

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

Annual Progress Report for 2007

by

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EXECUTIVE SUMMARY

Within the overall framework of conservation and recovery planning for threatened bull trout, we provide critical 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). We provide a template against which different strategies for monitoring and evaluation can be evaluated in terms of accuracy, precision, cost/effort, and limiting factors. Our goal is to provide the data and conservation assessment tools to aid in the efforts of the US Fish and Wildlife Service, to determine the necessary courses of action and management actions for recovery of bull trout populations throughout this as well as other provinces. The project was initiated in 2002 and has continued through 2008, with plans to continue work through 2009. To meet our goals, we have developed and implemented each year, a comprehensive mark-recapture program including two tag types, multiple capture techniques (both passive and active) and systematic sampling of two large study areas (South Fork Walla Walla and North Fork Umatilla) with a high degree of effort.

The efforts of this project have been part of a completed PhD dissertation (Al-Chokhachy 2006) and master's thesis (Homel 2007) and are currently part of an ongoing PhD dissertation (Bowerman, *In prep*) 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 and 2007) 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. *in press*; Al-Chokhachy and Budy *in press*; Al-Chokhachy et al. *in review*.

2007

In 2007, we sampled 22 reaches (~29% of the study site). Over the summer, a total of 331 bull trout were captured of which, 221 were tagged with PIT tags and 137 of those were tagged with floy tags. In 2007, as in years since 2003, most bull trout were tagged upstream of Burnt Cabin Creek; the smallest bull trout captured was 40 mm and the largest bull trout caught was 561 mm. We observed an increase in condition of large bull trout (>370 mm) from 2006, and there appears to be a trend of increasing condition since 2005 estimates. We found no significant changes in growth rates in the SFWW from 2006, and growth rates in the SFWW generally continued to be greater than in the NFUM. Over a 6-year period, the average abundance of all bull trout > 120 mm ranged from 7,287 (95% CI = 6,243 – 8,895) in 2002 up to 10,600 (95% CI = 8,080 – 16,598) in 2006, with 2007 estimated at 9976 (95% CI = 5950 -17851). Based

on the population growth rates (λ) calculated from these population estimates, it appears that both the SFWW ($\lambda=1.07$ 95% CI = 0.98 – 1.17) and the NFUM ($\lambda= 0.98$ 95% CI = 0.69 – 1.38) populations are stable; however, the 95% confidence intervals are wide and overlap 1 and thus limit current conclusions about trend with certainty.

Monitoring and evaluation of bull trout populations in the South Fork Walla Walla and North Fork Umatilla Rivers, Oregon

INTRODUCTION

When species are in decline or listed under conservation status across a large spatial area, estimates of population abundance and trend are critical for understanding the present and future status of the population (Soule 1987). In addition, the quantification of key demographic parameters (e.g., survival, growth) across age classes and life-history forms is an important part of the process of identifying factors that potentially limit the population, evaluating the importance of vital rates on overall trend, and ultimately directing future recovery and restoration activities. However, for many protected species, estimation of population abundance and demographic parameters is extremely difficult due to (1) their protected status, which limits estimation techniques that may be applied legally, (2) low numbers, (3) high variability, (4) the differential effects of environmental stochasticity at low abundance, (5) the immediate, short-term need for information that typically requires years to collect, and (6) logistical limitations in agency personnel time and/or funding. Nevertheless, population structure (including genetics), abundance, trend, and demographic characteristics are key components required for the recovery planning of any species.

In 1998, bull trout (*Salvelinus confluentus*) were officially listed as a Threatened Species under the 1973 Endangered Species Act (USFWS 1998). Bull trout are native to the northwestern United States and western Canada and are primarily an inland species which were once distributed from the McCloud River in California and the Jarbridge River in Nevada to the headwaters of the Yukon River in Northwest Territories (Cavender 1978). Today, however, bull trout exist only as subpopulations over a wide range of their former distribution (Rieman et al. 1997); bull trout are now considered extinct in the McCloud River system (Rode 1988) and other local extirpations have been documented (Goetz 1989). Throughout much of the species' range, resident and migratory populations occur and can coexist, representing a diverse population structure which may require a range of habitats (Goetz 1991; Rieman and McIntyre 1993). Habitat degradation (Fraley and Shepard 1989), barriers to migration (Rieman and McIntyre 1995; Kershner 1997), and the introduction of nonnatives (Leary et al. 1993) have all contributed to the decline in bull trout populations in the Columbia and Klamath River Basins. Bull trout populations may be further impacted by environmental

changes such as competition with introduced species (McMahon et al. 2007) and climate warming (Rieman et al. 2007).

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 ensure the long-term persistence of self-sustaining, complex interacting groups of bull trout distributed across the species's native range (Lohr et al. 1999). To meet this overall 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. Furthermore, the USFWS recovery-planning document (Lohr et al. 1999) embraces the idea of core areas. Conserving respective core areas within conservation units is intended to preserve genotypic and phenotypic diversity and allow bull trout access to diverse 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 (Whitesel et al. 2004).

Despite our growing body of knowledge on bull trout (see Budy et al. 2003, 2004, 2005, and 2006 for populations addressed in this document), there are still critical gaps in our information that potentially limit our ability to effectively manage bull trout and ensure their continued persistence (Porter and Marmorek 2005). These gaps include basic biological and demographic information for bull trout, detailed population assessment data (e.g., abundance, trend) for all but a few populations, life-history-specific information (e.g., migration timing and contributions of migratory versus resident fish), as well as the relative role of biotic interactions (e.g., competition with non-natives, food availability and declining salmonid populations). Within the overall framework of conservation and recovery planning for threatened bull trout, our research provides critical information on bull trout population abundance, trends in abundance, vital rates, robust evaluations of different monitoring techniques, 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 (age, life history, and tissue for genetic information), and the role of declining salmon in the parallel decline of bull trout. Most recently, we have added age-1 fish to our ongoing population evaluation and monitoring. Recent research suggests that population

growth may be limited by early life stage survival and demonstrates the need for further studies that examine factors affecting population dynamics at specific life stages (Al-Chokhachy 2006; Johnston et al. 2007).

We provide a template against which different strategies for monitoring and evaluation can be evaluated in terms of accuracy, precision, and cost per effort. 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 this and other provinces; preliminary data from 2002 - 2006 are currently being used by the USFWS Bull Trout Recovery, Monitoring, and Evaluation Technical Group (RMEG).

The South Fork Walla Walla River was initially selected as the comprehensive study area due to its abundance of both resident and migratory fish, complex water management issues associated with fish protection, and a diversity of habitat types. Expansion of research into multiple additional watersheds has allowed for comparisons of critical population-level metrics (e.g., population structure) across ecosystems and varying levels of bull trout abundance. To date, our work includes six years of population monitoring data (2002 - 2007) from one intensively monitored stream, as well as smaller-scale continuous population assessments for an additional system, the North Fork Umatilla River. Monitoring data in several streams allows us to investigate population trends and other key questions in greater detail and across a range of biotic and abiotic conditions.

STUDY AREAS

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 km² (Walla Walla Subbasin Summary Draft 2001). The tributaries of the Walla Walla River originate in the Blue Mountains at elevations near 1800 m. The mainstem Walla Walla flows for approximately 16 km in Oregon before splitting into the NF Walla Walla and the SF Walla Walla rivers.

The Walla Walla River historically contained a number of anadromous and resident, native salmonid populations including: spring and fall Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and coho salmon (*O.*

kisutch), redband trout (*O. mykiss* subpopulation), bull trout, mountain whitefish (*Prosopium williamsoni*), and summer steelhead (*O. mykiss*; the extent of fall Chinook, chum, and coho salmon 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 in the SF Walla Walla River by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). Populations of native redband trout, bull trout, mountain whitefish, sculpin (*Cottus* spp.), and dace (*Rhinichthys* spp.) still persist in the Walla Walla River, as well as introduced brown trout (*Salmo trutta*).

Little documentation exists on the historical distribution of bull trout in the Walla Walla Subbasin prior to 1990. Anecdotal evidence suggests that large fluvial bull trout were found to utilize the Columbia River. Telemetry studies in the mid-Columbia River region have shown bull trout have 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 populations spawn in the tributaries and headwaters of the Walla Walla River. However, recent telemetry studies with large (> 350 mm) bull trout have not confirmed use of the Columbia River (Mahoney 2001, 2002).

Within the Walla Walla River Basin, bull trout are arbitrarily divided into four populations based on geography: North Fork Walla Walla River, South Fork Walla Walla River, Mill Creek, and the Touchet River (Buchanan et al. 1997). Ratliff and Howell (1992) described the population status of bull trout as “low risk” in the SF Walla Walla River and Mill Creek, and “of special concern” in the NF Walla Walla River. Since that report, the status of the SF Walla Walla population has remained at low risk, but both the NF Walla Walla River and Mill Creek populations have been upgraded to “high risk” and “of special concern” respectively (Buchanan et al. 1997). Alterations to migratory corridors linking these populations have occurred, but the degree of genetic, geographical isolation is unknown.

The study site on the SF Walla Walla River spans nearly 21 km in length. The upper boundary was set at the confluence with Reser Creek (Reach 103), and the lower boundary was set above Harris Park Bridge (on public, county land; Budy et al. 2003, 2004, 2005). In order to account for spatial variation of the

study site and the distribution of bull trout, the study site was divided into 102 reaches, 200-m each, using Maptech mapping software (Figure 1).

An initial site was randomly selected from the list of reaches, and thereafter every fifth reach (an approximate 20% sample rate) was systematically designated for sampling in 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 mark. Total length was recorded for each reach. Location coordinates (UTM using GPS) were recorded at the boundaries of each reach.

North Fork Umatilla River

The Umatilla River Basin drains an area of approximately 6,592 km². The Umatilla River is 143 km long from mouth (at Columbia River RK 440) to where it divides into the NF and SF Umatilla rivers, each fork adding another 16 km in length. The Umatilla mainstem originates in Blue Mountains at 1289 m and descends to 82 m at confluence with Columbia River. Earliest documentation of bull trout in Umatilla basin is from ODFW creel reports dating from 1963. The mainstem Umatilla River is artificially confined for much of its length. Spawning occurs in the NF and SF Umatilla rivers, and in NF Meacham Creek. Along with being an important tributary for rearing and migration activities, redd counts indicate that the majority of redds in the Umatilla basin occur in the NF Umatilla River between Coyote and Woodward creeks. Peak spawning generally occurs between mid September and mid October over at least a two-month period (ODFW 1995, 1996) when daily average water temperatures ranged from 6-10 °C (ODFW 1996). Habitat in the NF Umatilla River is fairly complex with low levels of bedload movement, moderate levels of large organic debris, and relatively minimal flow events. Other species occurring in the basin include *O. mykiss* subspecies, sculpin (*Cottus* spp.), Chinook salmon, shiners (*Richardsonius balteatus*), suckers (*Catostomus* spp.), dace (likely *Rhinichthys* spp.), and northern pikeminnow (*Ptychocheilus oregonensis*). Two populations were recognized in the Umatilla basin: the NF Umatilla River rated “Of Special Concern” and the SF Umatilla River rated at “High Risk” (Buchanan et al. 1997).

The study site on the NF Umatilla River spans nearly 8 km in length. The upper boundary was set at the confluence of Johnson, Woodward, and Upper NF Umatilla creeks (416053 E, 5065070 N), and the lower boundary was set at the confluence of NF and SF Umatilla rivers (110407763 E, 5064070 N). In order to account for spatial variation of the study site and the distribution of bull trout, the

study site was divided into 41 reaches, approximately 200-m each, using Maptech mapping software (Figure 2).

An initial site was randomly selected from the list of reaches, and thereafter every fifth reach (an approximate 20% sample rate) was systematically designated for sampling in 2003. 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 mark. Total length was recorded for each reach. Location coordinates (UTM using GPS) were recorded at the boundaries of each reach.

METHODS

Size Designations

Since the onset of the bull trout population assessment in northeastern Oregon in 2002 and in any bull trout publications and reports published by the USGS Utah Cooperative Fish and Wildlife Research Unit at Utah State University, the following size designations for bull trout have been used. Bull trout smaller than 220 mm represent juvenile, not sexually mature fish (Al-Chokhachy 2006), and bull trout 220 mm or larger represent both resident and migratory sexually mature fish (Al-Chokhachy et al. 2005, Al-Chokhachy and Budy 2007). The >220 mm cutoff for sexually mature adults is a conservative estimate as we have found smaller adults in our study sites and smaller resident adult bull trout have been found in other systems (Washington Department of Wildlife 2000). Further size categories are used for population growth rate estimates and survival estimates where both PIT and T-bar anchor tags (Floy tags) are used for mark recapture events. Small bull trout are 120-220 mm, small adults are 220-370 mm, and large adults are >370 mm. The 120 mm cutoff was chosen as a safe size for inserting Floy tags and 23 mm PIT tags. The >370 mm category is used as a means to monitor migratory fish. This size cutoff was based on research by Rieman et al. (1993) and research performed at Flathead Lake (Shephard 1989). We do know, however that not all bull trout >370 mm are migratory (particularly in fluvial systems) but, there is a presumption that larger fish are migratory.

Fish Sampling

Capture.—We used multiple sampling techniques to capture bull trout including angling, and electroshocking down to a seine. All captured bull trout were weighed (nearest 0.1 g), measured (nearest mm total length, TL), and condition

(K_{TL}) was calculated (Fulton's $K_{TL} = W / L^3 * 100,000$). Scales were taken from a subsample of live, released fish. A small subsample of adults was taken in the SFWW for fecundity and sex ratio estimates. We also obtained information from mortalities (non-project related) found in each stream. From these subsamples, stomachs and hard parts (e.g., otoliths) were removed for age, growth, and diet analyses.

Marking.—In all study streams, bull trout (> 120 mm TL) were marked with unique PIT tags and T-bar anchor tags (Floy tags), and subsequently recaptured using a combination of passive in-stream PIT-tag antennae (hereafter detector; see below) and snorkeling resights. In 2007 we marked smaller bull trout (> 70 mm TL) in the SFWW stream with unique PIT tags. Prior to tagging, bull trout were anesthetized until they exhibited little response to stimuli. An 8-, 12- or 23-mm PIT tag was then placed into a small surgical incision on the ventral side of the fish, anterior to the pelvic fins. No sutures were required for closure of the incision. In addition, an external T-bar anchor tag, unique to year and stream, was inserted adjacent to the dorsal fin in bull trout (>120 mm TL). After surgery, scales were taken from the right side at the base of the dorsal fin for aging and growth information and in the SFWW adipose fins from bull trout (70-119mm) were removed for identification and genetic analyses. All 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.

Resighting.—To resight Floy-tagged fish, we conducted daytime bull trout snorkel surveys in 22 reaches (mean reach length = 244 m) of the SFWW, and 16 reaches (mean = 212 m) of the NFUM. To avoid double-counting fish, snorkeling surveys started at the highest reaches working downstream to the bottom of the study site, because many fish were migrating to the headwaters for spawning. This approach likely minimized the incidence of double counts. Water temperature, start, and end times were all recorded for each snorkeling session. All bull trout (tagged and untagged), *O. mykiss* spp., and mountain whitefish were enumerated and placed into 50-mm size classes, and all juvenile Chinook salmon were enumerated but not delineated by size. Accurate identification of fish species and size estimation was emphasized. In each channel unit snorkeled, two observers proceeded in an upstream direction while scanning for fish across their assigned lane, such that the entire channel was surveyed.

Recapture.—We recaptured previously tagged bull trout (2002 – current) using a combination of techniques including: electroshocking down to a seine, angling,

trap netting, and pass-through PIT-tag technology described below. All actively captured bull trout were passed over a handheld PIT-tag reader and checked for anchor tags from previous years. When recaptured, all bull trout were weighed and measured for estimates of annual growth, and we recorded information regarding location of recapture. Recapture events also provided critical information for estimates of bull trout survival, annual population estimates, and to parameterize the Pradel mark and recapture model.

Passive fish detection.—PIT-tag detectors were installed in-stream and continuously collect information on tagged bull trout from two locations within the SFWW. One detector is located at Harris Park Bridge (UTM coordinates: 110408261 E, 5076370 N) at the bottom of the study site, and the second detector is located just above the confluence with Bear Creek (approximately 7 km upstream; UTM coordinates: 110414281 E, 5077108 N). The Harris Park Bridge detector (WW1) has been running since mid-September 2002, and the Bear Creek detector (WW2) has been operational since mid-October 2002. Further as an extension of this project, detectors are located downstream at Nursery bridge, Burlingame diversion, and Oasis Bridge on the Walla Walla river. Having more detectors further downstream on the SFWW and on other rivers allows us to monitor fish migrations and connectivity within the Walla Walla basin. All detectors are linked either through phone or satellite, and data is uploaded to the PTAGIS website (www.psmfc.org/pittag/Data_and_Reports/index.html > under "Small-scale Interrogation Site Detections -Query").

The lone NFUM detector (UM1) is located on US Forest Service land under a road bridge (UTM coordinates: 110407659 E, 5064089 N) near the confluence with the South Fork Umatilla River. The detector has been collecting data since autumn 2004. Another detector (UM 2) has subsequently been installed on the main stem Umatilla River approximately 9 miles downstream of UM 1.

Growth

Growth information was obtained from bull trout previously tagged in the SFWW (2002-2006), and NFUM (2003-2006), and recaptured during the 2007 summer field season. Length and weight gains were determined between initial tagging and subsequent capture events. These length and weight gains were evaluated based on annual growth, and delineated by size class at initial tagging.

Population Estimates

We used snorkeling and tagging data to parameterize mark-resight population estimates using a Lincoln-Petersen bias-adjusted estimator (Chapman 1951), and estimated the overall population size for three size groupings of bull trout: > 120 mm, > 220 mm, and > 370 mm. We estimated the standardized population sizes for each reach using tagging and snorkeling data for each individual reach, calculated the average number of bull trout per 200 m across reaches, and multiplied this average by the total number of reaches in the site. To standardize the number of bull trout per 200 m for each reach, we divided each reach estimate by the actual reach length and multiplied this estimate by 200.

Population Growth Rate

Obtaining reliable estimates of population trend, to determine whether the population is increasing or decreasing is a particularly challenging task that requires several years of data. For this report we estimated population trend based on population estimates from the SFWW mark-resight data (2002-2007), SFWW redd count data (1994-2007) and the NFUM mark-resight data (2003-2007), via linear regression of log transformed annual changes in population growth rate (λ) as a function of time step (Budy et al 2007; Morris and Doak 2002).

Survival

SFWW.—In the SFWW, we estimated survival using the Barker model (e.g., Buzby and Deegan 2004) with five years of mark-recapture data (2002-2006). The Barker model is an open mark-recapture model, which similar to the Cormack-Jolly-Seber, incorporates the number of marked and recaptured fish in sampling events (June – August); however, the Barker model also incorporates recapture events that may occur between annual sampling events (e.g., detected at PIT-tag detectors).

We incorporated average growth rates into the analyses, which we calculated from individual recapture data, to create a stage-based model with four life stages representing 120 -170, 170 - 220, 220 - 270, 270 - 320, 320 -370, and > 370 mm size classes. Survival estimates and recapture probabilities were calculated using Program MARK software.

NFUM.—In the NFUM, where we have a significantly smaller sample size of marked and recaptured bull trout, we used four years of mark-recapture data (2003 – 2006) to estimate survival with a Cormack-Jolly-Seber (CJS) model. The CJS model is a simpler model than the Barker model, and does not require large sample sizes. Since the majority of fish captured in the NFUM are typically 120-170 mm, we did not delineate the NFUM into different size categories. Survival estimates and recapture probabilities were calculated using Program MARK software.

Diet Analysis

Stomach content collection and analysis.— The stomach content from ten sacrificed bull trout were used for diet analysis. All stomachs were preserved in 95% ethanol for further prey identification in our laboratory. We identified aquatic macroinvertebrates found in bull trout stomachs to order, and all fish prey to the species level. Prey fish were counted and weighed (blot-dry wet weights to nearest 0.001 g), while macroinvertebrate prey were weighed *en masse* by classification. Intact prey fish were measured to the nearest mm (backbone and standard length). Unidentified fish prey were apportioned into identified prey categories based on a weighted average of identified fish prey.

