Bull trout population assessment in northeastern Oregon: a template for recovery planning

Progress Report for 2011

by

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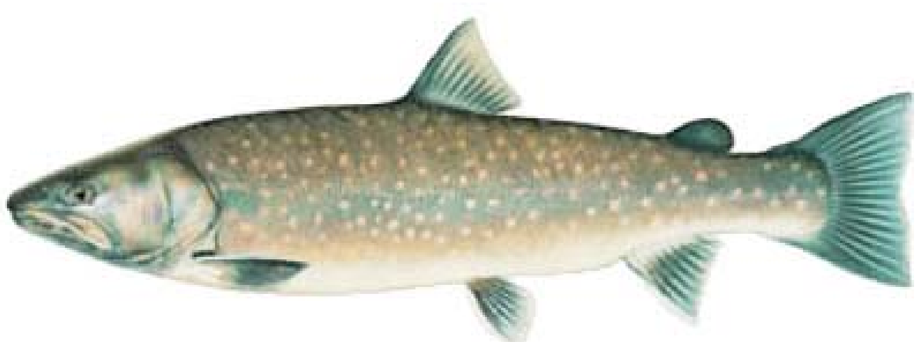
Draft – 5 September 2012 – Draft



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Suggested citation:

Budy, P., D. Epstein, T. Bowerman, and G.P. Thiede. 2012. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2011 Progress Report to US Fish and Wildlife Service. UTCFWRU 2012(2):1-80.

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ACKNOWLEDGMENTS

Funding for this project was provided by the US Fish and Wildlife Service and the US Geological Survey, Utah Cooperative Fish and Wildlife Research Unit.

We would like to thank Howard Schaller for securing funding and providing guidance and support. Don Anglin, Darren Gallion, Courtney Newlon, Marshall Barrows, and Ryan Koch of the USFWS Columbia River Fisheries Program Office also contributed to the success of this project. Dave Crabtree (USFS), Jackie Dougan (BLM), Brian Wolcott (WWBWC), and Phil Howell (USFS) provided information and support. We thank Bill Duke (ODFW), Paul Sankovich (USFWS), and Mike Lambert and Brian Mahoney (CTUIR) for contributing information, data, support, and logistics. George Ehmer helped maintain the upper Bear Creek PIT-tag antenna array along with Courtney Newlon, Marshall Barrows, and Ryan Koch. George Ehmer and John Ehart provided refreshments in the field and assistance transporting gear to and from field sites. Thanks to our 2011 summer field crew: Dave Epstein (Crew Leader), Dan Weber, and Hannah Moore.

Scientific Take Permit (13738 M1) was obtained with assistance from Darren Gallion and Ron Rhew of the USFWS CRFPO, as well as Grant Canterbury with USFWS, Regional Office, Region 1. Research was conducted under Utah State University IACUC Protocol 1082 and US Fish and Wildlife Service Section 10 permit number TE-702631, sub-permit number CRFPO-5.

EXECUTIVE SUMMARY

There are critical gaps in information that potentially limit our ability to effectively manage bull trout and ensure their continued persistence (Porter and Marmorek 2005; Al-Chokhachy et al. 2008). These gaps include quantification of population abundance and trend for all but a few populations, estimates of larval and juvenile survival rates, estimates of dispersal rates between populations, and life-history-specific information, such as the contribution of migratory versus resident fish to overall population growth and persistence. Our research seeks to address some of these knowledge gaps through long-term monitoring of a relatively large bull trout population in the South Fork Walla Walla River (SFWW). We provide essential information on abundance, trend, vital rates, habitat needs, and information on the potential for improving survival at one or more life stages. In addition, we gather information related to population structure (e.g., age, life history, and genetic components) and provide a template against which different strategies for monitoring can be evaluated in terms of accuracy, precision, cost/effort, and limiting factors. Our goal is to provide data and conservation assessment tools to aid in the efforts of the US Fish and Wildlife Service, to determine the necessary course of action for the recovery of bull trout populations throughout the study region and the rest of the species' range. The project was initiated in 2002 and has continued through 2011 (10 years). To meet our goals, each year we have developed and implemented a comprehensive mark- recapture program using two tag types, multiple capture techniques (both passive and active) and systematic sampling of two large study areas (SFWW and North Fork Umatilla rivers) with a high degree of effort. The year 2008 marked the fifth and final year of sampling and study in the North Fork Umatilla River while sampling has continued in the SFWW. 2008 marked the last year of field sampling by Utah State University.

The efforts of this project have been part of a completed PhD dissertation (Al-Chokhachy 2006) and MS thesis (Homel 2007) and are currently part of an on-going PhD dissertation (Bowerman, *in preparation*) and MS thesis research (Newlon, *in progress*) conducted through Utah State University. Results and syntheses of different components of the project are available in previous annual reports (Budy et al. 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, and herein) as well as in the peer-reviewed manuscripts: Al-Chokhachy et al. 2005; Al-Chokhachy and Budy 2007; Homel and Budy 2008; Homel et al. 2008; Al- Chokhachy and Budy 2008; and Al-Chokhachy et al. 2009; and Al-Chokhachy et al. 2010, Bowerman and Budy, *in review*.

2011 Field Season

We sampled 22 reaches during the 2011 field season (mid-July to mid-August), which accounted for approximately 26% of the study area. Over the summer, we handled 544 bull trout including 69 age-0, young-of-year (YOY; 46 – 65 mm TL, 0.5 – 2.2 g) bull trout. In 2011, the average bull trout captured and tagged measured 160 mm total length (TL; 1 SE = 3.9) and weighed 87.6 g (1 SE = 10.2). The smallest bull trout captured was 46 mm (0.9 g) and the largest bull trout caught was 687 mm TL (2.65 kg). Length-frequency distributions of bull trout captured in the SFWW have been relatively consistent from 2002 through 2011, with most captured fish in the 100 – 200 mm size range.

Of the 544 bull trout we handled in 2011, 453 were tagged with PIT tags and 164 of those were also tagged with T-bar anchor tags. In 2011, as in all years since 2003, most bull trout were tagged upstream of Burnt Cabin Creek. The greatest number of fish tagged in any single reach was in reach 68, just upstream of Table Creek. As in 2010, we performed snorkeling surveys in the same 22 reaches we sampled in the SFWW.

In 2011, condition estimates for juvenile (< 120 mm; K_{TL} ± 1 SE = 0.89 ± 0.006) and large adult (> 370 mm) bull trout (K_{TL} ± 1 SE = 0.98 ± 0.02) were above the 10-yr average, while condition of medium sized bull trout (120 – 370 mm TL; K_{TL} ± 1 SE = 0.89 ± 0.06) was close to the 10-year average. Across years and sizes, condition in 2011 was fairly high and quite similar to the average condition calculated in 2003, 2008 and the 10-year average (K_{TL} ± 1 SE = 0.89 ± 0.005). An evaluation of the relative weight (W_r) of the population also revealed stability through 10 years of data and indicated healthy fish in all size ranges. The W_r of all size classes was above the 10-year average in 2011.

The 2011 population estimate for bull trout > 120 mm was 11,193 (95% CI = 9,166 – 15,277), 1,868 (95% CI = 1,440 – 2,764) for bull trout > 220 mm and 804 (95% CI = 453 – 1,693) for bull trout > 370 mm in total length. All estimates were lower than estimates in 2010, which were the highest estimates during the 10-yr study. The population growth rate (lambda, λ) in the SFWW was relatively consistent among estimates obtained from each of several approaches, all of which suggested a stable population trend (e.g., $\lambda \approx 1$).

Stream temperatures in the SFWW were similar to previous years, with temperatures between August 2010 and August 2011 ranging from 0 - 14^{o}C in the lower part of the study area near Harris Park. Air temperatures were similar to past years, although the region experienced an unusually high winter snowfall and cooler than average spring temperatures, resulting in an extended and elevated spring runoff period. Peak discharge occurred in the SFWW on 17 January 2011 (estimated flow = 1040 cfs), with two smaller peaks in the spring, on 5 April 2011 (688 cfs) and 15 May 2011 (713 cfs). Elevated flows (> 300 cfs) were sustained through June and into July 2011, and the river did not reach base flow until mid-July.

Future

During 2011 and 2012, we will use data gathered from the 10 years of research on the SFWW to complete several comprehensive population viability type analyses that will help inform the bull trout Recovery Monitoring and Evaluation Technical Group (RMEG). We are currently working within RMEG to: 1) assign uncertainty scores to likely threats to bull trout populations across their range, 2) aid in building a gaming tool to identify strengths and weaknesses of the "Natureserve" scoring approach to assessing threat removal effectiveness, and 3) build a metapopulation Population Viability Analysis (PVA) model which we will use to compare demographic responses to threat removal with categorical responses based on expert opinion from "Natureserve" scoring. In 2012, we will also complete a comprehensive retrospective synthesis of all SFWW bull trout population data to date. This will include rerunning all survival models for as many age classes as possible, updating and rerunning the Pradel population trend model, and building an integrated population model (e.g., White and Lubow 2002) for evaluating the potential effectiveness of management actions and recovery planning.

Monitoring and evaluation of bull trout populations in the South Fork Walla Walla River, Oregon

INTRODUCTION

Conservation of endangered species requires an understanding of key factors driving and limiting populations. Therefore, estimates of population abundance and trend are necessary to evaluate present and future population status (Soulé 1987). Additionally, because the health of a population is ultimately determined by the fitness of its individuals, estimates of vital rates such as survival and growth are important for identifying factors that potentially limit the population (Morris and Doak 2003). As such, quantification of these key demographic parameters can help inform decisions geared toward recovering and sustaining wild populations of imperiled organisms.

Identification of limiting factors and population trends is important for the conservation of bull trout (*Salvelinus confluentus*), a species of char native to western North America. Bull trout have experienced dramatic declines in both distribution and abundance across much of their range, resulting in the species being listed as "threatened" under the Endangered Species Act (United States Fish and Wildlife Service 1999). Bull trout were once distributed from northern California northward to the headwaters of the Yukon River in western Canada (Cavendar 1978). Today, however, they have been extirpated from the southernmost extent of their historical range (Goetz 1989). Bull trout require cold, clean water, and are thought to prefer complex physical habitat (Fraley and Shepard 1989; Goetz 1989; Al-Chokhachy and Budy 2007). Numerous factors have contributed to the decline of bull trout populations, including habitat degradation (Fraley and Shepard 1989), barriers to migration (Rieman and McIntyre 1995), competition with introduced species (McMahon et al. 2007), and active eradication (Parker et al. 2007). In many locations, bull trout populations may also have been negatively impacted by changes in stream-flow regimes (Muhlfeld et al. 2011). Bull trout populations are likely to be further affected by environmental changes associated with climate warming and associated changes in stream temperatures (Rieman et al. 2007; Isaak et al. 2010). Because bull trout distributions are strongly associated with cold stream temperatures (Wenger et al. 2011), they are extremely susceptible to habitat loss as a result of warming stream temperatures (Isaak et al. 2010; Isaak et al. 2011). Many bull trout populations in the coterminous Unites States may also be at risk of inbreeding depression because of low effective population sizes (Ardren et al. 2011). Genetic studies suggest that there is little genetic exchange among most bull trout populations, due in part to the species' strong natal site fidelity, but probably exacerbated by the presence of instream flow barriers and loss of connectivity between spawning streams (Meeuwig et al. 2010).

Bull trout exhibit complex life-history strategies, and multiple life-history forms are known to coexist within a single population (Rieman and McIntyre 1993; Al-Chokhachy and Budy 2008; Homel et al. 2008). Resident fish may spend their entire lives in a single stream system, while migratory bull trout may be fluvial, adfluvial, or anadromous (McPhail and Baxter 1996; Brenkman and Corbett 2005), moving between headwater spawning streams out into larger rivers, lakes, or the ocean, according to the respective life-history type. This diversity of life-history forms further highlights the need for large-scale, long-term studies that can be used to evaluate populations which occupy a diversity of habitats, ranging from small spawning streams in high-elevation headwaters to large rivers used for migratory corridors and overwintering adult habitat (Watson and Hillman 1997; Schoby and Keeley 2011).

The goal of bull trout recovery planning by the U.S. Fish and Wildlife Service (USFWS) is to describe courses of action necessary for the ultimate delisting of this species under the Endangered Species Act, and to ensure the long-term persistence of self-sustaining, complex interacting groups of bull trout distributed across the species' native range (Lohr et al. 1999). To meet this goal, the USFWS has identified several objectives which require the type of information provided by this project: (1) maintain current distribution of bull trout within core areas in all recovery units and restore distribution where needed to encompass the essential elements for bull trout to persist, (2) maintain stable or increasing trends in abundance of bull trout in all recovery units, and (3) restore and maintain suitable habitat conditions for all bull trout life-history stages and strategies. The USFWS recovery-planning document emphasizes conserving core areas within conservation units to preserve genotypic and phenotypic diversity represented in different geographic locations, and to conserve bull trout populations across a range of habitats. The continued survival and recovery of individual core area populations is thought to be critical to the persistence of conservation units and in overall recovery of the Columbia River distinct population segment (DPS; Whitesel et al. 2004).

Recent research has contributed to our knowledge of individual bull trout populations in various parts of the species' range (e.g., Al-Chokhachy et al. 2010), as well as our understanding of issues managers face in trying to recover bull trout populations (Al-Chokhachy et al. 2009). However, there are still critical gaps in information that potentially limit our ability to effectively manage bull trout and ensure their continued persistence (Porter and Marmorek 2005; Al-Chokhachy et al. 2008). These gaps include quantification of population abundance and trend for all but a few populations (*but see* Al-Chokhachy and Budy 2008), estimates of larval and juvenile survival rates (*but see*

Bowerman and Budy, *in review*), estimates of dispersal rates between populations (Dunham and Rieman 1999), and life-history-specific information, such as the contribution of migratory versus resident fish to overall population growth and persistence. In addition, the relative contribution of different threats (e.g., passage versus water quality) is poorly understood and documented (Staples et al. 2004).

Our research seeks to address some of these knowledge gaps through long-term monitoring of a relatively large bull trout population in the South Fork Walla Walla River (SFWW). Each year, we use mark-recapture/resight data from the SFWW to estimate population size and structure, population trend, vital rates, and movement patterns (Al-Chokhachy and Budy 2008; Homel and Budy 2008, Bowerman and Budy, *in review*). Previous research on this population has allowed us to evaluate and compare different monitoring techniques (Al-Chokhachy et al. 2005; Al-Chokhachy et al. 2009), assess genetic differentiation between resident and migratory life-history types (Homel et al. 2008), evaluate movement patterns (Homel and Budy 2008), and compare demographic parameters and habitat use among several distinct populations (Al-Chokhachy and Budy 2007). Research on specific components of this greater project has included studies of other nearby bull trout populations in the Wenaha, John Day, and Umatilla rivers (Budy et al. 2005). By comparing methodologies among numerous years and sites, we also provide a template against which different strategies for monitoring and evaluation can be assessed in terms of accuracy, precision, and cost per effort (Al-Chokhachy et al. 2009). To date, our work includes ten years (2002 - 2011) of population monitoring data and vital-rate statistics from the SFWW. The data and conservation assessment tools provided by this project will ultimately help guide the USFWS in determining the necessary management actions for recovery of bull trout populations throughout the range of bull trout. For example, demographic data from 2002 - 2010 are currently being used by the USFWS Bull Trout Recovery, Monitoring, and Evaluation Technical Group (RMEG) to create a model to assess viability of bull trout populations. This information will be used to help inform bull trout recovery planning led by the USFWS.

In previous years, we have conducted research on several rivers, which allowed us to compare population abundance and distribution, as well as vital-rate statistics and habitat use, between populations of bull trout in the John Day, Umatilla, and Walla Walla river systems. From 2009 to 2011, our research focused solely on the South Fork Walla Walla River, located in Northeastern Oregon (Figure 1). The SFWW was initially selected as the comprehensive study area for this research because it contains a relatively high abundance of both resident and migratory fish and a diversity of habitat types, which allows us to study differences in such metrics as movement and survival in relation to life-history strategy. In addition, this watershed is the focus of numerous complex water management issues associated with fish protection, and thus provides an opportunity to apply research to active management decisions. Ten years of monitoring in the SFWW has provided one of the most comprehensive, continuous capture-recapture studies of fluvial bull trout in the region.

STUDY AREA

The South Fork Walla Walla River

The Walla Walla River in northeastern Oregon and southeastern Washington is a tributary of the Columbia River that drains an area of 4,553 km^2 (Walla Walla Subbasin Summary Draft 2001). Tributaries to the Walla Walla River originate in the Blue Mountains at elevations near 1800 m, and include the North and South Fork Walla Walla Rivers in Oregon, and Mill Creek and Touchet River, which enter the mainstem after it flows northward into Washington state.

The Walla Walla River historically contained a number of native anadromous and resident salmonid populations including bull trout, redband trout (*Oncorhynchus mykiss* subpopulation), mountain whitefish (*Prosopium williamsoni*), summer steelhead (*O. mykiss)*, spring and fall Chinook salmon (*O. tshawytscha*), chum salmon (*O. keta*), and coho salmon (*O. kisutch*), although the extent of fall Chinook salmon, chum salmon, and coho salmon within the system is not known (Walla Walla Subbasin Summary Draft 2001). Today, steelhead represents the only native anadromous salmonid still present in the Walla Walla River system. However, since 2000 there has been annual supplementation of adult Chinook salmon in the SFWW by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and there now appears to be natural reproduction in addition to ongoing supplementation (Mike Lambert, CTUIR, *personal communication*). Populations of native redband trout, bull trout, mountain whitefish, sculpin (*Cottus* spp.), and dace (*Rhinichthys* spp.) still persist in the Walla Walla River; introduced brown trout (*Salmo trutta*) are found in the lower portions of the basin.

Little documentation exists to describe the historical distribution of bull trout in the Walla Walla River Subbasin prior to 1990. Anecdotal evidence suggests that large fluvial bull trout utilized the Columbia River. Telemetry studies in the mid-Columbia River region have shown bull trout to use both primary and secondary tributaries for spawning (FERC Project 2145 Draft 2002). Therefore, it is presumed that bull trout had access to the Columbia River and all of its tributaries prior to the impoundment of the Columbia River (Buchanan et al. 1997). Today, resident and fluvial forms of bull trout exist in the Walla Walla (Walla Walla Subbasin Summary Draft 2001), and both life-history types spawn in the tributaries and headwaters of the Walla Walla River. Recent data demonstrate that bull trout travel throughout the Walla Walla River system and into the Columbia River (Budy et al. 2010; Anglin et al. 2010).

Within the Walla Walla River Basin, bull trout are divided into three distinct populations, which are currently considered two core areas based on geography and genetic analysis: SFWW and Mill Creek in the Walla Walla Core Area, and the Touchet River population and core area (Kassler and Mendel 2007). Ratliff and Howell (1992) described the population status of bull trout as "low risk" in the SFWW and Mill Creek. Since that report, the status of the SFWW population has remained at low risk, but the Mill Creek population has been upgraded to "of special concern" (Buchanan et al. 1997). Alterations to migratory corridors linking these populations have occurred, and recent genetic research suggests that the Mill Creek, SFWW, and Touchet River populations are genetically distinct (Kassler and Mendel 2007). The degree of connectivity among the three populations is unknown, but movement among populations of individual spawning-age fish has been documented (Budy et al. 2010).

The long-term study site on the SFWW spans nearly 21 km in length. The lower end of the study area begins at Harris Park Bridge (97 km upstream of the Columbia River; Budy et al. 2003, 2004, 2005) and ends at the confluence with Reser Creek (117.7 km upstream of the Columbia River; Reach 103). In order to account for spatial variation of the study area and the distribution of bull trout, the study site was divided into 103 reaches, each approximately 200 m in length, using Maptech mapping software (Figure 1).

An initial site was randomly selected from the list of reaches, and thereafter every fifth reach was designated as a long-term study reach (approximately 20% of the study area); these reaches have been sampled annually since 2002. The UTM coordinates from the mapping software were used to locate the general location of the bottom of each reach, and the closest pool tail to the coordinates was set as the true reach boundary. The reach continued upstream for at least 200 m and the top was set at the first pool-tail above the 200 m delineation. The length of each reach was then recorded along the thalweg. Location coordinates (UTM using GPS) were recorded at the boundaries of each reach.

METHODS

Size designations

The following size designations have been used since the onset of this bull trout population assessment in northeastern Oregon in 2002. Bull trout smaller than 220 mm are considered subadult, not sexually mature fish (Al-Chokhachy and Budy 2008) and bull trout 220 mm or larger represent both resident and migratory sexually mature fish (hereafter termed adult; Al-Chokhachy et al. 2005; Al-Chokhachy and Budy 2007). Considering bull trout that are 220 mm or greater to be sexually mature is a conservative estimate, as smaller sexually mature fish have been found in the study area and in other systems (WDFW 2000; Dunham et al. 2008). Additional size categories are used for population growth-rate estimates and survival estimates. For the purposes of this study, young of the year (YOY, age-0) fish are 0 - 69 mm; juvenile bull trout are 70 - 119 mm; immature subadults are 120 - 219 mm; small adults are 220 - 369 mm, and large, likely migratory, adults are ≥ 370 mm. This latter designation is based on the percent of fish within that age class found to be migratory in the SFWW by Al-Chokhachy and Budy (2008) and in other systems (Rieman et al.1993; Fraley and Shephard 1989). Not all bull trout > 370 mm are migratory (particularly in fluvial systems), but there is a presumption that most large fish are migratory and observations of movement patterns support this presumption (Budy et al. 2010). The size categories > 220 mm and > 370 mm are considered the most important for trend and population analyses. In 2010, age-at-length estimates were updated based on otolith analysis and the following age estimates were established: 70 - 120 mm = age-1, 120 - 220 mm = age-2 and age-3, 220 - 370 mm = age-4 and age-5, and > 370 mm = ≥ age-6.

Fish sampling

Capture.—We captured bull trout using multiple sampling techniques, primarily angling and electrofishing downstream to a seine. All captured bull trout were weighed (nearest 0.1 g) and measured (nearest mm total length, TL, and fork length, FL). These measurements were used to determine length-to-weight regressions and calculate condition (see below). Scales were taken from all tagged bull trout prior to release. Gonads, otoliths, stomach contents, and tissue samples were taken from a small subsample of sacrificed adults to estimate fecundity, sex ratio, age, and diet. Tissue samples may be used for future stable isotope analysis. Bull trout < 70 mm (age-0, YOY) were not marked, but were immediately measured for TL and weight and then returned to the stream to avoid predation by larger bull trout in the holding tanks.

Marking.— In all study reaches, each captured bull trout ≥ 70 mm TL was marked with a unique full-duplex (FDX; 134.2 kHz) PIT tag as well as an external mark, the latter of which was used to identify recaptures during snorkel surveys (“recapture” surveys). Bull trout from 70 to 120 mm were tagged with 12-mm PIT tags and fish ≥ 120 mm were tagged with 23-mm PIT tags. In addition to an internal PIT tag, all bull trout were given an external mark by either clipping the adipose fin on bull trout < 170 mm TL or inserting a T-bar anchor tag (unique to year and stream) on the right side, adjacent to the dorsal fin, on bull trout ≥ 170 mm TL. In 2009, we increased the minimum size of fish tagged with anchor tags from ≥ 120 to ≥ 170 mm TL, and we retained this protocol in 2010 and 2011. Fin clips were saved for later genetic analysis. Prior to tagging, bull trout were anesthetized until they exhibited little response to stimuli. A PIT tag was then inserted into the peritoneal cavity via a small incision on the ventral side of the fish, anterior to the pelvic fins, following the procedure prescribed by the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (1999). After tag implant, scales were taken from the right side at the base of the dorsal fin for aging and growth information. During recovery, all anesthetized fish were placed in a flow-through recovery container within the channel, monitored until full equilibrium was restored, and returned to slow-water habitat near individual capture locations.

Recapture.—We recaptured previously tagged bull trout (2002 – present) during capture surveys. All actively captured bull trout were passed over a handheld PIT-tag reader and checked for anchor tags from previous years. Any recapture was weighed (nearest 0.1 g) and both total length and fork length measured to the nearest mm for estimates of annual growth, and recapture location was recorded for movement analysis. Recapture events provide critical information for estimates of bull trout survival, growth rates, movement patterns, annual population estimates, and to parameterize the Pradel population trend model.

Tag retention.—We calculated a simple tag-loss rate for both PIT tags, inserted internally into the peritoneal cavity, and external anchor tags. We checked all recaptured fish for loss of each type of tag. We estimated tag loss by dividing the number of recaptured bull trout that had lost each type of tag by the total number of recaptured fish.

Resighting.—We used daytime snorkel surveys to resight marked bull trout within study reaches (mean reach length = 250 m). To avoid double-counting fish that were migrating upstream to the headwaters to spawn, we began surveys in the uppermost reaches of the study area and moved progressively downstream. Snorkel surveys were conducted on consecutive days until completion. We used this approach to minimize the incidence of counting the same fish twice in different reaches. Within each reach, two snorkel observers proceeded in an upstream direction while scanning for fish across their assigned lane, such that the entire stream channel was surveyed. Water temperature and sampling time were recorded for each reach snorkeled. All bull trout (tagged and untagged), *O. mykiss*, and mountain whitefish were enumerated and assigned to 50-mm size classes. Additionally, all juvenile and adult Chinook salmon encountered were enumerated. Accurate identification of fish species and size estimation was emphasized.

Passive fish detection.—Two passive in-stream PIT-tag antennas (PIA or detectors) are located within the study area that continuously collect information from PIT-tagged bull trout as fish swim past. One PIA is located at the Harris Park Bridge (river km 97; UTM coordinates: 110408261 E, 5076370 N) at the bottom of the study site, and the second PIA is located just above the confluence with Bear Creek (river km 105.6; UTM coordinates: 110414281 E, 5077108 N). The Harris Park Bridge PIA (WW1) has been operational since mid-September 2002, and the Bear Creek PIA (WW2) has been operational since mid-October 2002. The PIAs operate continually except for periods when maintenance is required. In 2011, the WW1 antenna was washed out by high flows and inoperable between 16 January and 30 June, and the WW2 PIA did not operate between 20 January and 28 September. Additional PIAs are located downstream in the Walla Walla River at Nursery Bridge, Burlingame Diversion, and Oasis Bridge. Additional PIAs downstream of the study area allows us to monitor fish migrations and connectivity within the Walla Walla River system. All detectors are linked either through phone or satellite, and data are uploaded to the PTAGIS website (<*www.psmfc.org/pittag/Data_and_Reports/index.html* > under "*Small-scale Interrogation Site Detections -Query*"). Resight data collected at PIAs between 2002 and 2011 is summarized in Appendix 4.

Condition indices.—We used two different indices of fish condition to evaluate relative health of individual bull trout and annual cohorts (Blackwell et al. 2000). We calculated Fulton's condition factor (K_{TL}) of bull trout captured from 2002 - 2011 using the equation described in Ricker (1975):

$$K_{TL} = (W / L^3) * 100,000 \quad (1)$$

where K_{TL} is the condition factor of a given fish, W is the weight of that fish and L is the total length of the fish. In 2011 we also evaluated a second index of condition, relative weight (W_r), for bull trout captured between 2002 and 2011. W_r is computed by dividing the measured mass of an individual by the "standard" or species-specific computed mass, as introduced by Wege and Anderson (1978). We used a standard-weight equation developed by Hyatt and Hubert (2000) using data from 13 populations of bull trout in the United States and Canada ($\log_{10}W_s = -5.327 + 3.115 \log_{10}TL$; where TL is the total length of a given fish). Based on this equation and the measured weight of each fish (W), a value for W_r for each fish is calculated by:

$$W_r = W / W_s * 100 \quad (2)$$

where W is the weight of the fish, and W_s is the standard weight for a bull trout calculated with the Hyatt and Hubert (2000) equation above.

Growth

We determined growth information from bull trout previously tagged in the study area and recaptured during the 2011 summer field season. This data was added to previous years of growth information to estimate average annual growth in total length (mm) and weight (g). To calculate growth, we divided the difference in length between captures (recapture TL - initial capture TL) by the number of days between initial capture and recapture events (from 1 to 4 years).

Diet, age, and fecundity

From 2002 – 2011, we have been collecting a small subsample of bull trout (ten or fewer individuals per year) for diet, age, and fecundity analyses. In 2011, we collected stomachs, sagittal otoliths, and gonads from 8 sacrificed bull trout. Stomach contents were partitioned into food types (i.e., macroinvertebrates, *Oncorhynchus* spp., etc.) and each type was quantified as percentage of diet by wet weight (g) and a count of prey by classification. Prior to being read, we mounted, sanded and polished sagittal otoliths. We then viewed otoliths under a microscope and counted annuli. We estimated fecundity of sacrificed bull trout by counting eggs from ripe females and then relating number or eggs per female to that individual's weight (g) and total length (mm).

Population estimates

We used tagging and snorkeling data to parameterize mark-resight population estimates using a Lincoln-Petersen bias-adjusted estimator (Chapman 1951). We estimated population size and 95% confidence intervals (Krebs 1999) for three size groupings of bull trout: > 120 mm, > 220 mm, and > 370 mm. We expanded these reach-based estimates to the entire study area to estimate abundance for the entire subpopulation within the upper SFWW.

