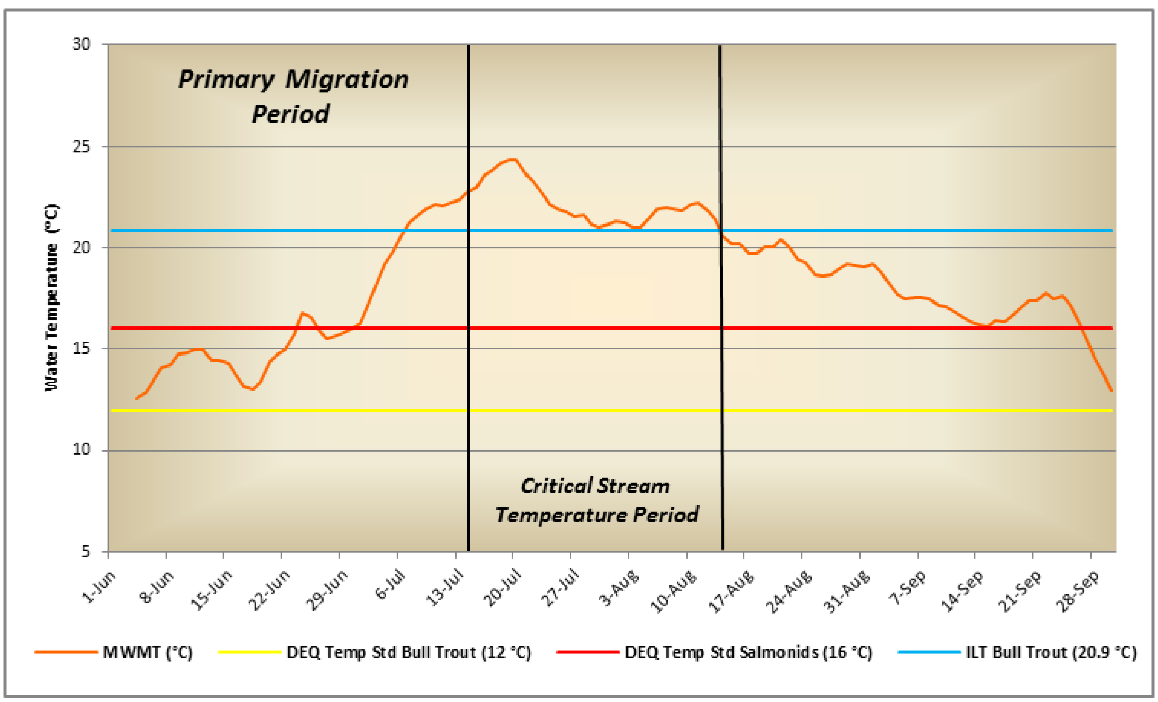


FIGURE 10A: LAKE CREEK DITCH BELOW NF-16 ROAD (SITE 10)