Fecundity

Each year (2002-2007) we sacrificed up to ten individual bull trout to evaluate age and length at sexual maturity, and to estimate a bull trout length-fecundity relationship for SFWW river population. We collected fish across all size classes (except age-0) during the first week of August to maximize egg development in females. We enumerated all eggs from mature females.

Temperature

We measured in-stream temperature every 90 minutes using temperature loggers at two sites in the SFWW (below Skiphorton Creek and below Bear Creek), and one site in the NFUM (Campground). We summarized temperature as daily maximum, average, and minimum for ease of assessment.

Movement

We measured bull trout movement patterns in the SFWW and NFUM using mark-recapture data and passive instream detectors. Movement information for the SFWW has been previously described in Budy et al. 2006 and for the NFUM in

Budy et al. 2007. Movement information is summarized in greater detail in the 2007 CRFPO bull trout status update (Anglin et al. 2008) and by Homel and Budy (in press).

RESULTS and DISCUSSION

Fish Sampling

We weighed (to the nearest 0.1 g) and measured (TL to the nearest mm) all captured bull trout. A separate length-weight relationship was calculated for each stream in each year based on all measured bull trout (Figures 3 and 4).

South Fork Walla Walla River

We sampled 22 reaches during the 2007 field season, which accounted for approximately 29% of the study site. Over the summer, a total of 331 bull trout were captured of which, 221 were tagged with PIT tags and 137 of those were tagged with floy tags. The number of tagged fish varied by sample reach (1 – 15 per reach; Figure 5). In 2007, as in years since 2003, most bull trout were tagged upstream of Burnt Cabin Creek (Figure 5). In 2007, the smallest bull trout captured was 40 mm (0.7 g) and the largest bull trout caught was 561 mm (1848.9 g). Length-frequency distributions of captured bull trout in the SFWW have varied little from 2002 through 2007, with most captured fish in the 100 – 150 mm size range (Figure 6). More large (> 400 mm) bull trout were captured in the SFWW compared to the NFUM (Figures 6 and 7).

Condition.—Condition (Fulton's K) of bull trout captured in the SFWW varied by size class and year. In 2007, we found a decrease in condition of juvenile (<120 mm) bull trout from 2006 estimates but still higher than 2005 estimates (Figure 8). We observed a large increase in condition large bull trout (>370 mm) from 2006 and there appears to be a trend of increasing condition since 2005 estimates (Figure 8). Juveniles and small adults (120-370 mm) exhibited similar condition as years 2004-2006 but there does appear to be a decreasing trend (Figure 8). When all size classes are combined, it appears that average condition in 2007 (Mean = 0.87 \pm 1 SE = 0.86 – 0.88) has decreased from 2006 values, and is more similar to overall condition values for 2004 and 2005 (Figure 9). Overall condition in the SFWW in 2007 was lower than values in the NFUM. Average condition for these populations was lower than that exhibited by Metolius River (Deschutes River basin, Oregon) adfluvial bull trout (mean K_{TL}

range: 1.02 – 1.65; Thiesfeld et al. 1999) and bull trout from southeast Washington (K_{FL} range: 1.00 – 1.23; Underwood et al. 1995).

Snorkel surveys.— We performed snorkeling surveys in 22 reaches in the SFWW in 2007. Unlike previous years, where more bull trout were observed in the study reaches upstream of Burnt Cabin Creek, in 2007 bull trout appeared to be more uniformly distributed across all study reaches (Figure 10) and numbers of fish observed during snorkel counts was substantially lower than previous years (Figure 10; Budy et al. 2004, 2005, 2006, 2007). Observations were likely biased toward fish > 120 mm (80 %) due to the cryptic nature of small fishes (Figure 11; Thurow 1997). In 2007, bull trout observed in the SFWW ranged from 70 to 520 mm (Figure 11). Reasons for the low numbers of observed fish in 2007 are not yet apparent. We suspect some of the difference may be due to having an entire new sampling crew from previous years. We will monitor this closely in the 2008 field season to differentiate between sampling error and true population changes.

North Fork Umatilla River

We sampled 16 reaches in 2007 which accounted for 43% of the study site. Bull trout were captured or observed in all sampled reaches. Over the summer, a total of 144 bull trout were captured and 100 were tagged with PIT and Floy tags. The number tagged varied by sample reach (1 to 21 per reach; Figure 12). Most bull trout captured in the NFUM (2003 - 2007) were in the 100 - 150 mm size range, and the largest bull trout captured in 2007 was a 531 mm fish (1514.3 g), while the smallest bull trout captured was 45 mm (0.8 g; Figure 7).

Condition.—Similar to previous years, condition (Fulton's K) in the NFUM in 2007 varied little across two size classes, as condition values for bull trout <120 mm and >120 mm were nearly identical (Figure 13). However, as we observed in the SFWW, condition of fish >370 mm was higher than that of the smaller size classes (Figure 13). Condition for all sampled bull trout was higher in the NFUM than in the SFWW ($K = 0.89$; 95% CI = 0.88 - 0.90; Figure 9). Overall condition was relatively high in 2007 compared to most previous years.

Snorkel surveys.— We performed snorkel surveys in all 16 reaches, and bull trout were observed in all sampled reaches (Figure 14). As with the number tagged, most bull trout (74% of total) were observed in stream reaches upstream of Coyote Creek (Figures 12 and 14). Observations appeared to be biased toward fish > 120 mm (66 %) although more fish < than 120 mm were observed

in the NFUM than in the SFWW (SFWW = 45, NFUM = 58, Figure 11). Bull trout observed in the NFU ranged from 70 to 470 mm. As in previous years since 2003, observed numbers of bull trout were substantially lower in the NFUM than in the SFWW (SFWW = 229, NFU = 172, Figure 11). Numbers of bull trout observed in 2007 were similar to those of previous years (Figure 14; Budy et al. 2004, 2005, 2006, 2007).

Growth

Since 2002 we have recaptured 72 bull trout in the SFWW and 4 bull trout in the NFUM for estimates of annual growth. Average annual growth of tagged bull trout varied across size classes and systems. In the SFWW, small bull trout (120-220 mm) exhibited larger annual growth in length, 63.5 mm/year (± 2 SE = 10), than small adults (220-370 mm), 49 mm/year (± 2 SE = 9), and significantly larger growth in length than large adults (>370 mm), 19.4 mm/year (± 2 SE = 4; Figure 15). In terms of body mass, the trend seemed to be opposite to that of length. Small and large adults exhibited higher growth rates, 138.7g/year and 180.1g/year than small bull trout, 99.6 g/year, although differences were not significant due to the large variability in annual growth rates (± 2 SE = 25.5, 76.9 and 25.6 respectively). Small bull trout in the NFUM grew slower than small bull trout in the SFWW in terms of length, 63 mm/year and weight, 87.3 g/year but once again the differences were not significant due to large variability in growth rates (± 2 SE = 18 and 24.7 respectively; Figure 15). We found no significant changes in growth rates in the SFWW from 2006 (Budy et al. 2007) and no recaptures were caught in the NFUM so growth reported here is the same as reported in 2007 (Budy et al. 2007).

Population Estimates

South Fork Walla Walla River.—The SFWW bull trout population was significantly larger than the NFUM population (Figure 18). Estimated abundance of bull trout in the SFWW depends greatly on size grouping. Over a 6-year period, the average abundance of bull trout > 120 mm has ranged from 7,287 (95% CI = 6,243 – 8,895) in 2002 up to 10,600 (95% CI = 8,080 – 16,598) in 2006, with 2007 estimated at 9976 (95% CI = 5950 -17851) (Figure 16). The abundance of bull trout > 220 mm has ranged from 2,700 in 2002 down to 894 in 2007 (95% CI = 465 - 3909). In 2007, we estimated the abundance of large bull trout (> 370 mm) at 434 with the sample size being too small for calculating confidence intervals. Whereas the population abundance of bull trout across all size classes appear to have decreased in 2007 the high variance does not allow us to make statements of significant population decreases (Figure 16). Sample

sizes were smaller in 2007 than in previous years since 2002 and this caused higher variance in estimates. A possible reason for us catching less fish in 2007 than previous years may be that we had an entire new sampling crew on the project.

North Fork Umatilla River.—Similar to population abundance trends observed in the SFWW, estimated abundance of bull trout in the NFUM also depends greatly on size grouping. Since 2003, the abundance of bull trout > 120 mm has ranged from a high of 2,434 (95% CI = 1,705 – 5,045) in 2004 to a low of 1,438 (95% CI = 1,077 – 2,426) in 2007; Figure 17). The abundance of bull trout > 220 mm has varied substantially over this period, from 343 in 2004 down to 61 in 2005, with a 2007 estimate of 365 fish. The abundance estimate of large bull trout (> 370 mm) for 2007 was approximately 22 fish, which is similar to the 2003 and 2004 estimates and much higher than the 5 and 2 bull trout estimated in 2005 and 2006 respectively (Figure 17). Overall, abundance estimates for the > 120 mm size category demonstrated high variability, but while there is no significant increase or decrease in population numbers there does seem to be a decreasing trend since 2003.

Population Growth Rate

Based on the population growth rates (λ) calculated from population estimates and redd data, it appears that both the SFWW ($\lambda=1.07$ 95% CI = 0.98 – 1.17) and the NFUM ($\lambda= 0.98$ 95% CI = 0.69 – 1.38) populations are stable (Figure 19). In our 2006 progress report, and reported by the USFWS in their 2008 update (Budy et al. 2007 and Anglin et al. 2008) the population of fluvial bull trout (>370 mm) appeared to be decreasing. Using the time series (1994 - 2007) of redd counts as a surrogate for fluvial bull trout it appears that this portion of the population is also stable in the SFWW ($\lambda= 1.11$ 95% CI = 0.87 – 1.41). A λ value greater than 1 indicates positive population trend, a value equal to 1 indicates no change in population growth rate, and a value less than 1 indicates that the population is declining. It is very important to note however, that as the 95% confidence intervals are wide and overlap 1, we cannot make these conclusions about trend with certainty at this time (Budy et al. 2007). Further data collection (a longer time series) and an update of the population growth rate estimate using a non biased open mark-recapture Pradel type model in program Mark will allow us to tighten the confidence intervals and be more certain about our conclusions.

Survival

South Fork Walla Walla River.—Since 2002, we have marked 1782 bull trout >120 mm for mark-recapture survival analyses. Model selection suggested that survival varied significantly across years, and that bull trout condition had a significant positive effect on bull trout survival (Beta = 45 %, SE = 0.05). Average annual survival estimates for the six life stages of bull trout in the SFWW ranged from 16 % (1 SE = 0.04) for 170 – 220 mm bull trout up to 49 % (SE = 0.08) for 270 – 320 mm bull trout (Figure 20). Since 2002, there has been a significant amount of variability in survival across years, an unsurprising pattern given natural variation in fish populations. Survival data are summarized in great detail in Al-Chokachy and Budy (in press) and although there are few other published field estimates of survival, ours are similar to values reported for other salmonids (Rieman and Apperson 1989; Tieman and McIntyre 1993) and are within the range observed by Rieman and Allendorf (2001) for bull trout.

North Fork Umatilla River.—In the NFUM, we have marked 376 bull trout for mark-recapture survival analyses since 2003. We found annual survival in the NFUM (34 %, SE = 0.23) to be generally similar to estimates for bull trout in the SFWW of similar size (120 – 170 mm; 28 %, 1 SE = 0.06); however, there was very high variance associated with the NFUM estimates, resulting from generally low capture probabilities (<0.10).

Diet Analyses

Using dissected stomachs of sacrificed fish, we quantified diet information from 10 bull trout from the SFWW in 2007. The primary prey items were sculpin (43%), terrestrial invertebrates (39%), and aquatic macroinvertebrates (17%). Aquatic macroinvertebrates included chironomids, plecopterans, dipterans, trichopteran, ephemeropterans, and coleopterans. We compared the diets of bull trout captured in the SFWW in 2003, 2005, 2006 and 2007. Our extremely small sample size (ESA permit limitations) limits conclusions about diet; however, we appeared to observe a change in stomach content in 2007 relative to all previous years (Figure 21). Before 2007, we found bull trout diets were consistently composed of macroinvertebrates (range = 57 – 75% of diet) and in 2007 we saw a shift to sculpin and terrestrial invertebrates. Similar to 2005 and 2006 we observed no evidence of cannibalism in bull trout diets in 2007.

Fecundity

We have only been able to obtain fecundity data from 12 sacrificed, mature females since 2002 in the SFWW. So far our data suggests that bull trout appear to reach sexual maturity near 200 mm, or ages 3 to 4, in the SFWW. The number of eggs increased significantly with size where the smallest female (205 mm TL) had 343 eggs and the largest fish (564 mm TL) had 3969 eggs (Figure 21). These data are consistent with research from adjacent basins, (Hemmingsen et al. 2001) which indicates bull trout may become sexually mature between 150-200 mm.

Temperature

We measured temperature using temperature loggers at two sites in the SFWW and one site in the NFUM. In the SFWW, daily minimum and maximum temperatures varied less across the year in the higher reaches near Skiphorton Creek (annual range = 1.9 – 9.8 °C), than lower reaches near Bear Creek (annual range = 1.1 – 13.5 °C; Figure 23). In the NFUM Campground site from July 2006 to July 2007, minimum and maximum temperatures ranged from 1.8 – 15.9 °C (Figure 24). Diel fluctuations were also less in upper reaches of the SFWW and were greater in the summer months (July and August 2006 and June and July 2007, Figure 23). The stream temperature ranges in the SFWW and the NFUM are well within the temperature standards recommended for habitat restoration criteria for bull trout (Buchanan and Gregory 1997). Temperatures fit within reported ranges for migratory cues, spawning, and rearing.

Movement

Although we have not formally summarized movement for this year, two fish which were tagged in the SFWW were recaptured by USFWS and CTUIR crews downstream of the town Milton-Freewater, OR. Because a relatively small proportion of the SFWW population are PIT tagged, these two fish represent a large number of bull trout migrating to the area downstream of Milton-Freewater (Anglin et al. 2008).

LITERATURE CITED

- Al-Chokhachy, R. 2006. An assessment of the dynamics and limiting factors of a fluvial bull trout population. Doctoral dissertation. Utah State University, Logan, Utah.
- 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, 2005 [Management Brief] American Fisheries Society 2005.
- Al-Chokhachy, R., and P. Budy. 2007 Summer Microhabitat Use of Fluvial Bull Trout in Eastern Oregon Streams *North American Journal of Fisheries Management* 27:1068–1081, American Fisheries Society 2007.
- Al-Chokhachy, R. and P. Budy. In press. Demographic characteristics, population structure, and vital rates of a fluvial population of bull trout in Oregon. *Transactions of the American Fisheries Society*. Accepted May 26, 2008.
- Anglin, D.R., D. Gallion, M. Barrows, C. Newlon, and R. Koch. 2008. Current Status of Bull Trout Abundance, Connectivity, and Habitat Conditions in the Walla Walla Basin. 2007 update. U.S. Fish and Wildlife Service, Columbia River Fisheries program Office. Vancouver, Washington
- Buchanan, D. V., and S. V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pages 119-126 in W. C. McKay, M. K. Berwin and M. Monita, editors, *Friends of the Bull Trout conference proceedings*. Bull Trout Task Force (Alberta), and Trout Unlimited Canada, Calgary.
- 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, 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.
- Buzby, K.M., and L.A. Deegan. 2004. Long-term survival of adult Arctic grayling (*Thymallus arcticus*) in the Kuparuk River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 61:1954-1964.
- 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.
- 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.
- Homel, K. and P. Budy. In press. 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. Accepted November 5, 2007.
- Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*: A literature review. Willamette National Forest, Eugene, Oregon.
- Goetz, F. 1991. Bull trout life history and habitat study. U.S. Department of Agriculture, Forest Service, Deschutes National Forest, Bend, Oregon.
- Hemmingsen, A. R., S. L. Gunckel, and P. J. Howell. 2001. Bull trout life history, genetics, habitat needs, and limiting factors in central and northeast Oregon. Bonneville Power Administration, Project 1994-05400, Portland, Oregon.

- Johnston, F.D., J.R. Post, C.R. Mushens, J.D. Stelfox, A.J. Paul, and B. Lajeunesse. 2007. The demography of recovery of an overexploited bull trout, *salvelinus confluentus*, population. Canadian Journal of Fisheries and Aquatic Sciences 64:113-126.
- Kershner, J.L., C.M. Bischoff, and D.L. Horan. 1997. Population, habitat, and genetic characteristics of Colorado River Cutthroat trout in wilderness and non-wilderness stream sections in the Uinta Mountains of Utah and Wyoming. North American Journal of Fisheries Management 17:1134-1143.
- Leary, R.F., F.W. Allendorf, and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology 7:856-865.
- 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.
- Mahoney, B. 2001. Walla Walla basin summer steelhead and bull trout radio telemetry project: 2001 Annual Report. Prepared by the Confederated Tribes of the Umatilla Indian Reservation for the Bonneville Power Administration. Portland, Oregon.
- Mahoney, B. 2002. Walla Walla basin summer steelhead and bull trout radio telemetry project: 2002 Annual Report. Prepared by the Confederated Tribes of the Umatilla Indian Reservation for the Bonneville Power Administration. Portland, Oregon.
- Morris, W.F., and D.F. Doak. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates, Sutherland, Massachusetts.
- ODFW (Oregon Department of Fish and Wildlife). 1995. Bull trout spawning ground surveys Umatilla and Walla Walla basins. September 1, 1995 to October 31, 1995. Progress Report (Preliminary). Umatilla Fishery District, Pendleton, Oregon.
- ODFW. 1996. Bull trout spawning ground surveys. Umatilla and Walla Walla basins. September 1, 1996 to October 31, 1996. Progress Report. Umatilla Fish District, Pendleton, Oregon.

- 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.
- 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.
- Rieman, B.E., and F.W. Allendorf. 2001 Effective population size and genetic conservation criteria for bull trout. *North American Journal of Fisheries Management* 21:756-764
- Rieman, B.E., and K.A. Apperson. 1989. Status and analysis of salmonid fisheries. Westslope cutthroat trout symposium and analysis of fishery information. Project F-73-R-II. Subproject Number 2. Job Number 1. Idaho Department of Fish and Game, Boise, Idaho.
- 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.C. Lee, and R.F. Thurow. 1997. Distribution, status, and the likely future trends of bull trout within the Columbia River and Klamath River basins. *North American Journal of Fisheries Management* 17:1111-1125.
- 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*: 1552-1565.
- Rode, M. 1988. Bull trout, *Salvelinus confluentus* (Suckley), in the McCloud river, status and recovery recommendations (draft). Inland Fishing Administration Report, California Dept. of Fish and Game.
- Soule, M.E. 1987. Viable populations for conservation. Cambridge University Press.
- Thiesfeld, S.L., J. C. Kern, A.R. Dale, M.W. Chilicote, and M.A. Buckman. 1999. Lake Billy Chinook sockeye salmon and kokanee research study 1996-1998. Contract Completion Report. FERC Number 2030. 153 pages.

- Thurrow, 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.
- Underwood, K.D., S.W. Martin, M.L. Schuck, and A.T. Scholz. 1995. Investigations of bull trout (*Salvelinus confluentus*), steelhead trout (*Oncorhynchus mykiss*), and spring chinook salmon (*O. tshawytscha*) interactions in southeast Washington streams. BPA report. Project Number 90-053. Contract Number DE-B179-91BP17758. 173 pages.
- USFWS (US Fish and Wildlife Service). 1998. Endangered and threatened wildlife and plants; determination of Threatened Status for the Klamath River and Columbia River Distinct Population segments of bull trout.
- Walla Walla Subbasin Summary *Draft*. 2001. Prepared for the Northwest Power Planning Council.
- 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>
- Washington Department of Wildlife. 2000. Final Bull Trout/Dolly Varden Management and Recovery Plan. Washington Department of Wildlife, Fisheries Management Division, Olympia, WA.

