Bull Trout Distribution, Movements and Habitat Use in the Walla Walla and Umatilla River Basins

2004 Annual Progress Report

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Abstract

A better understanding of Endangered Species Act-listed bull trout life history strategies is necessary to identify corrective actions that will make progress toward recovery in the Walla Walla and Umatilla basins. This report describes studies conducted by the U.S. Fish and Wildlife Service in 2004 on the lower South Fork Walla Walla River, mainstem Walla Walla River, and Umatilla River with the goal of providing detailed information to assist with development of recovery actions. These studies were designed to describe seasonal distribution and movements, and to determine the physical conditions that comprise suitable habitat for bull trout.

We conducted snorkel surveys in the Walla Walla River from June through November 2004 to describe the spatial and temporal distribution of bull trout. Bull trout were observed as far downstream as Nursery Bridge Dam during all months surveyed. Densities of bull trout were compared among months and between stream segments with different streamflow, water temperature, and physical habitat conditions to determine if densities varied as a function of impacted and un-impacted conditions, or as a function of changing seasonal conditions within the study area. Bull trout density was not significantly different across months within any of the three study segments. Densities were higher in the least impacted segment in the S.F. Walla Walla than in the most impacted segment downstream from the Little Walla Walla Irrigation Diversion during three of six months, but only higher than the middle, transitional segment during one of six months. Low abundance and cryptic behavior of bull trout resulted in small sample sizes that limited interpretation of results. Surprisingly, densities remained relatively consistent across months in downstream areas, even as flows decreased and water temperatures increased. Limited physical habitat as a result of low streamflows, high water temperatures, lack of continuous riparian cover, reduced groundwater inflow, and poor mesohabitat conditions all likely contributed to the reduced abundance of bull trout downstream from the diversion. Our observations suggest that bull trout are currently using areas characterized by low streamflows and elevated water temperatures, and any improvements that can be made to improve physical conditions will help bull trout express the migratory life history that requires use of these areas.

To better understand seasonal movements of bull trout, we operated a screw trap to monitor dispersal into downstream areas. Results indicated that downstream movement occurred from March through June, with the highest rate of movement from mid-May to early June. Length frequencies of bull trout captured at the screw trap indicated all but one fish were subadults. In order to lend some perspective to the total number of bull trout that may have passed the screw trap, we used the 10% trap efficiency calculated for steelhead at this site which, likely would have been higher than the trap efficiency for bull trout. This indicated that 320 bull trout may have passed this site dispersing into downstream rearing areas and expressing a migratory life history strategy.

Passive Integrated Transponder (PIT) detection arrays were installed in the upper S.F. Walla Walla River and in the ladders at Nursery Bridge Dam to describe bull trout movement patterns into the impacted river segment downstream from the Little Walla Walla Irrigation Diversion. The arrays at Nursery Bridge Dam detected only three bull trout out of a total of 28 (four adults, 24 subadults) that were PIT-tagged in the S.F. Walla Walla and moved downstream

past Harris County Park. Of the three bull trout detected, one was a subadult and two were adults. The subadult reared in the S.F Walla Walla before being detected at Nursery Bridge Dam in October of 2004, likely dispersing downstream. Detection histories of the two adult bull trout suggest upstream migrations in the spring to spawning areas and downstream dispersal in the fall to over-wintering areas.

Video monitoring equipment was installed in the West ladder at Nursery Bridge Dam to supplement video monitoring conducted in the East ladder by the Confederated Tribes of the Umatilla Indian Reservation with the goal of obtaining a more comprehensive estimate of bull trout movement past the dam. We detected three bull trout with the video equipment at the Nursery Bridge Dam West ladder, and 44 bull trout were detected with the video equipment at the East ladder. Counts of bull trout obtained from a trap in the West ladder and from PIT detections in the East ladder indicated the video equipment in the West and East ladders was missing some unknown number of fish. Considering these results, our conclusion is that comprehensive, accurate enumeration of bull trout movement past Nursery Bridge Dam may not be possible with the current video equipment configuration. The final configuration of the equipment likely improved our detection efficiency, so we plan to continue working with the configuration to determine if video monitoring can be a cost-effective, useful sampling method for estimating total bull trout movement past Nursery Bridge Dam.

Bull trout redd surveys were conducted in the S.F. Walla Walla River by the Oregon Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to maintain the time series of index abundance estimates, and to identify redd sites for development of a spawning habitat suitability model. The cumulative number of bull trout redds enumerated over the course of five surveys was 353. This redd count was the fifth highest out of the 11-year time series, and 23% greater than the 11-year average. We measured the microhabitat variables of depth, mean column velocity, nose velocity, substrate composition, and percent fines at 167 redd locations and 167 randomly selected locations without redds to determine the components of suitable bull trout spawning habitat and to build a spawning habitat suitability model. Bull trout selected slightly shallower depths, and slower velocities for redd sites in comparison to what was generally available. The most obvious microhabitat variable preference by bull trout was for smaller substrate sizes than were generally available. Further analysis of the microhabitat data using univariate logistic regression also suggested the best predictor of redd site selection was substrate size. Preliminary multivariate logistic regression analysis suggested that substrate, nose velocity, and mean column velocity together, provided the best model fit and served as the best predictors of redd site selection.

We measured microhabitat and mesohabitat data at rearing bull trout locations to determine the components of suitable bull trout rearing habitat and to build a rearing habitat suitability model. We measured the microhabitat variables of depth, mean column velocity, substrate composition, and cover at 57 rearing bull trout (use) locations and 57 randomly selected non-use locations. We measured the mesohabitat variables of water temperature, canopy cover, undercut bank, and cover type at 57 rearing bull trout (use) locations and 78 randomly selected non-use locations. Frequency distributions of microhabitat variable use and non-use indicated rearing bull trout were using specific habitats although the small sample size and low abundance of bull trout limited interpretation of preference patterns. Both subadult and adult bull trout consistently used the deeper, slower portion of the habitats where they occurred. Of the eight cover types that we measured, bull trout most often selected for large woody debris at the microhabitat scale relative to other cover types, and were more frequently associated with some type of cover rather than with no cover at all. Preliminary univariate logistic regression analysis suggested that the microhabitat variables of mean column velocity, cover, and depth had the highest association with rearing bull trout occurrence. Logistic regression analysis also indicated that the mesohabitat variables of overhanging vegetation, debris piles, small boulders, and water temperature demonstrated the highest association with rearing bull trout presence.

In the Umatilla River Basin, we used radio telemetry and PIT tag detection arrays to monitor the movements of bull trout. Two subadult bull trout were captured and radio-tagged near the confluence of the North and South Forks of the Umatilla on 17 November 2004 where they remained through the end of the year. A PIT tag detection array was installed on 20 October 2004 in the North Fork Umatilla River. One bull trout that was tagged in the upper North Fork Umatilla during the summer of 2004 was detected at the array between 20 October and 4 December 2004. Future telemetry efforts and PIT tag detections will provide more insight into the migratory patterns of this local bull trout population.

Introduction

Bull trout (*Salvelinus confluentus*) were officially listed as a Threatened Species under the Endangered Species Act (ESA) in 1998. The U.S. Fish and Wildlife Service (FWS) subsequently issued a Draft Recovery Plan (U.S. Fish and Wildlife Service 2002) which included Chapter 10, Umatilla-Walla Walla Recovery Unit Chapter. Chapter 10 was subsequently updated in 2004 (U.S. Fish and Wildlife Service 2004), and it is this document that is the current guide for recovery actions in the Umatilla and Walla Walla basins. The goal of bull trout recovery planning by the FWS is to describe courses of action necessary for the ultimate delisting of this species, and to ensure the long-term persistence of self-sustaining, complex interacting groups of bull trout distributed across the species' native range (U.S. Fish and Wildlife Service 2004). To meet this overall goal, the FWS has identified four recovery objectives, which establish the basis for work conducted by the Columbia River Fisheries Program Office (CRFPO) in these basins:

- Maintain current distribution of bull trout within the core areas and re-establish bull trout in previously occupied habitats,
- Maintain stable or increasing trends in abundance of bull trout,
- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies, and
- Conserve genetic diversity and provide the opportunity for genetic exchange.

Bull trout are native to the Walla Walla and Umatilla basins, and they exhibit two different life history strategies. Fluvial bull trout spawn in headwater streams and juveniles rear in these streams for one to four years before migrating downstream as subadults to larger mainstem areas, and possibly to the Columbia River where they grow and mature, returning to the tributary stream to spawn (Fraley and Shepard 1989). This same pattern can also be observed in the adfluvial life history strategy with the primary difference being subadult migration to a lake rather than larger mainstem river areas. Downstream migration of subadults generally occurs during the spring, although it can occur throughout the year (Hemmingsen et. al. 2002). These migratory forms occur in areas where conditions allow for movement from upper watershed spawning streams to larger downstream waters that contain greater foraging opportunities (Dunham and Rieman 1999). Stream-resident bull trout also occur in the Walla Walla and Umatilla basins, and they complete their entire life cycle in the tributary streams where they spawn and rear. Resident and migratory forms of bull trout may be found living together for portions of their life cycle, however it is unknown if they can give rise to one another (Rieman and McIntyre 1993). Bull trout size is variable depending on life history strategy. Resident adult bull trout tend to be smaller than fluvial adult bull trout (Goetz 1989). Under appropriate conditions, bull trout regularly live to 10 years, and under exceptional circumstances, reach ages in excess of 20 years. They normally reach sexual maturity in four to seven years (Fraley and Shepard 1989; McPhail and Baxter 1996).

When compared to other North American salmonids, bull trout have more specific habitat requirements. The habitat components that shape bull trout distribution and abundance include water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors (U.S. Fish and Wildlife Service 1998). Throughout their lives, bull trout require complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989; Watson and Hillman 1997). Juveniles and adults frequently inhabit side channels, stream margins, and pools with suitable cover (Sexauer and James 1997). McPhail and Baxter (1996) reported that newly emerged fry are secretive and hide in gravel along stream edges and in side channels. They also reported that juveniles are found in pools, riffles, and runs where they maintain focal sites near the bottom, and that they are strongly associated with instream cover, particularly overhead cover. Bull trout have been observed over-wintering in deep beaver ponds or pools containing large woody debris (Jakober 1995). Habitat degradation and fragmentation (Fraley and Shepard 1989), barriers to migration (Rieman and McIntyre 1995), and reduced instream flows have all contributed to the decline in bull trout populations in the Columbia River Basin.

In summary, bull trout need adequate streamflows and the corresponding habitat for each of the different life history functions at specific times of the year in order to persist in the Walla Walla and Umatilla basins. Instream flows and the associated habitat must be adequate to provide spawning opportunities, rearing opportunities, cover, forage, seasonal movement, migration opportunities, and over-wintering refugia.

Walla Walla Basin

Background

The Walla Walla Basin in northeastern Oregon (OR) and southeastern Washington (WA) is a tributary of the Columbia River that drains an area of 4,553 km^2 (Walla Walla Subbasin Plan 2004). The Walla Walla Basin is comprised of the Touchet River Subbasin, the Mill Creek Subbasin, and the Walla Walla River Subbasin. The primary headwater tributaries originate in the Blue Mountains and include the North and South Forks of the Walla Walla River, upper Mill Creek, and the North Fork, South Fork, and Wolf Fork of the Touchet River (Figure 1). The Walla Walla Basin historically supported a number of anadromous and resident, native salmonid populations including: spring and fall Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), redband trout (*O. mykiss* subpopulation), bull trout (*S. confluentus*), mountain whitefish (*Prosopium williamsoni*), and summer steelhead (*O. mykiss*) (Walla Walla Subbasin Plan 2004). Currently, steelhead are the only remaining native anadromous salmonid population in the Walla Walla Basin. A supplementation program for spring Chinook salmon was initiated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in 2000 in the S.F. Walla Walla River using outplanted adults to initiate spawning. The current plan is to continue supplementation using spring releases of spring Chinook hatchery smolts. Populations of native redband trout, bull trout, and mountain whitefish still persist in the Walla Walla Basin. Our work was focused on the Walla Walla River Subbasin during 2004.

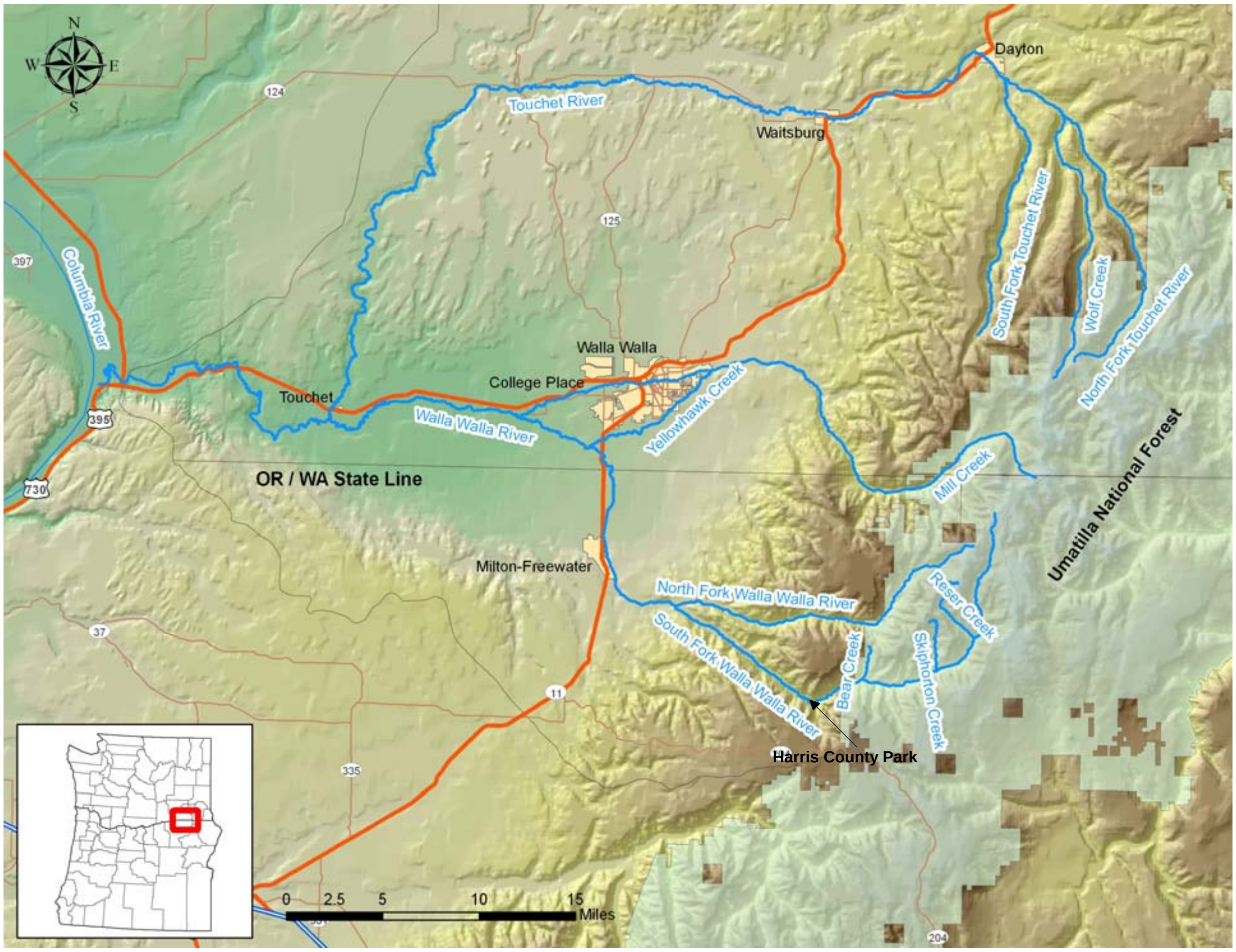

Figure 1. Map of the Walla Walla Basin showing the Touchet River, Mill Creek, and Walla Walla River subbasins, and the Umatilla National Forest.

Most bull trout in the Walla Walla River Subbasin spawn in the S.F. Walla Walla River between Skiphorton Creek and Reser Creek (Figure 1) during September and October. Spawning occurs within the Umatilla National Forest where habitat conditions are relatively pristine and un-impacted by human disturbance. Spawning by both resident and fluvial bull trout has been previously documented in the South Fork (Buchanan et al. 1997), and more recently documented during annual spawning ground surveys conducted by the Oregon Department of Fish and Wildlife (ODFW) and others.

ODFW collected information on bull trout movement and passage in the Walla Walla River while monitoring steelhead migrations through the West bank fish ladder at Nursery Bridge Dam (NBD) (river kilometer (rkm) 74.3) in Milton-Freewater, Oregon (OR). The trap was typically operated from December through late May/early June from 1994 to 2001 (T. Bailey, ODFW, pers. comm. February 2003). Trap data from 1994 through 2001 (Figure 2) suggested that upstream adult bull trout migration typically began in March, peaked in May, and probably neared completion in June. Although observations of bull trout passing the fish ladder decreased in June, the trap was pulled during the last half of May for four out of the eight years sampling was conducted, and it was pulled prior to mid-June during the remaining four years.

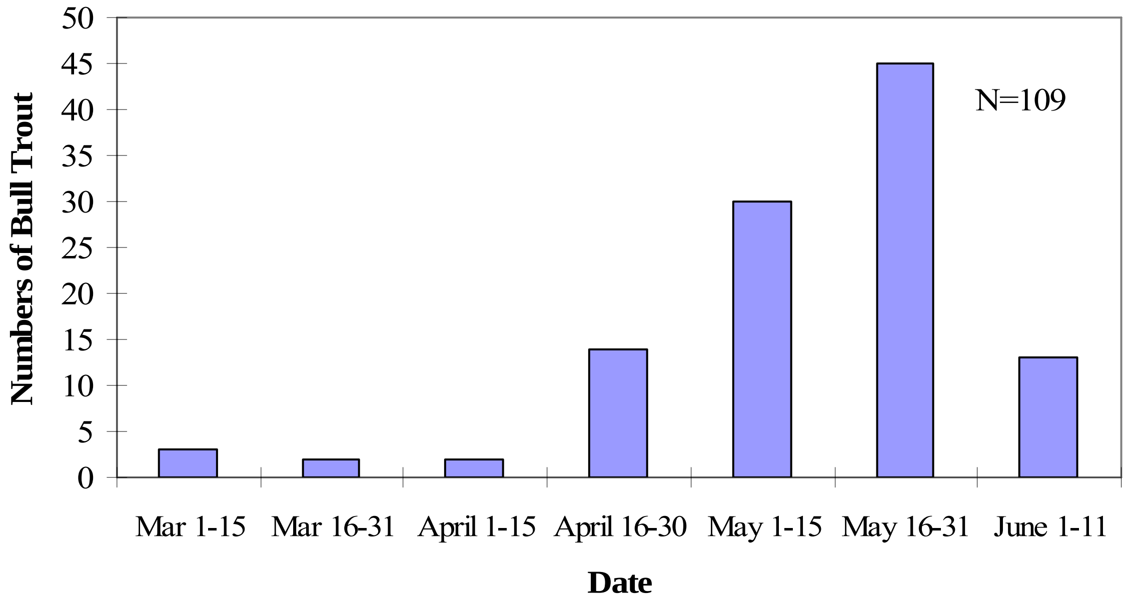

Figure 2. Total numbers of adult bull trout moving upstream in the Walla Walla River past Nursery Bridge Dam in Milton-Freewater, OR based on bi-weekly trap counts from 1994-2001 at the West bank fish ladder (T. Bailey, ODFW).

The CTUIR and ODFW conducted radio telemetry studies from 2001 through 2004 to monitor migration timing for adult fluvial bull trout moving between the S.F. Walla Walla River spawning area and mainstem wintering areas. They confirmed that some adult bull trout overwinter as far downstream as the OR/WA state line (Mahoney 2003).

The CTUIR also conducts video monitoring of fish passage at the East bank fish ladder at NBD. Observations are recorded by species and direction of travel, but fish size usually cannot be determined. Their observations included both large and small bull trout, likely representing both fluvial adults and subadults.

It is unclear if there is an active downstream migration of fluvial subadults from the S.F. Walla Walla spawning grounds as has been observed in adfluvial systems (Fraley and Shepard 1989), or if fish simply disperse downstream. The U.S. Geological Survey, Utah Cooperative Fish and Wildlife Research Unit (USGS) started a bull trout population assessment in the S.F. Walla Walla in 2002 to estimate abundance, size structure, and other demographics (Budy et al. 2003, 2004). As part of a mark-recapture study to estimate abundance, they applied both Passive Integrated Transponder (PIT) tags and Floy tags. They installed PIT tag detection systems or arrays in the upper S.F. Walla Walla River near Harris County Park and Bear Creek (Figure 1) to determine movement and survival. These arrays documented downstream movement of subadult bull trout during most months. These PIT-tagged bull trout subsequently moved downstream into our study area and were available for additional observations and/or detections. The total number of fish, or proportion of the population that disperses or migrates downstream from the S.F. Walla Walla spawning area to impacted mainstem habitats, and their fate as water temperatures increase during the summer irrigation months is unknown.

Physical habitat generally becomes increasingly degraded downstream from the Umatilla National Forest Boundary on the S.F. Walla Walla and mainstem Walla Walla rivers. Factors that have degraded physical habitat as well as stream channel morphology include historical in-channel gravel mining and the construction of flood control structures. Flood control measures required straightening of the channel, construction of levees to contain flood waters, and construction of grade control structures to dissipate energy from high water events. In addition, a section of the mainstem from Milton-Freewater, OR north to the WA state line was seasonally dry from the late 1800's through 2000. A major irrigation diversion in Milton-Freewater at Cemetery Bridge removed most or all of the streamflow during parts of the irrigation season (April-October). Natural seepage of the surface water through the streambed alluvium into the shallow subsurface aquifer together with the diversions, resulted in a dry streambed. This dewatering of the river often left large numbers of fish stranded in isolated pools (U.S. Fish and Wildlife Service 2004). Fishery biologists from ODFW and the CTUIR conducted salvage operations to move the stranded fish to watered areas upstream or downstream from the dewatered portion of the river. The traditional diversion of most of the surface water from the mainstem Walla Walla River and the subsequent dewatering of the channel and stranding of bull trout, steelhead, and other species, became both a political and legal issue following the listing of bull trout and steelhead as threatened under the ESA in 1998 and 1999, respectively. During the winter of 1999-2000, negotiations between local irrigators, the FWS, and environmental groups led to an out-of-court settlement to restore streamflows to the Walla Walla River. During 2002, 25 cubic feet per second (cfs) was bypassed at the Little Walla Walla River diversion near Cemetery Bridge in Milton-Freewater, OR, and since 2003, 27 cfs has been bypassed in June followed by 25 cfs for the rest of the summer to allow fish movement through the formerly dewatered area.

Quantitative habitat assessments may need to be conducted in the portions of the Walla Walla River where streamflow diversions and other impacts to stream channel integrity have reduced the amount of physical habitat that is available. Habitat suitability criteria will be required to conduct these assessments. However, few studies have been completed to determine habitat suitability criteria for bull trout (Baxter and McPhail 1997; Muhlfeld 2002). One study carried out by Fernet and Bjornson (1997) used a Delphi analysis to establish bull trout habitat preferences. Subsequently, they conducted an empirical study and found that preferences predicted from their analysis were suitable predictors of bull trout habitat use. Banish (2003) completed a habitat use study on bull trout in the eastern Cascades that found bull trout distributions to be influenced by microhabitat, mesohabitat, and stream-level variables using a logistic regression model. Budy et al. (2004) began data collection in 2003 to develop habitat preference curves and a logistic regression model to relate physical variables to bull trout occurrence. This work was conducted partly in the S.F. Walla Walla River, and transferability evaluations were conducted using the North Fork Umatilla and South Fork Wenaha rivers.

The goal of CRFPO studies in the Walla Walla Basin is to develop information and analyses to assist in assessing the relative merit of potential action strategies in making progress towards meeting the requirements outlined in Chapter 10, Umatilla-Walla Walla Recovery Unit of the Draft Recovery Plan (U.S. Fish and Wildlife Service 2004) for the recovery and delisting of bull trout. Specifically CRFPO studies were designed to address the following Recovery Plan Objectives:

- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies, and

- Conserve genetic diversity and provide opportunity for genetic exchange.

The habitat objective should be accomplished through a series of steps designed to restore and maintain suitable habitat conditions for all bull trout life history stages and strategies. The first step should consist of defining the physical conditions that comprise suitable bull trout habitat. The second step should be application of these habitat "criteria" to current conditions to determine the extent of the relevant stream that currently provides suitable habitat. The third step should consist of determination of the changes required to improve habitat in areas indicated in the recovery plan that do not currently provide suitable conditions. The fourth step should consist of implementing changes to restore and maintain suitable habitat conditions for all bull trout life history stages and strategies.

The genetic diversity objective should be accomplished by maintaining connectivity among local populations of bull trout to facilitate gene flow and genetic diversity. As the Recovery Plan discusses, connectivity consists of maintaining the fluvial component of each local population which includes providing conditions that allow fluvial adults to effectively move between spawning and wintering areas, and ensuring that movement of both fluvial adult and subadult bull trout can occur, at least seasonally, between local populations within each core area in the recovery unit. This includes establishing the physical conditions necessary for up- and down-stream fish passage, and providing a continuum of suitable physical habitat to ensure the persistence of fluvial life stages and provide the opportunity for genetic interchange between local populations within each core area.

The approach CRFPO used to plan studies in the Walla Walla Basin consisted of the following three steps:

- Identify information needed to assess if criteria for recovery objectives are being achieved;

- To that end, design and implement studies to describe bull trout distribution, movement, and seasonal habitat use patterns;

- Use this information and results from these studies to assist in guiding actions that will make progress towards bull trout recovery.

Study Area

Our study area in 2004 included the S.F. Walla Walla River (SFWW) from Harris County Park downstream to the mainstem Walla Walla River at the OR/WA state line, a distance of approximately 30 river kilometers (Figure 3).

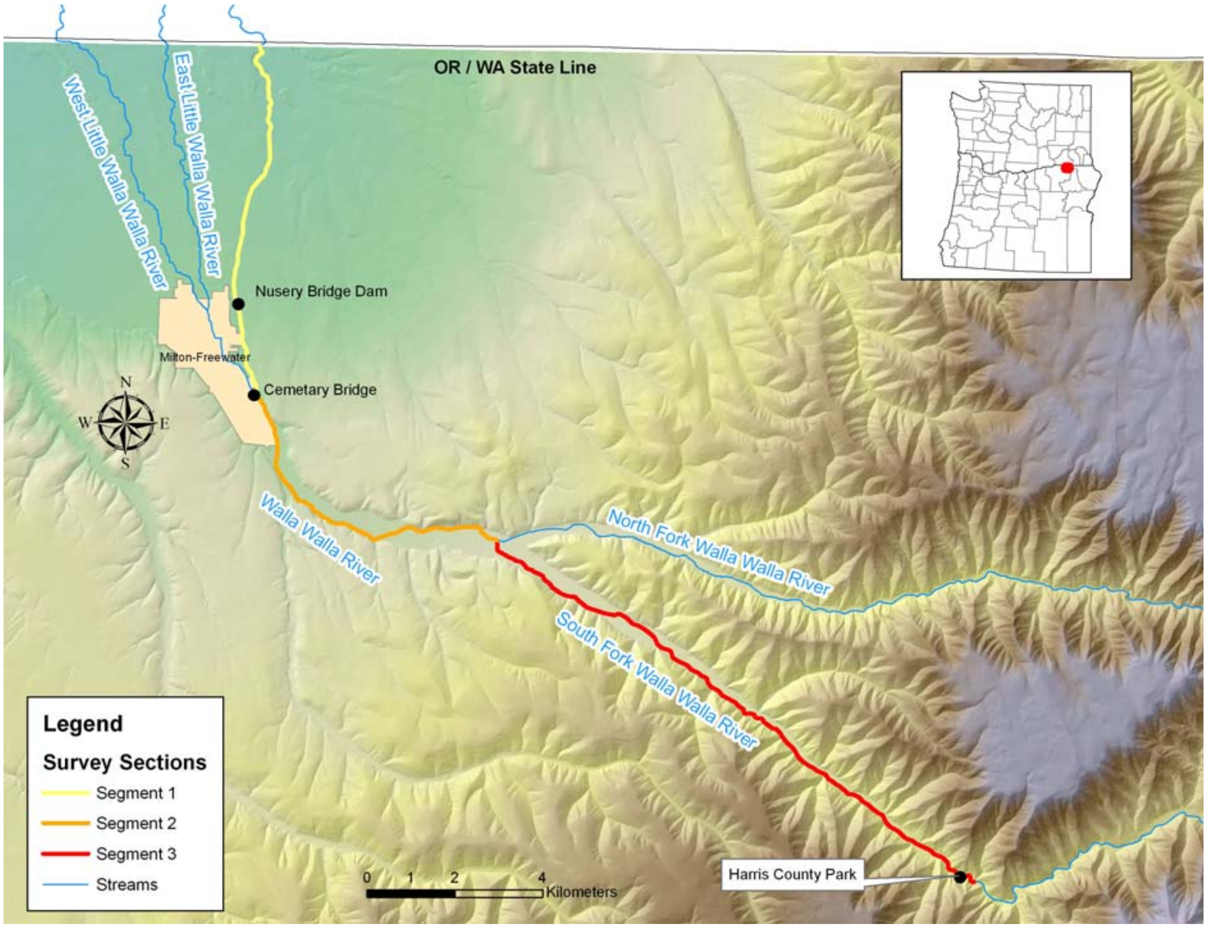

Figure 3. Map of the 2004 study area depicting 30 kilometers of the South Fork and mainstem Walla Walla Rivers divided into three segments.

We divided the study area into three segments that were based on changes in flow regime and habitat structure resulting, in part, from human impacts such as diversions, dikes, and channelization. Segment 1 from the OR/WA state line (rkm 67.1) upstream to Cemetery Bridge in Milton-Freewater, OR (rkm 76.3) has been the most severely impacted. The Walla Walla River Flood Control Project constructed by the U.S. Army Corps of Engineers (USACE) modified the channel of the Walla Walla River through the city of Milton-Freewater, OR. The project was completed in 1952 and consisted of numerous flood control structures. The channel was widened and straightened, and the gradient was shaped to facilitate the passage of flood waters through the city (Walla Walla Subbasin Plan 2004). In 2001, the USACE built a new fish passage facility on the east bank of the Walla Walla River at NBD (Figure 3) to facilitate passage over this grade control structure. An older fish ladder was already present at this site on the west bank of the river. Higher flows during the winter and spring resulted in gravel movement and deposition near NBD, which diverted streamflows away from the new East bank facility. Under these conditions when operational criteria for the East bank facility were not met, the West bank ladder was opened. In addition, one of the major irrigation diversions in the basin occurs at the upstream end of segment 1. The Little Walla Walla Diversion at Cemetery Bridge (Figure 3) removes approximately 66% or more of the streamflow from the mainstem Walla Walla River during the irrigation season. The resulting low summer flows in combination with physical changes associated with the flood control project contribute to elevated water temperatures that can be near lethal for salmonids during the summer through this segment.