Population growth rate

Obtaining reliable estimates of population growth rate (trend) to determine population trajectory is a particularly challenging task that requires multiple years of data. We estimated population trend using two different methods and three data types. Because each methodology has different sources of bias associated with it, comparison of different approaches can help improve confidence in the direction of the trend. First, we estimated trend via linear regression of log-transformed annual changes in population growth rate (λ) as a function of time step (Morris and Doak 2002; Budy et al. 2007) based on (1) redd count data (1994 - 2011) obtained from the USFWS and the Oregon Department of Fish and Wildlife (ODFW), and (2) population estimates from mark-resight data from this study (2002 - 2011). We compared these results with an estimate of trend using a temporal symmetry model (Pradel 1996; Nichols and Hines 2002) based on capture-recapture data from 2002 - 2009. For both approaches, we estimated trend for fish > 220 mm because this size class corresponded with the adult population within the SFWW (Al-Chokhachy and Budy 2008), as well as bull trout recovery goals as defined by USFWS. Additionally, we also performed separate trend analyses using both approaches for large bull trout (> 370 mm), because this size class contains the greatest proportion of individuals exhibiting migratory patterns within the SFWW, and the most fecund individuals (Al-Chokhachy and Budy 2008).

Survival

Survival estimates will not be updated again until 2012. See the 2007 annual report (Budy et al. 2008) for survival estimates of adults and the 2010 annual report (Budy et al. 2011) for survival estimates for juveniles (*see also* Al-Chokhachy and Budy 2008; Bowerman and Budy, *in review*).

Temperature

We monitored temperature at four sites in the SFWW from August 2010 to August 2011 using in-stream temperature loggers programmed to record temperatures at one hour intervals. Temperature was recorded at the top of the study area, just below Reser Creek (River km 117.7), in the middle of the upper portion of the study area near Skiphorton Creek (River km 112.9), the middle of the lower part of the study area near Bear Creek (River km 105.6), and just below the bottom of the study area, near Harris Park (River km 97).

Stream flow

We downloaded stream flow data (mean daily flow in cfs) from the Oregon Water Resources Department (OWRD) Near Real Time Hydrographic Data website: *http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/display_hydro_graph.aspx?station_nbr=14010000* measured at Station 1401000 on the South Fork Walla Walla River near Milton, Oregon (Umatilla Basin, Umatilla County, HUC = 17070102) for the period 1 January to 31 December 2011.

RESULTS

Fish sampling

We sampled 22 reaches during the 2011 field season (mid July to mid August), which accounted for approximately 26% of the study area. We handled 544 bull trout including 69 young-of-year (age-0; 46 – 65 mm TL, 0.5 – 2.2 g). In 2011, the average length of bull trout captured was 160 mm in length (TL; 1 SE = 3.9) and weighed 87.6 g (1 SE = 10.2; Figure 2). The smallest bull trout captured was 46 mm (0.9 g) and the largest bull trout caught was 687 mm TL (2650 g). From 2002 - 2011, length-frequency distributions of captured bull trout in the SFWW have consistently shown the majority of fish in the 100 – 200 mm size range (Figure 2). In 2002 - 2004, the proportion of fish was more evenly distributed among sizes compared to 2007 - 2009, when the relative proportion of juveniles was higher, and adults lower. Size distributions appear intermediate in the intervening years.

Of the 544 bull trout we handled in 2010, we tagged 453 with PIT-tags and 164 of those were also tagged with colored (orange) anchor tags (Figure 3). In 2011, as in all years since 2003, most bull trout were tagged upstream of Burnt Cabin Creek (Figure 3). We tagged the greatest number of bull trout in reach 68, between Table and Skiphorton creeks (Figure 3).

We developed strong annual weight-at-length relationships for bull trout between 2002 and 2011 (R^2 = 0.99; Table 1; Figure 4). A consistent fork length to total length relationship was also apparent for those bull trout measured in 2011 (R^2 = 0.99; Figure 5), similar to the conversion factor (TL = 1.049 * FL) used for bull trout in Hyatt and Hubert (2000).

Active recaptures in 2011.—During 2011 active sampling, we physically recaptured a total of 21 bull trout, of which 2 had been PIT tagged in 2007, 1 had been tagged in 2008, 3 had been tagged in 2009 and 15 had been tagged in 2010. All recaptured fish that did not have an anchor tag but were greater than 170 mm TL were marked with an orange anchor tag. New PIT tags were inserted into three recaptured fish that had lost the originally inserted PIT tag.

Table 1. Summary of the relationship between total length (mm) and weight (g) of bull trout in the South Fork Walla Walla River from 2002 to 2011. For each year, the number of fish included in the relationship (*n*), the equation of the power function fit to the data, and the R^2 value for the fit of the line to the data are provided.

Year	*n*	Equation	R^2
2002	299	$W = 4.01 \times 10^{-5} (TL)^{2.76}$	0.98
2003	797	$W = 1.44 \times 10^{-5} (TL)^{2.93}$	0.98
2004	740	$W = 9.87 \times 10^{-6} (TL)^{2.99}$	0.99
2005	644	$W = 6.53 \times 10^{-6} (TL)^{3.06}$	0.99
2006	445	$W = 4.74 \times 10^{-6} (TL)^{3.12}$	0.99
2007	331	$W = 3.81 \times 10^{-6} (TL)^{3.16}$	0.99
2008	402	$W = 8.00 \times 10^{-6} (TL)^{3.02}$	0.98
2009	606	$W = 4.27 \times 10^{-5} (TL)^{3.13}$	0.98
2010	604	$W = 3.75 \times 10^{-6} (TL)^{3.16}$	0.99
2011	544	$W = 8.14 \times 10^{-6} (TL)^{3.02}$	0.99

Tag retention.—In 2011, we recaptured 21 bull trout that had been tagged in previous years and retained at least one mark (a PIT tag or an anchor tag and/or fin clip). Of those, four had an external mark but were missing a PIT tag, resulting in a PIT-tag loss rate of 19%. Of the recaptures, eight had anchor tags and no fish had lost anchor tags. Based on tag loss data from bull trout recaptured between 2003 and 2011, we estimated a 9-year average PIT-tag loss rate of 10%, after incorporating the estimated anchor tag loss rate of 10% (the PIT-tag loss estimate without accounting for anchor tag loss was 9%).

Passive fish detection in 2011.—As in previous years, throughout the 2011 calendar year, bull trout were detected at various Passive In-stream Antennae (PIA) within the SFWW and main stem Walla Walla River system (Figure 1). Data from PIA detections were summarized by unique monthly detections at each site such that if a PIT-tagged fish was detected numerous times at the same PIA in one month, it was recorded only once. The greatest number of unique monthly detections occurred in July at the Harris Park PIA (WW1), and in October at the Bear Creek site (WW2; Figure 11). However, WW2 was inoperable from January – September 2011, so no fish were detected above WW1 during the summer spawning run. Marked bull trout were detected at WW1 only during summer months and into November. In contrast, fish were detected at the PIA at Nursery Bridge (NBA) in every month of 2011 except for February, and at Burlingame diversion (BGM) only during winter months.

Condition indices.—To assess the condition of bull trout in the SFWW and potential variation in condition through time, we calculated both the condition factor and relative weight of the population from 2002 to 2011. While there has been some variation in Fulton's condition factor (K_{TL}) of bull trout captured from 2002 – 2011, K_{TL} values for all size classes (< 120 mm, 120 – 370 mm, > 370 mm) have hovered around the mean throughout the ten-year period (Figure 6). The greatest variation between years was in the large adult size class (> 370 mm; 10-year mean ± 1 SE; 0.89 ± 0.017), followed by the juvenile size class (< 120 mm; 0.88 ± 0.010). The most stable size class was the subadult/small adult (120 – 370 mm; 0.89 ± 0.007).

In 2011, condition of juvenile (< 120 mm; K_{TL} ± SE; 0.89 ± 0.01) and large adult bull trout > 370 mm bull trout (0.98 ± 0.02) were greater than the 10-year average, while condition of small adult bull trout was similar to the 10-year average (120 – 370 mm TL; 0.89 ± 0.01; Figure 6). Across size groupings, condition in 2011 was similar to the 10-year average for the SFWW (0.89 ± 0.01; Figure 7).

The relative weight (W_r) of bull trout captured from 2002 – 2011 has varied by size class and year; however, W_r has stayed relatively consistent within size classes during the 10-year period (Figure 8). The greatest variation from 2002 - 2011 was in the juvenile size class (< 120 mm; 10-year mean ± SE; 109.5 ± 1.4), followed by the large adult size class (> 370 mm; 101.1 ± 1.1) and there was little variation in the subadult/small adult size class (120 - 370 mm; 103.1 ± 0.4). In 2011 the estimated W_r values were higher than the 10-year average for all size classes (< 120 mm; W_r ± SE = 112.8 ± 0.9; > 370 mm; 103.0 ± 2.4; 120 – 370 mm TL; 104.0 ± 0.8; Figure 8).

Snorkel surveys.—We performed snorkel surveys in 22 reaches in the SFWW study area in 2011. During snorkel surveys, we sighted a total of 580 bull trout within the reaches of the study area. Bull trout were observed in all 22 reaches, where reach 68 had the highest counts of bull trout (57 individuals) and reaches 3 and 8 had the lowest counts of bull trout (6 and 9 individuals, respectively; Figure 9). The majority of bull trout sighted were estimated to be in the 120 – 170 mm and 170 – 220 mm size classes (n = 102 and n = 124, respectively); however, bull trout as large as the 670 – 720 mm category and as small as the 0 – 70 mm category were also sighted (Figure 10). Sixty-two previously marked fish between 120 and 520 mm TL were re-sighted during snorkel surveys. Of these re-sighted fish, one had originally been tagged in 2008, two in 2009, five in 2010, and 54 in 2011.

Growth of recaptured fish

Since 2002, we have recaptured 124 bull trout in the SFWW for estimates of annual growth in total length (mm; Figure 11). We have only been PIT tagging bull trout < 120 mm since 2007, which explains why this size category has the fewest observations. Average annual growth in total length of tagged bull trout varied between subadults and adults. The smallest bull trout size classes (< 120 mm and 120 – 219 mm) exhibited similar annual growth in total length, 65.2 ± 13.7 mm/year (mean ± 2 SE) and 64.9 ± 8.0 mm/year, respectively (Figure 11). These subadult fish exhibited higher annual growth in total length than small adults (220 – 370 mm), 43.4 ± 7.5 mm/year, and much higher growth in total length than large adults (> 370 mm), 21.2 ± 7.1 mm/year.

We have recaptured 117 bull trout for estimates of annual growth in weight (mass in g; Figure 12). Adult bull trout added more body mass annually than subadults. Small (220 - 370 mm) and large (> 370 mm) adults exhibited the highest growth rates, 123.4 ± 30.9 g/year (mean ± 2 SE) and 182.0 ± 82.3 g/year, respectively. Subadult bull trout in the < 120 mm and 120 - 220 mm size classes exhibited the lowest growth in weight (37.8 ± 16.3 g/year and 88.6 ± 18.0 g/year), respectively (Figure 12).

Diet, age, and fecundity

We sacrificed eight bull trout in 2011 to collect stomach contents for diet analysis, sagittal otoliths for aging purposes, and gonads for fecundity analysis. Bull trout diet data are available from fish sacrificed from 2003 – 2011. Our diet samples indicate that, on average, fish (59.6% *Oncorhynchus mykiss*, 7.2 % bull trout, and 0.5% dace) were the predominant prey of bull trout in 2011 representing 67% of diets by wet weight (Figure 13). An additional portion of bull trout diet in 2011 was composed of macroinvertebrates (21.8%). Prey items extracted from bull trout stomachs have varied in content and proportion yearly, and in more recent years have been dominated by fish. In previous years, a large percentage of bull trout diet was composed of macroinvertebrates (Figure 13).

We also assessed the diet of bull trout from 2003 – 2011 based on the number of prey items of each category (i.e., percent occurrence) in their stomach (Figure 14). Based on count data, the vast majority of prey items consumed in 2011 were aquatic macroinvertebrates (67%). This is consistent with all other years (except 2007) when the majority of prey items consumed were also macroinvertebrates. After macroinvertebrates, the most abundant prey items by count found in bull trout stomachs from 2003 - 2011 were terrestrial insects and fish eggs (Figure 14).

Since 2002, 63 bull trout otoliths have been aged from individuals ranging in total length from 90 – 674 mm. The estimated age of sacrificed bull trout is between 1 and 10 years (Figure 15). In 2011, the eight sacrificed bull trout ranged in age from 4 (n = 1 fish) to 8 (n = 2 fish) years. The majority of the fish were age-5 (n = 4 fish) and the remaining fish was estimated to be age-7.

We estimated fecundity from 22 female bull trout captured from 2002 to 2011. We compared the number of eggs per female (EPF) to that individual's weight (mass in g, Figure 16) and total length (mm, Figure 17), and developed relationships based on power functions for both weight ($EPF = 18.99*[W]^{0.6967}$, $R^2 = 0.86$; Figure 16) and total length ($EPF = 0.0086*[TL]^{2.032}$, $R^2 = 0.84$; Figure 17).

Population estimates

Estimated abundance of bull trout in the SFWW varied among size groups. The 2011 population estimate for bull trout > 120 mm was 11,193 (95% CI = 9,166 – 15,277), 1,868 (95% CI = 1,440 – 2,764) for bull trout > 220 mm and 804 (95% CI = 453 – 1,693) for bull trout > 370 mm (Figure 18). Population estimates for all size groups were similar to those in 2009 but were lower than estimates from 2010 (Figure 18).

Population growth rate

The population growth rate (lambda, λ) or population trend in the SFWW from 2002 – 2010 was relatively consistent among various estimates obtained from the linear regression approach, all of which have confidence intervals that overlap 1, indicating that we cannot differentiate between a stable, increasing, or decreasing trend (Table 1). A λ value > 1 indicates positive population trend, a value of $\lambda = 1$ indicates no change in population growth rate, and a λ value < 1 indicates that a population is declining. Estimates based on linear regression were slightly higher using redd count data from 1994 – 2011 ($\lambda = 1.090$, 95% CI = 0.900 – 1.319) compared with estimates using redd count data from only 2002 - 2011 ($\lambda = 0.972$, 95% CI = 0.838 – 1.127; Table 2). These estimates were slightly lower than those using the linear regression approach for bull trout > 220 mm (λ = 1.265, 95% CI = 0.703 – 2.276; Table 2). The small number of bull trout > 370 mm resulted in large confidence intervals around the growth rate based on abundance estimates for this size group (λ = 1.337, 95% CI = 0.621 – 2.877; Table 2).

Population growth rate estimates from the temporal symmetry (Pradel) model based on 8 years of mark-recapture data (2002 – 2009) were slightly lower than those based on linear regression for bull trout > 220 mm (λ = 0.931, 95% CI = 0.893 – 0.971) and > 370 mm (λ = 0.931, 95% CI = 0.878 – 0.997; Table 2). While this approach is generally considered less biased than the regression-based approach, it can likewise be affected by sparse data (Hines and Nichols 2002). The precision of population growth rate estimates using the temporal symmetry model will improve with additional years of data collection, and will be more precise when we include an additional 2 years of data in 2012.

Table 2. Population growth rate (λ) estimates with 95% confidence intervals (CI) in the South Fork Walla Walla River from 2002 – 2011, based on linear regression of the log-transformed annual changes in population growth based on redd count data from index reaches (Redds) and population abundance estimates for bull trout > 220 mm and > 370 (Pop Est). Population growth estimates (± 95% CI) obtained using a temporal symmetry (Pradel) model based on mark-recapture data for bull trout > 220 mm and > 370 mm for 2002 – 2009 are also shown.

Estimate source	λ	Lower 95% CI	Upper 95% CI
Redds 1994 – 2011	1.090	0.900	1.319
Redds 2002 – 2011	0.972	0.838	1.127
Pop Est > 220 mm, 2002 – 2011	1.084	0.767	1.533
Pop Est > 370 mm, 2002 – 2011	1.265	0.703	2.276
Pradel > 220 mm, 2002 – 2009	0.931	0.893	0.971
Pradel > 370 mm, 2002 – 2009	0.931	0.878	0.997

Temperature

We collected continuous temperature data at three sites from mid-August 2010 to mid-August 2011. Over this one-year period, stream temperatures were warmest at the

Harris Park Bridge (range = 0.2 – 14.3 ^{o}C) and coldest at the site below Reser Creek (range = -0.2 – 9.1 ^{o}C; Figure 19). Data from the middle of the study area, near reach 78, was unavailable because the temperature logger was lost during high spring flows.

Stream flow

Air temperatures were similar to past years, although the region experienced an unusually high winter snowfall and cooler than average spring temperatures, resulting in an extended and elevated spring runoff period. Peak discharge occurred in the SFWW on 17 January 2011 (estimated flow = 1040 cfs), with two smaller peaks in the spring, on 5 April 2011 (688 cfs) and 15 May 2011 (713 cfs; Figure 20). Elevated flows (> 300 cfs) were sustained through June and into July 2011, and the river did not reach base flow until mid-July.

DISCUSSION

Ten years of mark-recapture data from bull trout in the South Fork Walla Walla River, Oregon, has allowed us to estimate a number of demographic parameters for this population, as well as to examine trends and natural variability within parameters. The data gathered over the course of this research project (2002 – 2011) is some of the most comprehensive population-level data that has been collected on a fluvial population of bull trout in the United States. It provides a comprehensive look at both the migratory and resident bull trout life histories that occur in the study area. This extensive dataset also allows us to investigate trends in size structure, condition, distribution, growth rate, and population abundance. This information is pertinent to bull trout restoration efforts as mandated by the Endangered Species Act (1973).

The bull trout population in the SFWW appears to be stable. The size structure of bull trout sampled within the study area is similar to other migratory bull trout populations (i.e., Fraley and Shepard 1989) and is relatively consistent from one year to the next, suggesting stable recruitment into larger size classes. Based on Fulton's condition factor, the condition for the SFWW bull trout population in 2011 was either similar to the 10-year average for each size class (< 120 mm and 120 - 370 mm) or higher than the 10-year average (> 370 mm), also indicating good population health. Average K_{TL} for the entire population has varied through the 10-year period, and it appeared to be relatively higher in 2011 than in the past few years. However, a problem with the use of K_{TL} is the assumption of isometric growth, which is rarely the case (Blackwell et al. 2000). As such, K_{TL} generally increases with length. This restricts our analysis of K_{TL} to individuals of the same length, and should generally not be used to compare between different size classes.

Additional indices of condition such as W_r allow us to compare the results of multiple indices to evaluate the health of the bull trout population in the SFWW. Additionally, W_r could allow us to compare the condition of the fish relative to other populations of bull trout. However, differences in W_r between populations may be due to life-history strategies such as fluvial versus adfluvial, and migratory versus resident populations. For this reason, we limited our comparison of W_r values to within the SFWW between years and in comparison with K_{TL}. The results of the analysis of W_r from 2002 – 2011 are quite similar to those of K_{TL}. While there was some variation in W_r from year to year, the average values did not drift much from the 10-year mean. Additionally, there was almost no variation in W_r for the subadult size class (120 – 370 mm); both within and between years and the condition of these fish appears to be very stable. Further, if a mean W_r of 100 can suggest ecological and physiological optimality, then condition of this bull trout population, especially juveniles, appears robust.

Estimates of abundance and trend in 2011 are similar to estimates of previous years, although 2011 population size estimates show a slight decrease compared with 2010 estimates. On the whole, we believe the population of bull trout in the SFWW is fairly stable, and the variation in estimates among years represents both natural environmental heterogeneity as well as potential sampling variation. Data suggest that the abundance of juvenile and subadult bull trout (70 – 170 mm) in the SFWW has increased in the past few years. However, changes in methodology could also have contributed to a positive bias of this estimate. In 2009, we increased the minimum size of fish that were marked with an external anchor tag from 120 mm to 170 mm. All PIT-tagged fish < 170 mm were marked by an adipose fin clip, but this latter marking was more difficult to observe during snorkel counts than the previously-used anchor tags. This change in methodology may have led us to undercount marked fish relative to unmarked fish in the small size class (120 – 170 mm), which are already more difficult to observe because of their cryptic nature (Thurow 1997), and would have resulted in higher population estimates.

The collection of otoliths from a wide size range (99 – 720 mm TL) of bull trout has allowed us to estimate age (age-1 to age-10) across a range of lengths of bull trout in the SFWW. The age-at-length data for bull trout in the SFWW provides an important base against which to compare other similar fluvial populations of bull trout, and improves our understanding of bull trout growth, lifespan, and senescence. Although counting otolith annuli is currently the most effective method for assessing age-at-length, there may be some error involved. Counting annuli on otoliths can be imprecise, particularly for bull trout, which have very small otoliths relative to many other species. Annuli become harder to discern in older fish, leading to greater variability for older age estimates. There may also be a difference in the rate of bone accumulation between migratory and resident fish. This could result in older estimates for migratory fish, which likely have more defined growth rings compared to resident fish. Above all, the amount of confidence given to age estimates from otoliths should reflect the sample size, which is relatively small (n = 63), although it is considerable compared to most bull trout populations, and provides important information.

Accurate estimates of population trend require many years of data, such as the data available from the SFWW bull trout population. The population trend estimates we calculated using the linear regression approach all have 95% confidence intervals that overlap 1.0, suggesting a stable population growth rate in the SFWW. However, for trend values estimated based on linear regression, a single annual abundance estimate can have a disproportionate influence on the resulting estimate of lambda (λ). With only ten years of data, an estimate of the population growth rate may be skewed by a single particularly low or high year and therefore should be viewed with caution. Results based on the more robust temporal symmetry model indicated that the population might be slightly declining and as such, care should be taken when interpreting these results until further analysis is complete.

In the 2011 field season, we successfully carried out an extensive sampling effort that resulted in a large quantity of high quality data on the SFWW bull trout population. However, in these efforts we commonly encountered sampling issues that may have affected some of our analyses. While collecting data, researchers took care to avoid electro-seining and snorkeling around Chinook salmon redds. Because it appears that the number of Chinook salmon spawning in the SFWW study area has increased during our sampling season over the past few years, it is possible that we could be sampling a slightly smaller portion of riverine habitat than we have in the past.

Certain environmental variables may have influenced the quality and consistency of data collected in 2011. Heavy snowfall during the winter of 2011 resulted in higher than average snowpack for much of the western US, including the Blue Mountains (120% of average) and the SFWW drainage. This heavy snowpack resulted in unusually elevated discharge in the SFWW for an extended duration in the spring of 2011, and dramatically altered the river channel in some parts of the study area (Appendix 3). In several of the study reaches, side channels had been abandoned, and most of the flow was routed through the main channel, resulting in elevated water velocities and a reduction in preferred bull trout habitat. This reduction in total bull trout habitat and quality of available habitat may have been a factor contributing to the lower population estimates in 2011 compared with 2010. It is possible that many of the bull trout within the system were concentrated in the best available habitat, some of which may have been found outside the study reaches sampled by this project. Additionally, elevated streamflows in 2011 made sampling bull trout with the electro-seining technique more difficult and possibly less effective. The 2011 field crew may have had greater difficulty capturing bull trout compared with some past years due to higher than average water velocities at the early part of the season.

The combination of information gathered from this ongoing, long-term study and additional research conducted on this bull trout population (e.g., Al-Chokhachy et al. 2009; Homel and Budy 2008) will provide the USFWS with important information on factors that affect population growth and stability, as well as vital rate information specific to migratory and fluvial life-history strategies (Al-Chokhachy and Budy 2008; Homel et al. 2008). It also provides useful information for present and future management and restoration actions. This research helps to fill gaps in what is known about the complex life-history strategies of bull trout and will help inform decisions made in recovery planning for the species. Information provided in this report is currently being used by the Bull Trout Recovery, Monitoring, and Evaluation Technical Group (RMEG) to assess the potential effect of various threats on long-term population viability of several bull trout populations, which will ultimately help inform decisions made in recovery planning for bull trout throughout their range.

LITERATURE CITED

Al-Chokhachy, R., P. Budy, and H. Schaller. 2005. Understanding the significance of redd counts: a comparison between two methods for estimating the abundance of and monitoring bull trout populations. North American Journal of Fisheries Management 25:1505-1512.

Al-Chokhachy, R. 2006. Identifying the limiting factors and trends of bull trout (*Salvelinus confluentus*) populations in Eastern Oregon. PhD dissertation. Utah State University, Logan, Utah.

Al-Chokhachy, R., and P. Budy. 2007. Summer microhabitat use of fluvial bull trout in Eastern Oregon streams. North America Journal of Fisheries Management 27:1068-1081.

Al-Chokhachy, R., and P. Budy. 2008. Demographic characteristics, population structure, and vital rates of a fluvial population of bull trout in Oregon. Transactions of the American Fisheries Society 137:262-277.

Al-Chokhachy, R., W. Fredenberg, and S. Spalding. 2008. Surveying professional opinion to inform bull trout recovery and management decisions. Fisheries 33:18-28.

Al-Chokhachy, R., P. Budy, and M. Conner. 2009. Detecting changes in bull trout population abundance: understanding the accuracy, precision, and costs of our efforts. Canadian Journal of Fisheries and Aquatic Sciences 66:649-658.

Al-Chokhachy, R., B.B. Roper, T. Bowerman, and P. Budy. 2010. A review of bull trout habitat associations and exploratory analyses of patterns across the Interior Columbia River Basin. North American Journal of Fisheries Management 30:464-480.

Anglin, D.R., D. Gallion, M. Barrows, S. Haeseker, R. Koch, and C. Newlon. 2010. Monitoring the use of the mainstem Columbia River by bull trout from the Walla Walla Basin. U.S. Fish and Wildlife Service, United States. 2009 Annual report to the The U.S. Army Corps of Engineers, Walla Walla District. Project BT-W-05-6.

Ardren, W.R., P.W. DeHaan, C.T. Smith, E. B. Taylor, R. Leary, C.C. Kozfkay, L. Godfrey, M. Diggs, W. Fredenberg, J. Chan, C.W. Kilpatrick, M.P. Small, and D.K. Hawkins. 2011. Genetic structure, evolutionary history, and conservation units of bull trout in the coterminous United States. Transactions of the American Fisheries Society 140:506-525.

Brenkman, S.J., and S.C. Corbett. 2005. Extent of anadromy in bull trout and implications for conservation of a threatened species. North American Journal of Fisheries Management 25:1073-1081.

Buchanan, D.V., M.L. Hanson, and R.M. Hooten. 1997. Status of Oregon's bull trout. Oregon Department of Fish and Wildlife. October 1997. Portland, Oregon.

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. 2002 Annual Progress Report to US Fish and Wildlife Service, Vancouver, Washington. 41 pages.

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. 2003 Annual Progress Report to US Fish and Wildlife Service, Vancouver, Washington. 70 pages.

Budy, P., R. Al-Chokhachy, K. Homel, and G.P. Thiede. 2005. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2004 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2005(3):1-93.

Budy, P., R. Al-Chokhachy, K. Homel, and G.P. Thiede. 2006. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2005 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2006(6):1-102.

Budy, P., R. Al-Chokhachy, and G.P. Thiede. 2007. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2006 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2007(1):1-83.

Budy, P., P.D. MacKinnon, T. Bowerman, and G.P. Thiede. 2008. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2007 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2008(6):1-62.

Budy, P., P.D. MacKinnon, T. Bowerman, and G.P. Thiede. 2009. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2008 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2009(1):1-57

Budy, P., T. Bowerman, and G.P. Thiede. 2010. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2009 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2010(3):1-48

Budy, P., L. B. Tennant, T. Bowerman, and G.P. Thiede. 2011. Bull trout population assessment in northeastern Oregon: a template for recovery planning. 2010 Annual Progress Report to US Fish and Wildlife Service. UTCFWRU 2011(5):1-90.

Cavender, T.M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus* from the American Northwest. California Fish and Game 64:139-174.

Chapman, D.G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

Dunham, J. B., C.V. Baxter, K.D. Fausch, W. Fredenberg, S. Kitano, I. Koizumi, K. Morita, T. Nakamura, B.E Rieman, K.A. Savvaitova, J. Stanford, E.B. Taylor, and S. Yamamoto. 2008. Evolution, ecology, and conservation of Dolly varden, white-spotted Char, and bull trout. Fisheries 33:537-550.

FERC Project 2145 Draft. 2002. Movement of bull trout within the Mid-Columbia and its tributaries 2001-2002. Bioanalysts.

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 63:163-143.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*: A literature review. Willamette National Forest, Eugene, Oregon.

Homel, K. 2007. Evaluating genetic population structure and movement patterns of bull trout (*Salvelinus confluentus*) in Northeast Oregon. Master's Thesis. Utah State University, Logan, Utah.

Homel, K. and P. Budy. 2008. Temporal and spatial variability in the migration patterns of juvenile and subadult bull trout (*Salvelinus confluentus*) in Northeast Oregon. Transactions of the American Fisheries Society 137:869-880.

Homel, K., P. Budy, M.E. Pfrender, T.A. Whitesel, and K. Mock. 2008. Evaluating genetic structure among resident and migratory forms of bull trout (*Salvelinus confluentus*) in Northeast Oregon. Ecology of Freshwater Fish 17:465-474.

Hyatt, M.H., and W.A. Hubert. 2000. Proposed standard weight equations for kokanee, golden trout and bull trout. Journal of Freshwater Ecology 15:559-563.

Isaak, D., S. Wollrab, D. Horan, and G. Chandler. 2011. Climate change effects on stream and river temperatures across the northwest U.S. from 1980-2009 and implications for salmonid fishes. Climatic Change 0165-0009:1-26.

Isaak, D.J., C.H. Luce, B.E. Rieman, D.E. Nagel, E.E. Peterson, D.L. Horan, S. Parkes, and G.L. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350-1371.

Kassler, T.W., and G. Mendel. 2007. Genetic characterization of bull trout from the Walla Walla River Basin. Washington Department of Fish and Wildlife.

Krebs, C.J. 1999. Ecological Methodology, second edition. Addison-Wesley Educational Publishers, Inc., U.S.A.

Lohr, S., T. Cummings, W. Fredenberg, and S. Duke. 1999. Listing and recovery planning for bull trout. U.S. Fish and Wildlife Service publication. Boise, Idaho.