APPENDIX B: Daily Average Stream Temperatures

FIGURE 1B

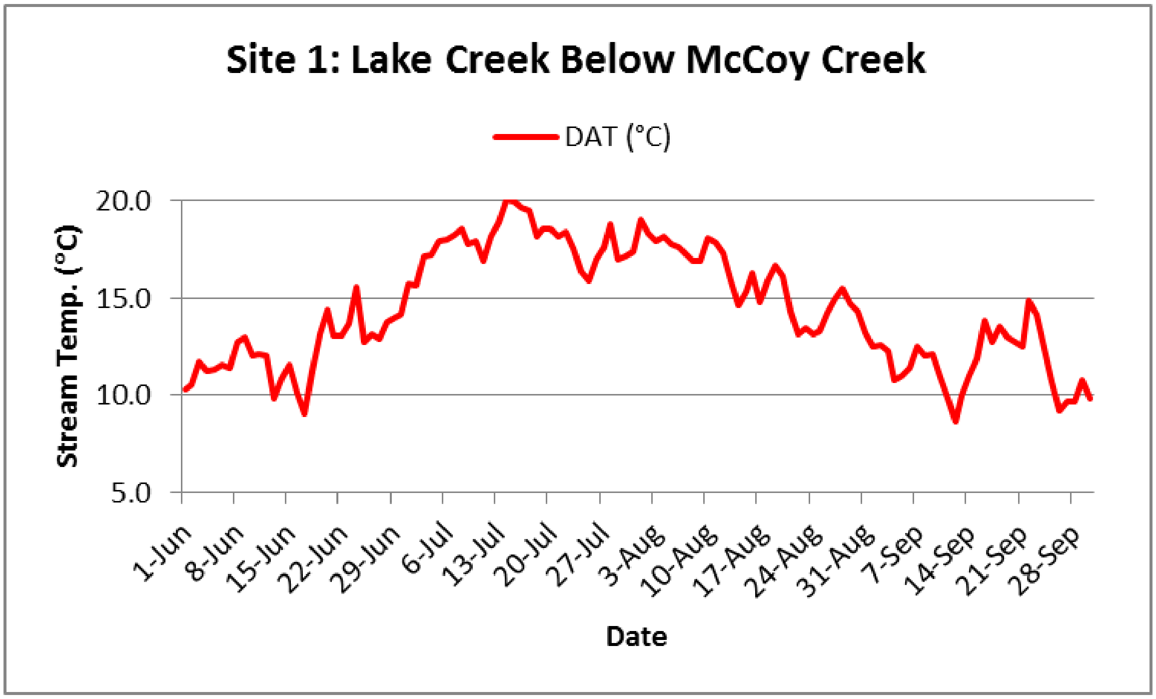


FIGURE 2B

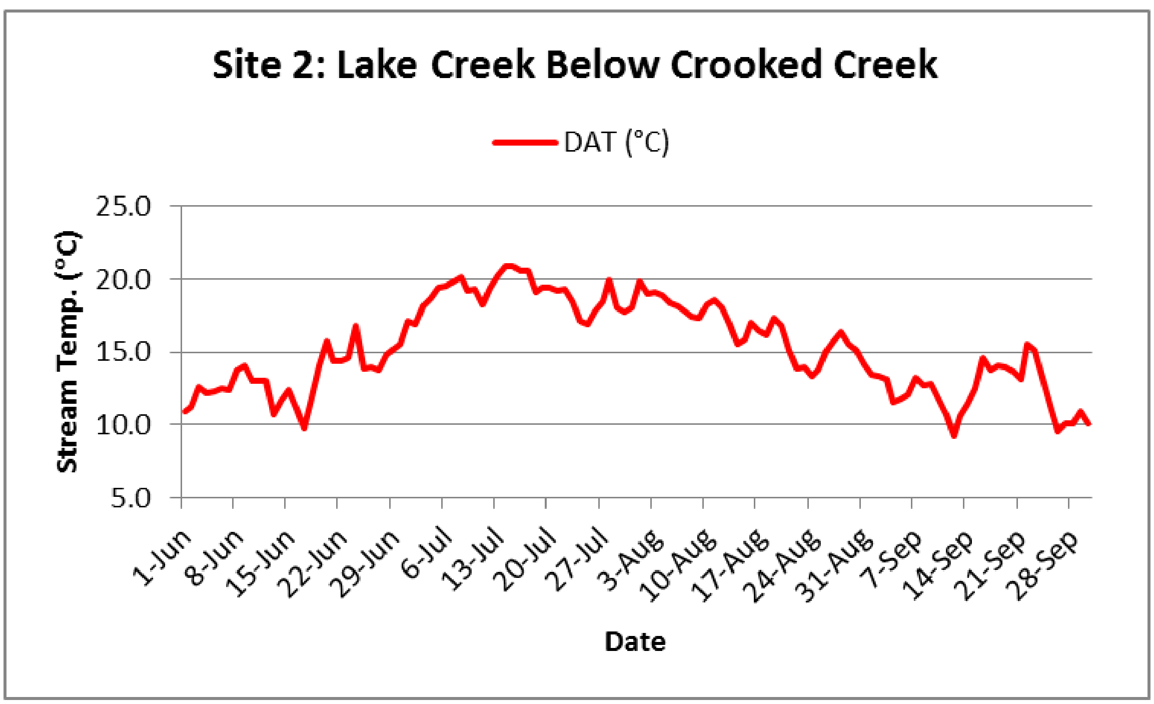


FIGURE 3B

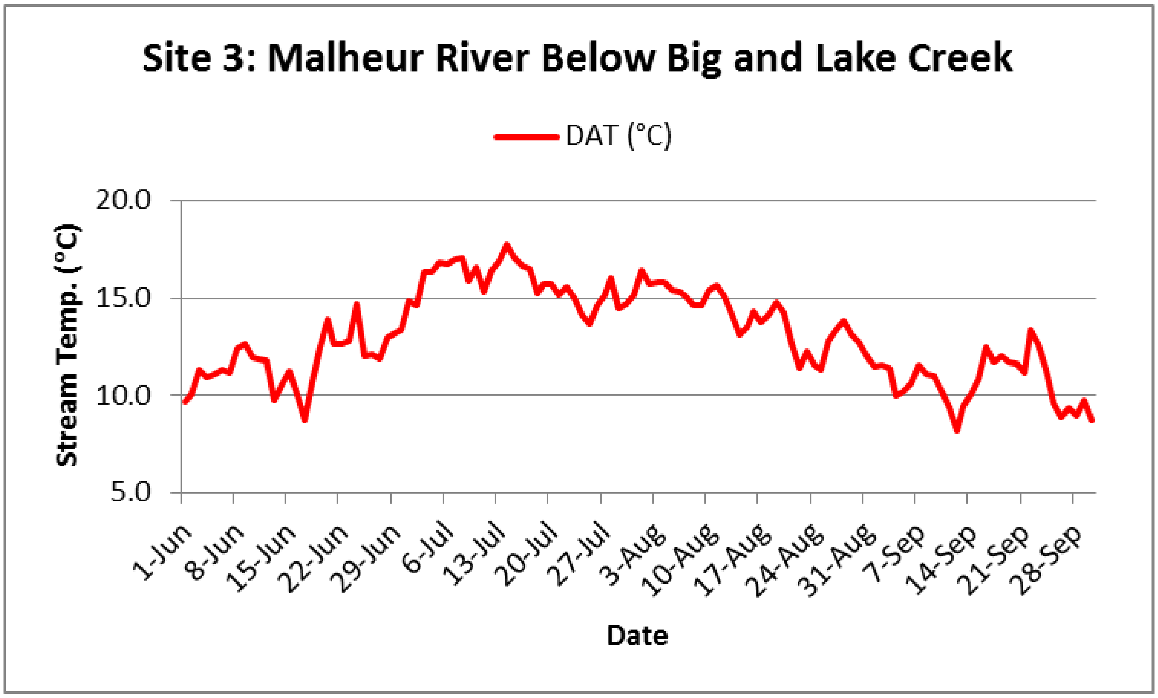


FIGURE 4B

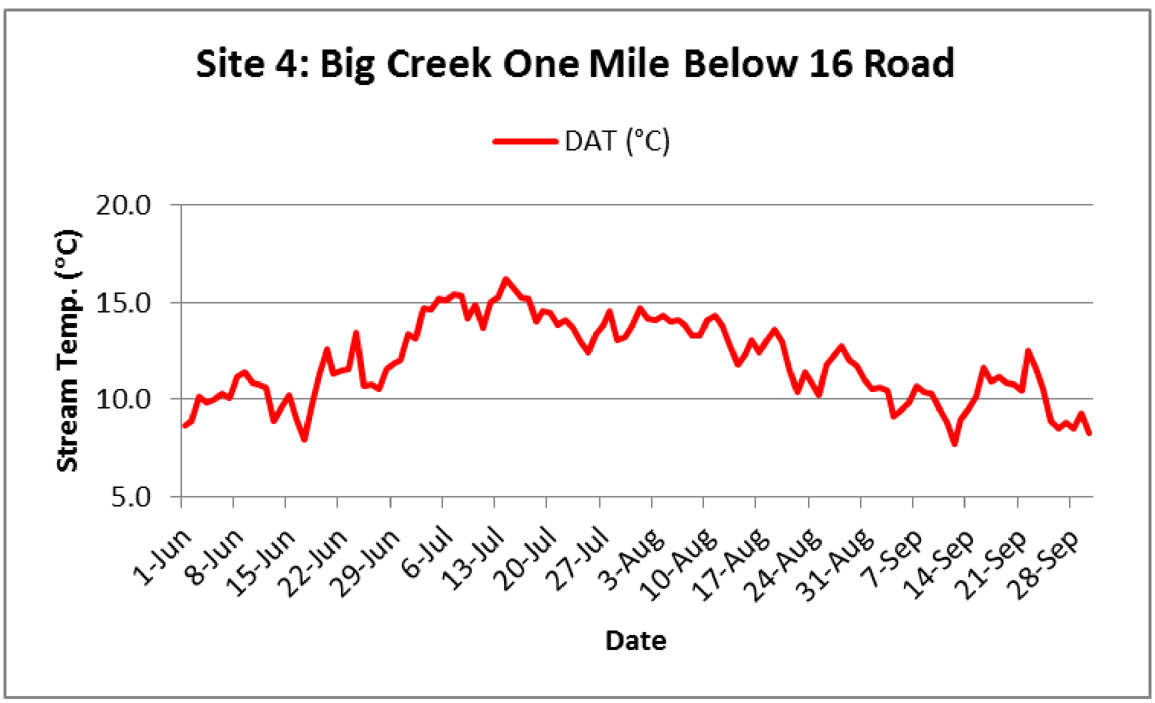


FIGURE 5B

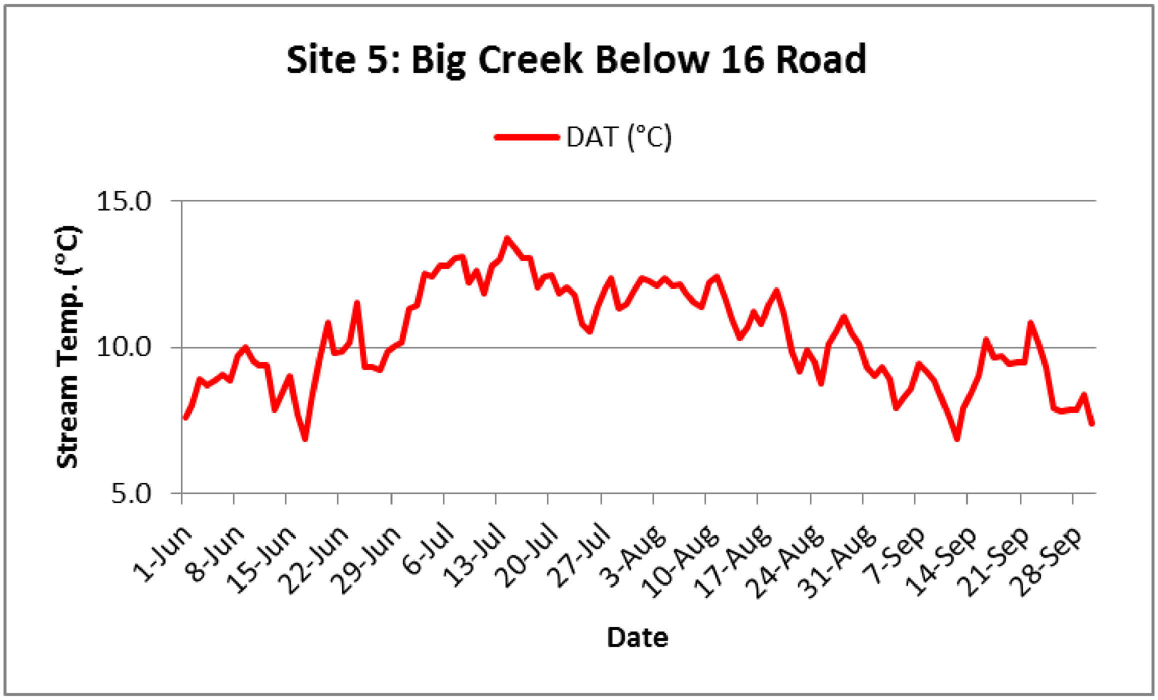
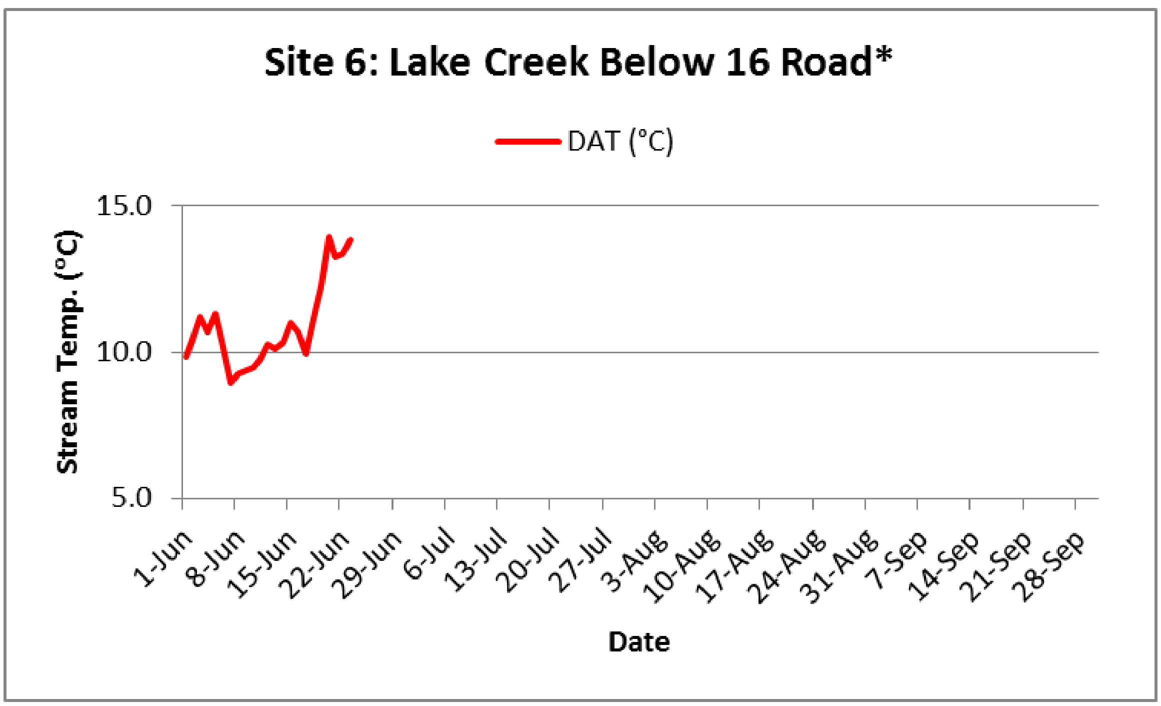