The physical conditions in segment 2 from Cemetery Bridge upstream to the confluence of the North and South Forks (rkm 84.2) have not been extensively altered although some channelization has occurred, numerous small diversions are present, and the riparian zone has been reduced. Streamflows are higher in this segment during the summer than in either segments 1 or 3, the gradient becomes flatter as the river transitions from the Blue Mountains to the floodplain, and substrate particle sizes are generally smaller as a result of the lower gradient. Segment 3 in the SFWW from the confluence of the North and South forks upstream to Harris County Park (rkm 96.3) is similar to segment 2 with slightly less streamflow from the absence of the North Fork input, a higher gradient, larger substrate particle sizes, and a more functional riparian zone. The riparian and stream habitat conditions are relatively pristine from Harris County Park upstream where most bull trout spawning occurs.

Study Objectives

Recovery objectives and criteria from Chapter 10 of the Draft Recovery Plan (U.S. Fish and Wildlife Service 2004) were the basis for our specific study objectives in 2004. Bull trout populations in the Walla Walla Basin consist of both resident and fluvial, or migratory life history strategies. Resident bull trout in the upper Walla Walla River local population are primarily located in the SFWW upstream from Harris County Park where impacts are minimal. Thus, our study objectives were designed to address the fluvial portion of this population. In addition, it is the fluvial portion of the population that enables interaction between local populations to provide the opportunity for genetic exchange. This has been referred to as connectivity, or “connecting” local populations of bull trout as well as bull trout Core Areas. In order to make progress towards these Recovery Objectives, the temporal and spatial distribution of the two relevant life history stages for fluvial bull trout were required.

Both temporal and spatial data were required to determine habitat use, migration patterns, and movement needs. In addition, identification of areas that limit fish passage were needed for determination of passage flows. The following specific study objectives were designed to provide this information during 2004:

1) Distribution – Determine the spatial and temporal distribution of adult and subadult bull trout in the Walla Walla River from Harris County Park to the OR/WA state line.

2) Movements – Describe bull trout movement patterns for adults between spawning and over-wintering areas, and movement and distribution patterns for rearing subadults in the Walla Walla River.

3) Habitat Suitability – Develop and validate habitat suitability models for spawning and rearing bull trout that can be used in the Walla Walla Basin and tested in other basins.

We also plan to develop instream flow targets for bull trout in the Walla Walla River in the future that will provide the functional elements for suitable habitat, and facilitate connectivity among the local populations in the Walla Walla River Core Area.

Methods

Distribution

Snorkel Surveys

The extent that bull trout disperse or migrate downstream from the South Fork spawning area to rear in impacted mainstem habitats, and their fate as water temperatures increase during the summer irrigation months is unknown. Snorkel surveys were conducted from June through November to determine the temporal and spatial distribution of rearing fish. Thermographs were also deployed to obtain a time series of water temperatures associated with distribution of bull trout. Snorkeling has been used to detect presence, measure abundance, determine habitat preferences, and observe behavior of many fish species (Helfman 1983). More specifically, snorkeling has been used to monitor and evaluate salmonid species throughout the northwestern United States (Schill and Griffith 1984; Thurow 1994; Bonneau et al.1995).

Our snorkel surveys were organized by study segment, and the study segments were further stratified based on mesohabitat type (i.e. riffle, race, pool) using results of habitat mapping surveys which took place at base flow during 2003. Earle and McKenzie (2001) suggest bull trout prefer pool habitat. Reconnaissance snorkel surveys we conducted in 2003 showed that although bull trout were present in all habitat types, they preferred pool habitats. In addition, pool habitat was more conducive to successful snorkel sampling on a monthly basis during varying seasonal flow conditions in the study area. Most of the land encompassing the habitat units in our study area is privately owned. Landowners were identified using Umatilla County assessment maps and then contacted in person to gain river access.

Pool habitat, exclusively, was sampled in June and July in all segments to determine longitudinal bull trout distribution. The preference of bull trout for pool habitat together with their low abundance allowed us to be more efficient by concentrating on pools during June and July for overall distribution. We subsequently added race habitats to our surveys to facilitate integration of habitat use data collection with the distribution snorkel surveys. We began data collection for development of a rearing habitat suitability model in August, and our data collection protocol was integrated with the general distribution surveys. Our targeted level of effort was 10 habitat units per segment per month. This level was not achieved because of high flows in June, and it was exceeded in segment 1 during July in an attempt to obtain better definition of distribution in the downstream, impacted segment. Survey efforts were standardized for August through November sampling. Ten (30 in segment 1 during July) habitat units were randomly chosen from each of the three segments each month. Data were collected to characterize overall distribution (# of observations per habitat unit) as well as to describe habitat use (measurement of micro- and mesohabitat variables at fish locations). At the beginning of each snorkel survey, turbidity and water temperature data were recorded at each unit that was sampled. Two snorkelers and one data recorder were required to survey each unit. Snorkelers began surveying at the downstream end of the unit and moved upstream reporting fish species and the number observed to the recorder. Estimated total fish lengths were recorded in 50-mm size classes starting with 25 mm. Chinook salmon and *O. mykiss* greater than 325 mm were combined into one category for each species. Data collection methods for habitat use are described in detail under the ***Habitat Suitability*** section of this report.

In addition to daytime snorkel surveys, we conducted night snorkel surveys to compare relative detection efficiency. Other researchers have found that higher detection efficiencies are more likely at night rather than during the day (Goetz 1994; Bonneau et al. 1995; Thurow and Schill 1996; Dunham et al. 2001). We conducted a total of 17 paired (i.e. within 24 hours) day and night snorkel surveys. Night snorkel locations were chosen based on crew safety and site accessibility. The same protocol was used for both daytime and night surveys. However, dive lights (Underwater Kinetics - model Light Cannon 100, 25 watt) outfitted with red filters (Thurow 1994) were used for night surveys.

We also established two monitoring sites in segment 1 to determine if bull trout would remain in the area under low flow and high water temperature conditions. One site was located at NBD pool (rkm 74.3) and the second site was located at a pool near the state line (rkm 68.3) (Figure 3). Our hypothesis that bull trout would move out of segment 1 as water temperatures increased during the summer months was based both on bull trout life history, and on existing water temperature criteria for rearing bull trout (USEPA 2003). These monitoring sites were snorkeled monthly in addition to the sites chosen randomly. They remained in the study-wide distribution group so it was possible for them to be chosen at random each month.

Water Temperature

Fifteen thermographs (Onset Computer, StowAway Tidbits) were deployed in the South Fork and mainstem Walla Walla River during June 2004 following the spring freshet to obtain a time series of water temperature data for comparison to bull trout distribution and movement over the course of the summer. Prior to deployment, the thermographs were checked for accuracy using the Oregon Watershed Enhancement Board (OWEB) water quality monitoring guidebook specifications (OWEB 1999), and the sampling frequency was set at a 30-minute interval. Manufacturer specifications reported an accuracy of +/- 0.2 ºC for the Onset StowAway Tidbit over a range from -5 ºC to 37 ºC. Each thermograph was placed in a 1 ½-in (3.81-cm) diameter metal pipe housing, 4-in (10.16-cm) in length. The metal pipe housing was secured to the bank using ¼-in (0.635-cm) stainless steel cable. In December 2004 temperature data were downloaded in the field with an Onset Optic Shuttle and transferred to a personal computer. Thermograph placement was based on Thermal Infrared Radiometry (TIR) data collected in August 2003 which suggested that water temperatures increase ~ 0.5 ºC every 1.6 km between rkm 67.5 and rkm 96.2 (Faux 2003). Throughout the 29-km study area, six thermographs were deployed in segment 1, five in segment 2, and four in segment 3 (Figure 4).

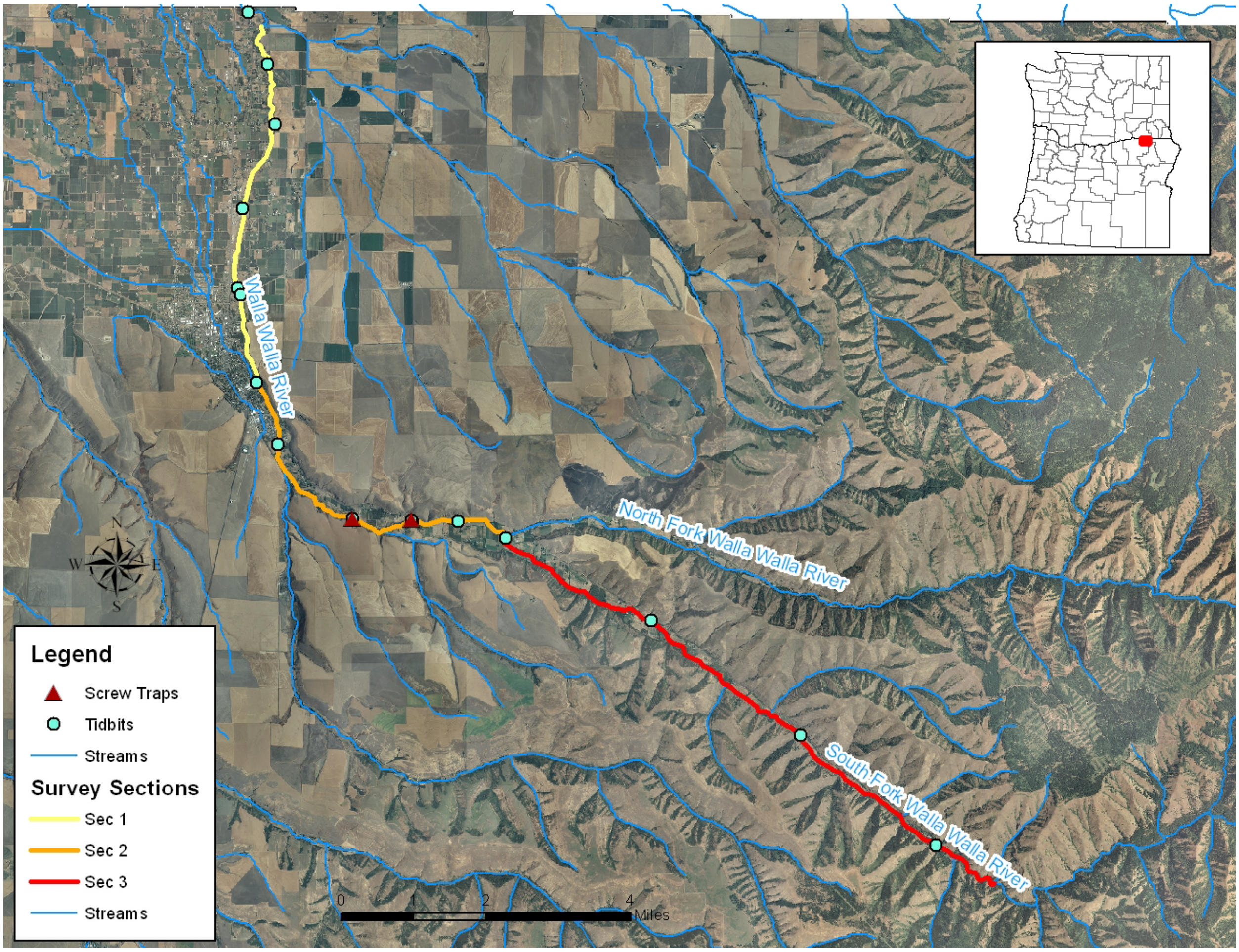

Figure 4. Distribution of thermographs throughout the three study segments in the Walla Walla study area, and location of the two screw trap sites used during 2004.

Movements

<u>Rotary Screw Trap</u>

A five-foot (1.52 m) diameter rotary screw trap (E. G. Solutions Inc. Corvallis, OR) was deployed in January, and March through June during 2004 to characterize the magnitude and timing of bull trout dispersal or downstream migration from the SFWW spawning area. Rotary screw traps have been useful in monitoring salmonid migrations and have been used effectively to capture bull trout in Mill Creek (Hemmingsen et al. 2001a).

The screw trap was initially deployed at a site in the Walla Walla River near Day Road (rkm 80.5), approximately four rkm downstream from the forks (Figure 4), and was operated intermittently in coordination with CTUIR personnel from 13 August 2003 to 23 January 2004. Operations were interrupted several times as a result of severe flow conditions, trap damage and repair, and limited personnel availability. The trap was checked daily when it was being fished to monitor streamflow and debris conditions, as well as to process any fish that were captured.

During high flows, the cone was raised and the trap was secured to the bank to avoid damage from debris. The screw trap was fished at the head of a swift pool that offered little room for adjustment in high flow situations. However, the trap site was accessible through private land which offered protection for the equipment from vandalism. Extremely high flow conditions on 29 January 2004 rendered anchor points at the site unusable, but resulted in no significant damage to the screw trap. An alternative sampling site was selected at Joe West Bridge (rkm 82.0) in March 2004 to provide additional flexibility for sampling under high flow conditions. Site configuration and trap deployment are shown in Figure 5. The river is notably wider, less turbulent, and offers for considerable adjustment to accommodate varying streamflow conditions in comparison to the Day Road site. The main drawback to this site was the visibility of the location adjacent to Walla Walla River Road. The screw trap was deployed at the Joe West Bridge site in coordination with the CTUIR from 23 March 2004 to 25 June 2004. The trap was fished continuously with the exception of several time periods when river flows were too high for safe operation. The trap was pulled for the season in June when recurring vandalism became a problem.

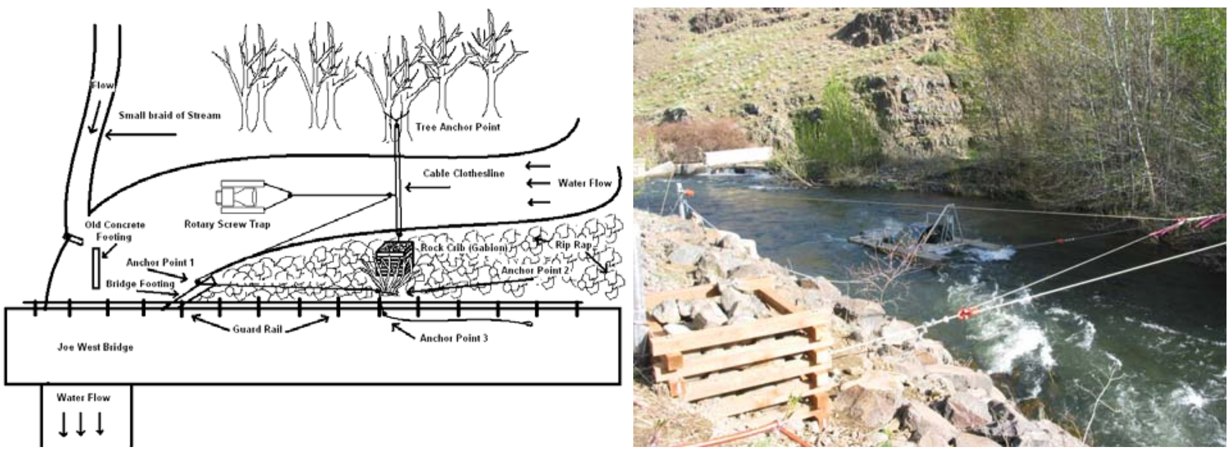

Figure 5. Diagram of site configuration (left) and operating rotary screw trap (right) deployed at the Joe West Bridge trap site during the 2004 field season.

Captured fish were removed from the screw trap live box with a dip net. Bull trout, Chinook, and *O. mykiss* were anesthetized in a bath of 40mg/L MS-222 (tricaine methanesulfonate), scanned for PIT tags, and measured for weight and length. Un-tagged bull trout ≥120 mm were tagged with 23 mm PIT tags when trained personnel were available, and released downstream from the trap. Bull trout < 120 mm were released, unmarked, downstream from the trap. Numbers of bull trout captured on any given day were not sufficient to conduct trap efficiency tests. Chinook and *O. mykiss* that were of sufficient size were tagged by the CTUIR with 12-mm PIT tags when possible. When CTUIR personnel were not present, up to 25 randomly selected individuals of each species were fin clipped. Groups of either PIT-tagged or fin-clipped fish were released at the designated release site upstream from the trap to determine trap efficiency. Weekly efficiencies for Chinook and *O. mykiss* were calculated as the percentage of marked fish recaptured within a weekly marking period (Thedinga et al. 1994). Since numbers of bull trout were not sufficient to determine screw trap efficiencies, we cooperated with the CTUIR to determine weekly efficiencies as described above for Chinook and *O. mykiss* that could be used to estimate efficiencies for bull trout.

PIT Tag Detection Arrays

Bull trout movements and distribution were also monitored using PIT tag arrays (Zydlewski et al. 2002). PIT tag arrays were installed previously at two locations in the SFWW (Budy et al. 2003), and in the East bank fish ladder at NBD (Figure 6). An additional array was installed in the West bank fish ladder at NBD on 15 April 2004 so bull trout could be detected when the ladder was seasonally opened for additional passage (Figure 7). PIT tag detection arrays consisted of full duplex interrogation systems (Destron Fearing FS1001A), antenna arrays custom built for each application, and a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission). Power was supplied either through a hard wire connection, or with combinations of solar panels, batteries, and generators. Remote data upload was accomplished through either a hard wired phone line or satellite communications when available. Neither option was feasible at the West bank Nursery Bridge fish ladder site. As a result, manual file uploads were required and conducted regularly. The East bank fish ladder antenna is linked by phone line to the internet, permitting data to be automatically uploaded to the PIT Tag Information System (PTAGIS) website every 6 hours.

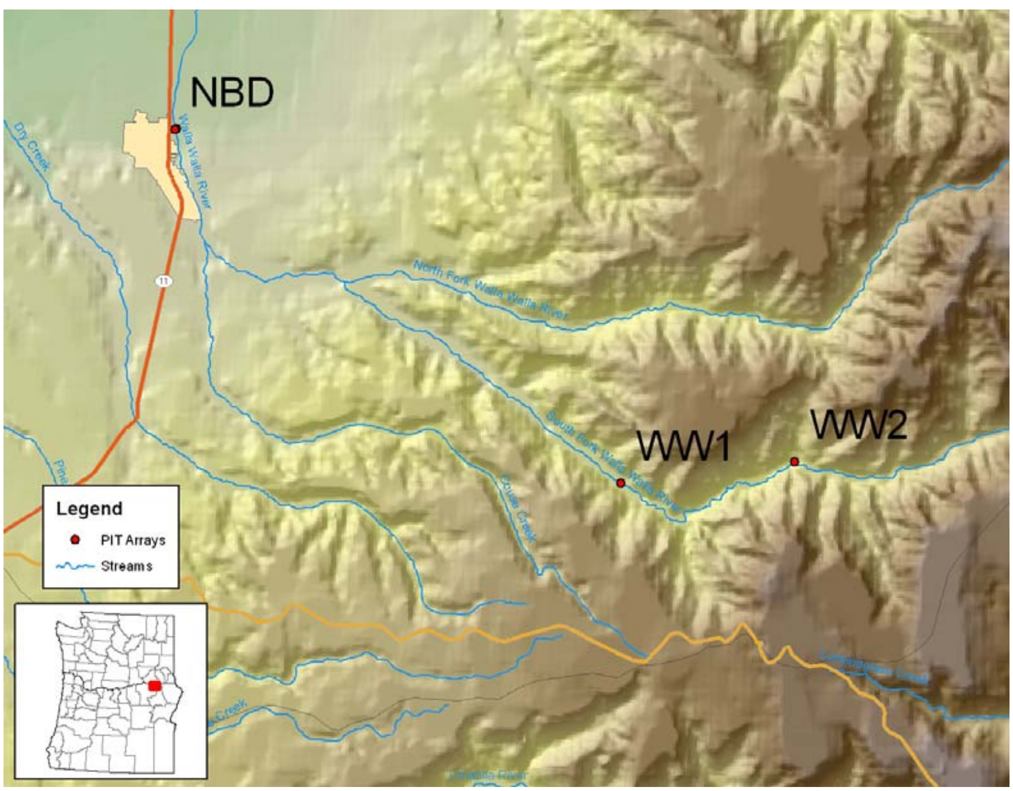

Figure 6. PIT tag detection array locations. WW1 near Harris County Park and WW2 near Bear Creek are located in the South Fork Walla Walla, and NBD is located at Nursery Bridge Dam.

Figure 7. PIT tag detection arrays at the West (foreground) and East (background) Bank Nursery Bridge Dam Fish Ladders. Arrows indicate PIT array antenna locations. The East Bank antenna is on the interior of the fish ladder and is not visible.

PIT tag detection arrays create the opportunity to passively monitor presence and movement of the relatively large number of PIT-tagged bull trout in the basin. Bull trout have been PIT-tagged for work described in this report, by the CTUIR for their Walla Walla Basin studies (Mahoney 2003), and in the SFWW as part of a population assessment study (Budy et al. 2003, 2004). In addition, the CTUIR have PIT-tagged large numbers of juvenile Chinook and *O. mykiss*. The relatively efficient passive monitoring using PIT tag detection arrays together with the ongoing comprehensive tagging effort is an important part of our goal to better understand migratory bull trout life history, and the temporal and spatial aspects of their distribution and movements.

Routine inspection and maintenance of PIT tag detection arrays were conducted to ensure reliable data collection and system operation. Antenna detection efficiency tests were conducted periodically to estimate the proportion of the antenna field that consistently detected a PIT-tag that passed through the apparent field. Since a sufficient number of bull trout were not available to conduct these tests, other methods were used. Initially, a float with an attached PIT tag was passed through the center of the antenna field 10 times per test. Detections were recorded and efficiency was calculated by dividing the total number of detections by the total number of trials and reported as a percent (Zydlewski et al. 2002). Separate trials were conducted for 12 and 23 mm PIT tags. Efficiency tests conducted in this manner may not be an accurate representation of the efficiency of PIT-tagged fish detection. The tests are more of an indication of the configuration and sensitivity of the antenna field. Actual fish are moving about in the water column, and their behavior varies among species. However, it is still useful to conduct regular tests to verify that the antenna field is active and determine the proportion of the water column where the field is active to provide some relative measure of detection efficiency.

Video Monitoring

Video monitoring to detect fish passage has been in place at the NBD East fish ladder since 2001. The CTUIR installed video equipment in the East bank ladder to monitor passage at the fish viewing window. Since the West bank fish ladder has been opened regularly, we installed video equipment to document passage via this route. A SeaViewer (Sea-Drop™ 550 Series – B&W) underwater camera (72° viewing angle) was mounted to the west wall of the concrete chute at the exit of the West bank fish ladder. Halogen flood lights were mounted directly above the camera to illuminate the viewing area at night. A plywood canopy was installed above the camera and lighting system to reduce inconsistent sunlight and glare. An aluminum weir was installed in the ladder exit to direct passing fish through the camera field, and a measuring board was mounted on the weir to estimate fish length (Figure 8). A SANYO (model DSR-3000) Digital Video Recorder (DVR) was housed in a dust and rain proof, lockable Hoffman NEMA box mounted near the ladder. The DVR uses motion detection software that detects movement within the viewing area. The sensitivity of the sensors can be adjusted to accommodate changing debris conditions. Video images recorded on the DVR were downloaded for viewing regularly, and date, time, species, direction of movement, visible marks, and estimated size of each fish in the images were recorded. If a fish remained stationary in front of the camera, or if only an image of its tail was recorded, it was tallied in an “other” category. After recorded video footage was viewed, select clips that detected fish were downloaded and stored.

Figure 8. Video monitoring system installed at the West bank fish ladder at Nursery Bridge Dam in 2004. Shown are the halogen floodlights, plywood canopy, and aluminum weir. The camera and measuring board are underwater.

Habitat Suitability

Determination of the physical habitat preferences of bull trout is an important step in the process of evaluating existing conditions and developing actions to improve the habitat. Bull trout preference for specific ranges of microhabitat and mesohabitat variables must be quantified before an assessment of current conditions can be conducted, and before changes can be recommended to improve current conditions. Microhabitat variables are those that occur at point locations and they include water depth, water column velocity, river bottom materials or substrate, and cover. Mesohabitat variables that affect physical habitat on a larger scale include water temperature, canopy cover (riparian habitat), and channel structural components such as undercut banks, large woody debris piles, or boulder fields. We defined mesohabitat units as pools, riffles, and races. Mesohabitat variables affect habitat conditions over a relatively larger area rather than at a point location. Our goal is to create and validate habitat suitability models for spawning adult and rearing subadult and adult bull trout in the mainstem and SFWW rivers. In 2004, we began to develop the models by collecting spawning habitat data at redd locations and non-use locations in the SFWW. This data collection effort was preceded by bull trout redd surveys in the SFWW including Reser and Skiphorton creeks. We also collected subadult and adult bull trout habitat data at locations where rearing fish were encountered during snorkel surveys and at non-use locations.

Redd Surveys

Multiple-pass spawning ground surveys were conducted by ODFW and FWS biologists every two weeks on the SFWW, Reser Creek, and Skiphorton Creek (Figure 9) during September, October, and November 2004 to obtain an annual index of abundance. Redd sizes were also recorded to account for resident and fluvial redds. Surveyors began at either the upstream or downstream end of a reach and walked/waded through the reach enumerating redds, recording redd size, and recording estimated lengths of adults seen within the reach. Bull trout redds were categorized into small (<0.5m), medium (0.5-1.5m) or large (>1.5m) size classes in an attempt to identify resident and migratory redds. Bull trout redds were assigned a unique number and marked with flagging to avoid counting redds multiple times and to identify individual redd locations. Typically, ODFW identified redds by hanging survey flagging on a nearby tree limb 1 to 2 days prior to habitat criteria being measured by FWS surveyors.

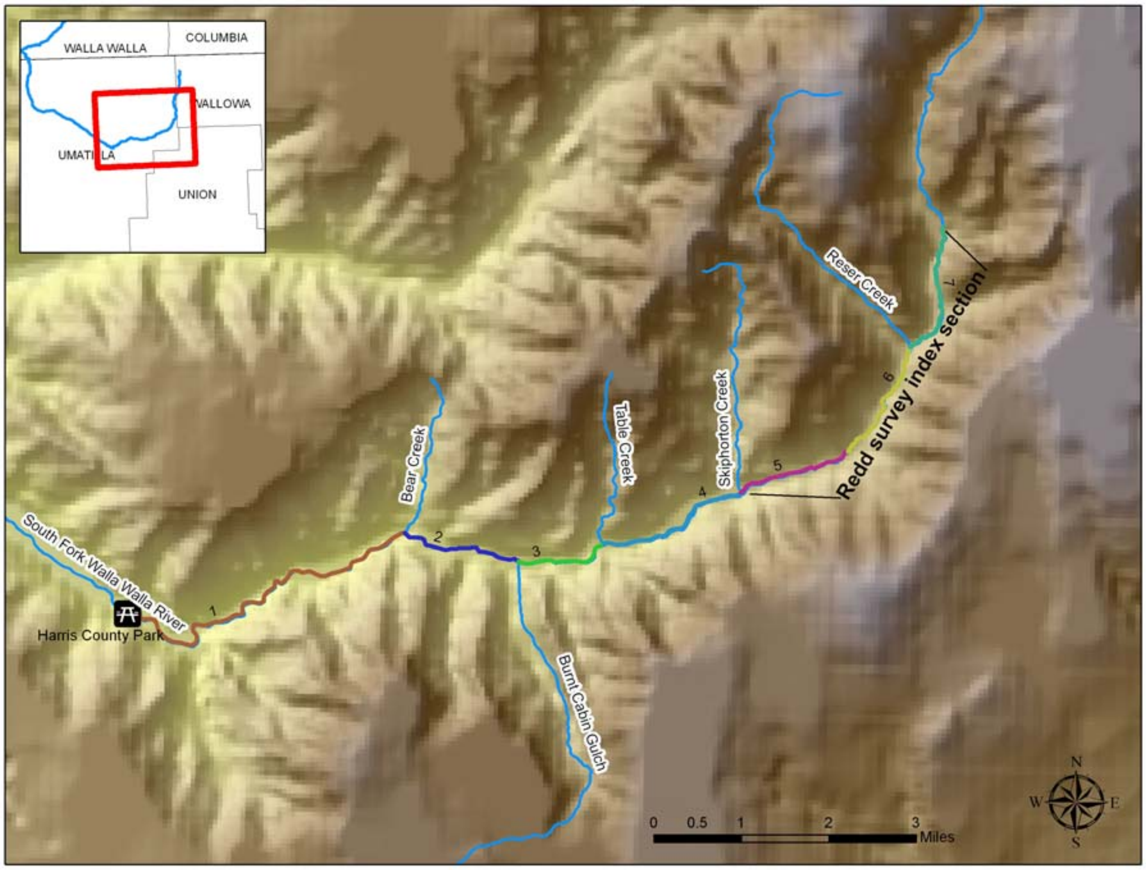

Figure 9. Map of the South Fork Walla Walla redd survey area showing reaches 1 through 7, Reser Creek, and Skiphorton Creek where surveys were conducted during 2004.

<u>Spawning Habitat Suitability Model</u>

Fluvial and resident bull trout spawn in the headwaters of the SFWW River. During fall 2004, we measured microhabitat variables at bull trout redds every two weeks to obtain use and non-use data to develop a habitat suitability model for spawning bull trout. Microhabitat variables determine the suitability of any particular location on the stream bottom for a bull trout redd. Surrounding mesohabitat conditions may be important in some areas, but in the SFWW where conditions are generally pristine, mesohabitat variables were continuous, uniform, and of good quality. As a result, we focused our data collection on microhabitat variables.

Surveyors measured the water depth, nose velocity, and mean column velocity at the upstream edge of the redd pit with a top-set wading rod and a Marsh-McBirney Flo-Mate Model 2000 flow meter. When measuring water velocities in eddies, the flow meter sensor was pointed directly into the current, just as a fish would be oriented (Rantz 1982). Surveyors then classified dominant and subdominant substrate size and percent fines at the redd. Substrate was categorized into six classes by diameter (Table 1), and percent fines was categorized into four classes (Table 2).

Table 1. Substrate types and particle sizes used to classify dominant and subdominant substrates for spawning bull trout.

