Bull trout population assessment and life-history characteristics in association with habitat quality and land use: a template for recovery planning

Annual Progress Report for 2003

by

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EXECUTIVE SUMMARY

Research was initiated in 2002 and continued and expanded through 2003. In 2003, we sampled 40% of the South Fork Walla Walla River (SFWW) study area (20% from 2002 reaches, 20% new), 468 fish were tagged, and all associated demographic and project assessment data were collected, analyzed, and synthesized. In addition, we completed detailed habitat assessments in the SFWW in 21 reaches; habitat availability and habitat use were quantified at the microhabitat scale, the mesohabitat (unit) scale, and at the macrohabitat (reach) scale. In 2003, we also expanded the fish population tagging and monitoring into the North Fork Umatilla River (NFUMAT); 20 reaches were sampled, 81 fish were tagged, and all baseline demographic and assessment data were collected, analyzed, and synthesized. Equipment was purchased and permits (US Forest Service) were received to install a passive PIT-tag antennae, (slated for June 2004), at the lowermost reach of the NFUMAT study area.

In 2003, population estimation resulted in an abundance estimate of 8533, a slight, but insignificant increase over 2002. These data suggest there is a large population of bull trout in the SFWW, ranging in size from 50 to 620 mm. Population estimates for the NFUMAT indicate that there are about 2500 fish (but with less certainty); bull trout were generally smaller ranging from 75 to 400 mm. The relationship between redd count-based abundance estimates and population estimates based on mark-recapture, for large fish, indicated that even with the application of a high estimate of fish per redd, redd counts significantly underestimate the population abundance. As observed in the previous year, in 2003, annual population estimation based on mark-resight appeared to be a robust technique, as demonstrated by several different data comparisons and evaluations.

Most fish movement in the SFWW occurred between the months of May to November, at both detection sites, and for all sizes of fish. Fish condition was greatest, and the most variable, for the intermediate adult size class (220 – 330 mm) and declined overall from 2002 to 2003, in the SFWW. Diet analyses demonstrated that bull trout in both systems consume a high proportion of aquatic invertebrates with less fish; a relatively high degree of cannibalism was noted. Future research, monitoring, assessment, and evaluation plans are discussed.

INTRODUCTION

When species are in decline or listed under conservation status across a large spatial area, estimates of population abundance are critical for understanding the status of the population as well as for recovery planning. In addition, the quantification of key demographic parameters (e.g., survival) is an important component in the process of identifying factors that potentially limit population growth rates overall. 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, and (5) the immediate, short term need information that typically requires years to collect.

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. They are primarily an inland species with a distribution from 41° N to 60° N latitude, from the southern limits in the McCloud River in California and the Jarbridge River in Nevada to the headwaters of the Yukon River in Northwest Territories (Cavender 1978). Resident and migratory populations exist within this range and can coexist together, representing a diverse population (Rieman and McIntyre 1993). Migratory bull trout exhibit complex life histories; juveniles rear in small natal tributaries for 1-3 years before migrating to larger systems for some period of time, then return to their natal streams to spawn (Fraley and Shepard 1989). 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 led to the decline in the bull trout populations in the Columbia River Basin and the Klamath River Basin. Today, bull trout exist only as subpopulations over a wide range of their former distribution (Rieman et al. 1997), and several local extirpations have been documented. Habitat fragmentation and degradation has partially isolated local populations (Rieman and McIntyre 1993).

The goal of bull trout recovery planning by the United States Fish and Wildlife Service (USFWS) is to describe courses of actions 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, USFWS has identified several objectives which require the type of information that will be 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. Further, the USFWS recovery-planning document (Lohr et al. 1999) embraces the idea of core areas. Conserving respective core areas and their habitats within recovery 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 recovery units and their role in overall recovery of the Columbia River distinct population segment.

For most threatened populations of bull trout in the Columbia River basin, little is known about the structure of the population (e.g., migratory versus resident and age), the status (e.g., size and trend), or the factors that may limit the population, naturally, or anthropogenically (Rieman and McIntyre 1993; Buchanan et al. 1997; USFWS 1998). These limitations are important to overcome, in order for proper status evaluation and for identifying management actions aimed at recovery (Meffe et al. 1997). For many bull trout populations, there is some knowledge of the migratory component, but very little is known about the resident component, or whether or not there are in fact two distinct life history forms present. Migratory bull trout have likely experienced greater declines due to their attempts to move through fragmented landscapes that often exist below their higher elevation, spawning and rearing tributaries (Rieman and McIntyre 1993); however, distinction between the two forms in nature has rarely been demonstrated, and recovery goals are vague as to which component of the population is included (Marmorek and Porter 2004). In addition, the total size of a population may be important for its persistence (Soule 1987), as larger populations are less vulnerable to stochastic environmental events (Rieman and McIntyre 1993). Finally, it is important to address habitat variables (water temperature, percent fines, habitat complexity, scale of habitat, etc.) that may affect the survival rates at critical life cycle stages (Rieman and McIntyre 1995). These variables may contribute to the stability, growth, or decline of the population (Stacey and Taper 1992; Rieman and Dunham 2000) through their effects at one or more life stages. Ultimately, variables such as habitat, that may limit growth and survival, must be linked to population structure and status.

The natural behavior and habitat preference of bull trout further hampers the limited amount of information on bull trout population structure, size, and demographics. These fish are typically thought to be nocturnal and demonstrate cryptic and elusive behavior (Shepard et al. 1984; Goetz 1991; Bonneau et al. 1995). Further, their potentially diverse habitat requirements, and presence in cold, high discharge, high gradient streams, make evaluation difficult (Pratt 1984; Goetz 1991). And, as noted above different life-history forms often coexist together (e.g., migrating and resident forms; Fraley and Shepard 1989; Goetz 1991; Rieman and McIntyre 1993) with no clear distinction between the two (or more) forms when they co-occur. Accordingly, there is a heavy reliance on redd counts to assess salmonid populations in the Columbia River Basin; however, redd surveys alone may be insufficient for bull trout. Detection of redds from small, sexually mature, resident fish can be difficult, and Dunham et al. (2001) demonstrated that in addition to substantial observer error in counting redds, bull trout spawning activity was highly variable both temporally and spatially. Finally, since bull trout are not obligate annual spawners (Rieman and McIntyre 1993), it may be difficult to monitor population status and trends solely using this method (Maxell 1999). Nevertheless, redd counts are economical and provide managers with estimates (albeit potentially biased) of population trends. The challenge lies in determining the relationship between redd counts and true population size and structure.

Within this overall framework, this project will provide critical information on bull trout population abundance and trends, relationships to habitat, and information on the potential for improving survival through habitat protection or restoration that will ultimately help guide the USFWS in determining the necessary courses of action and management actions for recovery. Thus, one of the primary purposes of our project is to quantify and evaluate bull trout population structure, abundance, survival, and population trends as a function of habitat quality and quantity. The South Fork Walla Walla River was initially selected as the comprehensive study area due to its potential as a core area for bull trout in the Columbia River Basin and complex and potentially contentious water management issues associated with fish protection. With an abundance of fish and diverse habitats, the Walla Walla River subbasin offers a unique opportunity to study bull trout population structure and dynamics, including bull trout survival. In addition, selected project goals (e.g., validation of habitat modeling) have required the extension of monitoring and evaluation into other nearby watersheds (e.g., North Fork Umatilla and Wenaha rivers). The data and conservation assessment tools provided by this project will be used in bull trout recovery planning and will provide a template for research, monitoring, and evaluation programs for bull trout populations throughout this as well as other provinces. Preliminary data from 2002 and 2003 are currently being used by the USFWS Bull Trout Research, Monitoring, and Evaluation Technical team (RMTEG; Marmaduke and Porter 2004).

BULL TROUT and the STUDY AREA

Genetic analysis suggests that bull trout populations from the John Day River basin and northeastern Oregon (including the Walla Walla, Umatilla and Grande Ronde basins) comprise a major genetic lineage (Spruell and Allendorf 1997).

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). 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 (*O. tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*) salmon, 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, and mountain whitefish 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).

Prior to this study, the majority of bull trout population assessment within the SF Walla Walla River has occurred through annual redd counts, which have been conducted in the SF Walla Walla River and Mill Creek since 1994. However, the status of the total population (all ages, resident and fluvial) of bull trout in the Walla Walla River and its tributaries is not known (Buchanan et al. 1997).

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 county land). 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 km^2. 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 (Contor et al 1995). 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^{o}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, suckers (*Catostomus* spp.), dace, and northern pikeminnow (*Ptychocheilus oregonensis*; CTUIR 1994, Himmingson et al. 1996). 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 5 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 21 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.

Multiple agencies are conducting coordinated research in our study area. Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) currently conduct research on the distribution and movement of bull trout within the lower sections of the Walla Walla River and Mill Creek (a tributary of the Walla Walla River), and limited movement and status monitoring occurs in the other tributaries. In addition, the USFWS is evaluating habitat limitations for juvenile fishes in the migratory corridor below our study area.

METHODS

Fish Sampling

Capture-- Multiple sampling techniques were used to capture bull trout including angling, electroshocking down to a seine, trap netting, and minnow trapping. 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 for fecundity and sex ratio estimates. We also obtained information from mortalities (non-project related) found in each stream. From this subsample, stomachs and hard parts (e.g., otoliths) were removed for age, growth, and diet analyses. Gonads were weighed (wet and dry weights and volume determined), eggs-per-female counted, and the diameter of a subsample of eggs was measured. Gonado-somatic index was calculated as the percent body weight that is gonad.

