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

2006 Annual Progress Report

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Abstract

A better understanding of bull trout *Salvelinus confluentus* life history strategies is necessary to identify corrective actions that will make progress toward recovery in the Walla Walla Basin. This report describes studies conducted by the U.S. Fish and Wildlife Service during 2006 on the South Fork Walla Walla River, the mainstem Walla Walla River and Mill Creek (tributary to the Walla Walla River) with the goal of obtaining detailed information on bull trout life history to assist with development and evaluation 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.

To better understand the distribution of bull trout, we operated PIT tag detection arrays in the South Fork Walla Walla River, Mill Creek, and the Mainstem Walla Walla River. We interpreted detection data while considering detection efficiency, migration patterns and past and present sampling efforts to describe the distribution of bull trout. Although bull trout were not detected during all months at South Fork Walla Walla River PIT arrays, it is likely bull trout were distributed in the South Fork Walla Walla River throughout the year. It is also likely bull trout were distributed down to Nursery Bridge Dam in the upper Walla Walla River during all months except August and September, when streamflows were generally low and stream temperatures were relatively warm. In Mill Creek bull trout were detected during all months at the most upstream PIT array at Kiwanis Camp Bridge. Although bull trout were not detected during all months at the lower Mill Creek PIT array at Mill Creek Diversion Dam, it is likely bull trout were distributed down to Mill Creek Diversion Dam throughout the year except August through October when streamflow was generally low and stream temperatures were relatively warm. No bull trout were detected at the lower Mainstem Walla Walla River detection array. Detection efficiency at the lower Walla Walla River PIT array from January through June was <11% and never reached 100% from July through December, as a result it is possible bull trout passed the array undetected. Therefore, bull trout distribution in this area is unknown.

To better understand the seasonal movements in the upper Walla Walla River and lower Mill Creek, bull trout detected at Nursery Bridge Dam or Mill Creek Diversion Dam were separated into adults and subadults and directional movement data was summarized. Adult upstream migrations were detected during April – June and downstream migrations were detected during October-December and February. Most detections of subadult bull trout suggest a downstream dispersal past the PIT arrays. Subadult bull trout were detected during all months except January–March and August–September. Adult and subadult bull trout may have passed undetected during January–March as a result of decreased detection efficiency associated with increased streamflow. The absence of detections during August and September suggest adult and subadult bull trout did not pass the arrays when flows were low and likelihood of detection was high.

To lead to a better understanding of bull trout distribution and movements in the WWR, we began tagging bull trout near Milton-Freewater, OR. We captured and PIT tagged 11 bull trout using dip nets and hook and line sampling between June 26 and July 19, 2006. We discontinued sampling on 19 July 2006 when water temperatures increased to unsafe sampling levels.

Determination of the physical habitat preferences of spawning and rearing bull trout is an important step in the process of evaluating existing conditions and developing actions to improve the habitat. We continued development of a spawning habitat suitability model by collecting validation data.

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 for the Umatilla-Walla Walla Recovery Unit (U.S. Fish and Wildlife Service 2002, Chapter 10). The goal of bull trout recovery planning in the Umatilla-Walla Walla Recovery Unit 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, Chapter 10-revised). 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 the Walla Walla Basin:

- 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, which are native to the Walla Walla Basin, exhibit two different life history strategies. Fluvial (migratory) 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 Basin, 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 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 Basin. Instream flows and the associated habitat must be adequate to provide spawning opportunities, rearing opportunities, cover, forage, seasonal movement, migration opportunities, and over-wintering refuges.

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 (Northwest Power and Conservation Council 2004). The Walla Walla Basin is comprised of the Touchet River Subbasin, the Mill Creek Subbasin, and the Walla Walla River (WWR) Subbasin. The primary headwater tributaries originate in the Blue Mountains and include the North and South Forks of the WWR, 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*) (Northwest Power and Conservation Council 2004). Currently, steelhead are the only remaining native anadromous salmonid population in the Walla Walla Basin. A supplementation program for Chinook salmon was initiated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in 2000 in the South Fork Walla Walla River (SFWWR) using outplanted adults to initiate spawning. The current plan is to continue supplementation using spring releases of Chinook salmon hatchery smolts. Populations of native redband trout, bull trout, and mountain whitefish still persist in the Walla Walla Basin.

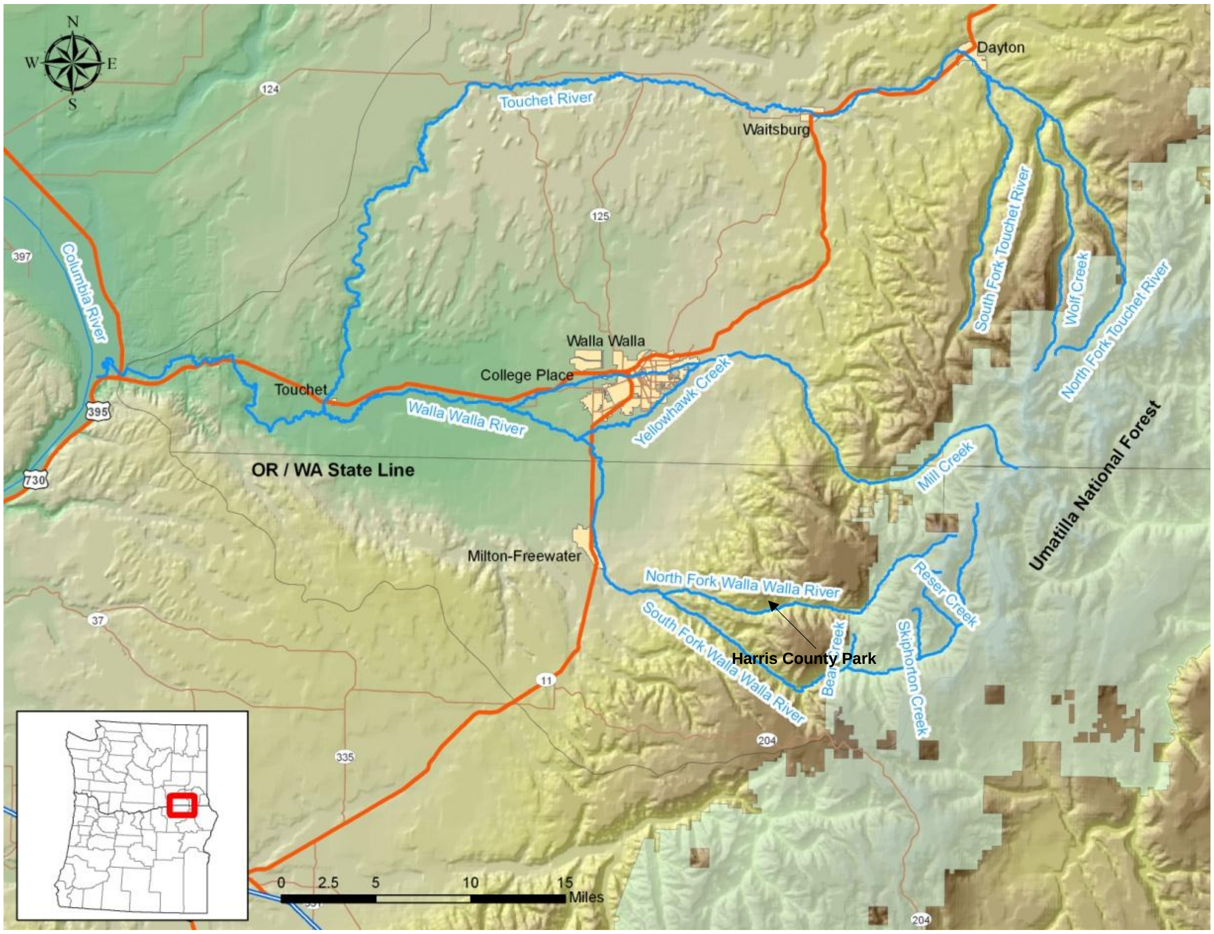

Figure 1. Map of the Walla Walla Basin showing the Touchet River, Mill Creek, and the WWR subbasins, and the Umatilla National Forest.

Most bull trout in the WWR Subbasin spawn in the SFWWR 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 SFWWR (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.

The ODFW collected data on bull trout movement and passage in the WWR while monitoring steelhead migrations through the West bank fish ladder at Nursery Bridge Dam (NBD; river kilometer [rkm] 74.3) in Milton-Freewater, OR. The trap was typically operated from December through late May/early June from 1994 to 2001 (T. Bailey, ODFW, pers. comm. February 2004). Trap data from 1994 through 2001 (Figure 2) suggested that upstream migration of adult bull trout 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 in four of the eight years sampling was conducted, and it was pulled prior to mid-June during the remaining four years.

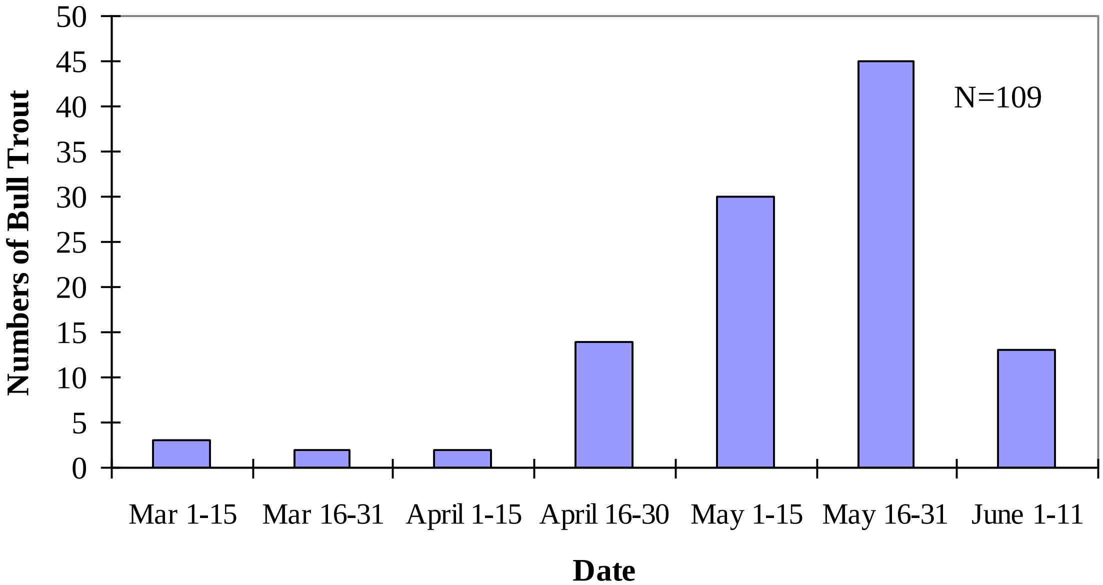

Figure 2. Total numbers of adult bull trout moving upstream in the WWR past NBD in Milton-Freewater, OR based on bi-weekly trap counts from 1994-2001 at the West bank fish ladder (T. Bailey, ODFW).

The CTUIR and ODFW conducted radio telemetry studies from 2001 through 2004 to monitor migration timing for adult fluvial bull trout moving between the SFWWR spawning area and mainstem wintering areas. They confirmed that some adult bull trout overwinter as far downstream as the OR/WA state line (Mahoney et al. 2006).

It is unclear if there is an active downstream migration of fluvial subadults from the SFWWR 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 SFWWR 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 SFWWR 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 SFWWR spawning area to impacted mainstem habitats, and their fate as water temperatures increase during the summer irrigation months is unknown. The ODFW have been capturing and PIT tagging bull trout in upper Mill Creek near rkm 42 since 2000 to investigate life history strategies, primarily focused on spawning migrations. In 2005 they initiated a study to investigate the seasonal movements of subadult fluvial bull trout in Mill Creek (Moore et al. 2006). They continued PIT tagging bull trout in upper Mill Creek and installed a PIT tag detection array at Kiwanis Camp Bridge (rkm 34.7). Although the work was focused in upper Mill Creek, PIT tagged individuals that survived and moved downstream into our study area were available for additional detections.

Physical habitat generally becomes increasingly degraded downstream from the Umatilla National Forest Boundary on the SFWWR and mainstem WWR. 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 WWR 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 WWR. 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 WWR 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 SFWWR, and transferability evaluations were conducted using the North Fork Umatilla and South Fork Wenaha rivers.