Substrate Type	Particle size (cm)	Particle size (inch)
Sand	<0.64	<.25
Pebble	0.65 – 2.54	0.25 - 1.0
Small Gravel	2.55 – 5.08	1.0 - 2.0
Large Gravel	5.09 – 7.62	2.0 - 3.0
Cobble	7.63 – 15.24	3.0 - 6.0
Boulder	>15.24	>6.0

Table 2. Percent fines codes and classification descriptions for spawning bull trout.

Code	Description
1	0 to 25 percent of visible substrate <0.64
2	26 to 50 percent of visible substrate <0.64
3	51 to 75 percent of visible substrate <0.64
4	76 to 100 percent of visible substrate <0.64

Once data were collected at the use point (redd), a non-use point was determined by pacing a random distance (one to six steps upstream or downstream and one to six steps toward either stream bank) away from the redd where the measurements were repeated.

Analytical methods included an examination of bull trout preferences for depth, velocity, and substrate, and development of a probabilistic model that could be used to predict the suitability of instream conditions for spawning bull trout. To determine bull trout preference for specific ranges of physical microhabitat variables, we compared empirical data on the ranges of the variables that were actually used at redd sites to the overall availability of variables and also to the range of values measured for the variables at non-use sites. Availability data were collected across 15 reaches between Harris County Park and Reser Creek by Utah State University (Budy et al. 2005). We compared frequency distributions of the microhabitat variables at redd sites to frequency distributions for overall availability of the variables to determine if spawning bull trout were selecting specific conditions at frequencies that were different than the frequencies of overall availability.

We used logistic regression analysis (SAS ver. 9.1, 2003) to determine the significance of individual microhabitat variables (univariate analysis) and to build and evaluate multivariate models for predicting bull trout spawning habitat. We used logistic regression because it is well suited for the examination of the relationship between a binary response (i.e., the presence or absence of redds) and various explanatory variables. We conducted a preliminary assessment of the habitat variables that were associated with redd locations using logistic regression techniques. We fit logistic models of the form:

$$\log_e\left(\frac{\pi(x)}{1-\pi(x)}\right) = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n + \varepsilon \ ,$$

where $\pi(x)$ is the probability of redd deposition associated with habitat variables $x_1, x_2, \ldots, x_n$, and $\beta_0, \beta_1, \ldots, \beta_n$ are estimated model parameters (coefficients), and ε is a binomially-distributed error term. We fit logistic models using each habitat variable, one at a time, and measured the degree of model fit using Akaike's Information Criterion (AIC) (Burnham and Anderson 2002). Lower values for the AIC indicated better-fitting models. Following these univariate analyses, we developed multivariate models using the highest-ranking variables identified in the univariate analyses. The highest-ranking variables were added to the multivariate model until AIC values indicated that adding additional variables did not improve model fit.

Rearing Habitat Suitability Model

Rearing bull trout occur both in the SFWW and in the mainstem downstream at least as far as the WA/OR state line. We collected microhabitat and mesohabitat data at locations where rearing bull trout were found during our snorkel surveys to develop a rearing habitat suitability model. Habitat use and non-use data were collected monthly from August through November in the study area during 2004. Data were recorded when a bull trout was observed during snorkel surveys without being disturbed. Microhabitat data were recorded at each fish location and mesohabitat data were recorded for the habitat unit where the fish was observed, for example, in a race or pool.

Microhabitat Data Collection

When rearing bull trout were observed, snorkelers marked their location with a colored washer, estimated total length, noted any marks, and identified nose depth. Snorkelers finished surveying the habitat unit and then returned to the location of the bull trout to measure microhabitat variables. Once data were collected at the fish location, a non-use point was determined by pacing a random distance (one to six steps upstream or downstream and one to six steps toward either stream bank) away from the fish location where the measurements were repeated. Water depth and mean column velocity were recorded using a top-set wading rod and a Marsh-McBirney Flo-Mate Model 2000 flow meter. Dominant and subdominant substrate size and percent fines were classified for a 0.5 m square around the location of the fish and the non-use point. The same substrate and percent fines classes were used as previously described for spawning bull trout. Finally, cover type was determined by the type of cover present within 0.5 m of the fish location or non-use point (Table 3).

Table 3. Cover types and descriptions used to characterize cover conditions for rearing bull trout.

Cover type	Description
Turbulence	Present if we could not accurately detect substrate composition
Large Woody Debris	Debris must be 10 cm in diameter, 1 m in length and within 1 m of the water surface
Boulder-Juvenile	Boulder must provide a sheltered area at least 5 cm deep and 10 cm long
Boulder-Adult	Boulder must provide a sheltered area at least 10 cm deep and 40 cm long
Undercut Bank-Juvenile	At least 5 cm deep and 10 cm long
Undercut Bank-Adult	At least 10 cm deep and 40 cm long
Overhanging Vegetation	Vegetation that is within 0.5 m from the fish location and within 1 m from the stream surface
Debris Pile	Aggregation of 10 or more pieces of large woody debris
Other	Other types of physical structure such as bank stabilization material
No Cover	None of the cover types described above

Mesohabitat Data Collection

Four categories of data were also collected for each mesohabitat unit (pool, race) we sampled during snorkel surveys; water temperature, canopy cover, undercut bank, and cover type. First, water temperature was recorded at the downstream end of the habitat unit before snorkelers entered the water. Following the snorkel survey, the other three mesohabitat variables were characterized for the habitat unit. Canopy cover was described as the percent coverage of tree foliage overhanging the unit and was classified into five categories (Table 4).

Table 4. Canopy cover codes and classification descriptions for rearing bull trout mesohabitat.

Code	**Description**
1	No canopy cover
2	1 to 25 percent canopy coverage
3	26 to 50 percent canopy coverage
4	51 to 75 percent canopy coverage
5	76 to 100 percent canopy coverage

The amount of undercut bank in a unit was visually determined and classified into five categories (Table 5). The undercut bank had to be at least 5 cm deep, segments of undercut bank had to be continuous for at least 10 cm, and the cumulative total of the undercut segments was then classified into one of the five categories.

Table 5. Undercut bank codes and classification descriptions for rearing bull trout mesohabitat.

Code	Description
1	No undercut banks
2	1 to 25 percent undercut banks
3	26 to 50 percent undercut banks
4	51 to 75 percent undercut banks
5	76 to 100 percent undercut banks

Finally, eight cover types were recorded as present or absent in the unit. The cover types used were the same used for rearing bull trout microhabitat characterization (Table 3) with the exception of the two undercut bank cover types. Undercut banks were characterized for mesohabitat conditions as described previously and in Table 5.

Analytical methods included an examination of bull trout preferences for microhabitat and mesohabitat variables, and the development of a probabilistic model that could be used to predict the suitability of instream conditions for rearing bull trout. To determine bull trout preference for specific ranges of physical microhabitat variables, we compared empirical data on the ranges of variables actually used at sites of rearing fish to variable ranges measured at non-use sites. We did not have the resources to collect information on the overall availability of microhabitat variables.

We used logistic regression analysis (SAS ver. 9.1, 2003) as discussed previously (see details in spawning habitat section) to determine the significance of individual microhabitat and mesohabitat variables (univariate analysis) for predicting bull trout rearing habitat. We fit univariate logistic models and examined the degree of model fit using AIC scores. We did not test multivariate models for rearing habitat because sample sizes were not sufficient.

Stream Gage

A Greenspan PS1200 pressure sensor and data logger were redeployed at Harris County Park Bridge (rkm 97.0) on 4 September 2004 to measure and record river stage. Monitoring river stage was important for several reasons. Field work conducted to build our spawning habitat suitability model consisted of marking redd locations in the SFWW during redd surveys, and returning at a later date to collect microhabitat data. Monitoring river stage assured that data collection was conducted under the same conditions that were present when the redds were constructed. In addition, monitoring river stage allowed us to determine the nature of instream working conditions for logistical planning.

The sensor was encased in PVC and anchored to the east bridge abutment. A staff gage was installed and surveyed relative to a local benchmark to establish the elevation of the gage and to provide the reference point for the pressure sensor. The data logger was linked via modem to the internet permitting river stage to be automatically uploaded at 15 minute intervals to the Fish Passage Center website (www.fpc.org).

Results

Distribution

Snorkel Surveys

A total of 121 bull trout were observed during daytime snorkel surveys conducted from June through November 2004. Snorkel survey efforts among the three segments varied in June and July. During June, streamflows were relatively high on the declining limb of the spring freshet. Streamflows recorded at the Washington State Department of Ecology stream gage at Pepper Bridge ranged from 171 to 730 cfs during the first half of June, and did not decline to less than 100 cfs until June 20. Successful, efficient snorkel surveys are difficult at flows greater than 100 cfs in the Walla Walla River. As a result, the number of habitat units sampled during June was less than the target of 10 (8, 3, 4 in segments 1, 2, 3, respectively), and bull trout observations were likely reduced as a result. Since our primary goal was to determine the extent of bull trout distribution in downstream areas where water temperatures were high and streamflows were low, we increased the level of effort to 28 habitat units in segment 1 during July to obtain more comprehensive coverage.

Bull trout densities were not significantly different across months within any of the study segments 1, 2, or 3 ($P = 0.992$, $P = 0.333$, $P = 0.726$) (Figure 10). Bull trout densities between study segments 1, 2, and 3 within a month were significantly different in July, September, and October ($P = 0.001$, $P = 0.019$, $P = 0.046$) but were similar during August and November ($P = 0.136$, $P = 0.264$). During July, September, and October, the density of bull trout was always lower in segment 1 than in segment 3 ($P < 0.001$, $P = 0.037$, $P = 0.057$), although the difference was not quite significant in October. Bull trout density in segment 2 was only less than the density in segment 3 during September ($P = 0.042$). There were no significant differences between segment 1 and 2 during any month.

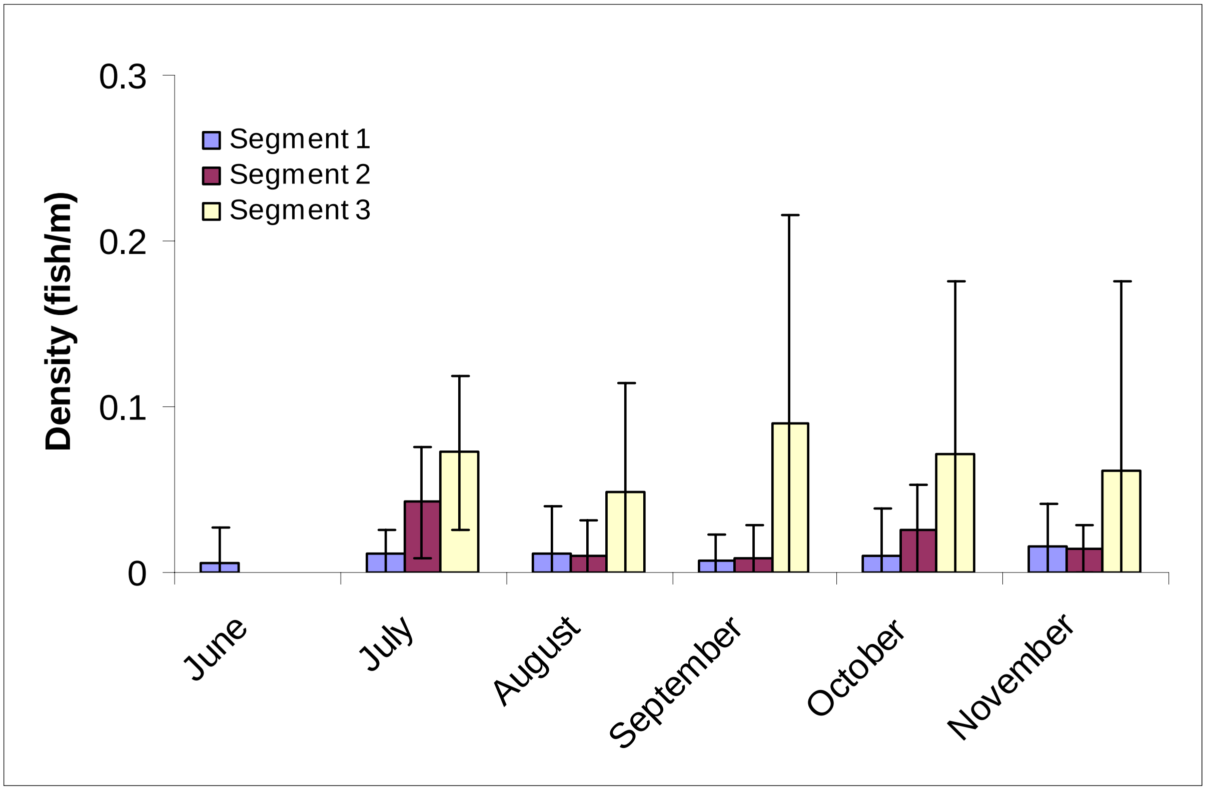

Figure 10. Monthly mean densities of bull trout observed by segment with 95% confidence intervals from snorkel surveys conducted from June through November, 2004.

No bull trout were observed downstream from NBD in segment 1 (Figure 3) from July through October. During June and November, bull trout were observed further downstream near the OR/WA state line, at approximately rkm 68.0. The estimated size of bull trout observed during snorkel surveys ranged from 100 mm to 550 mm, with subadult fish comprising 77% of the total observations (Figure 11).

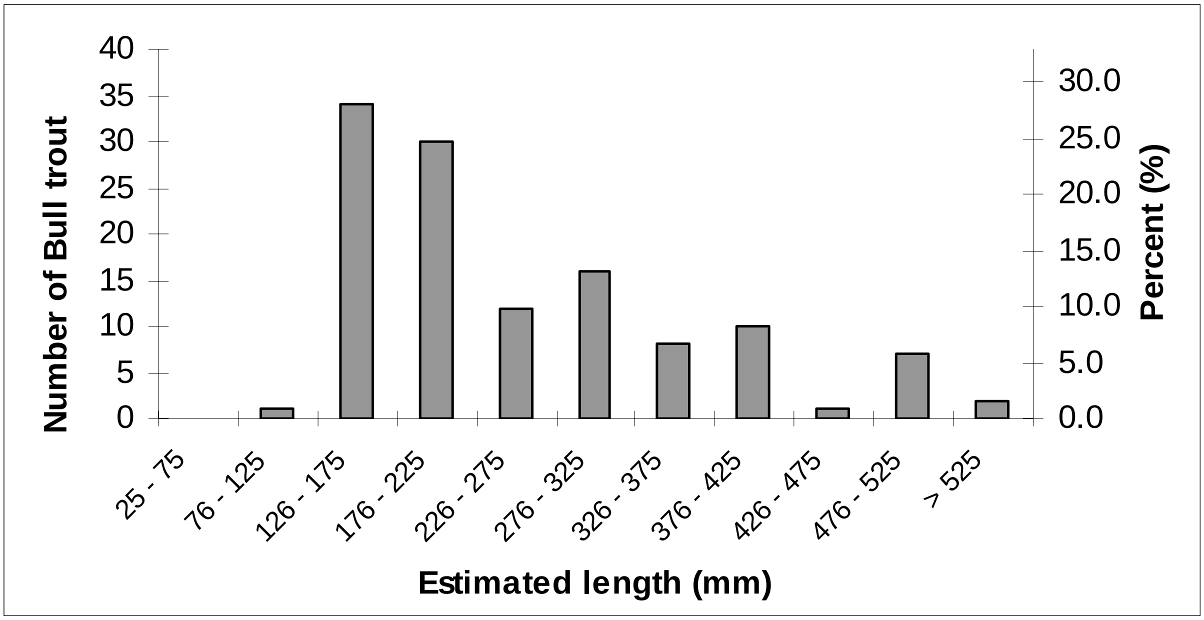

Figure 11. Length frequency histogram (n=121) for bull trout observed during daytime snorkel surveys from June through November, 2004.

We compared day and night snorkel surveys conducted within 24 hours at the same location. From a total of 20 habitat units that were sampled, more bull trout were observed during the day for five units, more were observed at night for five of the units, and the same number were observed during the day and at night for the remaining 10 units (Table 6). The mean number of fish per pool observed during daytime surveys was 1.40, and the mean number of fish per pool observed during nighttime surveys was 1.15. There was no significant difference in the mean number of bull trout observed during daytime surveys compared to nighttime surveys ($P = 0.45$).

Table 6. Number of bull trout observations during 20 paired day and night snorkel surveys conducted within a 24-hour period.

Date	Number of Bull Trout Observed	
	Day	Night
June 22	0	0
June 22	0	1
June 24	0	0
June 24	0	2
July 6	1	3
July 6	2	3
July 8	2	0
July 8	1	1
July 20	8	6
August 9	0	1
September 13	3	0
September 15	0	0
October 5	3	3
October 5	0	0
October 7	0	0
October 7	0	0
November 15	0	0
November 15	3	1
November 16	0	0
November 16	5	2

A total of 56 bull trout were observed during snorkel surveys at the NBD monitoring site during 2004. Only one of these fish was an adult > 325 mm (Table 7). The adult bull trout was observed during a November survey. Bull trout observed at the NBD monitoring site ranged in size from 100 to 400 mm and the maximum number of fish observed during a single survey was 14. No bull trout were observed during snorkel surveys at the state line monitoring site during 2004. However, two subadult bull trout (150 mm) were observed during a night distribution snorkel survey in June before monitoring site surveys were initiated.

Between June and November throughout segment 1, bull trout were observed in nine pools other than the NBD pool. In these pools, an average of two and maximum of four bull trout were observed.

Table 7. Number of bull trout (n = 56) by size class observed during snorkel surveys at the Nursery Bridge Dam monitoring site during 2004 and the associated water temperature.

Date	Water temperature (°C)	Average monthly water temperature (°C)	Subadult bull trout (≤ 325)	Adult bull trout (> 325)
July 22	ND	ND	9	0
August 11	15.4	16.3	14	0
August 13	16.2	16.3	12	0
September 17	12.2	12.9	8	0
October 7	14.2	9.8	8	0
November 16	7.9	6.3	4	1

ND = No data

Water Temperature

Average water temperatures generally increased in a downstream direction. Figure 12 shows the average temperature gradient during August throughout the study area.

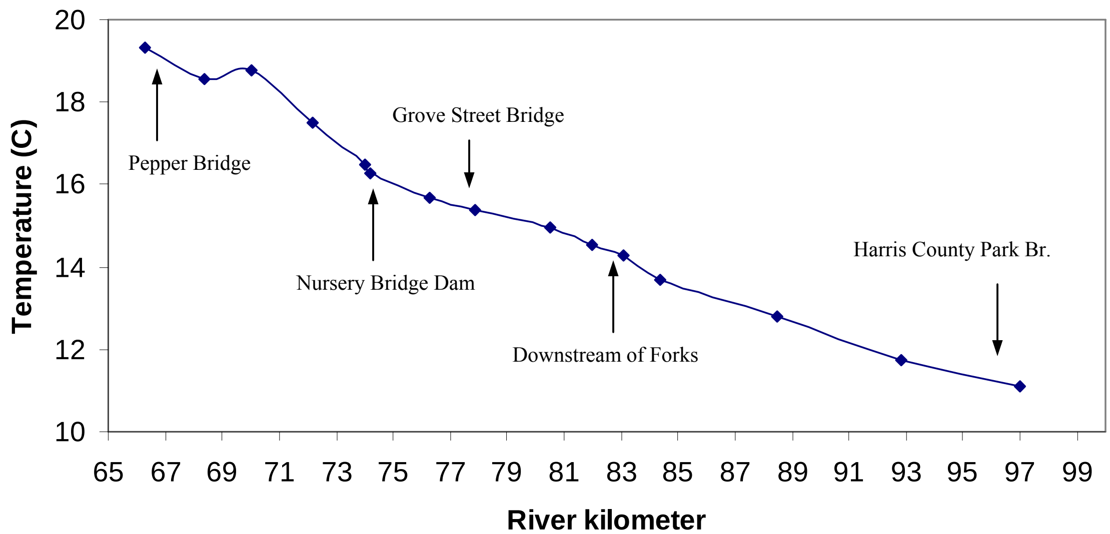

Figure 12. Average daily water temperature at 15 thermograph locations during August 2004. Blue diamonds represent thermograph locations. Several additional locations are labeled on the graph for reference.

In addition to increasing water temperatures in a downstream direction, the variability in the gradient was highest during the summer in July and August, when five temperature categories were observed, ranging from 10.1 to 20.0 °C (Figure 13). Variability decreased monthly from October through December when four, two, and one temperature categories were observed, respectively.

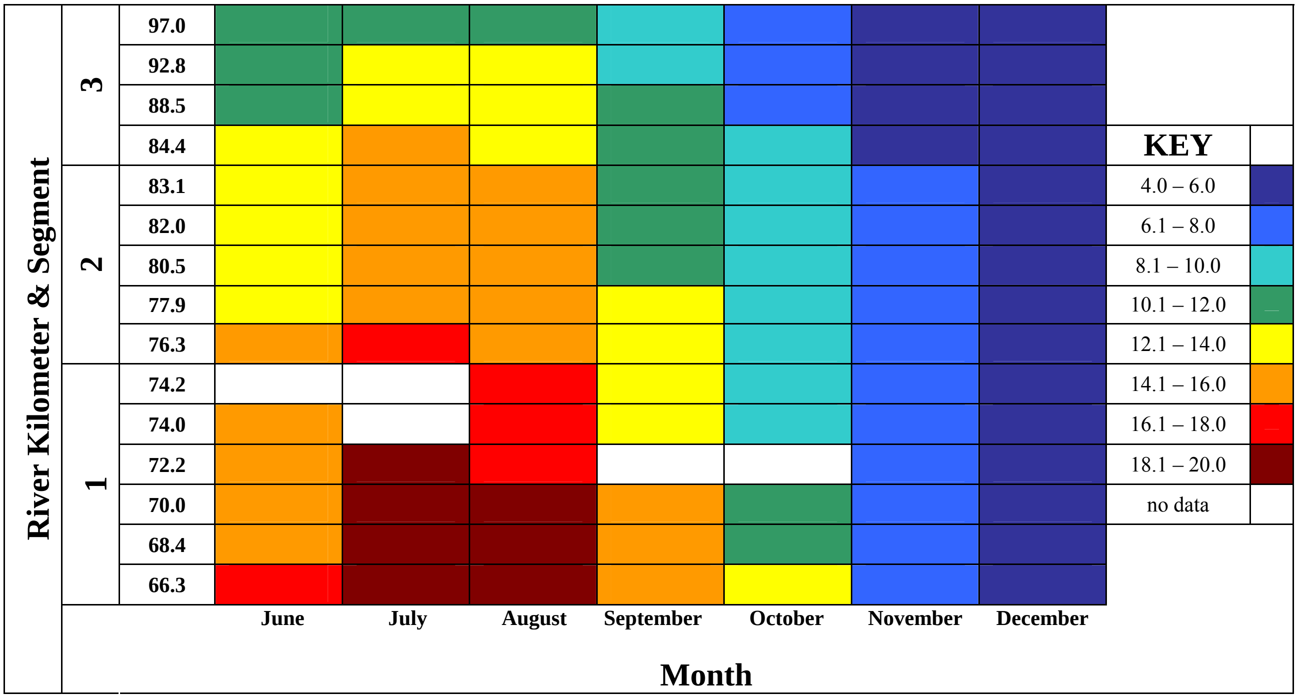

Figure 13. Average monthly water temperatures at 15 thermograph locations by 2 °C temperature category, study segment, and month.

Average daily minimum, maximum, and mean water temperatures along with the seven day average daily maximum (7DADM) temperature are shown in Table 8 by segment and month. July and August are the warmest months in all segments. Water temperature increases among segments are the largest between segments 2 and 1 during July, presumably as a function of the reduction in streamflow between these segments. The diel pattern in temperature can be observed in all months and segments, particularly during the summer. The difference between average daily minimums and maximums is greater in segment 1 compared to the upstream segments. The data suggest that the primary cause of this difference is relatively higher daily maximums in segment 1, again, likely because of the increased heating effect of solar radiation on both the reduced volume of water in this segment and on the substrate due to shallow water depths. A detailed summary of average daily minimum, average, and average daily maximum temperatures by month (June – December 2004) is presented in Appendix A.

Table 8. Average daily minimum, average daily maximum, daily mean and 7DADM water temperatures by segment from thermograph data.

		Month						
Segment		June	July	August	September	October	November	December
	Min	9.3	10.6	10.7	8.8	7.1	5.1	4.2
3	Mean	11.5	12.9	12.3	9.9	7.8	5.6	4.7
	Max	14.0	15.5	14.2	11.0	8.5	6.1	5.2
	7DADM	13.1	15.4	14.2	11.0	8.7	6.2	5.2
	Min	11.4	13.6	13.5	10.9	8.5	5.6	4.5
2	Mean	13.6	15.6	15.0	12.0	9.2	6.2	5.0
	Max	15.8	17.9	16.9	13.3	10.1	6.8	5.5
	7DADM	14.9	17.8	16.9	13.3	10.2	6.9	5.6
	Min	13.1	16.6	15.8	12.9	9.9	5.8	4.5
1	Mean	15.6	19.1	17.9	14.4	10.9	6.6	5.0
	Max	18.6	22.4	20.7	16.4	12.4	7.6	5.7
	7DADM	16.9	21.8	20.7	16.6	12.7	7.8	5.8

Movements

Rotary Screw Trap

The rotary screw trap was deployed at two sites during 2004 to monitor dispersal of bull trout into downstream areas. High river flows, equipment damage, and personnel availability limited sampling at the Day Road site to two days in January 2004. No bull trout were captured, however three *O. mykiss* and 17 Chinook salmon were captured during the two days of sampling. One of the *O. mykiss* and 16 of the Chinook salmon were PIT-tagged for other studies.

The trap was re-deployed at the Joe West Bridge site from mid March through June, and sampling was conducted for 58 days. Bull trout, Chinook salmon, and *O. mykiss* were captured during all four months sampled at this site. A total of 32 bull trout, 906 Chinook salmon, and 1,818 *O. mykiss* were captured (Table 9). Of the total catch, nine bull trout, 608 Chinook salmon, and 1,410 *O. mykiss* were PIT-tagged. Numbers of bull trout captured were insufficient for release groups to determine trap efficiency. The number of recaptures from these releases of Chinook and *O. mykiss* totaled 80 and 138, respectively. Average trap efficiencies calculated for all release groups were 17.7% and 10.1% for and Chinook salmon and *O. mykiss*, respectively (M. Lambert, CTUIR, pers. comm.).

Table 9. Length and weight data collected from bull trout, Chinook salmon, and *O. mykiss* captured at the Joe West Bridge screw trap site on the Walla Walla River in 2004. Length and weight ranges are in parentheses.

Species	Mean length (mm)	Mean weight (g)	Total # captured
Bull trout	166 (129-330)	42.3 (19.1-106.9)	32
Chinook salmon	85 (32-123)	6.9 (0.2-22.7)	906
O. mykiss	49 (26-248)	39.4 (0.1-175.8)	1818

Length frequencies of the 32 bull trout captured while operating the screw trap are presented in Figure 14. All fish captured, with the exception of one adult, were subadults. The catch rate for subadult bull trout steadily increased from March through June, with the rate increasing by a factor of seven over this time period (Figure 15). Sampling was only conducted for eight days during June, thus considering the increasing trend in the catch, the June catch rate could have likely been higher with more comprehensive sampling. In addition, because we were not able to sample during July, we could not determine if downstream movement would have continued to increase, or if peak movement occurred in June.

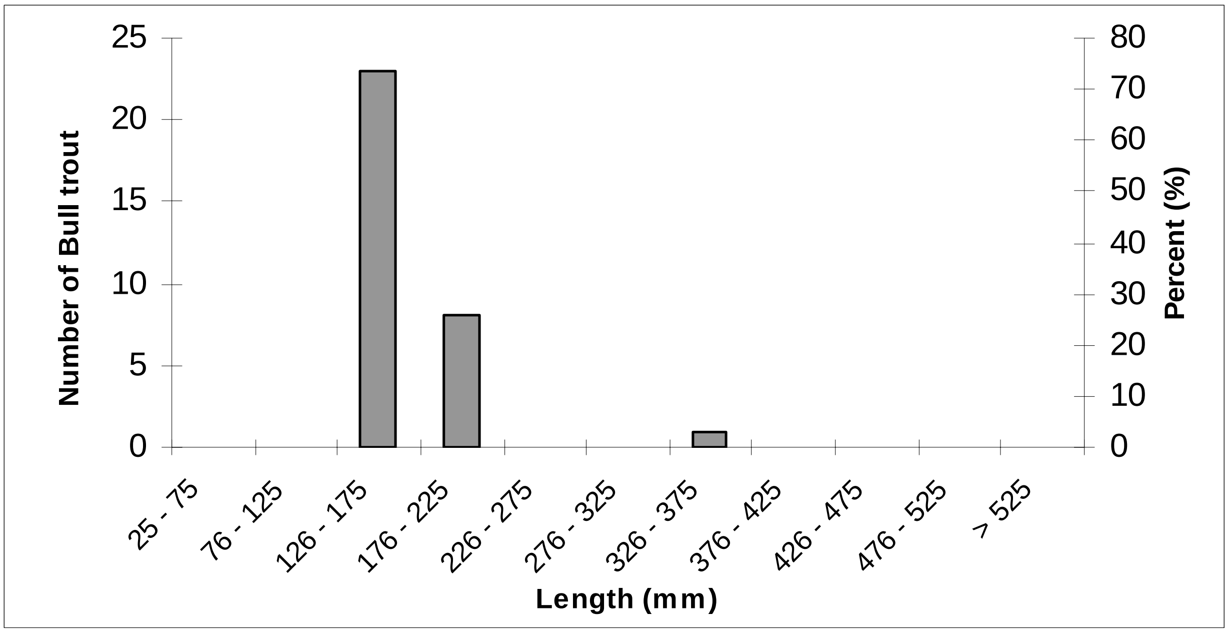

Figure 14. Length frequency histogram of bull trout captured in the screw trap from March through June, 2004.