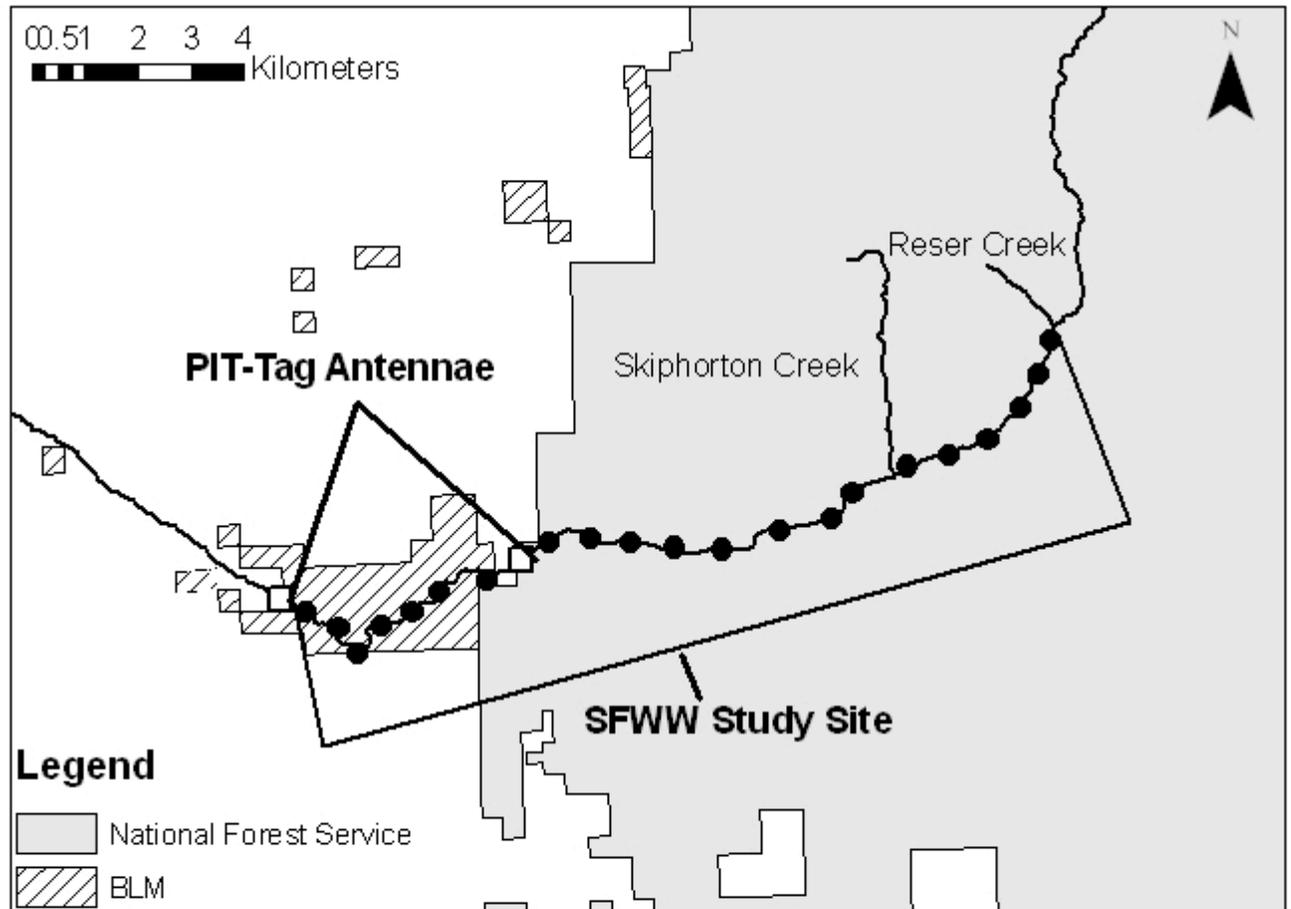


Figure 1. Map of the South Fork Walla Walla River showing original 22 study reaches (dark circles) and antennae locations (white squares).

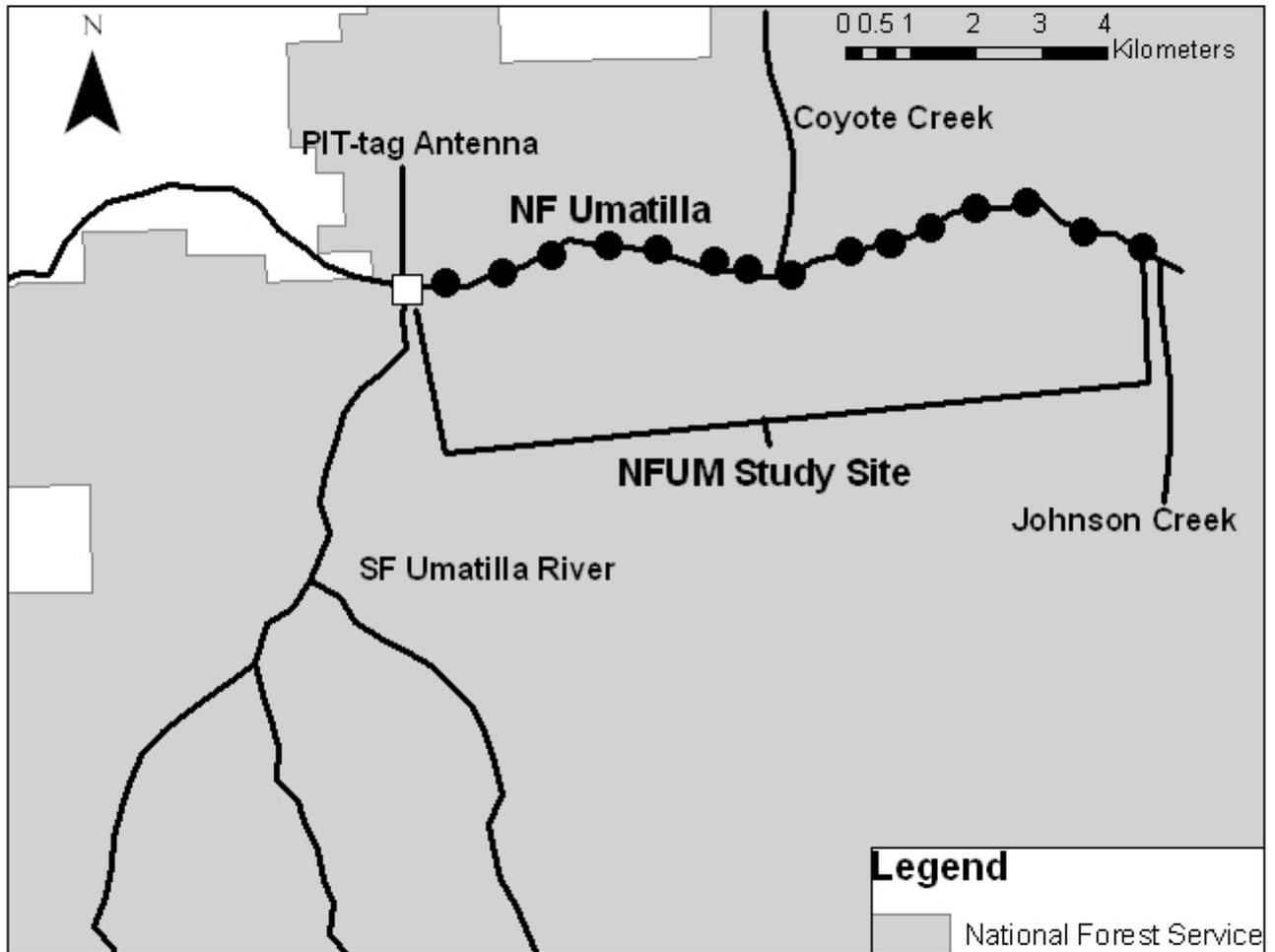


Figure 2. Map of the North Fork Umatilla River showing 15 study reaches (dark circles) and antenna location (white square).

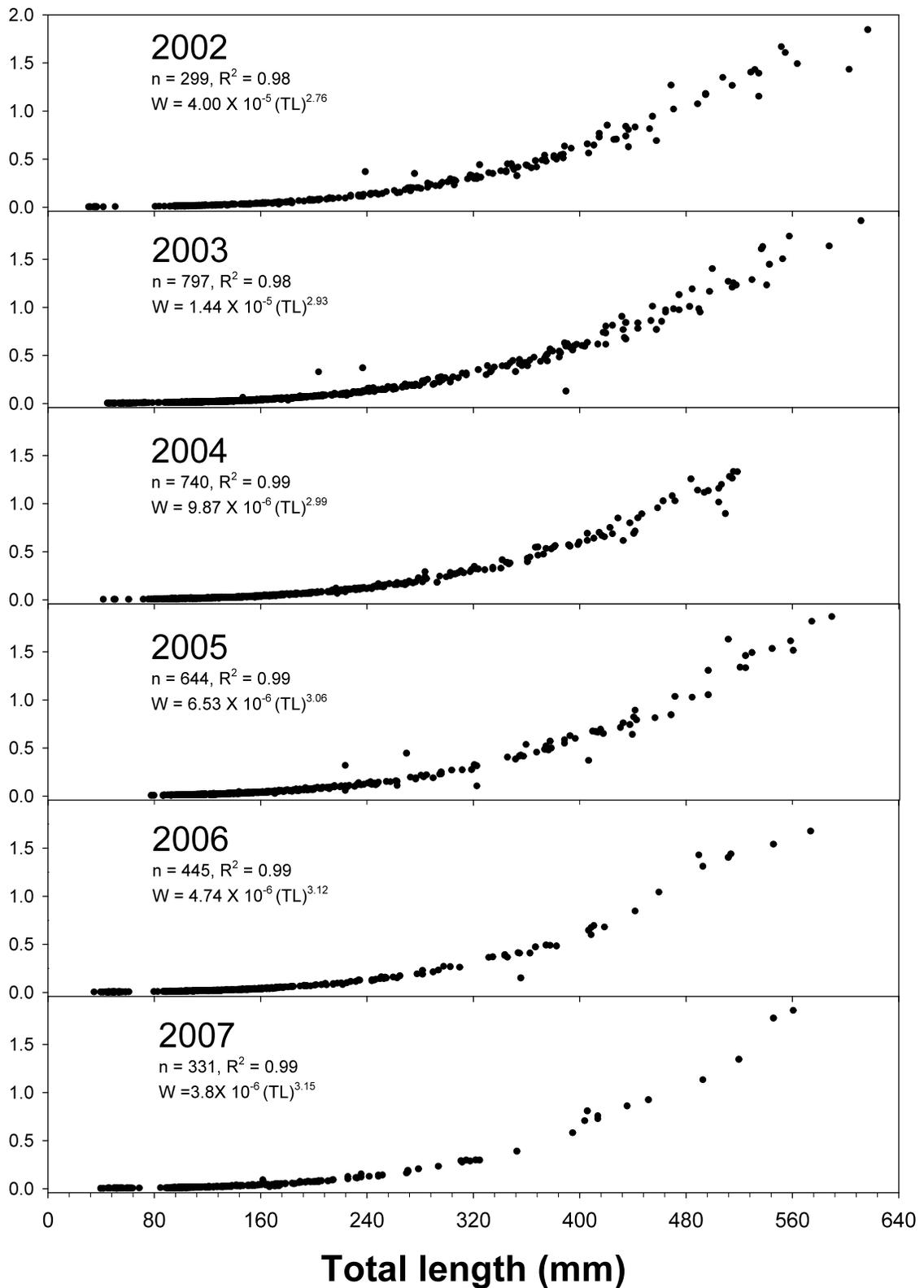


Figure 3. Length-weight relationship for all bull trout captured and handled in the South Fork Walla Walla River, 2002 - 2007. Regression equations and sample sizes are given.

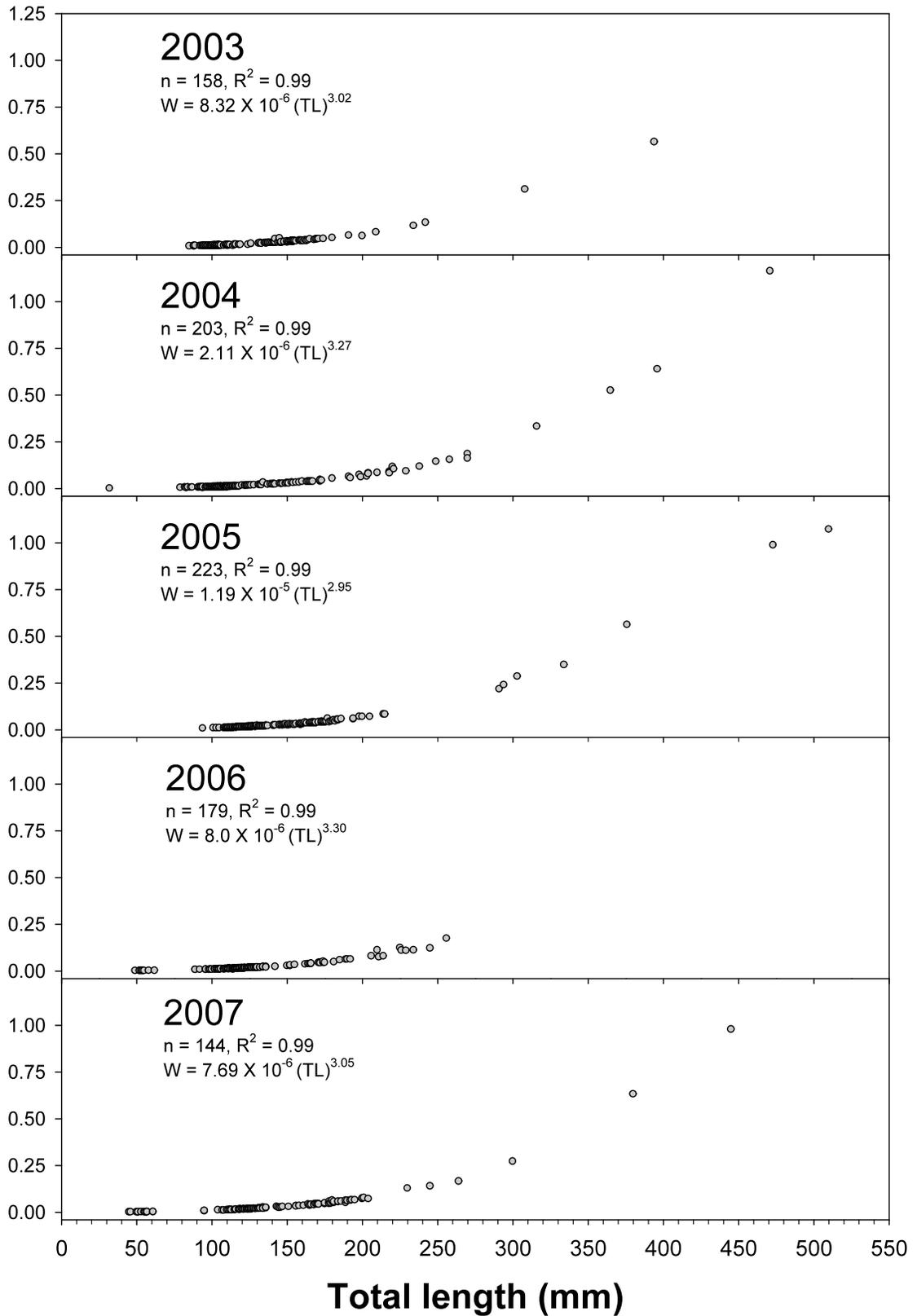


Figure 4. Length-weight relationship for bull trout captured and handled in the North Fork Umatilla River, 2003 - 2007. Regression equations and sample sizes are given.

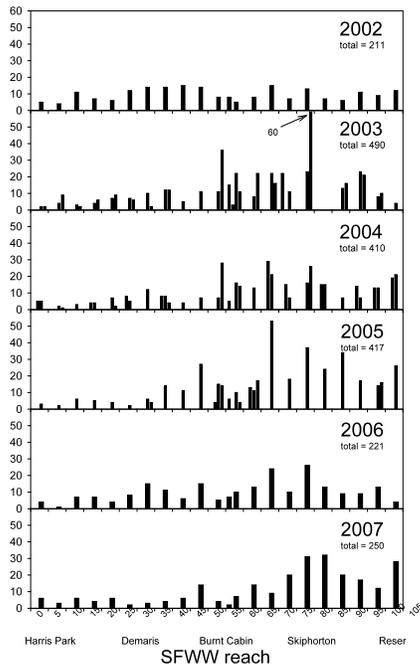


Figure 5. Number of bull trout tagged by reach in the South Fork Walla Walla River, 2002 - 2007. Reaches are numbered from bottom to top of the study site. Total numbers tagged are given below sample year. Note: 2007 numbers include bull trout <120mm. In 2003, 2004 and 2005 there was up to 50% more sites sampled.

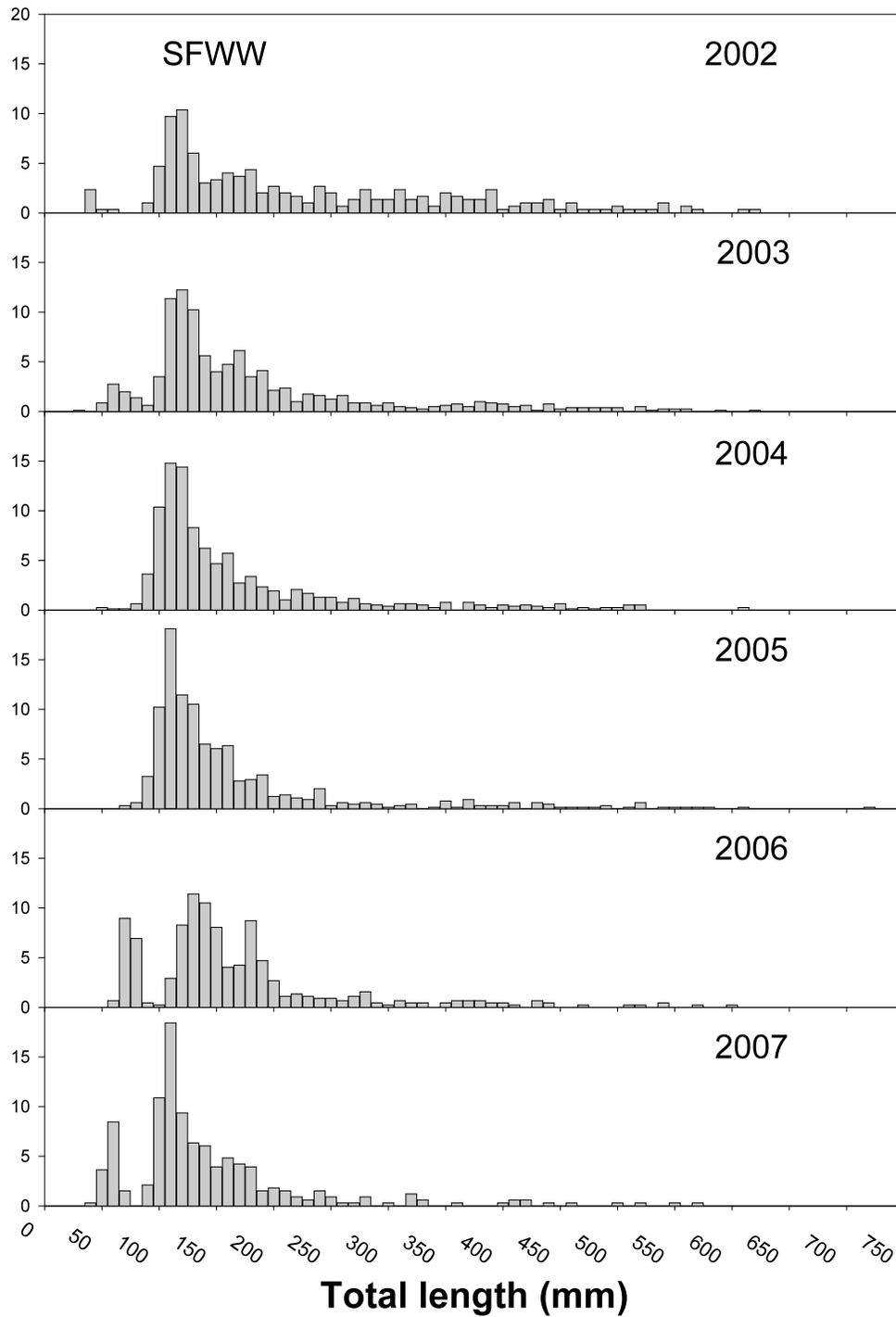


Figure 6. Length-frequency (% of catch) distribution of bull trout captured and handled in the South Fork Walla Walla River, 2002 - 2007.