McMahon, T.E., A.V. Zale, F.T. Barrows, J.H. Selong, and R.J. Danehy. 2007. Temperature and competition between bull trout and brook trout: A test of the elevation refuge hypothesis. Transactions of the American Fisheries Society 136:1313-1326.

McPhail, J. D., and J.S. 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.

Meeuwig, M.H., C.S. Guy, S.T. Kalinowski, and W.A. Fredenberg. 2010. Landscape influences on genetic differentiation among bull trout populations in a stream-lake network. Molecular Ecology 19:3620-3633.

Morris, W.F., and D.F. Doak. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates, Sutherland, Massachusetts.

Muhlfeld, C.C., L. Jones, D. Kotter, W.J. Miller, D. Geise, J. Tohtz, and B. Marotz. 2011. Asessing the impacts of river regulation on native bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) habitats in the Upper Flathead River, Montana, USA. River Research and Applications.

Nichols, J.D., and J.E. Hines. 2002. Approaches for the direct estimation of λ, and demographic contributions to λ, using capture-recapture data. Journal of Applied Statistics 29(1):539-568.

Parker, B.R., D.W. Schindler, F.M. Wilhelm, and D.B. Donald. 2007. Bull Trout Population Responses to Reductions in Angler Effort and Retention Limits. North American Journal of Fisheries Management 27:848-859.

PIT Tag Steering Committee. 1999. PIT Tag Marking Procedures Manual. Columbia Basin Fish and Wildlife Authority, Version 2.0.

Porter, M., and D.R. Marmorek. 2005. Bull Trout Recovery Monitoring and Evaluation Technical Working Group (RMEG) Workshop 3 (Dec. 16-17, 2004)- USFS Regional Office, 333 SW First Ave., Portland, Oregon – Workshop Report, Report prepared by ESSA Technologies Limited., Vancouver, BC for the US Fish and Wildlife Service, Vancouver, Washington. 113 pages.

Pradel, R. 1996. Utilization of capture-mark-recapture for the study of recruitment and population growth rate. Biometrics 52:703-709.

Ratliff, D.E., and P.J. Howell. 1992. The status of bull trout populations in Oregon. *In* Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1-382.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. USDA General Technical Report INT-302.

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., D.J. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River basin. Transactions of the American Fisheries Society 136:1552-1565.

Schoby, G. P., and E. R. Keeley. 2011. Home range size and foraging ecology of bull trout and westslope cutthroat trout in the upper Salmon River Basin, Idaho. Transactions of the American Fisheries Society 140:636-645.

Soule, M.E. 1987. Viable populations for conservation. Cambridge University Press. New York, New York.

Staples, D. F., M. L. Taper, and B. Dennis. 2004. Estimating population trend and process variation for PVA in the presence of sampling error. Ecology 85:923-929.

Thurow, R.F. 1997. Habitat utilization and diel behavior of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter. Ecology of Freshwater Fish 6:1-7.

USFWS (US Fish and Wildlife Service). 1999. Determination of threatened status for bull trout in the coterminous United States. Pages 58910-58933 in Federal Register 64.

Walla Walla Subbasin Summary *Draft*. 2001. Prepared for the Northwest Power Planning Council.

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.

Wege, G.W., and R.O. Anderson. 1978. Relative weight (W_r): A new index of condition for largemouth bass. Pages 79-91 *in* G. D. Novinger and J. G. Dillard (editors), New approaches to the management of small impoundments, Special Publication, Volume 5, American Fisheries Society, Bethesda Maryland.

Wenger, S. J., D. J. Isaak, J. B. Dunham, K. D. Fausch, C. H. Luce, H. M. Neville, B. E. Rieman, M. K. Young, D. E. Nagel, D. L. Horan, and G. L. Chandler. 2011. Role of climate and invasive species in structuring trout distributions in the interior Columbia River Basin, USA. Canadian Journal of Fisheries and Aquatic Sciences 68:988-1008.

White, G.C. and B.C. Lubow. 2002. Fitting population models to multiple sources of observed data. The Journal of Wildlife Management 66:300-309.

Whitesel, T.A., and 7 coauthors. 2004. Bull trout recovery planning: a review of the science associated with population structure and size. Science Team Report # 2004-01, U.S. Fish and Wildlife Service, Regional Office, Portland, Oregon. Website: *http://columbiariver.fws.gov/scienceteam.htm#product*

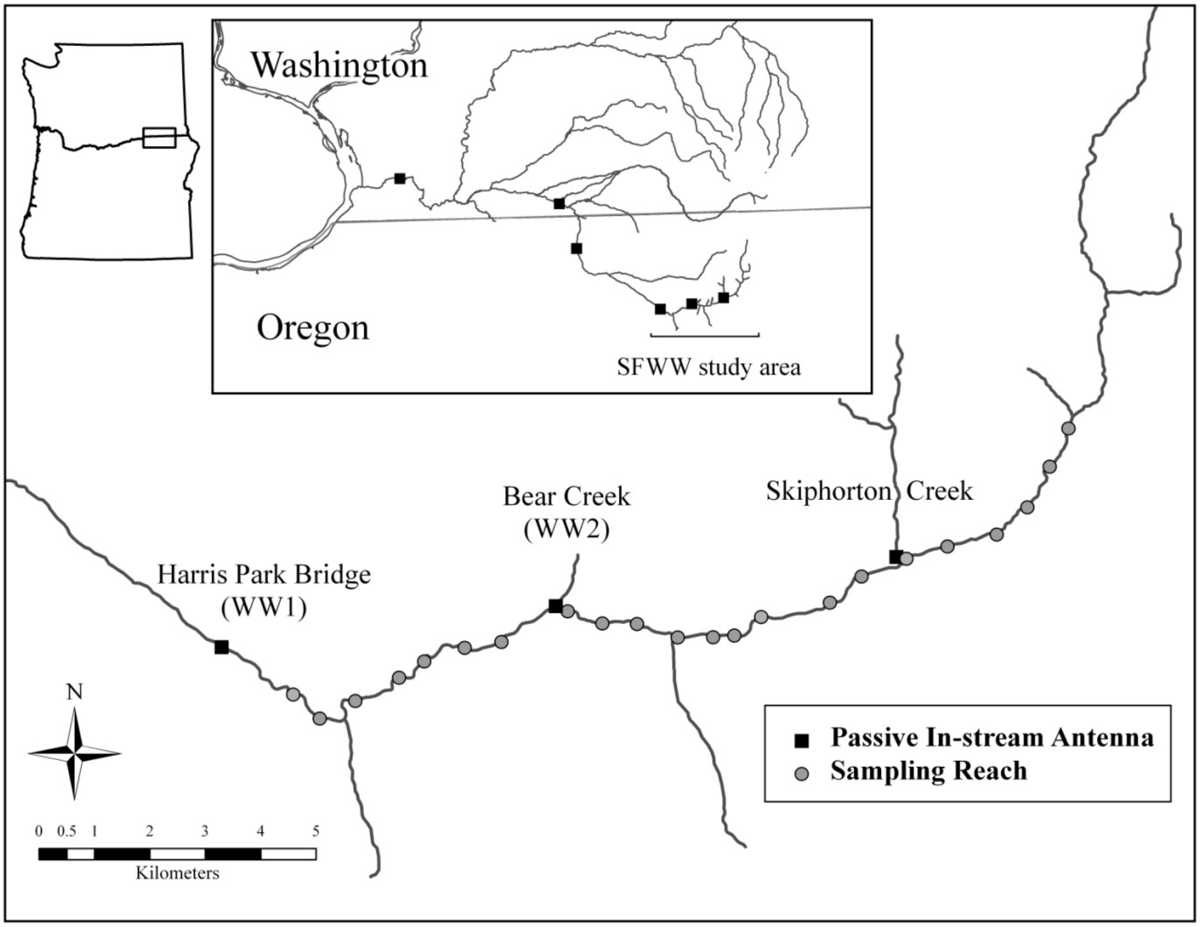
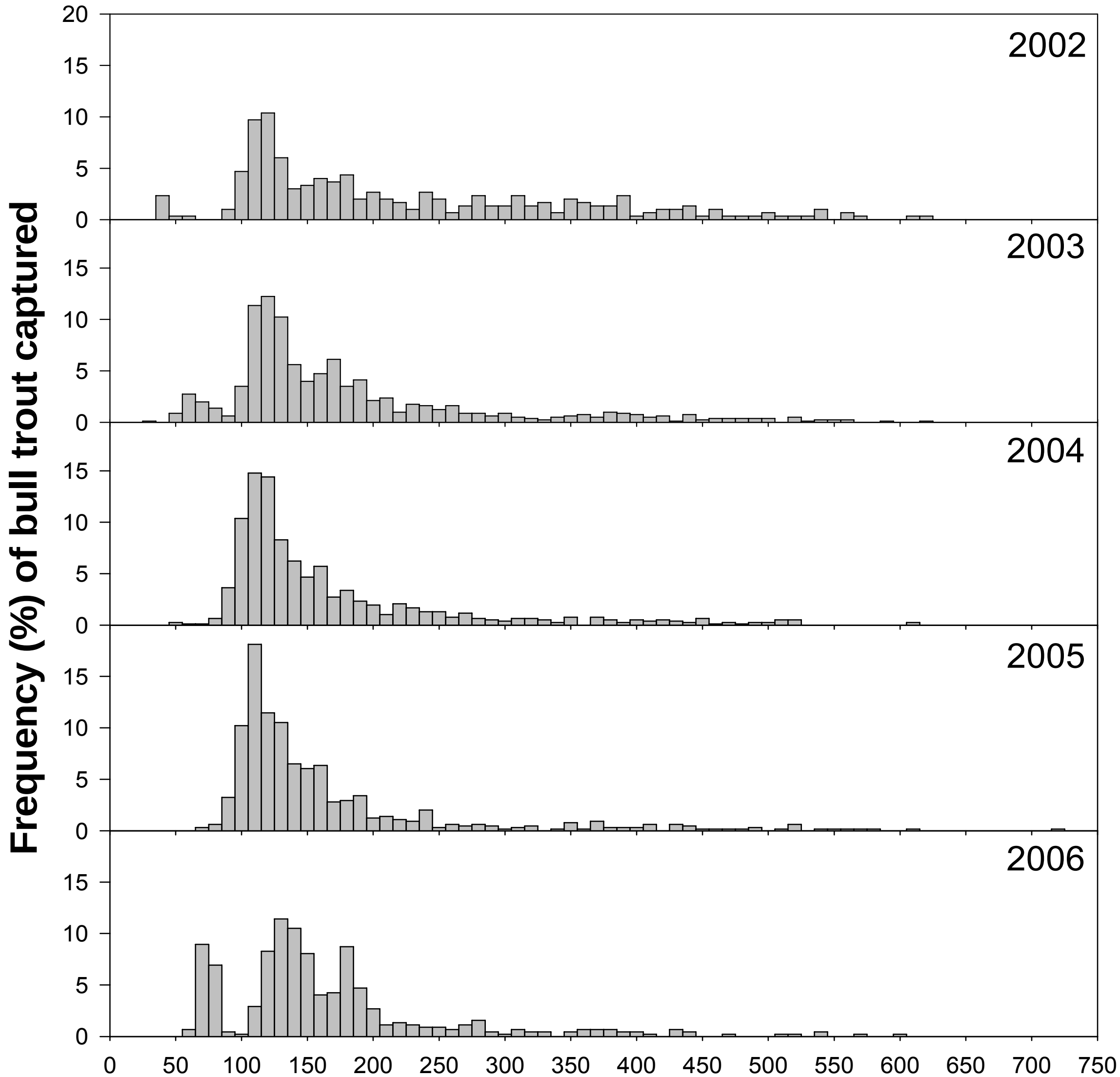


Figure 1. Map of the South Fork Walla Walla (SFWW) River, Oregon, showing original 22 study reaches (gray circles) and passive in-stream antenna (PIA or detectors) locations (black squares) within our primary study area in the SFWW and throughout the lower Walla Walla River. The PIA at Skiphorton Creek only operated from 2008 - 2010 and is no longer in operation.



Frequency (%) of bull trout captured
2002
2003
2004
2005
2006
0
5
10
15
20
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750

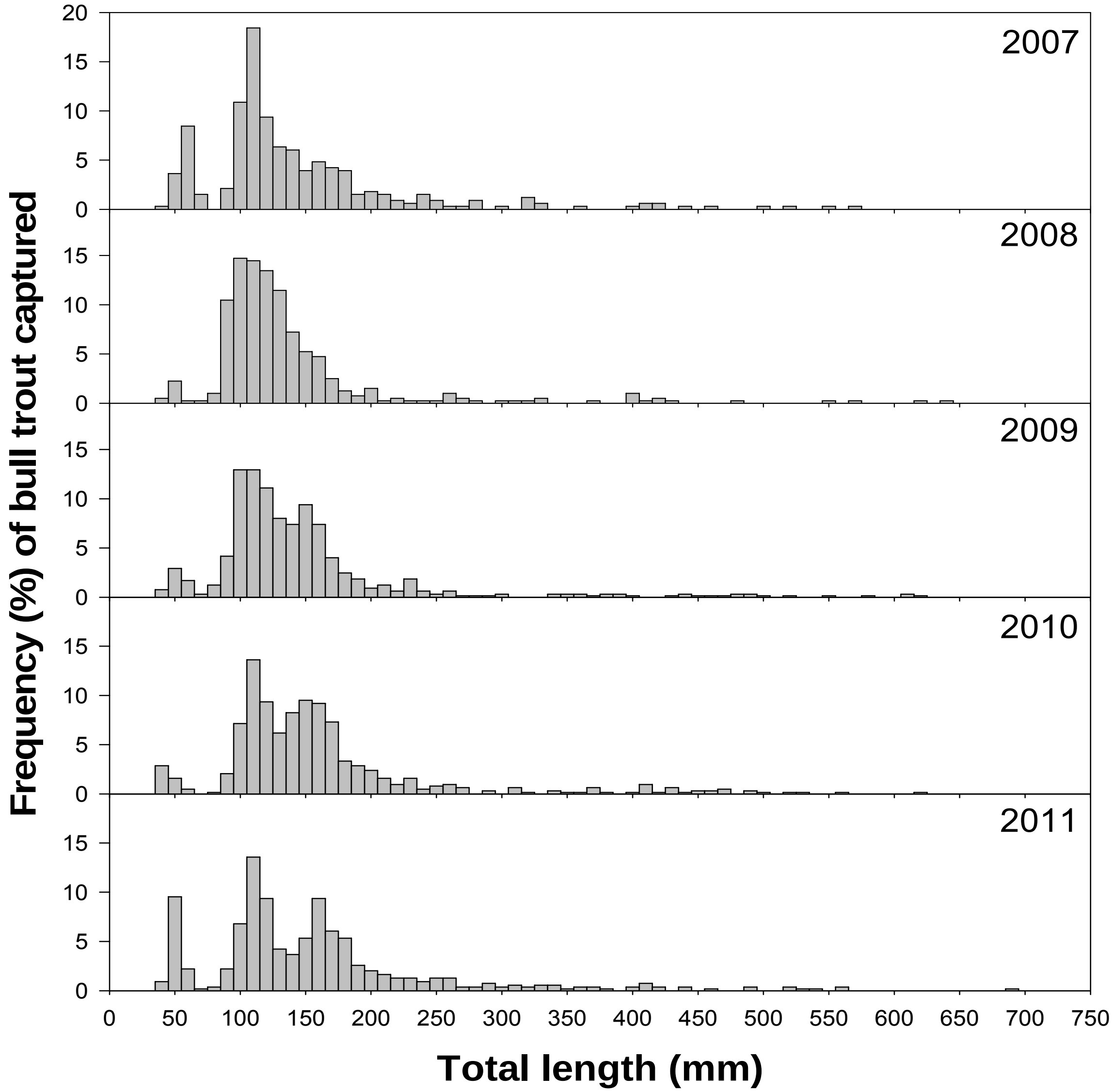
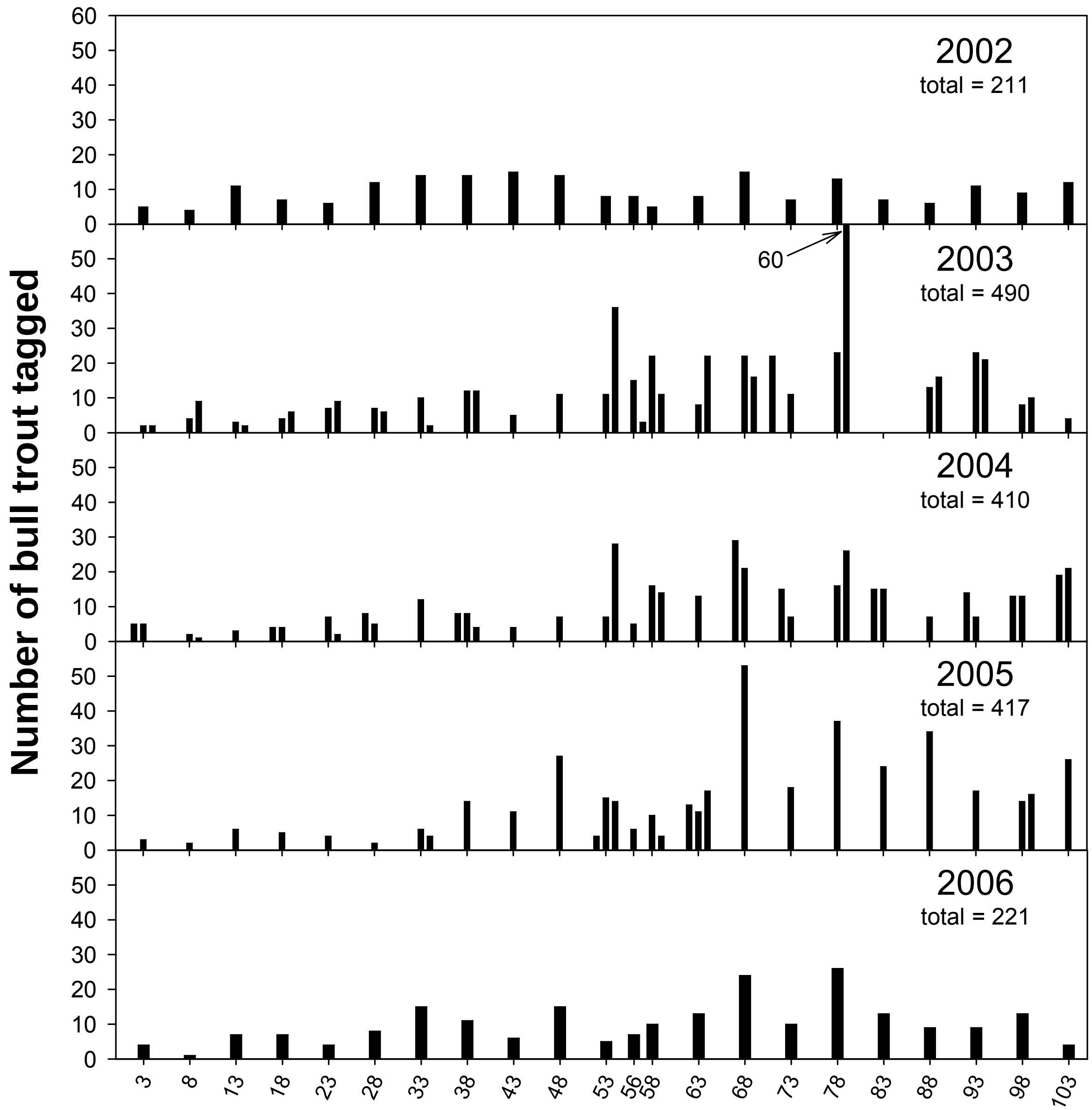


Figure 2. Length-frequency (% of total catch) distribution of bull trout captured and handled in the South Fork Walla Walla River, Oregon, 2002 – 2011.


Number of bull trout tagged
2002
total = 211
2003
total = 490
60
2004
total = 410
2005
total = 417
2006
total = 221
60
50
40
30
20
10
0
3
8
13
18
23
28
33
38
43
48
53
56
58
63
68
73
78
83
88
93
98
103

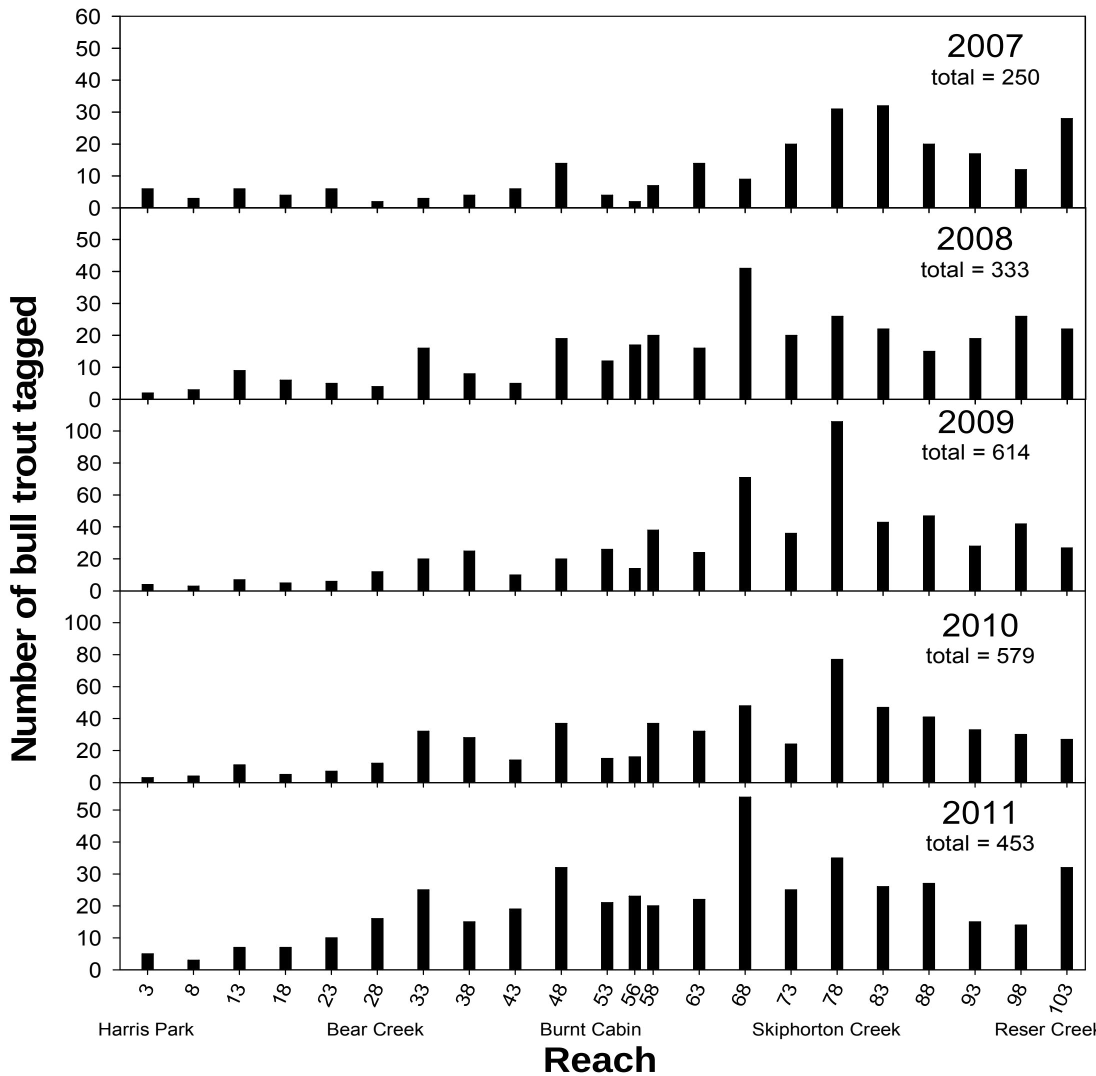
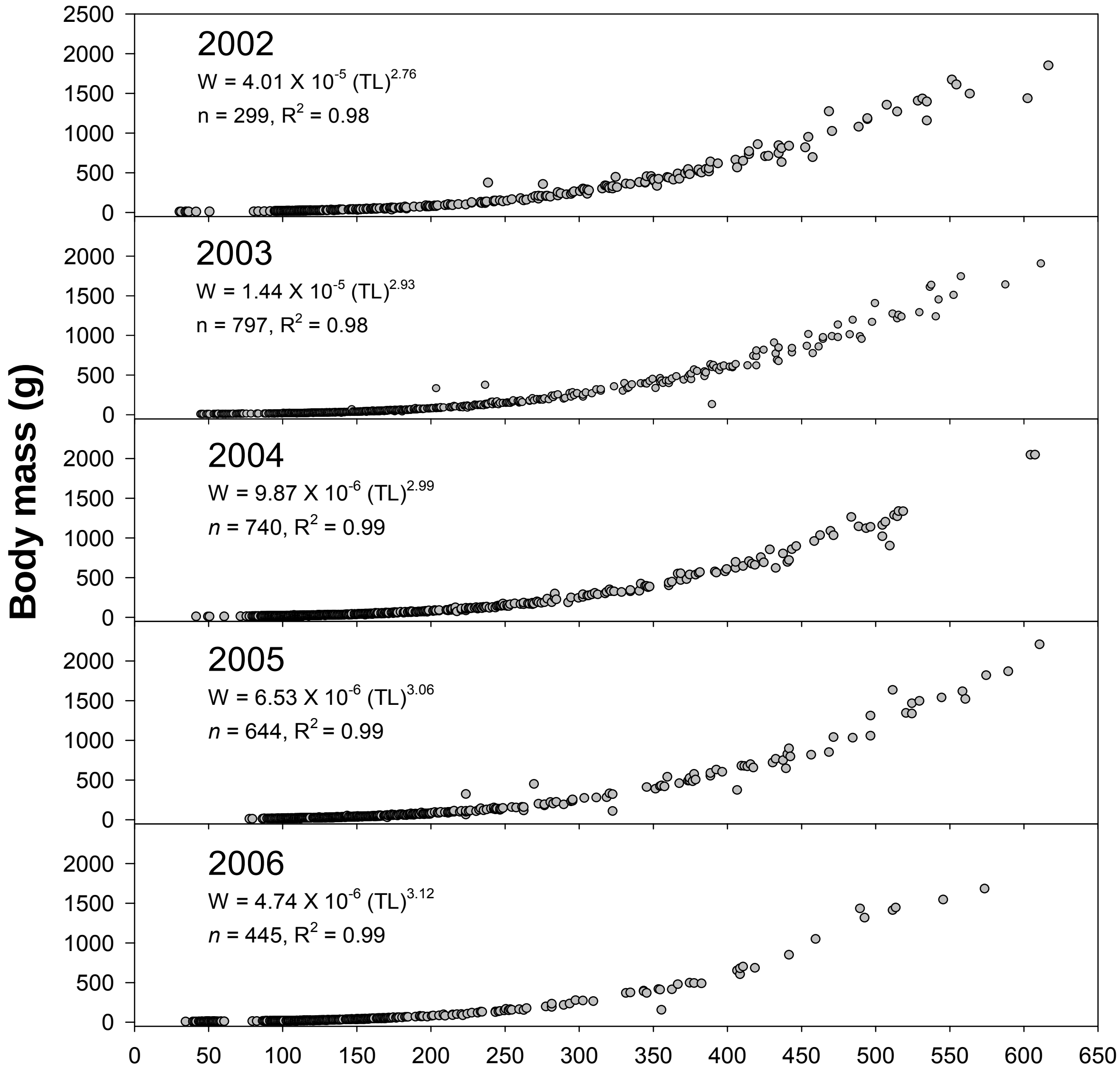


Figure 3. Number of bull trout tagged by reach in the South Fork Walla Walla River, Oregon, 2002 - 2011. Reaches are numbered from bottom (0 at Harris Park) to top (103 at Reser Creek) of the study site. Total numbers tagged are given below sample year. Note the scale change in the 2009 and 2010 panels.