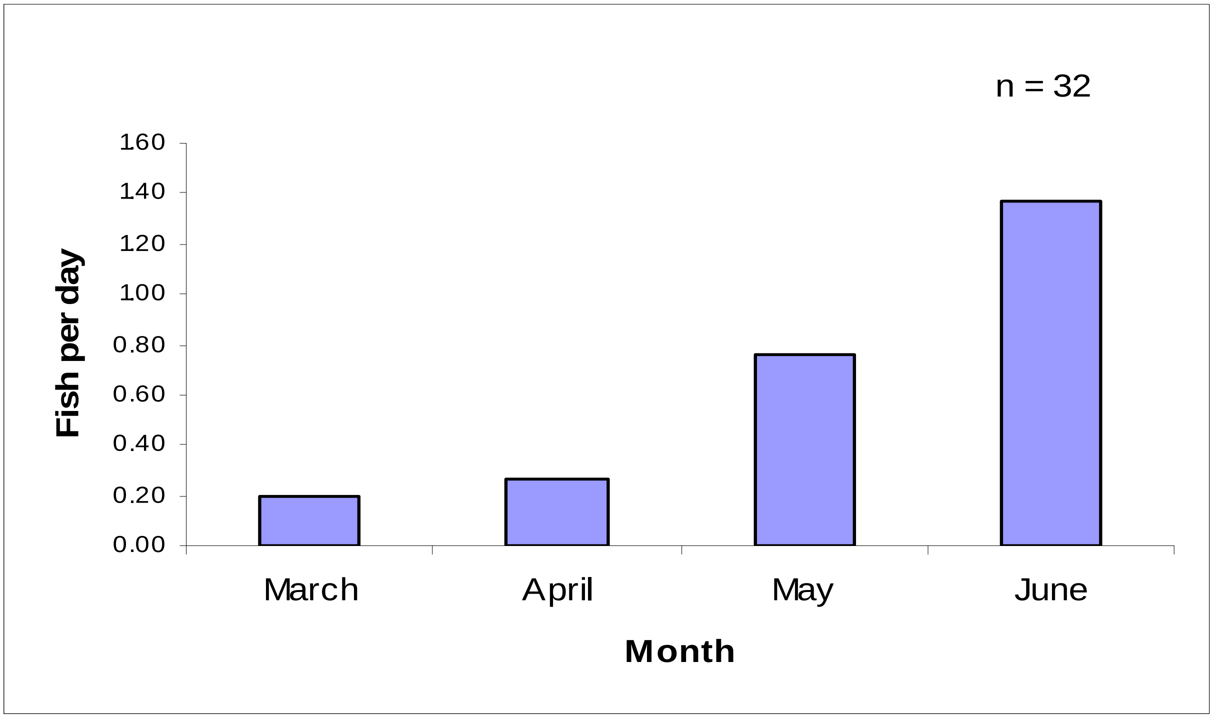

Figure 15. Average number of bull trout captured per day while operating a screw trap at Joe West Bridge during 2004. The screw trap was fished 5, 27, 17 and 8 days during March, April, May and June, respectively.

Length frequency distributions over time for Chinook salmon indicated two distinct length groups were captured during discrete time periods (Figure 16). Early in the season (late March to mid-May), larger Chinook salmon greater than 80 mm dominated the catch, while later in the season (late May to June), smaller Chinook less than 80 mm dominated the catch.

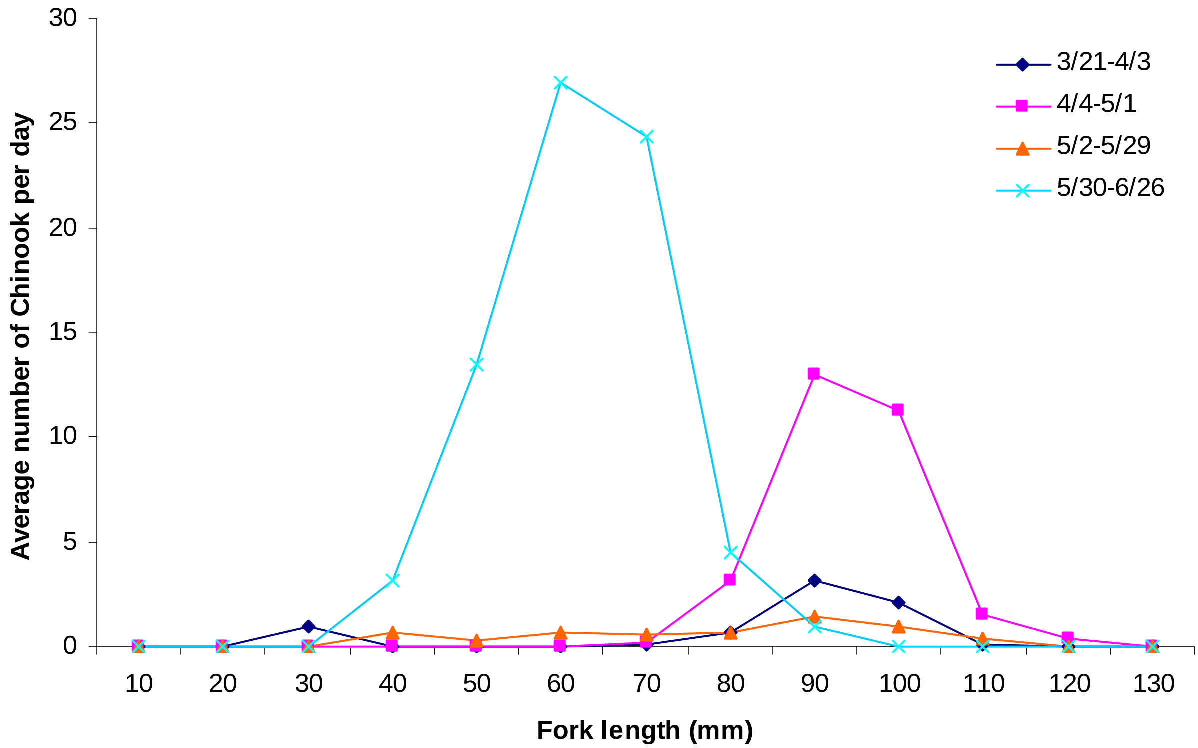

Figure 16. Fork lengths and average number of Chinook captured per day at the Joe West Bridge screw trap site separated into monthly sampling intervals from 21 March through 26 June, 2004.

Length frequency distributions over time for *O. mykiss* showed a pattern similar to that which was observed for Chinook salmon. Two distinct length groups were captured during discrete time periods (Figure 17). Early in the season (late March to mid-May), *O. mykiss* greater than 120 mm dominated the catch, while later in the season (late May to June), smaller *O. mykiss* less than 120 mm dominated the catch.

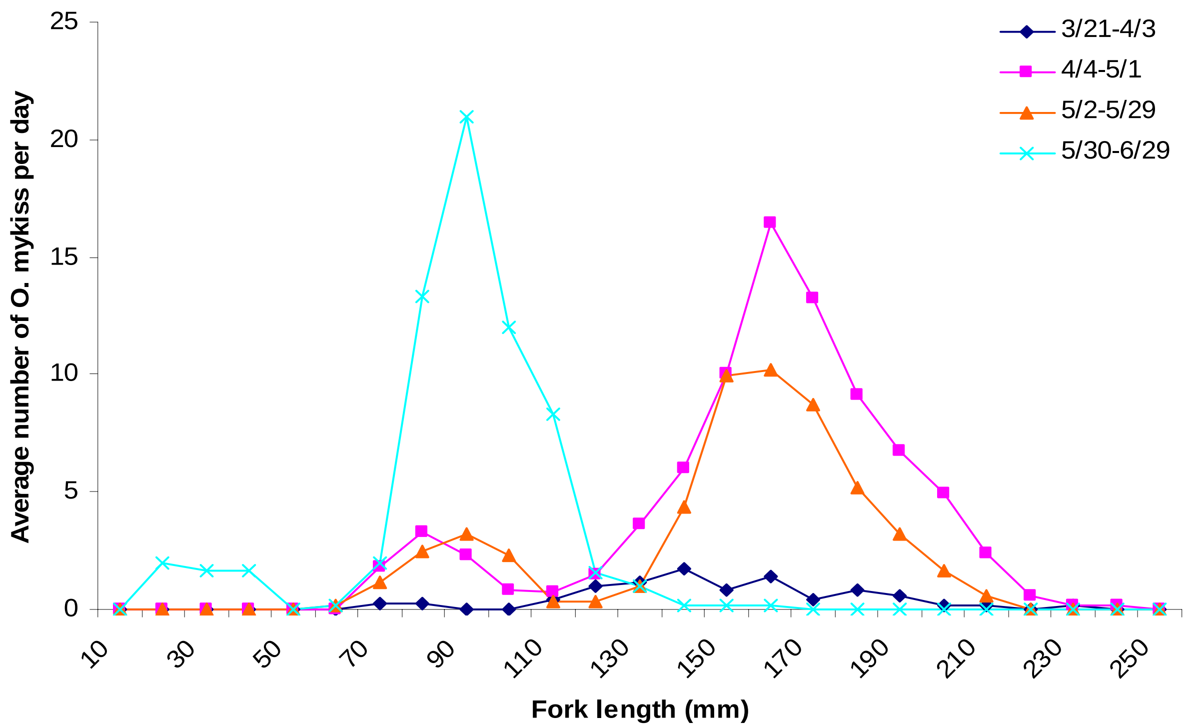

Figure 17. Fork lengths and average number of *O. mykiss* captured per day at the Joe West Bridge screw trap site separated into monthly sampling intervals during 21 March through 26 June, 2004.

PIT Tag Detection Arrays

A total of three PIT-tagged bull trout were detected at NBD during 2004. In addition, 33 wild *O. mykiss* and 144 Chinook salmon were detected (Table 10). Two of the Chinook salmon detections were from returning adults that had been PIT tagged in 2001 in the Walla Walla River as smolts.

Table 10. Total number of detections at each antenna at Nursery Bridge Dam in 2004.

Species	East bank ladder	West bank ladder	Total
Bull trout	2	1	3
Wild *O. mykiss*	19	14	33
Chinook salmon	131	13	144
Total	152	28	180

Two of the 3 bull trout detected at NBD were adults (Table 11). Detection histories for the adult bull trout suggest upstream movement in the spring and summer and downstream movement in the fall, which corresponds with spawning and over-wintering migration time periods. The subadult bull trout only had 2 detections, but likely dispersed from the Upper

SFWW in May, and continued to rear in the SFWW and mainstem Walla Walla until it arrived at NBD when it was detected in October.

Table 11. PIT tag detection histories, size at the time of tagging, estimated size at detection, and estimated age at tagging and detection for bull trout detected at the Nursery Bridge Dam PIT tag detection array. All fish were tagged in the South Fork Walla Walla River above the Harris County Park PIT array.

Tag ID	Date tagged (T)/ Date detected (D)	Length at tagging (T)/ Detection (D)[a]	Elapsed time between detections	Location tagged (T)/ Detected (D)[b]	Estimated age at tagging (T)/ Detection (D)[c]
3D9.1BF15A0A1A	7/25/2002 (T)	406 mm (T)	N/A	SFWW (T)	7+ (T)
	10/3/2002 (D)	409 mm (D)	2 months, 8 days	SFWW Harris Park (D)	7+ (D)
	6/5/2003 (D)	421 mm (D)	8 months, 2 days	SFWW Harris Park (D)	8 (D)
	6/9/2003 (D)	421 mm (D)	4 days	SFWW Bear Creek (D)	8 (D)
	11/29/2003 (D)	430 mm (D)	5 months,20 days	SFWW Harris Park (D)	8+ (D)
	6/5/2004 (D)	439 mm (D)	6 months, 6 days	Nursery Bridge (D)	8+ (D)
	7/9/2004 (D)	441 mm (D)	1 month, 4 days	SFWW Bear Creek (D)	9 (D)
	10/2/2004 (D)	445 mm (D)	2 months, 23 days	SFWW Bear Creek (D)	9+ (D)
	10/7/2004 (D)	445 mm (D)	5 days	SFWW Harris Park (D)	9+ (D)
3D9.1BF1B2B1B8	7/9/2003 (T)	453 mm (T)	N/A	SFWW (T)	9+ (T)
	8/23/2003 (D)	455 mm (D)	1 month, 14 days	SFWW Bear Creek (D)	9+ (D)
	9/28/2003 (D)	457 mm (D)	1 month, 5 days	SFWW Harris Park (D)	10 (D)
	6/21/2004 (D)	470 mm (D)	8 months, 24 days	Nursery Bridge (D)	10+ (D)
	7/14/2004 (D)	471 mm (D)	23 days	SFWW Harris Park (D)	10+ (D)
	8/5/2004 (D)	472 mm (D)	22 days	SFWW Bear Creek (D)	10+ (D)
3D9.1BF1B2DDB8	7/14/2003 (T)	146 mm (T)	N/A	SFWW (T)	1+ (T)
	5/22/2004 (D)	196 mm (D)	10 months, 8 days	SFWW Harris Park (D)	2+ (D)
	10/23/2004 (D)	221mm (D)	5 months, 1 day	Nursery Bridge (D)	2+ (D)

[a] – Detection length calculated using preliminary annual growth estimates from Budy et al. (unpublished).
[b] – SFWW Harris County Park = WW1; SFWW Bear Creek = WW2.
[c] – Tagging and detection age estimated using length at age data from Budy et al. (2004).

During 2004, the East bank ladder interrogation system operated a total of 356 days and the West bank ladder system operated for 238 days. Various power failures and equipment malfunctions at both ladders resulted in a total system down time of 2.4% for the East ladder and 8.5% for the West ladder (Table 12).

Table 12. Operational details for the NBD East and West PIT tag detection arrays during 2004.

East Bank Ladder

Date	System down time (hours)	Explanation
Aug 3 – Aug 8	141	Power failure
Oct 9 – Oct 12	70	Power failure

West Bank Ladder

Date	System down time (hours)	Explanation
May 18	1.5	Computer maintenance
May 26 – June 9	132	Power failure
June 24	13	Computer maintenance
Aug 3 – Aug 9	152.5	Power failure
Oct 9 – Oct 12	81.5	Power failure
Nov 3 – Nov 9	147.5	Computer hardware failure

Individual trial detection efficiencies for 23 mm tags ranged from 90 to 100% and 12 mm tags ranged from 0 to 90% (Table 13). Efficiencies differed dramatically between 12 and 23 mm tags, and between individual antennas for 12 mm tags. Overall, 23 mm tags were consistently detected and 12 mm tags were not.

Table 13. Efficiency test results for the NBD East and West PIT tag detection arrays during 2004. Upstream and downstream passes were averaged together by month and tag size.

East Bank Ladder PIT Tag Efficiency Test Results (%)

PIT tag size (mm)	September	October	November	Average
12	60	90	15	55
23	100	95	95	96.7

West Bank Ladder PIT Tag Efficiency Test Results (%)

PIT tag size (mm)	September	October	November	Average
12	0	0	0	0
23	100	100	N/A	100

Video Monitoring

Our underwater video monitoring system proved sturdy enough to withstand elevated discharges, high debris loads, and changing environmental conditions. Table 14 shows the number and direction of movement of adult fish detected between 22 April and 29 June 2004. A total of three bull trout were recorded using the West ladder at NBD on 2 May, 6 May, and 5 June 2004.

Table 14. Number and movement direction of fish detected at the NBD West bank ladder using a video monitoring system between 22 April and 29 June 2004.

Species	Upstream	Downstream	Stationary	Other	Total
Bull trout	1	1	0	1	3
O. mykiss	5	1	1	11	18
Chinook salmon	9	0	7	12	28
Sucker *spp.*	5	0	0	0	5
Mountain whitefish	1	1	0	3	5

Data were not recorded from 23 April to 29 April and from 26 May to 1 June due to a large number of false alarms from debris and a power outage. The majority of detections recorded by the DVR were triggered by juvenile Chinook salmon, *O. mykiss*, and debris. Additionally, during high flow events, increased turbidity reduced the camera's ability to detect fish passing through the weir. Between 6 May and 4 June the CTUIR operated the adult fish trap on the West bank ladder and, occasionally, fish were trapped by CTUIR but not detected by the camera.

Image quality varied during the time sampling was conducted. Turbidity reduced image quality regardless of equipment configuration. When water clarity was good, we reviewed images and made modifications to increase the quality. Modifications included installing a weir, installing an aluminum backboard and ruler, adjusting the lighting angle, and refocusing the underwater camera. Refocusing the camera was the last modification we made following review of the image of an adult Chinook (Figure 18).

Figure 18. Still-frame photograph of a Chinook salmon passing through the video monitoring site at the NBD West ladder. Radio tag antenna can be seen protruding from mouth.

Habitat Suitability

Redd Surveys

The 2004 redd surveys for the SFWW and tributaries were conducted by ODFW and FWS from 30 August through 4 November. The cumulative number of bull trout redds enumerated over five surveys was 353. We counted a total of 54 redds in the mainstem SFWW between the Reser Creek confluence and Section 20 Tributary confluence. During two surveys on Skiphorton and Reser creeks, 31 redds and seven redds, respectively, were identified. In the mainstem of the SFWW all of the redd observations were in the medium and large size category, with the majority in the medium category (Figure 19). We observed redds in all three size categories in Skiphorton Creek, and only medium sized redds in Reser Creek (Figure 19).

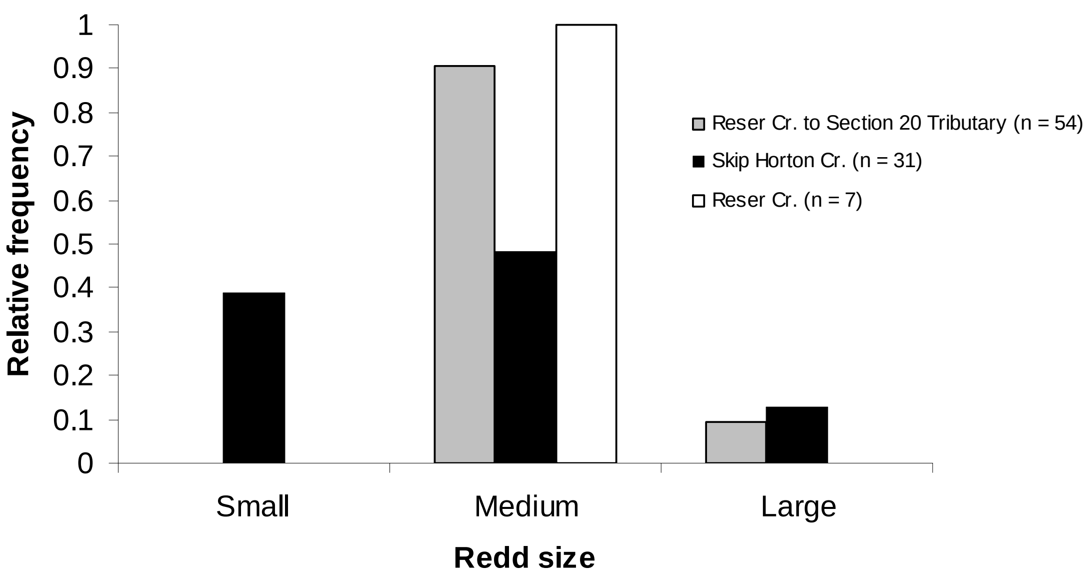

Figure 19. Relative frequencies of small (< 0.5 m), medium (0.5 – 1.5 m) and large (> 1.5 m) size redds enumerated by FWS personnel during 2004 redd surveys conducted on Skiphorton Creek, Reser Creek and the mainstem SFWW from the confluence of Reser Creek to the confluence of Section 20 tributary.

Spawning Habitat Suitability Model

Measurements of the microhabitat variables of depth, mean column velocity, nose velocity, substrate composition, and percent fines were collected at 167 use (redd locations) and 167 non-use locations, from the period of 21 September to 21 October 2004. Data were collected in redd survey Sections 1 through 7 (Figure 9) in the mainstem SFWW. The availability of microhabitat variables was characterized at 1,433 individual points in the SFWW spawning area by Utah State University researchers (Budy et al. 2005).

We found that 99% of the depths measured at bull trout redd sites ranged from 0.2 to 0.6 m, and the average depth was 0.27 m (Figure 20). In contrast, for non-use points we found that 85% of the depths ranged from 0.2 to 0.6 m, and the average depth was 0.34 m (Figure 20). In slight contrast, 90% of the depths measured for overall availability ranged from 0.2 to 0.6 m, and the average depth was 0.36 m (Figure 20). There was a significant difference between the frequency of depths used at redd sites for spawning compared to sites where no redds were present (non-use points) ($P = 0.001$). There was also a significant difference between the frequency of depths used for spawning and the frequency of overall depth availability ($P < 0.001$).

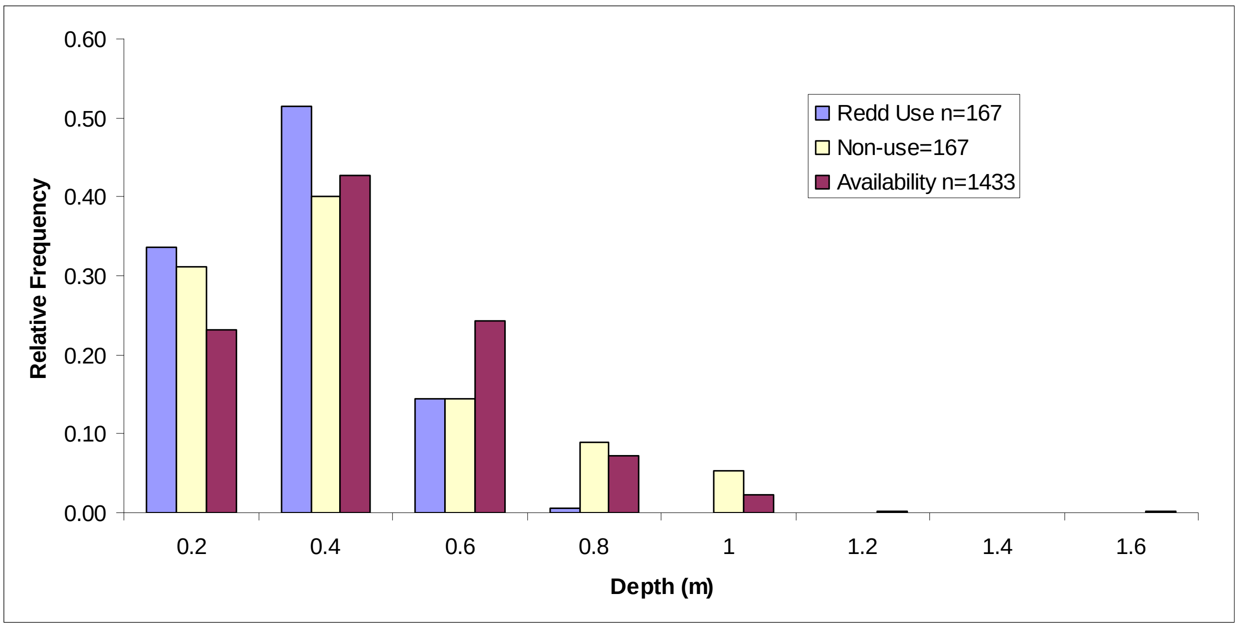

Figure 20. Relative frequency of depth use at bull trout redd locations, frequency of depths at sites that were not used for spawning, and frequency of available depths in the SFWW spawning area.

We found that 96% of the mean column velocities measured at bull trout redd sites ranged from 0.2 to 0.6 m/s, and the average mean column velocity was 0.25 m/s (Figure 21). In contrast, we found that only 52% of the velocities measured at non-use points ranged from 0.2 to 0.6 m/s, and the average velocity at these points was 0.57 m/s (Figure 21). Similarly, only 49% of the velocities measured for overall availability ranged from 0.2 to 0.6 m/s, and the average available velocity was 0.64 m/s (Figure 21). There was a significant difference between the frequency of velocities at redd sites compared to the frequency of velocities at sites where no redds were present ($P < 0.001$). There was also a significant difference between the frequency of velocities at redd sites and the frequency of overall velocity availability ($P < 0.001$).

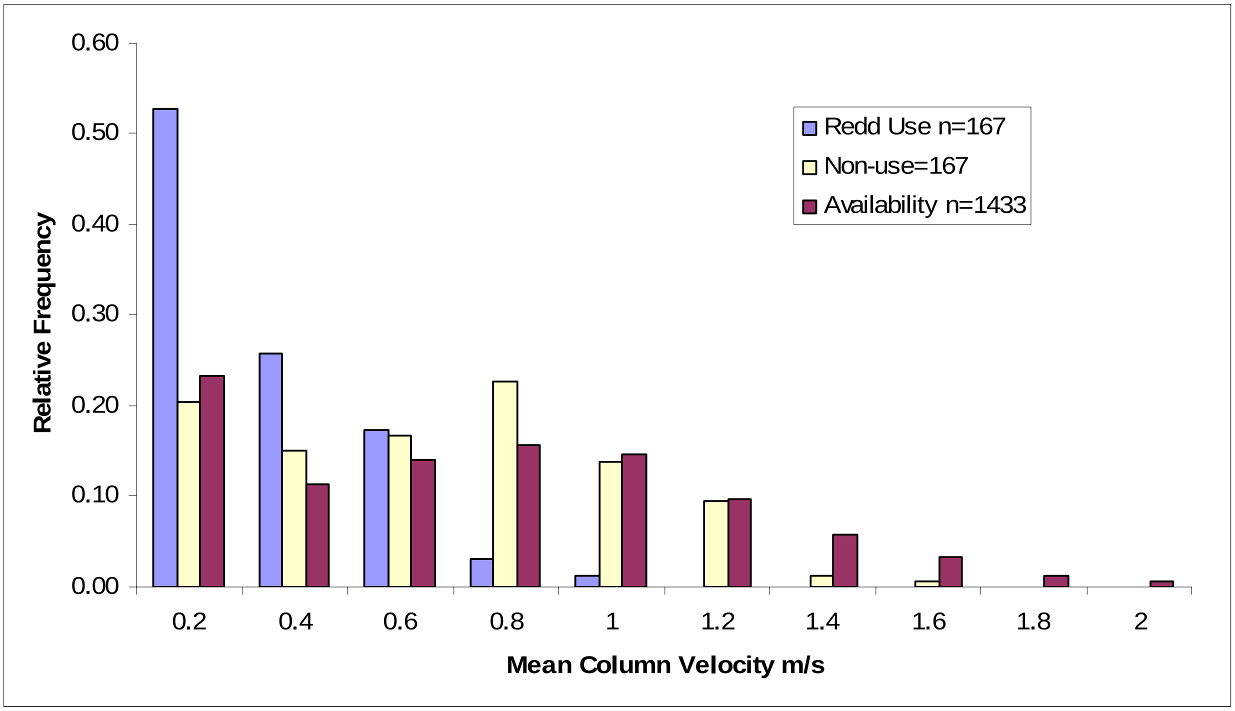

Figure 21. Relative frequency of mean column velocities at bull trout redd locations, frequency of mean column velocities at sites that were not used for spawning, and frequency of available mean column velocities in the SFWW spawning area.

We found that 100% of the nose velocities measured at bull trout redd sites ranged from 0.2 to 0.6 m/s, and the average nose velocity was 0.14 m/s (Figure 22). In contrast, we found that only 63% of the nose velocities measured at non-use points ranged from 0.2 to 0.6 m/s, and the average nose velocity was 0.56 m/s (Figure 22). In addition, 85% of the nose velocities measured for overall availability ranged from 0.2 to 0.6 m/s, and the average nose velocity was 0.31 m/s (Figure 22). There was a significant difference between the frequency of nose velocities at redd sites compared to the frequency of nose velocities at sites where no redds were present ($P < 0.001$). There was also a significant difference between the frequency of nose velocities used for spawning and the frequency of overall nose velocity availability ($P < 0.001$).

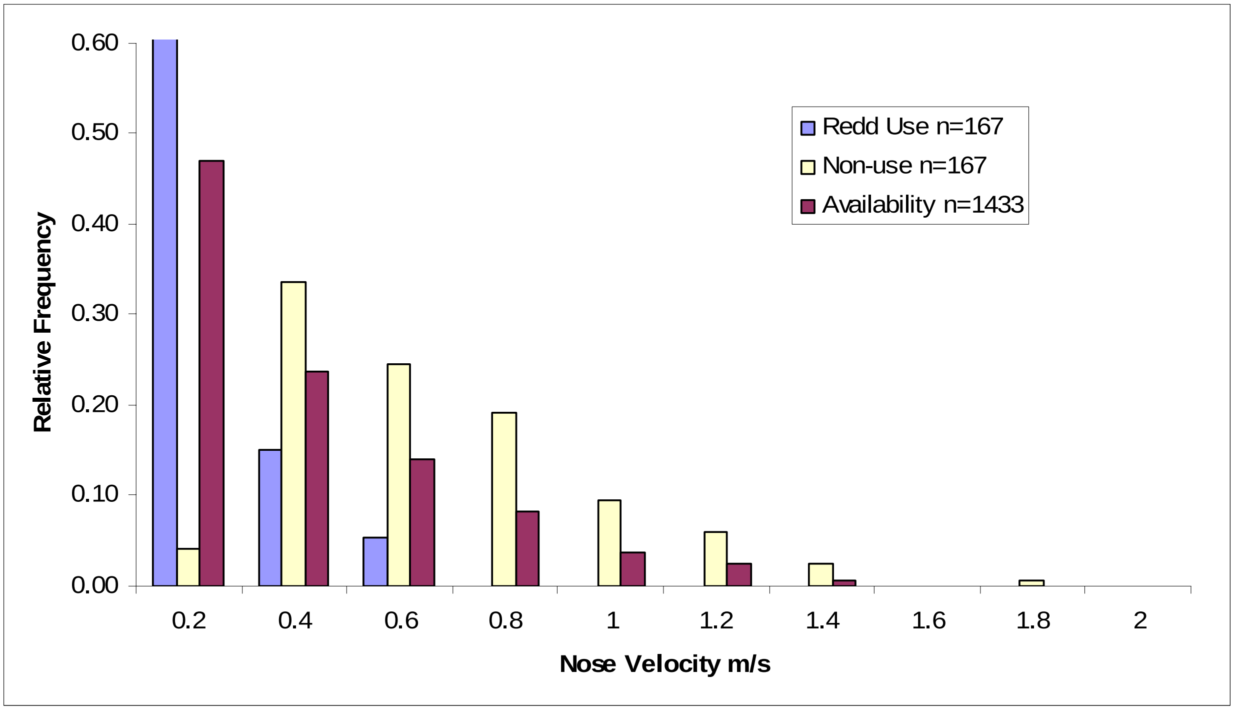

Figure 22. Relative frequency of nose velocities at bull trout redd locations, frequency of nose velocities at sites that were not used for spawning, and frequency of available nose velocities in the SFWW spawning area.

We found that 87% of the dominant substrate sizes measured at bull trout redd sites were in the pebble and small gravel categories (Figure 23). In contrast, only 7% of non-use and 18% of the available dominant substrate sizes were in the pebble and small gravel categories (Figure 23). There was a significant difference between the frequency of dominant substrate sizes at redd sites compared to the frequency at sites where no redds were present ($P = 0.001$). There was also a significant difference between the frequency of dominant substrate sizes at redd sites compared to the frequency of overall substrate sizes ($P < 0.001$).