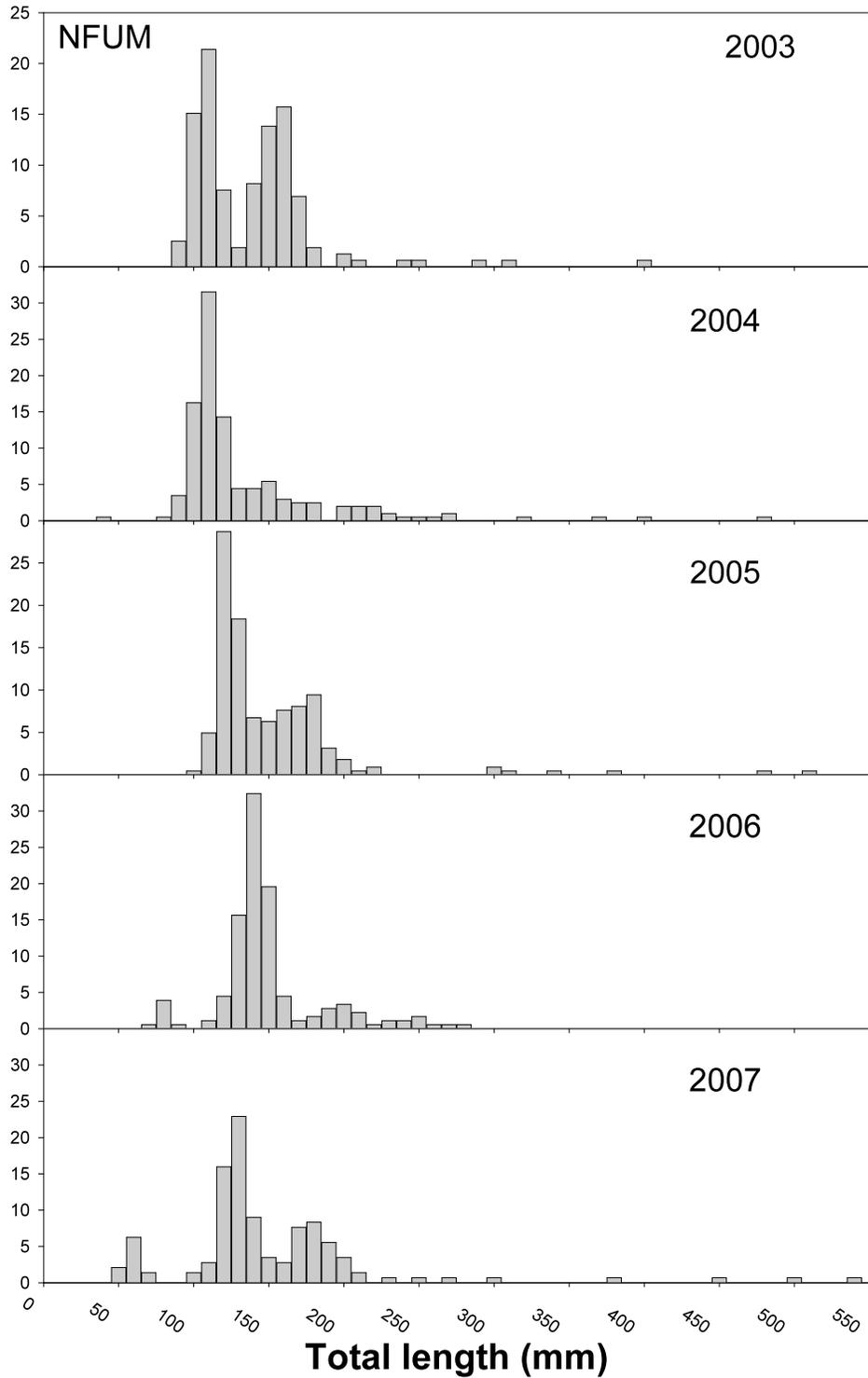


Figure 7. Length-frequency (% of catch) distribution of bull trout captured and handled in the North Fork Umatilla River, 2003 - 2007. Note difference in % scale.

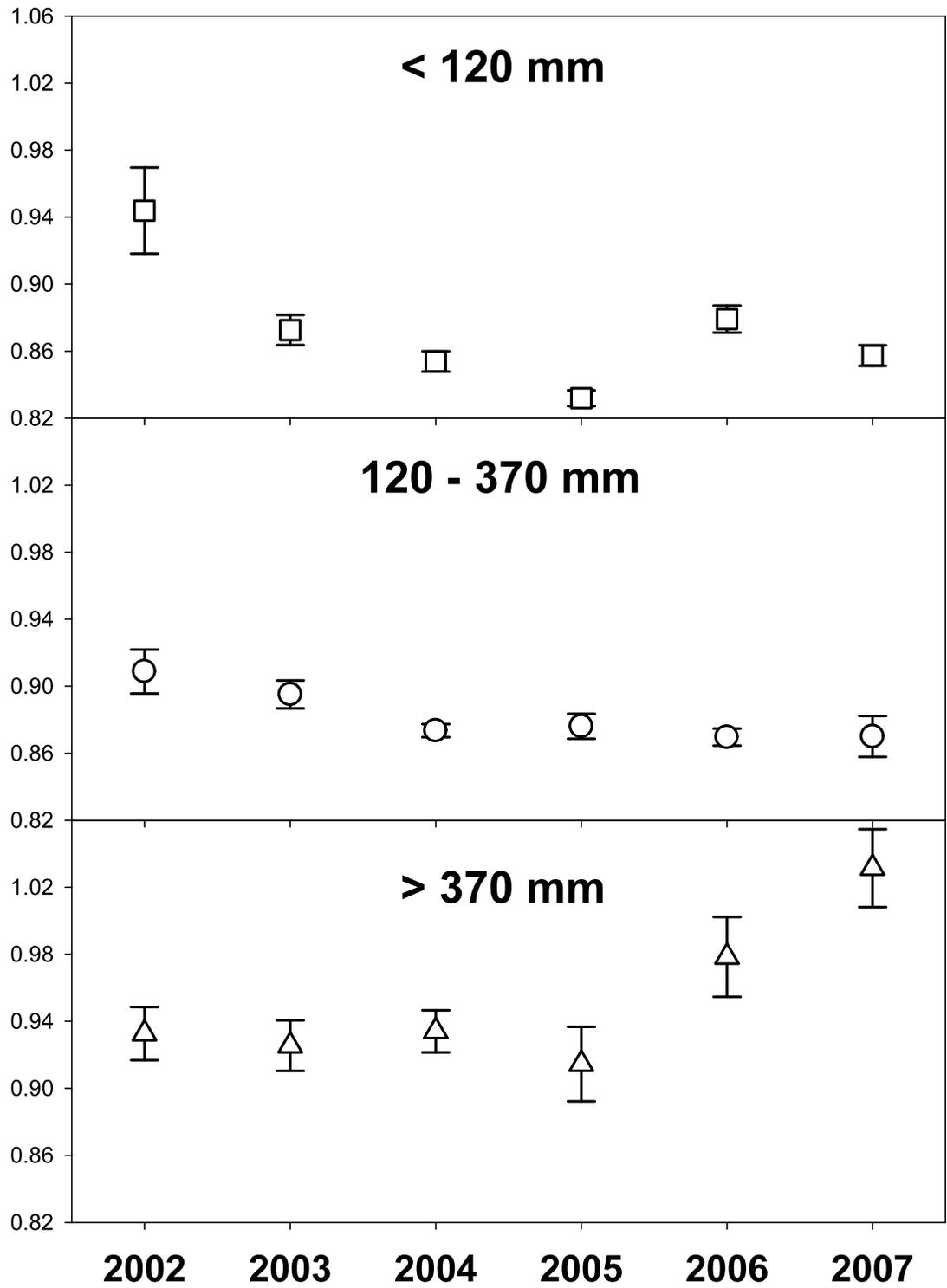


Figure 8. Condition (Fulton's $K \pm 1$ SE) of three different size classes of bull trout sampled in the South Fork Walla Walla River, 2002 - 2007.

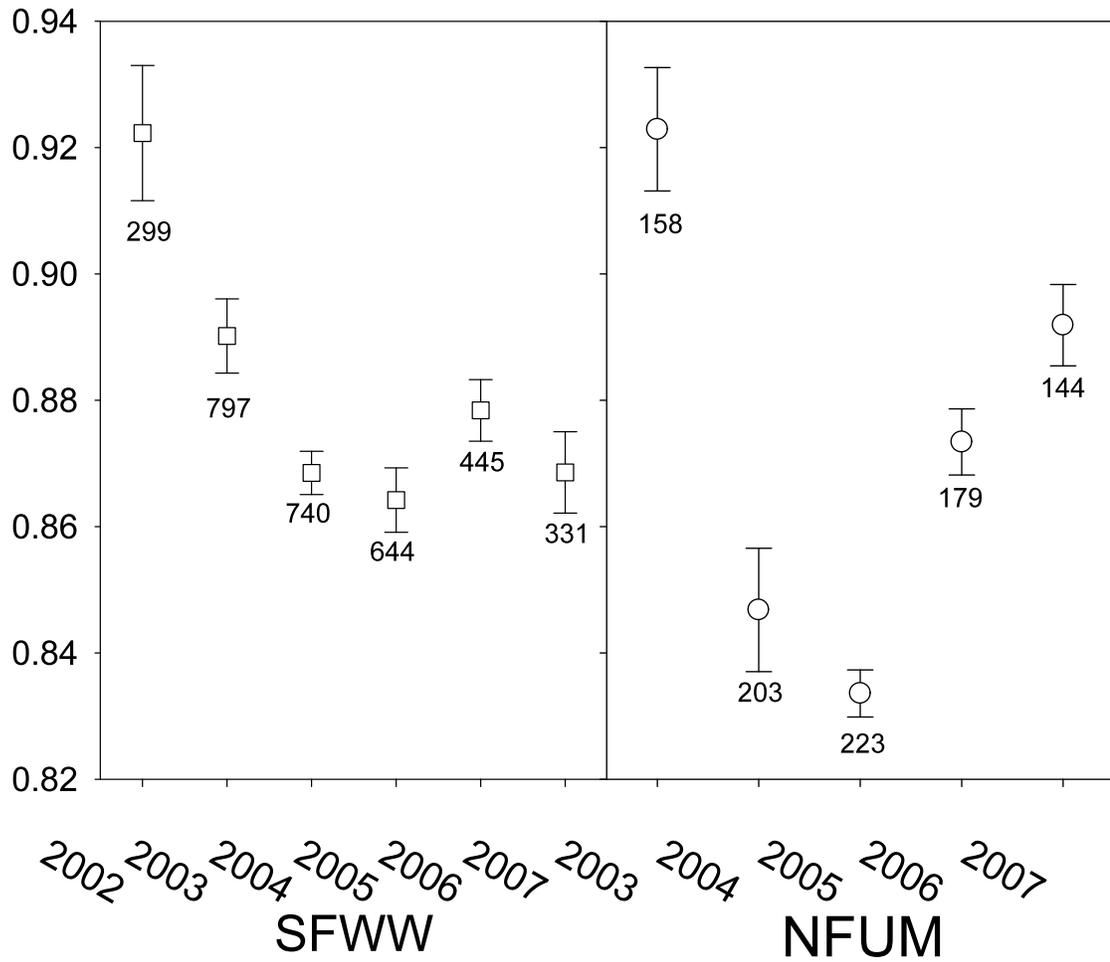


Figure 9. Average condition (Fulton's $K \pm 1$ SE) of bull trout (all sizes combined) sampled in the South Fork Walla Walla River (2002 - 2007) and North Fork Umatilla River (2003 - 2007). Sample size is given by error bars.

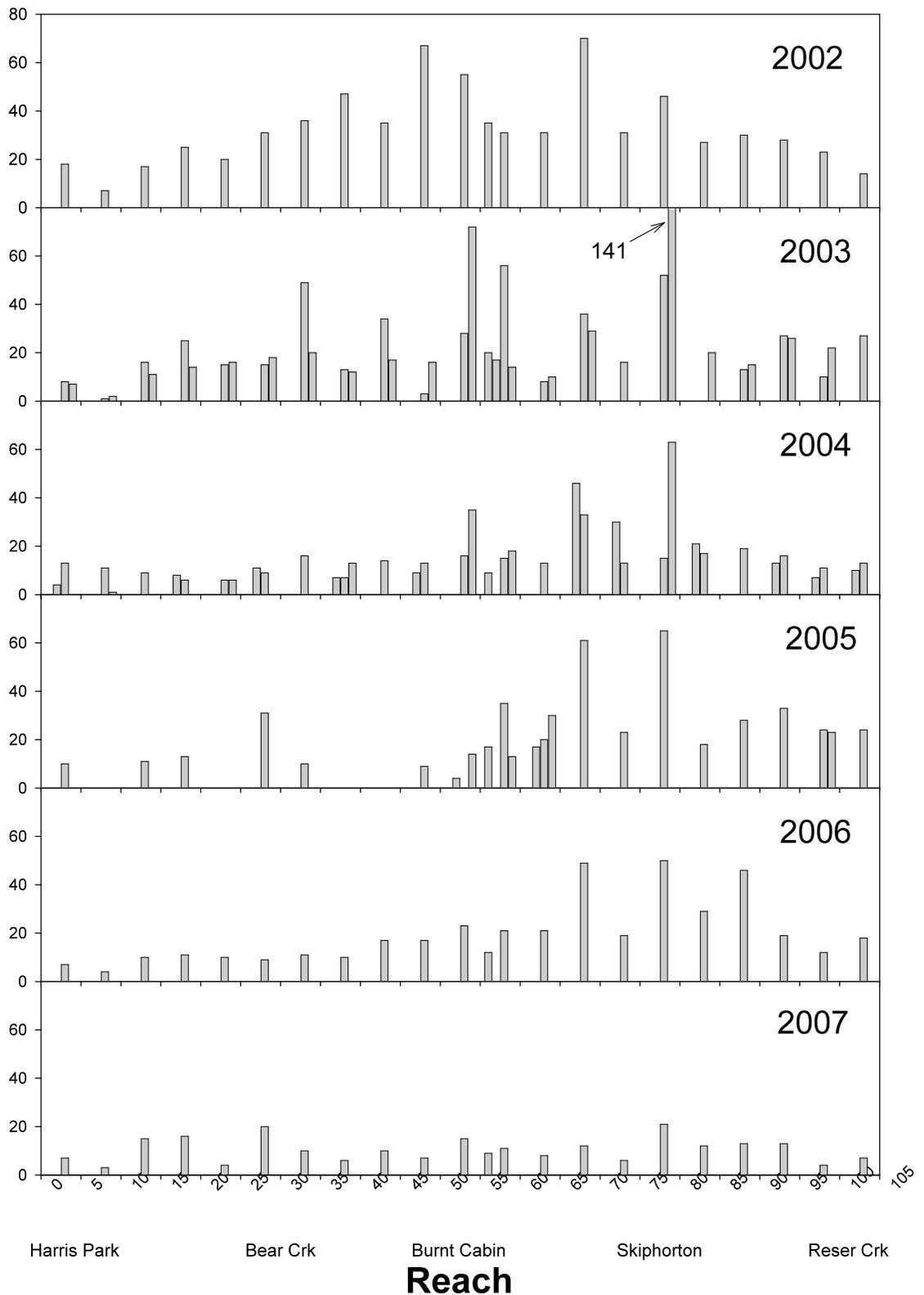


Figure 10. Number of bull trout by reach counted during snorkel surveys in the South Fork Walla Walla River, 2002 - 2007. Reaches are numbered from bottom to top of the study site. No bar implies that no sampling was conducted in a particular reach.

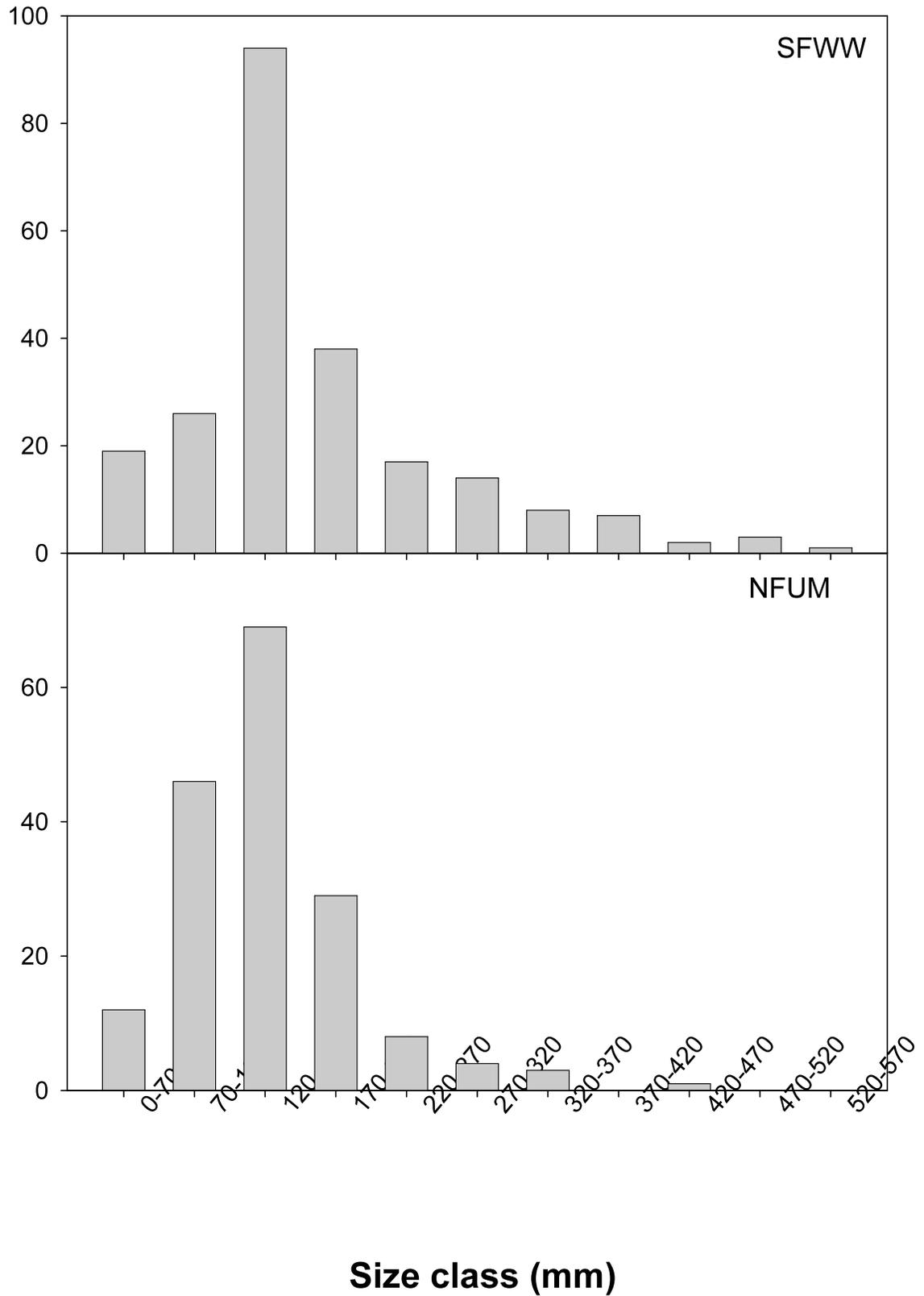


Figure 11. Number of bull trout in 50-mm size bins observed during snorkel surveys in the South Fork Walla Walla River and North Fork Umatilla River in 2007. Note changes in y-axis scales.