2002
W = 4.01 X 10-5 (TL)2.76
n = 299, R2 = 0.98
2003
W = 1.44 X 10-5 (TL)2.93
n = 797, R2 = 0.98
2004
W = 9.87 X 10-6 (TL)2.99
n = 740, R2 = 0.99
2005
W = 6.53 X 10-6 (TL)3.06
n = 644, R2 = 0.99
2006
W = 4.74 X 10-6 (TL)3.12
n = 445, R2 = 0.99
Body mass (g)
0
500
1000
1500
2000
2500
0 50 100 150 200 250 300 350 400 450 500 550 600 650

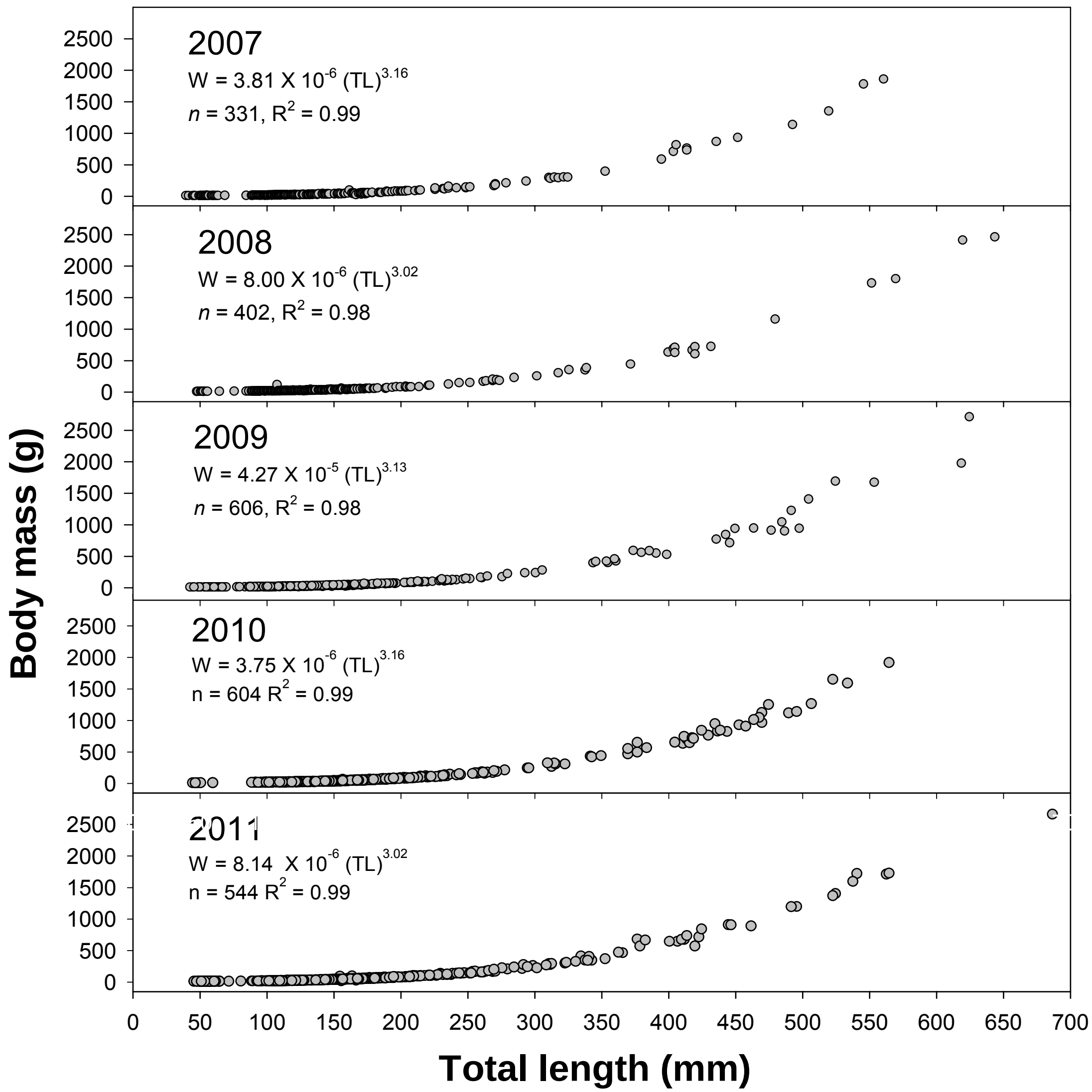


Figure 4. Length-weight regression for bull trout captured in the South Fork Walla Walla River, Oregon from 2002 – 2011. Regression equation, sample size (n), and R^2 values are given on each panel. Note the change in the maximum weight for 2007-2011 panels.

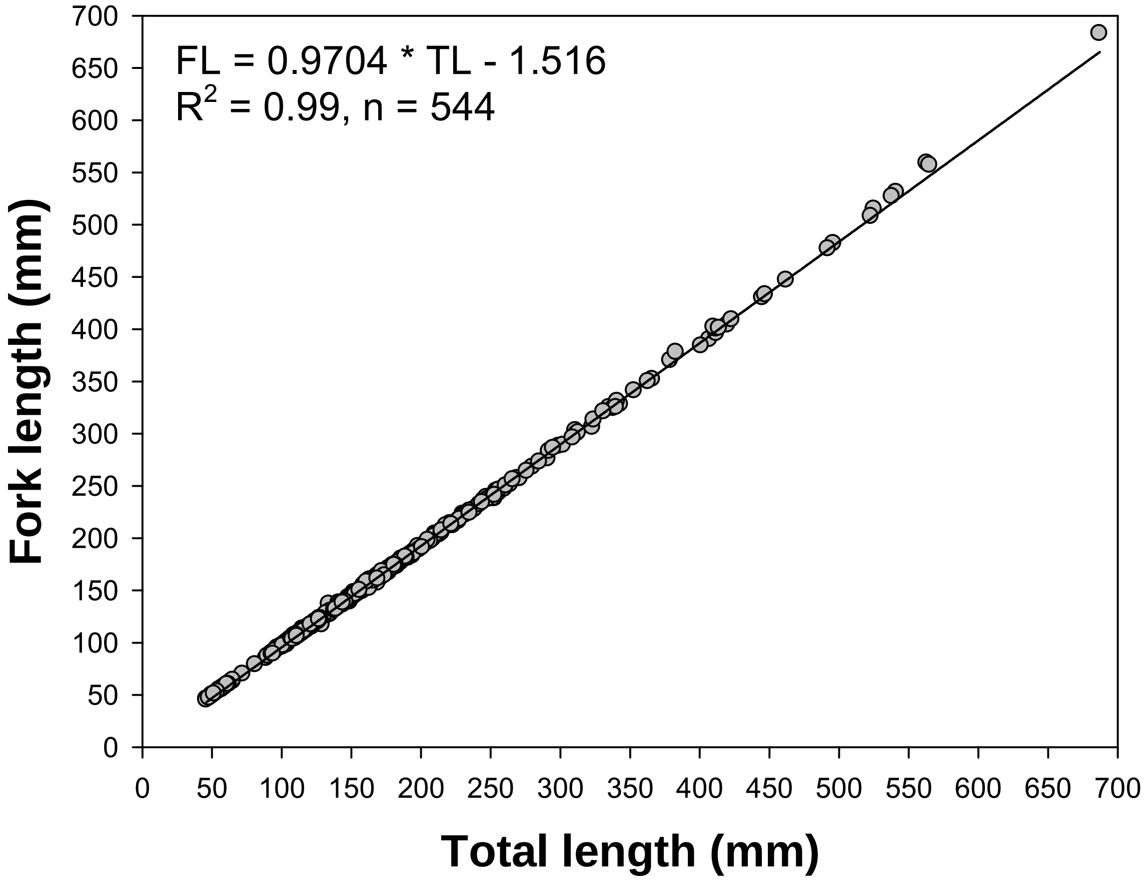


Figure 5. Relationship between total length (TL) and fork length (FL) for bull trout tagged in the South Fork Walla Walla River, Oregon, 2011. Linear regression equation, R^2 value, and sample size (n) are given on the figure.

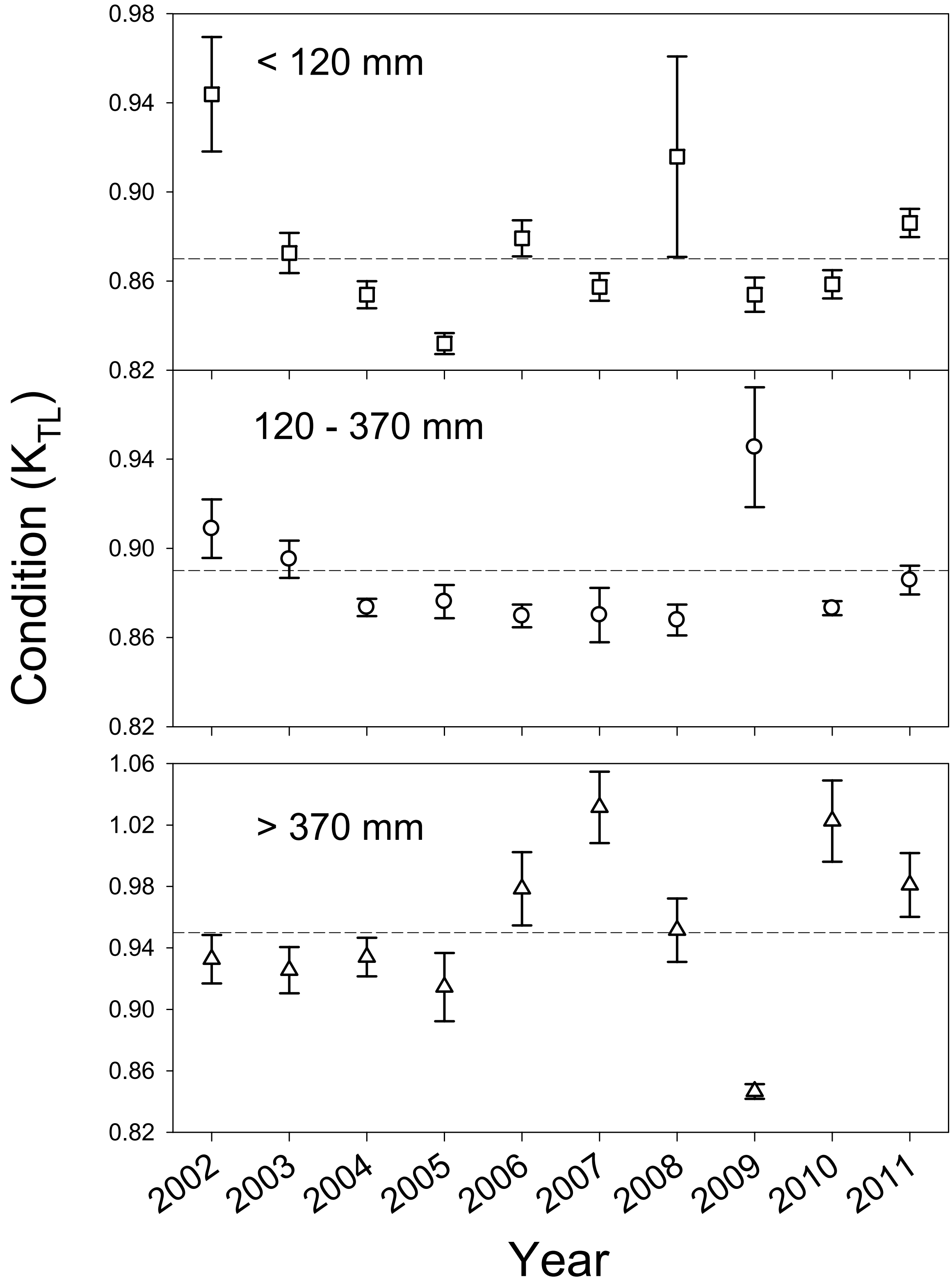


Figure 6. Fulton's condition factor ($K_{TL} \pm 1$ SE) of three different size classes of bull trout handled in the South Fork Walla Walla River, Oregon, 2002 - 2011. Dashed line represents size-specific, 10-year average K_{TL}.

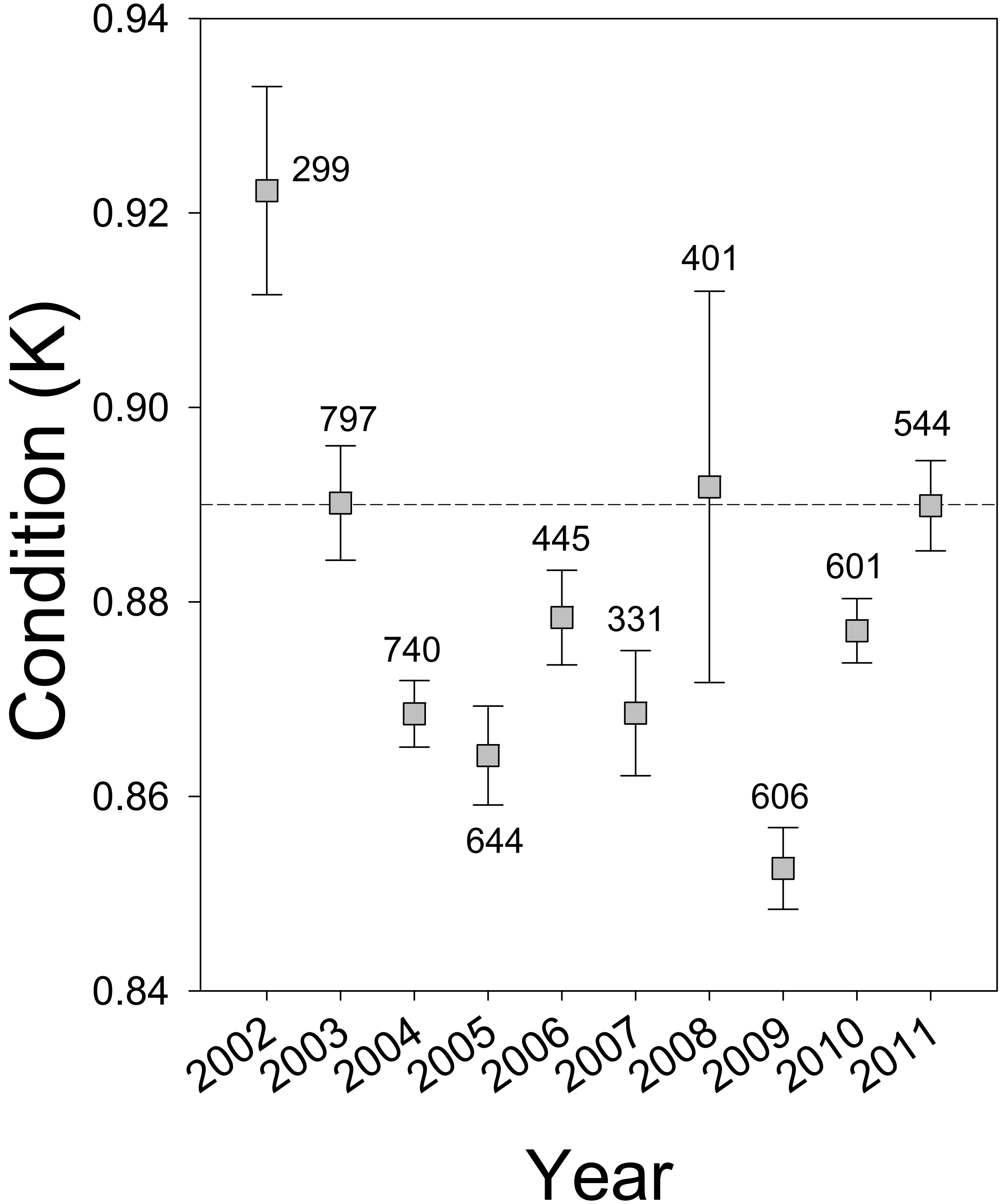


Figure 7. Average annual condition (Fulton's K_{TL} ± 1 SE) of bull trout (all sizes combined) sampled in the South Fork Walla Walla River, Oregon (2002 – 2011). Sample size is given adjacent to error bars. Dashed line represents across-year average K_{TL}; 0.89.

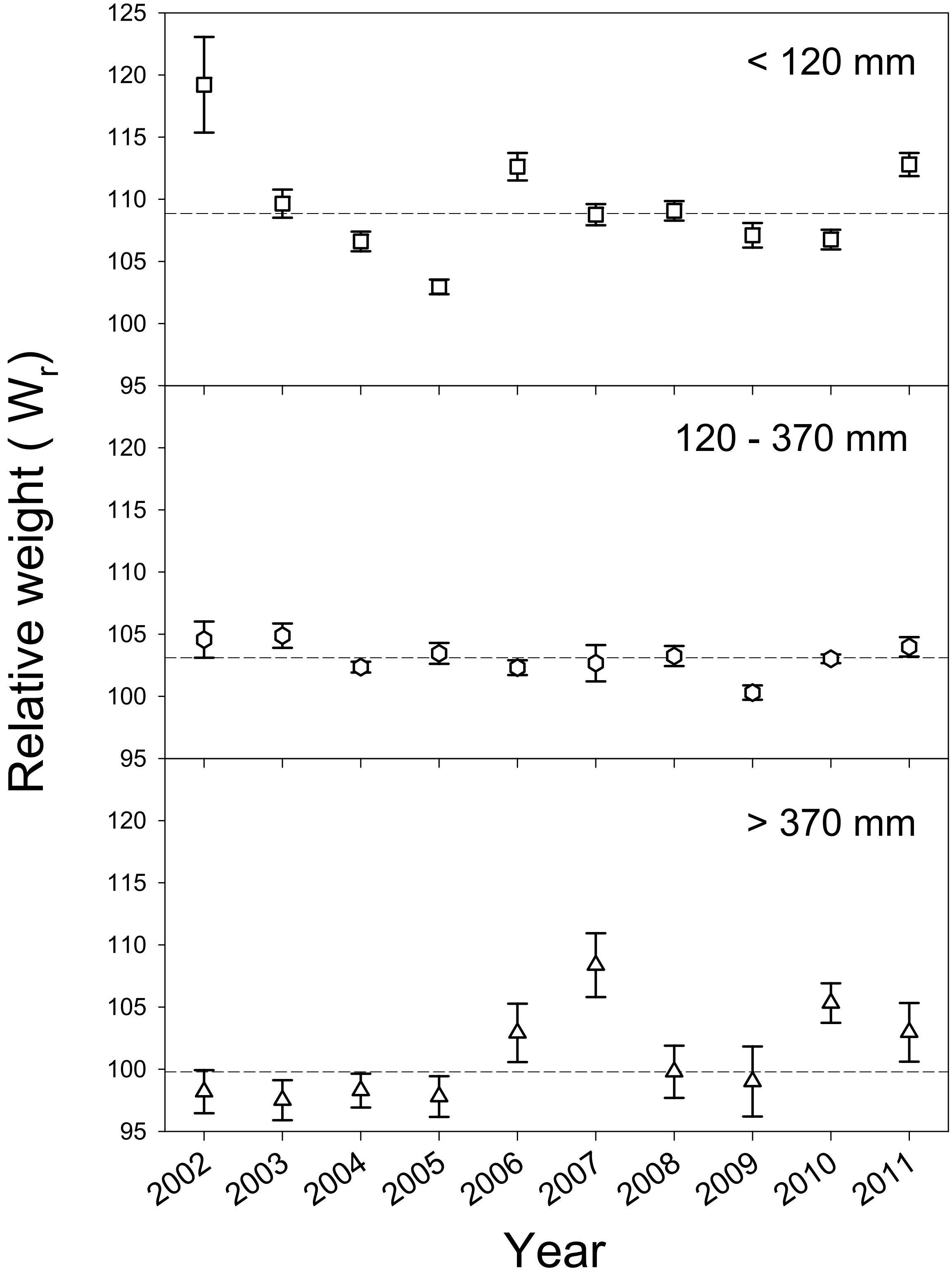
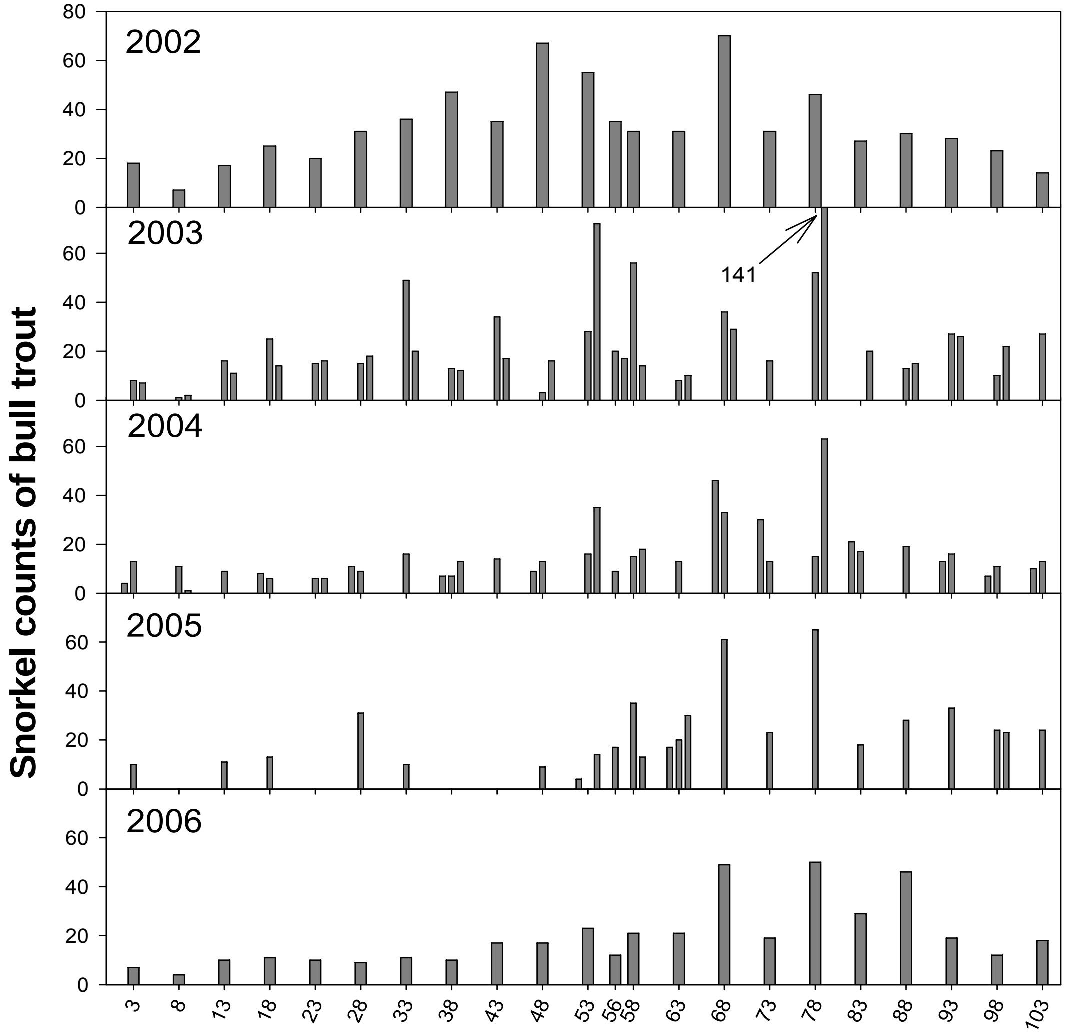


Figure 8. Relative weight ($W_r \pm 1$ SE) of three different size classes of bull trout handled in the South Fork Walla Walla River, Oregon, 2002 - 2011. Dashed line represents size-specific across-year average W_r.



Snorkel counts of bull trout
2002
2003
141
2004
2005
2006
0
20
40
60
80
3
8
13
18
23
28
33
38
43
48
53
56
58
63
68
73
78
83
88
93
98
103

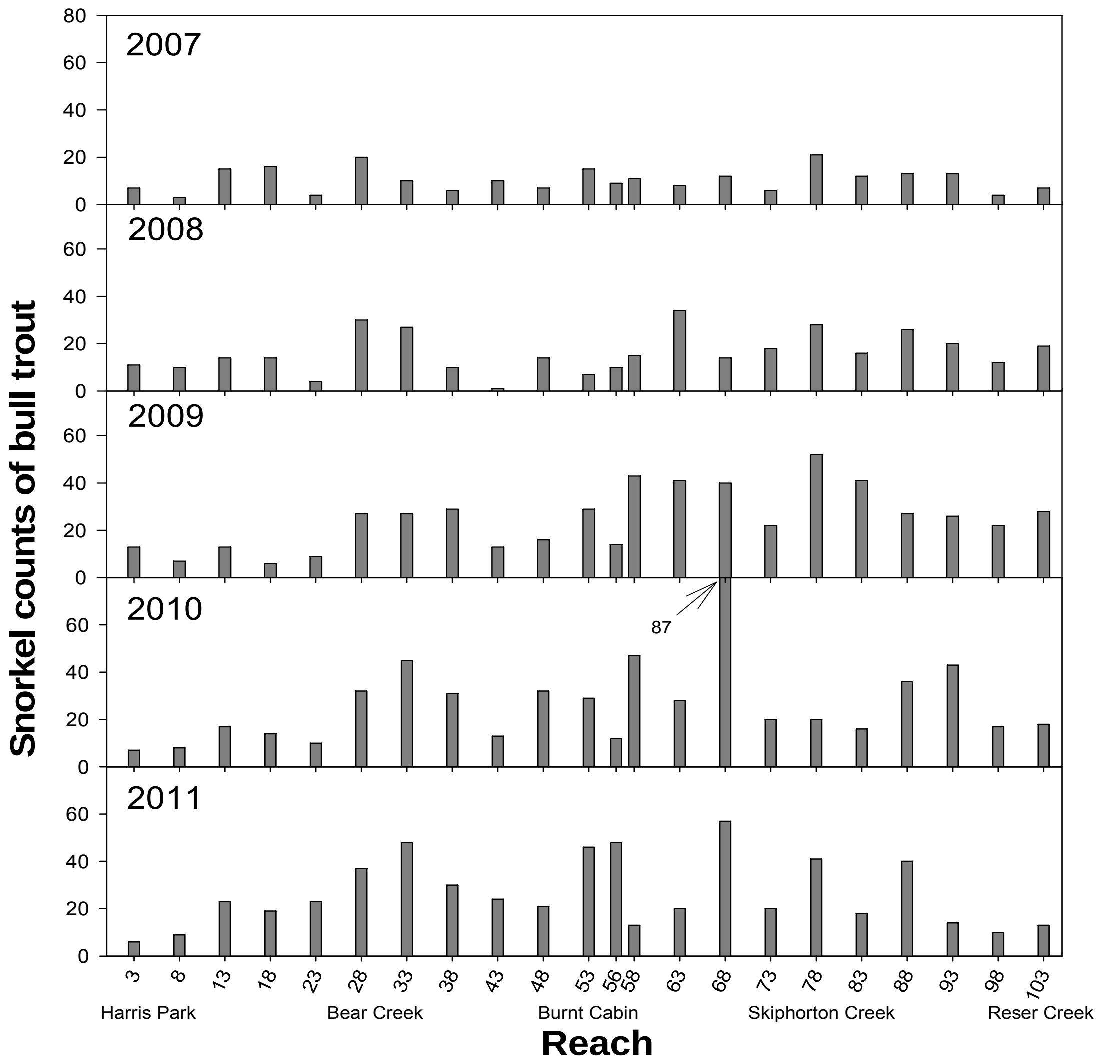


Figure 9. Number of bull trout counted during snorkel surveys in sample reaches of the South Fork Walla Walla River, Oregon, 2002 - 2011. Reaches are numbered from bottom (0 at Harris Park) to top (103 at Reser Creek) of the study site. No bar implies that no sampling was conducted in a particular reach. Percentage of stream sampled in 2003 and 2004 and 2005 represented approximately 47%, 47% and 30% of study area, respectively.

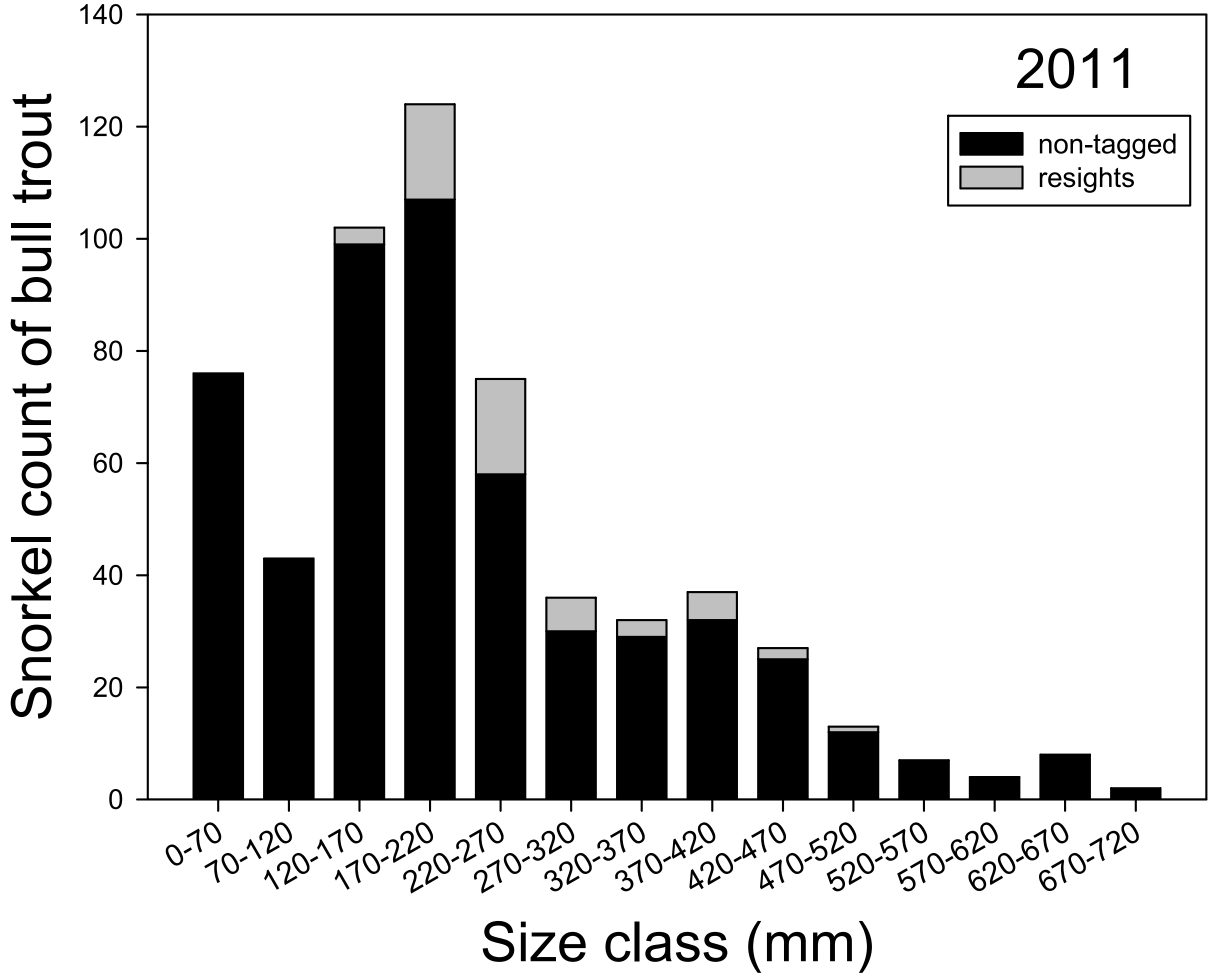


Figure 10. Number of bull trout in 50-mm size bins observed during snorkel-count surveys in all study reaches on the South Fork Walla Walla River, Oregon in 2011. Black bars are newly sighted fish and gray bars are resighted (previously marked) fish.