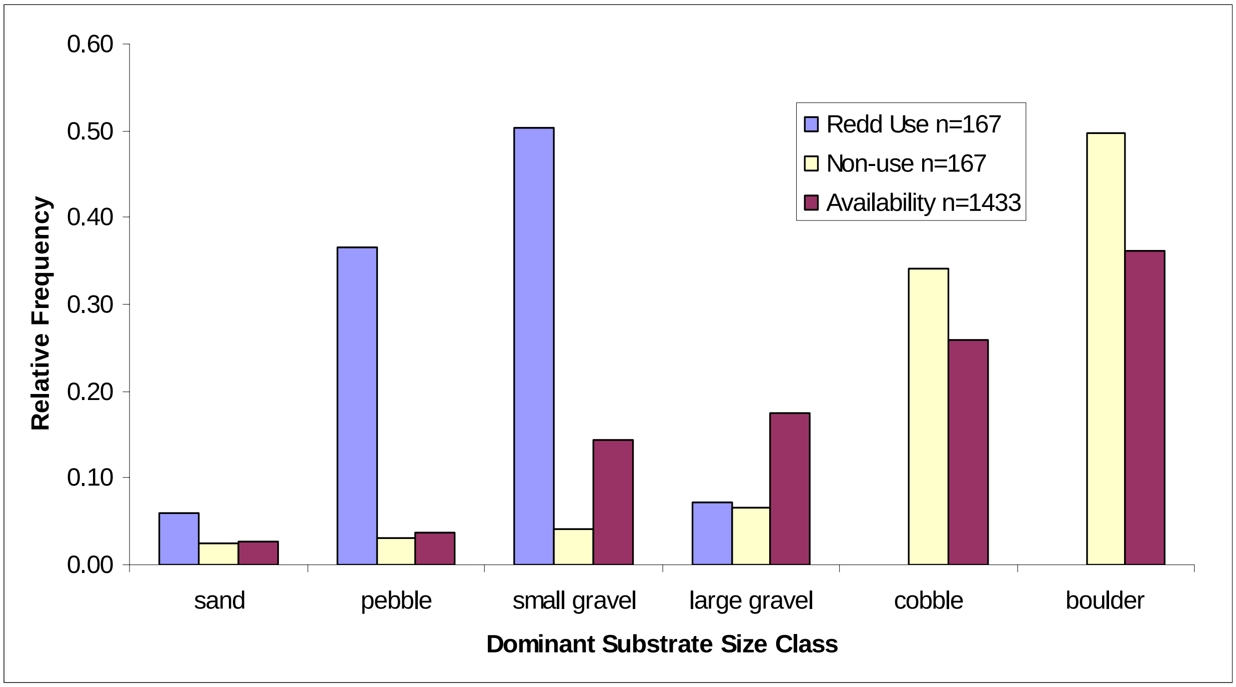

Figure 23. Relative frequency of dominant substrate size classes at bull trout redd locations, frequency of dominant substrate size classes at sites that were not used for spawning, and frequency of available dominant substrate size classes in the SFWW spawning area.

We found that 88% of the percent fines values measured at bull trout redd sites fell within the 0-25% category (Figure 24). Similarly, 95% of the percent fines values measured at bull trout non-use points fell within the 0-25% category (Figure 24). No percent fines availability information was available for the SFWW spawning area. There was no significant difference between the frequency of percent fines measurements at bull trout redd sites and percent fines at non-use points (P = 0.067).

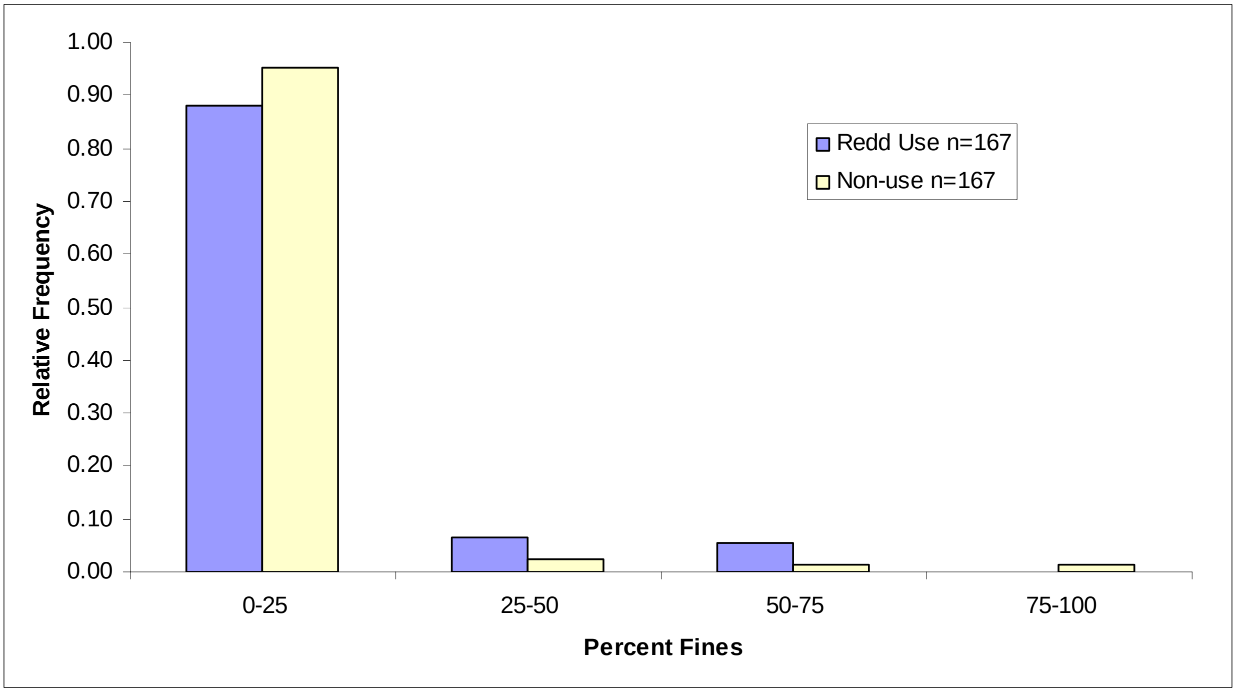

Figure 24. Relative frequency of percent fines at bull trout redd locations and frequency of percent fines at sites not used for spawning in the SFWW spawning area.

The statistical analyses for the spawning habitat probabilistic model were conducted using microhabitat use and non-use data from the SFWW study area. Depth, mean column velocity, nose velocity, substrate, and percent fines use and non-use data were analyzed using logistic regression procedures. First we evaluated the habitat variables in univariate models to help guide the structure of multivariate model candidates. Dominant substrate size class demonstrated the highest association with presence of a redd site (AIC score – 145.363), followed by nose velocity (AIC score – 212.803) as the next most influential variable (Table 15).

Table 15. Univariate models using microhabitat variables for bull trout spawning habitat ranked in order of importance to redd site selection based on Akaike Information Criterion (AIC) scores.

Microhabitat Variable	AIC Score
Substrate	145.363
Nose Velocity	212.803
Mean Column Velocity	368.794
Depth	454.578
Percent Fines	459.564

The next step in the analysis was to evaluate candidates for multivariate models using various combinations of habitat variables that best explained observations of redd site selection. Although the univariate analyses (Table 15) indicated a wide range of association (AIC) between each variable and redd site selection, we chose to assemble multivariate model candidates using combinations of all of the variables with the exception of percent fines. The combination of substrate, nose velocity, and mean column velocity had the lowest AIC score (82.263), and best explained observations of redd site selection in the SFWW study area (Table 16). A model using substrate, nose velocity, mean column velocity, and depth had the next lowest AIC score (83.437).

Table 16. Multivariate models using various combinations of microhabitat variables for bull trout spawning habitat ranked in order of importance to redd site selection based on Akaike Information Criterion (AIC) scores.

Microhabitat Variable	AIC Score
Substrate, Nose Velocity, Mean Column Velocity	82.263
Substrate, Nose Velocity, Mean Column Velocity, Depth	83.437
Substrate, Nose Velocity	91.657
Substrate, Nose Velocity, Depth	93.174
Substrate, Mean Column Velocity, Depth	138.296
Substrate, Mean Column Velocity	145.251

Since field data collection will not be complete until the end of the 2005 field season, we did not conduct any further multivariate model evaluations. Model evaluation and selection will be completed following the 2005 field season.

Rearing Habitat Suitability Model

Measurements of the microhabitat variables of depth, mean column velocity, substrate composition, and cover were collected at 57 rearing bull trout (use) locations and 57 non-use locations from August through November 2004. Habitat use/non-use observations were distributed throughout the study area as shown in Figure 25. As described previously, the non-use measurements were collected a random number of paces away from use locations. Mesohabitat variables were also characterized at habitat units where snorkel surveys were conducted from August through November. We partitioned our observations into subadult ($\leq$325 mm) and adult (>325 mm) categories to determine if different microhabitat conditions were used by smaller (n=45) and larger (n=12) bull trout.

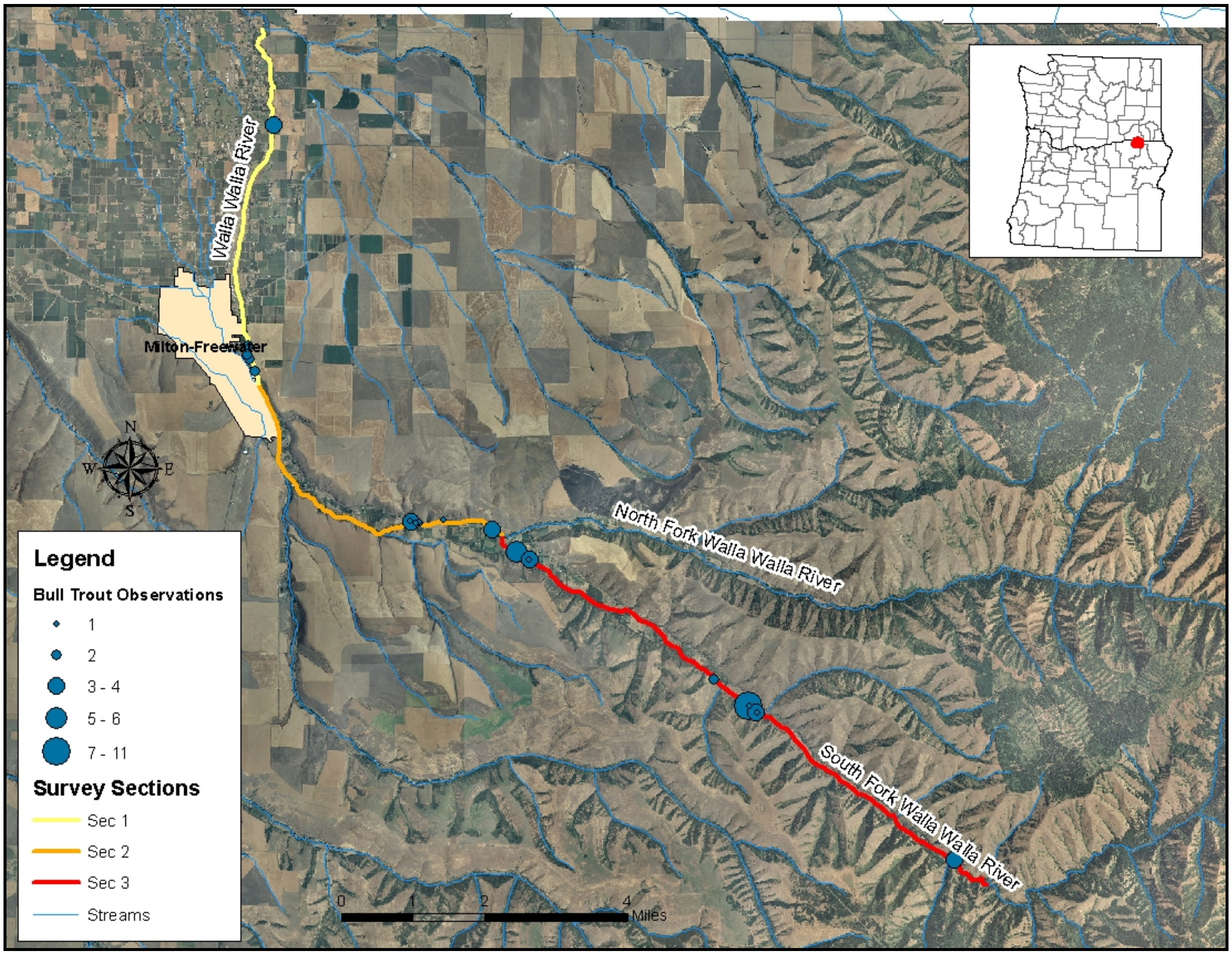

Figure 25. Map showing locations of data collection for rearing habitat use/non-use observations between the SFWW and OR/WA state line.

We found that 76% of the depths measured at subadult bull trout locations ranged from 0.6 m to 1.0 m, and the average depth was 0.85 m (Figure 26). For non-use points we found that only 56% of the depths measured were between 0.6 m and 1.0 m, and the average depth was 0.7m (Figure 26). There was a significant difference between the frequency of depths used by subadults at rearing locations and the frequency of depths at non-use points (P = 0.026). For adults, we found that 83% of depths measured at rearing locations ranged from 0.6 m to 1.0 m, and the average depth was 0.87 m (Figure 27). For non-use points we found that only 67% of the measured depths ranged from 0.6 m to 1.0 m, and the average depth was 0.63 m (Figure 27). There was no significant difference between the frequency of depths used by adults at rearing locations and the frequency of depths at non-use points (P = 0.076).

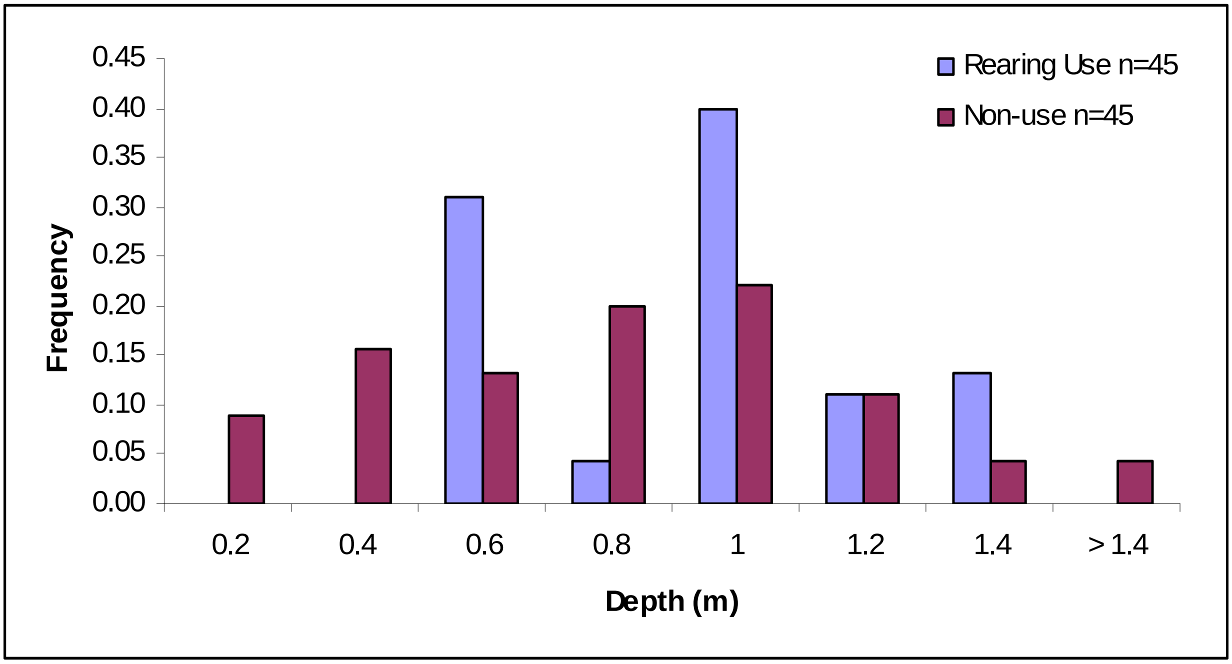

Figure 26. Relative frequency of depths used by subadult bull trout at rearing locations and depths measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

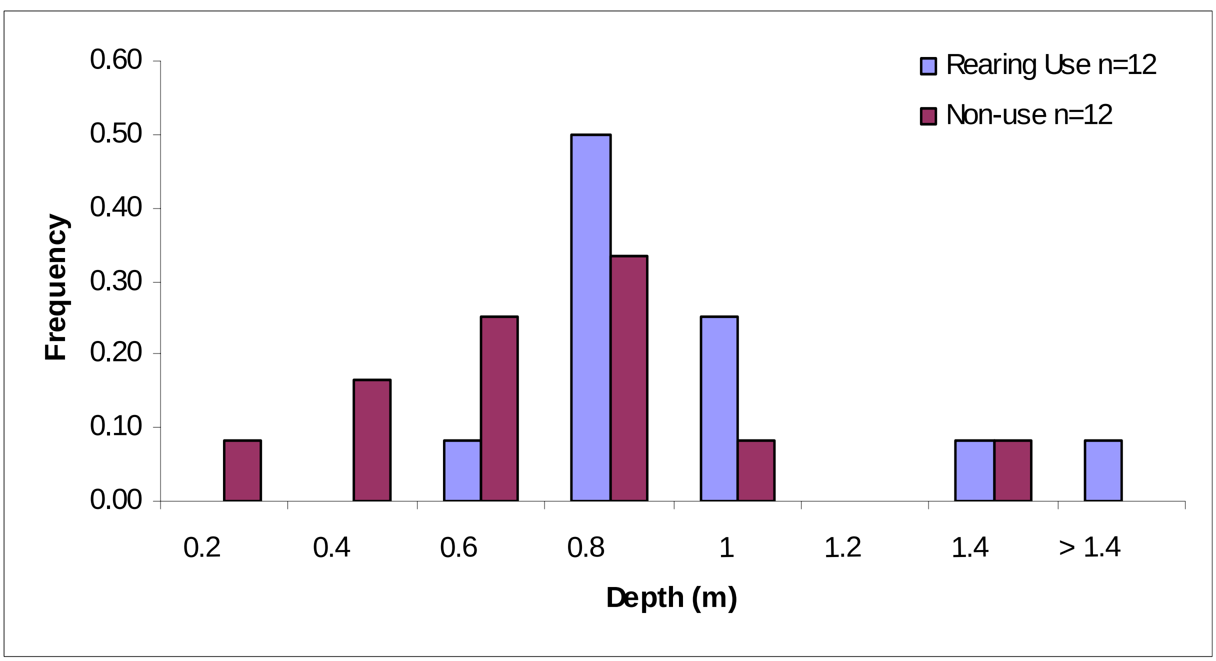

Figure 27. Relative frequency of depths used by adult bull trout at rearing locations and depths measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

We found that 89% of the mean column velocities measured at subadult bull trout use locations were less than 0.6 m/s, and the average mean column velocity used was 0.20 m/s (Figure 28). Similarly, for non-use points we found that 62% of the mean column velocities were less than 0.6 m/s, and the average mean column velocity was 0.47 m/s (Figure 28). For adult bull trout, we found that 100% of the mean column velocities measured at use locations were ≤ 0.6 m/s, and the average mean column velocity value was 0.15 m/s (Figure 29). In contrast, for non-use points we found that 42% of the mean column velocities were < 0.6 m/s, and the average mean column velocity was 0.65 m/s (Figure 29). There was a significant difference between the frequency of mean column velocities at use locations and the frequency of mean column velocities at non-use points for both subadult (P = .001) and adult bull trout (P = .009).

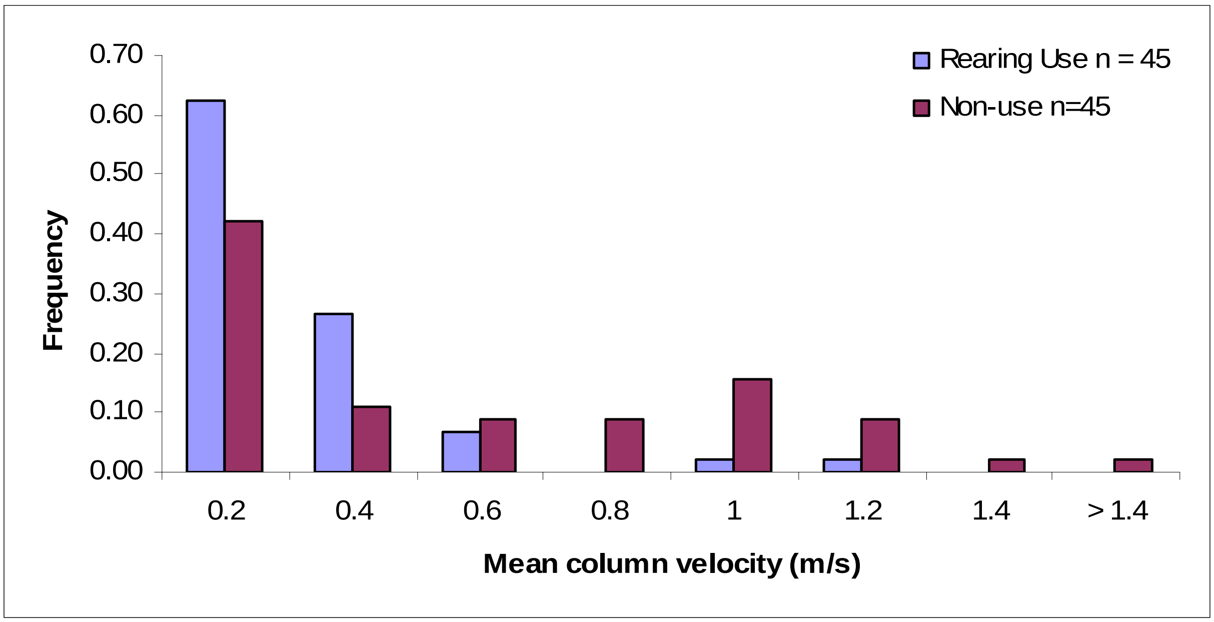

Figure 28. Relative frequency of mean column water velocities used by subadult bull trout at rearing locations and mean column water velocities measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

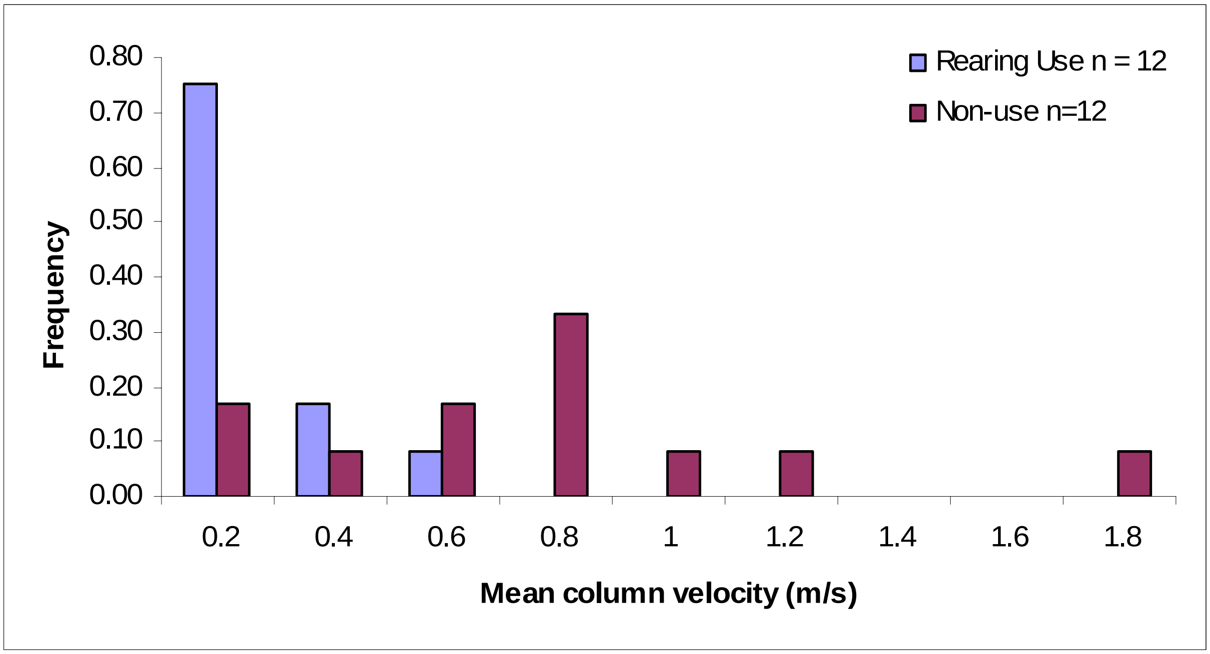

Figure 29. Relative frequency of mean column water velocities used by adult bull trout at rearing locations and mean column water velocities measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

We found that 84% of the substrate observations at subadult rearing locations fell within the boulder, cobble and large gravel categories (Figure 30). Similarly, 80% of the observations at non-use points fell within the boulder, cobble and large gravel categories (Figure 30). For adult bull trout, we found that 75% of the substrate observations at both rearing locations and non-use locations fell within the boulder, cobble, and large gravel categories (Figure 31). There was no significant difference between the frequency of substrate class observations at rearing locations and the frequency of observations at non-use locations for either subadult ($P = 0.954$) or adult ($P = 0.979$) bull trout.

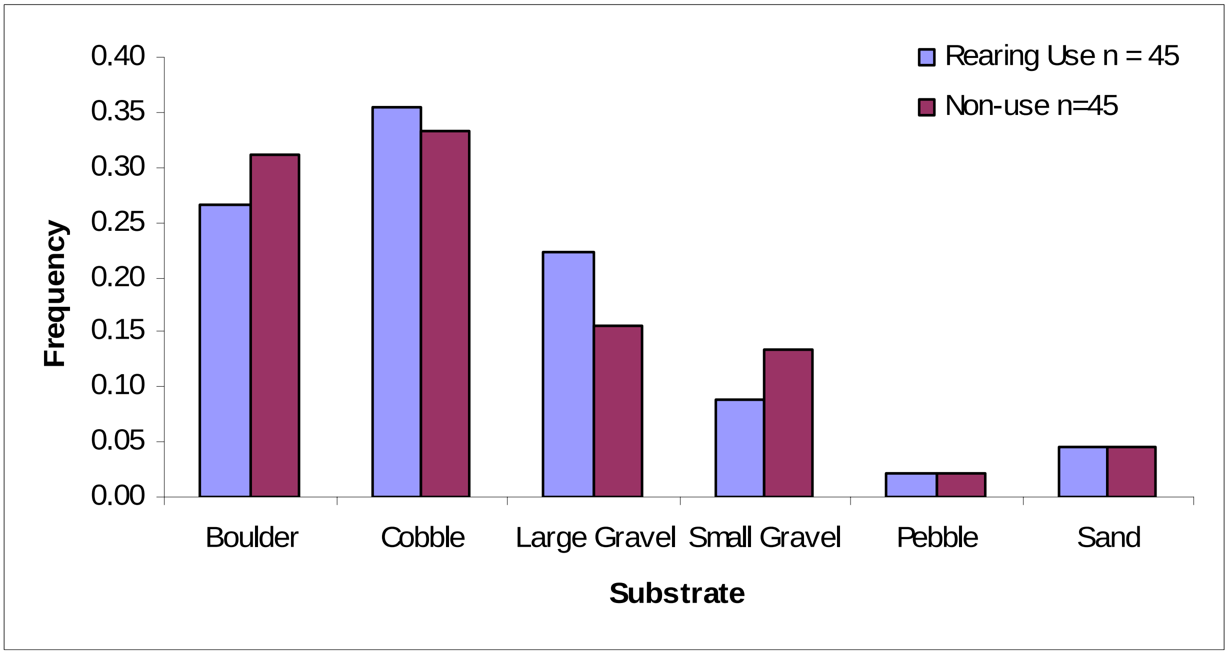

Figure 30. Relative frequency of dominant substrate class used by subadult bull trout at rearing locations and dominant substrate class measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

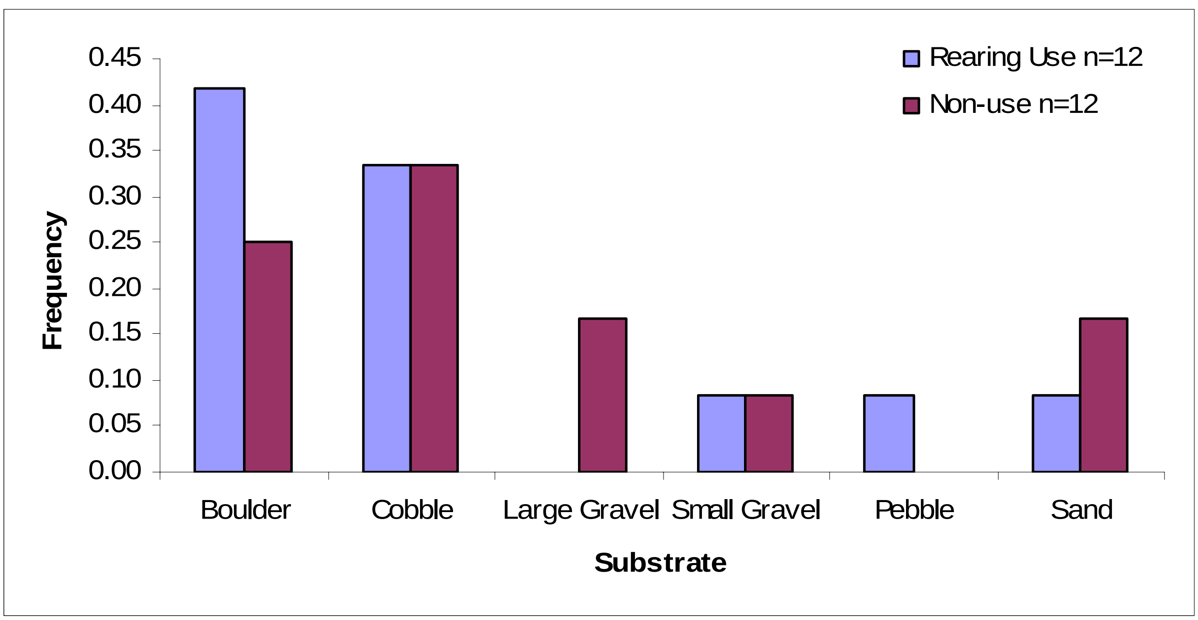

Figure 31. Relative frequency of dominant substrate class used by adult bull trout at rearing locations and dominant substrate class measured at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004.