Marking-- 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 PIT-tag array antennae (see below) and snorkeling resights. Prior to tagging, bull trout were anesthetized with clove oil (25 µL per liter of water) until they exhibited little response to stimuli. A 23-mm PIT tag was then placed into a 7-mm 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. After surgery, 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 monitored until full equilibrium was restored. All fish were 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 = 255 m) of the South Fork Walla Walla River (SFWW) in 2002, 40 reaches (mean = 238 m) of the SFWW in 2003, and 17 reaches (mean = 211 m) of the North Fork Umatilla River (NFUMAT) in 2003. In addition, nighttime snorkel counts were conducted in tandem with daytime counts on one date in two sections of the NFUMAT. 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) and were enumerated and placed into 50-mm size classes, and all *O.*

mykiss spp. and juvenile chinook salmon were enumerated but not delineated by size. Accurate identification of fish species and size estimation was emphasized. Habitat surveys were conducted in 2003 in a subsample of snorkeled reaches. 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. Incidental juvenile steelhead trout were counted and classified as age-1+ (76 – 127 mm) and age-2+ (> 127 mm), according to the size classes of the Idaho Department of Fish and Game General Parr Monitoring program. Snorkel-sample reach lengths were measured so that fish density (number per 100 m^2) could be determined.

Recapture-- Tagged bull trout were recaptured one month after PIT tagging and will continue for the duration of the study (minimum of two years). We began recapturing tagged and untagged individuals using a combination of techniques: seining, trap netting, and pass-through PIT-tag technology described below. Recaptured fish were passed over a PIT-tag detector, and all information about each individual fish was retained electronically. In addition, tagged bull trout were and will be recaptured (and resighted during snorkeling surveys) and released for the duration of the study to provide annual estimates of survival, annual population estimates, and to parameterize the Pradel mark and recapture model. Recapture location will also provide information about movement and subpopulation versus metapopulation structure (*see also below*). Again, all captured bull trout were weighed and measured before release, to obtain information about annual growth rates and the effects of fish size on survival.

Passive fish detection-- PIT-tag antennae have been installed and continuously collect information on tagged bull trout from two locations within the SFWW. One passive array is located at Harris Park Bridge (UTM coordinates: 110408261 E 5076370 N) at the bottom of the study site, and the second site is located just above the confluence with Bear Creek (approximately 7 km upstream; UTM coordinates: 110414281 E 5077108 N). The Harris Park site has been running since mid-September 2002, and the Bear Creek site has been operational since mid-October 2002. Both sites are linked either through phone or satellite to the internet, and data is uploaded to the PTAGIS website.

In winter 2003, a site was selected and permitting was obtained to construct an antennae array on the NFUMAT on US Forest Service land under a road bridge (UTM coordinates: 110407659 E, 5064089 N) near the confluence with the Umatilla River. That site is scheduled to be operational by June 2004.

Diet analysis-- Stomach contents were preserved in 95% ethanol and analyzed in the lab. Stomach contents were identified to species of prey fish (when possible) using vertebral keys. Aquatic invertebrates were identified to order and terrestrial invertebrates were classified explicitly. Prey fish were counted and weighed (blot-dry wet weights to nearest 0.001 g), while invertebrate prey were weighed *en masse* by classification. Intact prey fish were measured to the nearest mm (backbone and standard length).

Otolith aging-- Sagittae otoliths were removed and preserved in 95% ethanol. Otoliths were defleshed, mounted on the sagittal plane on a slide cover slip, and ground with slight finger pressure using 600-grit sandpaper. Grinding was alternated with microscopic inspection until an appropriate level was reached. Finally, the prepared otolith was examined and aged using light microscopy.

Growth

Growth information was obtained from SFWW bull trout tagged in 2002 and recaptured in 2003. Length and weight gains were determined between initial tagging and subsequent capture events. In addition, growth was determined from scrutiny of otolith-aging information and mean length-at-age analysis. Further growth data was inferred from length frequency data using size-at-age information. Growth rate was calculated as the difference in mean length (and mean weight) between length frequency modes.

The relationship between length and age (number of annuli) was fit to a Von Bertalanffy model:

$$L(t) = L_{\infty}[1 - e^{-k(t-t_0)}]$$

where L = length (mm), L_{∞} = horizontal asymptote (length at which growth slows or stops), k = curvature parameter (rate of approach towards the asymptote), and t_0 = x-intercept (Quinn and Deriso 1999). We compared standard nonlinear models, both additive and multiplicative forms as recommended by Quinn and Deriso (1999). All models were fit using the SAS nonlinear procedure.

Emigration, Immigration, and Movement

Bull trout movement information from in-stream passive PIT-tag antennae was obtained from two locations within the SFWW. One passive array is located at Harris

Park Bridge at the bottom of the study site, and the second site is located just above the confluence with Bear Creek (approximately 7 km upstream).

<u>Population Abundance</u>

Mark and recapture techniques provide a robust method for estimating population size, evaluating movement among streams and subpopulations, and for understanding population response to habitat quality and improvement or restoration (Cooch and White 2001). At a minimum, simple mark-recapture data can provide a non-lethal estimate of population size with confidence intervals (Krebs 1999). In addition, when mark-recapture information is specific to individuals or tagging location, analyses can also include individual covariates that relate an individual's survival to a specific habitat relationship (Franklin, *in press*; White et al., *in press*) or information about movement among streams, subpopulations, and metapopulation structure (White et al., *in press*), respectively. Further, with the appropriate study design, these techniques can potentially help overcome the inherent difficulties of assessing bull trout population abundance and can provide a simple response variable (lambda) for evaluating population growth under an array of parameters such as habitat quality, productivity, or management actions aimed at recovery (Pradel 1996; Franklin, *in press*).

Initial Peterson-model population estimates were obtained from snorkeling surveys and resighting individuals with external, Floy tags. Individual-specific mark-recapture data from PIT tags will be collected for the duration of this study and will be used to parameterize Cormack-Jolly-Seber and Pradel models for estimates of survival and population trends. Active and passive recaptures will be used to obtain more robust estimates of these parameters.

Snorkeling data were used to parameterize an initial population estimate using a Petersen mark-recapture approach. Reach-based counts were expanded to estimate stream subpopulation abundance.

Individual resights (from snorkel surveys) were used to parameterize a mark-recapture model for an initial population estimate for both study streams. To account for the possibility of recounting individuals during snorkeling surveys (Bailey 1952), a modified Petersen model was used:

$$N = M * (C+1) / (R+1)$$

where *N* is the population estimate, *M* is the number of tagged fish, *C* is the total number of fish recorded during snorkeling survey (tagged and non-tagged), and *R* is the number of fish seen with an external tag. Confidence intervals were obtained for the fraction of marked individuals (*R/C*) using graphical approximations of binomial 95% confidence intervals (Krebs 1999). The confidence interval values were subsequently multiplied by *M* for upper and lower confidence intervals around the population estimate.

Using the tagging and snorkeling data, a population estimates for each stream was calculated and compared with average annual redd counts (T. Bailey, ODFW, unpublished data). The population estimate was based on the mark-resight results per reach and expanded to the entire length of the study site with 95% confidence intervals. For this method, an individual population estimate was calculated per reach, using tagging and snorkeling data for each reach. Then, the estimate of bull trout per 200 m was averaged (pooled) for all reaches combined, and expanded to the length of the total study sites with 95% confidence intervals based on the average.

Population estimates of adult bull trout (> 300 mm in SFWW and > 220 mm in NFUMAT) were then compared to annual expanded redd counts by stream. Redd counts likely only represent the number of redds for predominantly large, reproductive migratory fish. To obtain an abundance estimate of adult bull trout based on redd counts, the number of bull trout per redd was expanded based on literature values of fish/redd (3.7, Taylor and Reasoner 1999; 3.2, Fraley and Shepard 1989; 1.2, 1.4, 1.5, 2.1; Baxter and Westover 2000).

Population Trends

We used the redd count data from the SFWW to calculate an estimate with 95% confidence intervals of the population growth rate (λ, lambda) of the reproductive population (number of redds) using the Dennis model (Dennis et al. 1991). The Dennis model is specifically used for count data and is based on regressing the change in abundance at each time step (y) as a function of the time step (x); using linear regression techniques, the slope of the regression line, μ, is the rate at which the mean of the normal distribution increases, and the mean squared residual is the rate the variance in the normal distribution increases through time or δ^2. Finally, the average population growth rate (λ, lambda) is calculated with 95% confidence intervals based on μ and δ^2 (*see* Morris et al. 1999).

RESULTS

Fish Sampling

Bull trout were captured or observed in almost all sampled reaches. Length frequency distributions of captured bull trout were similar in both streams in both years (Figure 3). All captured bull trout were weighed and measured, and a separate length-weight relationship was calculated for each stream (Figures 4 and 5) based on all measured bull trout. Additionally, bull trout > 120 mm TL were tagged with both an external Floy tag and a 23-mm PIT tag. Prior to release, scales were removed from the right, posterior position adjacent to the dorsal fin. Fish smaller than 120 mm were simply measured, weighed, and immediately released.