FIGURE 6B



*Incomplete data set due to air exposure

FIGURE 7B

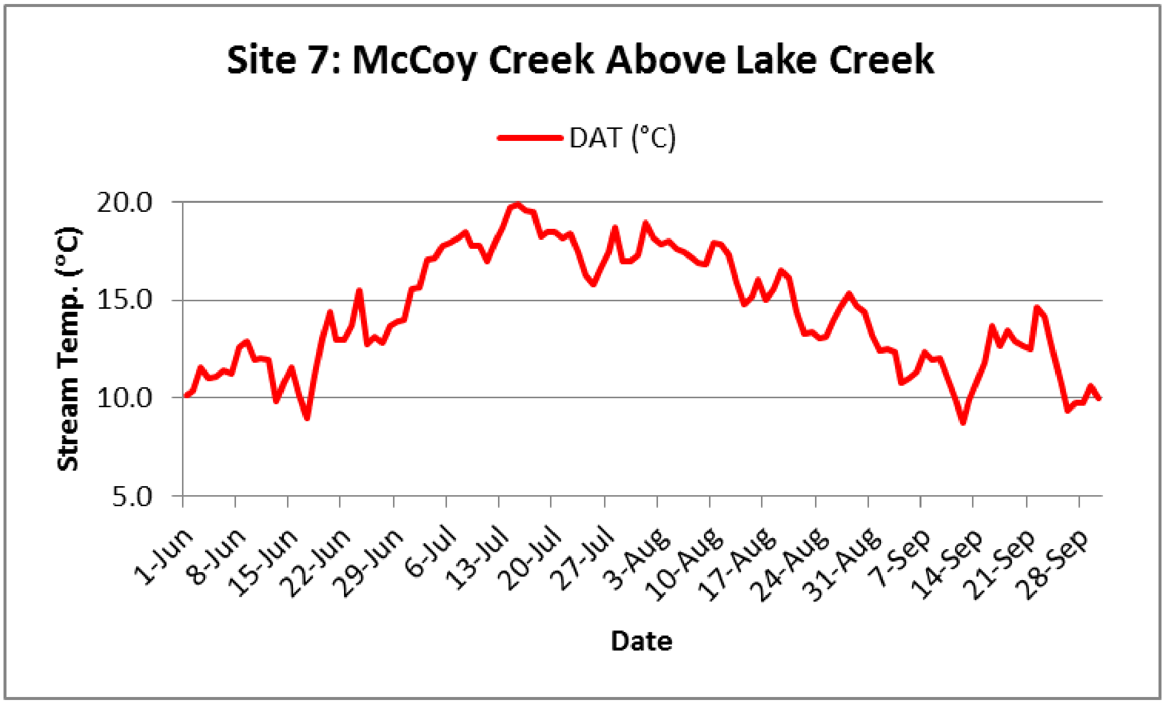
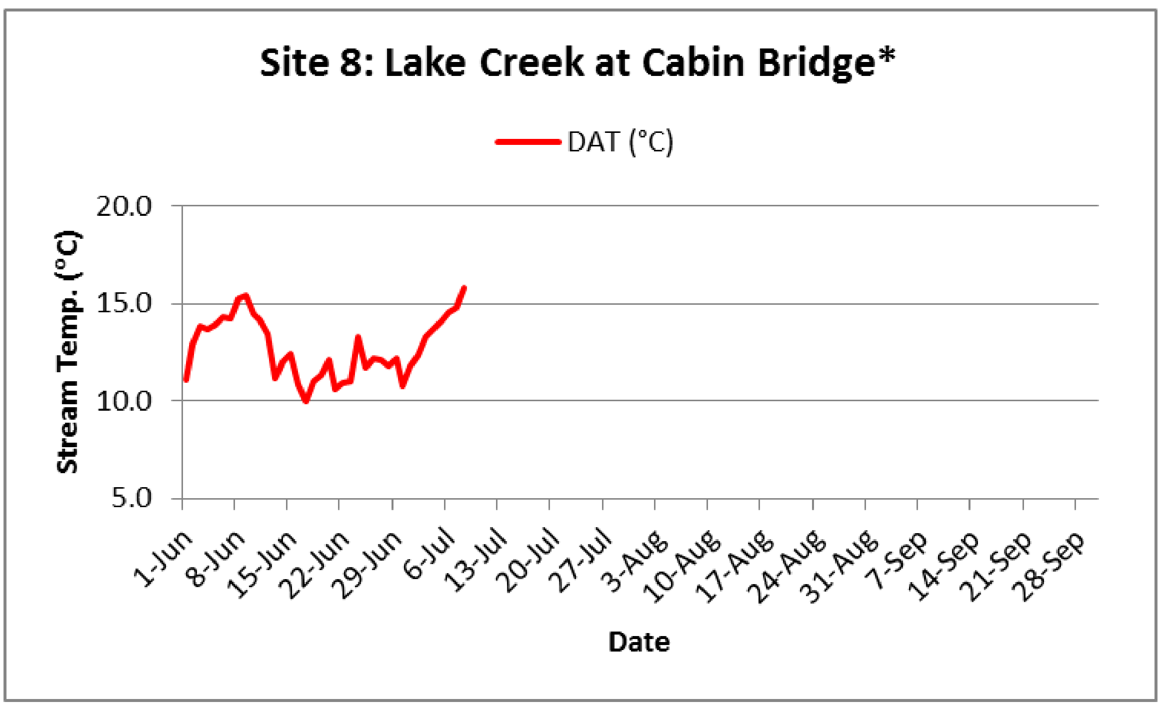


FIGURE 8B



*Incomplete data set due to air exposure

FIGURE 9B

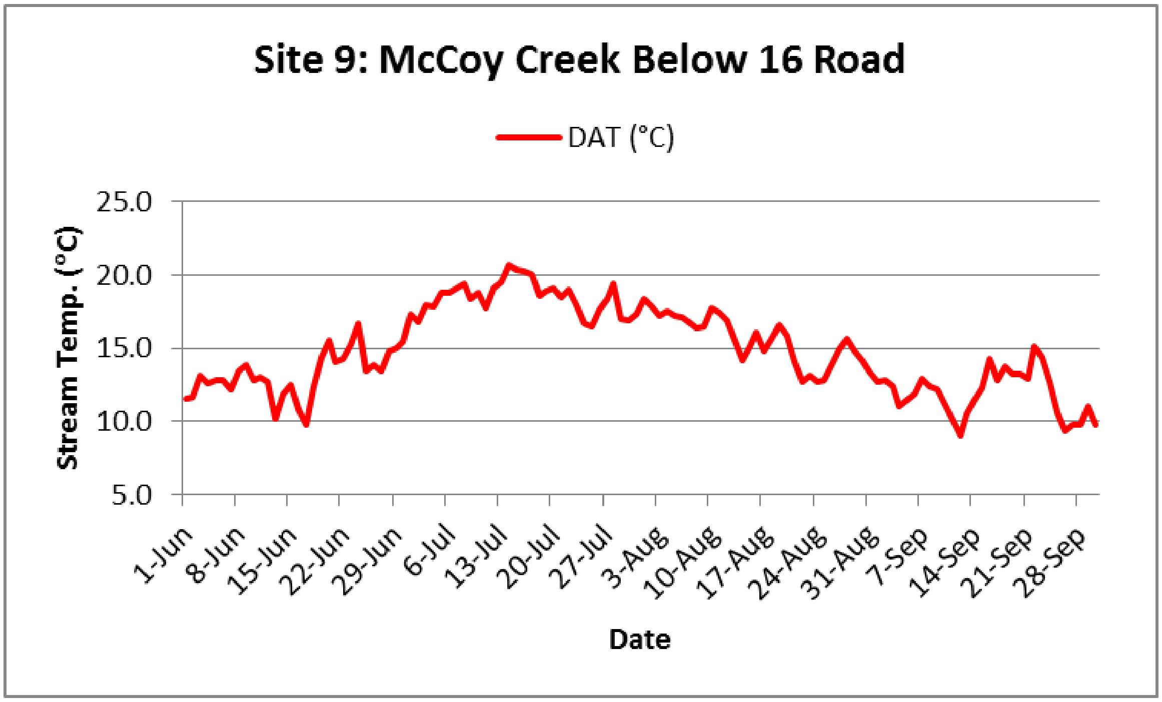
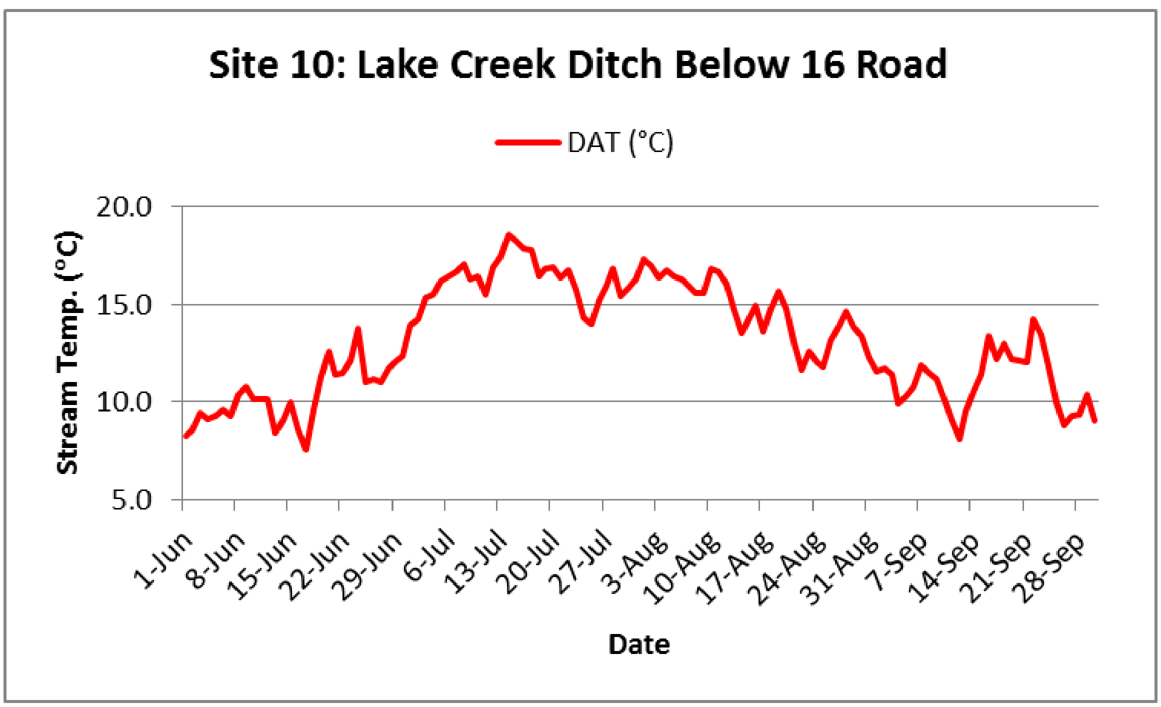