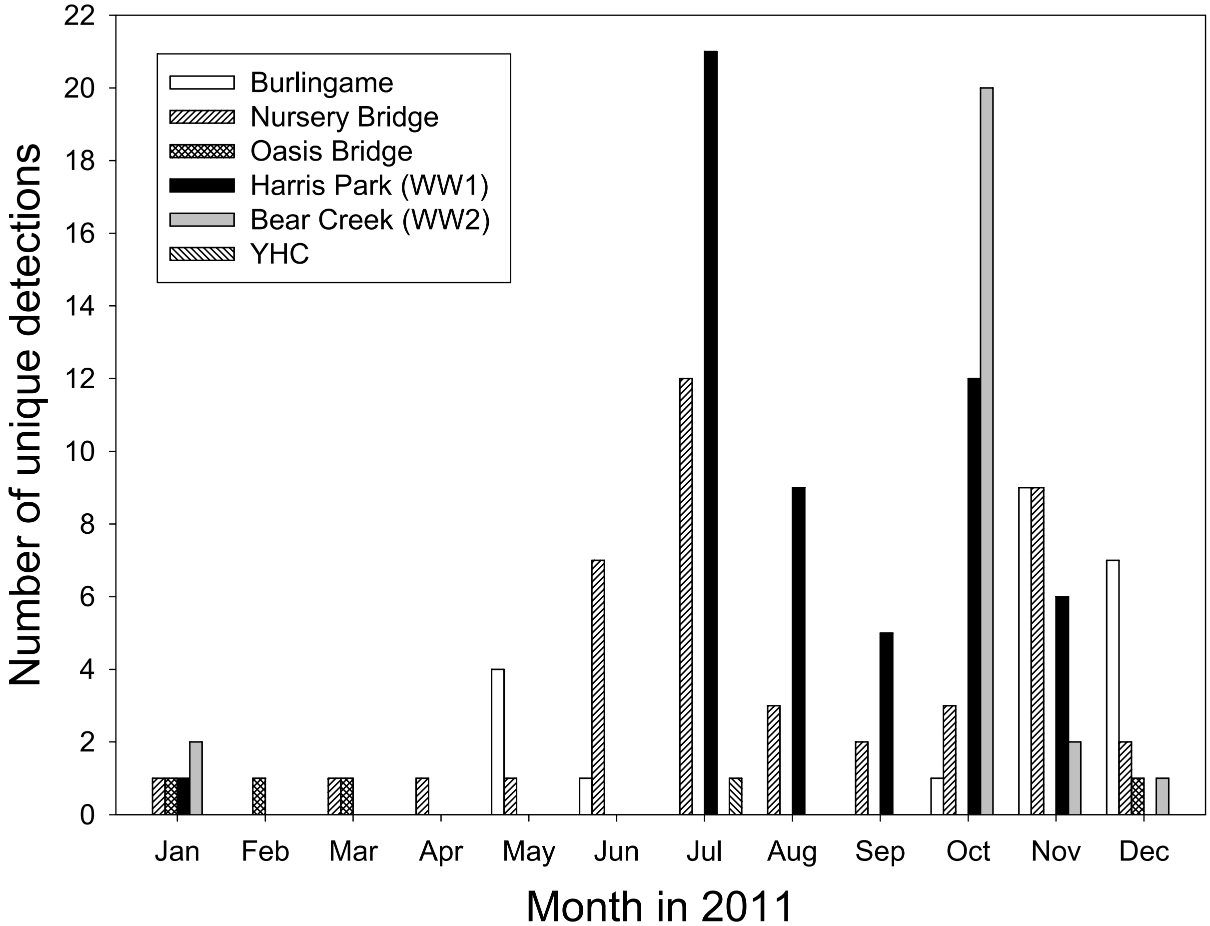


Figure 11. The number of unique PIT-tag detections per month in 2011 at each of the six passive in-stream antenna (PIA) arrays located in the South Fork Walla Walla River and mainstem Walla Walla River system, Oregon.

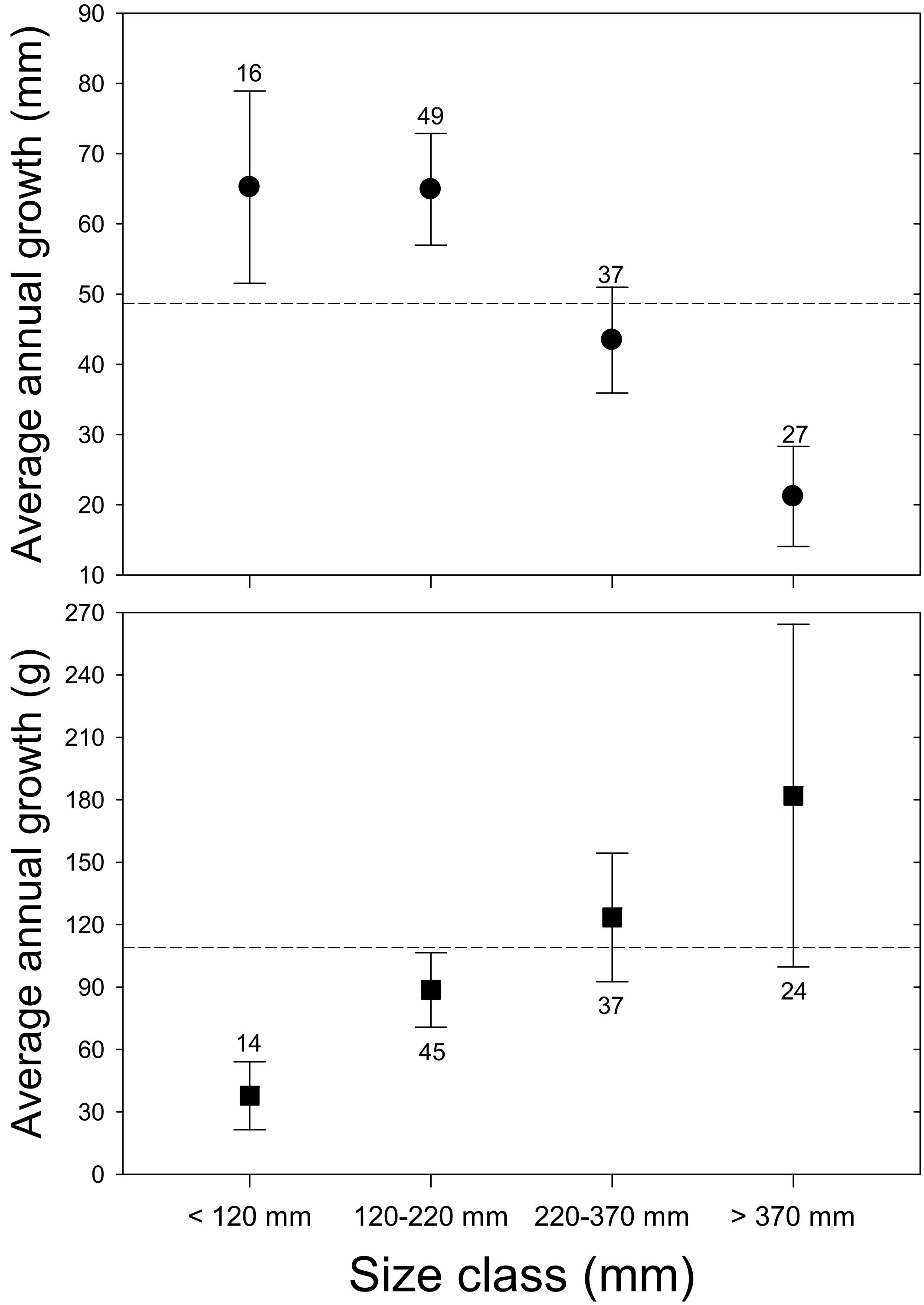


Figure 12. Average annual growth (± 2 SE) in total length (mm, top panel) and mass (g, bottom panel) for four size classes of bull trout tagged and recaptured in the South Fork Walla Walla River, Oregon, 2002 – 2011. Sample sizes are given above or below error bars. Dashed lines indicate mean across all size classes.

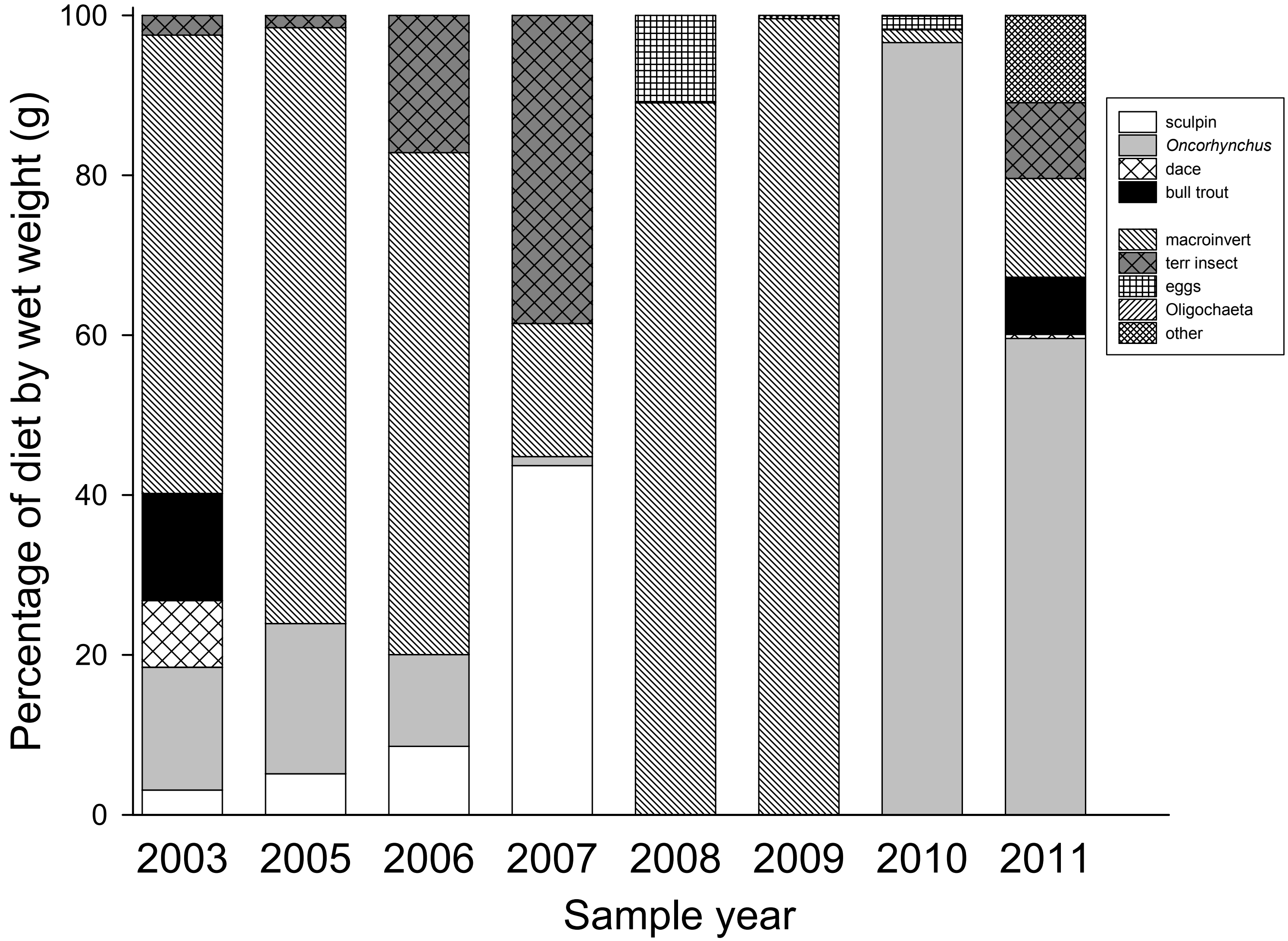


Figure 13. Bull trout diet composition from sacrificed and incidental bull trout takes in the South Fork Walla Walla River, Oregon, 2003-2011. Composition is based on percent wet weight of each prey type, where “macroinvert” includes all aquatic macroinvertebrates, and “other” includes items such as rocks and vegetation.

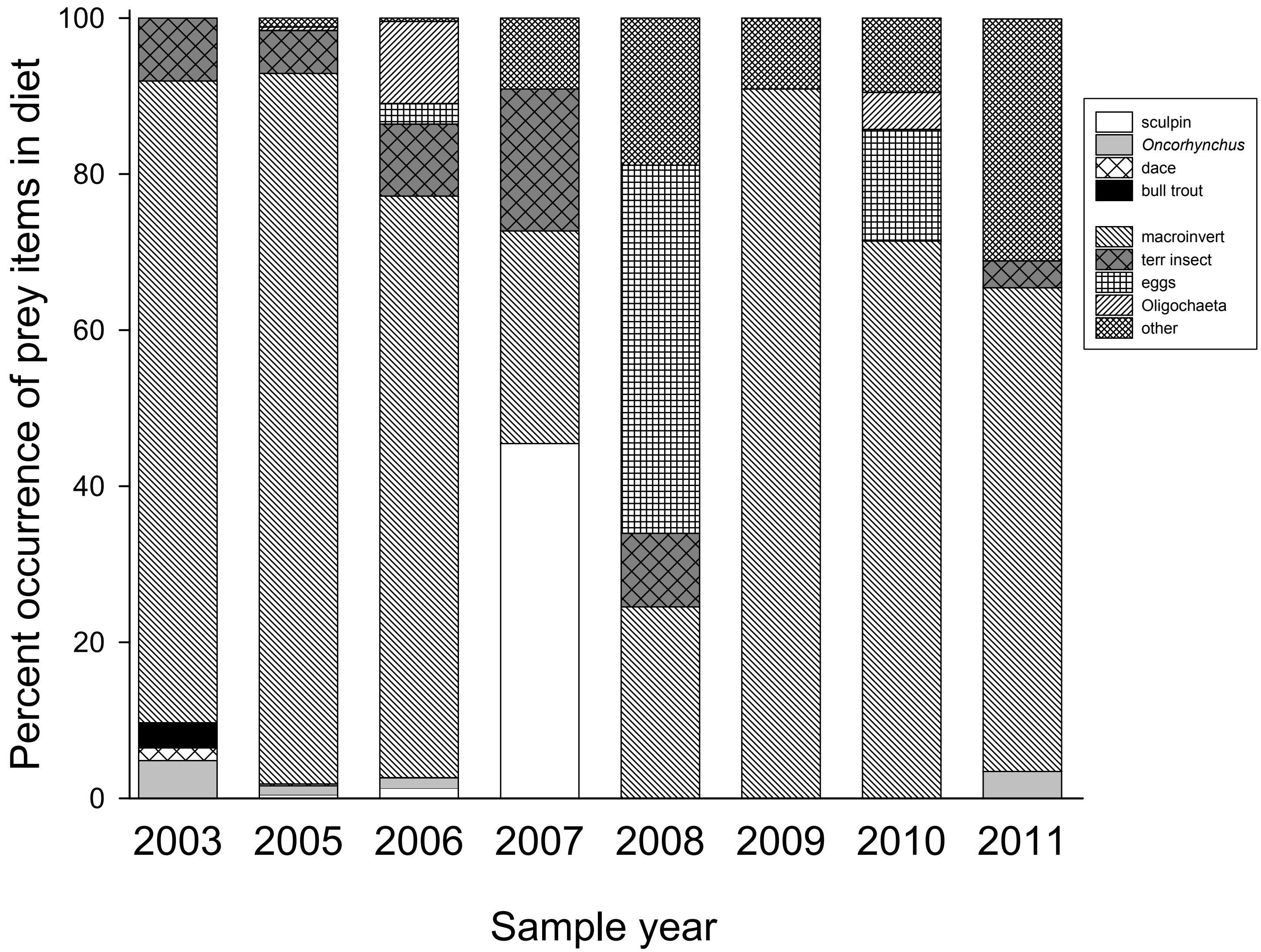


Figure 14. Bull trout diet composition from sacrificed and incidental bull trout takes in the South Fork Walla Walla River, Oregon, 2003-2011. Composition is based on the percent occurrence (count) of prey items in each category. "macroinvert" includes all aquatic macroinvertebrates, and "other" includes items such as rocks and vegetation.

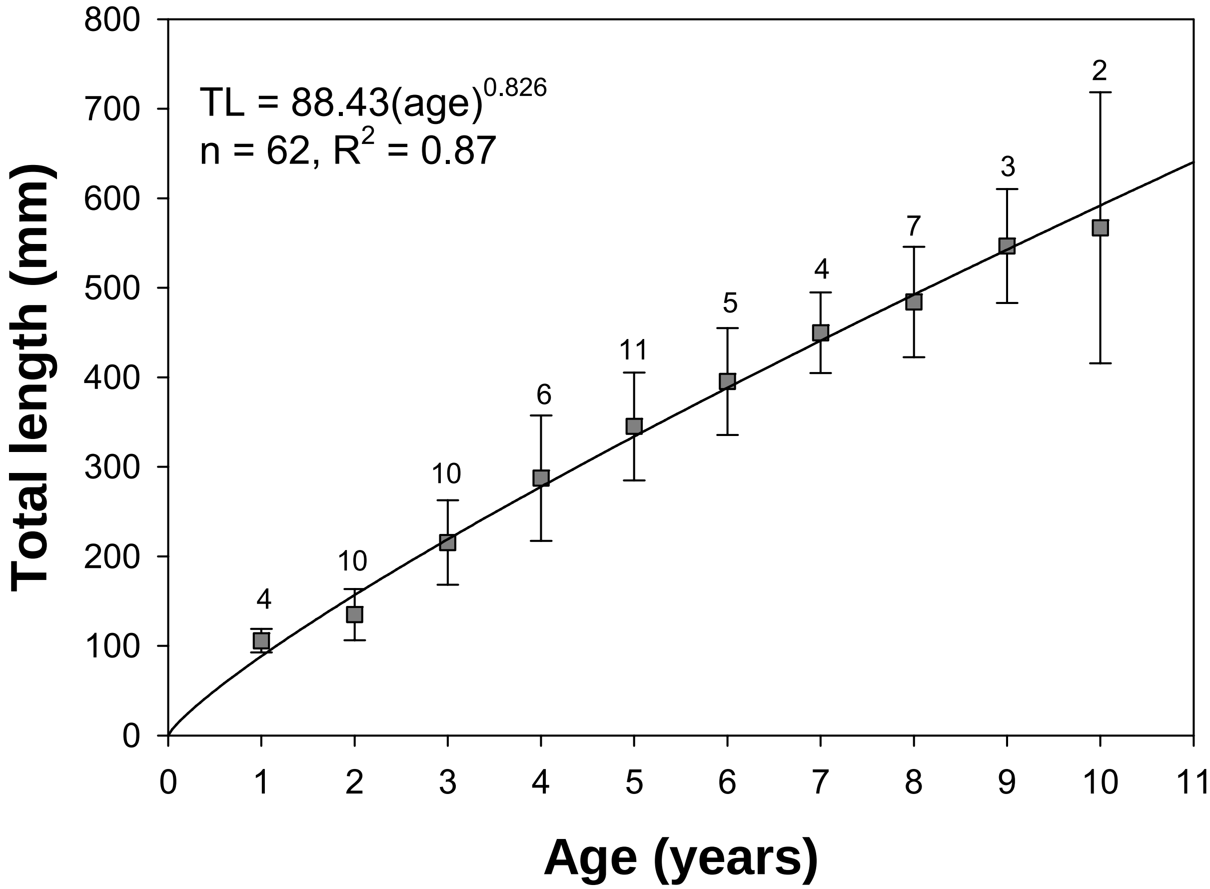


Figure 15. Bull trout total length (mm) and corresponding age estimated from otoliths of sacrificed or incidentally taken bull trout in the South Fork Walla Walla River, Oregon, 2002 - 2011. Sample size is given above error bars. Nonlinear regression equation is given and line represents best fit.

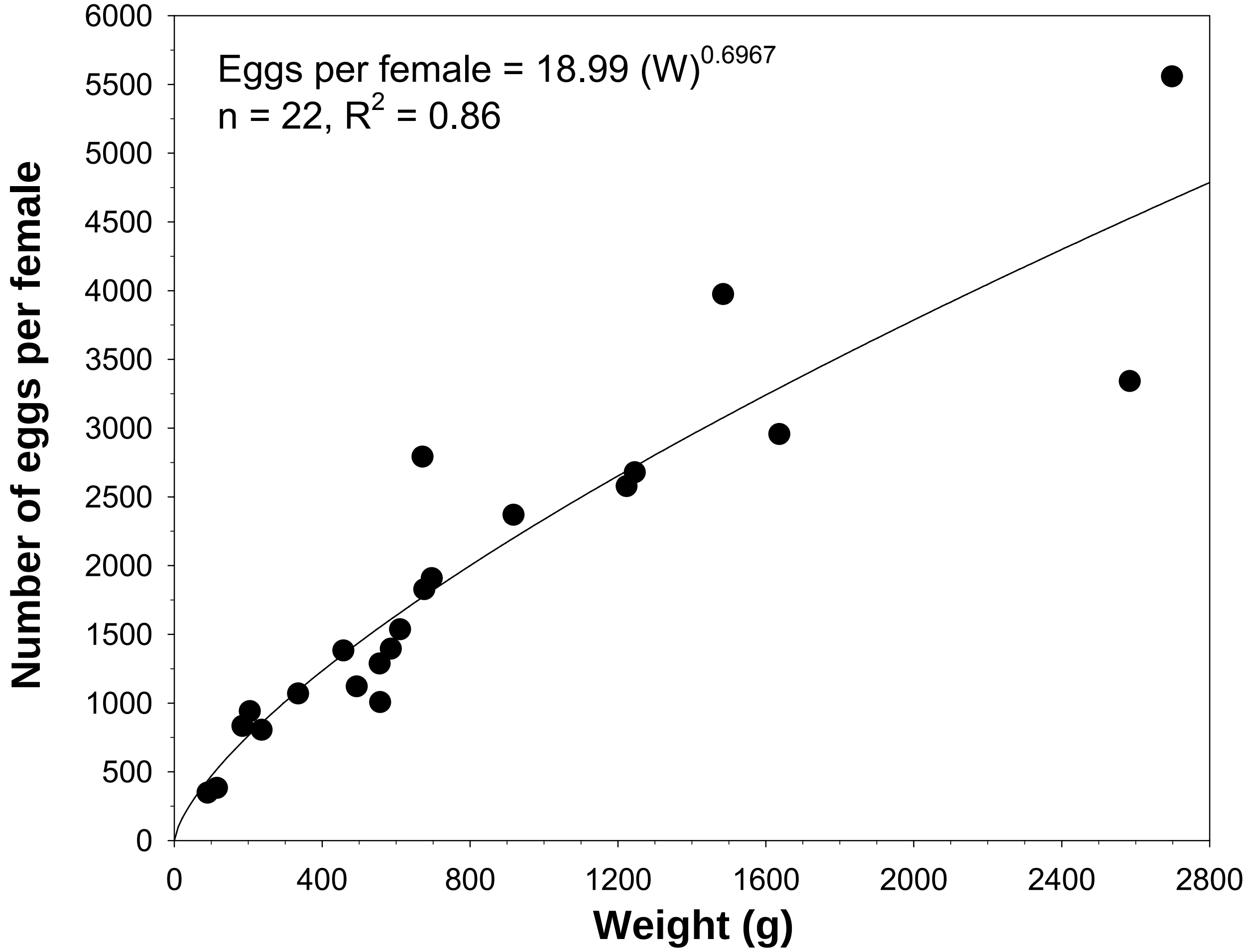


Figure 16. Female bull trout fecundity by weight (mass in g) based on sacrificed or incidentally taken fish in the South Fork Walla Walla River, Oregon, 2002 - 2011. Nonlinear regression equation is given and line represents best fit.

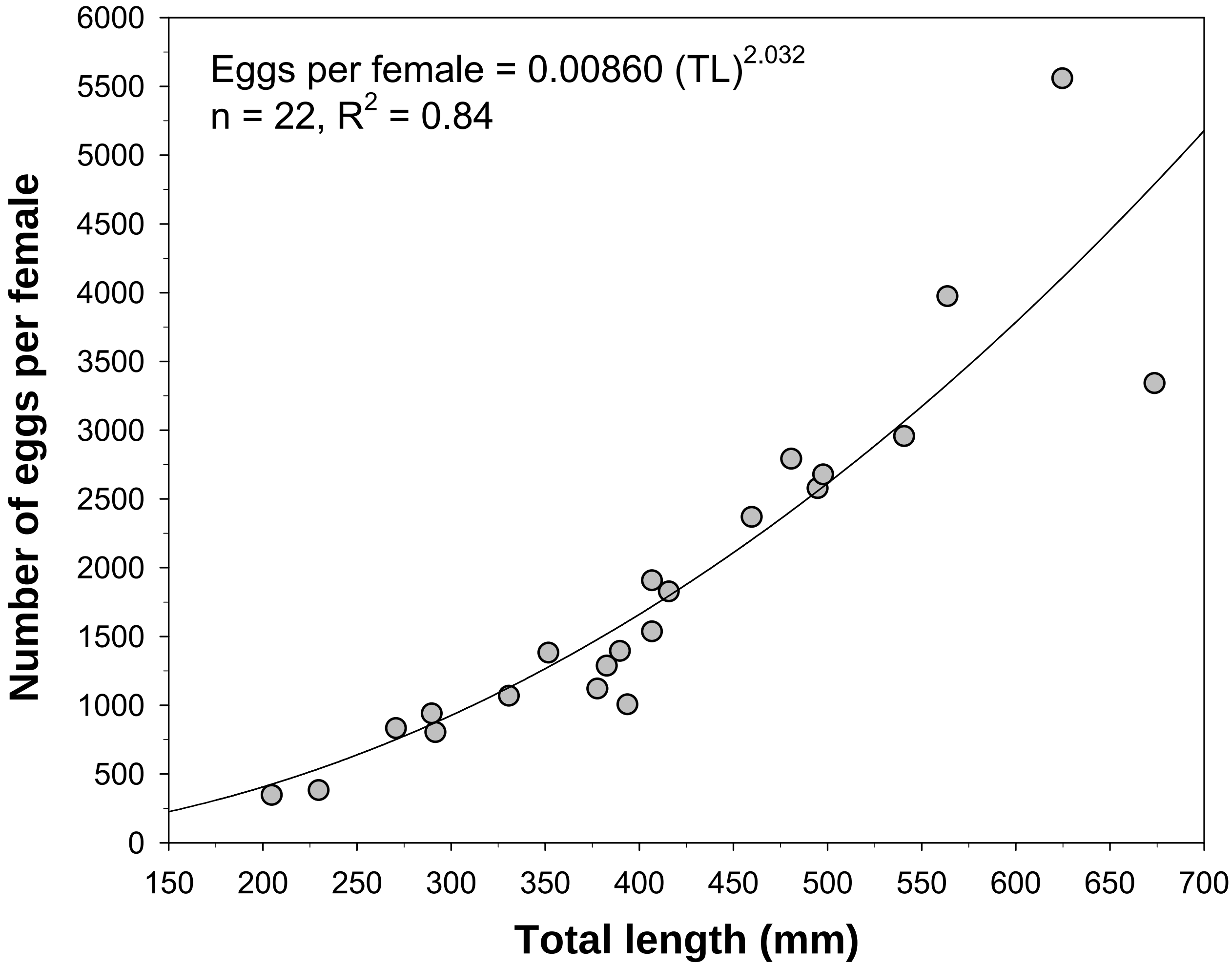


Figure 17. Female bull trout fecundity by total length (mm) based on sacrificed or incidentally taken fish in the South Fork Walla Walla River, Oregon, 2002 - 2011. Nonlinear regression equation is given and line represents best fit.