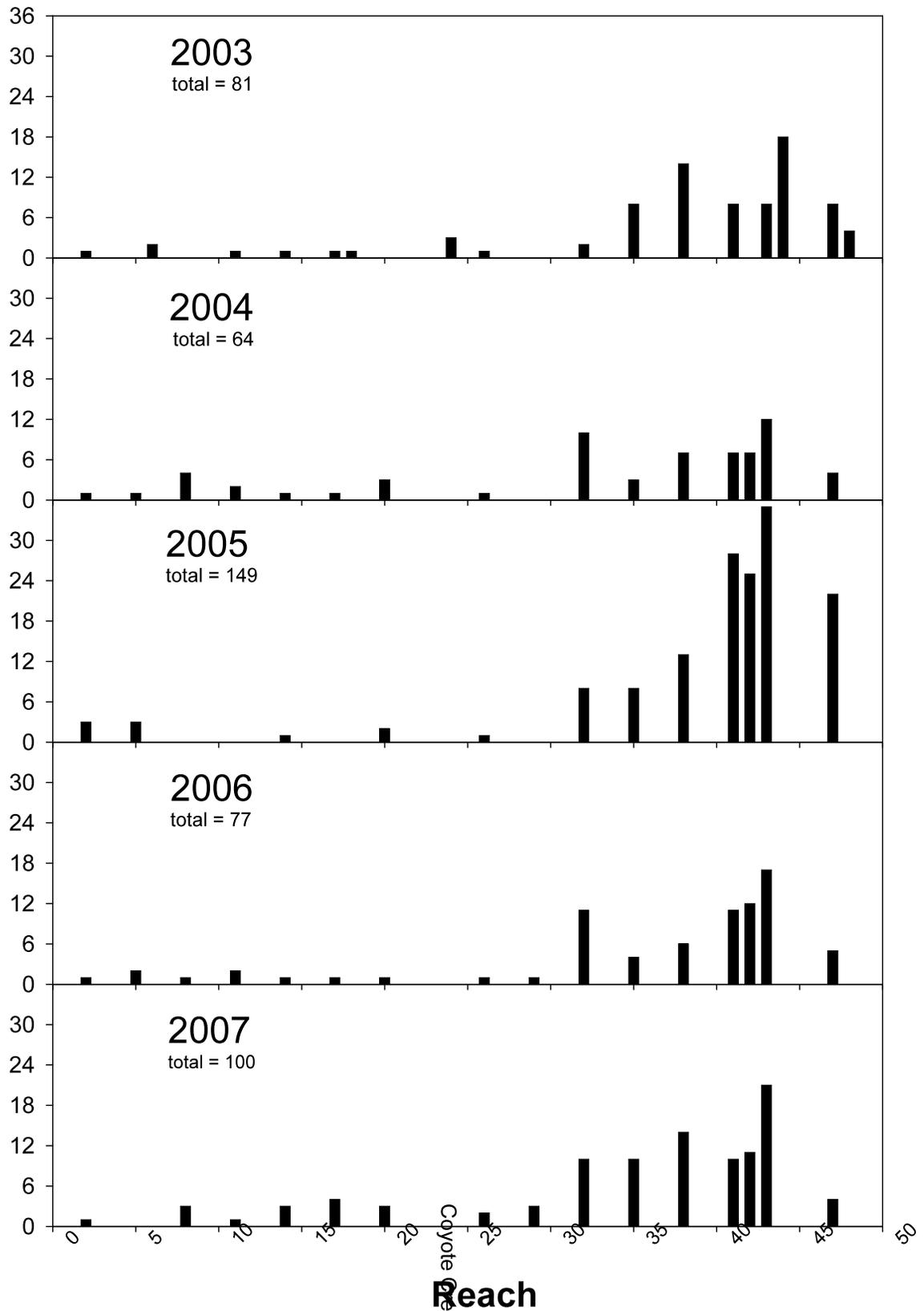


Figure 12. Number of bull trout tagged by reach in the North Fork Umatilla River, 2003 - 2007. Reaches are numbered from bottom to top of the study site. Total numbers tagged are given below sample year.

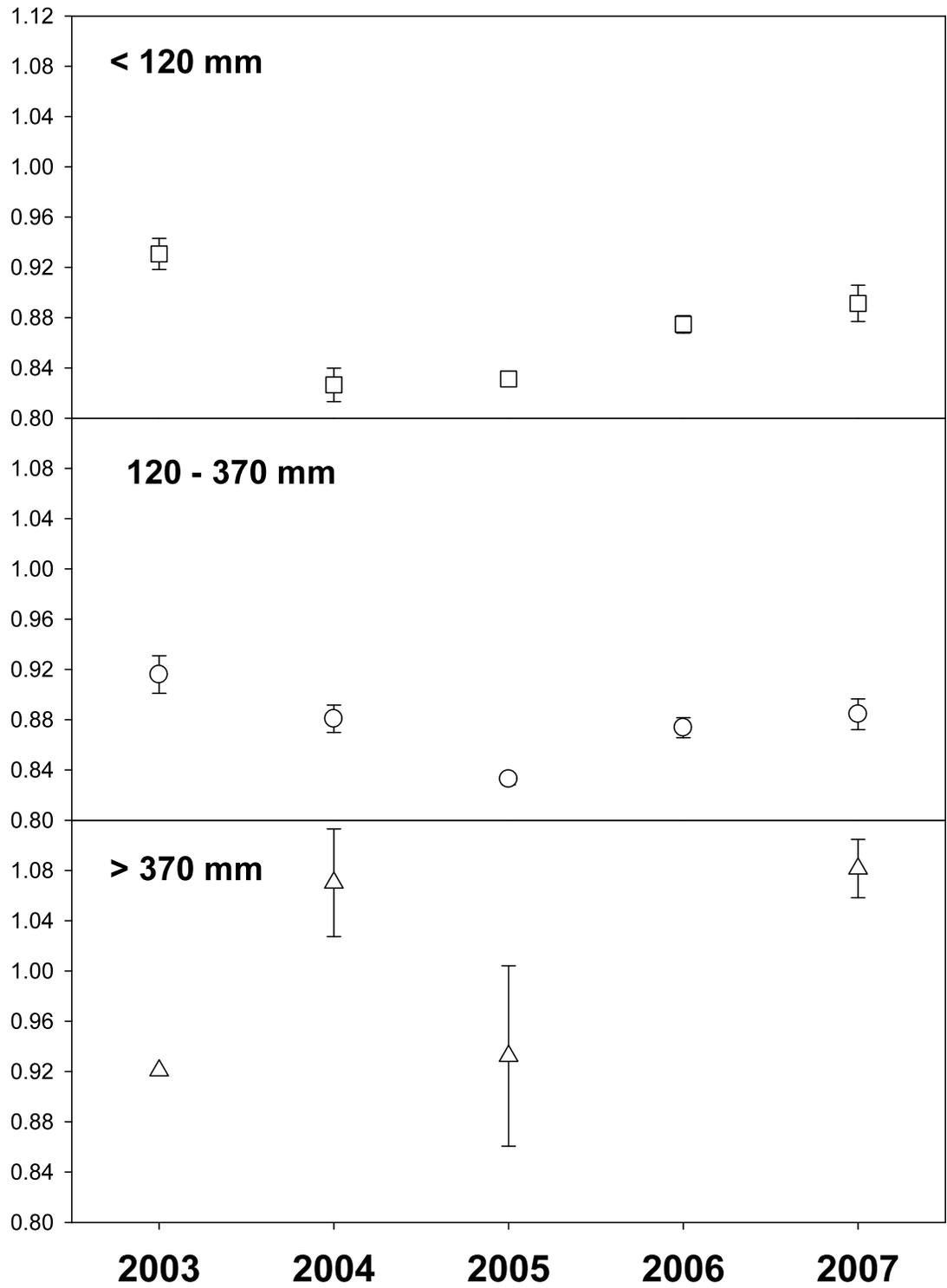


Figure 13. Condition (Fulton's $K \pm 1$ SE) of three different size classes of bull trout sampled in the North Fork Umatilla River, 2003 - 2007. Note: no bull trout >370 mm were captured in 2006.

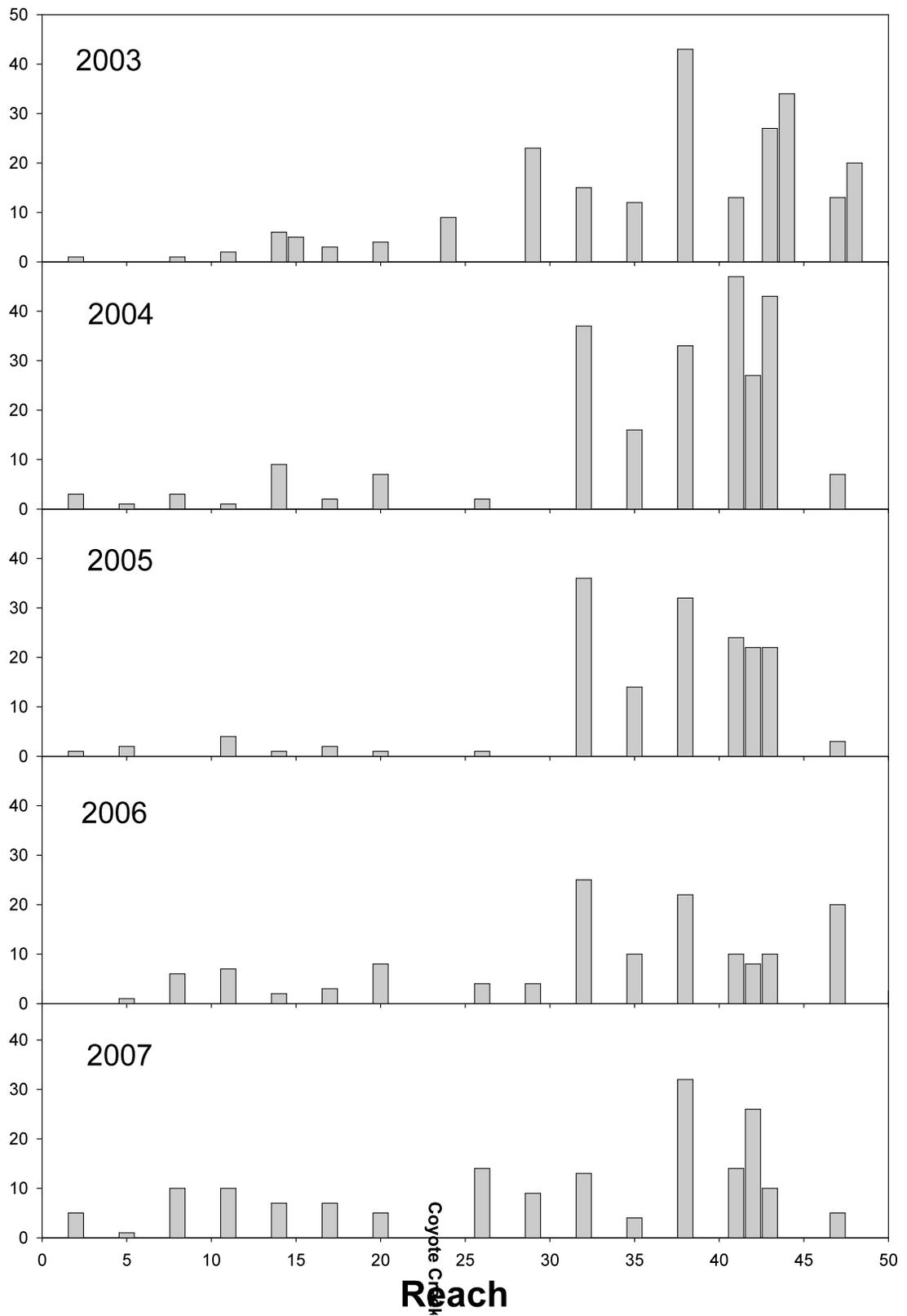


Figure 14. Number of bull trout counted by reach during snorkel surveys in the North Fork Umatilla River, 2003 - 2007. Reaches are numbered from bottom to top of the study site.

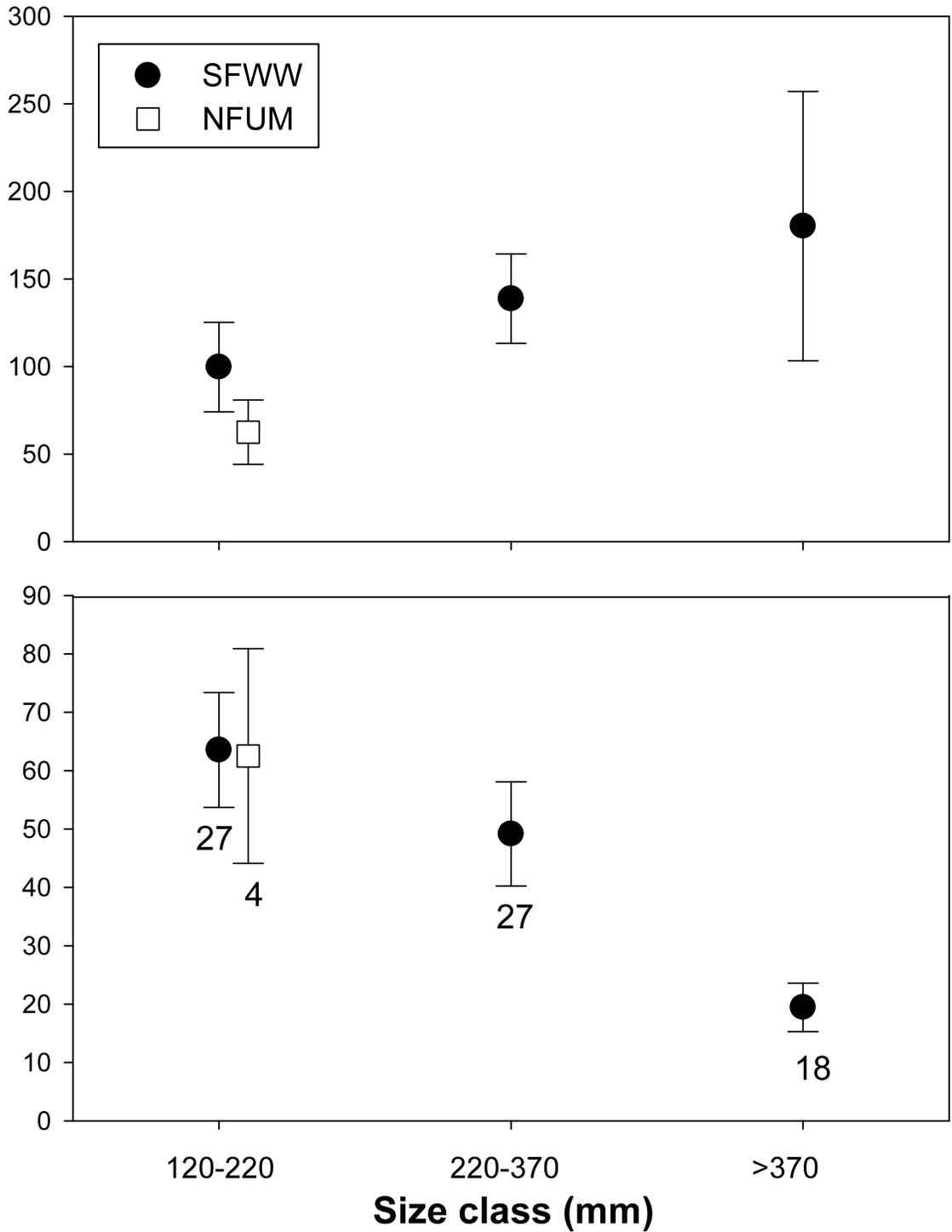


Figure 15. Average annual growth (± 2 SE) in weight (g, top panel) and length (mm, bottom panel) for three size classes of tagged and recaptured bull trout in the South Fork Walla Walla (SFWW), 2002 - 2007 and the North Fork Umatilla (NFUM) 2003 - 2007. Sample sizes are given below error bars. Note: no bull trout >220 mm have been recaptured for growth estimates in the NFUM.

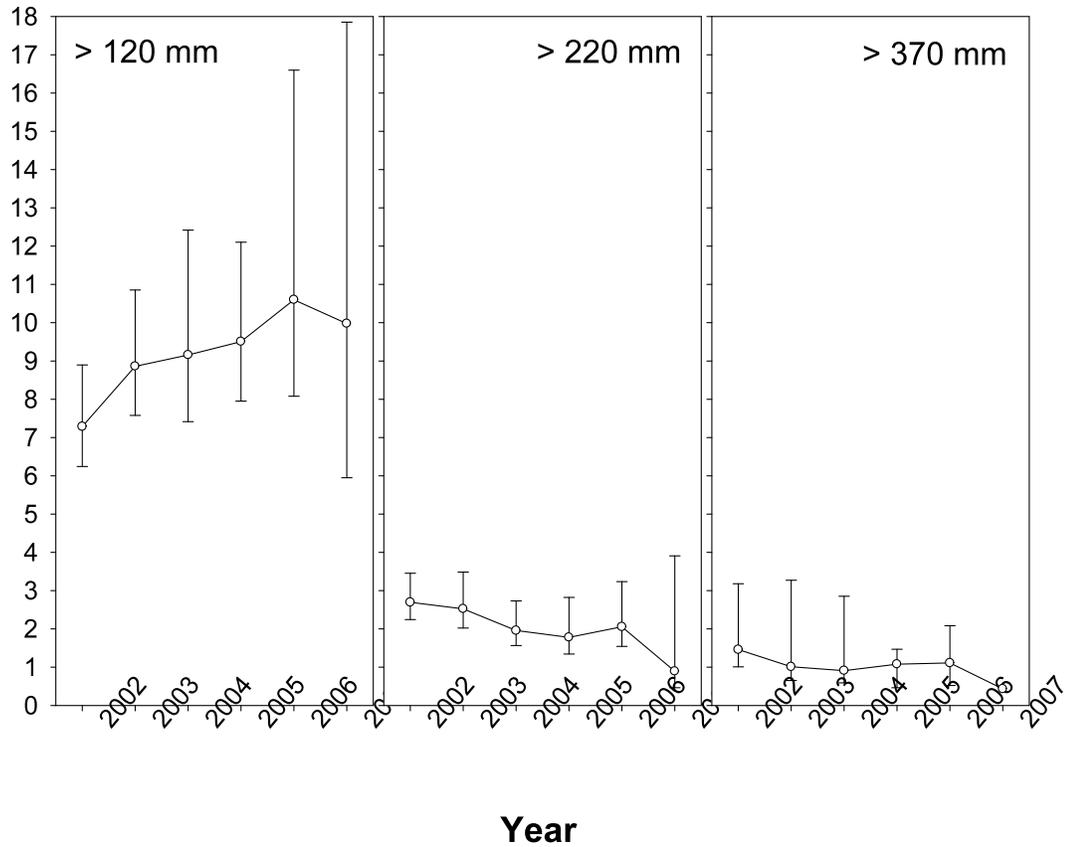


Figure 16. Annual population estimates (\pm 95% CI) for three size groupings of bull trout in the South Fork Walla Walla River, 2002 - 2007. Due to low sample size, no confidence intervals were obtainable for the bull trout population component $>$ 370 mm TL.