FIGURE 10B



Chapter 4:

Population Estimates and Removal of Brook Trout from High Lake—A Population Seed Source for the Upper Malheur River, Oregon

Kristopher Crowley
Burns Paiute Tribe Natural Resources Department
Burns, Oregon

Contents

Chapter 4: Population Estimates and Removal of Brook Trout from High Lake—A Population Seed Source for the Upper Malheur River, Oregon

Kristopher Crowley, Fish Biologist
Burns Paiute Tribe Natural Resources Department, Fisheries Program

4.1 Introduction

High Lake is a shallow lake approximately 5 acres in size located at approximately 7500' elevation in the Strawberry Mountain Wilderness in Grant County, Oregon. It is the source of Lake Creek, a major tributary to the Malheur River. A naturally fishless lake, High Lake has been inundated with invasive eastern brook trout since at least the 1930s (Bowers et al., 1993). Brook trout are a species well documented as detrimental to native trout populations through resource competition and the ability to hybridize with bull trout (Gunckel, 2001; Dunham et al., 2002; Ratliff and Howell, 1992; DeHaan et al., 2010). Brook trout currently are the only fish species present in High Lake and the upper reaches of its outflow, Lake Creek, allowing ideal spawning and rearing conditions free of competition. Due to the increased dispersal ability in the downstream direction, the stocking of headwater mountain lakes with brook trout can be especially detrimental (Adams, 1999; Paul and Post, 2001). High Lake is thought to be the major seed source of brook trout to Lake Creek, an Upper Malheur River headwater stream identified as Critical Habitat for ESA threatened bull trout (USFWS, 2002).

Since 2010, The Burns Paiute Tribe Natural Resource Department (BPT) has conducted electrofishing surveys to assess the feasibility and effectiveness of mechanical removal in Lake Creek (Poole and Harper, 2011; Harper, 2012; Harper, 2013; Crowley, 2014). It was perceived prior to these surveys that the brook trout population in High Lake serves as a seed source to Lake Creek and thus would be a source of heavy yearly recruitment of both mature and juvenile brook trout into areas where removal occurred. Without concurrent action to address brook trout in High Lake, benefits from mechanical removal in Lake Creek's ESA Critical Habitat for bull trout would be short lived and the likelihood of bull trout being extirpated would remain high. Therefore, funded by the Bureau of Reclamation, BPT conducted angling and gill netting surveys in High Lake in 2010-12 and 2014 during late summer and early fall. The purpose was to assess the feasibility of these methods as a means of control. It was expected that upon completion of the pilot year and three study years, future brook trout removal efforts in High Lake would ensue contingent upon the perceived benefit to bull trout downstream.

4.2 Methods

Brook trout spawn in Upper Malheur lakes and streams in the latter half of September (Perkins, 2011). In order to maximize the benefit of mechanical removal in the Lake, sampling occurred prior to this time. Due to extended winter time conditions in High Lake, it is only accessible in the summer months. Conveniently, warmer temperatures also promote increased activity and movement in brook trout which is conducive for angling and gill netting surveys.

2010 Pilot Year

2010 was a pilot year used for selecting effective mesh size in gill nets and establishing a base line population estimate for comparison to future years. The mark and recapture effort consisted of a two day angling period to initially mark fish on July 28th-29th, followed by a second sample taken using angling and gill netting consisting of 13 total sampling days from August through October. Concurrent with the recapture study, gill nets of different mesh size were used to determine effectiveness in High Lake for brook trout removal in order to guide future efforts. Gill nets were deployed over 12 days and consisted of 15 overnight net sets with ¾ inch mesh (approximately 100 meters long x 6 meters deep) and 33 net sets using a variety of different mesh sizes other than ¾ inch were also deployed. BPT deployed two ¾ inch mesh nets over the winter as well to be left under the ice and removed in the spring.

Sampling Gear and Methods

Each year after the pilot year, gill nets consisted of ¾ inch mesh and measured 100 meters long by six feet deep. Nets were tied off to the shore or woody material in the lake and were stretched tight using sand bags as anchors on both ends of the sinking line. Fish were collected from the nets daily. All fish captured were measured for length and weighed (when a scale was available and conditions permitted), checked for marks, and removed from the lake. Gill nets were always allowed at least an overnight soak between checks and were relocated as catch rates dropped each year to account for learned net avoidance behavior.

Angling surveys consisted of fly rods and spinning rods with casting bubbles. Dry flies were most frequently used. The most common fly patterns used were gray drakes, elk hair caddis, mosquitoes, and grasshoppers. After marking for population estimation studies, fish were allowed to recover from handling in live wells and were released with even distribution around the lake to promote mixing.

Population Monitoring and Removal

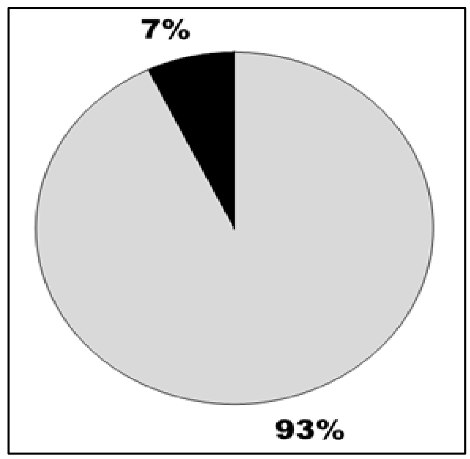
In 2011, BPT angled for fish on August 22nd to mark for a population estimate. We returned September 13th-22nd for the recapture effort comprised of gill netting and angling. As determined from the 2010 pilot study, ¾ inch mesh was used and 4 gill nets were deployed and emptied daily after overnight sets. BPT also angled daily and recorded fish captured during the recapture period. Fish were marked using caudal fin clips.

In 2012, BPT angled to mark fish on July 24th. The second sample for recapture began with angling on July 25th, 28th-30th, and August 1st. Gill nets (¾ inch mesh) were deployed July

27th and were checked and re-set daily. Wildfire prevented crews from sampling High Lake in 2013.

In 2014, BPT sampled in High Lake from August 20th through August 27th. Sampling from August 20th and 21st consisted of angling to mark fish. All fish that were captured and retained in healthy condition were tagged using visible implant elastomer (VIE) tags. This tagging method utilizes a two-part silicone based material that is mixed immediately before use. The tags were injected as a liquid subcutaneously into the transparent tissue on the fish's jaw. The liquid quickly cures into a pliable, biocompatible, and highly visible solid that remains with the fish throughout its life. On August 21st, gill nets were deployed for second sample where fish were captured, measured, and recaptures were accounted for. Fish were removed from nets after each overnight set, with the exception of August 25th when the nets were allowed a 48 hour soak time due to gear and logistical issues. The last day of sampling occurred on August 27th.

Figure 4.1. Pie Chart Showing the Percentage of Fish Captured in 3/4" mesh (gray; 15 net sets) and all other nets combined (black; 33 net sets) during 2010 pilot year.



4.3 Results

2010 Pilot Study

In 2010, 257 brook trout were caught, marked, and released during the first sampling effort. During the recapture effort, 2206 fish were captured, including 85 recaptures. ¾ inch mesh caught the vast majority of fish during the gill netting effort (1766 of 1902; Figure 4.1). Overwinter gill-netting resulted in unquantifiable data, equipment failure due to woody material in the lake, and no observable effect on the brook trout population.