The CRFPO bull trout studies were focused on the WWR and Mill Creek Subbasins in 2006 with the goal of collecting and analyzing life history data to assist in assessing the relative merit of potential action strategies in making progress towards meeting the recovery goal 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.

To make progress on the habitat objective, a number of steps may be required. A fundamental step should be to determine the physical conditions that comprise suitable bull trout habitat. A subsequent step should be application of these habitat "criteria" to current conditions in the Walla Walla Basin to determine whether suitable habitat conditions are present. Following this evaluation, potential changes in current conditions, or actions to improve bull trout habitat in the Basin should be identified. And finally, implementation of those changes and/or actions should be pursued on a prioritized basis.

The recovery objective that describes genetic diversity could be accomplished by maintaining physical connectivity among local populations of bull trout to facilitate gene flow and genetic exchange. 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 downstream fish passage, and providing a continuum of suitable physical habitat to ensure the persistence of fluvial life stages and to provide the opportunity for genetic exchange.

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

- Identify data 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 the data and analyses from these studies to assist in guiding actions that will make progress towards bull trout recovery.

Study Area

Our study area in 2006 included the WWR from Nursery Bridge Dam to the confluence of the WWR and Columbia River, and in Mill Creek Walla from Bennington Diversion Dam to the confluence of Mill Creek and the WWR (Figure 3).

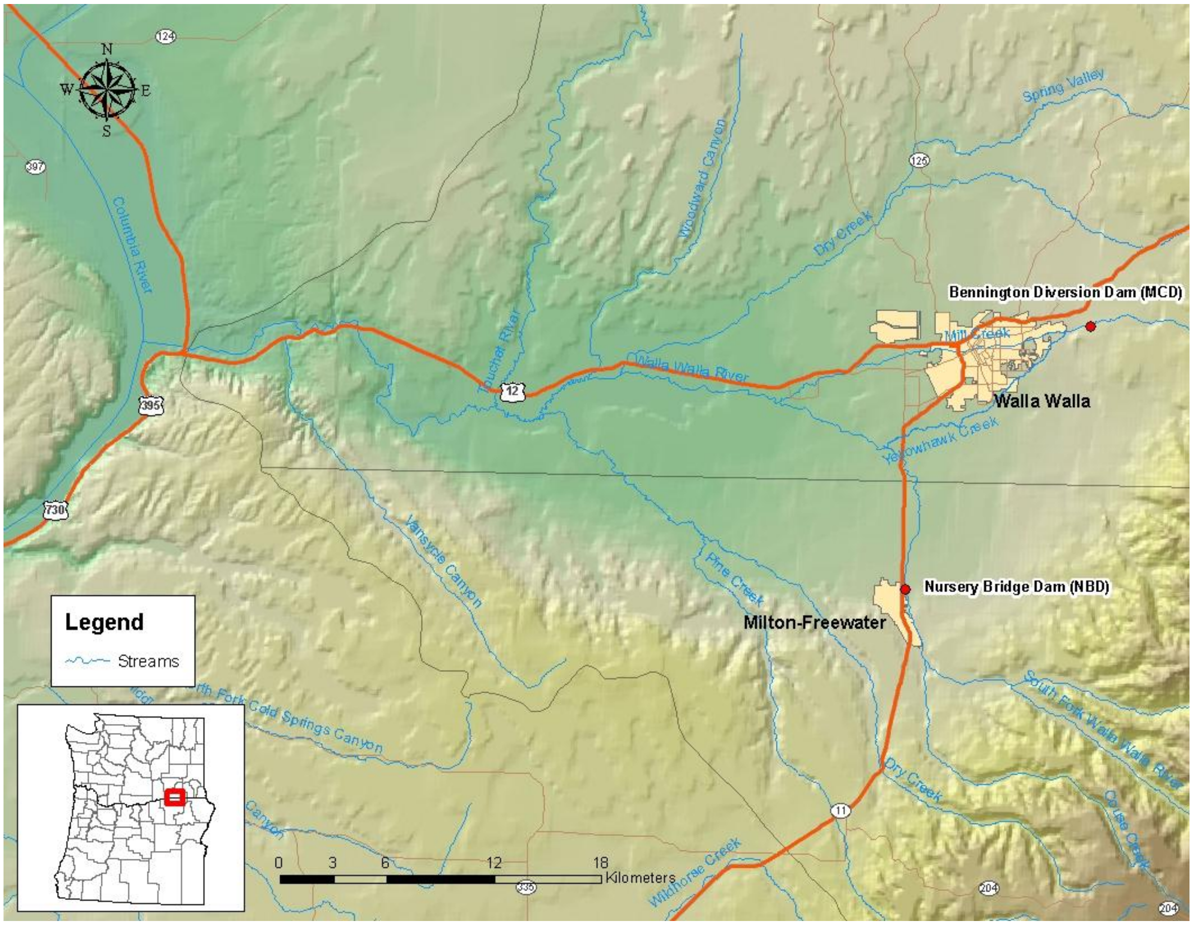

Figure 3. Map of the 2006 study area which included the WWR downstream from NBD, Mill Creek downstream from MCD and Yellowhawk Creek.

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 2006. Bull trout populations in the Walla Walla Basin exhibit both resident and fluvial, or migratory life history strategies. Resident bull trout in the upper WWR local population are primarily located in the SFWWR upstream from Harris County Park where impacts are minimal. Thus, our study objectives were designed to address the fluvial portion of this population. It is this 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 within a Core Area, as well as metapopulations of bull trout among Core Areas. In order to make progress towards these recovery objectives, the temporal and spatial distribution of the adult and subadult fluvial bull trout were required.

Temporal and spatial distribution data were required for bull trout 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 obtain these data during 2006:

1) <u>Distribution</u> – Determine the spatial and temporal distribution of adult and subadult bull trout in the SFWWR, WWR and Mill Creek and continue monitoring water in those areas.

2) <u>Movements</u> – Describe the movement patterns of adult bull trout between spawning and overwintering areas and of subadult bull trout within the SFWWR, WWR, and Mill Creek.

3) <u>Habitat suitability</u> – 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.

Methods

Distribution

Snorkel Surveys

Snorkel surveys were not conducted during 2006. During 2004-2005, the FWS conducted snorkel surveys in the SFWWR and WWR to answer two questions 1) Are there fewer bull trout in stream segments with degraded habitat in comparison to relatively pristine habitat, 2) Where is the lower extent of bull trout distribution during the summer and fall. We determined that there were fewer bull trout in the degraded habitat segments we investigated. Also, no bull trout were observed downstream of NBD during July through September in either 2004 or 2005. The lack of observations downstream from NBD from July through September suggest that bull trout are either not present or snorkel surveys may be too inefficient to detect bull trout presence at the densities which they exist in this stream segment. As a result, snorkel surveys were discontinued during 2006.

PIT Tag Detection Arrays

To monitor the distribution and movements of migratory bull trout we used a system of PIT tag detection arrays (Zydlewski et al. 2002). The relatively efficient passive monitoring throughout the year using PIT tag arrays provided temporal distribution data on bull trout detected at PIT tag arrays. The PIT tag arrays, also provided spatial information on bull trout distribution, but additional data may be required to infer distribution in between PIT tag arrays.

The PIT tag arrays were previously installed at 6 locations. WW1 and WW2 were located in the SFWWR (Budy et al. 2003), NBD and ORB were located in the WWR (Gallion et al. 2015a) and KCB (Moore et al. 2006) and MCD were located in Mill Creek (Figure 4). One additional array was installed near the head gate of Yellowhawk Creek (YHC). The PIT tag detection arrays consisted of full duplex interrogation systems (Destron Fearing FS1001A or FS1001M), antenna arrays custom built for each application, and a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission).

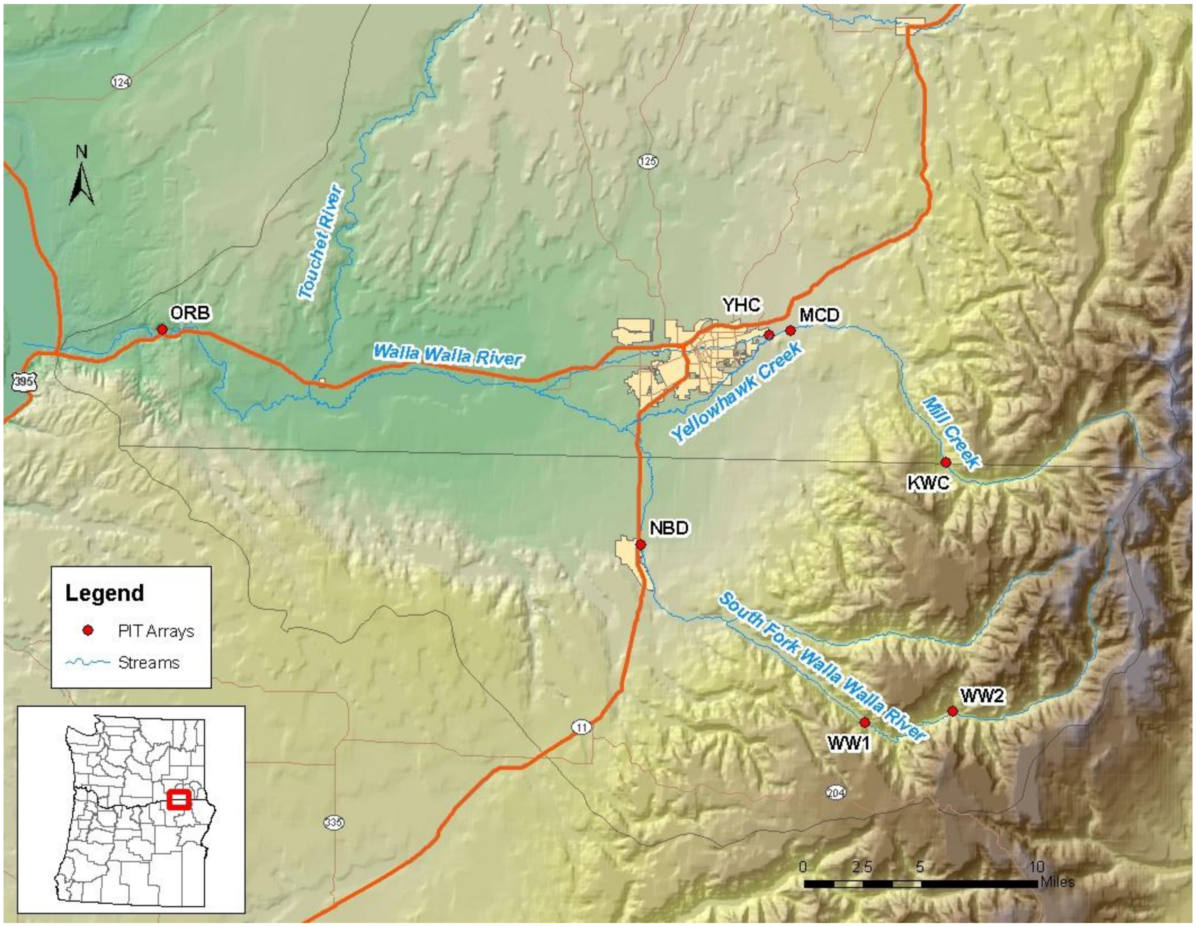

Figure 4. Locations of PIT tag detection arrays operated during 2006.

The KCB array was operated by the ODFW. The operational details of KCB are not readily available and are not reported here. Details regarding operation of WW2, WW1, NBD, MCD, YHC, and ORB are described below.

In coordination with USGS, we continued to operate the WW2 PIT tag detection array during 2006. The WW2 PIT tag detection array consists of a full duplex interrogation system (Destron Fearing FS1001A), a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission) and antennas custom built for this site. Two pass through (PT) antennas (Figure 5) were previously installed and spanned the entire stream width (Budy et al. 2003). The array was linked by satellite to the internet, permitting data to be automatically uploaded to the PIT tag Information System (PTAGIS) website every 24 hours.

Figure 5. Pass through antennas of the PIT tag detection array at WW2.

The WW1 PIT tag detection array consisted of a full duplex interrogation system (Destron Fearing FS1001A), a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission) and antennas custom built for this site. Two pass through (PT) antennas (Figure 6) were previously installed and spanned the entire stream width (Budy et al. 2003). Three additional pass over (PO) antennas were installed approximately 3 meters downstream of the pass through antennas on 17 October 2006. The antennas, which spanned the entire stream width, were strapped flat to the river substrate which reduced the potential for damage from high flows and debris. Although the orientation of the antennas greatly reduces the potential for damage, the detection efficiency is reduced, and the proportion of the water column monitored is less than the area monitored by the PT antennas. The PO antennas served as a "back up" if either of the PT antennas were damaged and could also allow us to infer direction of movement from detection data. In order to accommodate additional antennas, the original FS1001A transceiver was replaced with a FS1001M transceiver. The array was linked by phone to the internet, permitting data to be automatically uploaded to the PIT tag Information System (PTAGIS) website every six hours.