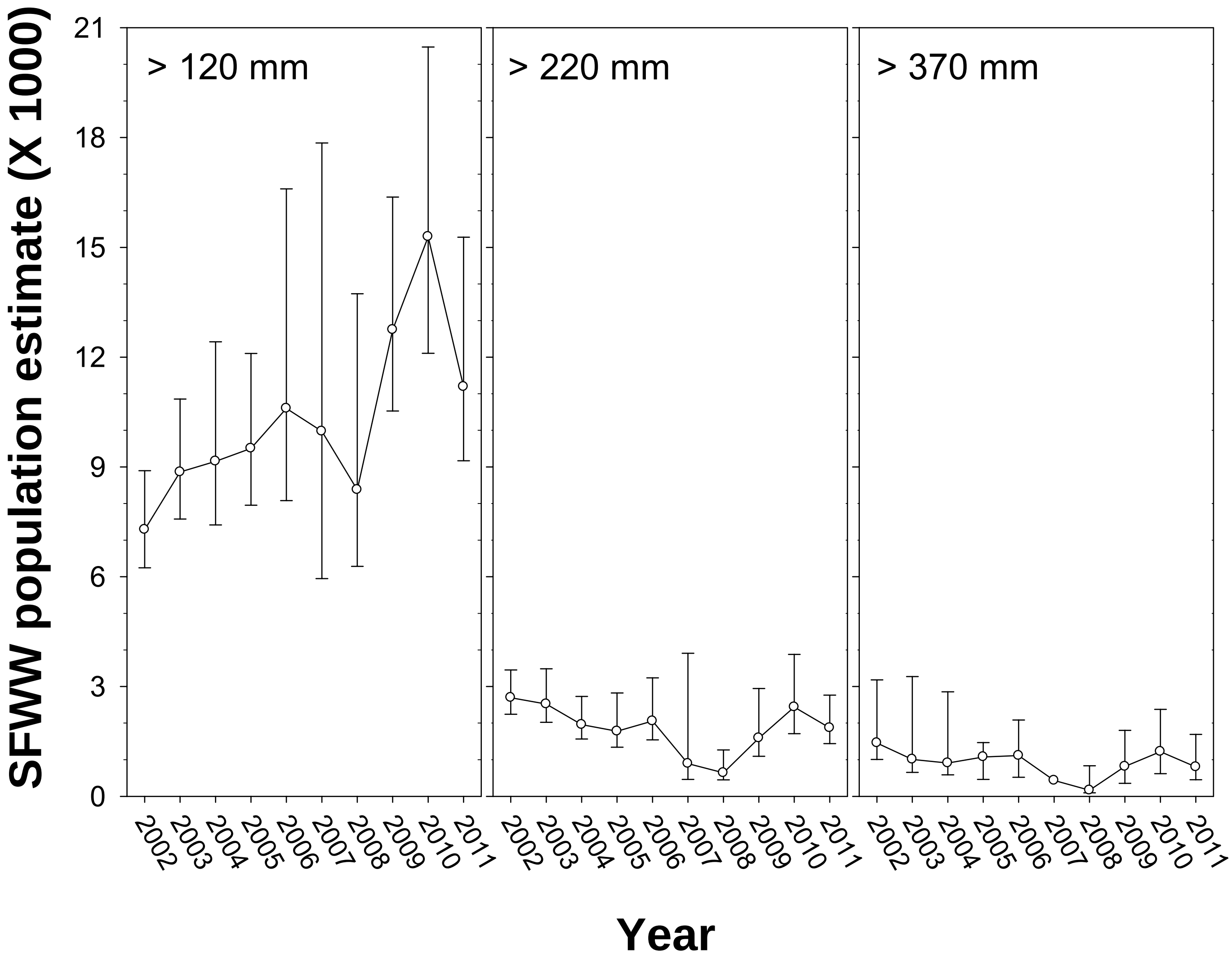


Figure 18. Annual population estimates (± 95% CI) for three size groupings of bull trout in the South Fork Walla Walla River, Oregon, 2002 - 2011. Due to low sample size, no confidence intervals were obtainable for the bull trout population component > 370 mm TL in 2007. Estimates were expanded to represent the entire stream area from Harris Park bridge upstream to Reser Creek.

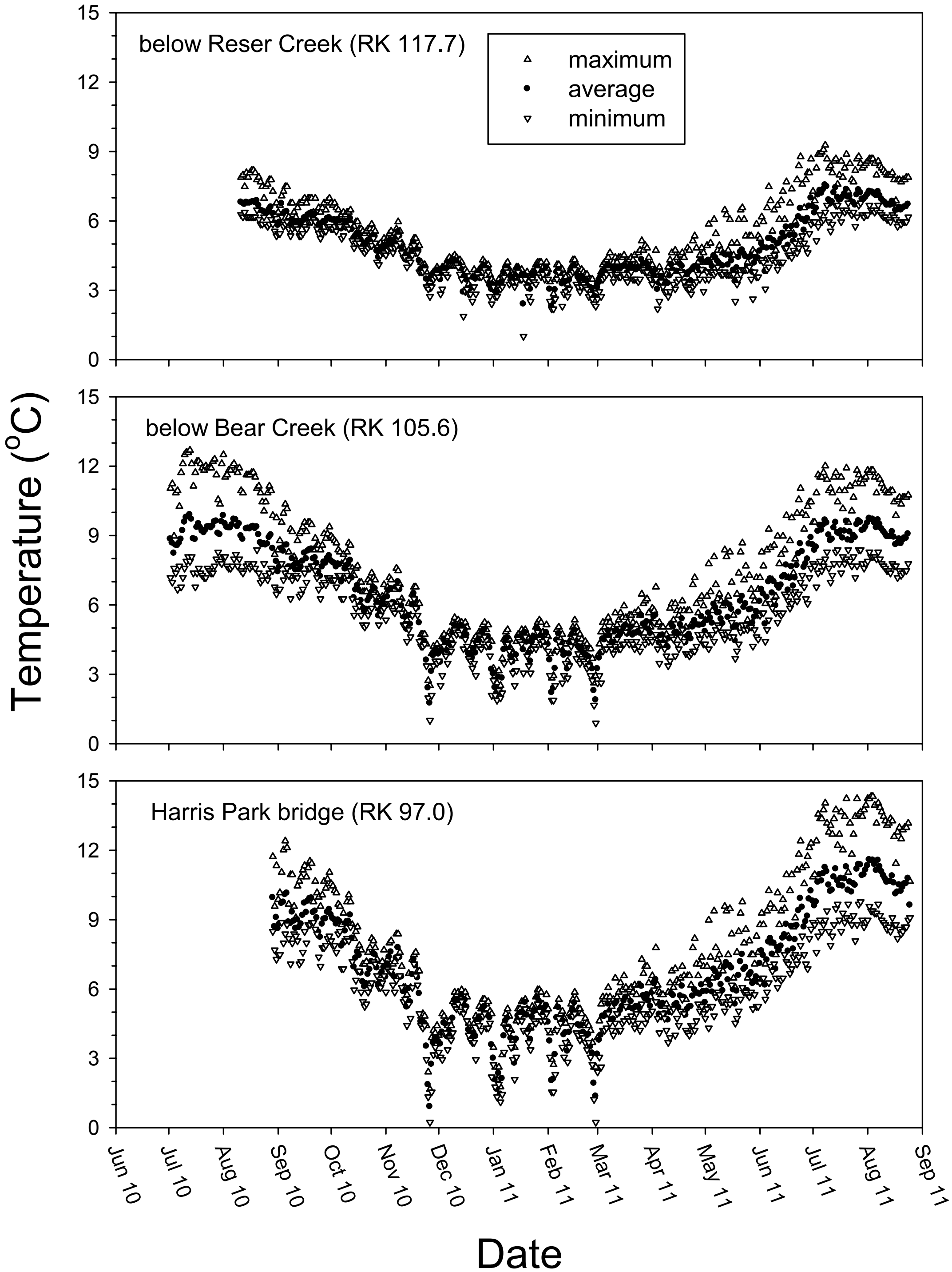


Figure 19. Daily temperatures (maximum, average, minimum) recorded at three locations in the South Fork Walla Walla River, Oregon, from July 2010 through September 2011. Data was not obtained from the location just downstream from Skiphorton Creek (RK 112.9) in 2011. River kilometers (RK) describe the distance of the location upstream from the confluence of the Walla Walla and Columbia rivers. Our study area is located between RK 97.0 and 117.7.

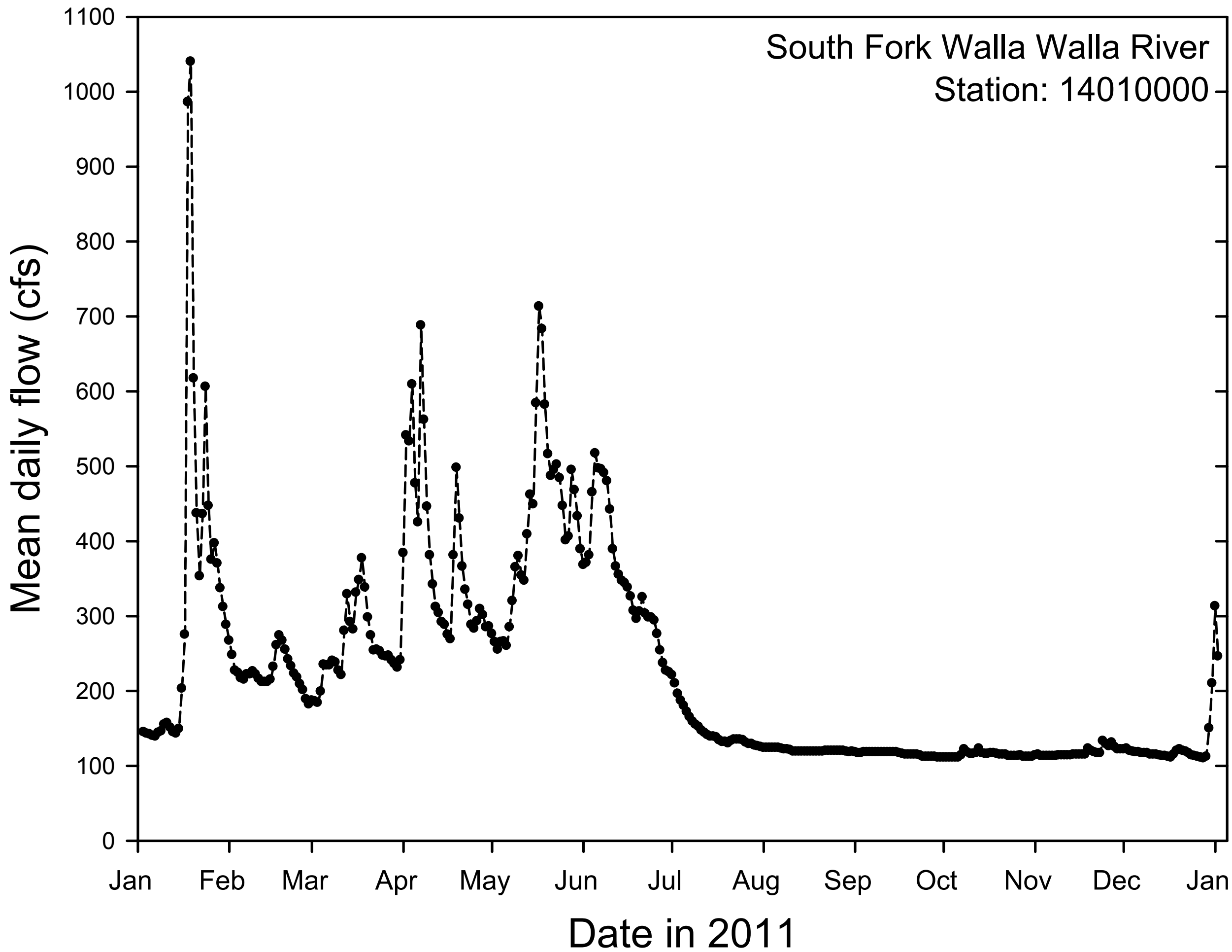


Figure 20. Mean daily flow measured at Station 1401000 on the South Fork Walla Walla River near Milton, Oregon (Umatilla Basin, Umatilla County, HUC = 17070102) from 1 January – 31 December 2011. 100 cfs = 2.83 m^3/s. Taken from OWRD Near Real Time Hydrographic Data website: *http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/display_hydro_graph.aspx?station_nbr=14010000* on 5 September 2012.

APPENDIX 1

Revised objectives and tasks specified to meet the annual project goals.

Objective 1. Comprehensive bull trout population assessment and monitoring **(annual)**:

Task 1.1 Marking.
Task 1.2 Recapture.
Task 1.3 Snorkel surveys for juvenile densities.
Task 1.4 Adult and egg information, egg-to-parr survival.

Objective 2. Innovative pass-through PIT-tag monitoring system **(annual)**:

Task 2.1 Tagging, detection, and fish movement.
Task 2.2 Working with USFWS-CRFPO to develop and maintain a comprehensive tagging database for the entire Walla Walla River Subbasin.
Task 2.3 Synthesis of ten years of tagging, recapture, movement, migration, and life-history patterns. **2012**.

Objective 3. Population vital rate data analysis: Based on information gathered as part of Objectives 1-2 above **(annual)**:

Task 3.1 Analysis of mark/recapture data: population estimates and movement.
Task 3.2 Analysis of additional population-level data (e.g., snorkel, redd counts etc.)
Task 3.3 Analysis of key vital rates and demographic characteristics: age, size, growth, survival, fecundity, cohort size estimates by size class, and life history expression.

Objective 4. Early life history and habitat variability study **(2007 - 2012)**:

Task 4.1 Synthesize data on juvenile abundance and habitat use throughout the watershed and assess distribution in relation to natural and anthropogenic-influenced (land use) variation in habitat type and quality, and in relation to annual climate fluctuations.

Objective 5. Use data and information described in Objectives 1-4 above to build a comprehensive (and transferrable) template for evaluating recovery options for bull trout and informing the RMEG NatureServ risk categorization process **(2010 - 2012):**

Task 5.1 Build, update, and improve population viability and persistence model.
Task 5.2 Connectivity and patch dynamics: Build and use predictive models to assess the importance of riverscape connectivity on the distribution of bull trout given habitat fragmentation and climate change. **(2008 - 2012)**
Task 5.3. Assess options for including indices of connectivity as a RMEG NatureServ ranking criteria.
Task 5.4. Use model to assess effects of management actions on long-term population persistence.

APPENDIX 2

A summary of other fish species sighted or captured in the South Fork Walla Walla River, Oregon, from 2002 to 2011 during bull trout surveys: Chinook salmon, steelhead salmon and rainbow trout *(Oncorhynchus mykiss)*, sculpin, and mountain whitefish

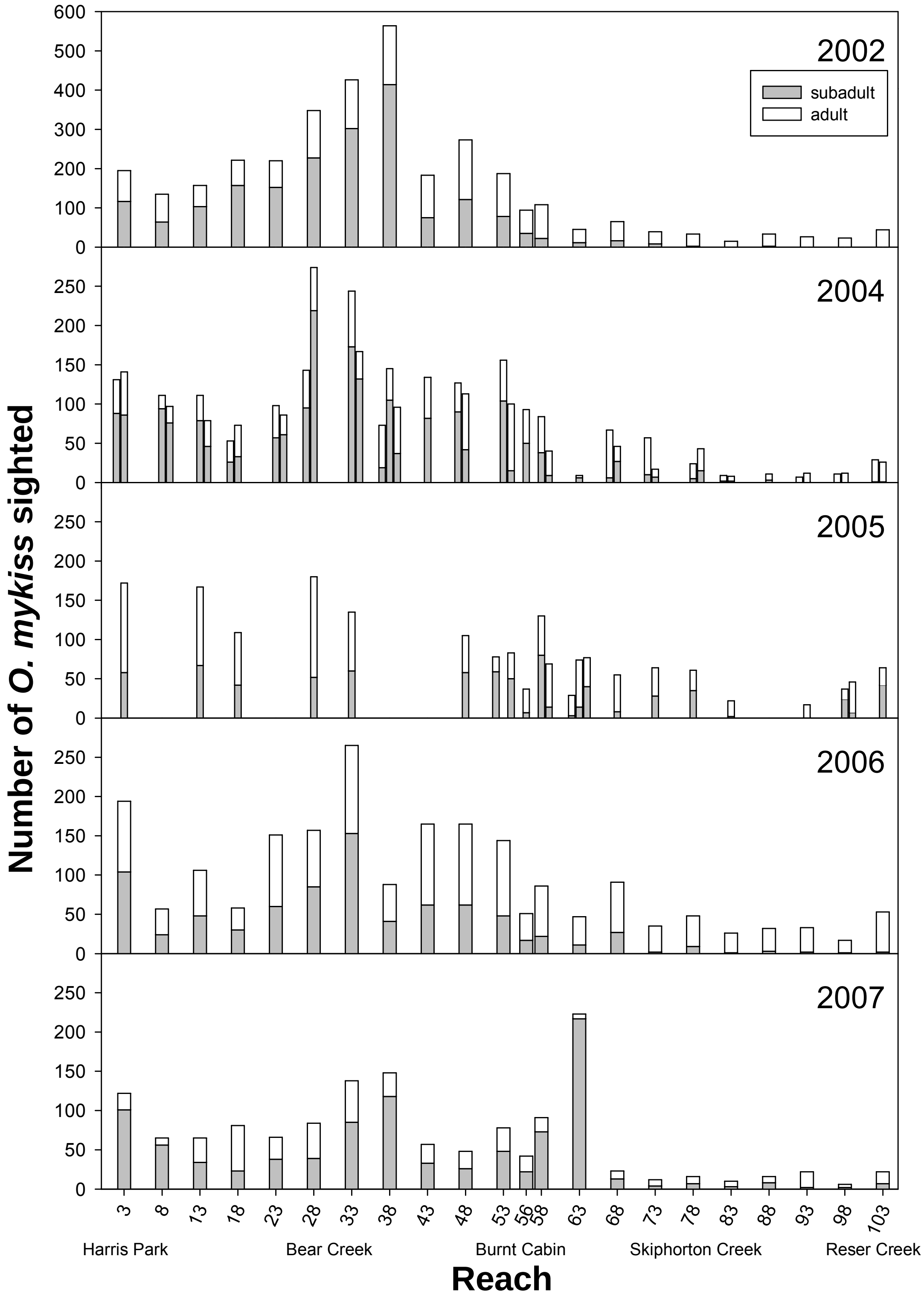


Figure A2.1. Number of adult and subadult *Oncorhynchus mykiss* (rainbow trout or steelhead salmon) sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2002 - 2007. Note the differences in scale among years, especially in 2002.

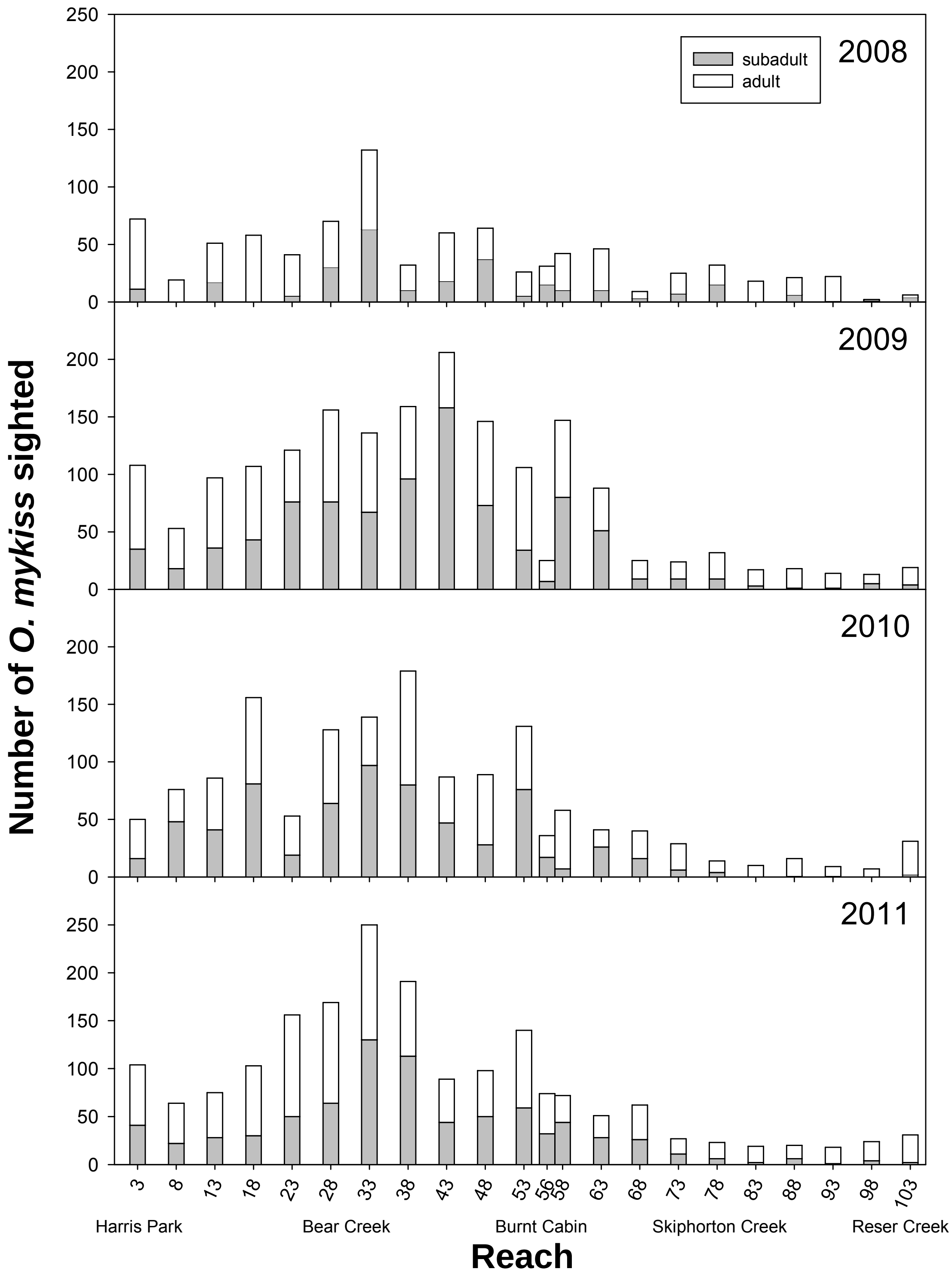


Figure A2.2. Number of adult and subadult *Oncorhynchus mykiss* (rainbow trout or steelhead salmon) sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2008 - 2011.

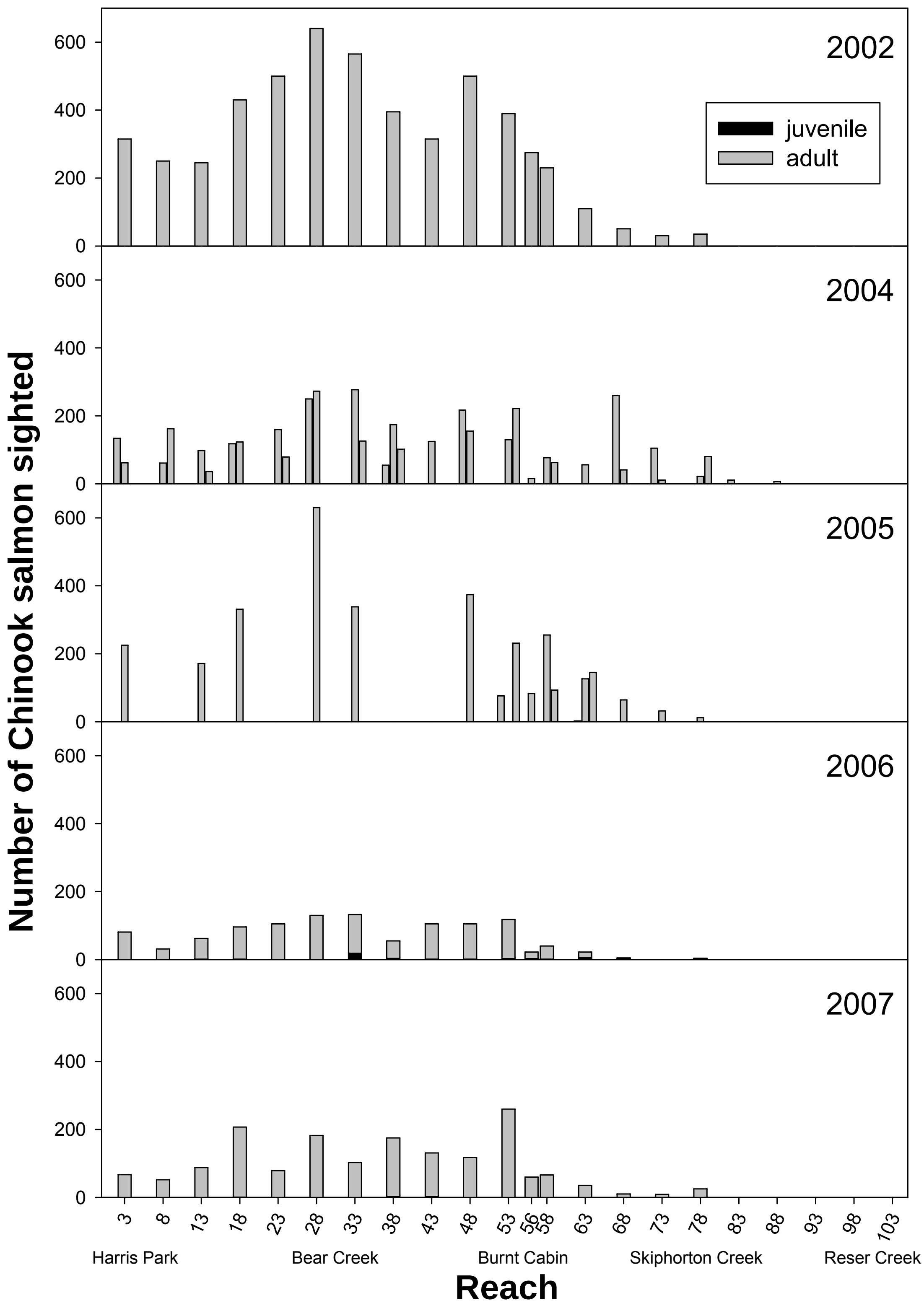


Figure A2.3. Number of juvenile and adult Chinook salmon sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2002 – 2007.

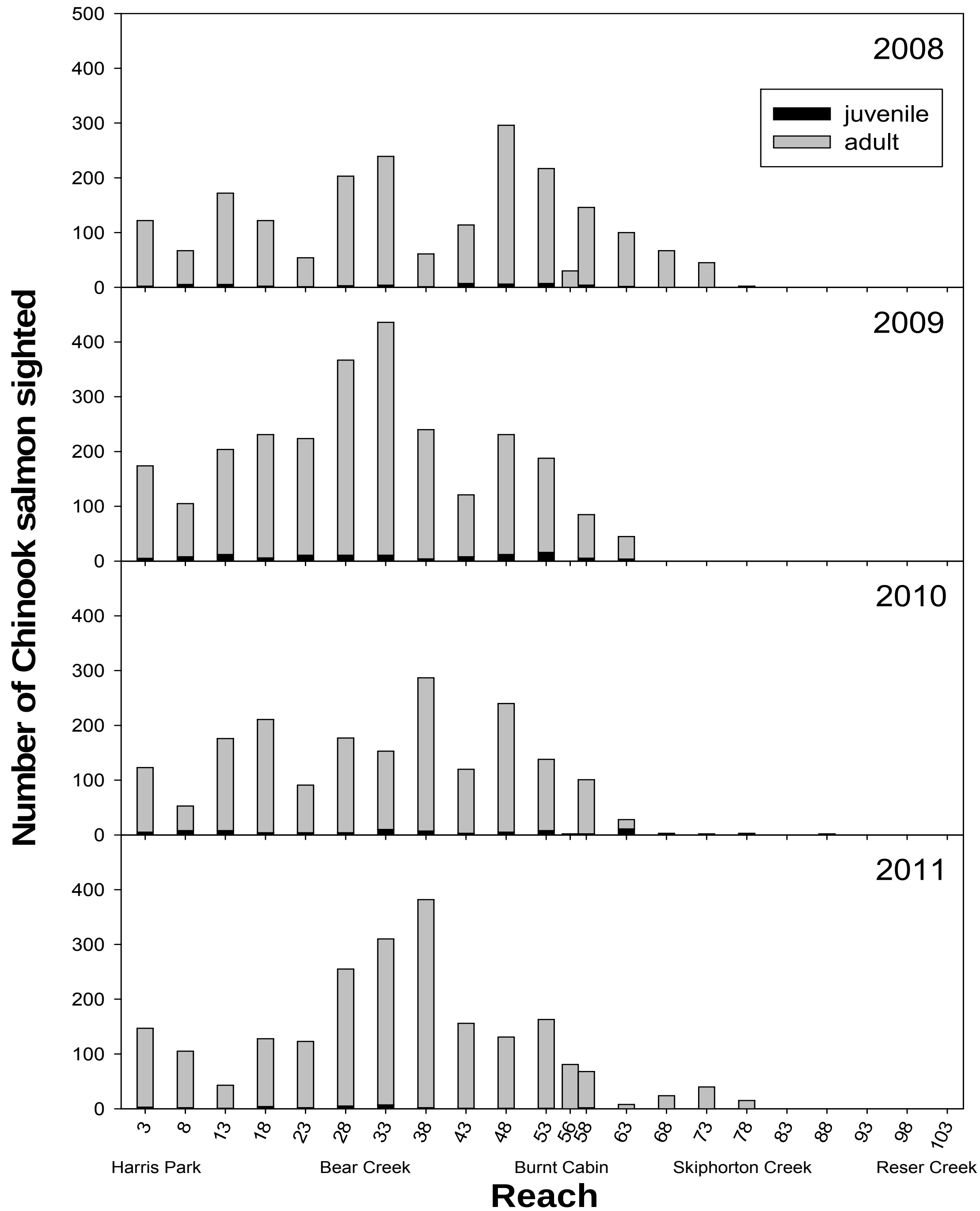


Figure A2.4. Number of juvenile and adult Chinook salmon sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2008 – 2011.