Condition-- Condition (Fulton's K) of bull trout varied by size class and year (Figure 6). In the SFWW, average condition declined significantly (t = 2.76, df = 1094, p = 0.006) from 2002 (0.92) to 2003 (0.89); however, condition of bull trout captured in the NFUMAT (0.92) was identical to condition of bull trout captured in the SFWW in 2002 (0.92; t = 0.01, df = 453, p = 0.99; Figure 7). Within the SFWW, condition of bull trout < 120 mm declined significantly between 2002 and 2003 (t = 2.84, df = 182, p = 0.005). Condition was greatest for bull trout in the 220 – 320 mm size class (mean range: 0.94 – 0.97), but was lower for bull trout greater than 320 mm (0.92 – 0.93) and even lower for bull trout > 500 mm (0.88 – 0.92). Average condition for these populations was lower than that exhibited by Metolius River (Deschutes River Basin, Oregon) adfluvial bull trout (mean condition range: 1.02 - 1.65; Thiesfeld et al. 1999) and bull trout from southeast Washington streams (K_{FL} range = 1.0 – 1.1; Underwood et al. 1995).

Fecundity-- Fecundity was measured on a small sample of female bull trout (captured in 2002 – 2003) ranging from 205 – 564 mm. Average eggs-per-female was 1404 $\pm$ 448 ($\pm$ 1 SE; n = 7), mean egg diameter was 3.43 $\pm$ 0.05 ($\pm$ 1 SE; n = 140), and gonado-somatic index (GSI) was 6.9 (Figure 8). Number of eggs-per-female was significantly related to female total length (Adjusted R^2 = 0.97), although sample size was very low (Figure 9). Average number of eggs-per-female from these populations is similar to an estimated 1145 eggs-per-female from Creston National Fish Hatchery (Kalispell, Montana) spawned bull trout (W. Fredenberg, Creston NFH, personal communication).

Diet analysis-- Bull trout diet items varied by stream. Diet items included fish (bull trout, *Oncorhynchus* spp., sculpin, dace), aquatic invertebrates (plecopterans, dipterans, trichopterans, ephemeropterans), and terrestrial insects (ants, spiders, etc.). Of the 20 stomachs analyzed, only 17% (n = 4) were empty. Overall, aquatic invertebrates were the predominant prey item (Figure 10). Fish (40% of diet by weight) and plecopterans (36% of diet) were the dominant prey of SFWW bull trout, while ephemeropterans (47% of diet) and plecopterans (34% of diet) were the dominant prey of NFUMAT bull trout. In the SFWW, bull trout exhibited cannibalism (13% of diet) and consumed other fish (*Oncorhynchus* spp., dace, sculpin; a combined 27% of diet), and bull trout as prey in diets ranged from 77 – 115 mm and *Oncorhynchus* as prey ranged from 45 – 124 mm. Fish were 13% of the diet of NFUMAT bull trout; however, sample size (n = 7) was low and only one bull trout's diet contained fish (a 27 mm unidentified fish). In general, only bull trout >300 mm consumed fish as prey.

South Fork Walla Walla River

We sampled 40 reaches during the 2003 field season, which accounted for approximately 47% of the study site. Using various sampling methods to sample bull trout, most (92%) were captured by electroshocking down to a seine (Figure 11). Trap netting was also a very effective collection method. Bull trout captured by electrofishing down to a seine were significantly smaller than bull trout captured in trap nets (Figure 12; $t = 7.34$, $df = 492$, $p < 0.001$). Over the summer, a total of 798 bull trout were captured of which, 486 were tagged with the number tagged varying by sample reach (2 - 60 per reach; Appendix Table 1).

The average bull trout captured was 176 mm ($\pm$ 3.7, 1 SE) and 120 g ($\pm$ 19.8). The smallest bull trout captured was 11 mm (0.5 g) and the largest bull trout caught was 612 mm (1.9 kg); however, the greatest proportion of bull trout captured or observed were in the 100 to 200 mm size range (Figure 13). Comparisons of the size-frequency distribution of bull trout sampled and captured (e.g., electrofishing, seining, trap netting, angling) to the size frequency distribution of bull trout observed during snorkeling surveys indicates we had an equal probability of sampling bull trout by both methods (Figure 13).

Snorkel surveys-- Snorkeling surveys were performed in 40 reaches in 2003. Observations were biased toward fish >120 mm due to the cryptic nature of small fishes. In 2003, bull trout observed ranged from 50 to 700 mm, similar to 2002 surveys, although less bull trout were observed in 2003 (Figure 14). Similar distributions, sizes and numbers of bull trout were observed in paired daytime versus nighttime snorkel surveys (Figure 15).

North Fork Umatilla River

We sampled 17 reaches in June and July 2003. Bull trout were captured or observed in all sampled reaches. Using various sampling methods to catch bull trout, most (95%) were captured by electroshocking down to a seine, while four bull trout were captured in minnow traps (Figure 11). Trap netting proved to be an unsuitable sampling method in this stream. Bull trout captured by electrofishing down to a seine (mean TL = 156 mm) were similar in size to bull trout captured in minnow traps (mean TL = 150; Figure 12). Over the summer, a total of 81bull trout were tagged (Appendix Table 1) with the number tagged varying by sample reach (1-18 per reach).

The average bull trout captured was 133 mm ($\pm$ 3.2, 1 SE) and 28 g ($\pm$ 4.1). The smallest bull trout captured was 85 mm (5.7 g) and the largest bull trout caught was 394 mm (563 g); however, the greatest proportion of bull trout captured or observed were in the 100 to 200 mm size range (Figure 13). Comparisons of the size-frequency distribution of bull trout sampled and captured (e.g., electrofishing, seining, minnow trapping) to the size frequency distribution of bull trout observed during snorkeling surveys indicates we had an equal probability of sampling bull trout by both methods (Figure 13).

Snorkel surveys-- Snorkeling surveys were performed in 17 reaches. Bull trout were seen in 15 sampled reaches. Observations were biased toward fish > 150 mm due to the cryptic nature of small fishes. A similar size distribution of bull trout was observed as in the SFWW, although 2-times fewer fish were seen (Figure 14). Similar distributions, sizes, and numbers of bull trout were seen in paired daytime versus nighttime snorkel surveys (Figure 15).

Growth

Tagged fish-- Annual growth of tagged bull trout varied by size class. Bull trout in the 220 – 320 mm size class grew significantly more in length than bull trout > 320 mm (t = 2.88, df = 17, p = 0.01); however, bull trout > 320 mm gained more weight than bull trout 220 - 320 mm (Figure 16). On average, big bull trout (> 320 mm) gained 0.5 g/day versus 0.3 g/day for medium-sized (220 – 320 mm) bull trout; however, instantaneous growth was significantly greater for medium-sized bull trout than for the largest bull trout (t = 2.74, df = 17, p = 0.01; Figure 16).

Inferred-- Annual growth estimates inferred from a length frequency distribution indicate steady length gain through age-4 (mean TL = 277 mm) followed by lesser length gain for fish over 300 mm (Figure 17). In contrast, bull trout age-2 and younger gained weight more slowly than larger and older bull trout ($\geq$ age-5, > 300 mm).

Otolith aging-- We aged 15 bull trout, age-1 through age-8 ranging in size from 104 mm (9.4 g) to 564 mm (1.5 kg). An additive, nonlinear von Bertalanffy growth model provided the best fit to length-at-age from otolith aging data (Figure 18; $L_\infty = 1125$, $t_0 = -0.373$, $k = 0.0671$, $F = 18.44$, $df = 16$, $p < 0.0001$). Despite the significant model and parameters, these data would suggest that growth continues to increase gradually with age, and then plateaus at 1125 mm. Thus for this data set, the plateau would not occur until after age 50, obviously not a biological reality. The failure of the data and model fit to properly asymptote is likely driven by the very small data set and perhaps the natural variability in size at age of the population. Resident fish and migratory fish would be expected to exhibit different growth trajectories, but for these data, we are unable to separate the two life-history forms, if they do in fact exist. Incorporation of additional fish in the future, in addition to the possible use of scales for non-lethal aging, will improve our analysis.

Emigration, Immigration, and Movement

Number of fish detections (i.e., recaptures) at the PIT-tag antennae and movement of bull trout in the SFWW varied by size-class and month. More bull trout were detected at the upper Bear Creek (WW2) antenna, almost 3-times as many detections as at the Harris Park (WW1) site (Figures 19 and 20). Most detections (and therefore movement) occurred from August - October 2003. In the SFWW, 46 bull trout were detected at the Harris Park Bridge PIT-tag detection array, of which 40 were moving downstream and 6 were moving upstream (Figure 21). At the Bear Creek array, 109 bull trout were detected; of which 47 moved downstream and 62 moved upstream (Figure 21). Large bull trout (> 320 mm) moved into the study section above Harris Park Bridge during May - June (Figure 21). Smaller bull trout (120 – 320 mm) moved downstream out of the study area from June to November while the large bull trout moved in to spawn. Large bull trout moved out of the study area from September - November, likely the period after spawning

Population Abundance

Population estimates for bull trout were calculated using the mark-resight data, with data summarized by reach then pooled (Figure 22). The density data from snorkeling surveys are also shown for comparison. Estimates varied by calculation method, ranging from 2150 to 8200 bull trout, (Table 1, Figure 22). Population estimates were highest for small (100 - 200 mm) bull trout and varied by size class (Figure 23).