Figure 6. Pass through antennas of the PIT tag detection array at WW1.

The NBD PIT tag detection arrays consisted of a full duplex interrogation system (Destron Fearing FS1001A or FS1001M), a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission) and antennas custom built for this site. Single antennas were installed previously towards the upstream end of the East bank ladder and in the West bank ladder (Anglin et al. 2008). A second antenna was installed toward the downstream end of the East bank ladder on 19 July 2006 (Figure 7). The array was linked by phone to the internet, permitting data to be automatically uploaded to the PTAGIS website every six hours.

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 upstream and downstream East bank antennas are on the interior of the fish ladder and are not visible.

The MCD PIT tag detection array consisted of a full duplex interrogation system (Destron Fearing FS1001M), a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission) and antennas custom built for this site. The site consisted of two antennas that were installed near the upstream and downstream ends of the fish ladder during 2005 and an additional antenna that was installed in the low flow outlet 10 August 2006 (Figure 8). We observed a decreasing trend in the amperage of the fish ladder antennas, so we replaced them on 21 August 2006. Antenna amperage of ladder antennas returned to expected levels following replacement. In general the ladder antennas were fully operational during 2006. Following installation, the low flow outlet antenna was functional until it was damaged by high flows on 13 December 2006. The antenna remained out of operation through 31 December 2006. The array was linked by phone to the internet, permitting data to be automatically uploaded to the PTAGIS website every six hours.

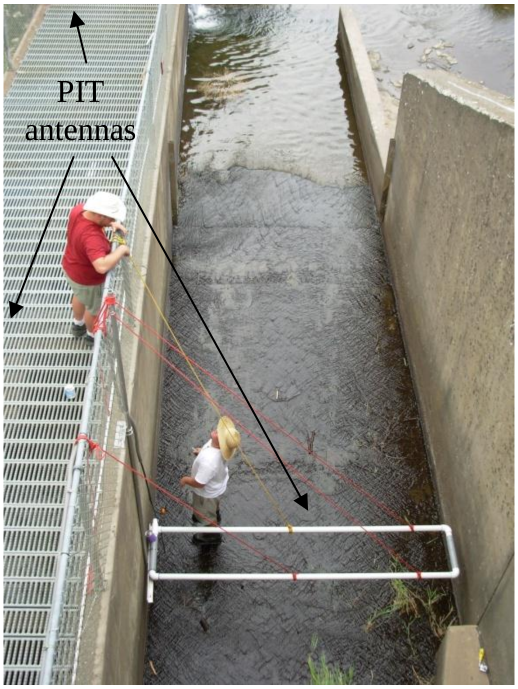

Figure 8. PIT tag detection array at MCD. Arrows indicates PIT array antenna locations in the fish ladder (left) and in the low flow outlet (right). The fish ladder antennas are not visible.

We installed a new PIT tag detection array at YHC on 12 December 2006. The YHC PIT tag detection array consisted of a full duplex interrogation system (Destron Fearing FS1001A), a laptop computer equipped with Minimon software (Pacific States Marine Fisheries Commission) and a single antenna custom built for this site. The antenna (Figure 9) was a PO design, which allowed fish and debris to pass over the antenna. The antenna was secured to the substrate using fence posts and straps. The site remained fully functional from 12 December through 31 December, 2006. Data from the array was recorded to a laptop computer and manually uploaded periodically to the PTAGIS.

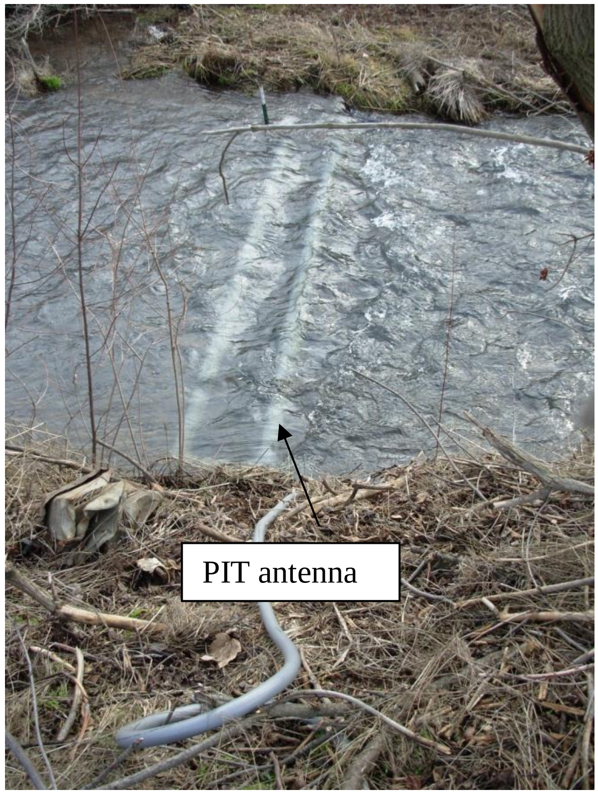

Figure 9. PIT tag detection array at YHC. Arrow indicates location of PIT array antenna that spans the width of Yellowhawk Creek.

In addition to PIT tag detection arrays operating in the middle of the Walla Walla Basin at MCD, NBD and YHC to investigate bull trout movements into degraded habitats, we continued operation and maintenance of an array at ORB to investigate use of the Columbia River by Walla Walla Basin bull trout. The ORB PIT tag detection site is located at Oasis Road Bridge in the lower WWR (Figure 10). The original site configuration consisted of a PT detection array comprised of six individual antennas. The PT antennas detect most PIT tagged fish when they pass through the inner space of the antenna structure. The floating design of our PT antennas maximizes the proportion of the water column monitored, but it is susceptible to damage from high flows and debris accumulation. We installed a second array in October 2006 as a backup to the original PT array should it be damaged by high flows or debris, and to acquire direction of fish travel. The second array is a PO detection array, also comprised of six antennas, and it was installed approximately 25 m upstream from the initial array (Figure 11). The antennas are strapped flat to the river substrate which reduces the potential for damage from high flows and debris. Although the orientation of the antennas greatly reduces the potential for damage, the detection efficiency is reduced, and the proportion of the water column monitored is small in comparison to the PT antennas.

Figure 10. Oasis Road Bridge pass through (PT) PIT detection array near the confluence of the WWR and Columbia River.

Figure 11. Oasis Road Bridge pass over (PO) PIT detection array located approximately 25 m upstream from the PT PIT detection array near the confluence of the WWR and Columbia River.

Although the PO array was located to minimize interference with the PT array, ambient electrical noise increased when both PIT tag detection arrays were operating. Each antenna array is controlled by a multiplexor which is configured to supply power to the array, set data collection protocols, and record PIT tags. Electrical noise is generated when the multiplexor energizes the antenna array to read PIT tags. When both PIT tag detection arrays were energized at the same time, electrical noise from the respective multiplexors interfered with one another. To reduce or eliminate this conflict, we configured each multiplexor to read on alternating temporal cycles on the scale of milliseconds. Data from the multiplexors were also recorded on a portable computer at the site, and regularly uploaded to the regional PTAGIS database via satellite modem. Routine inspection and maintenance of the antenna arrays was conducted when streamflows allowed to repair broken antennas and cables, and to remove debris from the antennas.

The total numbers of detections, not including orphan tags (tags that have been detected but are not yet associated with a particular release), are summarized by species for all PIT detection arrays in the Walla Walla Basin. We also report the monthly presence or absence of bull trout in a periodicity table. A bull trout detection at an array means that bull trout are distributed at that location at the time of detection. Bull trout are likely in an area for a longer time period than the moment at which it was detected. Also, we are only monitoring the portion of the population that is PIT tagged and each PIT tagged bull trout likely represents some larger number of untagged bull trout. Therefore, we believe each detection represents bull trout presence during the month it was detected. As a result, we summarize the data into monthly presence or absence at the PIT tag detection arrays.

Detection Efficiency

Routine inspection and maintenance of interrogation systems were performed to ensure reliable data collection and system operation. The PIT tag detection array operation and performance can affect the number of detections and should be considered when interpreting movement patterns observed in detection data. Two factors determine the efficiency of the PIT tag detection arrays to detect PIT-tagged bull trout within the passage routes monitored: site functionality and detection probability. Site functionality was summarized by the number of days one or more antennas were operational at each PIT detection array. Detection probability at WW1, NBD, MCD and ORB was determined by conducting antenna detection efficiency tests. Each test consisted of measuring the coverage of the electromagnetic field within and or around the antenna using both 12-mm and 23-mm PIT tags. Detection probability was calculated by dividing the area monitored by the electromagnetic field by the area where fish could pass (i.e. the size of the antenna). In general, efficiency tests were conducted monthly at the WW1, NBD, MCD, and ORB PIT tag detection arrays from January through October. Efficiency tests were not conducted during November and December due to personnel limitations. An additional factor was considered when estimating detection efficiency of the WW1 and ORB PT PIT tag detection arrays. Since both spanned the entire width of the WWR, detection efficiency was greatly affected by water stage height. Therefore, detection efficiency estimates for the WW1 and ORB PT PIT tag detection array also accounted for fluctuating stream levels. Methods for estimating detection efficiency at the ORB array are further described in Gallion and Anglin (2009). Methods to estimate detection efficiency for the WW1 array were similar to those described for ORB, except stage height for the month was measured on the day efficiency tests were conducted. We considered developing a detection efficiency monitoring protocol for the ORB PO array; however, we opted to conduct additional tests to evaluate noise levels and the effect of the ORB PO array on the PT array before developing a protocol. Similarly, we did not develop a monitoring protocol for the WW1 PO array. Lastly, no detection efficiency tests were conducted at KCB, WW2 or YHC. As stated earlier, the KCB PIT tag detection array was operated by the ODFW. Detection efficiency of the KCB PIT tag detection array are not readily available and are not reported. Due to the remote location of the WW2 PIT tag detection array, the site was visited irregularly and detection efficiency was not estimated at the PIT tag detection array. No detection efficiency estimates were conducted at the YHC PIT tag detection array because the site was installed late in the year on 12 December 2006.

We report efficiency tests using both 12-mm and 23-mm PIT tags. The results of 12-mm PIT tag efficiency tests are presented primarily, for other researchers in the WWR Basin. Although some bull trout have been tagged with 12-mm PIT tags, currently, most bull trout are tagged with 23-mm PIT tags (Weeber et al. 2007).

Water Temperature

To monitor water temperature, we placed thermographs (Onset Computer, StowAway Tidbits) at 18 sites in the Walla Walla Basin (Figure 12; Appendix A). Thirteen thermographs were deployed in the WWR, four thermographs were deployed in the SFWWR and one thermograph was deployed in Mill Creek. Thermograph data will be used in the interpretation of PIT tag detection array data. Prior to deployment, data loggers were checked for accuracy using Oregon Watershed Enhancement Board (OWEB) water quality monitoring guidebook specifications and sampling frequency was set to 30-min intervals (OWEB 1999). Manufacturer specifications report an accuracy of +/- 0.2 ºC for the Onset StowAway Tidbit (-5 ºC to + 37 ºC). Each thermograph was placed in 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. Every three months, temperature data were downloaded in the field with an Onset Optic shuttle and then transferred to a personal computer. Data were summarized using BoxCar Pro software version 4.3 (Onset Computer). Temperature data were verified using quality control measures as outlined in the OWEB protocol. If the difference between the data and the reference thermometer was outside the standard range of accuracy (i.e. > 0.4 °C difference) then it was noted (OWEB 1999). Based on Thermal Infrared Radiometry (TIR) data collected in August 2003 (Faux 2003), we placed thermographs so there was an increase ~ 0.5 ºC between thermographs.