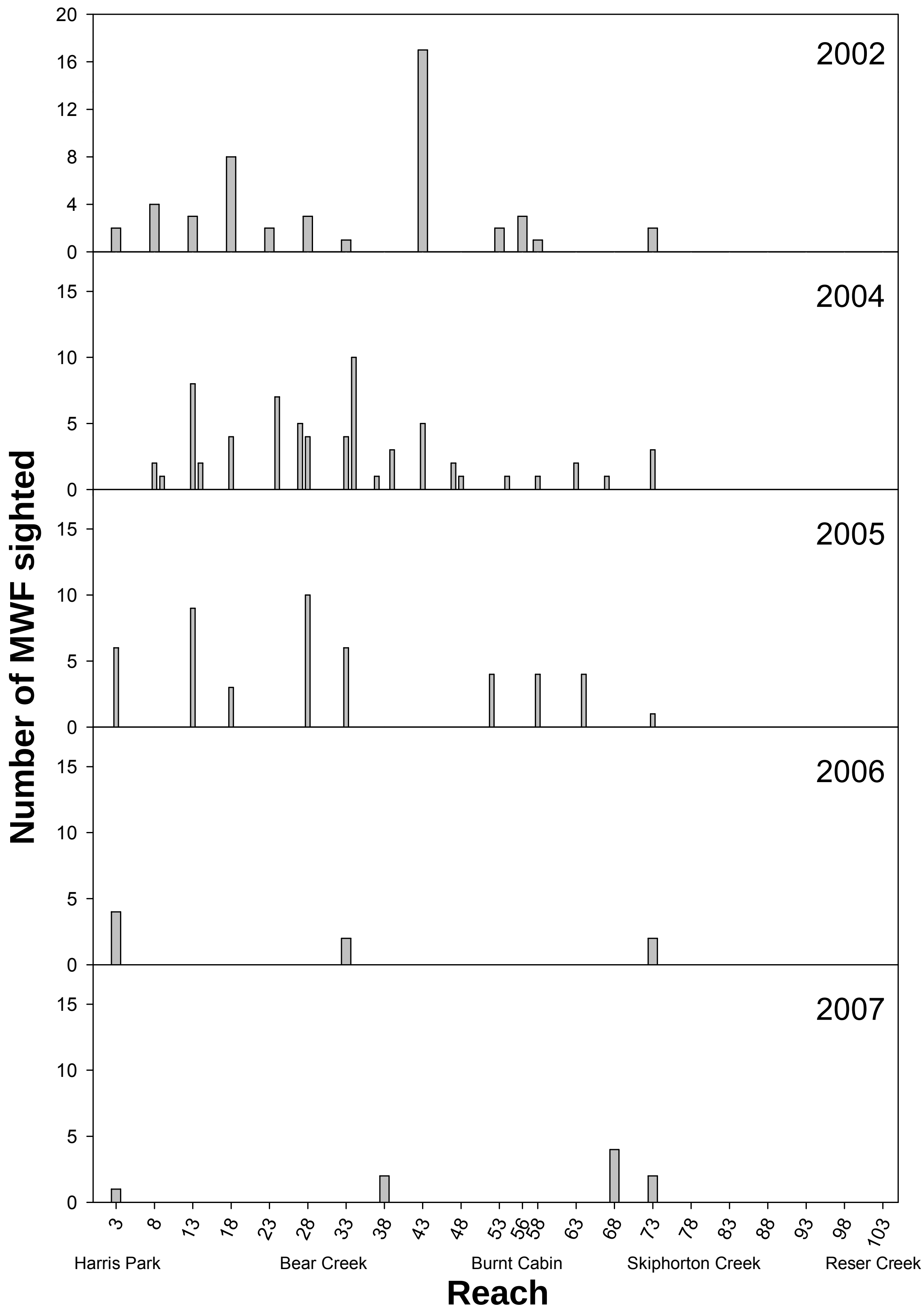


Figure A2.5. Number of mountain whitefish (MWF) sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2002 - 2007.

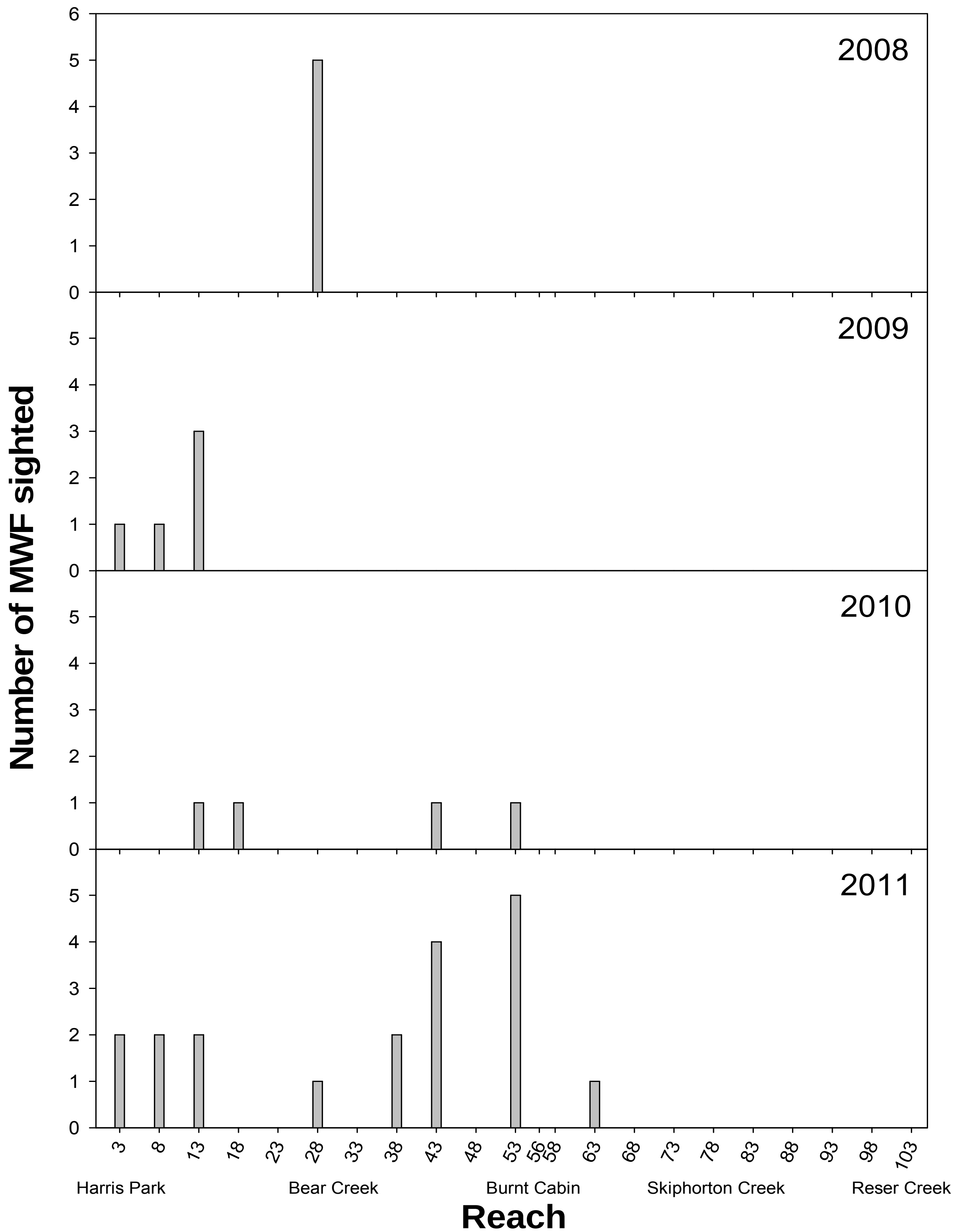


Figure A2.6. Number of mountain whitefish (MWF) sighted during snorkel surveys in the South Fork Walla Walla River, Oregon, 2008 - 2011.

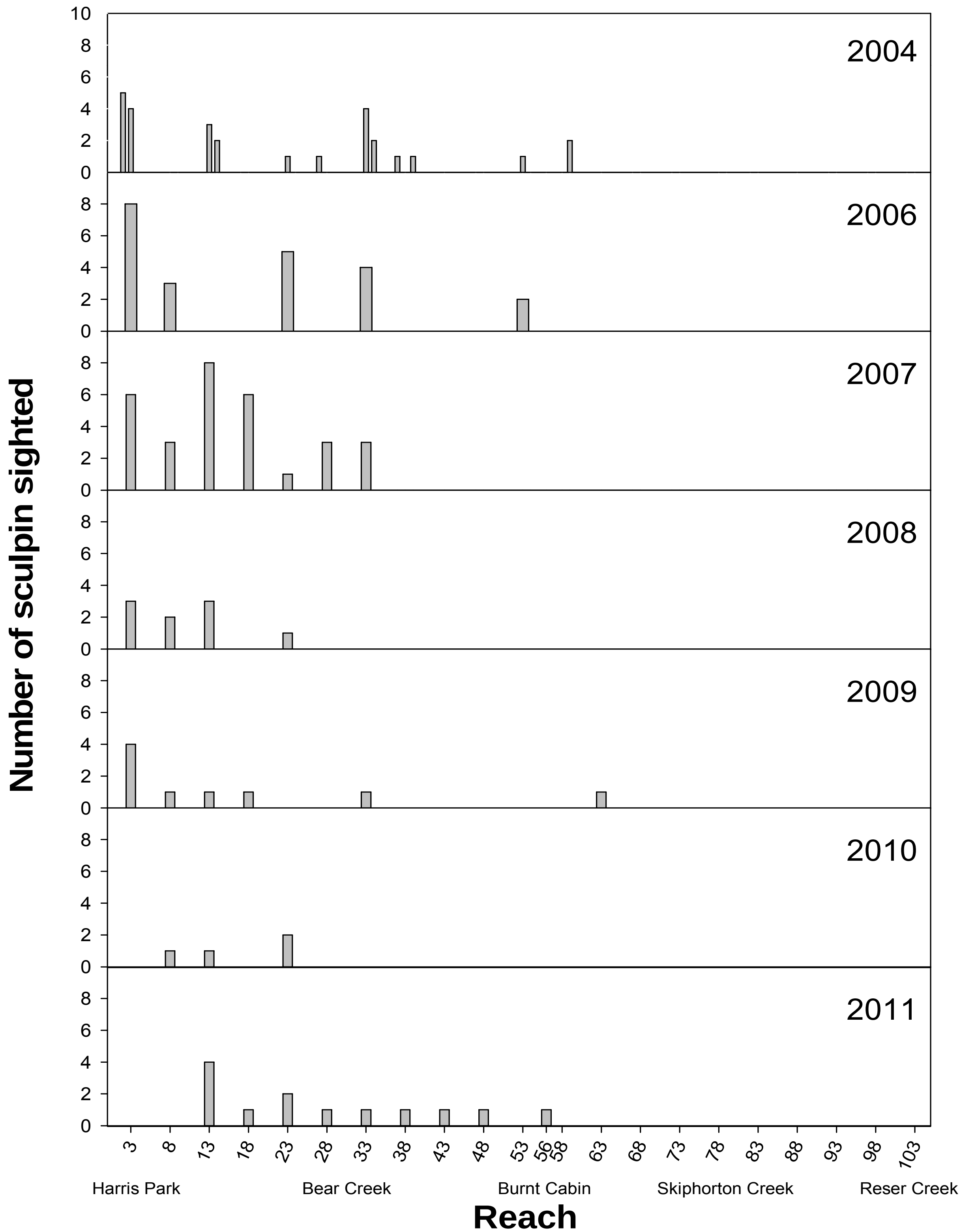


Figure A2.7. Number of sculpin (*Cottus* spp.) sighted during snorkel surveys in study reaches in the South Fork Walla Walla River, Oregon, 2004 - 2011.

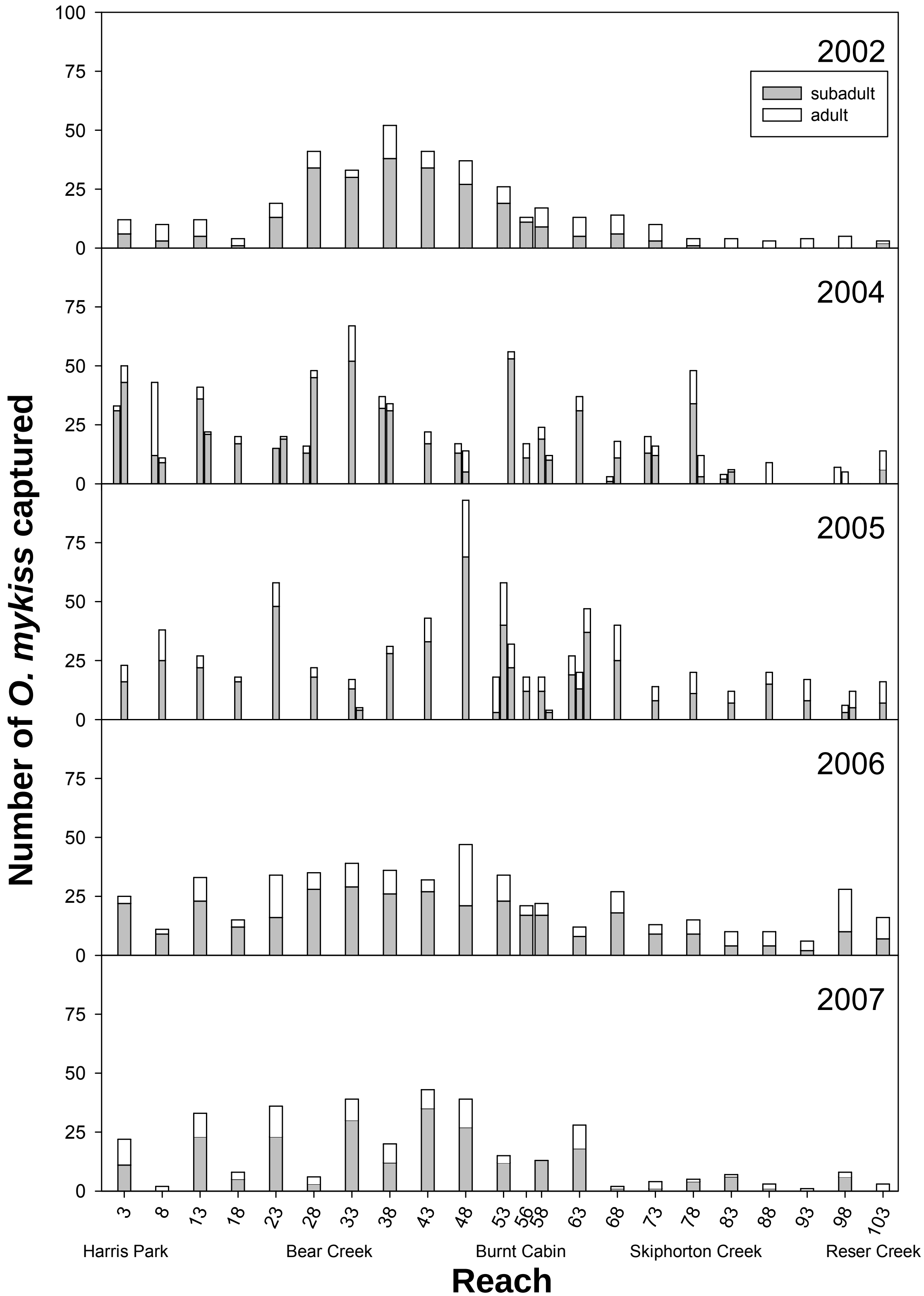


Figure A2.8. Number of subadult and adult *Oncorhynchus mykiss* (rainbow trout or steelhead salmon) captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla, Oregon, 2002 - 2007.

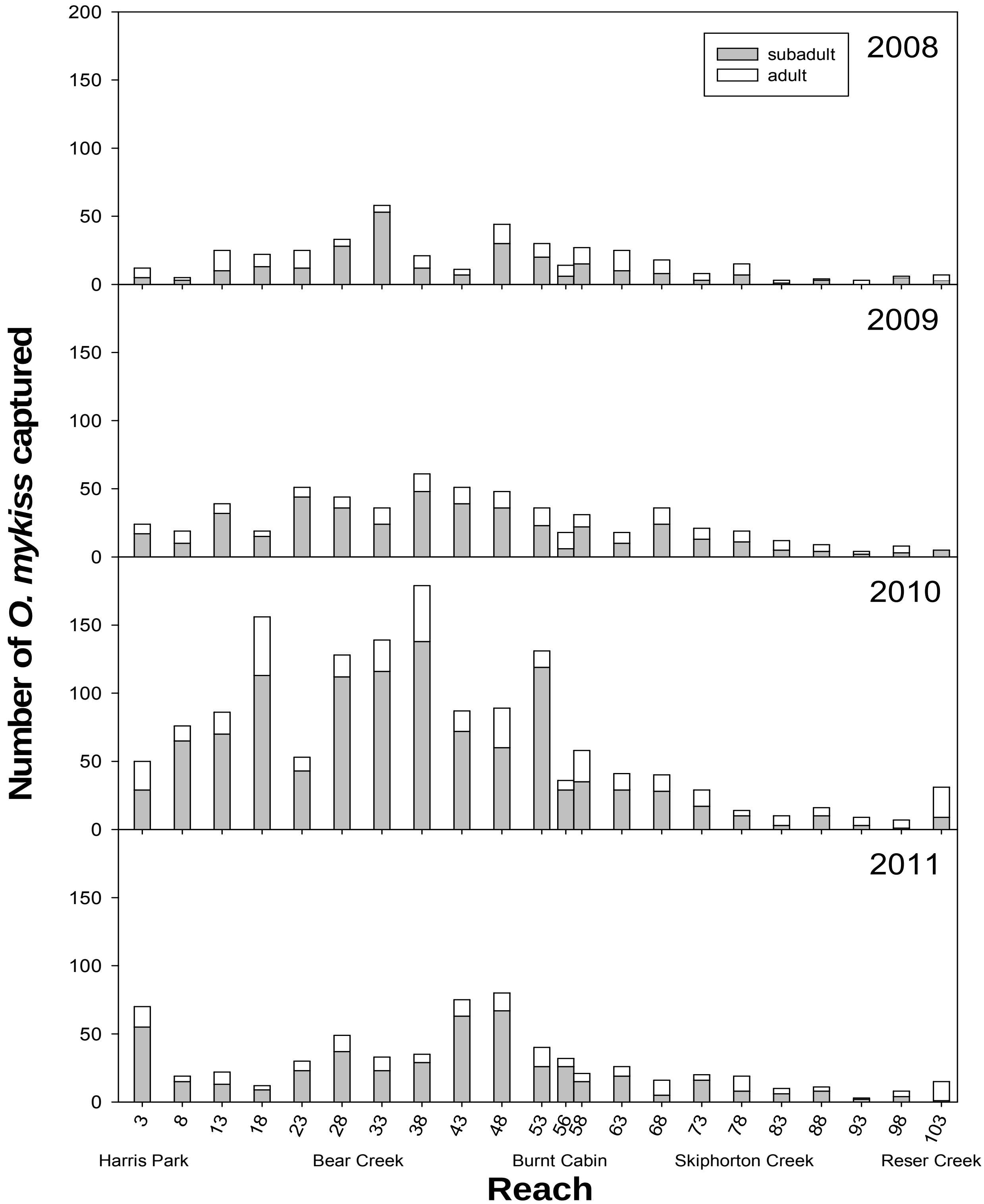


Figure A2.9.Number of subadult and adult *Oncorhynchus mykiss* (rainbow trout or steelhead salmon) captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla, Oregon, 2008 - 2011.

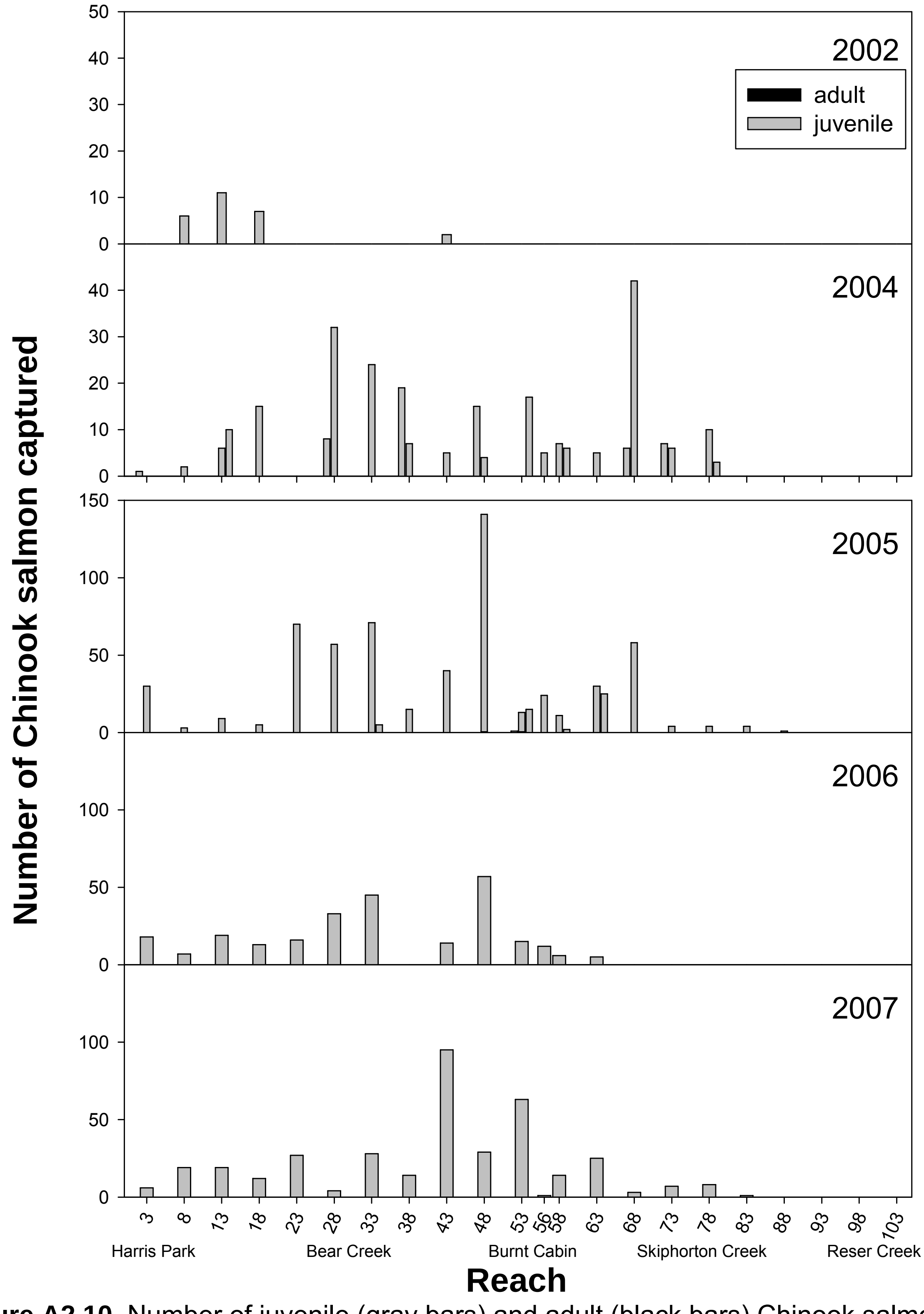


Figure A2.10. Number of juvenile (gray bars) and adult (black bars) Chinook salmon captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla, Oregon, 2002 - 2007. Note scale changes among years.

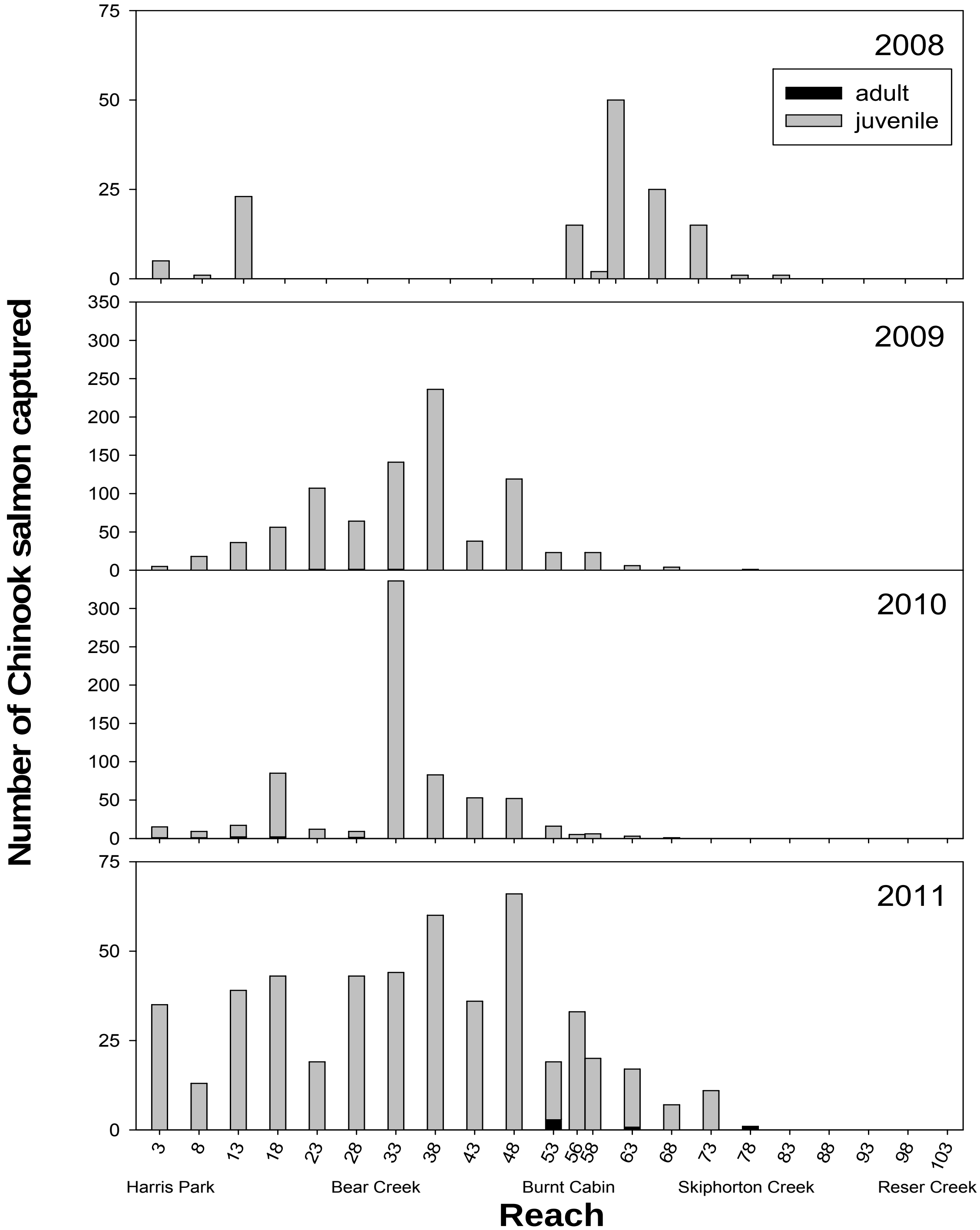


Figure A2.11. Number of juvenile (gray bars) and adult (black bars) Chinook salmon captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla, Oregon, 2008 - 2011. Note scale changes among years.

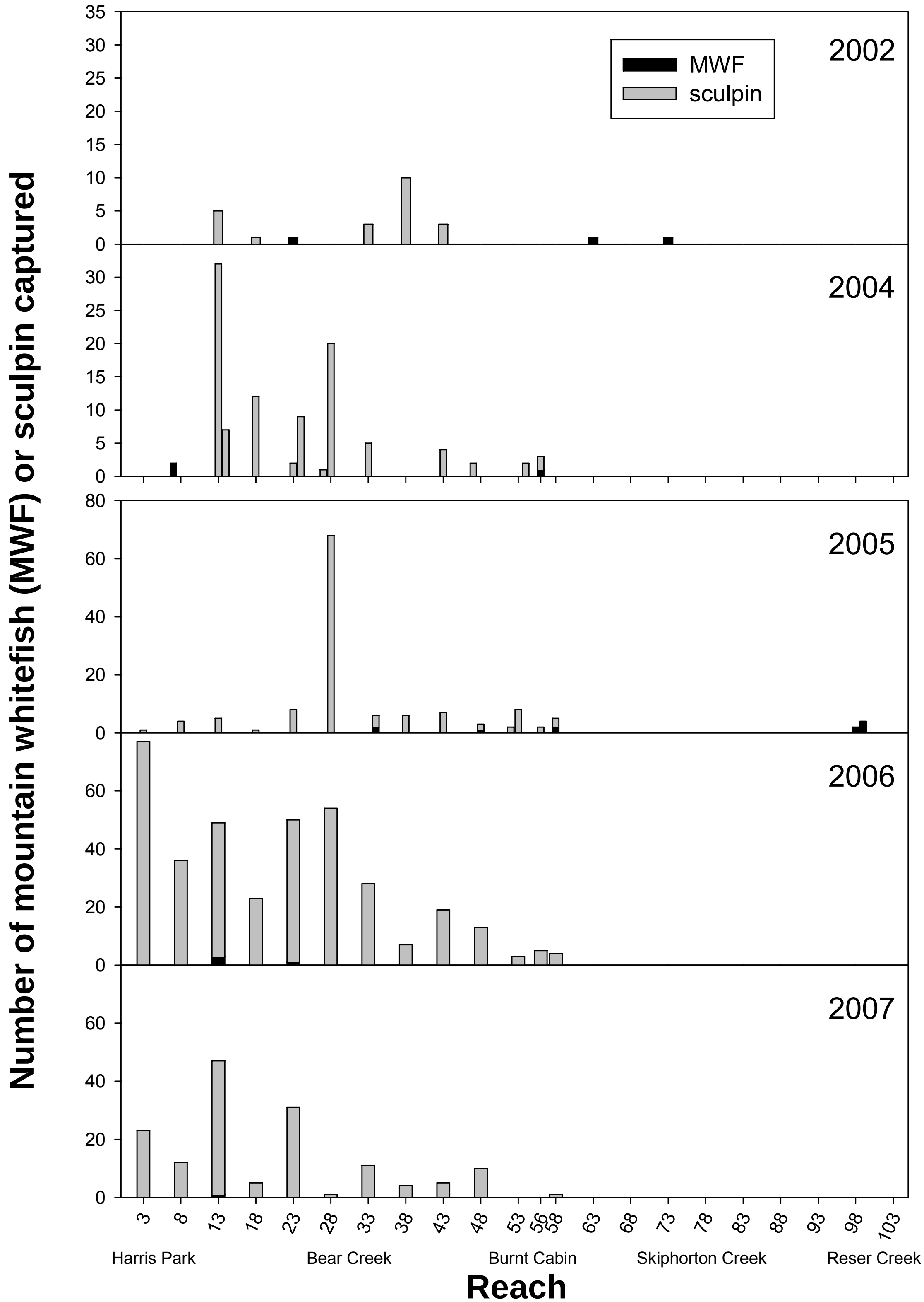


Figure A2.12. Number of sculpin (gray bars) and mountain whitefish (black bars) captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla River, Oregon, 2002 - 2007. Note scale changes among years.