Large woody debris was the most common cover type used by both rearing subadult and adult bull trout (Figures 32 and 33). Undercut banks were also used frequently by adult bull trout. The "no cover" category was the most commonly observed at non-use locations, suggesting bull trout prefer some form of cover. There were insufficient observations to statistically analyze each cover type for subadult and adult bull trout so we compared use of all types of cover with observations of no cover. There was a significant difference between the frequency of cover versus no cover used by subadults and the frequency of cover versus no cover at non-use locations (P = 0.010). Similarly, we also found a significant difference between the frequency of cover versus no cover used by adults and the frequency of cover versus no cover at non-use locations (P = 0.045).

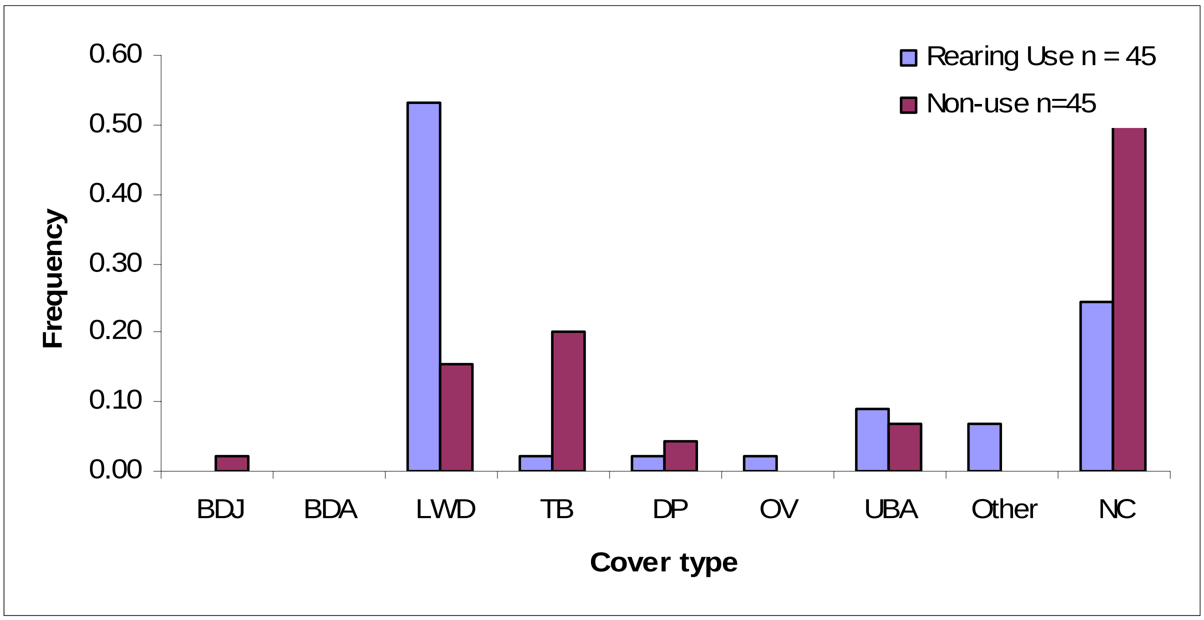

Figure 32. Relative frequency of cover type used by subadult bull trout at rearing locations and cover type at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004. Cover type codes are as follows: BDJ = boulder juvenile, BDA = boulder adult, LWD = large woody debris, TB = turbulence, DP = debris pile, OV = overhanging vegetation, UBA = undercut bank adult, Other = other cover types not listed, and NC = no cover.

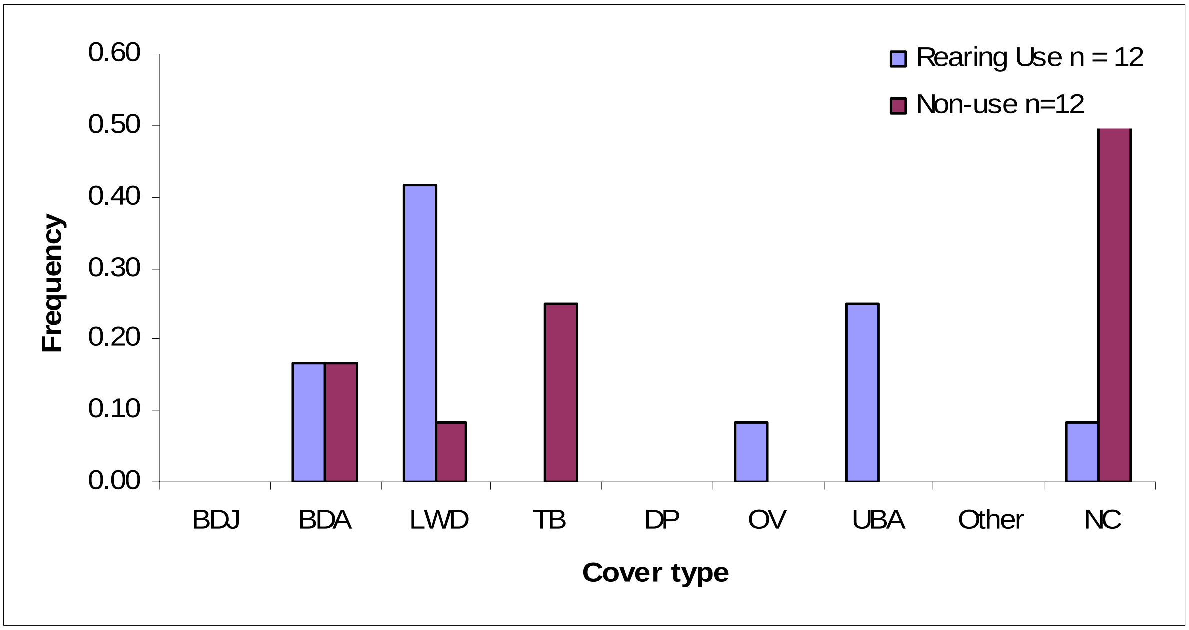

Figure 33. Relative frequency of cover type used by adult bull trout at rearing locations and cover type at non-use locations in our study area on the SFWW and mainstem Walla Walla rivers during 2004. Cover type codes are as follows: BDJ = boulder juvenile, BDA = boulder adult, LWD = large woody debris, TB = turbulence, DP = debris pile, OV = overhanging vegetation, UBA = undercut bank adult, Other = other cover types not listed, and NC = no cover.

The statistical analyses for the rearing habitat probabilistic model were conducted using microhabitat use and non-use data from the SFWW and mainstem Walla Walla study area. Logistic regression analysis was used to determine the association of subadult and adult bull trout with the microhabitat variables of depth, mean column velocity, substrate, and cover. First, we evaluated each of the variables in univariate models to help guide the structure of multivariate model candidates. Mean column velocity demonstrated the highest association with rearing use for both subadult and adult bull trout, with AIC values of 114.91 and 24.22, respectively (Table 17). Since our sample sizes were relatively small, we did not test various combinations of microhabitat variables in multivariate models. This testing is planned following completion of data collection when sample sizes are sufficient.

Table 17. Univariate model results for rearing subadult and adult bull trout microhabitat variables ranked in order of importance based on Akaike Information Criterion (AIC) scores.

Microhabitat Variable	**AIC Score**	
	Subadult (n=45)	Adult (n=12)
Mean column velocity	114.91	24.22
Cover	121.85	31.82
Depth	123.46	32.71
Substrate	135.65	40.27

Data were collected to characterize mesohabitat conditions at the habitat unit scale (pool, race) for subadult (n=45) and adult (n=17) bull trout. Our goal was to determine if mesohabitat conditions in a unit (in addition to microhabitat conditions) were associated with rearing bull trout presence/absence. Overhanging vegetation, debris piles, boulder-juvenile, and water temperature demonstrated the highest association with presence of both subadult and adult rearing bull trout (Tables 18 and 19). Overhanging vegetation and debris piles were most commonly associated with presence of rearing subadult bull trout, whereas water temperature and debris piles were most commonly associated with presence of rearing adult bull trout. Since our sample sizes were relatively small, we did not test various combinations of mesohabitat variables in multivariate models. This testing is planned following completion of data collection when sample sizes are sufficient. We also plan to test various combinations of both micro- and mesohabitat variables to determine if aspects of both sets of variables are influential in terms of rearing habitat selection by subadult and adult bull trout.

Table 18. Univariate model results for rearing subadult bull trout mesohabitat variables ranked in order of importance based on Akaike Information Criterion (AIC) scores.

Mesohabitat Variable	Subadult AIC Score
Overhanging Vegetation	128.116
Debris Pile	133.236
Boulder Juvenile	137.872
Water Temperature	140.473
Turbulence	141.545
Boulder Adult	141.561
Large Woody Debris	141.907
No Cover	142.370
Other Cover	143.865
Canopy Cover	147.099
Undercut Bank	147.234

Table 19. Univariate model results for rearing adult bull trout mesohabitat variables ranked in order of importance based on Akaike Information Criterion (AIC) scores.

Mesohabitat Variable	Adult AIC Score
Water Temperature	80.788
Debris Pile	82.449
Overhanging Vegetation	84.793
Boulder Juvenile	87.235
Boulder Adult	88.676
Turbulence	88.912
Large Woody Debris	88.922
No Cover	92.463
Other Cover	92.498
Canopy Cover	94.125
Undercut Bank	95.905

Stream Gage

Streamflows (i.e. river stage) in the SFWW at Harris County Park Bridge were steady at base flow (~90 cfs) throughout the bull trout spawning season during September and October. Rain events produced sharp, short-lived increases in streamflow and the corresponding river stage during November and December (Figure 34). River stage ranged from 1,974.70 to 1,976.07 feet and averaged 1,974.87 feet during this four month sampling period.

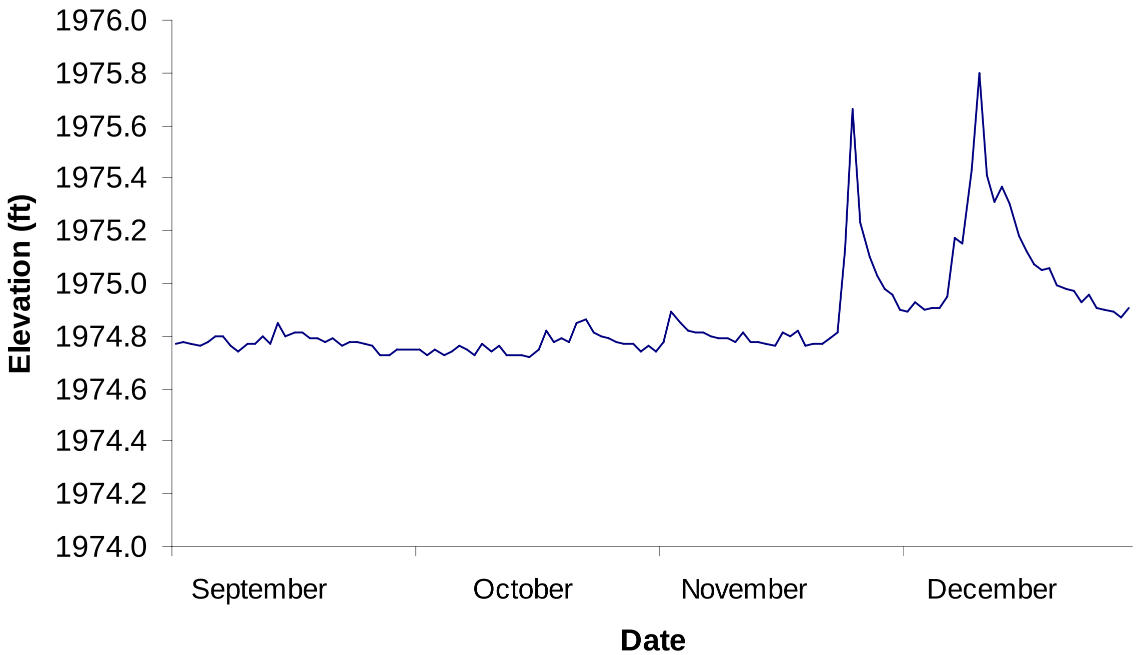

Figure 34. Daily average water surface elevation at the Harris County Park Bridge stream gage from September through December 2004.

Discussion

Distribution

Snorkel Surveys

Determining the spatial and temporal distribution and relative abundance of bull trout in the Walla Walla River from Harris County Park to the OR/WA state line is instrumental in understanding the life history, habitat use, and instream flow needs for bull trout in this section of the river. Many studies have stressed the need for accurate distribution and habitat use information in drainages where bull trout reside (e.g., Banish 2003; Mendel et al. 2001). These types of data are required at various spatial scales to understand the life history requirements and habitat needs of bull trout, and to focus restoration efforts that improve those attributes that are important to bull trout.

We conducted our snorkel surveys to address two specific questions regarding distribution; 1) Is bull trout density different among segments within each month considering the different physical conditions among the segments? and 2) Does bull trout density within a segment change across months as physical conditions change? Densities were always higher in segment 3 than in the downstream segments, although they were only significantly higher than densities in segment 1 during July, September, and October, and significantly higher than segment 2 densities during September. Variation around the mean densities resulted in wide confidence bounds for all of the estimates. This limited our ability to detect a significant difference between densities even if a difference was, in fact, present. Both low abundance and the cryptic behavior of bull trout probably contributed to these results. Considering our study area segments were designated to coincide with changes in physical conditions in the Walla Walla River, these results were not surprising. Base streamflows are relatively consistent between segments 2 and 3 (~90 cfs), although some additional flow is added in segment 2 from the North Fork. Base streamflows are substantially lower in segment 1, primarily from June through October (Figure 35) as a result of irrigation diversions at the Little Walla Walla Diversion. Streamflows range from about 15 to 30 cfs in segment 1 throughout the summer. This flow level in the Walla Walla River limits fish passage as well as the available habitat (i.e. physical living space), and contributes to elevated water temperatures.

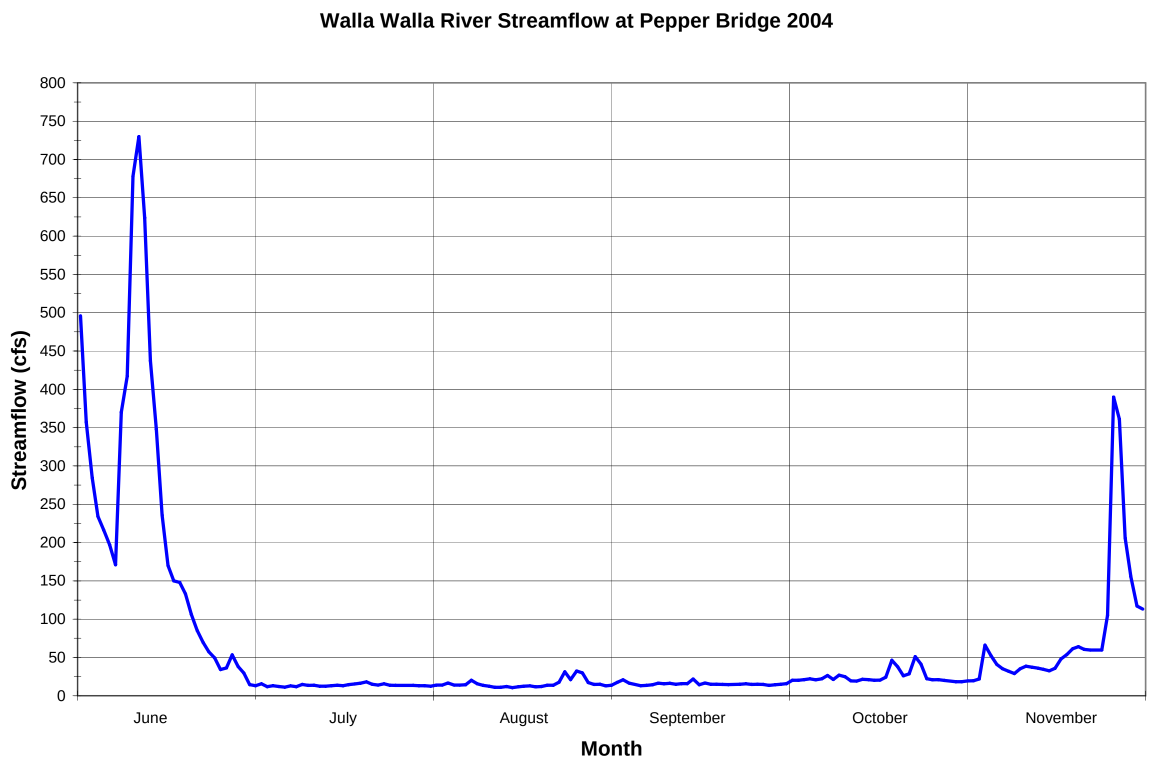

Figure 35. Streamflow measured in 2004 at the WDOE Pepper Bridge stream gage just downstream from the OR/WA state line on the Walla Walla River.

Water temperatures increase in a downstream pattern through the study area, becoming less suitable for bull trout. During the months of June through September, mean water temperatures range from approximately 10-13 °C in segment 3, to 12-16 °C in segment 2, to 15-19 °C in segment 1 (Figure 36). Increases in water temperature during the warmest months of July and August are relatively greater in segment 1 than in the upstream segments. This large increase in water temperature together with the large reduction in streamflow and poor quality mesohabitat conditions in segment 1 produce conditions that are marginal for bull trout. Poor riparian conditions, diking and stream channelization, and a lack of instream structure and cover, all limit the quality of habitat for bull trout in the downstream segments. Limited physical habitat as a result of low streamflows, high water temperatures resulting from low streamflows, lack of continuous riparian cover, reduced groundwater inflow, and poor mesohabitat conditions all likely contribute to the reduced abundance of bull trout in segment 1 compared to segments 2 and 3.

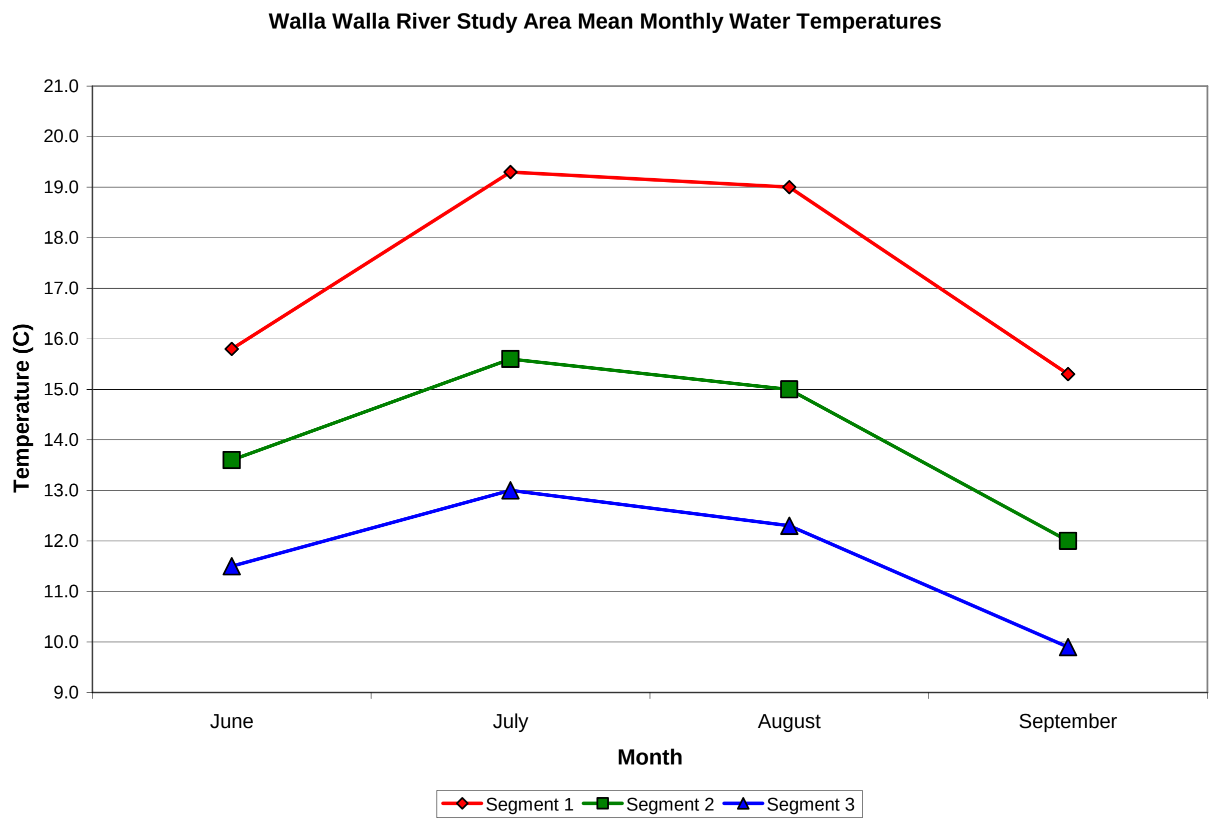

Figure 36. Mean monthly water temperature measured in 2004 at thermograph locations in study area segments 1, 2, and 3 on the Walla Walla River.

Differences in abundance of bull trout were observed within each of the segments across all months, although, variation around the mean densities limited our ability to detect significant differences. Densities in segment 3 varied somewhat between July and November, but were relatively consistent at a higher density level than we observed in downstream areas. Although, bull trout density in segment 2 appeared to be higher in July and October, and lower in August and September, over-lapping confidence intervals indicate these differences were not significant. Streamflows were consistent in these segments, and water temperatures, although not ideal, were tolerable, thus the consistent abundance of bull trout. Surprisingly, abundance appeared to be the most consistent in segment 1 across all months from June through November, although at low levels. We originally hypothesized that as streamflows declined, water temperatures increased, and conditions became marginal, bull trout would attempt to move back upstream to better conditions. The trend in abundance did not support this hypothesis. One possible explanation for this pattern could be associated with their migratory life history. In minimally impacted areas, fluvial subadult bull trout disperse into more productive downstream areas where food resources are more abundant than colder, headwater spawning areas. Subadults spend two to three years growing and maturing during this phase of their life history before returning upstream and recruiting into the spawning population. Their predisposition for this type of behavior may be strong enough to inhibit upstream movement as a response to these marginal conditions.

Many studies document higher bull trout encounters during night surveys than day surveys (Goetz 1994; Bonneau et al. 1995; Dunham et al. 2001). Our findings were not consistent with results from these studies. However, our results were consistent with Budy et al. (2004). They found similar abundance and distribution between paired day and night surveys in the SFWW. Our small sample size (n = 17) which reflected the low abundance of bull trout in our study area, could have affected these results. Water temperature may have also been a factor affecting these results. Some studies have shown when water temperatures are above 9°C, day and night snorkeling counts are similar (Bonar et al. 1997; Goetz 1994; Thurow and Schill 1996). During our surveys, eleven of seventeen paired day and night surveys were conducted when water temperatures exceeded 9°C.

It is not clear why higher numbers of bull trout were consistently observed at the NBD monitoring site compared to other pools throughout our study area. When water temperatures are high during the summer, bull trout may seek out larger, deeper pools that maintain slightly lower daily maximum water temperatures. Thermal stress can occur when water temperatures reach a threshold that produces significant changes to biological functions (McCullough et al. 2001). Selong et al. (2001) found that at constant temperatures greater than 18°C, bull trout had significantly reduced food consumption, growth, and food conversion efficiency, and exhibited outward signs of stress suggesting that extended exposure to elevated temperatures would rapidly deplete their energy reserves. Diel variation in water temperature in the Walla Walla River results in summer water temperatures near NBD that vary between approximately 14 – 22°C, with a mean of about 18°C. Although the experiments conducted by Selong et al. (2001) were at constant temperatures, we suspect bull trout may be experiencing similar effects from the diel pattern we observed. Since the larger, deeper pool at NBD exhibits slightly lower maximum daily water temperatures compared to surrounding areas, bull trout may reside there rather than moving further downstream or upstream. In addition, minimum daily water temperatures of about 14°C may provide enough relief to mitigate the higher temperatures experienced during the daily diel cycle. These daily low temperatures may also contribute the lack of movement out of the Nursery Bridge pool.

Water Temperature

Numerous studies have shown that bull trout are more sensitive to water temperature than other salmonid species, which in turn can affect growth, survival, and distribution (Shepard et al. 1983; Goetz 1989; Fraley and Shepard 1989). Our thermograph data indicated that water temperatures in the Walla Walla River were much higher than temperatures "normally" associated with bull trout habitat. Significant habitat alterations such as irrigation diversions, gravel push-up berms, levee construction, and riparian habitat removal have occurred in segment 1 and have likely contributed to warmer water temperatures. These same impacts can be observed in segment 2, although to a lesser degree, and water diversions in segment 2 are minor. Habitat alterations in segment 3 are the least extensive, and overall habitat conditions are the least impacted. The incremental effect of these modifications on water temperatures can be observed in Figure 36 and Table 8.

TIR data collected in 2003 revealed locations with cooler water temperatures within segment 1. Reconnaissance surveys to examine some of these locations showed a 3 to 6°C temperature difference between the ambient water temperature and the cool-water "seep". Water temperature measured approximately 20 meters upstream and downstream from the seep locations did not show a measurable influence from the seeps. These areas were not sampled for fish presence or usage, and their importance to bull trout is not known. Surveys should be conducted in the future to determine whether these areas are being used by bull trout as "cool-water refuges".

The Environmental Protection Agency (EPA) recommends a 12°C 7DADM ***upper optimal*** temperature for rearing (juvenile and subadult) bull trout before migration (USEPA 2003). They do not recommend specific migration temperature criteria, however, they believe that "rivers that currently meet or are restored to meet the 16 °C 7DADM summer maximum criterion will likely provide the cold water refuge that migrating adult bull trout are believed to need." 7DADM temperatures exceeded the EPA rearing criteria in all three segments during the months from June through September with the exception of segment 3 during September. Results from our snorkel surveys however, showed bull trout presence within each segment during all months, albeit at low densities. The EPA criteria are described as the ***"upper optimal"*** 7DADM. We conclude from our observations, that bull trout in the Walla Walla are able to tolerate significantly higher 7DADM temperatures than these criteria. We did not attempt to determine the level of thermal stress being experienced by bull trout in our study area, so we cannot assess whether any detrimental effects are occurring. However, our observations suggest that bull trout are currently using areas characterized by elevated water temperatures, and any improvements that can be made, even if they do not achieve currently accepted criteria, will improve conditions for bull trout and contribute to the expression of the migratory life history that requires use of these areas.

Movements

Rotary Screw Trap

The rotary screw trap was deployed primarily to determine if there was a time period when migratory bull trout migrated or dispersed into downstream rearing areas. The number of bull trout captured with the screw trap was relatively low (n = 32). Catch per unit effort was relatively low in March and April, and the highest in June. Length frequencies indicated all but one fish were subadults, likely one to three years old based on age-length relationships from Budy et al. (2004). Unfortunately, vandalism required us to remove the trap too soon to determine the overall pattern of downstream movement. Marked bull trout were released upstream from the screw trap, however none were recaptured and trap efficiency could not be determined. Trap efficiencies calculated by the CTUIR for steelhead and Chinook at this site ranged from 10-18%. It is unclear whether low screw trap efficiency or simply the number of bull trout moving past the trap during the trapping period resulted in the low catch. Subadult bull trout behavior during downstream migration is largely unknown, however rearing studies have indicated that older juveniles and adults are primarily bottom dwellers and often are associated with coarse substrates such as large cobbles and boulders (Watson and Hillman 1997, Fraley and Shepard 1989). Our snorkel surveys showed an average nose depth of 9.7 cm for undisturbed rearing bull trout in pools and races. The tendency of bull trout to be bottom-oriented may have contributed to the relatively low number of subadult bull trout captured by the screw trap. In order to lend some perspective to the total number of bull trout that may have passed this location, we used the 10% efficiency calculated for steelhead which, presumably would likely have been higher than the trap efficiency for bull trout. This would indicate that 320 bull trout would have passed the site. We hope to identify a site where sampling can be conducted to span a longer time period and produce a more comprehensive estimate of the pattern of migration or dispersal.

Our screw trap operations during 2004 indicated downstream movement of bull trout occurred from March through June, with the highest movement from mid-May to early June. Hemmingsen et al. (2002) found that downstream movement of smaller bull trout on Mill Creek occurred year-round and peaked in April, but their screw trap sample site was much closer to the spawning area. Of the months we sampled, the peak catch occurred during June, two months later than observed by Hemmingsen et al. (2002). This may have been a result of the relatively greater distance of our sample site downstream from the South Fork spawning area as compared to the site used by Hemmingsen et al. (2002). Since screw trap captures increased from May into June, and we did not sample later than June, expanded screw trap operations throughout the summer and fall would be required to describe the temporal pattern of subadult bull trout migration into downstream rearing areas of the mainstem Walla Walla River.

We also noted an interesting pattern of outmigration by steelhead and Chinook. Analysis of length frequency data suggested different migration timing for two size groups of both species. Larger steelhead and yearling Chinook, >120 mm and > 80 mm respectively, were captured primarily from March to May. These larger individuals were likely on their way downstream during the spring freshet to the ocean as outmigrant smolts. From May to June, smaller juvenile steelhead and Chinook, < 120 mm and < 80 mm respectively, were captured.

These smaller juveniles may have been dispersing to downstream rearing areas vacated by outmigrant smolts. This migration timing and dispersal is consistent with the description of Chinook life history summarized by Healey (1991).

PIT Tag Detection Arrays

In September and October of 2002, the FWS/USGS installed two PIT tag detection arrays on the SFWW; WW1 is located at Harris County Park Bridge (rkm 97.0) and WW2 is located near Bear Creek at rkm 105.6. We added detection arrays at NBD (rkm 74.3) in 2003 and 2004 to determine how many PIT-tagged subadult bull trout from the SFWW moved into downstream rearing areas, how many PIT-tagged adults moved downstream past NBD to over-winter and upstream past NBD to the SFWW spawning grounds, and to describe movement patterns. Although detection arrays are now present in both fish ladders at NBD, fish passage is still possible over the grade control structure (dam) during most streamflows. Bull trout have been PIT-tagged by USGS researchers since the summer of 2002 in the South Fork for a population assessment, and these fish were the source for downstream detections. During 2004, a total of 28 bull trout that were tagged in the SFWW moved downstream, past WW1, presumably demonstrating a migratory life history. The three bull trout we detected at NBD represented 11% of the total.