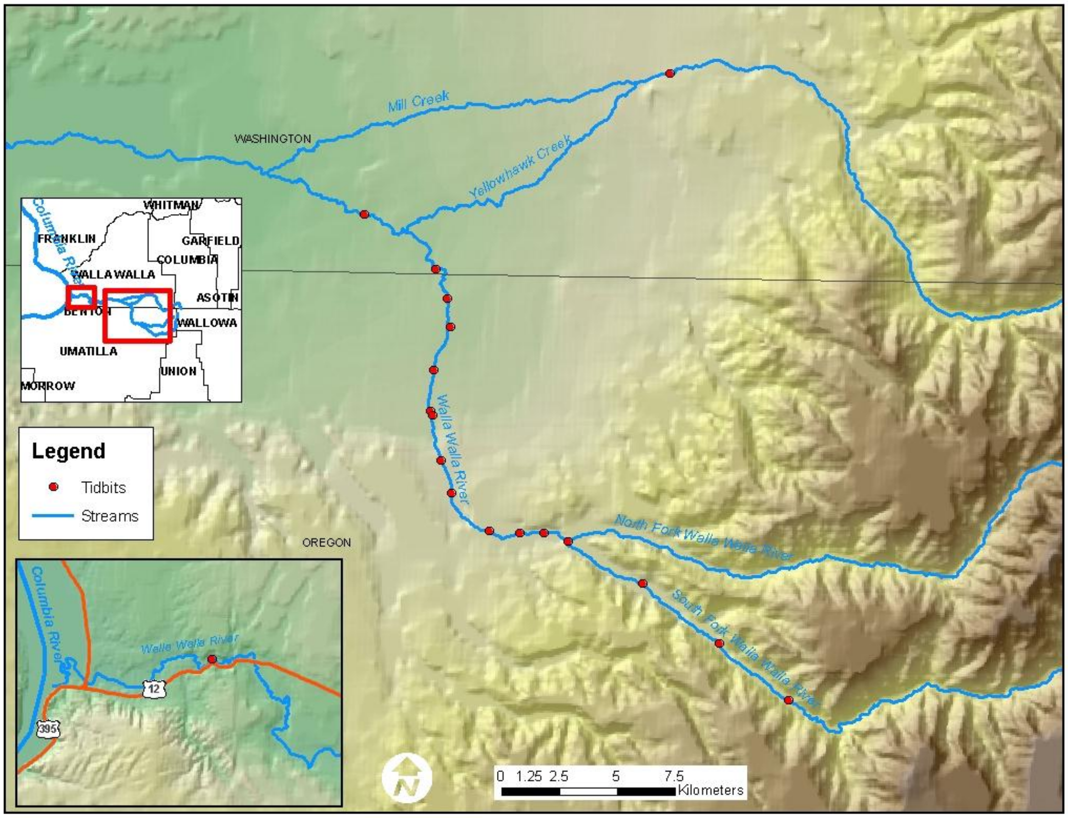

Figure 12. Distribution of thermographs throughout the SFWWR, mainstem WWR and Mill Creek.

Movements

Rotary Screw Trap

The FWS operated a five-foot (1.52 m) diameter rotary screw trap (E. G. Solutions Inc. Corvallis, OR) at Day Road (rkm 80.5) and Joe West Bridge (rkm 82.0) during 2004 and only at Joe West Bridge during 2005 to characterize the magnitude and timing of bull trout dispersal or downstream migration from the SFWWR spawning area. A downstream dispersal of subadult bull trout was detected during the spring of 2004 and 2005, but we could not calculate capture efficiency of the trap for bull trout because insufficient numbers of bull trout were captured. As a result it was unclear whether bull trout were dispersing downstream at other times of the year and the magnitude of the dispersal could not be determined. Therefore, the screw trap was not utilized during 2006.

PIT Tag Detection Arrays

To describe bull trout movement patterns, we report the unique monthly detections of adult and subadult bull trout. We define a unique monthly detection as an individual bull trout, identified by a unique PIT tag code, detected within a month. Since we summarize data throughout the year, it is possible for an individual bull trout to be detected in more than one month. Adult and subadult bull trout were separated because they may move in different directions during different seasons. Bull trout ≥300 mm at the time of tagging, were considered adults. Bull trout ≤250 mm at the time of tagging, and detected within one year of the tagging date, were considered subadults. Since we are focused on movements of fluvial bull trout, we summarize unique monthly detections at the NBD, MCD, and YHC PIT tag detection arrays. No bull trout were detected at the ORB PIT tag detection array.

We also summarize direction of movement for subadults and adults. We used three methods to determine direction of movement of bull trout. First, we examined the timing of detections at antennas within arrays that had two antennas arranged from upstream to downstream. For instance, antennas located at the upstream and downstream ends of the ladders at the NBD and MCD PIT tag detection arrays. Second, if directional antennas were not present at the PIT tag detection array or if the PIT tag was only detected at a single antenna, we looked at the detection history at other PIT tag detection arrays to determine direction of movement. Lastly if the tag was not detected at any other PIT tag detection arrays, we used the release location of the fish to determine the direction of movement.

Bull Trout Sampling/PIT Tagging

Our objective was to capture bull trout that were likely to migrate downstream, through the Walla Walla Basin and into the Columbia River. Previous data indicated the Walla Walla bull trout local population consisted of both resident and migratory fish, and that the migratory fish used different spatial scales to complete their life cycle. We reviewed dispersal and migration data to determine the appropriate time periods to sample migratory bull trout, and planned our field sampling for locations lower in the Basin to increase the likelihood that PIT tagged bull trout would include "longer range" migrants that were more likely to use a spatial scale that included the lower WWR, the Columbia and/or Snake rivers.

Past studies (Budy et al. 2003, 2004, 2005) showed bull trout PIT tagged in the SFWWR were detected moving downstream past the WW1 PIT detection array (Figure 4) during both spring and fall. Screw trap sampling near Milton-Freewater, OR also indicated a spring dispersal period for subadult bull trout (Anglin et al. 2008, Gallion et al. 2015a, 2015b). In addition, results from a past telemetry study indicated overwintering migratory adult bull trout move downstream from October through December, and the lower limit of the winter distribution was near the OR/WA state line (Mahoney et al. 2006). No evidence existed to suggest that either adult or subadult bull trout moved further downstream to areas near the mouth of the WWR. Since the data discussed above included only bull trout that had been tagged or sampled in the upper reaches of the WWR or Mill Creek, we hypothesized that a sampling and tagging effort further downstream during the appropriate time periods (spring, fall) might result in migrants that were more likely to use lower reaches of the WWR and possibly the Columbia River. Bull trout in nearby Recovery Units migrate considerable distances when habitat conditions allow. In the Upper Columbia Recovery Unit, adult bull trout from the Entiat, Wenatchee, and Methow Core Areas regularly use the Columbia River. Radio tagged bull trout from the Upper Entiat River out-migrated an average distance of 75.7 km to overwintering locations (Nelson and Nelle 2008). In the Snake River Recovery Unit, bull trout from the Tucannon Core Area have been documented using the Snake River (Faler et al. 2008). Habitat conditions in the mainstem WWR become highly impacted near Milton-Freewater, OR from irrigation withdrawals and channel modifications for flood control. Low streamflows downstream from Milton-Freewater, OR, particularly during late spring through early fall, may affect observed dispersal and migration patterns of bull trout. Therefore, our efforts to capture and PIT tag bull trout were focused near Milton-Freewater, OR and downstream, to target fish that had already migrated a substantial distance downstream in the system, and would potentially be more likely to use the mainstem Columbia River.

We sampled for bull trout using dip nets, hook and line, and a beach seine between 26 June and 19 July, 2006. Sampling was conducted at several locations between Milton-Freewater, OR and the OR/WA state line. Sampling was terminated for the summer after 19 July because water temperatures exceeded $18^{o}C$, creating a risk of stress and mortality to the fish. Captured bull trout were anesthetized with tricaine methanesulfonate (MS 222) and tagged with a 23-mm PIT tag. The tag was inserted into the body cavity through a 5 mm ventral incision. The incision was then sealed with Nexaband, a topical tissue adhesive.

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 WWR and SFWWR.

<u>Redd Surveys</u>

The FWS personnel were not available to assist with spawning ground surveys during 2006. Installation of new PIT tag detection arrays, repairs to existing arrays and validation of the spawning habitat suitability model, precluded our participation.

<u>Spawning Habitat Suitability Model</u>

We began to develop the spawning habitat suitability models by collecting spawning habitat data at redd locations and non-use locations in the SFWWR during 2004 (Anglin et al. 2008) and continued this effort in 2005 (Gallion et al. 2015a). Habitat criteria incorporated into the model include water depth, water velocity and substrate size. No Results or Discussion are included in this report regarding development of the spawning habitat model. During 2006 a field exercise was conducted to collect validation data for the spawning habitat suitability model. Prior to the onset of spawning from 22 to 24 August, the 3.6 km reach that extends from 2.4 km downstream of Reser Creek to 1.2 km miles upstream of Reser creek was surveyed. Data collected during past spawning ground surveys suggest that SFWWR bull trout typically spawn in substrates ≤7.62 cm. Surveyors walked/waded the reach and flagged locations where substrate was ≤7.62 cm. The substrate size, water depth and water velocity were collected at each of the flagged locations. During 16 and 17 October a second survey was conducted to determine whether redds had been constructed at the flagged locations. This information will be summarized in a manuscript and submitted to a peer review journal.

Rearing Habitat Suitability Model

We previously describe methods for data collection to develop a probabilistic rearing habitat suitability model for bull trout (Gallion et al. 2015a). No additional data were collected during 2006 and no Results or Discussion are included in this report regarding development of the spawning habitat model. This information will be summarized in a manuscript and submitted to a peer review journal.

Stream Gage

The FWS installed a stream gage at Harris Park in 2002 to monitor stream flows while conducting field work. The OWRD gage #140100000 is located approximately 2 km upstream and the data is now available on the internet, therefore we discontinued reporting data for the Harris Park stream gage.

Results

Distribution

PIT Tag Detection Arrays

Total individual detections at the WW1 detection array were 63, 21, 8, and 3 for bull trout, Chinook salmon, *O. mykiss* and mountain whitefish respectively (Table 1).

Table 1. Total number of individuals detected by species at each antenna site in the WWR, Mill Creek and Yellowhawk Creek in 2006.

	Number of detections				
Antenna site	**Bull trout**	**Chinook salmon**	***O. mykiss***	**Coho**	**Mountain whitefish**
WW1	63	21	8	0	3
NBD	20	118	6	0	4
KCB	523	13	2	0	0
MCD	56	26	5	0	0
YHC	1	0	0	0	0
ORB	0	81	41	1	0

Bull trout detected at WW2 ranged in size from 123 to 574 mm when initially PIT tagged. Bull trout were observed at WW2 during all months except January, March and April 2006 (Table 2).

Table 2. Bull trout periodicity table at PIT tag detection arrays in the Walla Walla Basin. Blue cells indicate bull trout presence.

PIT Array	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SFWWR and WWR												
WW2		●			●	●	●	●	●	●	●	●
WW1	●	●		●	●	●	●	●	●	●	●	
NBD		●	●	●	●	●	●			●		
ORB												
Mill Creek												
KCB	●	●	●	●	●	●	●	●	●	●	●	●
MCD	●			●	●	●	●				●	●
YHC												●

Bull trout detected at WW1 ranged in size from 124 to 574 mm when initially PIT tagged. Bull trout were observed at WW1 during all months except March and December 2006 (Table 2).

Total individual detections at the NBD PIT tag detection arrays were 20, 118, 6 and 4 for bull trout, Chinook salmon, steelhead and mountain whitefish, respectively (Table 1). Bull trout detected ranged in size from 132 to 531mm when initially PIT tagged. The presence or absence of bull trout at NBD during 2006 are shown in Table 2. Bull trout were observed at NBD from February through July, and October, 2006.

Total individual detections at KCB were 523, 13, and 2 for bull trout, Chinook salmon, and steelhead respectively (Table 1). Bull trout detected ranged in size from 114 to 530 mm when initially PIT tagged. The presence or absence of bull trout at KCB during 2006 are shown in Table 2. Bull trout were observed at KCB during all months of 2006.

Total individual detections at MCD were 56, 26, and 5 for bull trout, Chinook salmon, and steelhead respectively (Table 1). Bull trout detected ranged in size from 119 to 479 mm when initially PIT tagged. The presence or absence of bull trout at MCD during 2006 are shown in Table 2. Bull trout were observed at MCD during January, April, May, June, July, November, and December.

Only one bull trout was detected at YHC. This fish was released on 16April 2006 at the screw trap in upper Mill Creek. Following release, it passed MCD undetected and was subsequently detected at YHC on 20 December.