Three Year Removal and Population Monitoring (2011-12; 2014)

In 2011, 210 brook trout were initially captured and marked. The recapture effort yielded 807 total fish, including 42 recaptures.

In 2012, 80 brook trout were captured, marked, and released in the first sample. Subsequently, 711 brook trout were captured in the second effort, including 31 recaptures.

In 2014, during angling surveys to mark fish, 89 brook trout were captured. Of these, 85 were VIE tagged and released back into the lake. The other four fish resulted in mortality during handling and were noted, but not tagged or considered for the population estimation. During the second sampling effort, gill nets captured 1778 brook trout. Of these, 43 fish were recaptures. See table 4.1 for total captures and recaptures by day.[1]

Table 4.1 2014 Captures and Recaptures by date for second sample gill netting.

Date	Total Captures	Recaptures
8/22/2014	909	13
8/23/2014	518	11
8/24/2014	155	6
8/26/2014	142	6
8/27/2014	54	7
Total	1778	43

Year	Population Estimate	95% Confidence Range	Total Fish Removed from High Lake
2010	6621	5544-8403	2206
2011	3965	3002-5447	807
2012	1802	1282-2621	711
2014	3477	2598-4766	1778

Table 4.2 Population estimates and brook trout removal by year.

Data Analysis

In order to estimate population size we used the single direct census adjusted[2] Peterson estimate (below; Ricker, 1975). Ricker also suggests Poisson distribution tables, using recaptures (R) as the entering variable, in order to obtain a confidence range. We calculated this based on 95% confidence (results in table 4.2)

$$\frac{(M+1)(C+1)(C-R)}{(R+1)^2(R+2)}$$

M=number of fish caught, marked and released

[1] The net pulls were not completed on August 22nd due to time constraints. Approximately 50 meters of the fourth net was not pulled and was added to the August 23rd sampling data.

[2] Chapman (1951) shows that with ordinary direct sampling, populations tend to be overestimated. We used Chapman's adjusted formula (omitting -1 due to a large sample size) to account for this bias, although it was likely very minimal due to a high number of recaptures (Ricker, 1975).

C= total number of fish caught in second sample (unmarked + recaptures)

R= Number of recaptures

4.4 Discussion

Brook trout are well documented as detrimental to native trout populations (Gunckel, 2001; Dunham et al., 2002; Ratliff and Howell, 1992; DeHaan et al., 2010). As a seed source for brook trout in Lake Creek and the Upper Malheur River, limiting the population in the lake is critical to ensure the persistence of bull trout populations downstream. In order to relieve bull trout in ESA Critical Habitat in Lake Creek, BPT has mechanically removed brook trout from the system since 2010.

Through four study years, gill netting has been demonstrated to be effective in reducing the population of brook trout in High Lake. Based on the pilot year, ¾ inch mesh accounted for 93% of the captures (Figure 4.1). The size class captured was dominant in the lake each subsequent year we sampled as well, as indicated by angling surveys. Each year that fish were removed, the following year yielded a population estimate of roughly 40-60% of the previous year (Table 4.2). However, after the lake remained unsampled for a full year due to wildfire, populations rebounded, nearly doubling in size from the last sampling year. Netting that occurred in 2011 and 2012 resulted in significantly fewer catches than years where removal did not occur the prior year (2010 and 2014). This is possibly due to a combination of learned behavior for net avoidance and the ability for increased recruitment during years when the lake was not sampled. However, despite lower catch numbers in 2011-12, positive effects were still observed by steep decreases in population estimates.

Although there is a clear benefit to a yearly removal effort of brook trout in High Lake, this approach is not sustainable indefinitely and is unlikely to result in eradication as Lake Creek serves as a source for potential emigration of brook trout back into the lake. Although BPT also conducts yearly removal efforts in Lake Creek (Harper, 2012; Harper, 2013; Crowley, 2014), eradication is not attainable by mechanical methods due to complex stream features such as wet meadows, springs, and subterranean flow. Therefore, BPT conducting mechanical control activities in both High Lake and its outflow combine to only curtail the brook trout population, and thus provide limited benefit for native species downstream such as ESA listed bull trout.

Gill netting high alpine lakes to remove non-native trout species has been demonstrated to be successful in controlling nonnatives, especially in historically fishless lakes where the nonnative is the only fish present (Knapp, 1998). High Lake gill netting each year has had a substantial effect on brook trout population in the lake. While this level of population reduction may not occur in every future year, BPT is compelled that gill netting should continue to serve as a viable option for population control in the lake until comprehensive eradication can be achieved via other methods. The response seen in 2014 after no sampling occurred in the year prior suggests the need for a gill netting effort in High Lake at least yearly to maximize the benefit to downstream native trout. BPT recommends that gill netting and other mechanical removal efforts in High Lake and Lake Creek only be a short-term placeholder until comprehensive eradication can be achieved. In terms of maximizing benefit to native species, cost, and staff time; an eradication strategy utilizing piscicide would be the best approach to brook trout in High Lake and Upper Lake Creek. High Lake containing only nonnative brook trout eliminates the necessity for native salvage and greatly decreases the chance of adverse effects on bull trout. In addition to the relative simplicity of piscicide treatment due to the target fish being the only species present, brook trout eradication in Upper Lake Creek and High Lake would offer an enormous benefit to native species downstream. With this area available to brook trout as a nursery with no competition for resources, any control efforts downstream are greatly limited, as populations are able to rebound yearly. Piscicide treatment in High Lake and Upper Lake Creek would also serve as a pilot study for further treatments in the basin and BPT's goal of basin wide brook trout eradication.

4.6 Recommendations

As BPT natural resource department staff continues work toward designing and implementing a piscicide treatment plan for Upper Lake Creek and High Lake, mechanical removal efforts in Lake Creek and High Lake should continue yearly to reduce brook trout in the system. In order to maximize results and minimize staff time, High Lake should be sampled using gill nets for a minimum of four overnight sets per year since the majority of fish were captured within this time (see table 4.1). Population estimates do not need to continue yearly as a reduction in populations has been demonstrated by this study. However, it is recommended that a population estimate be conducted every 3-5 years as needed to monitor success until eradication can be achieved. As indicated by table 4.1, during years in which population estimates are obtained, gill netting should occur for a longer period (6-8 days) as a substantial portion of recaptures occurred on these days during the three year study.

4.7 Acknowledgements

BPT would like to thank the U.S. Bureau of Reclamation, Native Affairs Program for providing continued funding for the experimental removal of brook trout in High Lake.

4.6 References

Bowers, W.L., P.A. Dupree, M.L. Hanson, R.R. Perkins. 1993. Bull Trout Population Summary Malheur River Basin. Oregon Department of Fish and Wildlife. Hines, OR. Unpublished report.

DeHaan, P. W., Schwabe, L. T., & Ardren, W. R. (2010). Spatial patterns of hybridization between bull trout, *Salvelinus confluentus*, and brook trout, *Salvelinus fontinalis* in an Oregon stream network. *Conservation Genetics*, *11*(3), 935-949.

Dunham, J.B., S.B. Adams, R.E. Schroeter, and D.C. Novinger. 2002. Alien Invasions in Aquatic Ecosystems: Toward an Understanding of Brook Trout Invasions and Potential Impacts on Inland Cutthroat Trout in Western North America. Reviews in Fish Biology and Fisheries 12:373-391.

Gunckel, S.L. 2001. Feeding Behavior and Diet of Native Bull Trout *Salvelinus confluentus* and Introduced Brook Trout *Salvelinus fontinalis* in two Eastern Oregon Streams. Master's Thesis. Oregon State University, Corvallis.

Harper, D. 2012. Selective Removal of Brook Trout *Salvelinus fontinalis* in Lake Creek, Upper Malheur River, Oregon. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Harper, D. 2013. Selective Removal and Abundance estimation of Brook Trout *Salvelinus fontinalis* in Lake Creek, Upper Malheur River, Oregon. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2012 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Knapp, R. A. and Matthews, K. R. (1998), Eradication of Nonnative Fish by Gill Netting from a Small Mountain Lake in California. Restoration Ecology, 6: 207–213. doi: 10.1111/j.1526-100X.1998.06212.xPaul, A.J. and J.R. Post. 2001. Spatial Distribution of Native and Nonnative Salmonids in Streams of the Eastern Slopes of the Canadian Rocky Mountains. Transactions of the American Fisheries Society 130:417-430.

Perkins, R. 2012. 2011 Bull Trout Spawning Survey Report. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2011 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Poole, A. and D. Harper. 2011. 2010 High Lake Brook Trout Suppression. "Evaluate the Life History of Native Salmonids in the Malheur Subbasin." FY 2010 Annual Report. Project No. 1997-01900. (BPA Report BOE/BP-00006313-5).

Ratliff, D.E. and P.J. Howell. 1992. The Status of Bull Trout Populations in Oregon. Pages 10-17 in P.J. Howell and D.V. Buchanon, editors. “Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society.” Corvallis, OR.

U.S. Fish and Wildlife Service. 2002. Chapter 14, Malheur Recovery Unit, Oregon. 71 P. In: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, OR.