Detection histories for each of the three bull trout detected at our NBD detection array revealed migration patterns. The detailed detection history table presented in the Results section of this report is repeated here as Table 20 for reference associated with the following discussion regarding these migrations. We used length-at-age relationships from Budy et al. (2004), and preliminary growth rate versus size relationships from their work to add additional information to these migration patterns. One of the three bull trout detected at NBD was a subadult that measured 146 mm at the time of tagging. This fish reared in the upper South Fork for over 10 months before it moved downstream past WW1 during the spring of 2004. It then reared for an additional five months over the spring, summer, and fall in the South Fork and mainstem Walla Walla River before it was detected at NBD.

The remaining two bull trout were large, fluvial adults. The estimated age of the first fish at tagging was nine years. Since this fish was tagged in July, it may have subsequently spawned in late August or September, then moved downstream past WW2 and WW1. The next detection for this fish was almost nine months later at NBD in June of 2004. This coincides with the time when adults are moving back upstream towards the spawning grounds. Apparently, this adult passed downstream from NBD to over-winter without being detected. Following the June detection at NBD, this fish was detected passing WW1 in July, and WW2 in August on its way back to the spawning grounds.

Table 20. PIT tag detection histories, size at the time of tagging, estimated size at detection, and estimated age at tagging and detection for bull trout detected at the Nursery Bridge Dam PIT tag detection array. All fish were tagged in the South Fork Walla Walla River above the Harris County Park PIT array.

Tag ID	Date tagged (T)/ Date detected (D)	Length at tagging (T)/ Detection (D)[a]	Elapsed time between detections	Location tagged (T)/ Detected (D)[b]	Estimated age at tagging (T)/ Detection (D)[c]
3D9.1BF15A0A1A	7/25/2002 (T)	406 mm (T)	N/A	SFWW (T)	7+ (T)
	10/3/2002 (D)	409 mm (D)	2 months, 8 days	SFWW Harris Park (D)	7+ (D)
	6/5/2003 (D)	421 mm (D)	8 months, 2 days	SFWW Harris Park (D)	8 (D)
	6/9/2003 (D)	421 mm (D)	4 days	SFWW Bear Creek (D)	8 (D)
	11/29/2003 (D)	430 mm (D)	5 months,20 days	SFWW Harris Park (D)	8+ (D)
	6/5/2004 (D)	439 mm (D)	6 months, 6 days	Nursery Bridge (D)	8+ (D)
	7/9/2004 (D)	441 mm (D)	1 month, 4 days	SFWW Bear Creek (D)	9 (D)
	10/2/2004 (D)	445 mm (D)	2 months, 23 days	SFWW Bear Creek (D)	9+ (D)
	10/7/2004 (D)	445 mm (D)	5 days	SFWW Harris Park (D)	9+ (D)
3D9.1BF1B2B1B8	7/9/2003 (T)	453 mm (T)	N/A	SFWW (T)	9+ (T)
	8/23/2003 (D)	455 mm (D)	1 month, 14 days	SFWW Bear Creek (D)	9+ (D)
	9/28/2003 (D)	457 mm (D)	1 month, 5 days	SFWW Harris Park (D)	10 (D)
	6/21/2004 (D)	470 mm (D)	8 months, 24 days	Nursery Bridge (D)	10+ (D)
	7/14/2004 (D)	471 mm (D)	23 days	SFWW Harris Park (D)	10+ (D)
	8/5/2004 (D)	472 mm (D)	22 days	SFWW Bear Creek (D)	10+ (D)
3D9.1BF1B2DDB8	7/14/2003 (T)	146 mm (T)	N/A	SFWW (T)	1+ (T)
	5/22/2004 (D)	196 mm (D)	10 months, 8 days	SFWW Harris Park (D)	2+ (D)
	10/23/2004 (D)	221mm (D)	5 months, 1 day	Nursery Bridge (D)	2+ (D)

[a] – Detection length calculated using preliminary annual growth estimates from Budy et al. (unpublished).
[b] – SFWW Harris County Park = WW1; SFWW Bear Creek = WW2.
[c] – Tagging and detection age estimated using length at age data from Budy et al. (2004).

The second fluvial adult, estimated to be age seven at the time of tagging, was detected at WW1 in October, likely on its way to over-winter in downstream areas. The next detection was eight months later at WW1 during the time of upstream migration to the spawning grounds. It is likely this fish over-wintered somewhere between WW1 and NBD because it was not detected at NBD. It was subsequently detected passing WW2, presumably to spawn. Following spawning, it remained in the upper South Fork for five months until it was detected passing downstream of WW1 during November. The next detection was at NBD, six months later when the fish was moving back upstream to spawn again. Similar to the other fluvial adult, this fish likely over-wintered downstream of NBD and was not detected on it’s way downstream. This fish was then detected at WW2 during July and October, prior to, and following spawning. Five days later in October, it was detected passing WW1 on it’s way to over-wintering areas.

These migration patterns revealed useful life history information for both subadults and adults with a relatively high level of detail. The subadult bull trout reared for two to three years in the South Fork before migrating downstream for continued rearing. Based on the assumption that bull trout recruit into the spawning population at age 5, this subadult will likely need to spend at least two more years rearing, possibly in areas downstream from Milton-Freewater. This suggests that adequate rearing habitat needs to be available in this area to accommodate the migratory bull trout life cycle.

The two adult bull trout showed a migration pattern similar to what has been observed using radio telemetry (Mahoney 2003). This generally consists of migrating upstream through Milton-Freewater prior to, and throughout June, followed by arrival at the South Fork spawning grounds in July and August, then moving back downstream to over-winter during September through November. Based on these two adults, over-wintering occurred both upstream and downstream from Milton-Freewater. This may suggest that upstream passage needs to be adequate during the later stages of migration through early summer (June), and during the downstream migration to over-wintering areas in the fall, particularly September and October.

Following the initial effort associated with detection array installation and the ongoing efforts to PIT-tag bull trout, passive monitoring of movement has yielded cost effective data regarding migration patterns. We hope to not only continue the effort to PIT-tag bull trout in the South Fork and at locations in downriver areas, but also to expand the detection array system to provide more comprehensive spatial coverage of the Walla Walla River and eventually Mill Creek to further understand the migratory life history of fluvial bull trout.

PIT tag efficiency tests provided a relative measure of antenna performance which is an indication of the likelihood that a PIT-tagged fish will be detected. Our efficiency tests portrayed a "worst case" scenario, in that estimates of less than 100% were the result of a small "hole" in the center of the antenna. In reality, fish passing in close proximity to the edges of the antenna would be detected at near 100% efficiency. Thus, fish behavior is an important factor to consider when designing these types of detection arrays. Results of efficiency tests for 23 mm PIT tags indicated near a 100% detection rate. The majority of PIT-tagged bull trout in the Walla Walla basin have been tagged with 23 mm PIT tags. Considering the low bull trout abundance in downstream areas, we hope our high efficiency rates and fine tuning of the arrays will result in very few undetected fish moving past these sites. Though our efficiency test results indicated that detection of 12 mm tags ranged from extremely poor to inconsistent at NBD, 177, 12 mm tags were detected during 2004. Monthly variations in efficiency test results at the East bank antenna for both tag sizes were largely due to ambient noise caused by screen motors which are run as needed to clean debris from the fish ladder screens.

Video Monitoring

Our video monitoring in the West ladder at NBD was intended to supplement video monitoring conducted at the East ladder by the CTUIR with a goal of obtaining a relatively comprehensive estimate of bull trout movement past NBD. Since our PIT tag detection array only collects data for PIT-tagged bull trout, we did not have a quantitative estimate of total passage at NBD. Following the results from video monitoring in 2004, our conclusion is that comprehensive, accurate enumeration of bull trout movement past NBD may not be possible with the current equipment configuration and other available resources. Counts of bull trout obtained from the trap in the West ladder and from PIT detections in the East ladder indicated the video equipment in the West and East ladders was missing some unknown number of fish. Likely reasons for this included time periods of low visibility from high turbidity conditions, and fish position during passage. If fish position was such that it did not trigger the motion detector in the DVR (e.g. low in the field of view near the substrate), the fish passed undetected.

Various adjustments were made to increase the efficiency of the video equipment in the West ladder for detecting bull trout. Initially, fish had to exit the ladder suspended in the middle of the water column for the camera to obtain images sufficient for personnel to determine species and size. Because of the limited field of view of the camera and periods of high turbidity (low visibility), a weir was installed to direct fish to a more viewable position in relation to the camera. To further improve detection and the viewing area, an aluminum backboard and ruler were installed, the lighting angle was adjusted, and the underwater camera was refocused, making the fish more visible for identification purposes. Reducing the viewing area where fish could hold at the ladder in addition to adjusting the motion detection sensitivity when necessary to accommodate for changing water conditions helped decreased the number of false alarms. The final configuration of the equipment likely improved our detection efficiency, and we plan to continue refining our methods to determine if video monitoring is a cost-effective, useful sampling method for estimating total bull trout movement past NBD.

Habitat Suitability

Redd Surveys

Redd surveys were conducted in the SFWW to provide an annual relative index of abundance. Size classes were recorded in an attempt to separate resident and migratory bull trout redds. Resident bull trout redds in the Little Minam River (Powder River Basin) ranged in size from 0.24 m – 1.5 m with a mean of 0.7 m, and a standard deviation of 0.3 m. Redds in Mill Creek (Walla Walla River Basin) ranged in size from 0.4 m – 2.5 m with a mean of 1.27 m, and a standard deviation of 0.59 m (Bellerud et al. 1997). Redds in Mill Creek were not identified as resident or fluvial. Although the typical fluvial redd is larger than the typical resident redd, fluvial and resident redd sizes overlap. To reduce the uncertainty associated with identifying a redd as resident or fluvial, other data such as fish presence or known distribution of fluvial and resident spawners should be evaluated along with redd size.

Spawning Habitat Suitability Model

Our habitat suitability model task was intended to focus on fluvial, migratory bull trout. We plan to minimize the influence of physical data associated with resident spawners and their redds within our spawning model by eliminating use of data collected in Skiphorton Creek and Reser Creek where resident bull trout are believed to be more prevalent. Empirical data presented in this report were collected entirely from the SFWW, however all redd sizes were included. Additional screening of redd size data may be conducted before we finalize our spawning habitat suitability model to further minimize the influence of resident bull trout by only including the larger size classes of redds (e.g. >0.5 m).

Frequency distributions of microhabitat variable use, non-use, and availability observations lend insight into the types of spawning habitat bull trout prefer. Bull trout selected slightly shallower depths for redd sites in comparison to what was generally available. We observed a similar pattern for both mean column and nose velocities, although the selection of the lower end (< 1 m/s) of the available velocity range (< 2 m/s) by bull trout was a more significant departure from available conditions compared to the depth observations. The most obvious microhabitat variable preference by bull trout was for smaller substrate sizes. This variable was also the best predictor in a logistic regression univariate model followed by nose velocity. This was not surprising considering that the hydraulics of the stream, particularly velocity, largely determine the distribution of bed materials. The size of materials used for redd construction are usually partly a function of the body size of the particular species that is constructing the redd, and partly a function of the energy required to move those materials. Observations of conditions at bull trout redds supported this concept with the consistent selection of smaller bed materials at locations where velocity conditions reduced the energy required from the fish to move the materials. The univariate analysis also showed that depth and percent fines were not important predictors for redd site selection. With some minimum threshold, depth usually becomes secondary in importance for selection of suitable redd sites, primarily because of the overriding importance of velocity and substrate conditions. Percent fines was not a factor in redd site selection, and was not used in the univariate analysis. The watershed of the S.F. Walla Walla River does not have any significant sources of sediment or fines, and most fines that enter the stream are likely washed downstream as a function of the gradient and annual spring freshet. Thus the presence of fines is consistently low, and similar between redd sites and other areas of the stream.

Evaluation of the candidate multivariate logistic regression models produced patterns that followed the logic behind the univariate model results. This can be observed not only from the AIC scores themselves, but also from the effect of the addition and removal of individual variables. The different combinations of substrate and the two velocity variables demonstrate the relative association of redd sites with these metrics. The model using substrate and both of the velocity variables had the best AIC score as expected, and follows the previous univariate model discussion. Removing the mean velocity variable only, increased the AIC score by about 9.4 points, while removing the nose velocity variable only, increased the AIC score by about 63 points. This indicates that nose velocity has a much stronger association with redd site location than mean velocity. In addition, the two models with only the mean velocity variable (no nose velocity) had the highest AIC scores and the weakest association with redd sites. The addition of depth to any of the substrate/velocity combination models did not have a large effect on AIC scores. This was further evidence that depth is not a significant driver for redd site selection. Multivariate model evaluation will be completed and a suitability model will be finalized following completion of field data collection in 2005.

Rearing Habitat Suitability Model

Frequency distributions of microhabitat variable use and non-use indicated rearing bull trout were using specific habitats although the small sample size and low abundance of bull trout limit interpretation of preference patterns. Both subadult and adult bull trout consistently used the deeper, slower portion of the habitats where they occurred. Substrate observations indicated use of larger bed materials by both subadults and adults, presumably for the cover they provided, although there was not a significant difference between use and non-use observations. Of the eight cover types that occurred in the stream, bull trout consistently selected for large woody debris at the microhabitat scale, which is consistent with bull trout cover use patterns elsewhere (Muhlfeld et al. 2002, Watson and Hillman 1997). In addition, bull trout were more frequently associated with one of the cover types we described rather than with no cover. These observations are consistent with the cryptic and predatory behavior characteristics of bull trout.

We also collected data on mesohabitat conditions across each of the habitat units (race, pool) we observed. We hypothesized that overall habitat conditions (mesohabitat) in a unit may affect the tendency of rearing bull trout to use the microhabitat conditions in that unit. In other words, given similar microhabitat conditions between two habitat units, rearing bull trout would more commonly be found in those units with higher quality mesohabitat conditions. Again, our sample size limited the extent to which we could examine this hypothesis.

Preliminary univariate model evaluations using logistic regression analysis indicated that of the microhabitat variables we examined, mean column velocity was the best predictor for presence of both subadult and adult bull trout, followed by cover and depth. There was very little difference between the association of cover and depth with bull trout presence/absence, perhaps because use of depth may be essentially for the associated cover value. Univariate model evaluations for mesohabitat variables were more difficult to interpret. There was not a large difference in the association of bull trout with the range of variables we examined. Overhanging vegetation (riparian condition), debris piles (logjams), water temperature, and small boulders were the best mesohabitat predictors for both adult and subadult bull trout.

Often in habitat suitability studies, species are separated into different size classes because they exhibit changing patterns of utilization as they grow (Bovee 1986). For our study, the delineation between small and large fish was based on the size of bull trout captured at the Mill Creek diversion trap presumably returning to spawn in the upper watershed (T. Moore, ODFW, pers. comm.). We will continue to examine habitat variables separately for subadult and adult bull trout to determine if patterns of habitat use are different, and whether separate models will be required.

Analysis of microhabitat and mesohabitat variables for rearing bull trout should be considered preliminary due to the relatively small sample sizes from a single sample year. Additional data collection will increase our sample sizes and help to determine which variables are more consistently associated with rearing bull trout presence/absence.

Stream Gage

This stream gage was installed as a monitor for flows in the South Fork during the spawning season and to provide conditions associated with construction of a hydraulic model. A rating curve is currently under development to translate river stage into streamflow.

Plans for 2005

Following exploratory work conducted in 2003, we established two-year goals, objectives, and tasks for 2004 and 2005. We assumed two years would be required to accomplish our objectives considering the low abundance of bull trout in our study area. Thus we are planning on maintaining our work for an additional year during 2005 with an adjustment in our snorkel surveys. We will continue to conduct snorkel surveys to monitor distribution of bull trout within our study area, however, we will focus on segments 1 and 2 to concentrate our efforts in the more impacted downstream areas. Index pool surveys will continue with the same amount of effort as 2004. Night snorkel surveys may be discontinued based on the survey results from 2004. Thermographs will remain in similar deployment locations for 2005 for year round water temperature characterization. We are planning to expand our PIT tag detection array system with the addition of two new PIT tag arrays during early 2005. These arrays are providing useful information on movement patterns and expansion of the system will allow a more comprehensive, thorough understanding of movements of individual fish between spawning and rearing or over-wintering habitats. One antenna array, consisting of three separate antennas, will be added to Bennington Dam, a USACE site located on Mill Creek. A second array will be installed near the mouth of the Walla Walla River to investigate use of the mainstem Columbia River by Walla Walla basin bull trout. A single bull trout was observed at the McNary Dam adult fish counting facility by the smolt monitoring program on 21 December 2004. The bull trout was not marked so its origin is unknown, but the nearest bull trout populations are in the Walla Walla and Umatilla basins. We also have plans to increase efficiencies at the East bank antenna at NBD. Relocation of the antenna or constructing a shielded antenna could possibly help overcome ambient electrical noise caused by the fish screen cleaning motors.

The ODFW will continue video monitoring operations at the exit of the West bank fish ladder at NBD during 2005 utilizing and advancing techniques and equipment initially designed and deployed by CRFPO biologists.

Both the pressure sensor and the combination sensor will remain in operation throughout 2005. Ongoing quality assurance activities will include checking parameter measurement accuracy quarterly and performing recommended maintenance. A stage-discharge rating curve will also be developed in 2005.

We will complete data collection for our habitat suitability models during 2005. Spawning ground surveys will be conducted to obtain data for the spawning habitat model, and data for the rearing habitat model(s) will be collected during snorkel surveys.

Umatilla Basin

Background

Habitat conditions in the Umatilla River Basin are similar in many respects to those in the adjacent Walla Walla River Basin. The North Fork Umatilla River supports most, if not all, of the bull trout spawning in the basin and flows through the North Fork Umatilla Wilderness (Figure 37). It converges with the South Fork to form the Umatilla River, which flows for about 144 km to its confluence with the Columbia River. The upper 2.5 km of the Umatilla River is on U.S. Forest Service land. The river flows through private land for the remainder of its length. Small, forested private holdings in the upper section give way primarily to dryland agriculture that stretches to the town of Pendleton (rkm 86.0). There are no major water diversions in this reach, but 16 small diversions (ditches or pumps) were noted in 1994 (Contor 1995). Summer water temperatures may be suitable for salmonids only in the upper 16 km, from a point just upstream from the mouth of Meacham Creek to the mouth of the North Fork Umatilla River (Contor 2004). Bull trout may be limited further to the upper 6 km at times during the summer (C. Contor, CTUIR, pers. comm.). The high summer water temperatures are believed to be a result of habitat alterations in the tributaries and mainstem, including removal of riparian vegetation, channelization, logging, and grazing (U.S. Fish and Wildlife Service 2004).

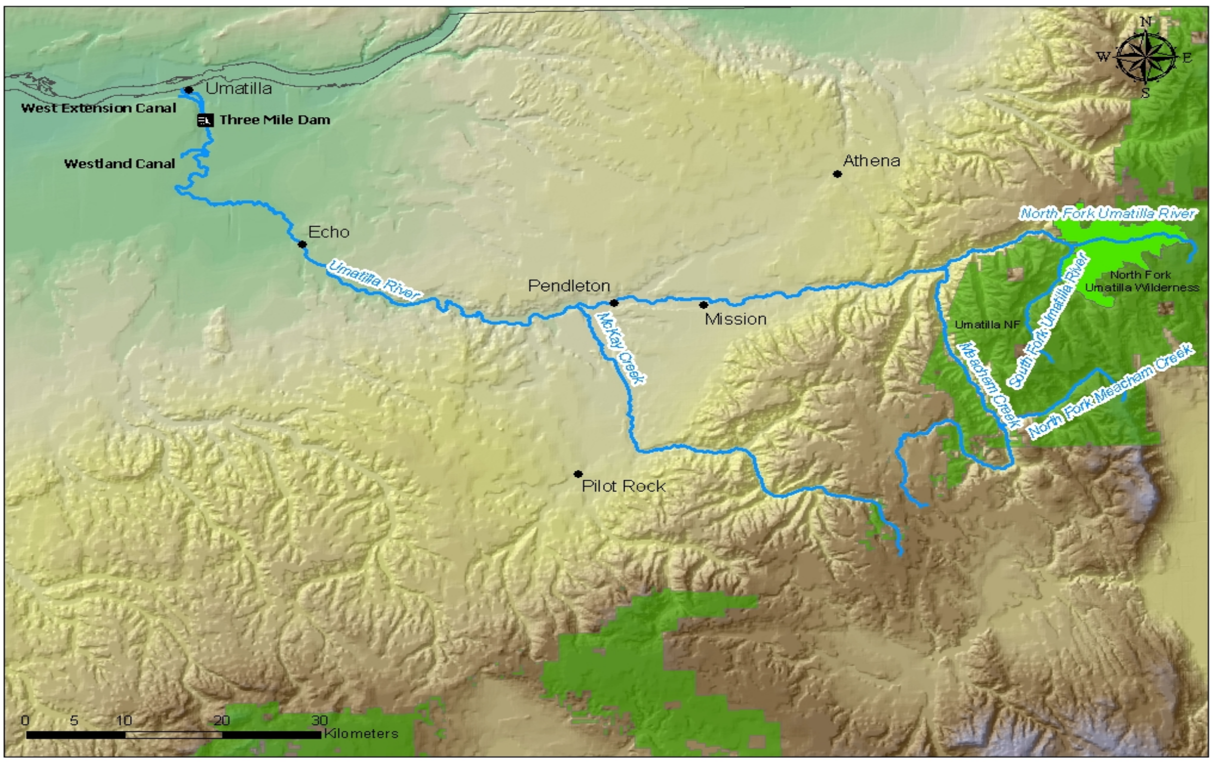

Figure 37. Map of the Umatilla Basin showing Three Mile Dam, Umatilla National Forest, and North Fork Umatilla Wilderness.

Along the river downstream from Pendleton, irrigated agriculture dominates, and there are six major irrigation dams and diversions. Historically, sections of the lower river were often dewatered during the irrigation season (March-October). Congress enacted the Umatilla River Project Act in 1988 to ensure adequate flows were provided for migrating salmon and steelhead. As part of the project, water has been pumped from the Columbia River into the basin for agricultural use, and an equivalent amount has been left in the Umatilla River to allow for fish passage. Despite this "water exchange", there continues to be time periods (typically from mid-July to late August) when sections of the mainstem Umatilla River downstream from the Westland Canal (rkm 43.0) and the West Extension Canal (rkm 6.0) (Figure 37) have inadequate streamflows to provide fish passage. During these periods, upstream-migrating salmonids are trapped at Three Mile Dam (rkm 6.0), hauled upstream by truck, and released in the upper river. Downstream migrants trapped at a juvenile collection facility at the Westland diversion are hauled to the Columbia River and released. All of the dams in the lower river have ladders, but they are designed for passage of adult salmon and steelhead. It is not known if bull trout can negotiate them. The 16-km section of the mainstem Umatilla River downstream from the mouth of McKay Creek (rkm 82.0) is the only section of the lower river thought to have summer temperatures suitable for salmonids (Contor 2004). This section of the stream is kept artificially cool by hypolimnetic water releases from McKay Reservoir.

The Draft Bull Trout Recovery Plan (U.S. Fish and Wildlife Service 2004) identifies two local populations of bull trout in the Umatilla River basin. The Upper Umatilla River local population includes bull trout in the North Fork and South Fork Umatilla rivers. Despite the inclusion of the South Fork in the complex, it is likely the North Fork supports the majority of this local population. No redds have been observed in the South Fork since 1994, and at that time only one redd was counted. The second local population is the North Fork Meacham Creek local population. North Fork Meacham Creek and its tributary, Pot Creek, may have supported bull trout spawning in the recent past. Two bull trout redds were identified in North Fork Meacham Creek in 2002, but none have subsequently been observed (S. Starcevich, ODFW, pers. comm.).

Recent population surveys in the North Fork Umatilla River indicate bull trout abundance is fairly low. Redd counts in an index reach that encompasses all but a small portion of the available spawning habitat rose from a low of 19 in 1995 to a high of 144 in 1999, and have ranged from 45 to 48 the last three years (J. Stephenson, USFWS, pers. comm.). From 50 to 56 redds have been counted over the last three years during more extensive surveys that included all known spawning habitat (S. Starcevich, ODFW, pers. comm.). Mark-recapture studies conducted in 2003 and 2004 indicated there were approximately 2,000 to 2,500 bull trout in the 120-220 mm size class and about 25 larger, fluvial adult-sized fish (Budy et al. 2004; R. Al-Chokhachy, Utah State University, pers. comm.). No information is available on the abundance of fluvial and resident fish in the population, but based on redd sizes observed during spawning surveys, there appear to be some resident female spawners present (T. Bailey, ODFW, pers. comm.).

Telemetry studies of fluvial adult bull trout captured in the upper Umatilla River and lower North Fork showed those fish, for the most part, migrated seasonally within the area between rkm 118.0 on the Umatilla River and rkm 9.0 on the North Fork (Sankovich et al. 2003, 2004; J. Germond, ODFW, pers. comm.) (Figure 38). One individual was recorded as far downstream as rkm 63.0, but none were observed in the more highly impacted lower river. CTUIR biologists operated screw traps at various locations (rkm 68.0, 122.0, and 128.0) on the Umatilla River in the 1990s (Contor et al. 1995, 1996, and 1997). No bull trout were caught at the lower trap site. The two upper traps captured four to 139 bull trout each year. Based on the lengths of these fish (147-395 mm fork length (FL)) they were likely a mix of fluvial adults and subadults. Other observations of subadults in the upper drainage have been made infrequently in Ryan and Iskuulpa creeks (Figure 38).

There have been only eight recorded observations of bull in the lower Umatilla River since 1995. Five bull trout have been captured in the upstream migrant trap at Three Mile Dam (rkm 6.0), one each on 26 June 1995 (size unknown), 28 May 1996 (300 mm), 13 June 1999 (254 mm), 7 June 2000 (343 mm), and 10 May 2002 (330 mm). One bull trout (size and date of capture unknown) was observed at a juvenile collection facility at Westland Canal. Two others were captured incidentally at rkm 42.0 and 68.0 in a steelhead fishery and presumably were larger individuals given the gear type. Finally, two smaller bull trout were salvaged from McKay Creek in November 1999 after water releases from McKay Reservoir ended for the winter.

The factors limiting bull trout production in the Umatilla basin currently are not well understood, although several have been proposed (U.S. Fish and Wildlife Service 2004). A more complete understanding of the life history and migratory patterns of bull trout in the basin is required to begin identification of limiting factors. Past telemetry work provided a description of the seasonal movements of fluvial adult bull trout, although that description may not have been comprehensive given the documented presence of some larger bull trout in the lower Umatilla River since 1995. Subadult migrations for the most part have not been described. Thus, our goal in 2004 was to begin to develop a more detailed understanding of the life history and migratory patterns of bull trout in the basin including gaining an understanding of potential restrictions to subadult movement and distribution due to barriers, low flow conditions, or high stream temperatures. Both the Draft Recovery Plan for bull trout (U.S. Fish and Wildlife Service 2004) and Draft Umatilla/Willow Subbasin Plan (Northwest Power and Conservation Council 2004) place importance on conducting such an investigation.

The recovery objectives, criteria, and tasks described in the Draft Recovery Plan for bull trout were discussed earlier under the Walla Walla Basin section, and these objectives, criteria, and tasks are also the basis for our work in the Umatilla Basin.

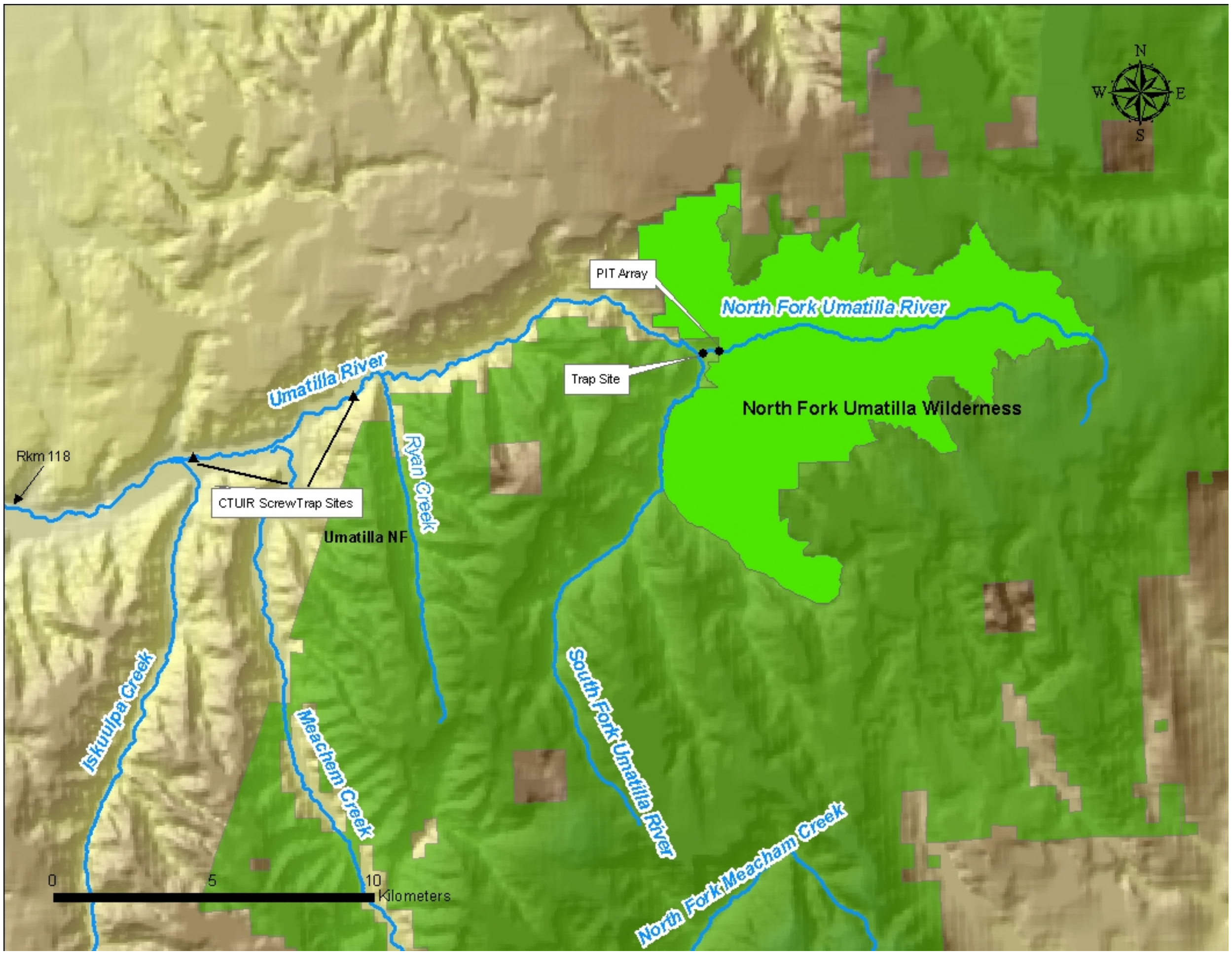

Figure 38. Map of the upper Umatilla Basin showing the CTUIR screw trap sites, downstream migrant trap site, and PIT tag detection array location.