No bull trout were detected at ORB during 2006. Total individual detections at ORB were 81, 41, and 1 for Chinook salmon, steelhead and Coho salmon, respectively (Table 1). Fish detected at the ORB antenna were released in the SFWWR, WWR, Touchet River, Mill Creek, Ringold Hatchery, Tucannon River, Snake River and Eldorado Creek.

Detection Efficiency

The PIT tag detection array operation can affect the number of detections and should be considered when interpreting patterns observed in detection data. The number of days of operation and downtime for WW2, WW1, MCD, and ORB PIT tag detection arrays are reported in Table 3. The NBD East and West bank ladder and the YHC PIT tag detection arrays did not have any system downtime during 2006.

Table 3. Operational details for the WW1, MCD, and ORB PIT tag detection arrays during 2006.

Date	System down time (days)	Explanation
	WW2	
4 Jan – 19 Jan	16	Site ran out of propane
8 Mar – 17 Mar	10	Site ran out of propane
25 Apr – 26 Apr	1	Site ran out of propane
	WW1	
20 Jan – 23 Jan	4	Power outage
28 Feb	1	Power outage
4 Oct		Site maintenance
	MCD	
30 Apr – 5 May	6	Power outage
	ORB	
Jan 1 - Jan 25	25	Array Antennas blew out
Feb 23 – Mar 1	70	Power outage
Oct 1 – Oct 3	3	Site maintenance

Detection efficiency ranged from 7 to 100% of 23-mm tags at the South bank antenna at WW1 (Table 4). Low efficiencies during January and June were due to the antenna being out of tune. After the antenna was tuned, efficiency returned to near 100%. Detection efficiency of 23-mm tags at the South bank antenna averaged 80%. Detection efficiency ranged from 82 to 100% at the North bank antenna and averaged 97%. Detection efficiency of 12-mm tags at the South bank antenna ranged from 0 to 10%, except in October when it was 50%. Detection efficiency averaged 6% at the South bank antenna. Detection efficiency of 12-mm tags at the North bank antenna ranged from 0 to 10%, except for October when it was 100%. Detection efficiency at the North bank antenna averaged 12%. Detection efficiencies of 12-mm tags were relatively high during October at the South bank (50%) and North bank (100%) due to low flows and the installation of an auto-tuning transceiver. Overall, 23-mm tags were consistently detected and 12-mm tags were not.

Table 4. Efficiency test results for the South bank, and North bank WW1 PIT tag detection arrays during 2006. NM = not measured.

PIT tag size (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
South Bank PIT Tag Efficiency Test Results (%)													
12	0	10	18	0	6	0	NM	0	0	50	NM	NM	6
23	7	100	100	95	100	14	NM	100	100	100	NM	NM	80
North Bank PIT Tag Efficiency Test Results (%)													
12	0	10	0	0	0	0	NM	0	0	100	NM	NM	12
23	82	100	100	95	100	100	NM	100	100	100	NM	NM	97

Average detection efficiency was 100% for 23-mm tags at the upstream East bank ladder, downstream East bank ladder, and West bank ladder antennas (Table 5). Similarly, average detection efficiency of 12mm PIT tags was high (>80%) at the downstream East bank ladder, and West bank ladder antennas. Efficiency tests differed dramatically between 12- and 23-mm tags at the upper East bank ladder antenna. Detection efficiency of 12mm PIT tags ranged from 0 to 100% and averaged 56%, whereas detection efficiency of 23-mm PIT tags was always 100%. Overall, 12 and 23-mm tags were consistently detected at the lower East bank and West bank ladder antennas. Whereas, only 23-mm tags were consistently detected at the upstream East bank ladder antenna and 12-mm tags were not.

Table 5. Efficiency test results for the upper and lower East bank, and West bank NBD PIT tag detection arrays during 2006. NM = not measured.

PIT tag size (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Upstream East Bank Ladder PIT Tag Efficiency Test Results (%)													
12	56	30	30	0	0	100	100	100	43	100	NM	NM	56
23	100	100	100	100	100	100	100	100	100	100	NM	NM	100
Downstream East Bank Ladder PIT Tag Efficiency Test Results (%)													
12	NP	NP	NP	NP	NP	NP	100	100	100	100	NM	NM	100
23	NP	NP	NP	NP	NP	NP	100	100	100	100	NM	NM	100
West Bank Ladder PIT Tag Efficiency Test Results (%)													
12	NM	NM	80	100	100	100	NM	NM	NM	NM	NM	NM	95
23	NM	NM	100	100	100	100	NM	NM	NM	NM	NM	NM	100

Detection efficiency at the MCD ladder antennas was 100% for 23-mm tags from January through December 2006 (Table 6). Detection efficiency for 23-mm tags was 100% during September and October at the low flow outlet antenna. Detection efficiency of 12mm tags at the ladder antennas was 100% during all months except for February at the upstream ladder antenna when it was 91%. Although detection efficiency of 12-mm tags at the low flow outlet was only measured during October, it measured 0%. Average detection efficiency was 85% for 12-mm tags. Overall, both 12- and 23-mm tags were consistently detected at the MCD ladder antennas. Whereas, only 23-mm tags were consistently detected at the low flow outlet, and 12-mm tags were not.

Table 6. Efficiency test results for the downstream ladder antenna, upstream ladder antenna and the low flow outlet antenna at the MCD PIT tag detection array during 2006. NM = not measured. NP=antennas were damaged or not present.

PIT tag size (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Downstream Ladder PIT Tag Efficiency Test Results (%)													
12	100	100	100	100	100	100	100	100	100	100	NM	NM	100
23	100	100	100	100	100	100	100	100	100	100	NM	NM	100
Upstream Ladder PIT Tag Efficiency Test Results (%)													
12	100	91	100	100	100	100	100	100	100	100	NM	NM	99
23	100	100	100	100	100	100	100	100	100	100	NM	NM	100
Low Flow Outlet PIT Tag Efficiency Test Results (%)													
12	NP	NP	NP	NP	NP	NP	NP	NP	NM	0	NM	NM	0
23	NP	NP	NP	NP	NP	NP	NP	NP	100	100	NM	NM	100

Detection efficiency of 23-mm PIT tags ranged from 2 to 99% at the ORB PIT detection array during 2006 (Table 7). Detection efficiency was relatively low (≤11%) during January through May, when only up to two antennas were operating. We completed antenna replacement in June and July, 2006, and detection efficiency increased to 74% - 99% from July through November. Detection efficiency decreased from 84% in November to 54% in December when high streamflows damaged two of the six antennas.

Table 7. Percent area monitored for individual antennas and average monthly percent detection efficiency at the ORB PIT detection array. NM=antenna efficiency not measured; NP=antennas were damaged or not present.

	Antenna						
Date	1	2	3	4	5	6	Detection Efficiency
January	NP	NP	NP	NP	NP	NC	2%
February	NP	NP	NP	NP	NP	100%	5%
March	NP	NP	NP	NP	NP	100%	5%
April	100%	NP	NP	NP	NP	100%	6%
May	100%	NP	NP	NP	NP	100%	10%
June	100%	NP	NP	NP	NP	100%	11%
July	NP	NP	100%	100%	100%	100%	74%
August	100%	100%	100%	100%	100%	100%	93%
September	NM	NM	NM	NM	NM	NM	99%
October	100%	100%	100%	100%	100%	100%	99%
November	NM	NM	NM	NM	NM	NP	84%
December	NM	NM	NP	NP	NM	NM	54%

Water Temperature

Average water temperature generally increased in a downstream direction in the SFWWR and WWR. Figure 13 shows the average temperature gradient during August in the SFWWR and throughout the study area. A detailed summary of average daily minimum, average, and average daily maximum temperatures by month (January – December 2006) is presented in Appendix A.

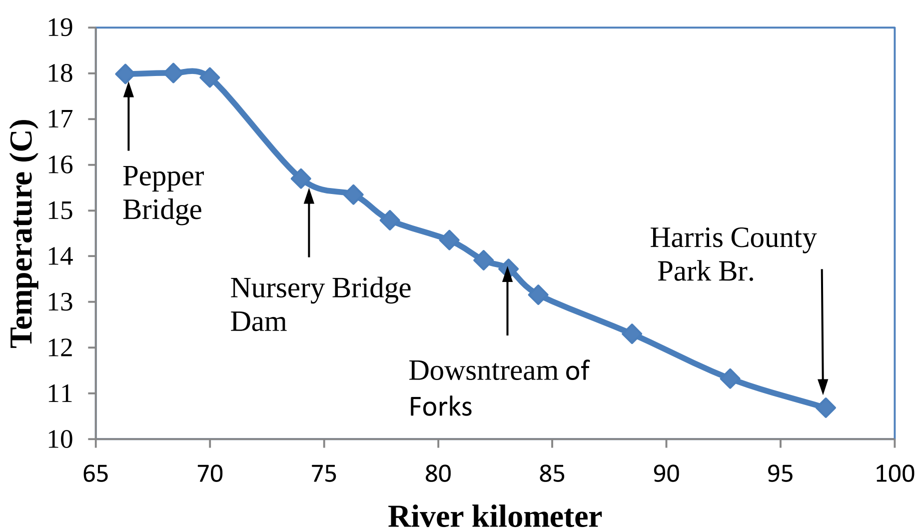

Figure 13. Average daily water temperature at 13 thermograph locations during August 2005. Blue diamonds represent thermograph locations. Several additional locations are labeled on the graph for reference.

Movements

<u>PIT Tag Detection Arrays</u>

Unique monthly detections of all bull trout were summarized to describe bull trout distribution in the Distribution section of this report. Here, we partition those data into adults (≥300 mm) or subadults (≤250 mm) and summarize their direction of movement. Of the 20 bull trout detected at NBD, six were adults, nine were subadults, and five could not be classified. Adult bull trout were detected passing NBD during February, April, May, June, November and December (Figure 14). The highest movement activity for both adults and subadults occurred during the months of June and October.

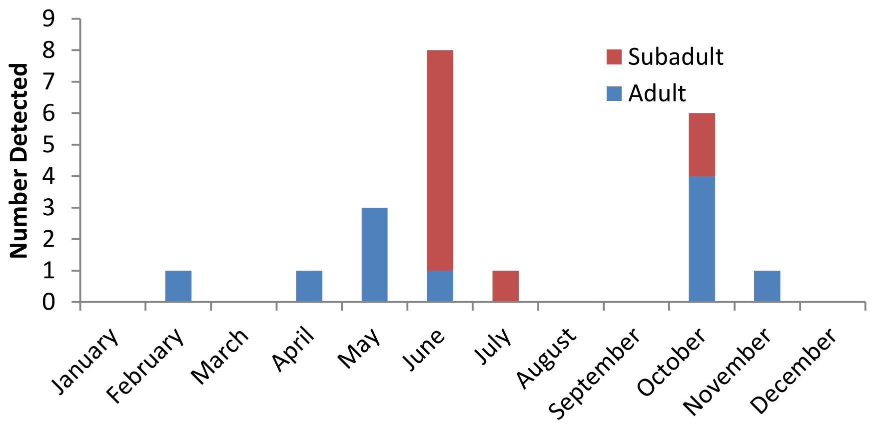

Figure 14. Monthly PIT detections of adult and subadult bull trout at NBD during 2006.

Detection histories for the adult bull trout suggest peak movement in May and October, although only 1 to 4 fish were detected in any given month. Downstream movement of adult bull trout occurred during February and October 2006 (Figure 15). Upstream movement of adult bull trout occurred during April, May and June. Of the six adult bull trout, three were only detected during a single month, while the remaining three were detected in more than one month. Three individuals were detected moving upstream during April, May or June and downstream during February or October. The direction of movement for one individual was unknown during May. It appeared to be rearing in the NBD area, as it was detected at both East and West NBD ladders during May and then moved upstream during June and downstream during October.