Chapter 5:

Monitoring Brook Trout using Environmental DNA in High Lake System

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MONITORING BROOK TROUT USING ENVIRONMENTAL DNA IN HIGH LAKE SYSTEM

Prepared for:

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Burns Paiute Tribe

Prepared by:

Scott Blankenship
Gregg Schumer

May 22, 2015

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Table of Contents

List of Figures

List of Tables

INTRODUCTION

Recovery Criteria for the Malheur Recovery Unit Bull Trout (*Salvelinus confluentus*) require stable or increased abundance of local populations and the reestablishment of connectivity between the separated populations (USFWS 2002). Other necessary actions include a reduction or elimination of threats from invasive (non-native) Brook Trout (*Salvelinus fontinalis*) interactions within the Upper Malheur River Basin (USFWS 2002). Full recovery of Malheur River Bull Trout is contingent upon minimizing the threats posed by Brook Trout interaction. Within the Lake Creek system, non-native Brook Trout introduced into a head water impoundment, High Lake, threaten downstream Bull Trout populations in Lake Creek via hybridization (DeHaan 2009). Lake Creek supports spawning populations of the federally threatened Bull Trout. Brook trout suppression and/or eradication activities throughout said essential Bull Trout habitat in the Upper Malheur include Brook Trout removal in High Lake, seasonal fish weir operations to prevent upstream brook trout movements, and a large-scale chemical treatment effort in streams lacking Bull Trout.

The use of environmental DNA (eDNA) as a tool for species detection has been demonstrated in freshwater environments (Jerde et al. 2011, Teletchea 2009; Thomsen et al. 2011). Previous work in High Lake has shown the ability to detect Brook Trout DNA from water samples (Blankenship et al. 2012). While the eDNA monitoring tool has had greatest application in detection of “cryptic” (visually-evasive) species, Blankenship et al. (2012) showed eDNA could be used for trend analysis of a non-desirable species. This is an important development, as the distribution of invasive species can be difficult to document, intensive eradication efforts could be prioritized based on distribution information, and the success of removal efforts could be confirmed by the absence of non-native species DNA.

The project reported here extended the initial work reported by Blankenship et al. (2012), having a primary objective of enhancements to sampling protocols, with Cramer Fish Sciences (CFS) and Burns Paiute Tribe (BPT) collaborating to test a new eDNA field filtration protocol intended to i) eliminate the requirement of transporting water from the field, ii) increase the ease with which field samples can be obtained, iii) increase the volume of water that can be assayed for DNA, and iv) decrease the time from collection to analysis. Secondarily, enhanced field sampling methods would also build on results from previous field season collections, laboratory analysis, and statistical evaluations to maximize detection efficiency. The goal is to develop a method that provides a reliable means to detect the presence of Brook Trout and estimates their biomass from the eDNA metric. The controlled nature of the High Lake site makes it a great system in which to evaluate and develop a thorough understanding about monitoring Brook Trout using eDNA methods. Further, the outfall into Lake Creek provides a means to extend the method to flowing water sites. This comprehensive information will enable the development of generalized sampling frameworks that model efficiency gains from field and/or laboratory activities and provide a means to extend proven occurrence and utilization monitoring protocols to system-wide surveys and other important species such as Bull Trout.

Using the quantitative Polymerase Chain Reaction (qPCR) technique developed from previous work (Blankenship et al. 2012) and updated filtration technology, water samples were analyzed for the presence of Brook Trout *e*DNA in the Lake Creek system. Within the 2014 sampling period, water samples were collected from both High Lake and Lake Creek using *e*DNA-specific filtration protocols. Coincident with the *e*DNA sampling events, the BPT staff conducted Brook Trout population surveys. Brook Trout were observed at all sites and their eDNA was detected in all water samples analyzed.

METHODS

Field Sampling

An approximate 10 km section of Lake Creek up to High Lake was surveyed by BPT staff at 84 sites (Figure 1) in the summer and fall of 2014. Thirty sites were randomly chosen from the 84 site regime to collect eDNA (water) samples. Water samples were also collected from High Lake during both summer and fall events. During the summer sampling event, eDNA (water) samples were obtained from 18 (of the proscribed 30) sites in Lake Creek and nine eDNA (water) samples were obtain from High Lake (Figure 1; Table 1). During the fall sampling event, eDNA samples were taken from the 30 proscribed sites and nine eDNA samples were taken from High Lake (Figure 1; Table 1).

EDNA samples were obtained from field sites using a water filtration method. Water was pumped from the stream using a battery operated peristaltic pump, with organic material sequestered in a Millipore Sterivex Filter Column (www.millipore.com). A video was produced describing the protocol in its entirety (view here: Protocol Video). Each eDNA sample was collected using sterile materials and filters were kept on ice while in the field. Filters were frozen prior to shipping, and all filters were shipped on wet ice to Cramer Fish Sciences for processing and analysis.

Laboratory Analysis

DNA was isolated from each filter following manufactures extraction protocols (www.mobio.com). Established QA/QC controls were used during each step of laboratory processing. Following extraction of DNA, each sample was interrogated for the presence of the Brook Trout DNA barcode using the quantitative polymerase chain reaction (qPCR) method developed in Blankenship et al. (2012). Positive detections of target species (i.e., Brook Trout) DNA were transformed into DNA concentrations using the standard curve constructed by Blankenship et al. (2012).

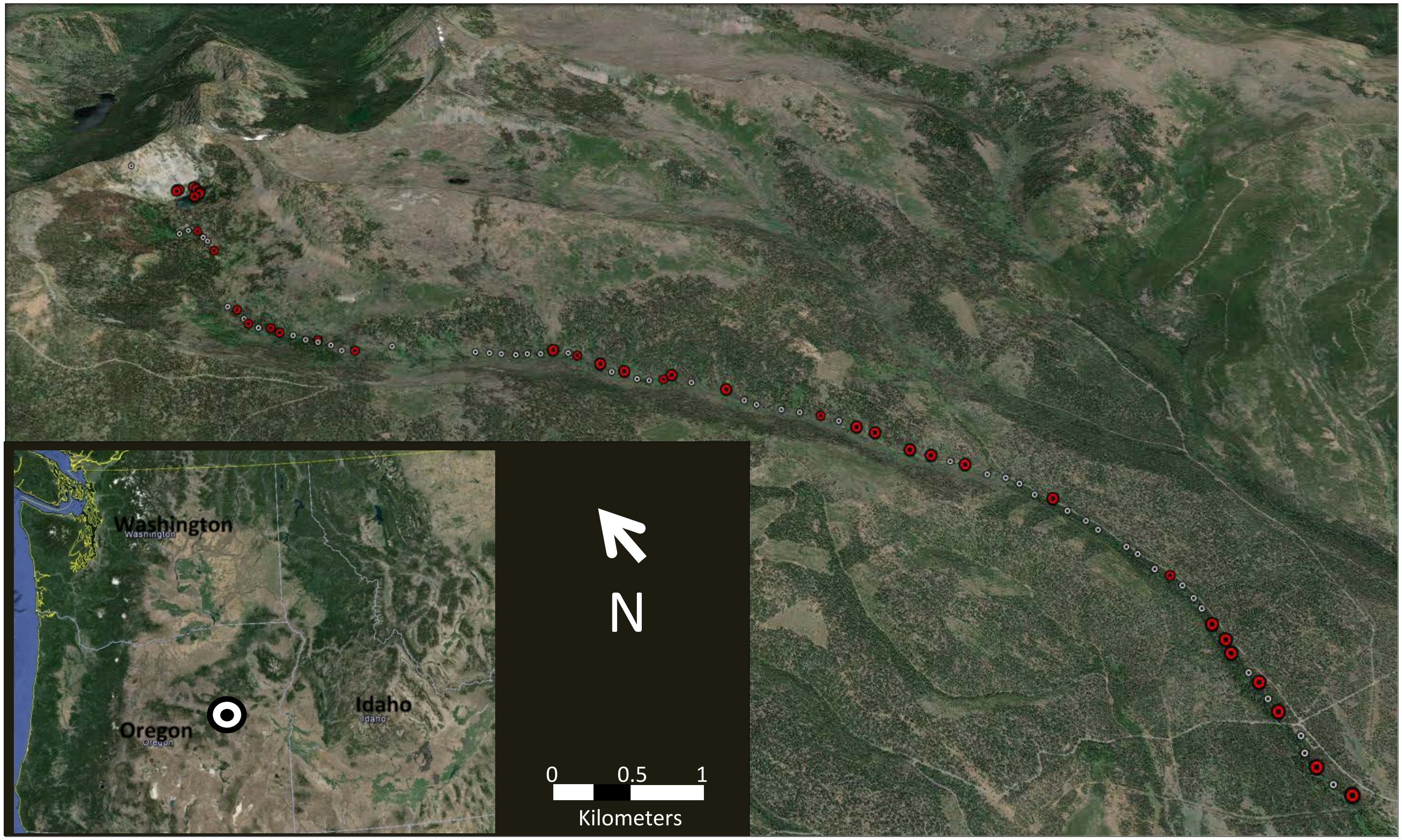

Figure 1. Study location and sampling transect. Points shown in red were sampled for eDNA.

Table 1. 2014 sampling and analysis summary. Site ID, location (Latitude, Longitude), and Brook Trout density per meter (BT/m) were provided by Burn Paiute Tribe. Lab ID, qPCR cycling detection threshold (C(t)) and DNA concentration in milligrams per liter (DNA [mg/L]) were provided by Cramer Fish Sciences.