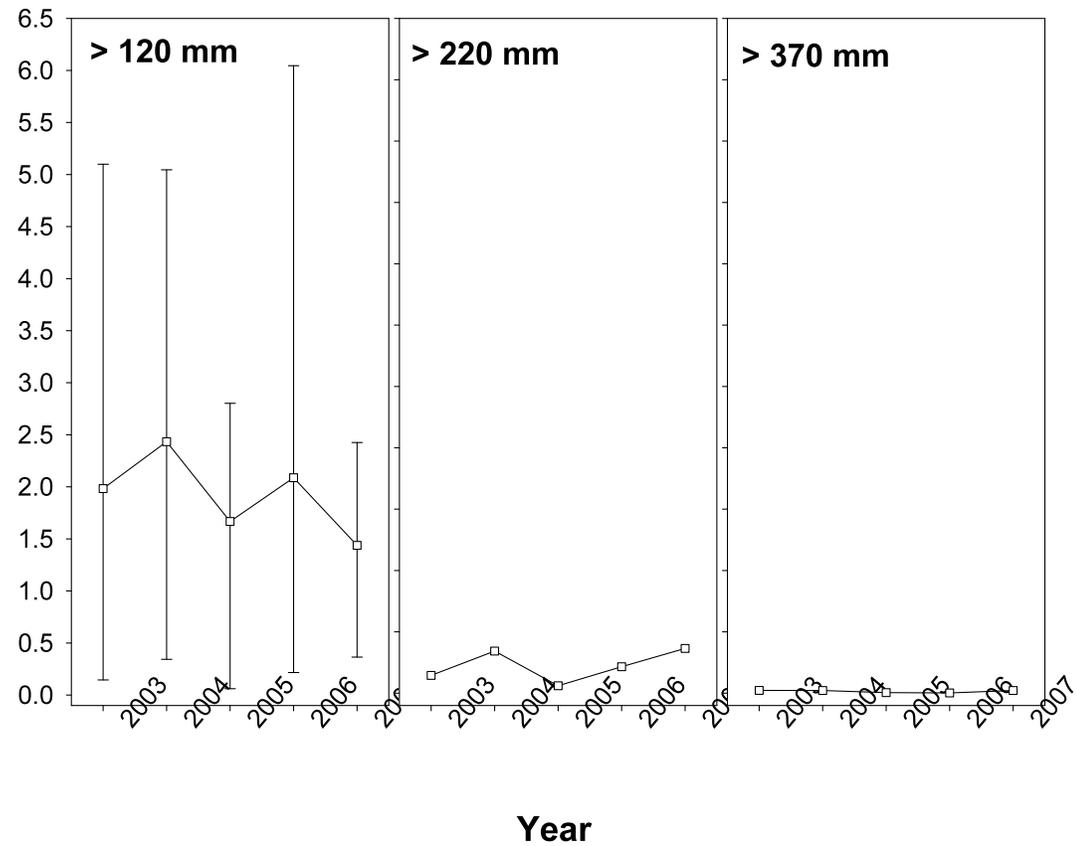


Figure 17. Annual population estimates (\pm 95% CI) for three size groupings of bull trout in the North Fork Umatilla River, 2003 - 2007. Due to low sample sizes, no confidence intervals were obtainable for the bull trout population component $>$ 220 mm or $>$ 370 mm TL.

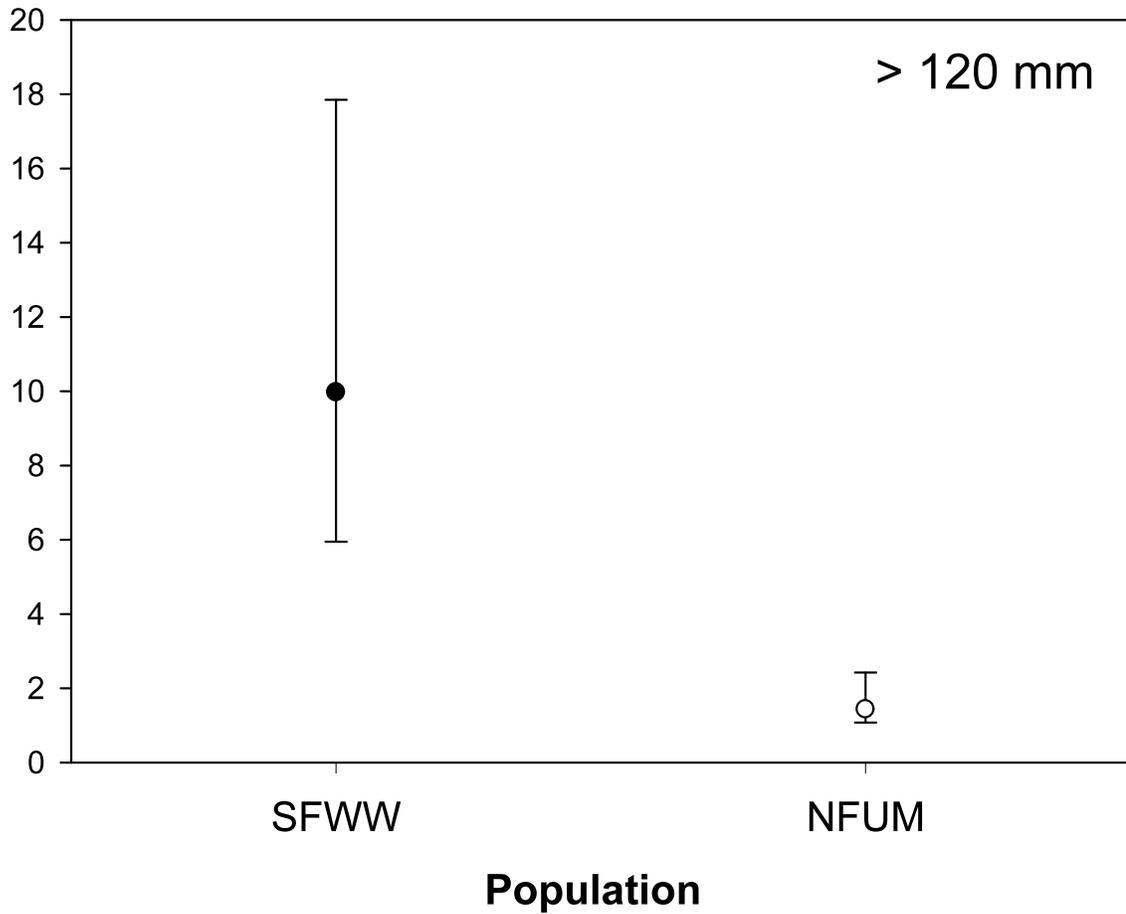


Figure 18. Annual population estimates (\pm 95% CI) for two populations of bull trout (> 120 mm TL), in the South Fork Walla Walla (SFWW) and North Fork Umatilla (NFUM) rivers in 2007.

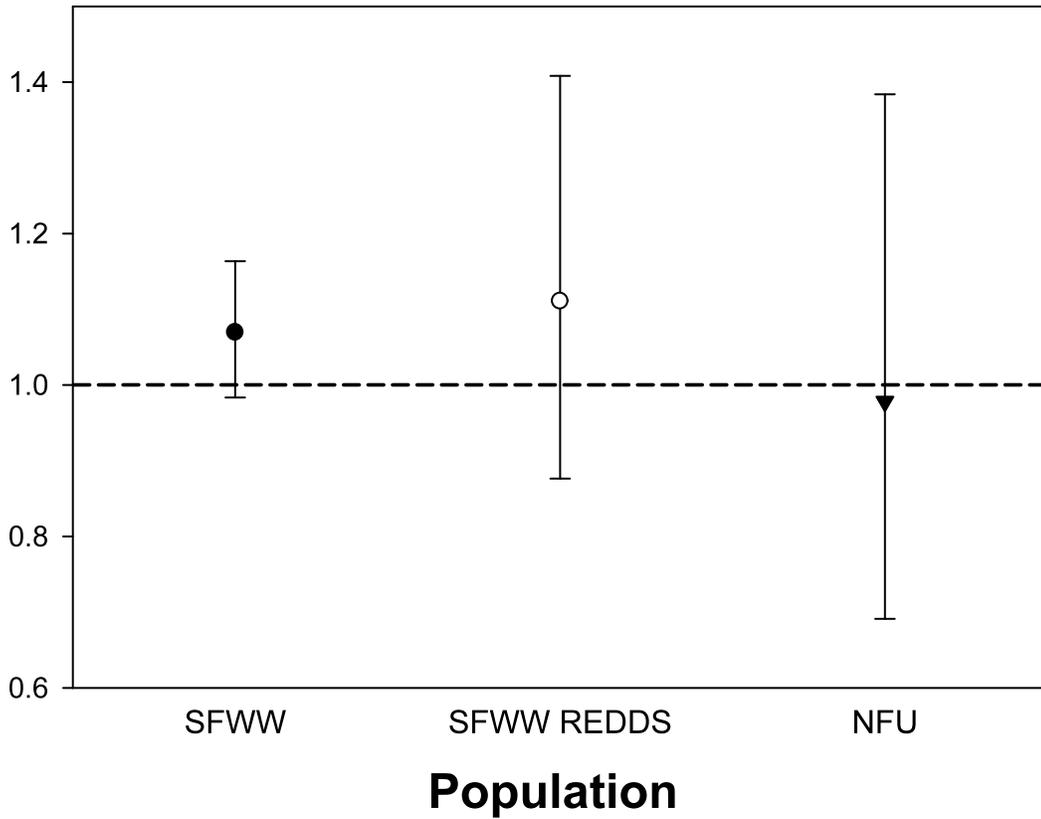


Figure 19. Population growth estimates (\pm 95% CI) for all bull trout >120 mm in the South Fork Walla Walla River (2002-2007) and the North Fork Umatilla River (2003-2007, as well as the population growth estimate (\pm 95% CI) based on redd data collected in the South Fork Walla walla River (1994-2007).

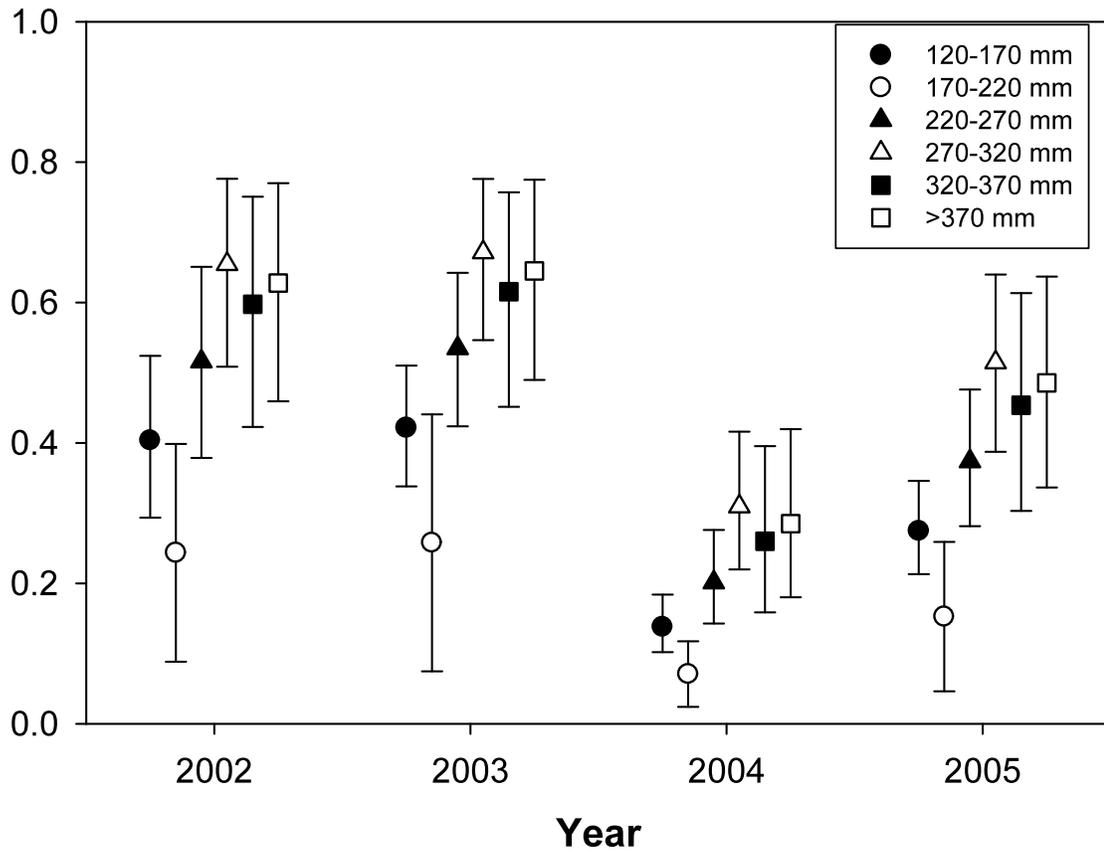


Figure 20. Survival estimates (± 2 SE) for six size classes of bull trout in the South Fork Walla Walla River over the period 2002 to 2006 (Alchokhatchy and Budy, in press.)

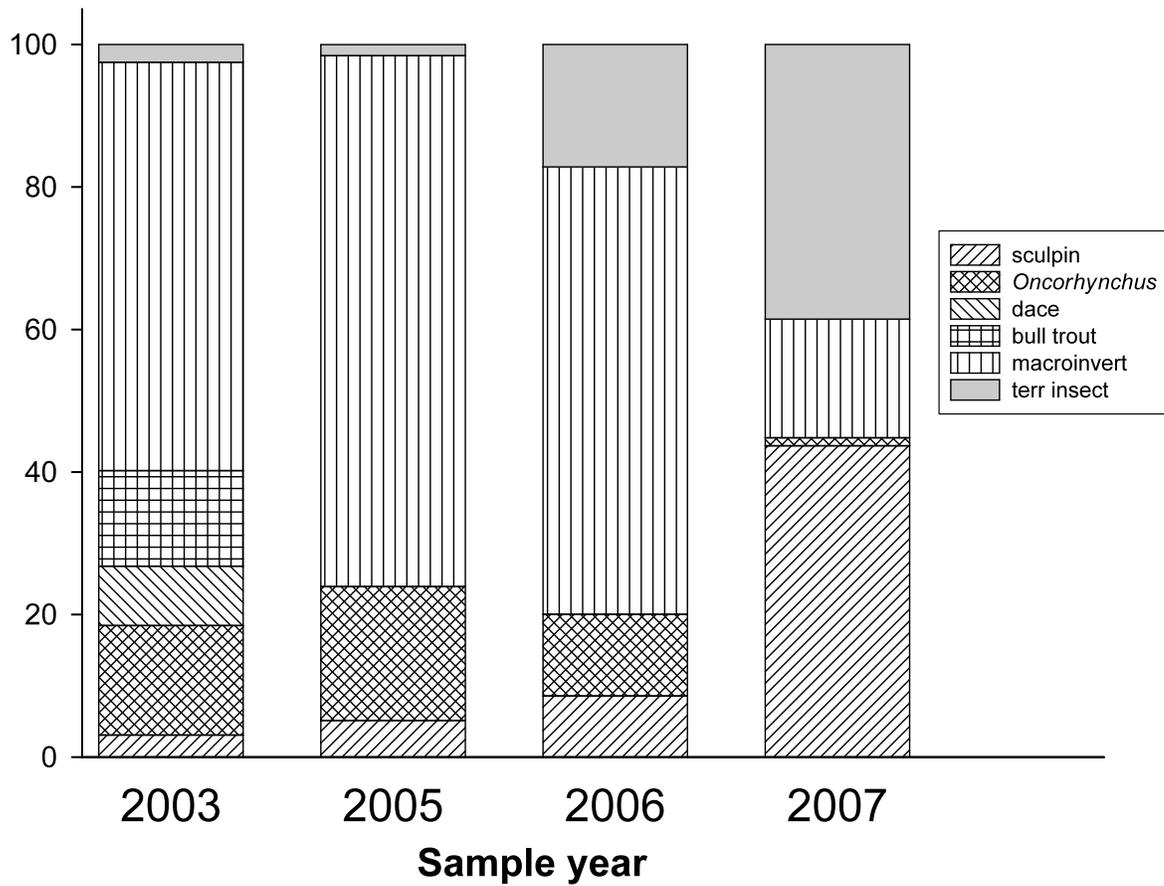


Figure 21. Diet composition (% of diet by wet weight) of bull trout captured in the South Fork Walla Walla River in 2003, 2005, 2006, and 2007. “*Oncorhynchus*” includes all salmonid species, except bull trout. “Macroinvert” includes all aquatic invertebrates. “Terr insect” includes all terrestrial invertebrates.

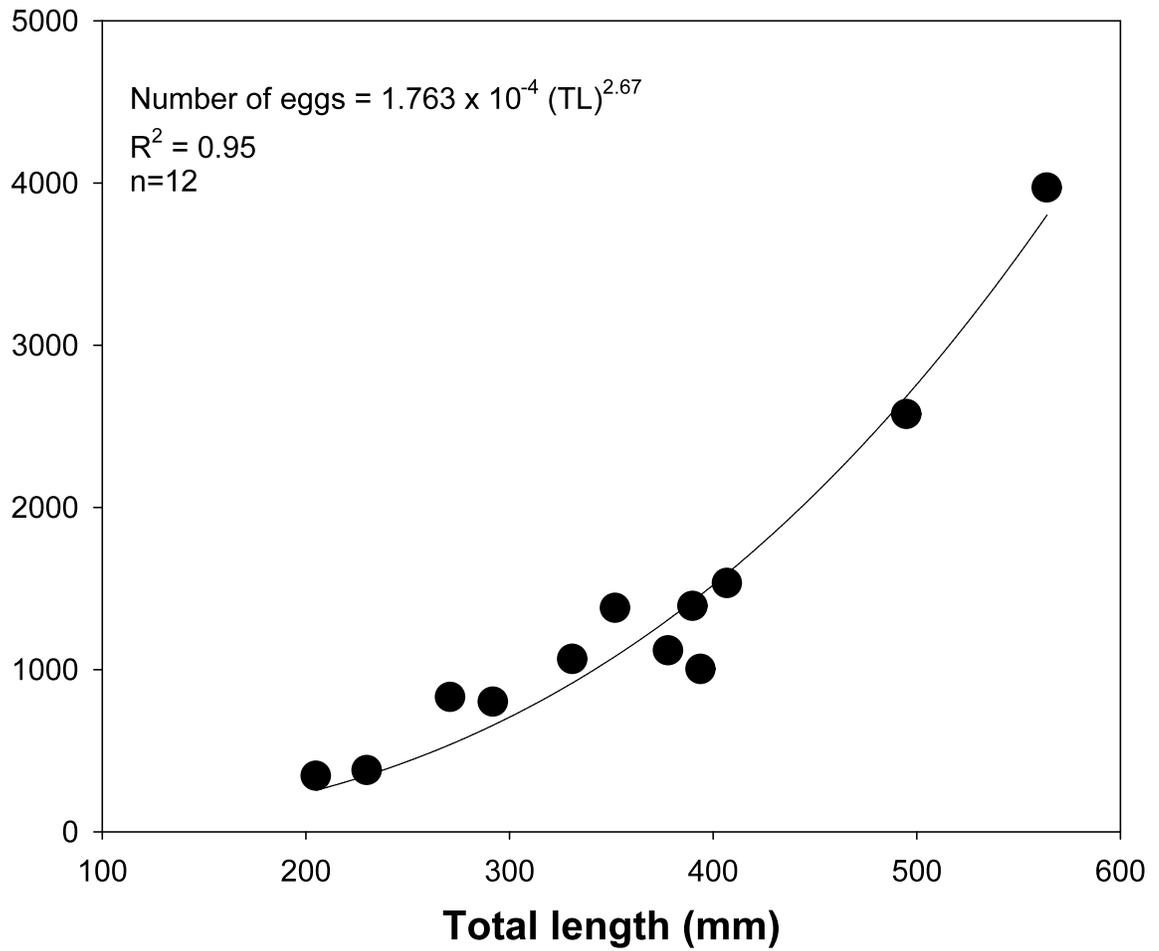


Figure 22. Female length-fecundity relationship for South Fork Walla Walla river bull trout (2002-2007).