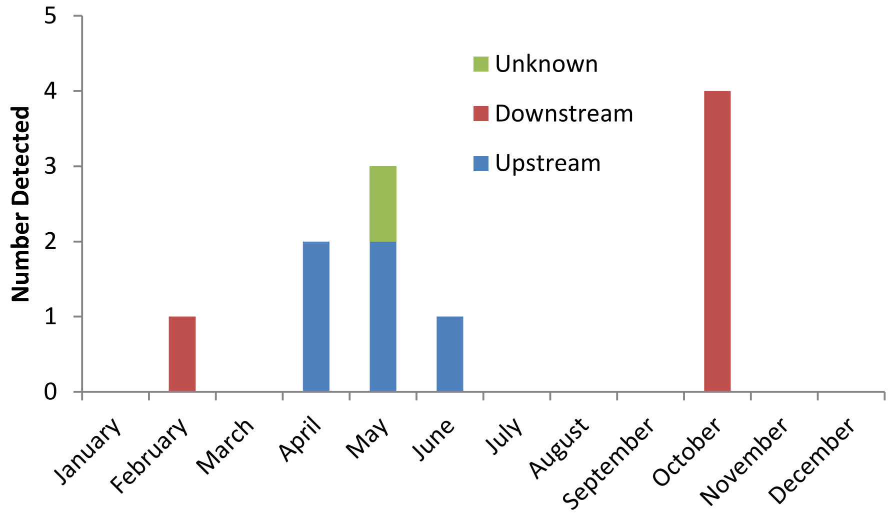

Figure 15. Direction of monthly adult bull trout movement at NBD during 2006.

Detection histories for the subadult bull trout suggest peak movement occurred during June. Downstream movement of subadult bull trout occurred at NBD during June and October (Figure 16). Upstream subadult bull trout movement only occurred during June. It is interesting to note that the three subadult bull trout that moved upstream past NBD were tagged at NBD within two days of their upstream movement. Direction of movement for one subadult was unknown during July. It was detected dispersing downstream in June and was only detected on one antenna during July, and may have been rearing in the area.

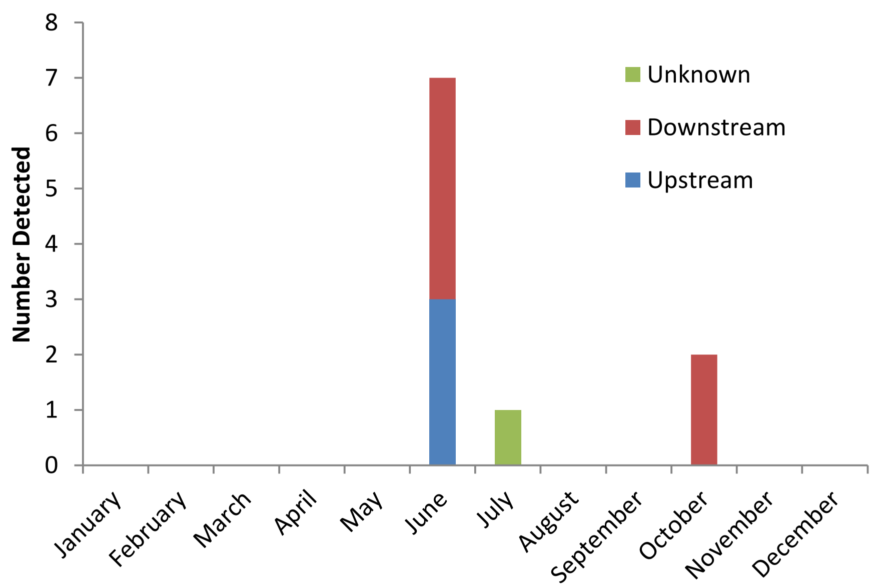

Figure 16. Direction of monthly subadult bull trout movement at NBD.

Unique monthly detections at MCD during 2006 of adult and subadult bull trout are shown in Figure 17. Of the 56 bull trout detected at MCD, 11 were adults, 43 were subadults and two were not classified as adults or subadults. Peak movement for both adult and subadult bull trout occurred during June and November 2006. No adult or subadult movement occurred at MCD during January through March and August through October 2006.

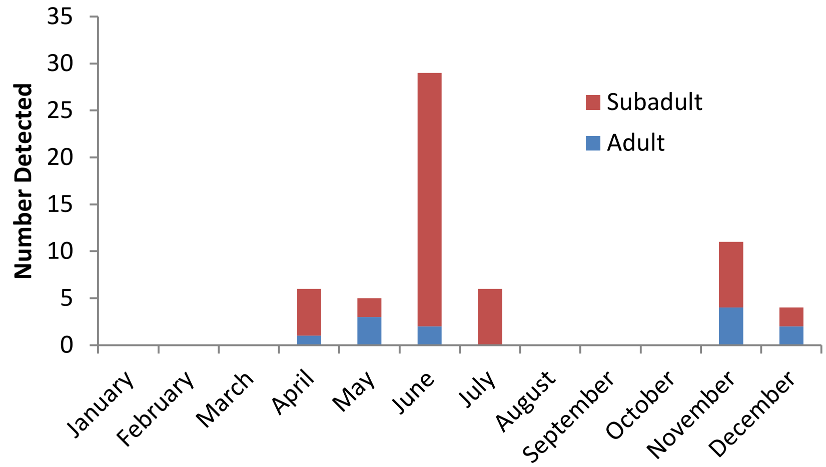

Figure 17. Monthly PIT detections of adult and subadult bull trout at MCD during 2006.

Detection histories for the adult bull trout at MCD suggest upstream movement occurred during April, May and June and December and downstream movement occurred during November and December (Figure 18). Interestingly, the adult that moved upstream during December, moved upstream through the MCD ladder on 18 December and 26 December. The fish most likely passed MCD downstream prior to 18 December and between 18 and 26 December through the low flow outlet undetected. The low flow outlet antenna was not operational from 13 December to 31 December 2006. Given the numerous detections and apparent upstream and downstream movement, this fish may have been rearing in the MCD area. No adult movement occurred at MCD during January through March or July through October.

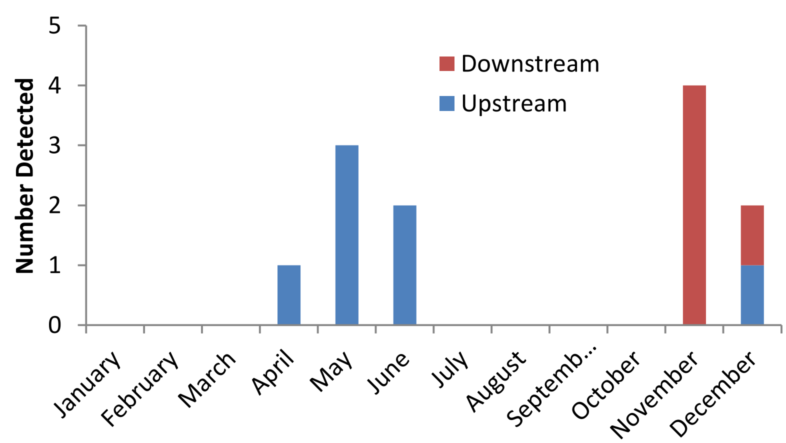

Figure 18. Direction of monthly adult bull trout movement at MCD.

Detection histories for the subadult bull trout at MCD suggest downstream movement during April, May, June, July, November and December (Figure 19). Upstream movement occurred during June and December. Direction of movement could not be determined for one subadult, as it was detected in June and then only on one ladder antenna during July. The fish may have been rearing near MCD. The vast majority (43 of 48 detections) of subadult movement at MCD was in a downstream direction. Peak downstream movement occurred during June when 23 subadults dispersed downstream. No subadult movement was detected during January through March or August through October.

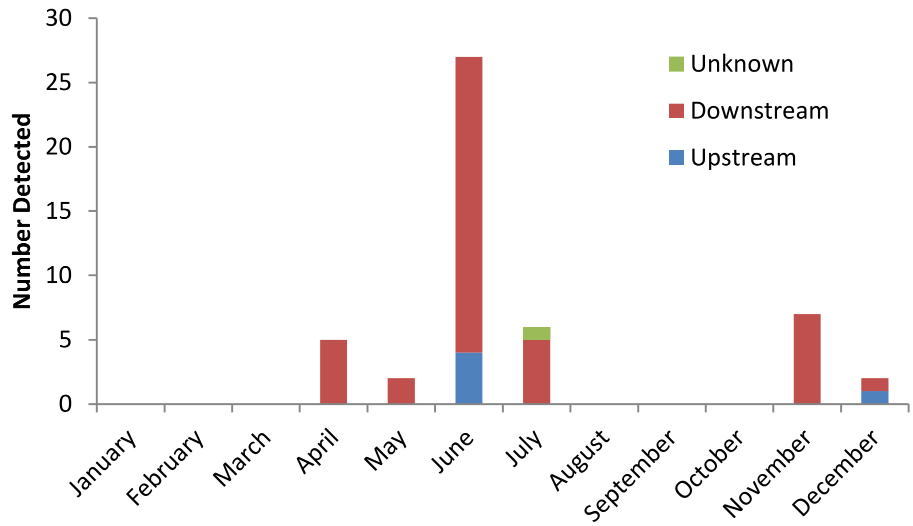

Figure 19. Direction of monthly subadult bull trout movement at MCD.

Only one bull trout was detected at YHC. This fish was released on 16 April 2006 at the screw trap in upper Mill Creek. Following release, it passed MCD undetected and was subsequently detected at YHC on 20 December.

Bull trout PIT tagged in the Walla Walla Basin have the opportunity to be detected at PIT detection arrays at dams in the Columbia River. No bull trout were observed at Priest Rapids Dam, McNary Dam and Ice Harbor Dam adult fish counting facilities during 2006.

Bull Trout Sampling/PIT Tagging

We captured and PIT tagged 11 bull trout using dip nets and hook and line sampling between 26 June and 19 July, 2006. Water temperatures increased to unsafe sampling levels after 19 July 2006. No fish were captured using a beach seine. All of the bull trout were captured in the vicinity of Milton-Freewater, OR. Fish size ranged from 153-250 mm with an average size of 199 mm.

Discussion

Distribution

PIT Tag Detection Arrays

Bull trout were detected at the WW2 PIT tag detection array during all months except January, March and April. Due to the remote location, no detection efficiency estimates are available, but the site was down during January, March and April for 16, 10, and 1 days respectively. It is possible bull trout passed the array during those months undetected. Although bull trout were not detected at the WW2 PIT tag detection array during January, March and April in 2006, bull trout were detected during all months in 2004 (Budy et al. 2005). The WW2 PIT tag detection array is located within the SFWWR bull trout spawning area. The habitat is relatively pristine and temperatures are not limiting during January, March and April, therefore, bull trout were likely distributed in the SFWWR down to WW2 throughout the year.

Bull trout were detected at the WW1 PIT tag detection array during all months except March and December. Detection efficiency in March was 100% for both the North and South bank antennas. Although detection efficiency was not measured during December, average efficiencies were 80% and 97% for the North and South Bank antennas. The site operated throughout the months of March and December. Therefore it is unlikely that PIT tagged fish passed the array undetected. Although bull trout were not detected during March and December in 2006, bull trout were detected during all months, including March and December in 2004 (Budy et al. 2005) and 2005 (Budy et al. 2006). The habitat at WW1 is relatively pristine and temperatures are not limiting during March and December, therefore, bull trout were likely distributed in the SFWWR down to WW1 throughout the year.

Bull trout were detected during all months at NBD except January, August, September, November and December. Detection efficiency of the PIT tag detection array should be considered when interpreting detection results. There are three fish passage routes at NBD. Fish may pass through the East bank Ladder, the West bank ladder or over the spillway. At NBD only the ladders were monitored. Detection efficiency of 23-mm tags was 100% in the upstream East bank ladder, downstream East bank ladder, and West bank ladder antennas (Table 5). During periods of higher flow, which generally occurs from late fall through spring (Figure 20), fish can pass over the spillway and would not be detected by the PIT array. Therefore it is possible that bull trout passed the NBD PIT array over the spill way undetected during January, November and December. It is unlikely that bull trout passed the NBD PIT array undetected during August and September because fish passage was likely restricted to the ladder, due to low stream flow, and efficiency tests suggest the array would detect 100% of PIT tagged fish that passed through the ladder. Therefore, it is possible bull trout were distributed near Nursery Bridge during all months except August and September, when streamflow is generally low and stream temperatures relatively warm. Snorkel surveys conducted during the summer and fall of 2004 (Anglin et al. 2008) and 2005 (Gallion et al. 2015a) suggest bull trout are typically distributed from the SFWWR down to Nursery Bridge.