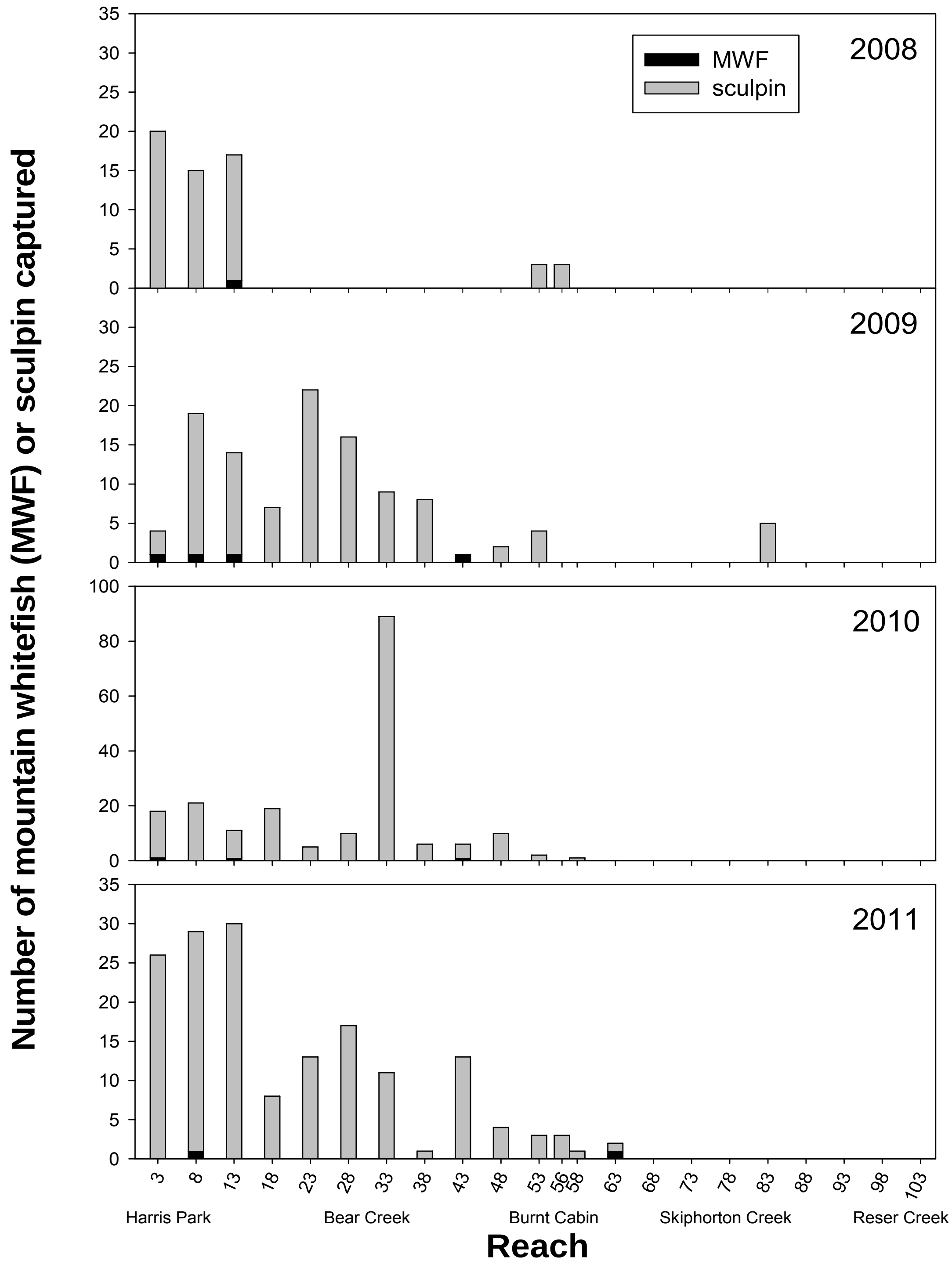


Figure A2.13. Number of mountain whitefish (black bars) and sculpin (gray bars) captured (and thereafter immediately released) during sampling for bull trout in the South Fork Walla Walla, Oregon, 2008 - 2011. Note scale changes among years.

APPENDIX 3

Photographs of the South Fork Walla Walla River, Oregon, in 2011 demonstrating geomorphic change due to high flows in the winter and spring of 2011

Figure A3.1. Reach 53 of the South Fork Walla Walla River, Oregon in 2011. This image depicts the high-velocity habitat commonly found in the study reaches during 2011.

Figure A3.2. An abandoned channel in reach 53 of the South Fork Walla Walla River, Oregon in 2011. Many such channels that may have contained a large portion of the flow and suitable bull trout habitat in previous seasons were abandoned in 2011 following the geomorphic changes caused by high runoff during the winter and spring of 2011. Abandonement of large channels resulted in higher flow and therefore water velocities within active channels in 2011.

Figure A3.3. Downstream view of an abandoned channel within Reach 53 of the South Fork Walla Walla River, Oregon in 2011. High discharge during the winter and sustained high runoff in the spring of 2011 resulted in widespread geomorphic changes in the South Fork Walla Walla River, including routing of new channels and abandonment of other channels. Numerous side channels such as this one were abandoned in 2011, and streamflow was re-routed into other channels, potentially resulting in a change in stream velocities and available bull trout habitat.

Figure A3.4. Upstream view of an abandoned channel within Reach 53 of the South Fork Walla Walla River, Oregon in 2011.

Figure A3.5. Adult bull trout captured and released in the South Fork Walla Walla River, Oregon, in July 2011.

APPENDIX 4

Ten-year summaries of bull trout marked and resighted throughout the Walla Walla River Subbasin, 2002 - 2011

Between 1998 - 2011, a large number of bull trout were marked with PIT tags in three tributaries and in the mainstem of the Walla Walla River. Marked bull trout were then manually recaptured and resighted at passive in-stream antennas (PIAs) at numerous locations throughout the Walla Walla River Subbasin (Figure A4.1). The U.S. Forest Service (USFS) and U.S. Fish and Wildlife Service (USFWS) captured and marked bull trout in upper Mill Creek from 1998 - 2011 via a screw trap, weirs, and angling. In the Touchet River, the Washington Department of Fish and Wildlife (WDFW) captured and marked bull trout between 2002 through present at several screwtrap and adult trap locations. Between 2002 and 2011, Utah State University (USU) captured and marked bull trout within river reaches spaced regularly throughout the South Fork Walla Walla River using a combination of “electro-herding” downstream to a seine and angling. The USFWS also captured and tagged bull trout from 2004 to present at several locations throughout the main stem Walla Walla River. Bull trout have also been captured and marked with PIT tags when captured at screw traps operated by the Confederated Tribes of Umatilla Indian Reservation (CTUIR) in the mainstem Walla Walla River.

Recaptures of marked bull trout occurred at locations where fish were captured. PIT-tag detections at PIAs were considered resights of marked fish. Recapture and resight data are collectively referred to as resight observations. Resight observation data were compiled to summarize how many bull trout marked in each year were resighted in subsequent years after marking. Summaries of the number of bull trout marked in each tributary and resighted at specific observation sites throughout the Walla Walla Subbasin are also presented.

Table A4.1. Location of passive in-stream antennas (PIA) located in the Walla Walla River Subbasin. River kilometer represents the distance upstream from the mouth of the Columbia to the site. Dates of operation are general, and do not include temporary periods when sites were not in operation due to mechanical failures.

PIA site code	PIA site name	Stream	River km	Dates of operation
BGM	Burlingame diversion dam	Walla Walla River	61.0	2007-present
KCB	Kiwanis camp bridge	Mill Creek	89.0	2005-2011
LWD	Lowden diversion dam	Walla Walla River	51.0	2007-present
MCD	Bennington diversion dam	Mill Creek	74.0	2005-present
NBA	Nursery bridge dam	Walla Walla River	74.0	2003-present
ORB	Oasis road bridge	Walla Walla River	10.0	2005-present
RSB	Roosevelt street bridge	Mill Creek	70.0	2010-2011
SKIP	Skiphorton Creek	tributary to SFWW	113.0	2008-2009 (Jun-Sept)
WW1	Harris park bridge	SFWW	97.0	2002-present
WW2	below Bear Creek	SFWW	106.0	2002-present
YHC	Yellowhawk at headgate	Yellowhawk Creek	78.0	2006-present

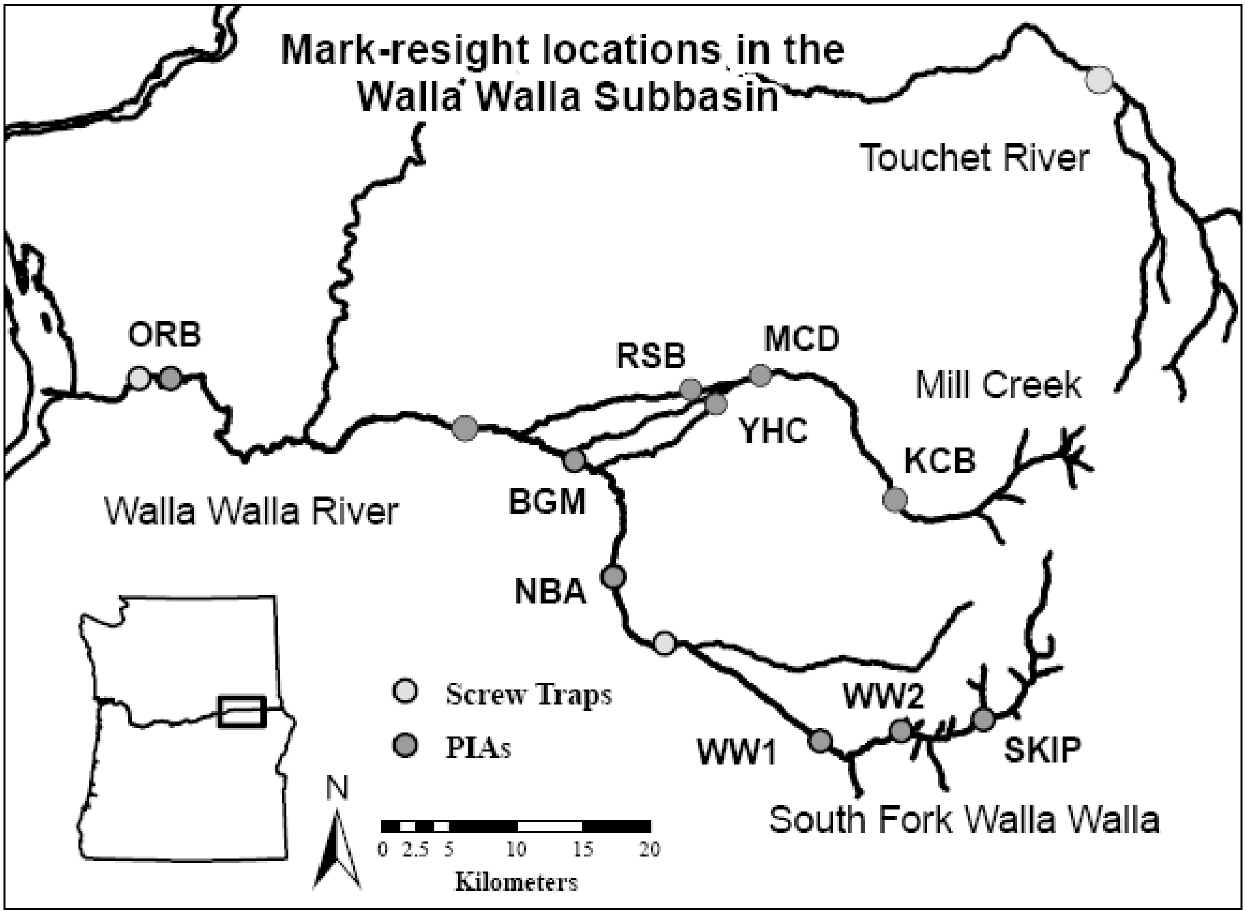


Figure A4.1 Map of Walla Walla River subbasin showing the primary capture areas and resight locations at passive in-stream antennas (PIAs). Site abbreviations are defined in Table A4.1.

Table A4.2. Counts of bull trout marked in the South Fork Walla Walla River, Oregon, 2002 - 2011, and resighted per year at a PIA anywhere in the Walla Walla River subbasin. Detections are unique per fish per year (i.e., a fish was counted as a resight only once in a year, even if it was detected at multiple PIAs within that year).

		Resights per year										
Tag year	**Total tagged**	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
2002	211	19	33	20	8	1	2	1	0	0	0	84
2003	522		86	70	23	18	5	2	0	0	0	204
2004	412			65	31	14	6	2	1	0	0	119
2005	426				30	44	13	7	4	3	3	104
2006	224					47	34	7	3	1	0	92
2007	485						19	37	20	7	2	85
2008	597							45	59	42	6	152
2009	847								67	207	25	299
2010	580									79	35	114
2011	452										19	19
Total	4756	19	119	155	92	124	79	101	154	339	90	1272

Table A4.3. Counts of bull trout marked anywhere in the mainstem Walla Walla River, Oregon, 2004-2011, and resighted per year at a passive in-stream antenna (PIA) anywhere in the Walla Walla River system (including the South Fork Walla Walla River). Detections are unique per fish per year (i.e., a fish was counted as a resight only once in a year, even if it was detected at multiple PIAs within that year).

		Resights per year								
Tag year	**Total tagged**	2004	2005	2006	2007	2008	2009	2010	2011	Total
2004	9	0	2	1	1	1	1	1	1	8
2005	7		3	1	0	0	0	0	0	4
2006	13			4	0	0	0	0	0	4
2007	95				41	18	6	5	2	72
2008	246					152	40	10	7	209
2009	167						73	42	18	133
2010	253							116	56	172
2011	139								76	76
Total	929	0	5	6	42	171	120	174	160	678

Table A4.4. Counts of bull trout marked by Utah State University in the South Fork Walla Walla River, Oregon, 2002 - 2011, and resighted at passive in-stream antennas or recaptured (active capture) at various locations throughout the Walla Walla Subbasin. Detections are unique per site per year (i.e., a fish was counted only once per site in each year, but the same individual fish would have been counted if it was detected at different locations in that year). The total number of fish marked per year is given in the first row. Resight/recapture locations are grouped by stream. Site abbreviations are given in Table A4.1. Dashes represent years when data could not be collected because the site was not in operation.

		Bull trout tagged in South Fork Walla Walla River									
	Year =	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Total tagged in SFWW =	211	522	412	426	224	485	597	847	580	452
	Resight location	**Number resighted or recaptured**									
South Fork Walla Walla River	SKIP	--	--	--	--	--	--	21	30	--	--
	WW1	11	43	70	53	61	46	43	52	141	43
	WW2	11	105	130	53	102	63	58	93	277	26
	SFWW active	3	28	23	25	10	9	5	15	21	18
Mainstem Walla Walla River	BGM	--	--	--	--	--	7	8	3	18	17
	LWD	--	--	--	--	--	0	1	0	1	0
	NBA	--	0	3	11	16	10	9	16	48	31
	ORB	--	--	--	0	0	0	1	0	5	4
	WW active	--	--	0	0	0	1	2	2	17	13
Mill Creek	MCD	--	--	--	0	0	0	0	0	0	0
	KCB	--	--	--	0	0	0	0	0	0	0
	RSB	--	--	--	--	--	--	--	--	0	0
	MILL active	0	0	0	0	0	0	0	0	0	0
Yellow-hawk	YHC	--	--	--	--	0	0	0	1	0	1
Touchet	TOUCHET active	0	0	0	0	0	0	0	0	0	0
Columbia River	MC1/MCJ/PRA	0	0	0	0	0	0	0	0	0	0

Table A4.5. Counts of bull trout marked by USFWS and CTUIR in the mainstem Walla Walla River, Oregon and Washington, 2004-2011, and resighted at passive in-stream antennas or recaptured (active capture) at various locations throughout the Walla Walla Subbasin. Detections are unique per site per year (i.e., a fish was counted only once per site in each year, but the same individual fish would have been counted if it was detected at different locations in that year). The total number of fish marked per year is given in the first row. Resight/recapture locations are grouped by stream. Site abbreviations are given in Table A4.1. Dashes represent years when data could not be collected because the site was not in operation.

		Bull trout tagged in the mainstem Walla Walla River							
	Year =	2004	2005	2006	2007	2008	2009	2010	2011
	Total tagged mainstem WW =	9	7	13	95	246	167	253	139
	Resight location	**Number resighted or recaptured**							
South Fork Walla Walla River	SKIP	--	--	--	--	1	0	--	--
	WW1	0	3	2	4	12	24	33	53
	WW2	0	2	2	4	10	18	31	19
	SFWW active	0	0	0	0	0	1	1	0
Mainstem Walla Walla River	BGM	--	--	--	22	96	59	88	83
	LWD	--	--	--	0	2	6	9	14
	NBA	0	2	4	21	115	94	130	102
	ORB	--	0	0	4	7	9	19	25
	WW active	0	0	0	4	37	28	44	37
Mill Creek	MCD	--	0	0	0	0	0	0	0
	KCB	--	0	0	0	0	0	0	0
	RSB	--	--	--	--	--	--	0	0
	MILL active	0	0	0	0	0	0	0	0
Yellow-hawk	YHC	--	--	0	0	0	0	0	0
Touchet	TOUCHET active	0	0	0	0	0	0	0	0
Columbia River	Columbia River	0	0	0	0	0	3	0	0

Table A4.6. Counts of bull trout marked by USFWS and USFS in Mill Creek, Washington, 2002-2011, and resighted at passive in-stream antennas or recaptured (active capture) at various locations throughout the Walla Walla Subbasin. (Fish were marked in Mill Creek beginning in 1998, but only data from 2002 are reported here). Detections are unique per site per year (i.e., a fish was counted only once per site in each year, but the same individual fish would have been counted if it was detected at different locations in that year). The total number of fish marked per year is given in the first row. Resight/recapture locations are grouped by stream. Site abbreviations are given in Table A4.1. Dashes represent years when data could not be collected because the site was not in operation.

		Bull trout tagged in Mill Creek									
	Year =	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Total tagged Mill Creek =	116	67	68	618	1248	1056	868	364	401	7
	Resight location	**Number resighted or recaptured**									
South Fork Walla Walla River	SKIP	--	--	--	--	--	--	1	0	--	--
	WW1	0	0	0	0	0	0	1	0	1	0
	WW2	0	0	0	0	0	0	1	0	1	0
	SFWW active	0	0	0	0	0	0	0	0	0	0
Mainstem Walla Walla River	BGM	--	--	--	--	--	9	11	3	9	1
	LWD	--	--	--	--	--	0	1	1	0	0
	NBA	--	0	0	0	0	0	5	1	1	0
	ORB	--	--	--	0	0	2	0	0	4	0
	WW active	--	--	0	0	0	0	3	0	1	0
Mill Creek	KCB	--	--	--	165	523	377	572	194	246	7
	MCD	--	--	--	25	57	63	136	68	61	22
	RSB	--	--	--	--	--	--	--	--	1	0
	MILL active	98	100	81	76	31	62	52	63	57	10
Yellow-hawk	YHC	--	--	--	--	1	32	42	11	29	2
Touchet	TOUCHET active	0	0	0	0	0	0	0	1	0	0
Columbia River	Columbia River	0	0	0	0	0	0	0	0	0	0

Table A4.7. Counts of bull trout marked by WDFW in the Touchet River and tributaries, Washington, 2002-2011, and resighted at passive in-stream antennas or recaptured (active capture) at various locations throughout the Walla Walla Subbasin. Fish were marked in the Touchet River watershed beginning in 2001, but only data from 2002 are reported here. Detections are unique per site per year (i.e., a fish was counted only once per site in each year, but the same individual fish would have been counted if it was detected at different locations in that year). The total number of fish marked per year is given in the first row. Resight/recapture locations are grouped by stream. Site abbreviations are given in Table A4.1. Dashes represent years when data could not be collected because the site was not in operation.

		Bull trout tagged in Touchet River and tributaries									
	Year =	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total tagged Touchet =		11	41	55	41	37	28	114	130	115	73
	Resight location	**Number resighted or recaptured**									
South Fork Walla Walla River	SKIP	--	--	--	--	--	--	0	0	--	--
	WW1	0	0	0	0	0	0	0	0	0	0
	WW2	0	0	0	0	0	0	0	0	0	0
	SFWW active	0	0	0	0	0	0	0	0	0	0
Mainstem Walla Walla River	BGM	--	--	--	--	--	0	0	0	0	1
	LWD	--	--	--	--	--	0	0	0	0	0
	NBA	--	0	0	0	0	0	0	0	0	0
	ORB	--	--	--	0	0	0	0	0	0	0
	WW active	--	--	0	0	0	0	0	0	0	1
Mill Creek	KCB	--	--	--	0	0	0	0	0	0	0
	MCD	--	--	--	0	0	0	0	0	0	1
	RSB	--	--	--	--	--	--	--	--	0	0
	MILL active	0	0	0	0	0	0	0	0	0	0
Yellow-hawk	YHC	--	--	--	--	0	0	0	0	0	1
Touchet	TOUCHET active	2	1	8	7	14	13	5	19	27	40
Columbia River	Columbia River	0	0	0	0	0	0	0	0	0	0

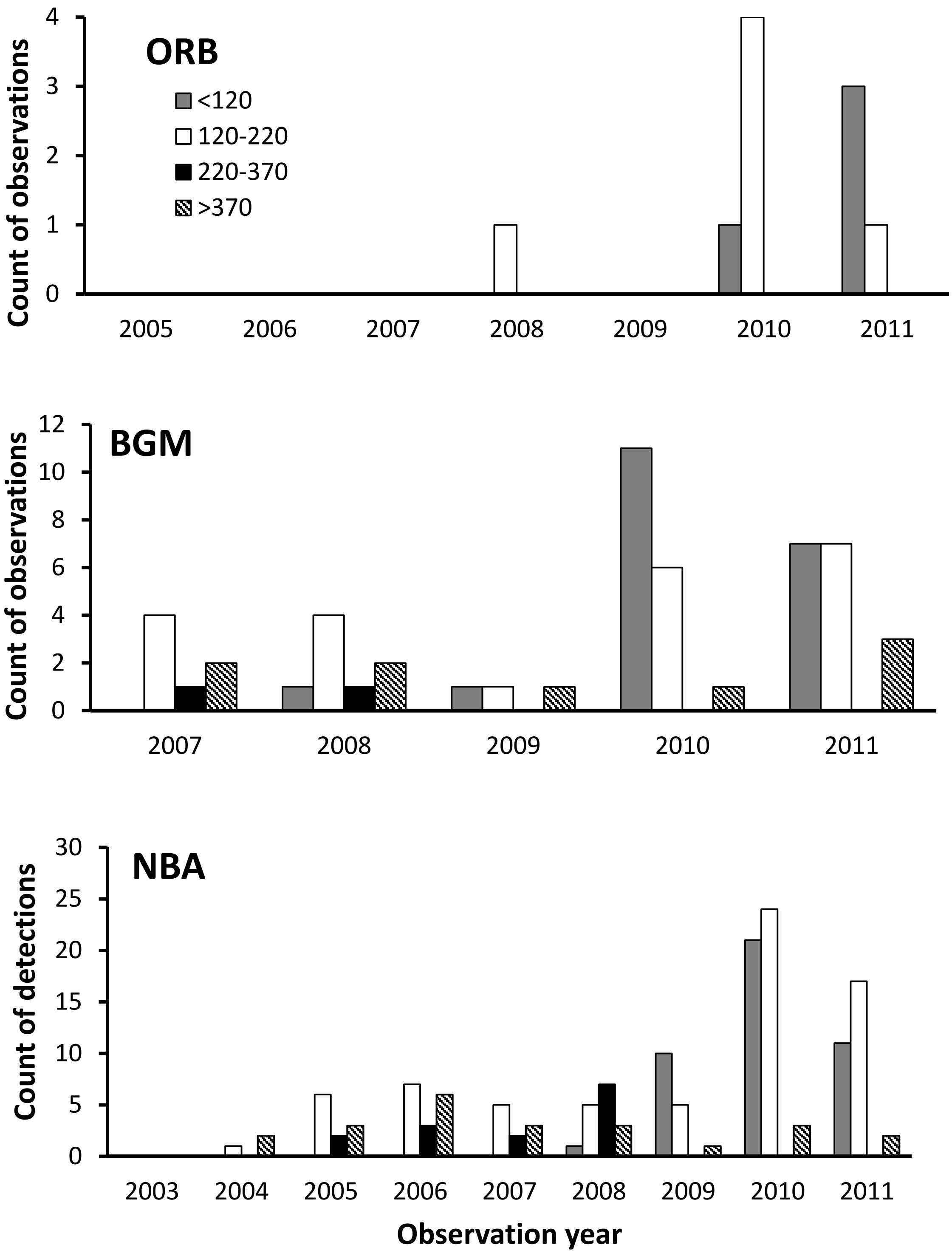


Figure A4.2. Number of individual bull trout detected per year at each of three passive in-stream antenna sites on the Walla Walla River, in Oregon and Washington: Oasis road bridge (ORB), Burlingame diversion (BGM), and Nursery bridge (NBA). Size classes (in mm TL) represent the size of each fish at the time of initial tagging. Observations are unique per individual fish per year. Note changes in axis scales.

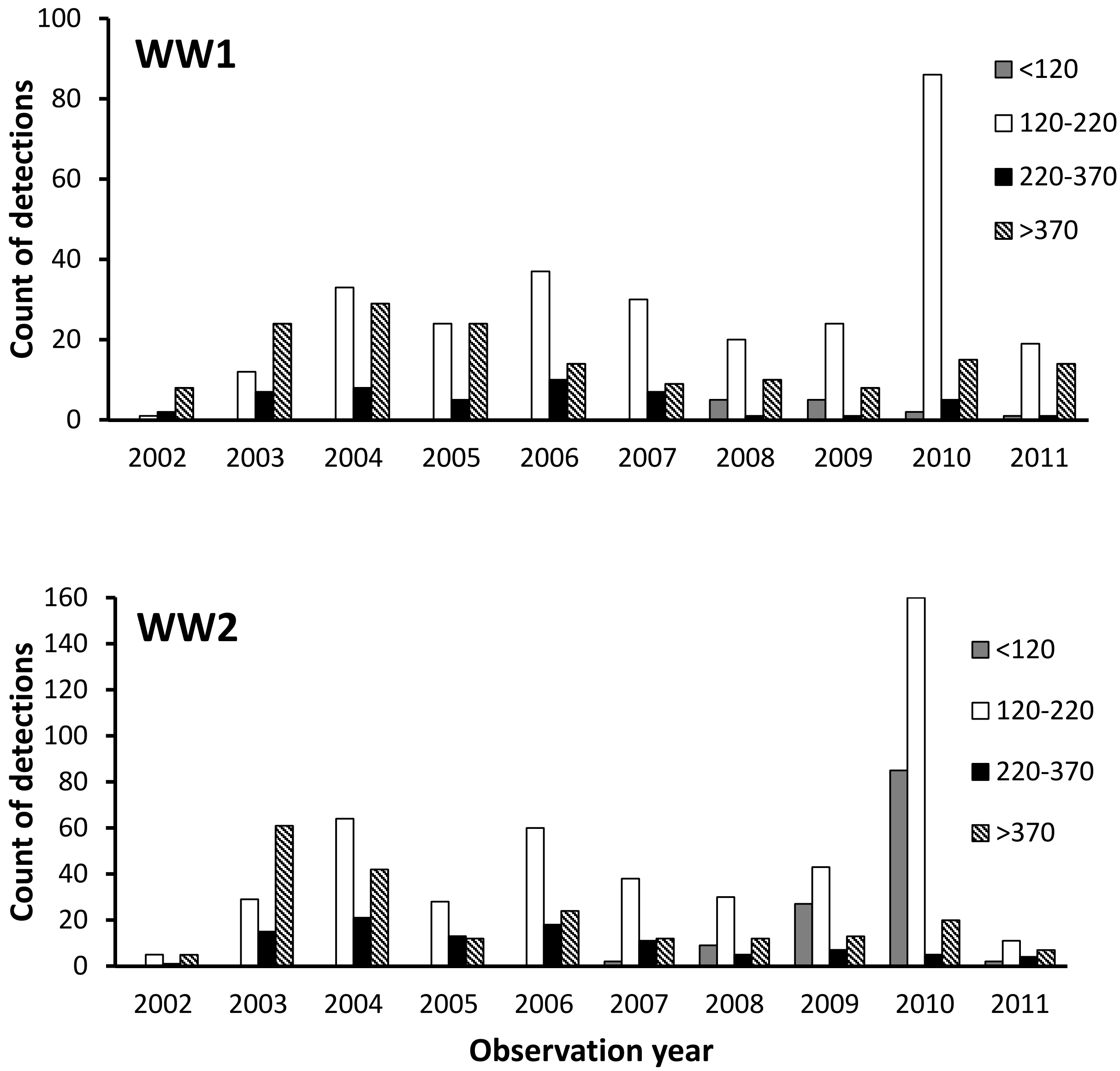


Figure A4.3. Number of individual bull trout detected per year (2002 – 2011) at each of two passive in-stream antenna (PIA) sites in the South Fork Walla Walla River, Oregon: Harris Park bridge (WW1) and Bear Creek (WW2). Size classes (in mm TL) represent the size of each fish at the time of initial tagging. Observations are unique per individual fish per year. Note changes in y-axis scales.