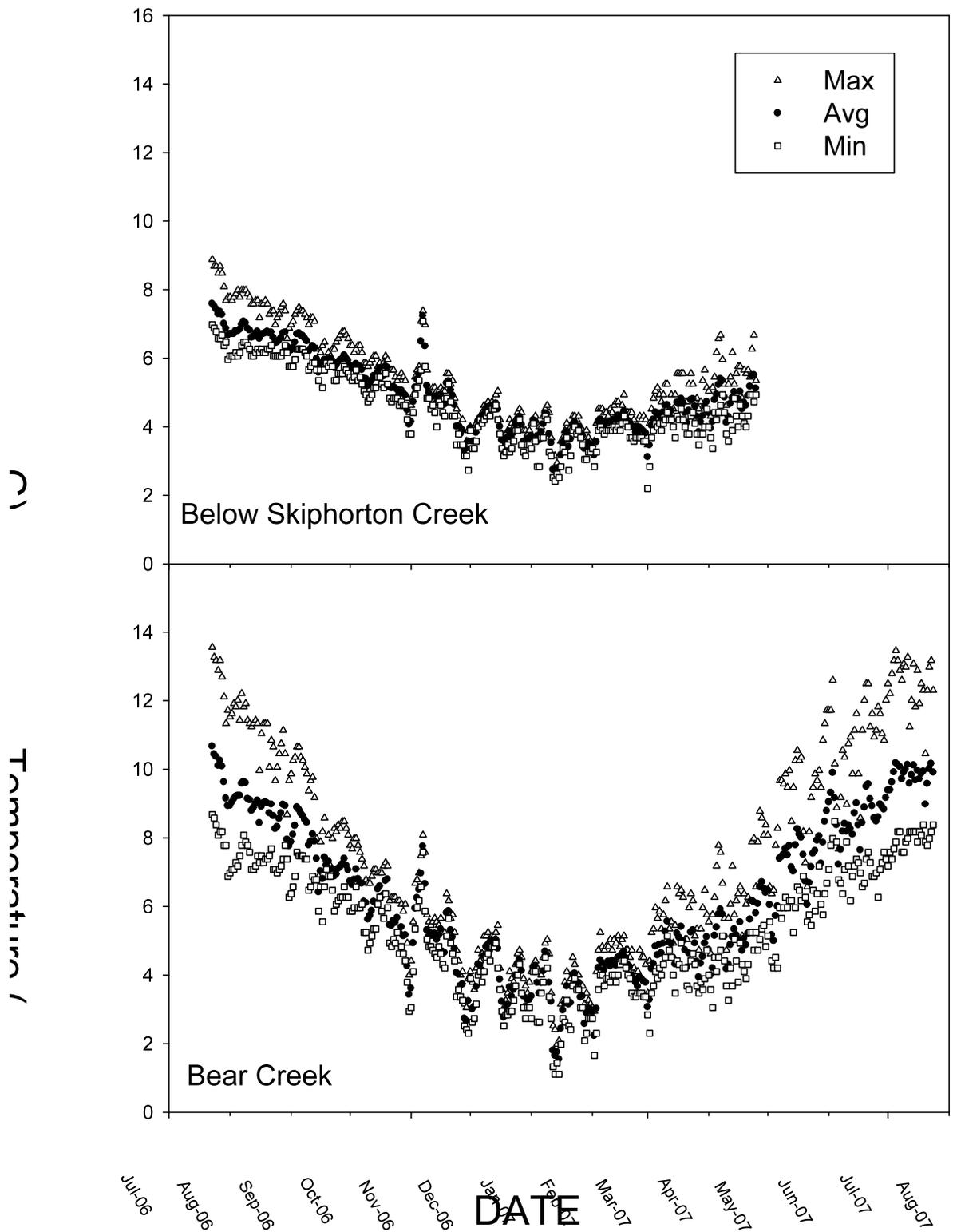


Figure 23. Daily temperatures (maximum, mean, minimum) recorded at two locations (Skiphorton Creek is higher and Bear Creek is lower in the study area) on the South Fork Walla Walla River, July 2006 - June 2007.

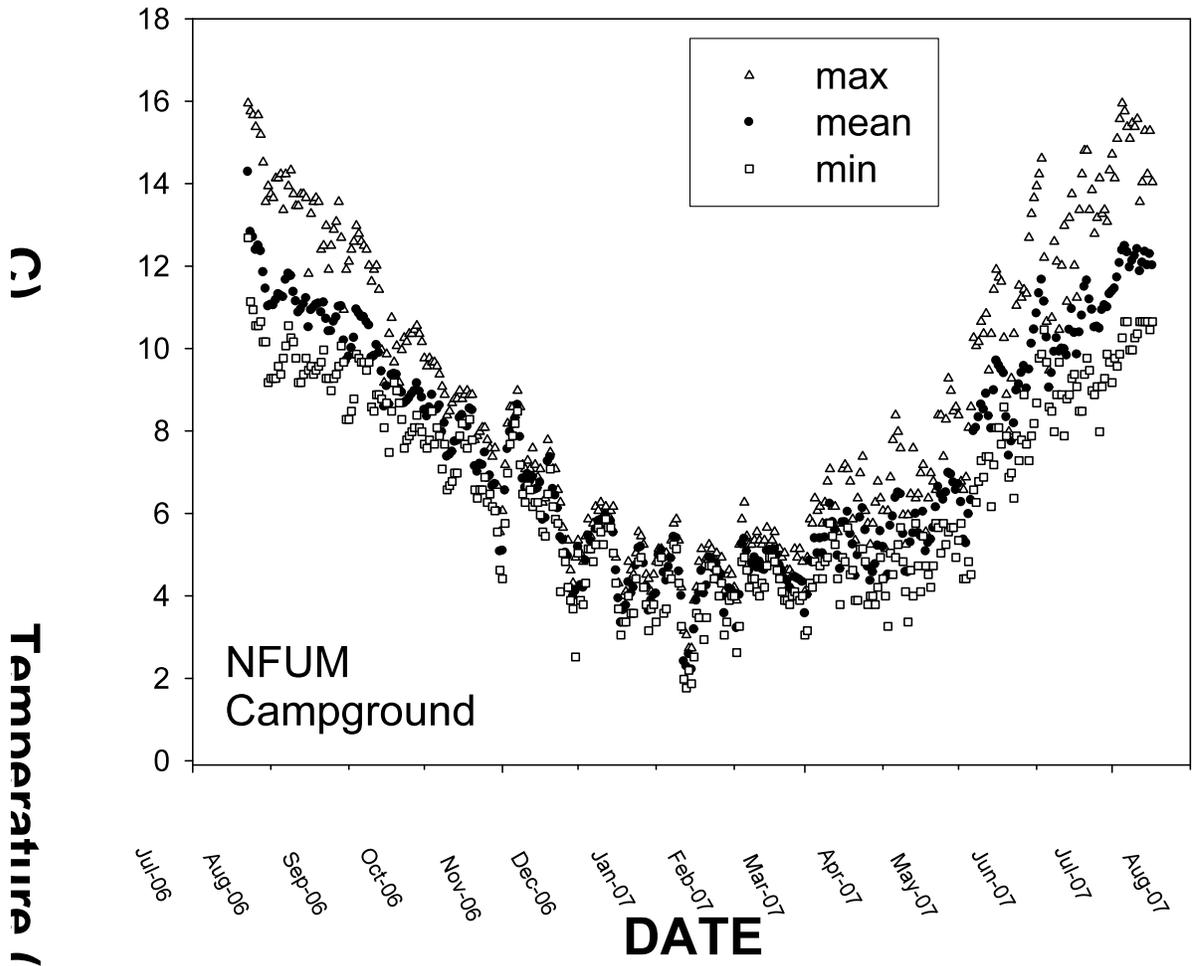


Figure 24. Daily temperatures (maximum, mean, minimum) recorded at one location (campground is at bottom of study area) on the North Fork Umatilla River July 2006 - July 2007.

Appendix 1

Pilot assessment of juvenile bull trout growth, abundance, and survival.

INTRODUCTION

Many salmonids utilize a range of habitats throughout different life stages (Hilborn et al. 2003), and factors limiting survival may vary for different life stages. In order to prioritize recovery efforts for imperiled populations, it is critical to identify which life stages are most vulnerable and how environmental factors affect growth and survival at critical life stages.

Populations of bull trout, *Salvelinus confluentus*, have experienced declines in distribution and abundance across much of their historic range (McPhail and Baxter 1996). Bull trout may be particularly sensitive to environmental perturbations because of their narrow requirements for spawning and rearing habitat, including cold water temperatures (Selong et al. 2001) and complex habitat (Spangler and Scarnecchia 2001). The conservation and recovery of bull trout populations requires knowledge about factors limiting population growth, including which life stages have the greatest impact on overall population growth rates.

For many fish, early life-stage survival and vital rates play an important role in determining adult population dynamics (Rice et al. 1987). Bull trout population models show that survival rates for juvenile size classes (<220 mm) may have large impacts on overall population growth (Al-Chokhachy 2006; Johnston et al. 2007). Results from Johnston et al. (2007) suggest that survival of juveniles was influenced by density-dependent mortality during early juvenile stages (egg stage to age-1), which regulated recruitment into the adult population. This study did not identify a mechanism behind this population bottleneck, but it clearly demonstrated the need to examine life history stages independently when considering factors that influence overall population growth. Factors which reduce egg and juvenile survival may significantly impact bull trout population growth and further studies are needed to identify factors limiting these early life stages (e.g., spawning, egg incubation, emergence, early rearing stages), as well as assess the relationship between early life-stage survival and overall population demographics (Shea and Mangel 2001).

While studies have quantified habitat use for juvenile bull trout (Goetz 1997; Spangler and Scarnecchia 2001), few have identified limiting factors for this life stage. Sampling of juvenile bull trout can be difficult due to their benthic orientation, cryptic behavior, and diel or nocturnal behavior (Fraley and Shepard 1989). Long-term studies that assess survival and potential limiting factors during early life stages are critical components in understanding what drives overall population growth for bull trout. Survival and movement information during this critical life stage will aid in the development of recovery and management strategies for imperiled populations (Homel and Budy 2007).

In this study, we began preliminary research to assess growth and estimate abundance and apparent survival for juvenile bull trout (70-220 mm) in two tributaries to the South Fork Walla Walla River. We actively marked juvenile fish during two different sampling events in order to: 1) obtain preliminary abundance estimates and 2) mark a sub-set of the juvenile population in order to estimate apparent survival and growth via future mark-recapture sampling.

STUDY AREA

Skiphorton Creek originates in the foothills of the Blue Mountains of northeastern Oregon and enters the South Fork Walla Walla River (SFWW) approximately 110 kilometers upstream from the confluence of the South Fork and mainstem Walla Walla River. Much of the bull trout spawning in this system occurs in the SFWW in the proximity of Skiphorton Creek and in several small tributaries, including Skiphorton Creek. Juvenile rearing takes place throughout much of the SFWW, with high densities of juveniles in Skiphorton Creek and the Upper SFWW River.

We captured juvenile bull trout in Skiphorton Creek and the Upper SFWW River above the confluence with Reser Creek. We sampled approximately 335 meters of the Upper South Fork Walla Walla above Reser Creek and approximately 500 m of Skiphorton Creek, which was divided into 8 contiguous reaches of approximately 50 m in length.

METHODS

In 2007, we initiated a pilot study to assess the effectiveness of juvenile capture techniques and collect baseline data on juvenile abundance and distribution. This research will be used to estimate apparent survival and movement patterns for juvenile bull trout (70-220 mm) in the mainstem and tributaries to the SFWW

River, with a particular focus on Skiphorton Creek, a tributary which provides rearing habitat for a relatively high density of juvenile bull trout.

Fish Sampling

Fish capture and marking.—We used multiple sampling techniques to capture juvenile bull trout, including electrofishing downstream to a seine, snorkeling and disturbing substrate above a seine, and baited minnow traps. All captured fish were scanned for PIT tags. Fish <70 mm (age-0) were weighed and measured and quickly returned to shallow, slow-water habitat. We anaesthetized fish >70 mm and once fish were unresponsive to stimuli, we used a surgical incision to insert 8-mm or 12-mm PIT tags in the ventral cavity, anterior to the pelvic fins. All captured fish were weighed to the nearest 0.1 grams, and measured to the nearest mm total length (TL). Condition (K_{TL}) for each fish was calculated using the following formula: Fulton's $K_{TL} = W/L^3 \times 100,000$. Adipose fins were clipped to identify marked fish and preserved for potential future genetic research. Scales were taken from the right side at the base of the dorsal fin for aging and growth information, and fish were placed in a flow-through recovery container within the channel and released to slow-water habitat near the point of capture after full equilibrium was restored.

Recapture.—Tagged bull trout were recaptured 47 days (in the Upper SFWW) or 34 days (in Skiphorton Creek) after initial PIT tagging to assess over-summer growth (July through mid-August) and to estimate population size. Recapture methods included seining and electrofishing to a seine. Recaptured fish were passed over a handheld PIT-tag detector, and lengths and weights were recorded to obtain information about growth rates and condition. Future recapture information will be obtained from mark-recapture sampling and via pass-through PIT-tag antennae located in the mainstem SFWW downstream from the study sites. Additional recapture events will provide estimates of juvenile growth and survival and juvenile movement patterns.

Growth

Over-summer growth information was obtained from juvenile bull trout tagged in Skiphorton Creek and the Upper SFWW at the beginning of the study season (late June/early July) and recaptured at the end of the study season (mid-August). Differences in length and weight were determined between initial tagging and subsequent capture events and delineated by size class at initial tagging.

Population Estimates

We used numbers of tagged fish to parameterize mark-recapture population estimates using a Chapman bias-adjusted estimator (Hayes et al. 2007; Krebs 1999) and estimated the overall population size for fish 70-220 mm in Skiphorton Creek and the Upper SFWW.

Other Species

We counted all *Oncorhynchus mykiss* and Chinook salmon, *Oncorhynchus tshawytscha*, caught during sampling in both Skiphorton Creek and Upper SFWW River, and placed them in two size classes, <150 mm and >150 mm.

RESULTS and DISCUSSION

Fish Sampling

Fish capture and marking.—We established preliminary study sites in Skiphorton Creek and the Upper SFWW River. All captured bull trout were weighed and measured, and a separate length-weight relationship was calculated for each stream system (Figure A1).

A total of 239 fish were captured in Skiphorton Creek during two discrete capture events, of which 153 were tagged. The number of fish tagged varied between sample reaches (Figure A2). In the Upper SFWW, a total of 151 fish were caught during two capture events, of which 82 were tagged. In Skiphorton Creek, a total of 14 fish were recaptured in the second sampling event; in the Upper SFWW River, 10 fish were recaptured.

In these two systems, fish length ranged from 36 to 211 mm (Figure A1). Length-frequency distribution for captured bull trout was similar between the two study areas; tight clusters in length-frequency distributions suggest that age-0 fish range between 36-62 mm in length, age-1 fish range from 79-139 mm, and age-2 fish likely range between 140-180 mm in length (Figures A1 and A3). The highest frequency of fish captured in both systems was between 90 - 110 mm in length (Figure A3). The small numbers of fish >180 mm and the complete absence of fish >211 mm caught during sampling suggests that larger fish (likely age-2 and older) leave these headwater systems and move downstream into the mainstem SFWW River.

Condition.—Condition was similar between systems and between different age classes of fish (Figure A4). In Skiphorton Creek, average condition for all size classes decreased slightly between the July (for all size classes <170 mm, mean $K=0.88$) and August sampling events (for size classes <170 mm, mean $K=0.84-0.87$). Condition for fish in the Upper SFWW River showed greater variability between and among size classes than in Skiphorton Creek (mean $K=0.82-0.94$).

Growth

Tagged fish.—We recaptured 14 fish in Skiphorton Creek and 10 in the Upper SFWW; we estimated over-summer growth for recaptured fish, although the sample size was small. Juvenile fish in the Upper SFWW grew more throughout the summer than did fish in Skiphorton Creek (Figure A5). Mean growth for age-1 fish in Skiphorton Creek equaled 6.3 mm and 1.64 g versus 12.3 mm and 3.7 g in the Upper SFWW. Mean growth for age-2 fish in Skiphorton Creek was 2.76 mm and 1.11 g versus 14.3 mm and 7.1 g in the Upper SFWW. Time between sampling dates was 34 days in Skiphorton Creek and 47 days in the Upper SFWW. In August, fish in the Upper SFWW were significantly longer and heavier than those in Skiphorton Creek (difference in length, $p=0.04$; difference in weight $p=0.03$). This was likely a result of higher water temperatures in the Upper SFWW throughout most of the study period (Figure A7). Tagged fish in Skiphorton Creek exhibited no difference in mean length and weight from the sampled population (Figure A6), indicating that carrying a PIT tag during the time between sampling events did not appear to affect growth.

Population Estimates

Using catch information from the stream sections sampled, we estimated the abundance of juvenile bull trout (70-220 mm) in 500 meters of Skiphorton Creek and 335 meters of the Upper SFWW. We estimated the abundance to be 563 (95% CI = 332-794) in Skiphorton Creek and 321 (95% CI 188-435) in the Upper SFWW.

Other Species

No Chinook salmon were captured or observed in either Skiphorton Creek or the Upper SFWW. In both systems, few *O. mykiss* were captured during both sampling events (Figure A8).

FUTURE

In 2008, we will continue tagging and monitoring juvenile bull trout in Skiphorton Creek and throughout the SFWW, along with monitoring abiotic variables that may potentially influence bull trout growth and survival (e.g., flow, temperature). We will conduct three active mark-recapture events in Skiphorton Creek, spaced evenly throughout the summer in order to allow sufficient time for fish to recover after handling (Bateman and Gresswell 2006). In both Skiphorton Creek and the SFWW, we will gather continuous recapture data from in-stream PIT-tag passive antennae arrays (detectors). Recapture data will allow us to estimate apparent survival rates for juvenile bull trout (70-220 mm) and assess juvenile movement patterns in both a small tributary that appears to provide primarily rearing habitat (Skiphorton Creek) and in the larger mainstem SFWW, which provides both juvenile rearing and resident adult habitat.

LITERATURE CITED

- Al-Chokhachy, R. 2006. An assessment of the dynamics and limiting factors of a fluvial bull trout population. Doctoral dissertation. Utah State University, Logan, Utah.
- Bateman, D.S. and R.E. Gresswell. 2006. Survival and growth of Age-0 steelhead after surgical implantation of 23-mm passive integrated transponders. *North American Journal of Fisheries Management* 26:545-550.
- Fraley, J.J., and B.B. Shepard. 1989. Life-history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. *Northwest Science* 63:133-143.
- Goetz, F.A. 1997. Diel behavior of juvenile bull trout and its influence on selection of appropriate sampling techniques. *Friends of the Bull Trout Conference Proceedings*:387-402.
- Hayes, D.B., J.R. Bence, T.J. Kwak, and B.E. Thompson. 2007. Abundance, biomass, and production. Pages 327-374 in: Guy, C.S., Brown, M.L., editors. *Analysis and interpretation of freshwater fisheries data*. American Fisheries Society, Bethesda, Maryland.
- Hilborn, R., T.P. Quinn, D.E. Schindler, and D.E. Rogers. 2003. Biocomplexity and fisheries sustainability. *Proceedings of the National Academy of Sciences of the United States of America* 100:6564-6568.
- Homel, K., and P. Budy. Accepted. 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*.
- Johnston, F.D., J.R. Post, C.R. Mushens, J.D. Stelfox, A.J. Paul, B. Lajeunesse. 2007. The demography of recovery of an overexploited bull trout, *Salvelinus confluentus*, population. *Canadian Journal of Fisheries and Aquatic Sciences* 64:113-126.
- Krebs, C.J. 1999. *Ecological methodology*. Addison-Wesley Educational Publishers, Inc., U.S.A.
- 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.

- Rice, J.A., L.B. Crowder, M.E. Holey. 1987. Exploration of mechanisms regulating larval survival in Lake Michigan bloater: a recruitment analysis based on characteristics of individual larvae. *Transactions of the American Fisheries Society* 116(5):703-718.
- Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout with application of an improved method for determining thermal tolerance in fishes. *Transactions of the American Fisheries Society* 130:1026-1037.
- Shea, K., M. Mangel. 2001. Detection of population trends in threatened coho salmon. *Canadian Journal of Fisheries & Aquatic Sciences* 58:375-385.
- Spangler, R.E., and D.L. Scarnecchia. 2001. Summer and fall microhabitat utilization of juvenile bull trout and cutthroat trout in a wilderness stream, Idaho. *Hydrobiologia* 452:145-154.