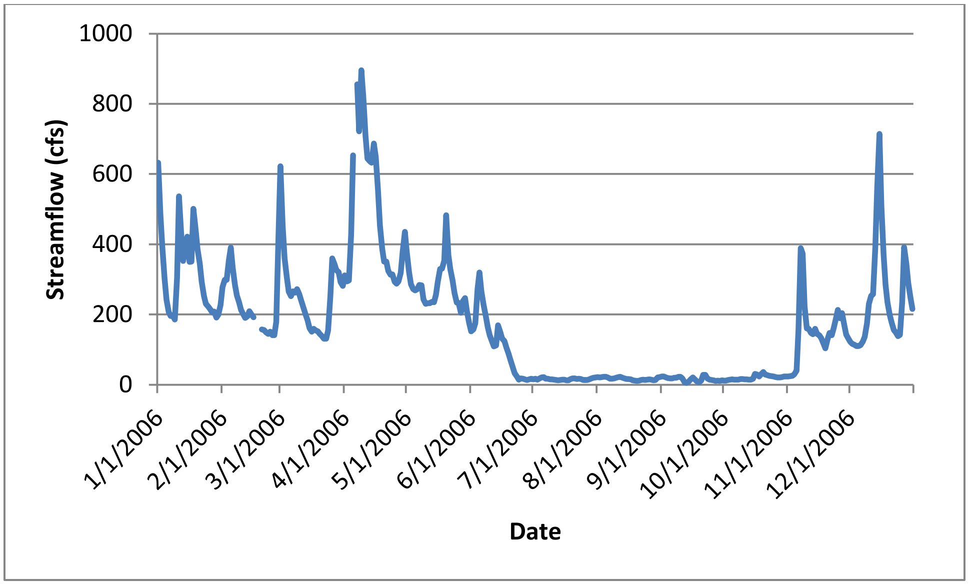

Figure 20. Daily average streamflow at the Pepper Bridge stream gage from January through December 2006.

Bull trout were detected at KCB during all months. Bull trout distribution is likely the most constricted during summer when water temperatures are relatively warm. The ODFW also conducted night snorkeling to determine summer distribution and abundance of subadult bull trout (Weeber et al. 2007). Bull trout were observed at 12 of 13 random snorkel locations, suggesting bull trout were distributed down to rkm 24, 5.5 km upstream from Bennington dam.

Bull trout were detected at MCD PIT tag detection array during all months except February, March, August, September, and October. Detection efficiency tests suggest the ladder antennas were 100% efficient throughout the year, but the low flow outlet antenna was not installed until 10 August 2006. Spill at MCD typically only occurs when stream discharge exceeds 400 cfs. Streamflow for Five Mile Road Bridge stream gage is presented in Figure 21. This is the closest upstream gage and is located approximately 5 km upstream from the MCD array. Spill exceeded 400 cfs on 1 March 2006. Therefore, bull trout may have passed MCD undetected through the low flow outlet during February or March or over the spillway during March. It is unlikely that bull trout passed the MCD PIT array undetected during August through October because fish passage was likely restricted to the ladder, due to the low stream flow, and efficiency tests suggest the array would detect 100% of PIT tagged fish that passed through the ladder. In summary, bull trout were likely distributed near MCD during all months except August through October when streamflow was generally low (< 40 cfs) and stream temperatures were relatively warm.

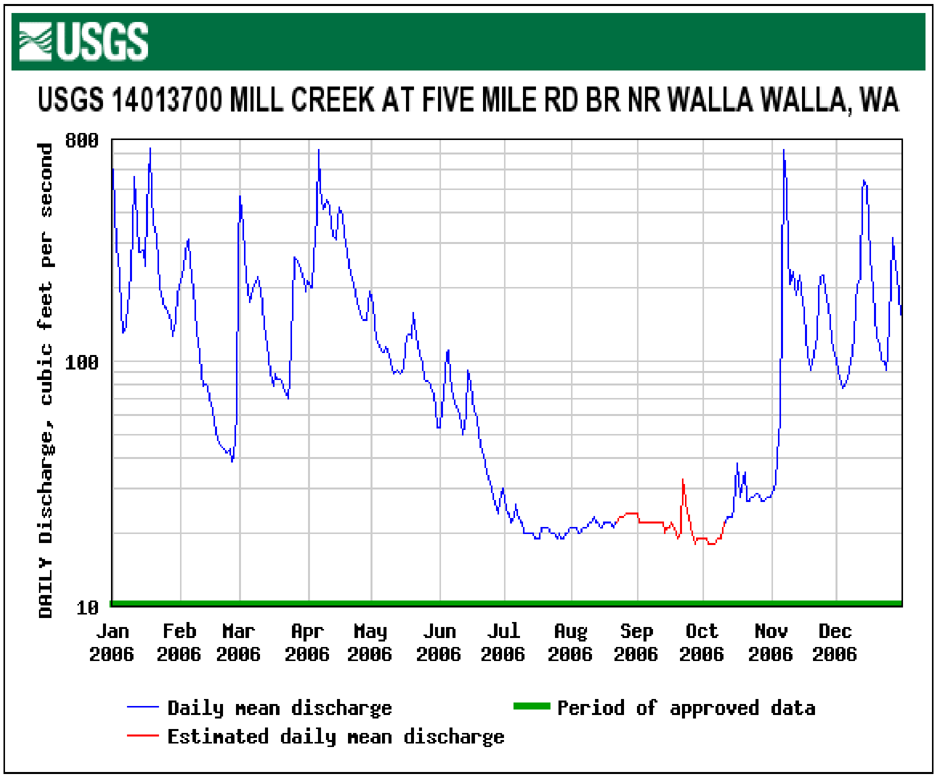

Figure 21. Daily average stream flow at the Five Mile Road Bridge stream gage from January through December 2006.

One bull trout was detected at the YHC PIT tag detection array on 20 December 2006. Since the array was only in operation from 12 December to 31 December 2006, bull trout distribution at YHC from January through November is unknown. The YHC array is located approximately 1.6 km downstream from the MCD PIT tag detection array. Given that bull trout were detected at MCD during December (Table 2) and the single detection at YHC, it is likely bull trout were distributed between MCD and YHC during December.

No bull trout were detected at the ORB detection array. Detection efficiency from January through June was <11% and never reached 100% from July through December (Table 7), as a result it is possible bull trout passed the array undetected. Therefore bull trout distribution in this area is unknown.

Detection Efficiency

Detection efficiencies at WW1 were very low during January (7%) and June (14%). The low efficiencies were the result of the antenna and transceiver drifting out of tune. A multiplexor transceiver was installed in October 2006. The new transceiver has an “auto tune” feature which automatically adjusts capacitance to keep the antenna in tune. Although efficiency was not measured during November or December, we anticipate the multiplexor will eliminate the dramatic fluctuations observed during January and June.

Detection efficiency tests at NBD differed dramatically between 12- and 23-mm tags at the upper East bank ladder antenna Table 5. Detection efficiency of 12-mm PIT tags ranged from 0 to 100% and averaged 56%, whereas detection efficiency of 23-mm PIT tags was always 100%. This was likely the result of electromagnetic noise from electric motors which are located near the antenna and are periodically activated to clear debris from screens located at the facility. Apparently, the electromagnetic noise compromised the ability of the antenna to read the weaker return signal from the 12-mm PIT tag.

Detection efficiency test suggest that the low flow outlet was 100% efficient at detecting bull trout tagged with 23-mm PIT tags (Table 6). Detection efficiency is determined by placing a tag varying distances away from the antenna until the proportion of the passage channel that is monitored is determined. This does not account for water velocity. Water velocities in the low flow channel, which is smooth concrete chute, (Figure 8) can be quite fast. The transceiver rotates monitoring each of the three antennas present at MCD. It may be possible that fish are able to pass the low flow outlet undetected as the transceiver monitors the ladder antennas in the array. As a result, detection efficiency of the low flow outlet may have been less than 100%.

Detection efficiency at ORB may have been less than the values reported in Table 7 due to the random accumulation of debris on the antennas between site visits. The accumulation of debris likely would have caused the antennas to “sink” due to the increased resistance from the debris in the current, thereby reducing the proportion of the river cross section monitored.

Water Temperature

Numerous studies have shown that bull trout are sensitive to temperature, which can affect and ultimately determine distribution (Shepard et al. 1984; Goetz 1989; Fraley and Shepard 1989). Thermograph data revealed that water temperature increased incrementally from Harris Park (0.24 °C/km) in a downstream direction and did not expose any evident deviations from this trend until NBD. Water temperature increased 0.55 °C/km between NBD (rkm 74.3) and Tumalum Bridge (rkm 70.4). Significant habitat alterations such as irrigation diversions, levee construction and riparian habitat removal have occurred downstream from NBD and have likely contributed to the temperature increase. Water temperature increased 0.03 °C/km between Tumalum Bridge and Pepper’s Bridge (rkm 66.3). There is a prominent seep approximately 1.5 km below Tumalum Bridge, which could be the reason for the slight increase in temperatures between Tumalum and Pepper’s Bridge.

Movements

PIT Tag Detection Arrays

In 2006, six adult and nine subadult bull trout were detected at the NBD detection array. There are three fish passage routes at NBD, the east bank ladder, the west bank ladder and the spillway. Adult bull trout movement was not detected during January, March, July, August, September, November and December. Detection efficiency in the ladders is estimated to be 100% (Table 5). Therefore it is unlikely adult bull trout migrated through the ladders at NBD undetected. Adult movement may have occurred but may not have been detected during January, March, November and December, when it was possible for adult bull trout to pass over the spillway during higher stream flows (Figure 18). Adult bull trout movement was not detected during July through September. Since ladder efficiency was estimated to be %100, it is unlikely adult bull trout passed NBD through the ladders undetected. Streamflow at NBD from July through October was at base flow and passage was likely restricted to the ladders. Therefore it is unlikely adult bull trout passed NBD undetected during July through October. In summary, upstream migration was observed during April, May and June, which corresponds with the likely upstream migration period for spawning adults. Downstream migration was observed during February and October and may have occurred from January through March, November and December.

PIT tag detection data suggest subadult bull trout did not pass NBD during January through May, August, September, November and December. There are three fish passage routes at NBD, the east bank ladder, the west bank ladder and the spillway. Detection efficiency in the ladders is estimated to be 100% (Table 5). Therefore it is unlikely subadult bull trout migrated through the ladders at NBD undetected. Subadult movement may have occurred but may not have been detected during January through May, November and December, when it was possible for subadult bull trout to pass over the spillway during higher stream flows (Figure 18). Subadult bull trout were also not detected during August and September. Since ladder efficiency was estimated to be %100, and streamflow at NBD during August and September was at base flow and passage was likely restricted to the ladders, it is unlikely subadult bull trout passed NBD through the ladders undetected. Therefore it is unlikely subadult bull trout passed NBD undetected during August and September. The PIT tag detection histories suggest subadult bull trout movement at NBD occurred during June, July and October. Subadult movement may have also occurred during Jan through May, November and December.

In 2006 11 adult and 43 subadult bull trout were detected at the MCD detection array. Detection histories for the adult bull trout suggest movement in April, May and June, November and December (Figure 16). Adult bull trout were not detected at the MCD array during January through March, and July through October. There are three fish passage routes at MCD. Fish may pass through the ladder, the low flow outlet or over the spillway. At MCD only the ladder and low flow outlet were monitored, the spillway was not. Detection efficiency tests suggest the ladder antennas were 100% efficient at detecting 23-mm PIT tags from January through March (Table 6) therefore it is unlikely adult bull trout passed through ladder undetected during this time. Spill at MCD typically only occurs when stream discharge exceeds 400 cfs and spill exceeded 400 cfs during January and March 2006 (Figure 18). The low flow outlet antenna was not installed until August. Therefore, adult bull trout may have passed MCD undetected over the spillway during January or March or through the low flow outlet during January through March. Adult bull trout also were not detected during July through October 2006. Since detection efficiency tests suggest the ladder antennas were 100% efficient at detecting 23-mm PIT tags from July through October (Table 6), it is unlikely that PIT tagged adult bull trout migrated through the ladders at the MCD array undetected, during this time. Streamflow at MCD was <40cfs from July through October (Figure 19), therefore, spill did not occur and the low flow outlet was likely closed which limited passage to the ladder. As a result, it is unlikely adult bull trout passed MCD during July through October. The upstream migration of adult bull trout was detected from April through June and a downstream migration was detected during November and December, which corresponds with spawning and over-wintering migrations. Adult bull trout may have also dispersed downstream from January through March to overwintering locations.