Methods

Movements

Radio Telemetry

We chose to use radio telemetry to describe the distribution and movement of subadult bull trout in the Umatilla River subbasin. We attempted to capture bull trout for tagging by operating a downstream migrant trap in the North Fork Umatilla River from 23 September to 17 November 2004. We selected this timeframe for several reasons. First, based on screw-trapping data collected in the mid-1990s (Contor et al. 1995, 1996, and 1997; and C. Contor, CTUIR, pers. comm.), we expected fall trapping would offer the greatest likelihood of capturing a sufficient number of subadults large enough for tagging. Second, the expected life of our radio tags was approximately 9.5 months. By tagging fish in fall, we could monitor movement during the fall-spring period, when bull trout are not restricted by warm water temperatures from migrating throughout the Umatilla River. Finally, it was unlikely we could maintain a trap in the North Fork during the winter and early spring because the upper portion of the road leading to the North Fork is not maintained during the winter and is typically impassable due to snow.

The trap was installed initially, about 200 m upstream from the mouth of the North Fork (Figure 38) and designed as described by Hemmingsen et al. (2001b), with a perforated aluminum fyke connected to a holding box by a 15-cm diameter, plastic irrigation pipe, and with weir panels extending upstream from the fyke in a v-shape and spanning about two-thirds of the stream's width. In early October, deciduous tree leaves began to accumulate in large numbers on the fyke and weir panels, slowing flow into the fyke and making the trap inefficient. Therefore, we modified the trap and moved it 20 m downstream. At this location, there was a plunge next to one bank that dropped about 0.5 m onto a shallow, bedrock shelf that transitioned quickly into a pool. We anchored a 1-m diameter, 2.4-m long, throatless hoop net in the stream so that it led from the head of the plunge, down into the bedrock area. A 1-m wide, 7-m long net pen was attached to the hoop net's exit and anchored in the pool to provide slack water refuge for trapped fish. Weir panels were angled upstream from the mouth of the hoop net and across the thalweg to direct downstream migrants into the hoop net. This trap design relied on the shallowness of the bedrock area and high water velocity at the base of the plunge to prevent fish from jumping or swimming up out of the hoop net's entrance from below. Because the hoop net had no throat, leaves passed readily through it and settled out in the net pen, which was of sufficient size to hold a large quantity of leaves and still provide ample room for trapped fish.

We had trapped no subadults by 9 November 2004, so on that date we began snorkeling at night in an attempt to locate bull trout and capture them with a dip net. We continued snorkeling through December, as stream conditions allowed. We initially focused our search in the mainstem Umatilla River. It supports no bull trout spawning, so we could be certain any smaller bull trout observed would be subadults and not resident fish or fluvial juveniles. After finding few subadults in the upper 10 km of the mainstem, we began snorkeling the North Fork. We decided to snorkel it rather than search lower in the Umatilla River because we assumed the winter distribution of subadults would be similar to that of fluvial adults, which winter primarily in the upper 20 km of the Umatilla River (Sankovich et al. 2003; J. Germond, ODFW, unpublished report), and because the habitat in the upper and lower 10 km of that 20 km reach is similar. It seemed likely, therefore, that we would find no more bull trout in the lower 10 km than we had in the upper 10 km of the mainstem, which appeared to be highly under-seeded. We risked radio-tagging non-migratory fish in the North Fork; however, we believed there was a good chance any subadult-sized fish we might tag would become migrants and leave before summer 2005. None of 76 bull trout that were 120-220 mm FL when captured and marked in the North Fork during summer 2003, were observed in the North Fork in summer 2004 (R. Al-Chokhachy, Utah State University, pers. comm.). We had snorkeled a 2-km reach of the North Fork near the upper limit of the bull trout distribution by the end of the reporting period. Bull trout density was highest in this reach the preceding summer (Robert Al-Chokhachy, Utah State University, pers. comm.).

We began snorkeling each evening with the onset of darkness and continued until as late as 2300 hours. We focused on slower, deeper-water habitats, particularly those containing large woody debris; however, we also inspected other habitats periodically. When bull trout in the target size class (196-250 mm) were located, we attempted to capture them by slowly herding them with a dive light into a dip net and quickly lifting it from the water.

Our tagging methods followed those described by Sankovich et al. (2003), except the hypodermic needle used to guide the radio tag antenna through the body wall was shielded with a cocktail straw. We also used a portable, battery-powered water pump rather than a turkey baster to irrigate the gills. The radio tags (Lotek model NTC-4-2L) had a 12 hr on and 12 hr off duty cycle, 7.8-8.2 s burst rate, and expected life of 295 d. They weighed 2.1 g in air and were $\leq$3% of the host fish's weight. We chose to exceed Winter's (1996) "2% rule" for three reasons. First, using a length/weight relationship developed by Budy et al. (2004) for bull trout in the North Fork Umatilla River, we determined bull trout weighing 70 g (tag weight equal to 3% of fish weight) versus 105 g (2%) would be about 196 mm FL versus 225 mm FL. Reducing the size limit for tagging would allow us to better represent the subadult population, which was likely weighted heavily toward fish under 225 mm FL (see, for example, the screw-trapping data reported in Hemmingsen et al. 2002). Second, Winter (1996) offered no justification for the "2% rule," and Brown et al. (1999) subsequently showed transmitters weighing up to 12% of a fish's weight had no effect on swimming performance. Finally, Jakober et al. (1998) found the distance moved by radio-tagged bull trout did not differ between fish with transmitter weights less than or greater than 2% of body weight.

No data were available for Umatilla River bull trout to indicate the upper length limit for subadults that might distinguish them from fluvial adults. In nearby Mill Creek (Walla Walla River Basin), downstream migrants captured in December-August, when post-spawning fluvial adults generally would not be returning downstream, were almost all <250 mm FL (Hemmingsen et al. 2001c, 2002). Thus, we set the upper limit for tagging at 250 mm FL.

We tracked the radio-tagged fish by road. Bull trout generally move little in winter once they locate suitable habitat, so we tracked only once per month. Fish positions were recorded using a GPS unit. The coordinates were later entered into a mapping program (MAPTECH's Terrain Navigator) to determine the location, in river kilometers, of each individual.

PIT Tag Detection Array

Bull trout movements out of the North Fork Umatilla River were also monitored using a PIT tag detection array near the mouth of the North Fork (Figure 38). The PIT tag detection array consisted of a full duplex interrogation system (Destron Fearing FS1001A), an antenna array custom built for this application, and a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission). Power was supplied with an onsite combination of solar panels, batteries, and a generator. Remote data upload was accomplished using satellite communications (Figure 39).

Figure 39. PIT tag detection array in the North Fork Umatilla River. On the left is the shed that houses the electronics, computer, and generator. Solar panels and satellite dish are visible on the roof. On the right the antenna array can be seen mounted to a bridge.

PIT tag detection arrays enable passive monitoring of the presence and movement of the bull trout that were PIT-tagged in the North Fork. Bull trout were PIT-tagged in the North Fork during 2003-2004 as part of an ongoing population assessment study (Budy et al. 2003, 2004). The relatively efficient passive monitoring using PIT tag detection arrays together with the ongoing comprehensive tagging effort is an important part of our goal to better understand migratory bull trout life history, and the temporal and spatial aspects of their distribution and movements.

Routine inspection and maintenance of PIT tag detection arrays were conducted to ensure reliable data collection and system operation. Antenna detection efficiency tests were conducted periodically to estimate the proportion of the antenna field that consistently detected a PIT tag that passed through the apparent field. Methods used to conduct efficiency tests were described earlier in this report.

Results

Movements

Radio Telemetry

We trapped only one bull trout in the North Fork Umatilla River in 2004. It was captured at the lower trap site on 19 October and was 293 mm FL. It was likely a fluvial adult at this size, so we did not tag it. We also trapped 167 juvenile Chinook salmon (*Oncorhynchus tshawytscha*), 59 juvenile steelhead or rainbow trout (*O. mykiss*), three mountain whitefish (*Prosopium williamsoni)*, and 13 sculpin (*Cottus spp.*).

While snorkeling at night, we found 13 bull trout, nine in the Umatilla River and four in the North Fork. Five of the bull trout, all observed in the mainstem on 17 November 2004, were estimated to be the appropriate size for tagging. We were able to capture and tag two of them. They were released at their capture sites at rkm 142.8 and 143.2 (Table 21) and remained at those locations through the end of the year.

Table 21. Date of release, radio tag code, fork length (FL), weight (Wt), and capture and release location of subadult bull trout in the Umatilla River.

Date of Release	Tag code	FL(mm)	Wt(g)	Rkm
11/18/04	050	195	76	143.2
11/18/04	049	190	70	142.8

PIT Tag Detection Array

The PIT tag detection array was installed and brought online on 20 October 2004. Only one PIT-tagged bull trout was detected. This fish was a subadult (229 mm) when it was tagged in the North Fork on 15 July 2004 during the previous summer. It was detected between 20 October and 04 December at the array.

Discussion

Movements

Radio Telemetry

We were unsuccessful trapping fall-migrating subadult bull trout in the North Fork Umatilla River. We believe their absence in the catch was a reflection of their abundance, not of poor trap efficiency. The North Fork population appears to have declined to a relatively small size in recent years. Redd counts in the index reach have fallen from 99 – 144 during 1999 – 2001, to 45 – 48 during 2002 – 2004 (John Stephenson, USFWS, pers. comm.), and only about 25 fluvial adults were estimated to be present in the North Fork the past two summers (although the estimates were imprecise; R. Al-Chokhachy, USU, pers. comm.). The abundance of bull trout in the 120-220 mm size class was estimated at 2,505 (95% confidence limits of 2,088 and 4,005) and 1,976 (1,375-4,190) during the summers of 2003 and 2004, respectively (Budy et al. 2004; R. Al-Chokhachy, USU, pers. comm.). Given these figures, the presence of non-migratory, resident bull trout in the population, and that most subadults migrate downstream in spring and early summer (see, for example, Hemmingsen et al. 2001a), it is plausible that fall migrants were few in number, if not entirely absent.

Although we did not evaluate the efficiency of our trap, we do not believe avoidance of the trap by bull trout was a problem. Other salmonids appeared to be captured readily. In addition, almost all were captured after rain events increased stream discharge. Subadults likely were not migrating downstream with the dry weather and base flows that prevailed during the brief period when the original trap was operating inefficiently due to leaf accumulations. Finally, when the trap and a PIT tag array located about 100 m downstream from it were operating simultaneously (20 October to 17 November 2004), only one PIT-tagged bull trout (229 mm when tagged in summer 2004) was detected passing the array. One hundred and forty-two bull trout captured and tagged in the North Fork in summer 2003 and 2004 potentially would have been available for detection (Budy et al. 2004; R. Al-Chokhachy, USU, pers. comm.).

We located only a small number of bull trout while snorkeling the upper 10 km of the Umatilla River and the upper end of the bull trout distribution in the North Fork. Assuming our snorkeling efficiency was not low, this suggests subadult density in the mainstem was low, as might be expected given the relatively small population size. We anticipated finding more bull trout in the upper North Fork than we did given the density observed during studies the preceding summer. It is possible that many had emigrated from that area before we snorkeled it. Jakober et al. (1998) observed extensive downstream movement of bull trout with declining fall water temperatures in two Montana headwater streams. If this type of movement occurred in the North Fork, we would expect, based on the absence of bull trout in the trap catch in fall, most of the bull trout remaining in the North Fork to be between the trap site and the lower end of the reach we snorkeled. We plan to spend the winter of 2004-05 snorkeling in this area in an attempt to locate fish for tagging.

PIT Tag Detection Array

The North Fork Umatilla array did not become operational until fall of 2004. The single subadult that was detected, reared for an additional 3-5 months in the North Fork before moving into downstream rearing areas. Although subadult bull trout have been observed to migrate downstream during the fall, spring migrations have also been observed and may be the primary time period for downstream dispersal. We hope to determine how many of the 142 bull trout that were PIT-tagged during the previous two summers in the North Fork eventually move downstream. We assume the level of downstream migration will be an indication of the relative proportion of the population that is fluvial or migratory.

Plans for 2005

We will continue snorkeling the North Fork Umatilla River through the winter in an attempt to capture subadult bull trout for tagging. We will operate a rotary screw trap for this purpose in the Umatilla River, at a site about 400 m downstream from the mouth of the North Fork, from April through June. Radio-tagged bull trout will be tracked throughout the year. We will consider installing a PIT tag array at rkm 127.0 if the tracking and spring trapping data indicate it would be useful to do so.

We will begin to investigate the life history and migratory patterns of bull trout from the North Fork John Day River drainage by radio tagging fluvial and subadult-sized bull trout. We will work with cooperators from Utah State University to capture fish for tagging. We will also tag any bull trout captured by investigators from ODFW operating screw traps in the North Fork, Middle Fork, and mainstem John Day rivers, and seining in the John Day River below the town of Spray, OR.

References

Al-Chokhachy, R. Utah State University. Personal communication. 2004.

Bailey, T. ODFW. Personal communication. 2004.

Banish, N. P. 2003. Diel summer habitat use by bull trout, Salvelinus confluentus, in eastern Cascade streams. Master's Thesis. University of Georgia, Athens, Georgia.

Baxter, J. S. and J. D. McPhail. 1997. Diel microhabitat preferences of juvenile bull trout in an artificial stream channel. North American Journal of Fisheries Management 17:975-980.

Bellerrud, B. L., S. Gunkel, A. R. Hemmingsen, D. V. Buchanan, and P. J. Howell. 1997. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon. 1996 Annual Report. Bonneville Power Administration. Portland, OR.

Bonar, S. A., M. Divens, and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout and dolly varden. Washington Department of Fish and Wildlife, Research Report RAD97-05, Olympia, Washington.

Bonneau, J. L., R. F. Thurow, and D. L. Scarnecchia. 1995. Capture, marking, and enumeration of juvenile bull trout and cutthroat trout in small, low-conductivity streams. North American Journal of Fisheries Management 15:563-568.

Bovee, K. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Instream Flow Inf. Pap. 21. U.S. Fish Wildlife Service Biol. Rep. 86(7).

Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge the "2% Rule" for biotelemetry. North American Journal of Fisheries Management 19:867-871.

Buchanan, D., M. L. Hanson, R. M. Hooton. 1997. Status Of Oregon's Bull Trout, Distribution, Life History, Limiting Factors, Management Considerations, and Status. 1997 Technical Report, Report to Bonneville Power Administration, Contract No. 1994BI34342, Project No. 199505400, 185 electronic pages (BPA Report DOE/BP-34342-5).

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 Proceedings of the Friends of the Bull Trout Conference. Calgary, Alberta.

Budy, P., R. Al-Chokhachy, and G. P. Thiede. 2003. Bull trout population assessment and life-history characteristics in association with habitat quality and land use in the Walla Walla River Basin: a template for recovery planning. Annual Progress Report for 2002. USGS Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah.

Budy, P., R. Al-Chokhachy, and G. P. Thiede. 2004. Bull trout population assessment and life-history characteristics in association with habitat quality and land use: a template for recovery planning. Annual Progress Report for 2003. USGS Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information –theoretic approach. 2nd edition. Springer-Verlag. New York, N.Y.

Contor, C. R., E. Hoverson, and P. Kissner. 1995. Umatilla basin natural production monitoring and evaluation, Annual Progress Report 1993-94. Bonneville Power Administration, Portland, Oregon.

Contor, C. R., E. Hoverson, P. Kissner, and J. Volkmann. 1996. Umatilla basin natural production monitoring and evaluation, Annual Progress Report 1994-95. Bonneville Power Administration, Portland, Oregon.

Contor, C. R., E. Hoverson, P. Kissner, and J. Volkmann. 1997. Umatilla basin natural production monitoring and evaluation, Annual Progress Report 1995-96. Bonneville Power Administration, Portland, Oregon.

Contor, C. R. 2004. Umatilla basin natural production monitoring and evaluation, 1999-2002 Summary Report. Bonneville Power Administration. Portland, Oregon.

Contor, C. R. Personal communication. 2004.

DeVries, P. 1997. Riverine salmonid egg burial depths: review of published data and implications for scour studies. Canadian Journal of Aquatic Science. 54: 1685-1698.

Dunham, J.B., and B.E. Rieman. 1999. Metapopulation structure of bull trout: Influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications. 9: 642-655.

Dunham, J. B., B. E. Rieman, and G. L. Chandler. 2001. Development of field-based models of suitable thermal regimes for interior Columbia Basin salmonids. Final Report to U.S. Environmental Protection Agency, Seattle, WA. Interagency Agreement #00 IA-11222014-521.

Earle, J. E., and J. S. McKenzie. 2001. Habitat use by juvenile bull trout in mountain streams in the Copton Creek drainage, Alberta and its relation to mining activity. Pages 121-128 *in* M. K.

Faux, R. N. 2003. Aerial surveys in the Walla Walla River Basin: Thermal infrared and color videography. Report to the U.S Fish & Wildlife Service, Columbia River Fisheries Program Office.

Fernet, D. A., and C. P. Bjornson. 1997. A Delphi analysis of bull trout habitat preference criteria with comparison to information collected from Smith-Dorrien Creek, Alberta. Pages 435-442 *in* W. C. Mackay, M. K. Brewin, and M. Monita, editors. Friends of the Bull Trout Conference Proceedings, Bull Trout Task Force, Calgary, Alberta.

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

Germond, J. ODFW. Personal communication. 2004.

Goetz, F. 1989. Biology of the bull trout. United States Department of Agriculture, Forest Service, Willamette National Forest, literature review, Eugene, Oregon.

Goetz, F. A. 1994. Distribution and juvenile ecology of bull trout (Salvelinus confluentus) in Cascade Mountains. Master's thesis. Oregon State University, Corvallis.

Healey, M. C. 1991. Life history of chinook salmon (Oncorhynchus tshawytscha). Pages 313-393 *in* C. Groot and L. Margolis editors. Pacific Salmon Life Histories. UBC Press, Vancouver, British Columbia.

Helfman, G. S. 1983. Underwater Methods. Pages 349-369 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Hemmingsen, A. R., B. L. Bellerud, S. L. Gunckel, and P. J. Howell. 2001a. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1998 Annual Report. Bonneville Power Administration, Portland, Oregon.

Hemmingsen, A. R., B. L. Bellerud, D. V. Buchanan, S. L. Gunckel, J. S. Shappart, and P. J. Howell. 2001b. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 1997 Annual Report. Bonneville Power Administration, Portland, Oregon.

Hemmingsen, A. R., S. L. Gunckel, P. M. Sankovich, and P. J. Howell. 2001c. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 2000 Annual Report. Bonneville Power Administration, Portland, Oregon.

Hemmingsen, A. R., S. L. Gunckel, P. M. Sankovich, and P. J. Howell. 2002. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon, 2001 Annual Report. Bonneville Power Administration, Portland, Oregon.

Jakober, M. J. 1995. Autumn and winter movement and habitat use of resident bull trout and westslope cutthroat trout in Montana. Master's thesis, Montana State University, Bozeman, 1995.

Jakober, M. J., T. E. McMahon, R. F. Thurow, and C. G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Lambert, M. 2004. Personal communication. CTUIR.

Mahoney, B. 2003. Summer Steelhead and Bull Trout Radio Telemetry. Chapter Six, *in* Contor, C. R. and A. D. Sexton, editors. Walla Walla Basin Natural Production Monitoring and Evaluation Project Progress Report, 1999-2002. Confederated Tribes of the Umatilla Indian Reservation. Report submitted to Bonneville Power Administration, Project NO. 2000-039-00.

McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of technical literature examining the physiological effects of temperature on salmonids. Issue paper 5. Environmental Protection Agency, EPA-910-D-01-005.

McPhail, J.D., and J. Baxter. 1996. A Review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Fisheries Management Report No. 104. Department of Zoology, U.B.C., Vancouver, B.C.

Mendel, G., D. Karl, and T. Coyle. 2001. Assessment of salmonid fishes and their habitat conditions in the Walla Walla River basin: 1999 Annual Report. Washington Department of Fish and Wildlife. Report to Bonneville Power Administration, Contract No. 1998BI07035, 105 electronic pages (BPA Report DOE/BP-07035-2).

Moore, T. 2004. Personal communication. Oregon Department of Fish and Wildlife.

Muhlfeld, C., S. Glutting, R. Hunt, D. Daniels, and B. Marotz. 2002. Hungry Horse mitigation Flathead River native species project 2001 progress report. Montana Fish Wildlife and Parks, Kalispell, Montana.

Northwest Power and Conservation Council. 2004. Draft Umatilla/Willow Subbasin Plan.

Northwest Power and Conservation Council. 2004. Walla Walla Subbasin Plan.

OWEB. July 1999. The Oregon Plan for Salmon and Watersheds. Water Quality Monitoring Technical Guidebook (version 2.0). Oregon's Watershed Enhancement Board. http://oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf.

Rantz, S. E. 1982. Measurement and Computation of Streamflow. USGS Water Supply Paper 2175. http://water.usgs.gov/pubs/wsp/wsp2175/index.html.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124:285-296.

Rieman, B. E. and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. United States Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-302, Ogden, Utah.

Sankovich, P. M., S. L. Gunckel, A. R. Hemmingsen, I. A. Tattam, and P. J. Howell. 2003. Migratory patterns, structure, abundance, and status of bull trout populations from subbasins in the Columbia Plateau, 2002 Annual Report. Bonneville Power Administration, Portland, Oregon.

Sankovich, P. M., S. J. Starcevich, A. R. Hemmingsen, S. L. Gunckel, and P. J. Howell. 2004. Migratory patterns, structure, abundance, and status of bull trout populations from subbasins in the Columbia Plateau and Blue Mountain Provinces, 2003 Annual Report. Bonneville Power Administration, Portland, Oregon.

Sexauer, H.M. and P.W. James. 1997. Microhabitat use by juvenile bull trout in four streams located in the eastern Cascades, Washington. Pp. 361-370 in Friends of the Bull Trout Conference Proceedings (Mackay, W.C., M.K. Brewin, and M. Monita, eds.). Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary, AB.

Schill, D. J., and J. S. Griffith. 1984. Use of underwater observations to estimate cutthroat trout abundance in the Yellowstone River. North American Journal of Fisheries Management 4:479-487.

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 in fishes. Transaction of the American Fisheries Society 130:1026-1037.

Shepard, B. B., and P. J. Graham. 1983. Fish resource monitoring program for the upper Flathead basin. Montana Department of Fish, Wildlife and Parks. EPA Contract R008224-01-4, Kalispell.

Starcevich, S.J. ODFW. Personal communication. 2004.

Stephenson, J. USFWS. Personal communication. 2004.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management. 14:837-851.

Thurow, R. F. 1994. Underwater methods for study of salmonids in the intermountain west. United States Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-GTR-307, Ogden, Utah.

Thurow R. F., and D. J. Schill. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second order Idaho stream. North American Journal of Fisheries Management 16:314-323.

U.S. Environmental Protection Agency. 2002. Draft: EPA Region 10 guidance for Pacific Northwest state and tribal temperature water quality standards. 2nd Public Review Draft, October 10, 2002. 36 pp.

U.S. Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

U.S. Fish and Wildlife Service. 1998. Klamath River and Columbia River bull trout population segments: status summary. Prepared by the Service's bull trout listing team.

U.S. Fish and Wildlife Service. 2002. Chapter 11, Umatilla-Walla Walla Recovery Unit, Oregon and Washington. 153 p. *In*: U.S. Fish andWildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

U.S. Fish and Wildlife Service. 2004. Unpublished revised draft. Chapter 10, Umatilla-Walla Walla Recovery Unit, Oregon and Washington. 160 p. May 10, 2004.

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.

Winter, J. 1996. Advances in underwater biotelemetry. Pages 555-590 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda, Maryland.

Zydlewski, G. B., C. Winter, D. McClanahan, J. Johnson, J. Zydlewski, and S. Casey. 2002. Evaluation of Fish Movements, Migration Patterns, and Population Abundance with Streamwidth PIT Tag Interrogation Systems, Project No. 2001-01200, 72 pages, (BPA Report DOE/BP-00005464-1).

Appendix A

Table A1. Average minimum, mean, and average maximum monthly temperature data from June through December 2004 for 15 thermographs located on the Walla Walla River.

Thermograph Location			Average monthly temperatures (°C)											
			June			July			August			September		
	Segment	rkm	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Site 15 (Harris County Park)	3	97.0	8.5	10.6	13.4	9.3	11.7	14.9	9.3	11.1	13.5	7.9	9.0	10.4
Site 14 (CTUIR hatchery)	3	92.8	8.8	11.1	13.8	9.8	12.4	15.2	9.9	11.7	13.8	8.2	9.4	10.6
Site 13 (Red Steel Bridge)	3	88.5	9.7	11.8	14.1	11.1	13.4	15.5	11.2	12.8	14.2	9.2	10.2	11.0
Site 12 (Upstream of forks)	3	84.4	10.4	12.5	14.8	12.1	14.3	16.4	12.2	13.7	15.2	9.9	10.9	12.0
Site 11[a] (Downstream of forks)	3	83.1	11.0	13.1	15.2	12.9	14.9	16.9	12.9	14.3	15.9	10.5	11.4	12.6
Site 10 (Joe West Bridge)	2	82.0	11.1	13.3	15.5	13.2	15.2	17.3	13.1	14.5	16.3	10.7	11.6	12.9
Site 9 (Day Road)	2	80.5	11.5	13.5	15.8	13.7	15.6	17.8	13.6	15.0	16.8	11.0	12.0	13.3
Site 8 (Upstream of Grove St Bridge)	2	77.9	11.7	13.9	16.2	13.9	16.0	18.4	13.8	15.4	17.4	11.1	12.3	13.7
Site 7 (Cemetery Bridge)	2	76.3	11.8	14.1	16.5	14.1	16.3	18.9	14.0	15.7	17.9	11.3	12.5	14.1
Site 6[b] (Nursery Bridge Dam)	1	74.2	NA	NA	NA	NA	NA	NA	14.4	16.3	19.1	11.5	12.9	15.1
Site 5[c] (Downstream NBD)	1	74.0	12.3	14.7	17.5	NA	NA	NA	14.6	16.5	19.3	11.6	13.1	15.2
Site 4[d] (Levee Section)	1	72.2	12.6	15.5	19.1	15.0	18.3	22.8	14.8	17.5	21.4	NA	NA	NA
Site 3[e] (Downstream of Tumalum)	1	70.0	13.3	15.8	19.2	16.7	19.4	22.8	16.4	18.8	21.9	12.9	15.0	17.8
Site 2 (Between Tumalum & Pepper's)	1	68.4	13.4	15.5	18.1	17.3	18.8	20.9	17.2	18.6	20.4	14.0	15.2	16.5
Site 1 (Pepper's Bridge)	1	66.3	13.7	16.2	19.3	17.3	19.8	23.0	17.4	19.6	21.9	14.3	15.7	17.5

[a] Thermograph found dry during 19 June to 22 June 2004 and moved to new location 25 m downstream. Data removed from dataset.
[b] Thermograph not launched until 20 July 2004.
[c] Thermograph found dry on 20 July 2004 and re-launched immediately.
[d] Thermograph found dry on November 9. Data showed thermograph was dry from 18 September to 9 November 2004. Data for November includes 9 November to 30 November 2004.
[e] Thermograph location was suspected to dry up. Thermograph was moved to a new location 380 meters downstream on 25 June 2004.

Table A1 (continued).

Thermograph Location		Average monthly temperatures (°C)										
			October			November			December			
	Segment	rkm	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	
Site 15 (Harris County Park)	3	97.0	6.5	7.2	8.1	4.9	5.4	5.9	4.1	4.6	5.0	
Site 14 (CTUIR hatchery)	3	92.8	6.7	7.5	8.2	4.9	5.4	5.9	4.1	4.6	5.0	
Site 13 (Red Steel Bridge)	3	88.5	7.3	8.0	8.6	5.1	5.7	6.2	4.2	4.7	5.2	
Site 12 (Upstream of forks)	3	84.4	7.8	8.5	9.1	5.3	5.9	6.4	4.3	4.9	5.4	
Site 11[a] (Downstream of forks)	3	83.1	8.3	8.9	9.6	5.5	6.1	6.6	4.4	4.9	5.4	
Site 10 (Joe West Bridge)	2	82.0	8.4	9.0	9.8	5.6	6.1	6.7	4.4	5.0	5.4	
Site 9 (Day Road)	2	80.5	8.6	9.2	10.1	5.1	5.7	6.2	4.5	5.0	5.5	
Site 8 (Upstream of Grove St Bridge)	2	77.9	8.6	9.4	10.3	5.6	6.3	6.9	4.5	5.0	5.6	
Site 7 (Cemetery Bridge)	2	76.3	8.7	9.6	10.6	5.7	6.4	7.0	4.5	5.1	5.7	
Site 6 [b] (Nursery Bridge Dam)	1	74.2	8.8	9.8	11.3	5.5	6.3	7.2	4.4	4.9	5.5	
Site 5 [c] (Downstream NBD)	1	74.0	8.9	9.9	11.4	5.6	6.4	7.2	4.4	5.0	5.6	
Site 4 [d] (Levee Section)	1	72.2	NA	NA	NA	5.5	6.4	7.4	4.6	5.2	5.9	
Site 3 [e] (Downstream of Tumalum Bridge)	1	70.0	9.6	11.1	13.3	5.5	6.5	7.9	4.4	5.0	5.7	
Site 2 (Between Tumalum & Pepper's)	1	68.4	10.8	11.7	12.6	6.1	6.9	7.8	4.5	5.1	5.9	
Site 1 (Pepper's Bridge)	1	66.3	11.2	12.1	13.3	6.5	7.2	8.0	4.5	5.1	5.8	

[a] Thermograph found dry during 19 June to 22 June 2004 and moved to new location 25 m downstream. Data removed from dataset.
[b] Thermograph not launched until 20 July 2004.
[c] Thermograph found dry on 20 July 2004 and re-launched immediately.
[d] Thermograph found dry on 9 November 2004. Data showed thermograph was dry from 18 September to 9 November 2004. Data for November includes 9 November to 30 November 2004.
[e] Thermograph location was suspected to dry up. Thermograph was moved to a new location 380 meters downstream on 25 June 2004