Comparisons of large, likely fluvial fish (> 300 mm in SFWW and > 220 mm in the NFUMAT), to expanded redd counts generally demonstrated a lower estimate of population abundance for that category of fish, when redd counts were used as compared to mark-recapture estimates. In the SFWW, 2002 and 2003, mark-recapture estimates for large fish were 271 and 175% greater than population abundance estimated based on redd counts; however, results were dependent on the assumed number of fish per redd (as demonstrated by the upper and lower error bars on Figure 24). Results were similar when the two estimation techniques were compared for the NFUMAT; however, the confidence intervals surrounding large fish based on mark-recapture were extremely wide, indicating low certainty for that size category of fish. Linear regression for mark-recapture estimates of large fish versus redd count-based estimates of adult abundance for these three data points (SFWW 2002, 2003, and NFUMAT 2003) resulted in a good model fit with a positive slope (R^2 = 0.85; p_2 = 0.25), regression results should be viewed with caution, however, due to the small sample size (n = 3).

Table 1. Population estimates and 95% confidence intervals calculated by various methods for bull trout in the South Fork Walla Walla and North Fork Umatilla rivers, summer 2002 and 2003. Redd counts are total counts by stream by year (T. Bailey, ODFW, unpublished data).

	South Fork Walla Walla River		*South Fork Walla Walla River*		*North Fork Umatilla River*	
Estimate type (based on)	2002 Population estimate	95% CI	2003 Population estimate	95% CI	2003 Population estimate	95% CI
Pooled mark-recapture using reach totals	7,028	5,948 – 8,721	8,533	7,839 – 11,470	2,505	2,088 – 4,005
Snorkel counts	3,390	2,690 – 4,090	1,741	1,145 – 2,337	437	280 – 583
Redd counts	330		362		49	

Populations Trends

Based on redd counts from 1994 to the present, the trend analysis suggests that bull trout populations in the SFWW and the NFUMAT are stable or increasing in population size; SFWW: λ= 1.15 (0.94 - 1.42), NFUMAT: λ = 1.17 (0.81 - 1.69). Lambda (*λ*), as shown here, represents the status and direction of change of the population. A population experiencing negative growth results will have a *λ* value of less than one, a *λ* value of greater than one represents a population experiencing positive growth, and a *λ* value of one results when a population exhibits no growth (considered stable). Lambda values for both populations were greater than one, indicating an increasing trend in abundance of larger, reproductive fish. However, for both populations, the lower 95% confidence intervals for lambda is less than one, indicating that we can not rule out the possibility that the populations are actually declining. Note also that these values of lambda are limited by the temporal and spatial variability of bull trout redds, potential observer errors in detecting redd presence, and the unknown, but likely, large bias for underestimating resident spawners (*see Discussion*).

DISCUSSION

In 2003, research from 2002 was continued and expanded to meet overall project objectives; all fish population-based research for the SFWW was continued and expanded. We sampled 40% of the SFWW study area (20% from 2003, 20% new), 468 fish were tagged, and all the baseline demographic and project assessment data were collected, analyzed, and synthesized. In 2003, for needed contrast, we also expanded the fish population tagging and monitoring into the next tributary in the subbasin, the NFUMAT, where bull trout population status was unknown. Twenty reaches were sampled, 81 fish were tagged, and all the baseline demographic and project assessment data were collected, analyzed, and synthesized. Preliminary day-night and seasonal abundance precision comparisons were initiated. Equipment was purchased and appropriate permits were submitted and received to install an additional passive PIT-tag antennae, slated for installation in the NFUMAT in June 2004, at the lowermost reach of the NFUMAT study area.

In 2003, population estimation resulted in a subadult to adult (fish > 50 mm) abundance estimate of 8533, a slight, but insignificant increase over 2002 (N hat = 7028). These data suggest there is a large population of bull trout in the SFWW, ranging in size from as small as 50 mm to as large as 620 mm. Population estimates for the NFUMAT indicate that there are about 2500 fish; however, estimates from only one year of data should be viewed with caution. In this system, bull trout were generally smaller ranging from 75 mm to only 400 mm (*but see below*). For both study areas, the largest portion of the population is composed of fish 120 - 220 mm, with slightly more fish in the largest size class (> 320 mm) and the fewest in the intermediate size class (220 - 320 mm). These data, in combination with the size-frequency data, indicate the potential for (1) a population bottleneck around age-2 and age-3, or (2) a gap in our estimation techniques, potentially associated with migratory fish, or (3) perhaps most likely, some combination of (1) and (2). Accumulated data on emigration (possible after the third year of study) will allow us to quantify the contribution of immigration and emigration, to the observed pattern (Forsman et al. 1996). Although based solely on redd counts, lambda values for both populations were greater than one, indicating an increasing trend in abundance; 95% confidence intervals overlapping one (i.e., < 1), however, indicate that we can not rule out the possibility that the populations are actually declining.

Given the reliance of on redd counts for bull tout monitoring through out the Columbia Basin, it is important to understand the relationship between these counts and population estimates based on mark-recapture. Redds in this system appear to be made primarily by large, possibly migratory fish, given the size of the redds and the fish occasionally observed using them. Thus for purposes of comparison, we assume large fish (> 220 or > 300, depending on system) are fluvial and adjusted the mark-recapture population estimates for that proportion of adults based on estimates of the number of fish per redd from a variety of sources. Given that the Wigwam River (Canada) estimate of 1.2 fish/redd (Baxter and Westover 2000) may be an underestimate, as those fish are very large, and that the McKenzie and Middle Fork Willamette basin estimate (3.7 fish/redd; Taylor and Reasoner 1999) is likely an overestimate, (given the contribution of adfluvial fish) it seems likely that for our systems, the “true” number of adults based on redd counts lies somewhere in between. Thus even with the application of a high estimate of fish per redd, it appears that redd counts significantly underestimate the population abundance; the degree of negative bias is determined by assumptions of the number of fish per redd and of the size distribution of fish thought to be constructing redds that can be observed in these systems.

Although an understanding of the degree of negative bias is important for population viability analyses, for monitoring and evaluation, it is more important to evaluate whether or not the redd counts represent a consistent index of the true population (Eberhardt 1982; Krebs 1999). In other words, when the annual population abundance is high, are the annual redd counts also high, and do we see a similar pattern across systems? Data are too preliminary to provide a conclusive answer for the Walla Walla River subbasin at this time, but based on this preliminary analysis (n = 3), we found a correspondence between the two techniques (positive slope and a high R^2 for regression). Nevertheless, the redd-count based estimates do not provide a consistent annual index of the population abundance as compared to mark-recapture. Population estimates for large fish were considerably higher in 2002, as compared to 2003, for the SFWW, but the corrected redd count estimates remained similar, regardless of assumptions applied. The two estimation techniques provided similar estimates for the NFUMAT, but with wide confidence intervals and thus less certainty. This lack of a consistent trend between mark-recapture and redd count-based abundance estimation is further confounded by the findings of Dunham et al. (2001), who demonstrated that in addition to substantial observer error in counting redds, bull trout spawning activity was highly variable both temporally and spatially. As with other estimation techniques described here, additional years or both mark-recapture and migration rates will contribute significantly to our understanding of the relationship between redd count based and mark-recapture based population estimation, for the fluvial component of the population.

As observed in the previous year, in 2003, annual population estimation based on mark-resight appeared to be a robust technique well suited to this question and for bull trout sampled in the SFWW, with little known bias. Size frequency comparisons of fish observed snorkeling versus those caught sampling overlap and demonstrate an extremely similar pattern. In the NFUMAT, the same comparison indicates a potential size bias, such that smaller fish are sometimes missed while snorkeling, and larger fish are missed while sampling. We suspect the prior to be a result of the large degree of habitat complexity (e.g., LWD) in the NFUMAT, which likely hinders observation of small fish in some locations. The latter, our lower efficiency of capturing larger fish, may be a result of timing and sample location. In 2004, we will adjust our sampling to better correspond with the presence of large migratory fish (both temporally and spatially). Regardless, in the NFUMAT, all estimates are influenced by a much lower density of fish overall, leading to great variability in most cases. In contrast to Dunham et al. (2001), day versus night comparisons of bull trout observed during snorkel surveys demonstrated little difference in abundance or size distribution. Finally, for both systems, the mean recapture-capture ratio (0.12 – 0.28) remains reasonable, and we are able to systematically and effectively sample a large proportion (20 to 40%) of the study areas. The combination of these results indicates that mark-recapture techniques provide a robust population assessment methodology for bull trout in these types of systems.

Most fish movement occurred between the months of May through November, at both detection sites, and for all sizes of fish. At the lower antennae, at the bottom of the study area, large fish (> 320 mm) appeared to move more in the later months (September through November) while smaller fish (120 - 320 mm) moved more a few months earlier (July and August). At the mid-site detection antennae, fish movement was concentrated around July and August for both size categories of fish, with large fish demonstrating movement into September. For those fish for which the direction of movement could determined, upstream movement was greatest between may through September; these were primarily large fish presumably on their migration up to the spawning grounds. Downstream movement occurred primarily between July and November, with smaller fish demonstrating a distinct out-migration early in the summer and large fish moving out, presumably after they spawn, later in the summer. Temporal movement patterns for large PIT-tagged bull trout are similar to those exhibited by radio tracked bull trout in both SFWW (Mahoney 2002 *Draft*), and in Mill Creek (Hemmingsen et al. 2001), a tributary of the Walla Walla River. However, the larger proportion of out-migrating, small bull trout that occurs in the late summer in the SFWW appears to be more prominent than the out-migration data collected from screw-traps in Mill Creek (Hemmingsen et al. 2001), where the majority of small fish downstream movement occurred earlier, in April, May and June. Ultimately, annual movement data will be used to estimate annual emigration and immigration rates, which can then be used to (1) correct survival and population trend estimates (Forsman et al. 1996) and (2) contribute to our understanding of population structure in the SFWW (migratory versus resident).