PIT tag detection data suggest subadult bull trout did not pass MCD during January through March and August through October (Figure 17). There are three fish passage routes at MCD. Fish may pass through the ladder, the low flow outlet or over the spillway. At MCD only the ladder and low flow outlet were monitored and, the spillway is not. Detection efficiency tests suggest the ladder antennas were 100% efficient at detecting 23-mm PIT tags from January through March (Table 6) therefore it is unlikely subadult bull trout passed through the ladder undetected during this time. Spill at MCD typically only occurs when stream discharge exceeds 400 cfs and spill exceeded 400 cfs during January and March 2006 (Figure 18). The low flow outlet antenna was not installed until August. Therefore, subadult bull trout may have passed MCD undetected over the spillway during January or March or through the low flow outlet during January through March. Subadult bull trout also were not detected at MCD during August through October. Streamflow at MCD was <40cfs from August through October (Figure 19), therefore, spill did not occur and the low flow outlet was likely closed which limited passage to the ladder. As a result, it is unlikely subadult bull trout passed MCD during July through October. In summary, subadult bull trout dispersed downstream at the MCD detection array during April through July, November and December. They may have also dispersed passed MCD from January through March.

<u>Bull Trout Sampling/PIT Tagging</u>

All 11 of the bull trout were captured in the vicinity of Milton-Freewater, OR. Fish size ranged from 153-250 mm with an average size of 199 mm. Screw trap captures reported by Anglin et al. (2008) and Gallion et al. (2015a) suggest a downstream movement of similar sized bull trout during the same time period. Therefore, these fish were likely subadults that were dispersing downstream to rear.

Plans for 2007

We will assist other agencies to conduct redd surveys to monitor the spawning population of bull trout in the SFWWR and Mill Creek.

We will continue investigating bull trout distribution and movements using snorkeling, radio telemetry and PIT tag detection arrays. We will reinitiate snorkeling to determine bull trout distribution below Nursery Bridge Dam and to determine if bull trout locations are associated with cold water seeps. This snorkeling effort will be conducted in conjunction with a temperature study being conducted by the Walla Walla Basin Watershed Council and Oregon State University. Snorkel surveys will also be conducted between MCD and the division structure at Yellowhawk creek to determine the spatial and temporal distribution of bull trout. Bull trout distribution and movements in the impacted areas below MCD and NBD will also be monitored using radio telemetry. Lastly, distribution and movements of bull trout will be monitored using PIT arrays. We will continue operating PIT tag detection arrays at WW1, WW2 NBD, MCD, YHC, ORB and we will install a new array at Burlingame Dam.

We will deploy and maintain thermographs in conjunction with operation of the PIT arrays, radio telemetry and snorkel surveys. These data will help to understand bull trout response to seasonal changes in water temperature.

We will conduct barrier surveys from the Little Walla Walla Diversion to Burlingame Dam. Surveys will be conducted under low flow conditions and passage conditions for adult and subadult bull trout will be assessed.

We will collect additional mesohabitat data at bull trout use and non-use locations for use in the rearing habitat suitability model.

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Appendix A

Table A1. Average minimum, mean and average maximum monthly temperature data from January to December 2006 for 17 thermographs located on the WWR and one thermograph (Bennington Dam), located on Mill Creek.

Thermograph Location			Average monthly temperatures (°C)											
			January			February			March			April		
		rkm	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Site 15	(Harris Park)	97	4.6	5.0	5.4	3.2	3.9	4.5	4.2	5.0	6.0	4.9	5.9	7.4
Site 14	(CTUIR Hatchery)	92.8	4.7	5.1	5.5	3.1	3.8	4.5	4.2	5.1	6.1	5.0	6.2	7.7
Site 13	(Red Steel Bridge)	88.5	4.9	5.3	5.8	3.2	3.9	4.6	4.5	5.4	6.3	5.4	6.6	8.1
Site 12	(Upstream of forks)	84.4	5.1	5.5	5.9	3.3	4.0	4.7	4.7	5.6	6.7	5.7	7.0	8.5
Site 11	(Downstream of forks)	83.1	5.1	5.5	6.0	3.2	4.0	4.8	4.6	5.7	6.9	5.8	7.2	8.8
Site 10	(Joe West Bridge)	82	5.1	5.6	6.0	3.2	4.0	4.8	4.7	5.7	7.0	5.8	7.2	8.8
Site 9	(Day Road)	80.5	5.2	5.7	6.1	3.3	4.1	4.9	4.8	5.9	7.2	6.0	7.4	9.0
Site 8	(Upstream of Grove St. Bridge)	77.9	5.2	5.7	6.2	3.2	4.0	5.0	4.7	5.9	7.3	6.0	7.5	9.3
Site 7	(Cemetary Bridge)	76.3	5.2	5.7	6.2	3.2	4.1	5.0	4.9	6.0	7.4	6.4	7.6	9.0
Site 6 [a]	(Nursery Bridge Dam)	74.2	NA	NA	NA	NA	NA	NA	4.9	6.1	7.8	6.1	7.6	9.4
Site 5	(Downstream of NBD)	74	5.0	5.5	6.1	3.0	3.9	4.9	4.6	5.9	7.4	5.9	7.5	9.2
Site 4 [b]	(Levee Section)	72.2	5.1	5.7	6.3	3.0	4.0	5.1	4.8	6.1	7.7	6.1	7.7	9.5
Site 3 [c]	(Downstream of Tumalum)	70	5.3	5.9	6.5	NA	NA	NA	NA	NA	NA	6.5	8.1	10.0
Site 2 [d]	(Between Tumalum & Pepper's)	68.4	5.1	5.6	6.3	3.0	4.0	5.2	4.9	6.2	7.9	5.8	7.2	8.8
Site 1	(Pepper's Bridge)	66.3	5.0	5.6	6.3	2.9	4.0	5.2	4.9	6.2	8.0	6.3	8.0	9.8
Site 16 [e]	(Burlingame)	60.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Site 18	(Oasis Road Bridge)	10.1	5.3	5.7	6.1	3.5	4.1	4.6	7.1	7.6	8.2	10.0	10.6	11.3
Site 19 [f]	(Bennington Dam)	18.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A1 (continued)

Thermograph Location		rkm	May Min	May Avg	May Max	June Min	June Avg	June Max	July Min	July Avg	July Max	August Min	August Avg	August Max
Site 15	(Harris Park)	97	5.8	7.2	9.2	8.3	10.1	12.5	9.3	12.1	15.6	8.4	10.7	13.5
Site 14	(CTUIR Hatchery)	92.8	6.0	7.5	9.4	8.7	10.5	12.8	10.0	12.8	15.8	9.1	11.3	13.7
Site 13	(Red Steel Bridge)	88.5	6.4	8.0	9.8	9.3	11.2	13.2	11.2	13.7	15.9	10.3	12.3	13.8
Site 12	(Upstream of forks)	84.4	7.0	8.5	10.1	10.3	11.8	13.4	12.8	14.7	16.3	11.6	13.2	14.4
Site 11	(Downstream of forks)	83.1	7.3	9.0	10.9	10.6	12.5	14.5	13.1	15.3	17.6	12.0	13.7	15.6
Site 10	(Joe West Bridge)	82	7.3	9.0	10.9	10.6	12.5	14.6	13.2	15.5	17.9	12.1	13.9	15.9
Site 9	(Day Road)	80.5	7.6	9.2	11.2	10.9	12.8	14.9	13.7	15.9	18.5	12.6	14.3	16.5
Site 8	(Upstream of Grove St. Bridge)	77.9	7.8	9.6	11.6	11.2	13.2	15.3	14.1	16.4	19.0	12.9	14.8	17.1
Site 7	(Cemetary Bridge)	76.3	8.4	9.7	11.1	12.1	13.5	14.8	15.2	17.0	18.9	13.3	15.3	17.9
Site 6 [a]	(Nursery Bridge Dam)	74.2	7.9	9.8	11.8	11.5	13.7	16.0	14.6	17.1	20.1	NA	NA	NA
Site 5	(Downstream of NBD)	74	7.8	9.6	11.7	11.5	13.6	16.0	14.7	17.4	20.7	13.4	15.7	18.7
Site 4 [b]	(Levee Section)	72.2	7.9	9.8	12.0	10.6	12.6	14.7	NA	NA	NA	NA	NA	NA
Site 3 [c]	(Downstream of Tumalum)	70	8.3	10.3	12.7	11.3	13.2	15.5	16.3	20.4	25.2	14.2	17.9	22.4
Site 2 [d]	(Between Tumalum & Pepper's)	68.4	NA	NA	NA	NA	NA	NA	17.4	20.1	23.0	15.4	18.0	20.8
Site 1	(Pepper's Bridge)	66.3	8.3	10.4	12.8	12.5	14.8	17.6	17.1	19.7	22.9	15.6	18.0	20.7
Site 16 [e]	(Burlingame)	60.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Site 18	(Oasis Road Bridge)	10.1	15.0	15.9	16.8	18.7	20.3	21.8	23.2	25.2	27.0	20.1	22.2	24.1
Site 19 [f]	(Bennington Dam)	18.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Average monthly temperatures (°C)

Table A1 (continued).

Thermograph Location		Average monthly temperatures (°C)												
			Sept			Oct			Nov			Dec		
		rkm	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Site 15	(Harris Park)	97	7.5	8.9	10.6	5.6	6.5	7.5	4.8	5.4	5.9	3.6	4.0	4.5
Site 14	(CTUIR Hatchery)	92.8	7.9	9.3	10.8	5.8	6.7	7.6	4.9	5.5	6.1	3.6	4.0	4.5
Site 13	(Red Steel Bridge)	88.5	8.9	10.1	11.1	6.4	7.2	7.8	5.0	5.6	6.2	3.5	4.0	4.4
Site 12	(Upstream of forks)	84.4	9.9	10.8	11.7	6.9	7.6	8.2	5.1	5.8	6.3	3.5	4.0	4.5
Site 11	(Downstream of forks)	83.1	10.1	11.3	12.6	7.2	8.0	8.8	5.4	6.1	6.6	3.5	4.0	4.5
Site 10	(Joe West Bridge)	82	10.3	11.5	12.9	7.3	8.1	9.0	5.4	6.1	6.7	3.5	4.0	4.5
Site 9	(Day Road)	80.5	10.6	11.8	13.4	7.6	8.4	9.4	5.5	6.2	6.9	3.6	4.1	4.6
Site 8	(Upstream of Grove St. Bridge)	77.9	10.8	12.1	13.8	7.7	8.5	9.5	5.6	6.3	7.0	3.6	4.1	4.6
Site 7	(Cemetary Bridge)	76.3	11.3	12.7	14.5	8.0	9.0	10.1	5.9	6.6	7.3	3.8	4.4	4.9
Site 6 [a]	(Nursery Bridge Dam)	74.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Site 5	(Downstream of NBD)	74	11.2	12.9	15.4	7.7	8.9	10.6	5.4	6.2	7.0	3.3	3.8	4.4
Site 4 [b]	(Levee Section)	72.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Site 3 [c]	(Downstream of Tumalum)	70	11.7	14.7	18.6	7.8	9.8	12.9	5.5	6.4	7.4	3.4	4.0	4.6
Site 2 [d]	(Between Tumalum & Pepper's)	68.4	12.9	15.0	17.2	11.4	12.8	14.3	NA	NA	NA	NA	NA	NA
Site 1	(Pepper's Bridge)	66.3	13.1	14.9	16.9	9.7	11.0	12.2	5.9	6.7	7.5	3.4	3.9	4.5
Site 16 [e]	(Burlingame)	60.8	NA	NA	NA	8.6	9.6	10.5	6.2	6.9	7.7	3.6	4.1	4.7
Site 18	(Oasis Road Bridge)	10.1	16.0	17.3	18.5	10.2	11.1	11.9	4.5	5.0	5.6	1.2	1.6	1.9
Site 19 [f]	(Bennington Dam)	18.5	NA	NA	NA	9.1	10.3	11.9	6.2	6.9	7.6	3.4	4.0	4.5

[a] Thermograph was lost. No data from 1 January through 8 March and 18 June through 31 December 2006.
[b] Thermograph out of water 23 June to 18 July 2006. Site discontinued.
[c] Thermograph was lost, no data from 18 January to 4 April, 2006. Thermograph out of water, no data 19 June to 18 July 2006.
[d] Thermograph was buried in sediment from 4 April to 18 July 2006.
[e] Thermograph was first deployed on 22 October 2006.
[f] Thermograph was first deployed on 6 October 2006.