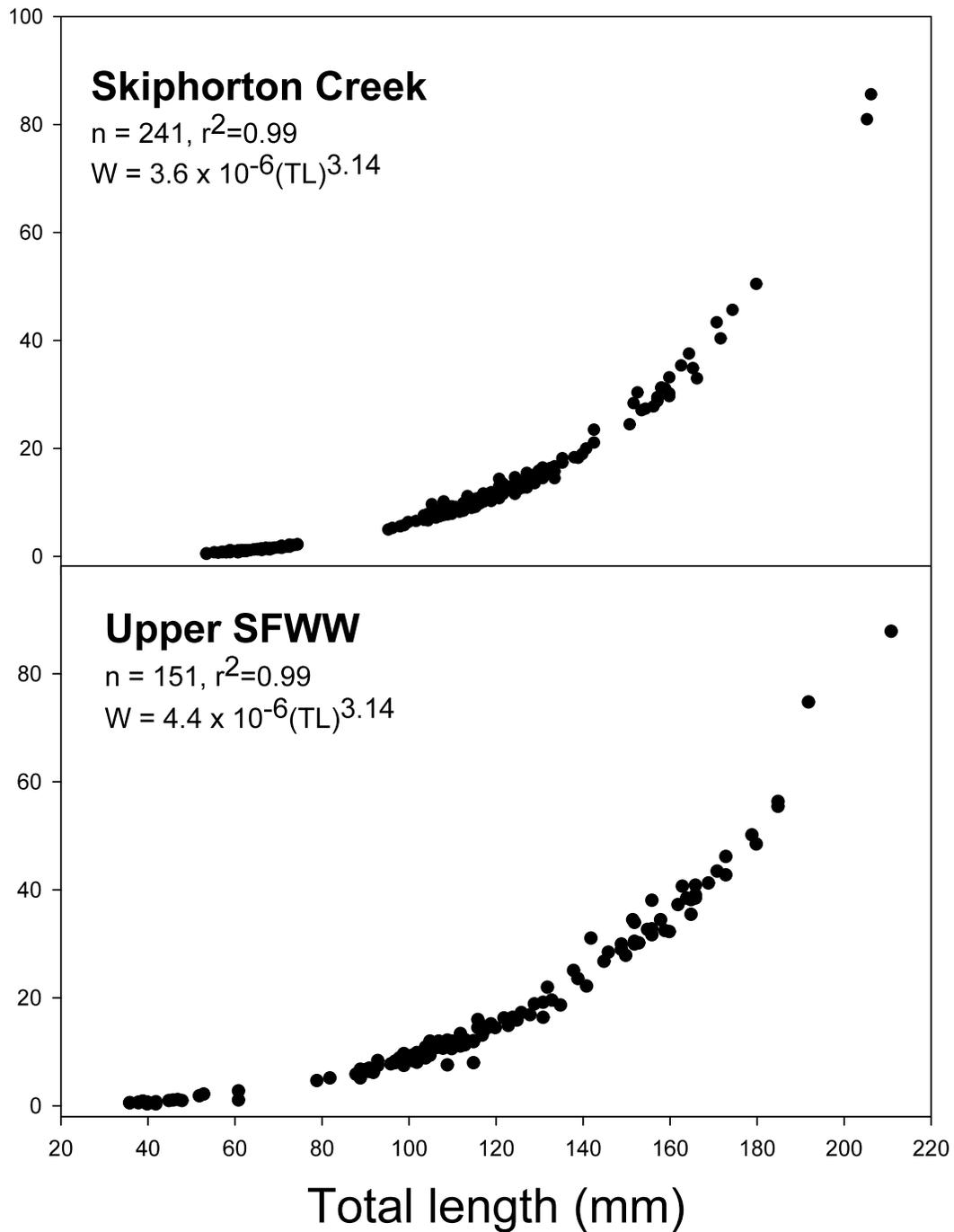


Figure A1. Length-weight relationship for all bull trout captured and handled in Skipthorton Creek and Upper South Fork Walla Walla River, 2007. Regression equations and sample sizes given.

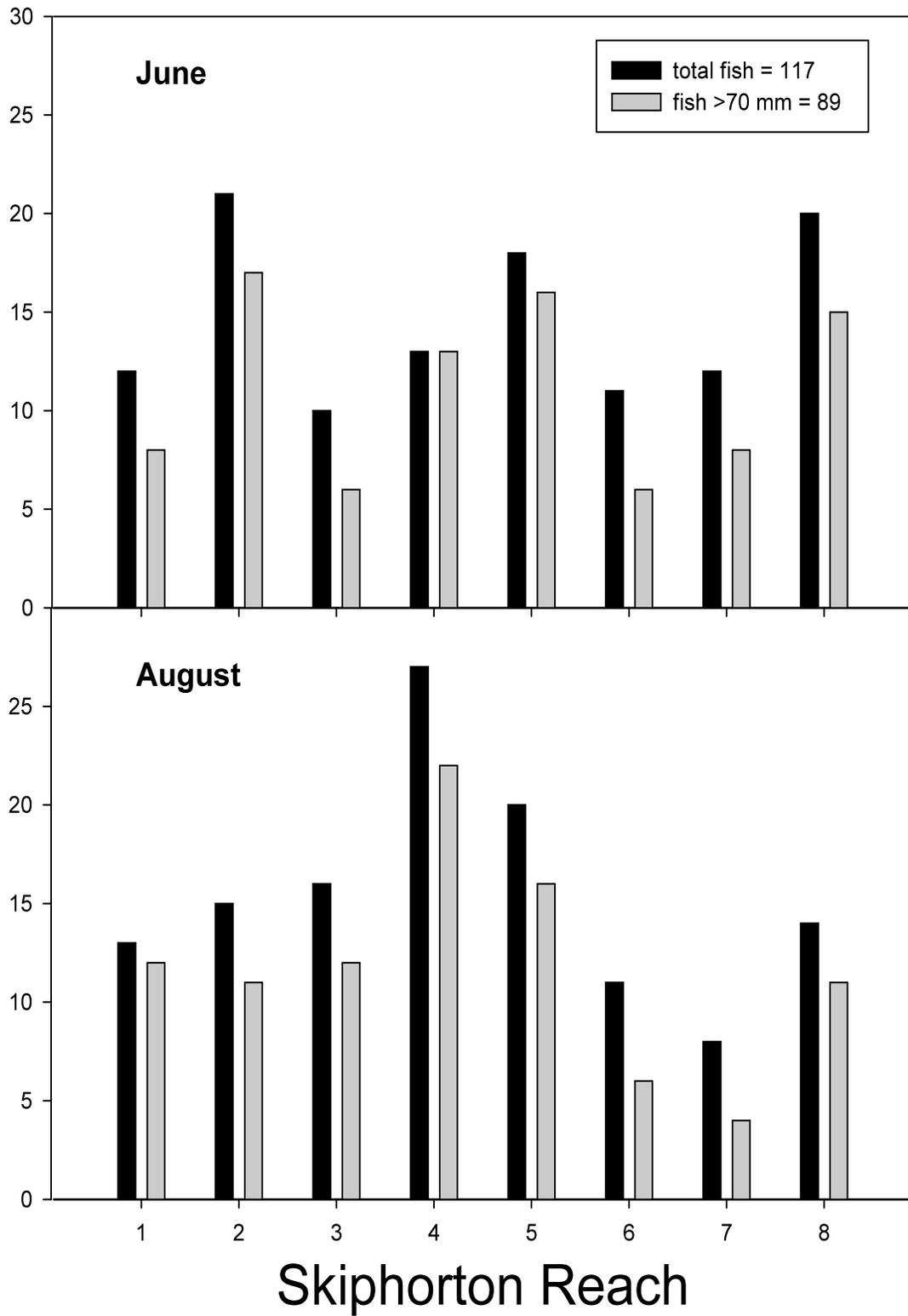


Figure A2. Number of bull trout tagged by reach in Skiphorton Creek (each reach is approximately 50 m in length). Reaches are numbered from downstream to upstream end of study site. Total numbers of fish caught in each reach are given.

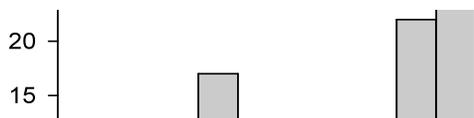
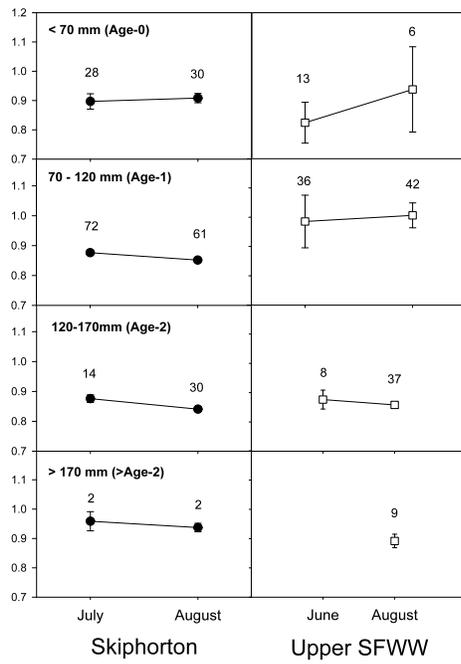


Figure A3. Length-frequency (% of catch) distribution of juvenile bull trout captured and handled in Skiphorton Creek and Upper South Fork Walla Walla River, 2007.

Figure A4. Condition (Fulton's $K \pm 1$ SE) for four different size classes of bull trout sampled in Skiphorton Creek and Upper South Fork Walla Walla River, 2007. Sample size is given above error bars. Time between sample periods was 34 days in Skiphorton Creek and 47 days in Upper SFWW River.



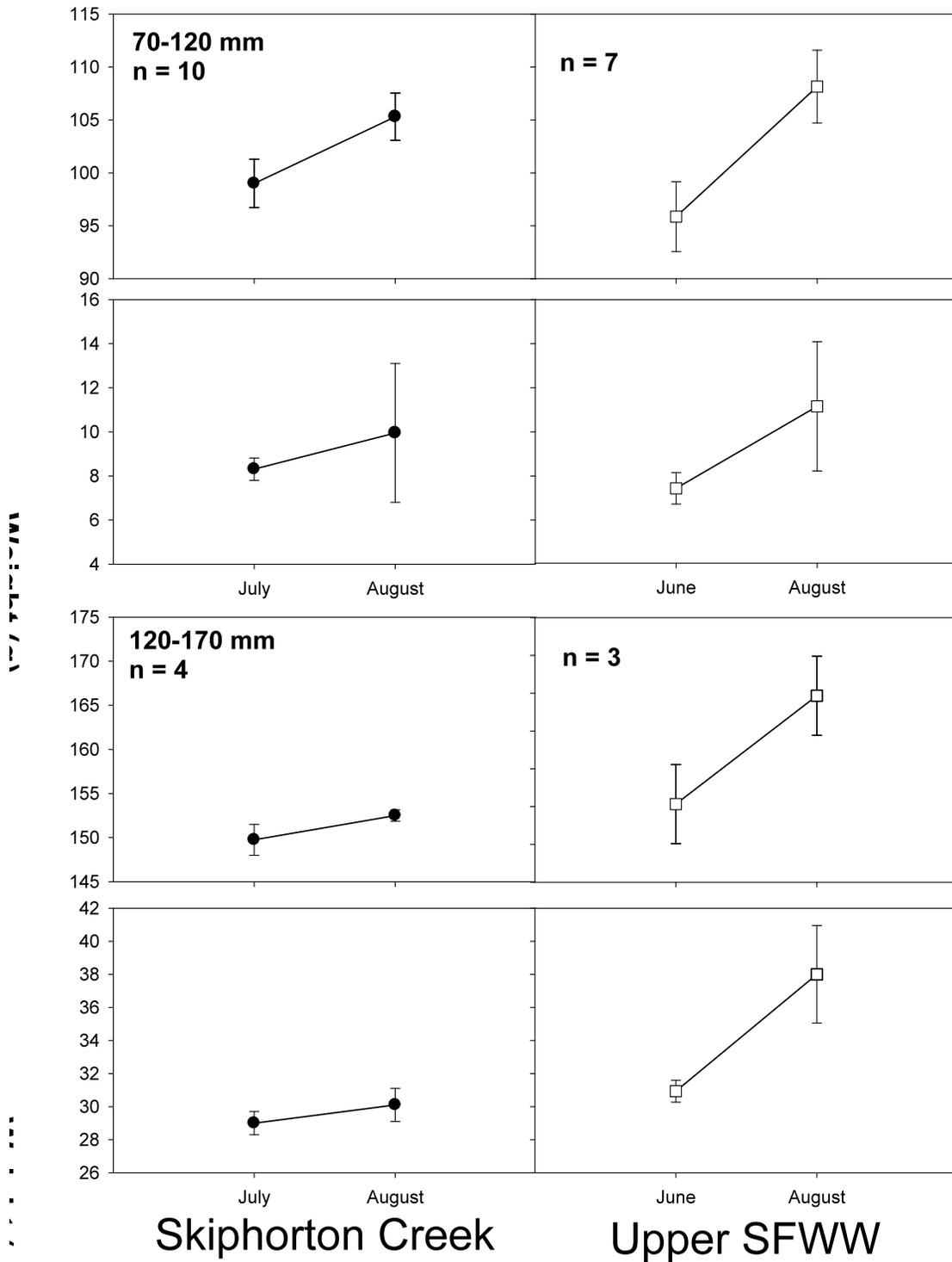


Figure A5. Lengths and weights (± 1 SE) for two size classes of juvenile bull trout recaptured in Skiphorton Creek and Upper South Fork Walla Walla River, measured during two discrete sampling events. Time between sampling dates was 34 and 47 days, respectively. Sample sizes are given.

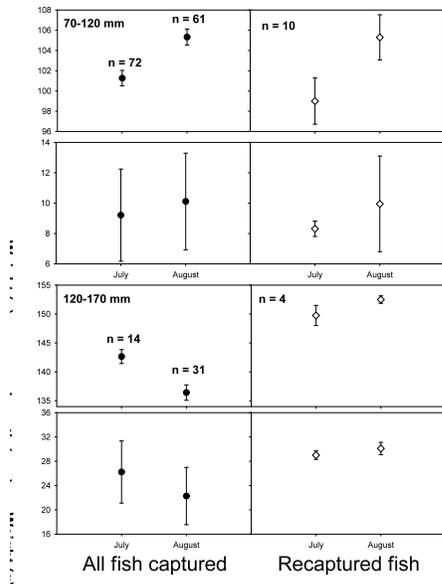


Figure A6. Mean lengths and weights (± 1 SE) for all fish captured in Skiphorton Creek compared with recaptured PIT-tagged fish. Tagged fish show no difference in size from non-tagged fish. The apparent decline in fish size for non-tagged fish in August is a result of more small fish moving into the 120-170 mm size category.

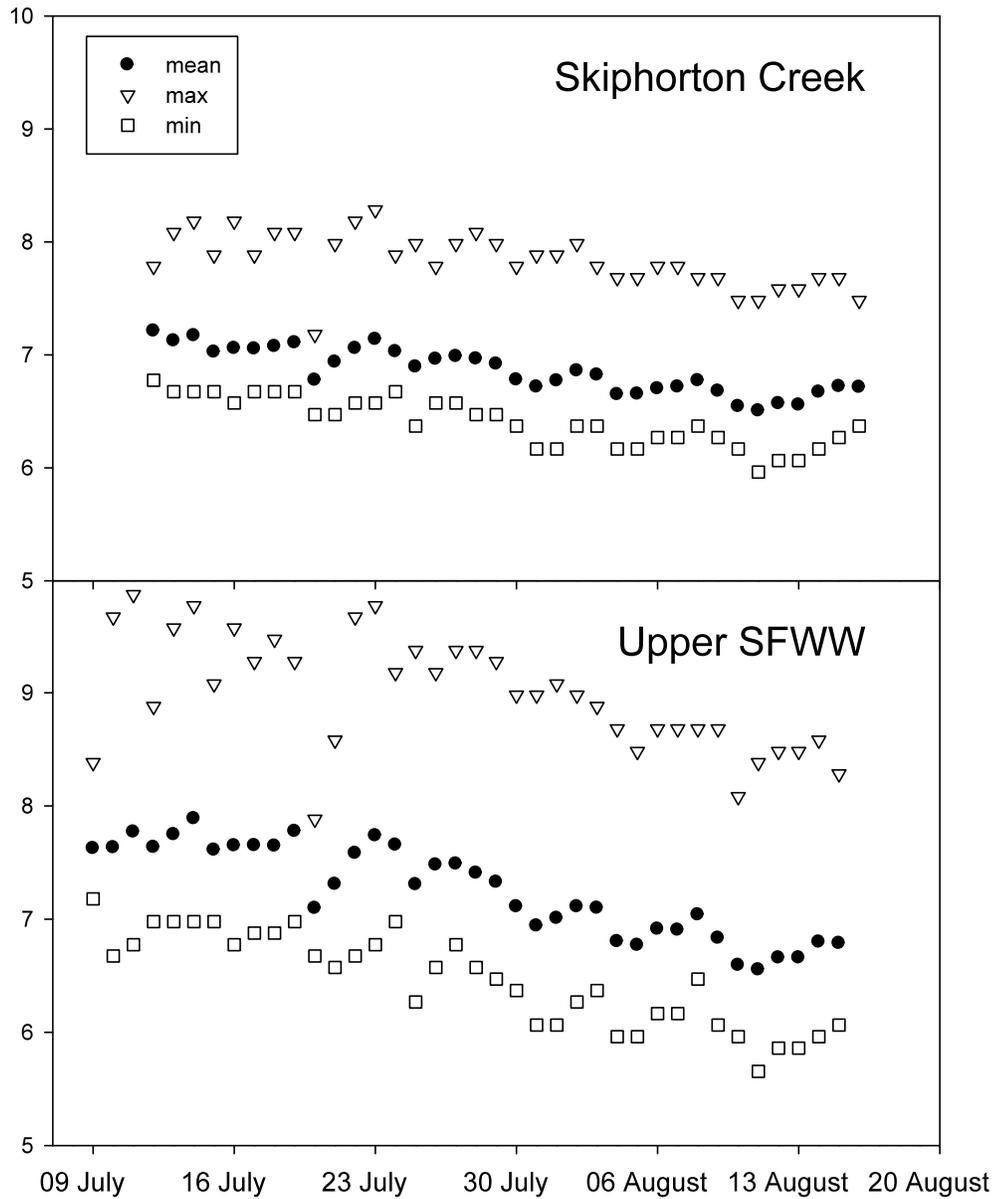


Figure A7. Daily temperatures (maximum, mean, minimum) recorded in Skiphorton Creek and Upper South Fork Walla Walla River study sites during the time period between capture events, July 7-August 15, 2007.

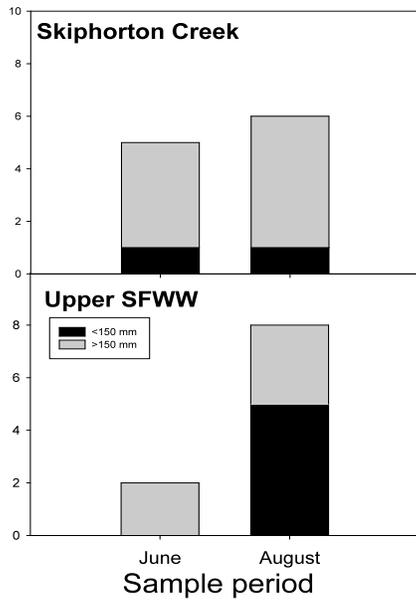


Figure A8. Number of *Oncorhynchus mykiss* in two different size classes caught during two discrete sampling events in Skiphorton Creek and Upper South Fork Walla Walla.

APPENDIX 2

Original objectives and tasks specified to meet the overall 5-year project goals.

Objective 1. Comprehensive bull trout population assessment and monitoring.

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. Comprehensive stream and riparian habitat assessment and monitoring.

Task 2.1 Habitat assessment.

Objective 3. Innovative pass-through PIT-tag monitoring system.

Task 3.1 Tagging, detection, and fish movement.

Objective 4. Data analysis.

Task 4.1 Analysis of mark-recapture data: population estimates and movement.

Task 4.2 Analysis of snorkel data: parr density and habitat use.

Task 4.3 Analysis of adult and egg data: egg-to-parr survival.

Task 4.4 Analysis of habitat attributes in relation to fish survival and density.

Objective 5. Summarizing available information into a simple population model.

Task 5.1 Assemble and summarize all existing bull trout population and life-history data for the selected tributaries of the Walla Walla Subbasin.

Task 5.2 Building the population life-cycle model.

Objective 6. Describe current habitat conditions and land use patterns as they relate to bull trout survival and growth.

Task 6.1 Summarize and quantify all available habitat data.

Task 6.2 Exploring the relationship between habitat and bull trout population status indicators.

Task 6.3 Model calibration and validation.