We observed an intriguing pattern in condition indices across the different size categories for both years of data in the SFWW and in 2003 (only one year so far) in the NFUMAT. Condition (Fulton's K) was greatest, and the most variable, for the intermediate adult size class (220 – 330 mm). This observation is interesting, given that the lowest abundance is observed in this intermediate size class. The high variability and low abundance again points to a bottleneck, change in fish life history, or sampling issue for this size class (*see above*). It is possible that this intermediate adult size class demonstrates an ontogenetic diet switch, from a diet composed largely of invertebrates to a diet composed largely of fish. The high degree of variability in condition indices could thus be an artifact of averaging across individuals, some of which have made the switch to consumption of fish recently (or even have a fish in their stomach at the time they were weighed), versus individuals who are still consuming primarily invertebrates. We also observed a substantial decline in condition overall, between 2002 and 2003, in the SFWW. This drop in condition could be influenced to some degree, however, by the fact that many more small fish were collected in 2003 relative to 2003. Younger fish may exhibit lower condition values due to fast growth rates and lack of weight relative to length, and Fulton's condition index (K) is limited when comparisons are made across large size differences (Murphy and Willis 1996). Nevertheless, the sample size is high for both years, and the size range is similarly wide; these results thus suggest that condition did in fact decline to some degree between 2003 and 2002.

Diet analyses demonstrated that bull trout sampled in the SFWW and NFUMAT consumed a high proportion of aquatic invertebrates with a smaller proportion of fish in the diet. Fish consumption ranged from about 17 - 40%, with species consumed divided between *Oncorhynchus* spp., bull trout, dace and sculpin in the SFWW and composed completely of unidentified salmonids in the NFUMAT. It is important to note that our small sample size of sacrificed fish limits our ability to extrapolate from these data, and we cannot separate out size classes or ages to evaluate ontogenetic diet shifts. Nevertheless, growth data from tagged and recapture fish demonstrated a greater weight gain of fish > 320 mm, a pattern that could be a result of a greater proportion of fish in the diet. The relatively high degree of cannibalism is notable and may be both body size (Juanes 2003) and density dependent (Polis 1981). Cannibalism can benefit the predator through increased survival and/or fecundity (Babbitt and Meshaka 2000) and increased growth and/or decreased competition (Claessen et al. 2000; Persson et al. 2000).

FUTURE

The objectives and tasks of the original Study Plan are provided in Appendix II.

In 2004, fish population monitoring and tagging will continue in the SFWW and in the NFUMAT. Habitat assessment work, (Objective 2 in Study Plan), as described above for the SFWW, will be completed in the NFUMAT. Habitat use and availability and bull trout distribution data for the NFUMAT and SF Wenaha rivers will be used to validate the applicability and effectiveness of the habitat selection model (under development). The NFUMAT provides reasonable contrast in habitat and system size to our baseline system (i.e., SFWW); however, few large bull trout remain in the NFUMAT. Thus, our large-scale validation effort (Objectives 2 and 6) requires habitat assessment (use and availability) in a similar tributary of the Columbia River, where bull trout population structure and habitat are similar to the SFWW, and large fish are still abundant. Therefore, we will conduct one-time snorkeling and habitat surveys in the SF Wenaha River (Upper Grande Ronde subbasin, Oregon), a stream meeting those criteria. The Wenaha River may contain one of Oregon's healthiest bull trout populations with its extensive wilderness areas and a current distribution comparable to probable historic distributions (Buchanan et al. 1997).

In addition, to meet the concerns of the USFWS Bull Trout Recovery, Monitoring, and Evaluation Technical Working Group (RMETG), we are adding an evaluation of spatial and temporal heterogeneity in sampling precision and accuracy. Three sites on the SFWW and three sites on the NFUMAT will be selected as index sites. Based on these sites, sampling precision and accuracy will assessed over time (i.e., diel and seasonal) and space (i.e., across the study area). These data are necessary to fully meet Objectives 1,2,3 and 4 of the Study Plan, and the goals of the RMTEG. Further, to continue to meet Objectives 1-4 and for Objective 6 of the Study Plan, we will evaluate the potential for expanding our assessments (population and habitat-based) into the John Day River. A pilot study will be completed based on a review of the available data, collaboration meetings with local biologists and managers, permitting considerations, and perhaps an initial site visit in 2004 to evaluate feasibility of implementing full sampling in 2005.

During the summer filed season of 2004, genetic samples will continue to be taken from all handled fish; in 2003, tissues samples (fin clips) were taken from approximately 400 bull trout in the SFWW. In the fall of 2004, an initial and random subsample of these tissue samples will be evaluated for genetic variation. Post hoc comparison of known migrant versus known resident fish (based on tagging and encounter history) will be evaluated for genetic distinction. Based on the results of this initial genetic analysis, additional samples will be evaluated accordingly. A subsample of tissue from thirty small adults (< 320 mm) will also be collected in 2004, from each of the two primary upper tributaries (Reser and Skiphorton creeks), to further evaluate for genetic distinction in smaller fish, thought to be resident.

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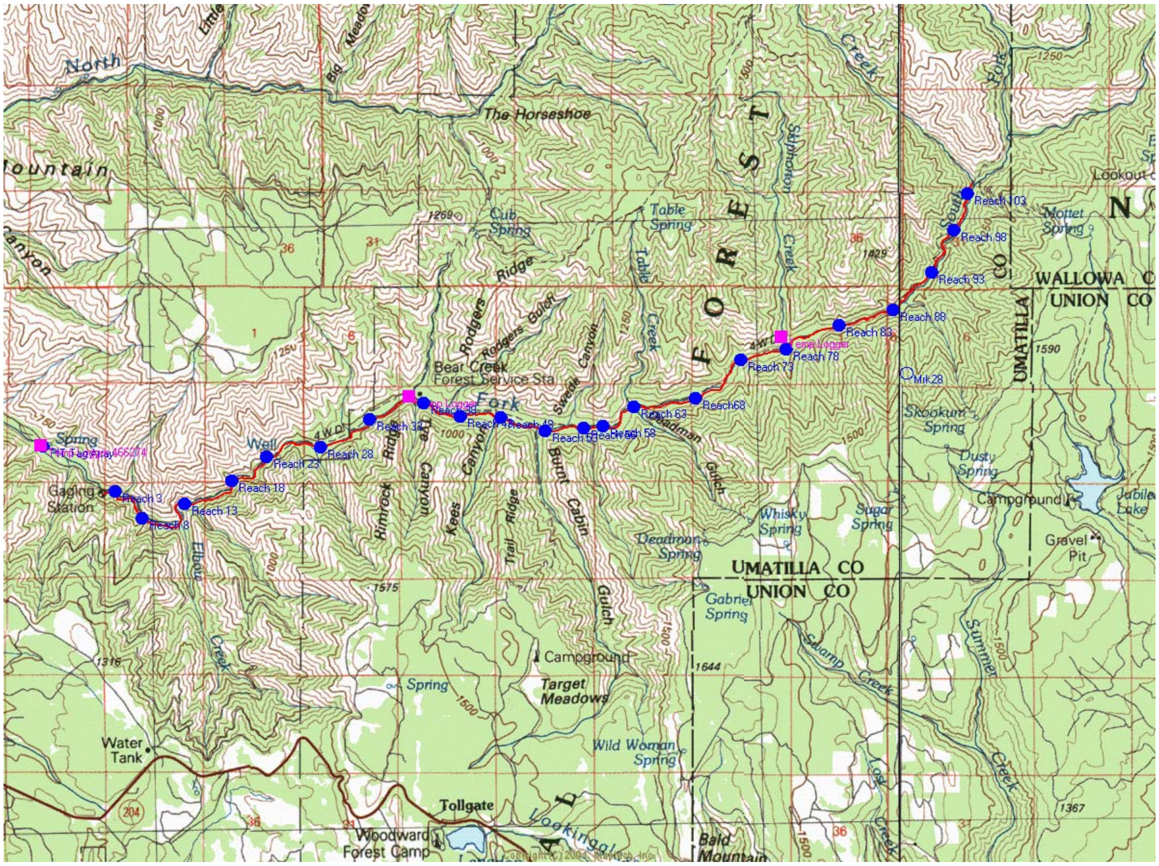


Figure 1. Map of the South Fork Walla Walla River showing original 22 study reaches (dots).

Figure 2. Map of the North Fork Umatilla River showing the 20 study reaches (squares).