SiteID	Latitude	Longitude	Category	Event	LabID	C(t)	DNA[mg/L]	BT/m
1	44.208304	-118.6407113	Lake Creek	sample1	1	35.1	0.0002	0.19
1	44.208304	-118.6407113	Lake Creek	duplicate	1b	28.1	0.0240	0.19
3	44.2103	-118.6408919	Lake Creek	sample1	2	27.8	0.0295	0.16
6	44.213473	-118.6393653	Lake Creek	sample1	3	31	0.0032	0.18
8	44.215215	-118.6384497	Lake Creek	sample1	4	29.5	0.0091	0.38
10	44.217272	-118.6381062	Lake Creek	sample1	5	31.6	0.0021	0.28
11	44.218029	-118.6374387	Lake Creek	sample1	6	28.6	0.0170	0.23
12	44.21915	-118.6370942	Lake Creek	sample1	7	28.6	0.0170	0.15
24	44.230754	-118.637804	Lake Creek	sample1	8	30.4	0.0049	0.27
29	44.235764	-118.6412865	Lake Creek	sample1	9	29.5	0.0091	0.70
31	44.237476	-118.6430497	Lake Creek	sample1	10	29.3	0.0105	0.74
32	44.238559	-118.6441318	Lake Creek	sample1	11	29.5	0.0091	0.53
33	44.240846	-118.6453727	Lake Creek	sample1	12	33.7	0.0005	1.07
35	44.241886	-118.6462659	Lake Creek	sample1	13	30	0.0065	0.54
42	44.248906	-118.6532754	Lake Creek	sample1	14	29.9	0.0069	0.15
45	44.251787	-118.6564249	Lake Creek	sample1	15	30.1	0.0060	0.19
49	44.25362	-118.6597833	Lake Creek	sample1	16	30.7	0.0040	0.15
52	44.254978	-118.6611243	Lake Creek	sample1	17	30.5	0.0046	0.11
55	44.257503	-118.6639138	Lake Creek	sample1	18	30.6	0.0043	0.10
3A	44.283329	-118.682602	High Lake	pre-spawn	19	29.5	0.0091	-
3B	44.283204	-118.682771	High Lake	pre-spawn	20	31	0.0032	-
3C	44.283079	-118.683315	High Lake	pre-spawn	21	29.9	0.0069	-
2A	44.284085	-118.682901	High Lake	pre-spawn	22	29.7	0.0080	-
2B	44.283882	-118.682823	High Lake	pre-spawn	23	-		-
2C	44.283785	-118.68275	High Lake	pre-spawn	24	29.3	0.0105	-
1A	44.284326	-118.684482	High Lake	pre-spawn	25	30.1	0.0060	-

1B	44.284444	-118.684369	High Lake	pre-spawn	26	30.1	0.0060	-
1C	44.284406	-118.684188	High Lake	pre-spawn	27	29.5	0.0091	-
1	44.208304	-118.6407113	Lake Creek	sample2	28	-		0.19
3	44.2103	-118.6408919	Lake Creek	sample2	29	32.2	0.0014	0.16
6	44.213473	-118.6393653	Lake Creek	sample2	30	30.7	0.0040	0.18
8	44.215215	-118.6384497	Lake Creek	sample2	31	ND	0.0000	0.38
10	44.217272	-118.6381062	Lake Creek	sample2	32	30.4	0.0049	0.28
11	44.218029	-118.6374387	Lake Creek	sample2	33	30	0.0065	0.23
12	44.21915	-118.6370942	Lake Creek	sample2	34	31.3	0.0026	0.15
16	44.222877	-118.6359204	Lake Creek	sample2	35	31.6	0.0021	0.38
3A	44.283329	-118.682602	High Lake	spawning	36	31.4	0.0025	-
3B	44.283204	-118.682771	High Lake	spawning	37	30.8	0.0037	-
3C	44.283079	-118.683315	High Lake	spawning	38	30.4	0.0049	-
2A	44.284085	-118.682901	High Lake	spawning	39	31.1	0.0030	-
2B	44.283882	-118.682823	High Lake	spawning	40	29.4	0.0098	-
2C	44.283785	-118.68275	High Lake	spawning	41	29.9	0.0069	-
1A	44.284326	-118.684482	High Lake	spawning	42	30.6	0.0043	-
1B	44.284444	-118.684369	High Lake	spawning	43	28.6	0.0170	-
1C	44.284406	-118.684188	High Lake	spawning	44	30	0.0065	-
Control					45	31.6	0.0021	-
24	44.230754	-118.637804	Lake Creek	sample2	46	30.3	0.0053	0.27
29	44.235764	-118.6412865	Lake Creek	sample2	47	28.1	0.0240	0.70
31	44.237476	-118.6430497	Lake Creek	sample2	48	28.3	0.0209	0.74
32	44.238559	-118.6441318	Lake Creek	sample2	49	27.9	0.0275	0.53
33	44.240846	-118.6453727	Lake Creek	sample2	50	28.3	0.0209	1.07
35	44.241886	-118.6462659	Lake Creek	sample2	51	26.8	0.0587	0.54
37	44.244005	-118.6479531	Lake Creek	sample2	52	29.7	0.0080	0.43
42	44.248906	-118.6532754	Lake Creek	sample2	53	29.5	0.0091	0.15
45	44.251787	-118.6564249	Lake Creek	sample2	54	27.9	0.0275	0.19
46	44.251856	-118.6572536	Lake Creek	sample2	55	28.6	0.0170	0.14
49	44.25362	-118.6597833	Lake Creek	sample2	56	25.2	0.1769	0.15

52	44.254978	-118.6611243	Lake Creek	sample2	57	28	0.0257	0.11
53	44.256473	-118.6622813	Lake Creek	sample2	58	26.3	0.0829	0.11
55	44.257503	-118.6639138	Lake Creek	sample2	59	26.7	0.0629	0.10
64	44.263422	-118.6790019	Lake Creek	sample2	60	32	0.0016	0.10
67	44.265451	-118.6812021	Lake Creek	sample2	61	29.6	0.0085	0.07
70	44.267378	-118.6836251	Lake Creek	sample2	62	30.2	0.0056	0.10
71	44.268101	-118.6840466	Lake Creek	sample2	63	30.3	0.0053	0.11
73	44.269323	-118.6854598	Lake Creek	sample2	64	31.6	0.0021	0.10
75	44.270986	-118.6856201	Lake Creek	sample2	65	31.2	0.0028	0.02
78	44.277161	-118.6844809	Lake Creek	sample2	66	32.7	0.0010	0.04
81	44.279551	-118.6848249	Lake Creek	sample2	67	31.4	0.0025	0.02

RESULTS/DISCUSSION

There were 19 eDNA samples taking from Lake Creek during the summer sampling event, where a duplicate collection was made at site 1 (Table 1). Of the nine eDNA samples obtained from High Lake, only eight were analyzed, as the filter corresponding to site 2B (Lab ID 23) was broken. All eDNA samples collected from summer event and analyzed tested positive for Brook Trout DNA (Table 1). Twenty-nine eDNA samples collected in the fall from Lake Creek (Lab ID 28 filter broken), as well as the nine High Lake eDNA samples tested positive for Brook Trout DNA (Table 1). These were the expected results as Brook Trout were observed at all sites, ranging in density from 0.20-1.1 Brook Trout per meter (Table 1). The field control (Lab ID 45) tested positive for Brook Trout; however this was not a laboratory artifact, as both elution controls and all three no template qPCR controls were negative.

A scatter plot showing the relationship between estimated Brook Trout density and Brook Trout eDNA concentration within water samples was generated (Figure 2). There was no apparent relationship. Even with the four largest eDNA concentration values remove (i.e., plausible outliers; fall event sites 35, 49, 53, 55), the R^2 value was 0.316, suggesting a poor correlation between the two metrics (data not shown).

There was an indication that the eDNA samples collected during the fall (second) sampling event contained higher concentrations of DNA. A paired two sample comparisons of means was statistically significant (p-value=0.46; one-tailed test). Yet, this result was largely driven by a few high concentration values observed in fall samples (Figure 3).

The primary objective of this study was to implement a more effective eDNA detection method using filtration of water in the field. This procedure was a success, as the target species was detected using DNA methods from all sites where concurrent population surveys confirmed its presence. Additionally, observed DNA concentrations were considerably higher than initial 2011-12 study effort (Blankenship et al. 2012). Given results reported here, the probability of detection could be estimated at 100%. This is a required metric to know for subsequent sampling designs associated with occupancy modelling. Further, the probability of detection can be used to determine how many samples are required to detect a species, if it is present. Using binominal sampling theory,

$$p^* = 1 - (1 - p)^K$$

if a target species has a 90% occupancy probability and a 90% probability of detection, then taking a duplicate sample (i.e., two samples) from a site gives a 99% probability of detecting species at least once during a survey, if it is present. For comparison, if the probability of detection is instead 50%, with the occupancy probability remaining at 90%, then five samples achieve a 97% probability of detecting species at least once during a survey. This is a useful metric given the eradication efforts planned in the system. Compliance monitoring will require an understanding of detection limits and a means of interpreting non-detects. With that in mind, the next aspect of eDNA monitoring to determine is the distance at which a single Brook Trout can be detected. A controlled application of the sampling protocol used in this study could establish this threshold, where a known number of fish are introduced into a fishless system (via live car) and systematic sampling occurs downstream at fixed intervals.