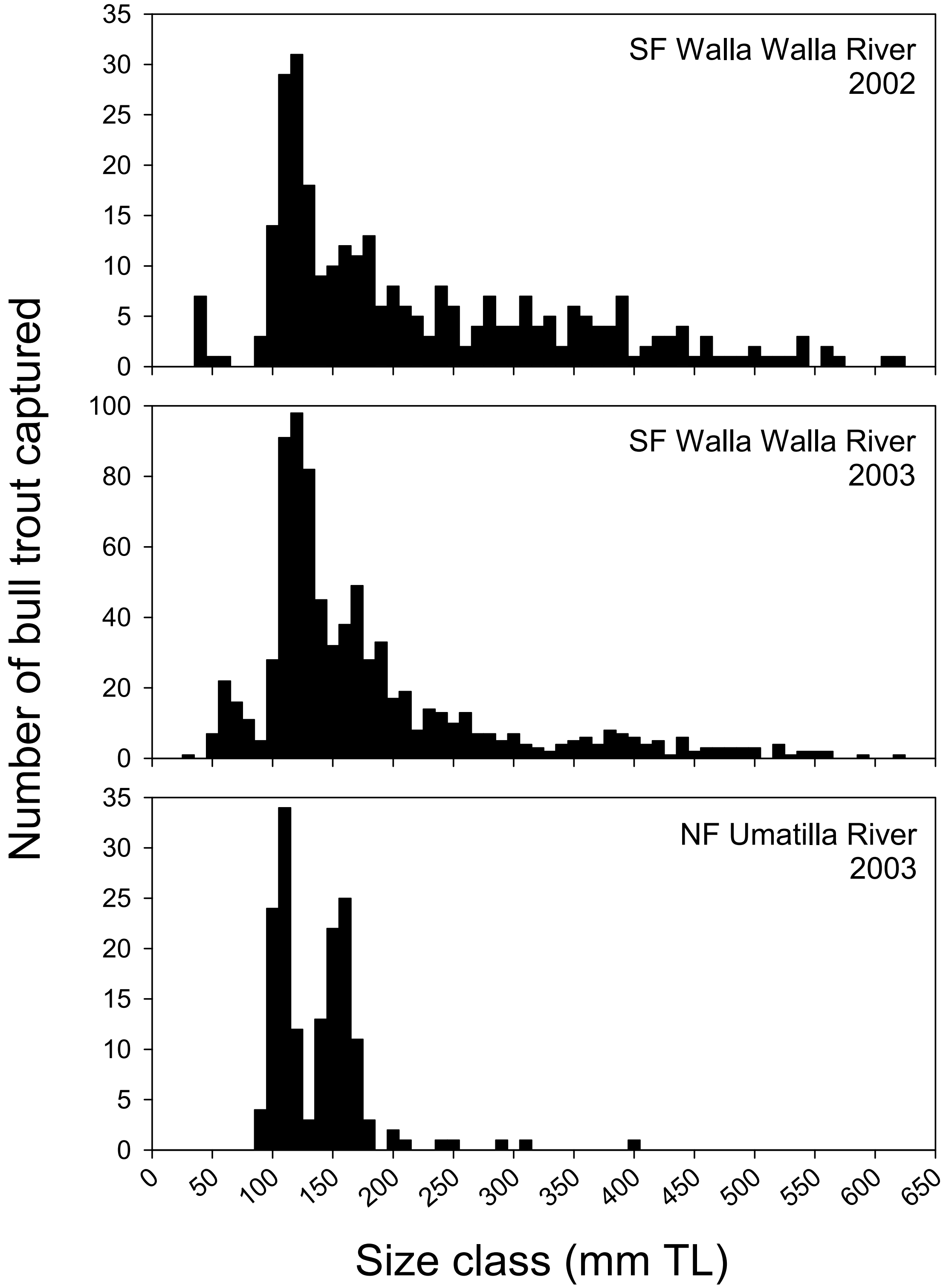


Figure 3. Length frequency distribution of bull trout captured in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Note changes in y-axis scales.

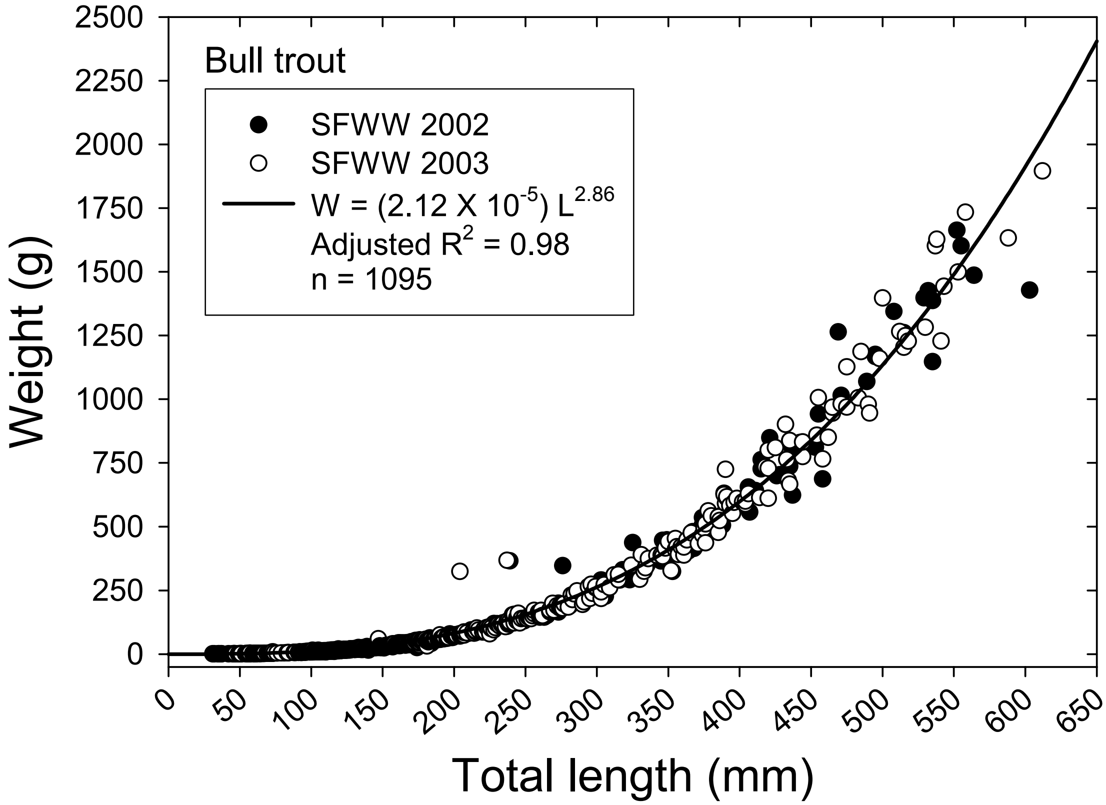


Figure 4. Length-weight relationship for bull trout captured in the South Fork Walla Walla River, 2002-2003. Regression equation and sample size are given.

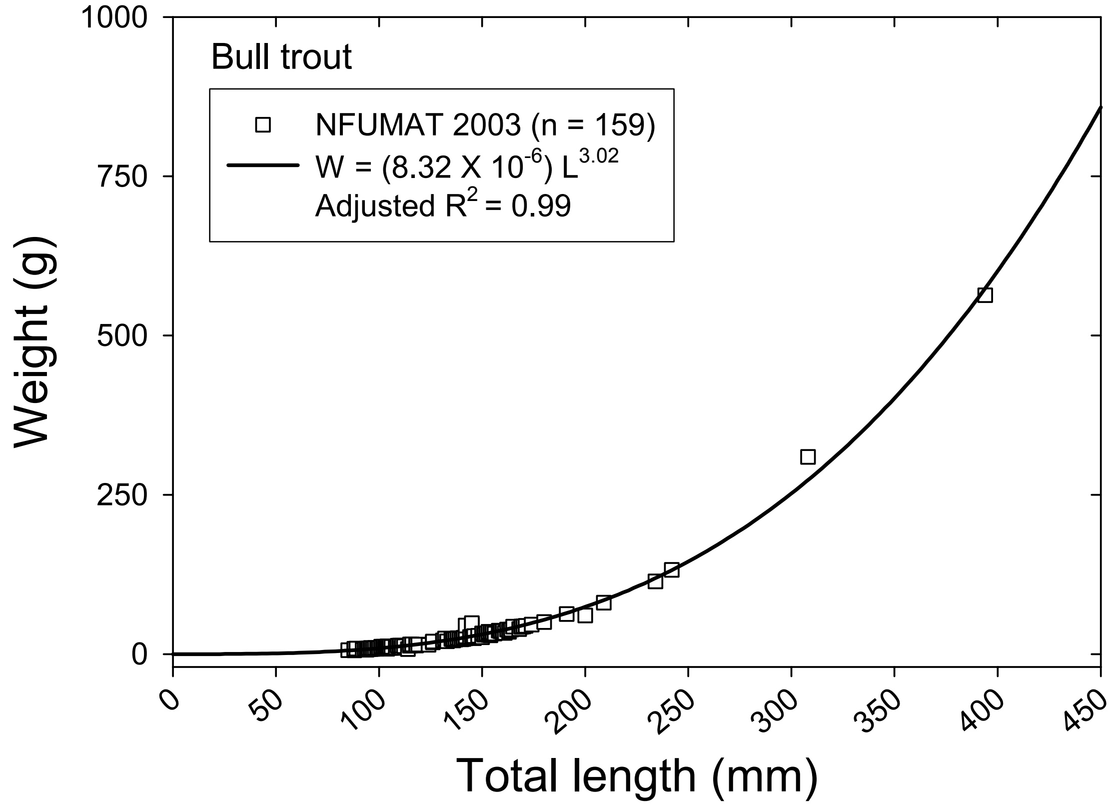


Figure 5. Length-weight relationship for bull trout captured in the North Fork Umatilla River, 2003. Regression equation and sample size are given.

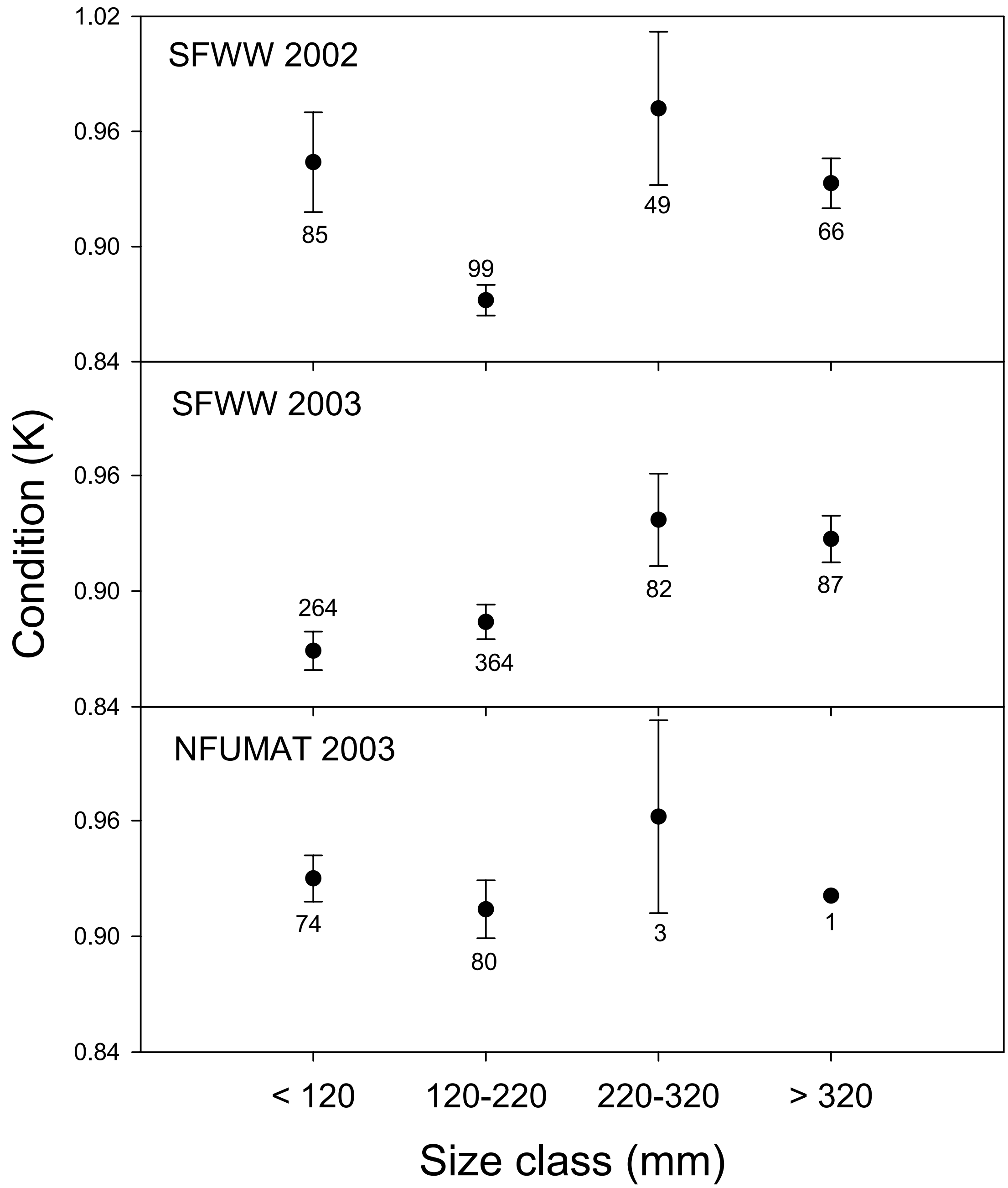


Figure 6. Condition (Fulton's K) of bull trout by size class sampled in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate + 1 standard error. Sample sizes are given near error bars.

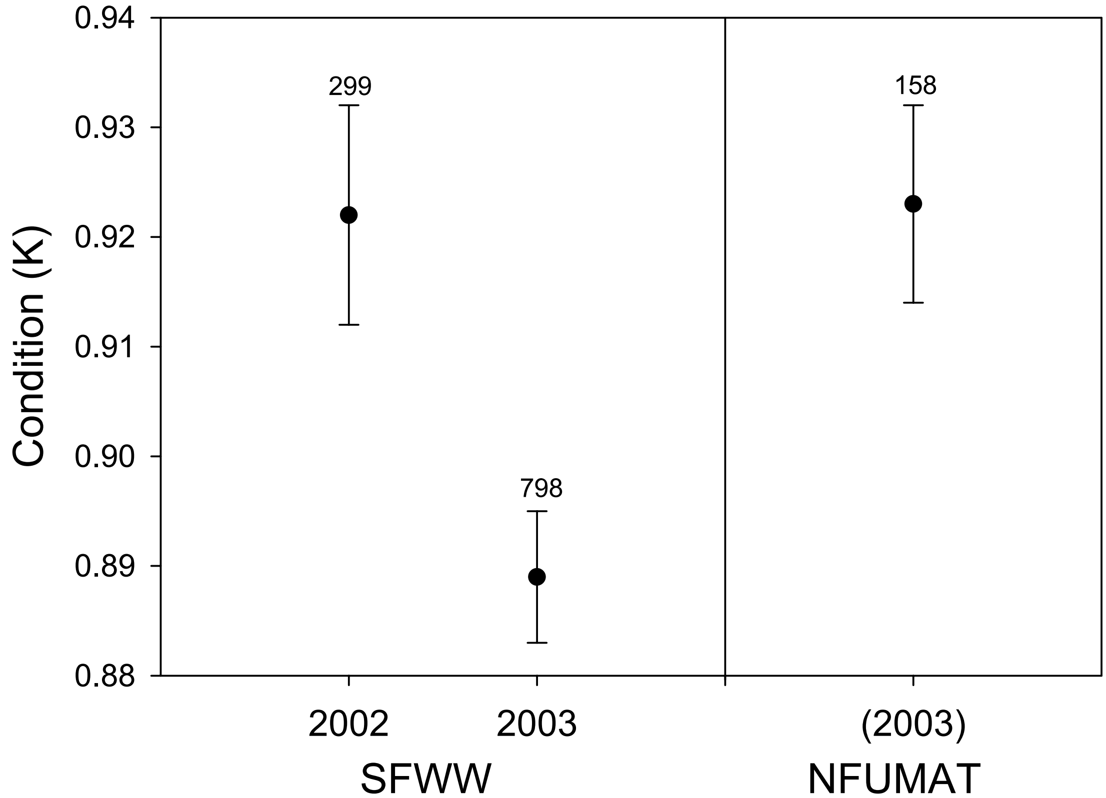


Figure 7. Average condition (Fulton's K) of bull trout (all sizes combined) sampled in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate + 1 standard error. Sample size is given above error bars.