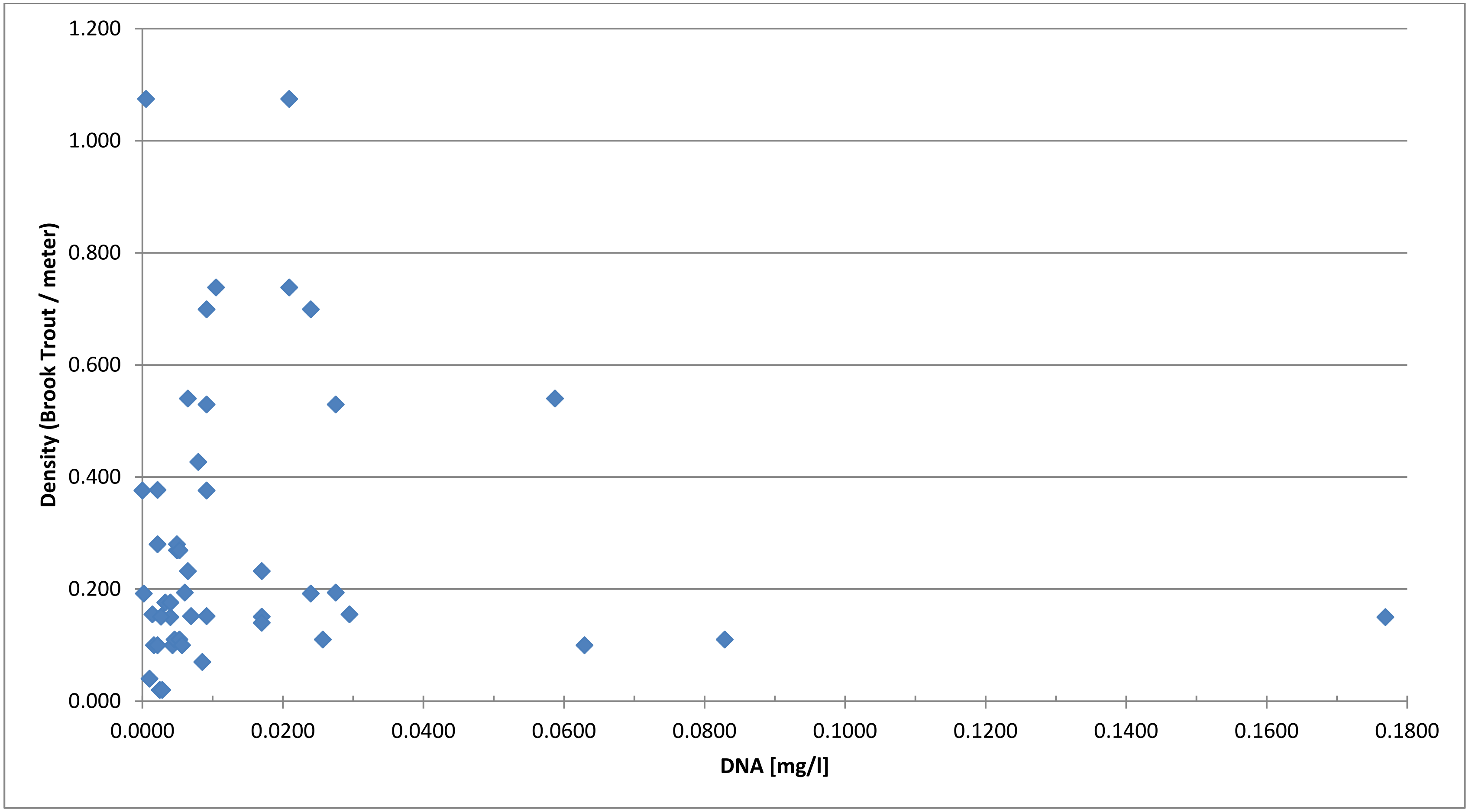

Figure 2. Estimated in-river Brook Trout density against Brook Trout DNA concentrations detected in water samples from same sites.

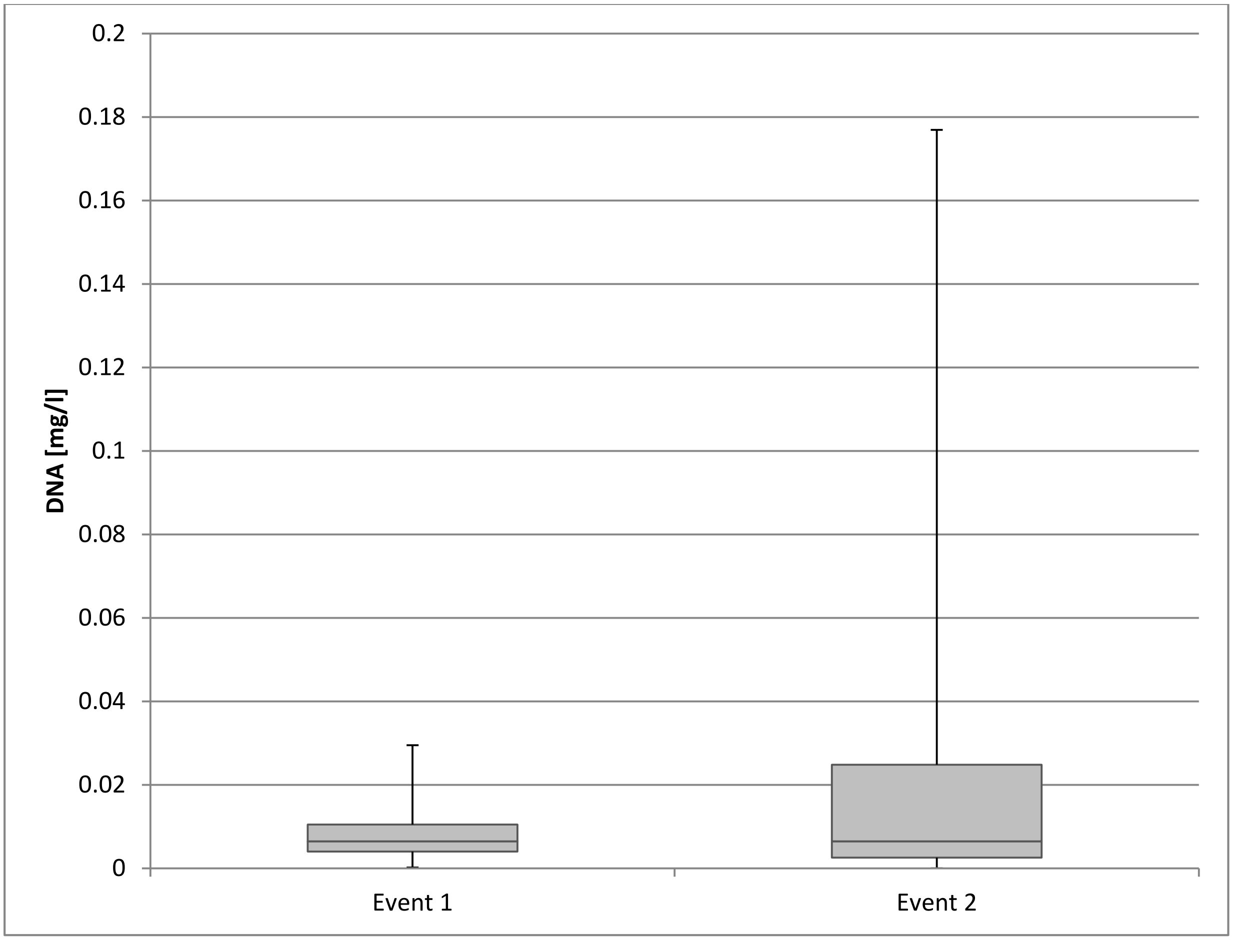

Figure 3. Distributions of DNA concentrations from summer (Event 1) and fall (Event 2) sampling.

REFERENCES

Blankenship, S., M. Teply, L. Dominguez, and G. Schumer. 2012. Sampling and analysis to assess brook trout (Salvelinus fontinalis) population trends in High Lake (Oregon) using environmental DNA monitoring. Report to Burns Paiute Tribe.

Jerde, C.L., A.R. Mahon, W. L. Chadderton, and D.M. Lodge. 2010. "Sight-unseen" detection of rare aquatic species using environmental DNA. Conservation Letters 00(2011) 1-8.

Teletchea, F. 2009. Molecular identification methods of fish species: reassessment and possible applications. Rev Fish Biol Fisheries 19 (3): 265-293.

U.S. Fish and Wildlife Service. 2002. Chapter 14, Malheur Recovery Unit, Oregon. 71 p. In: U.S. Fish and Wildlife Service. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon.

DeHaan PW, Schwabe LT, and WR Ardren. 2010. Spatial patterns of hybridization between bull trout, Salvelinus confluentus, and brook trout, Salvelinus fontinalis in an Oregon stream network. Conservation Genetics 11: 935-949.

Takahara T., Minamoto T., Yamanaka H., Doi H., Kawabata Z. 2012. Estimation of Fish Biomass Using Environmental DNA. PloS ONE 7(4): e35868.

Thomsen, P., J. Kielgast, L. Iversen, C. Wiuf, M. Rasmussen, M. Gilbert, L. Orlando, and E. Willerslev. 2011. Monitoring endangered freshwater biodiversity using environmental DNA. Molecular Ecology. doi: 10.1111/j.1365-294X.2011.05418.x