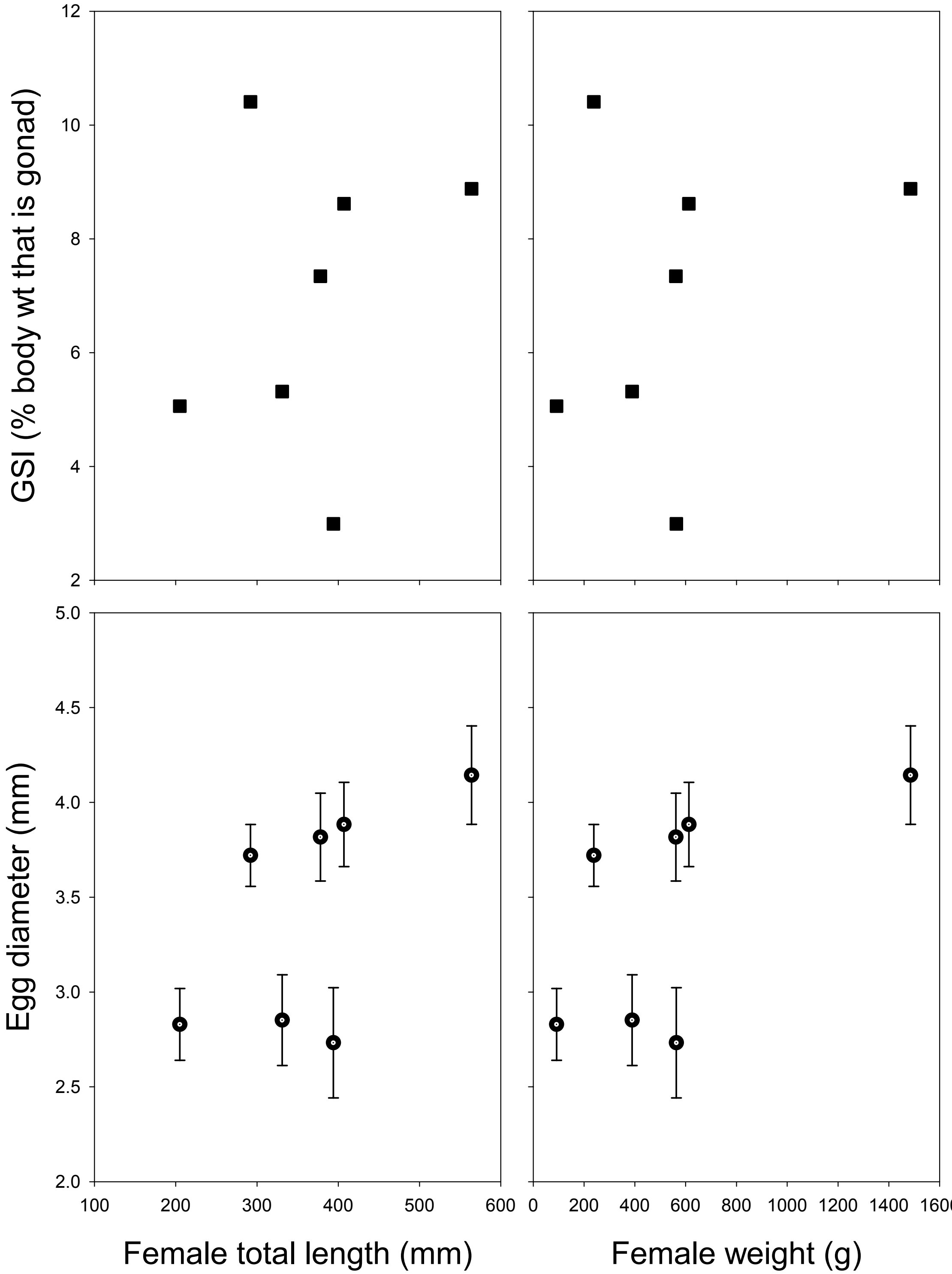


Figure 8. Gonado-somatic index (GSI, top panels) and egg diameter as a function of size of female bull trout captured from the South Fork Walla Walla River, 2002-2003, and North Fork Umatilla River, 2003. Error bars indicate + 1 standard error.

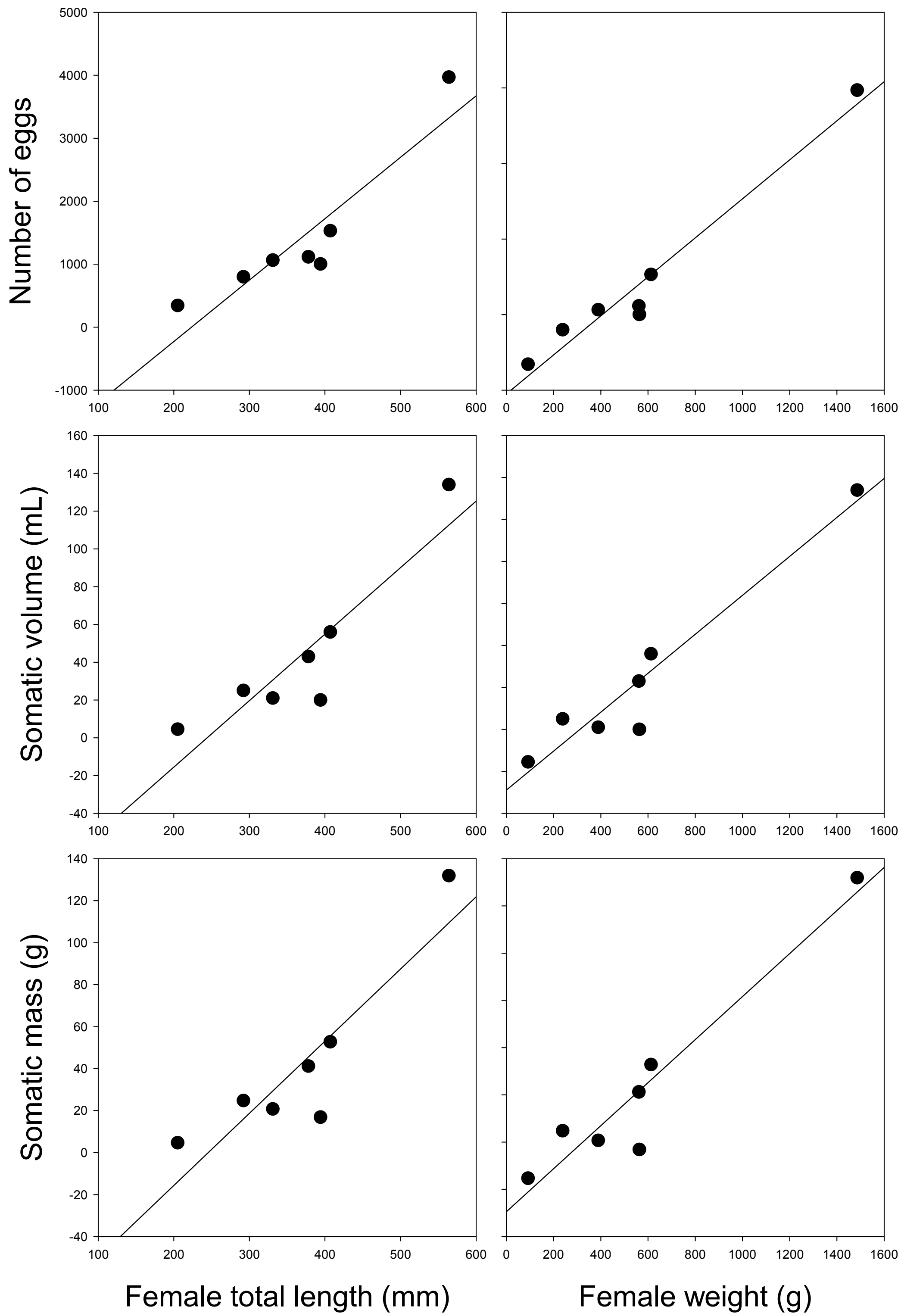


Figure 9. Eggs-per-female (top panels), somatic volume, and somatic mass (bottom panel) as a function of size of female bull trout captured in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Regression lines are given.

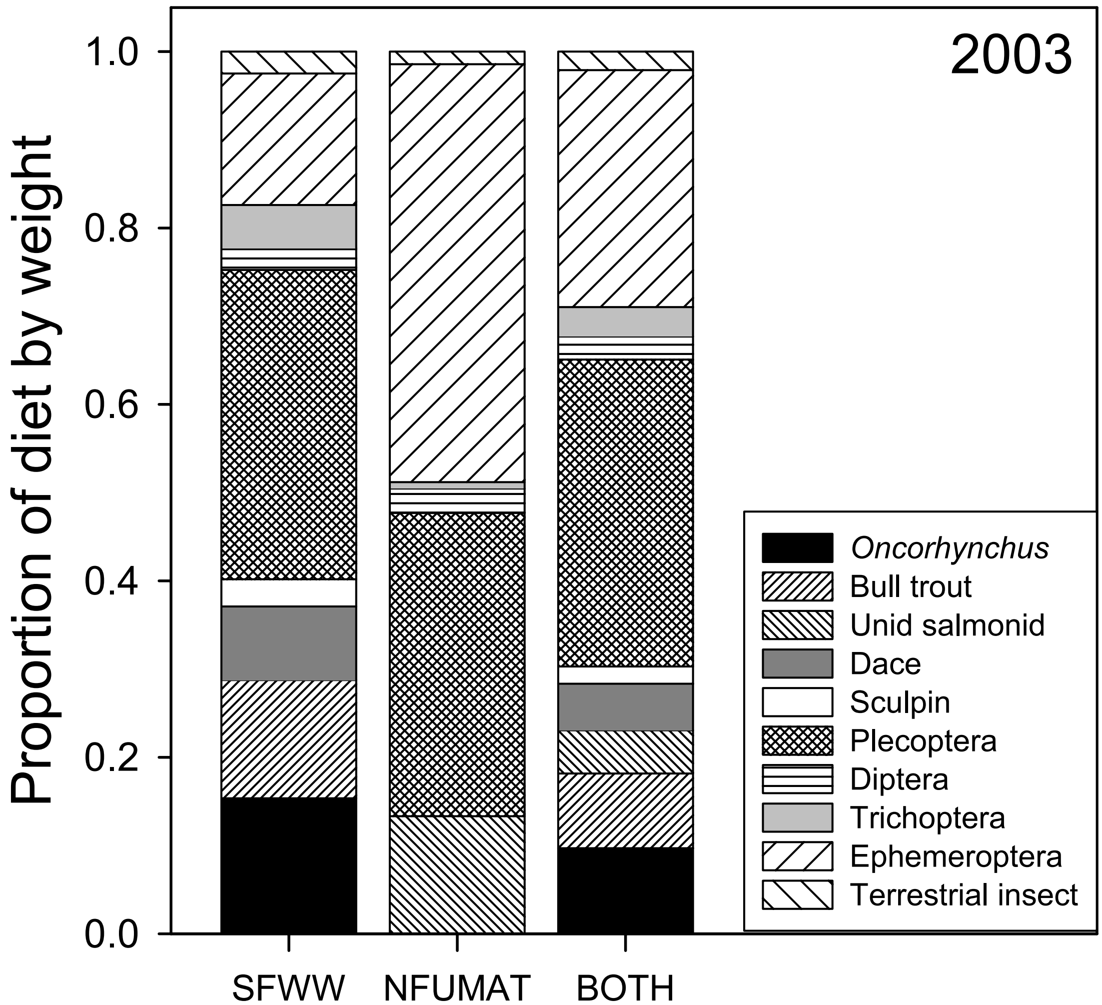


Figure 10. Diet composition (proportion of diet by wet weight) of bull trout taken from the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). "Both" is the average of both rivers combined. "Unid salmonid" = unidentified salmonids (salmon and trout).

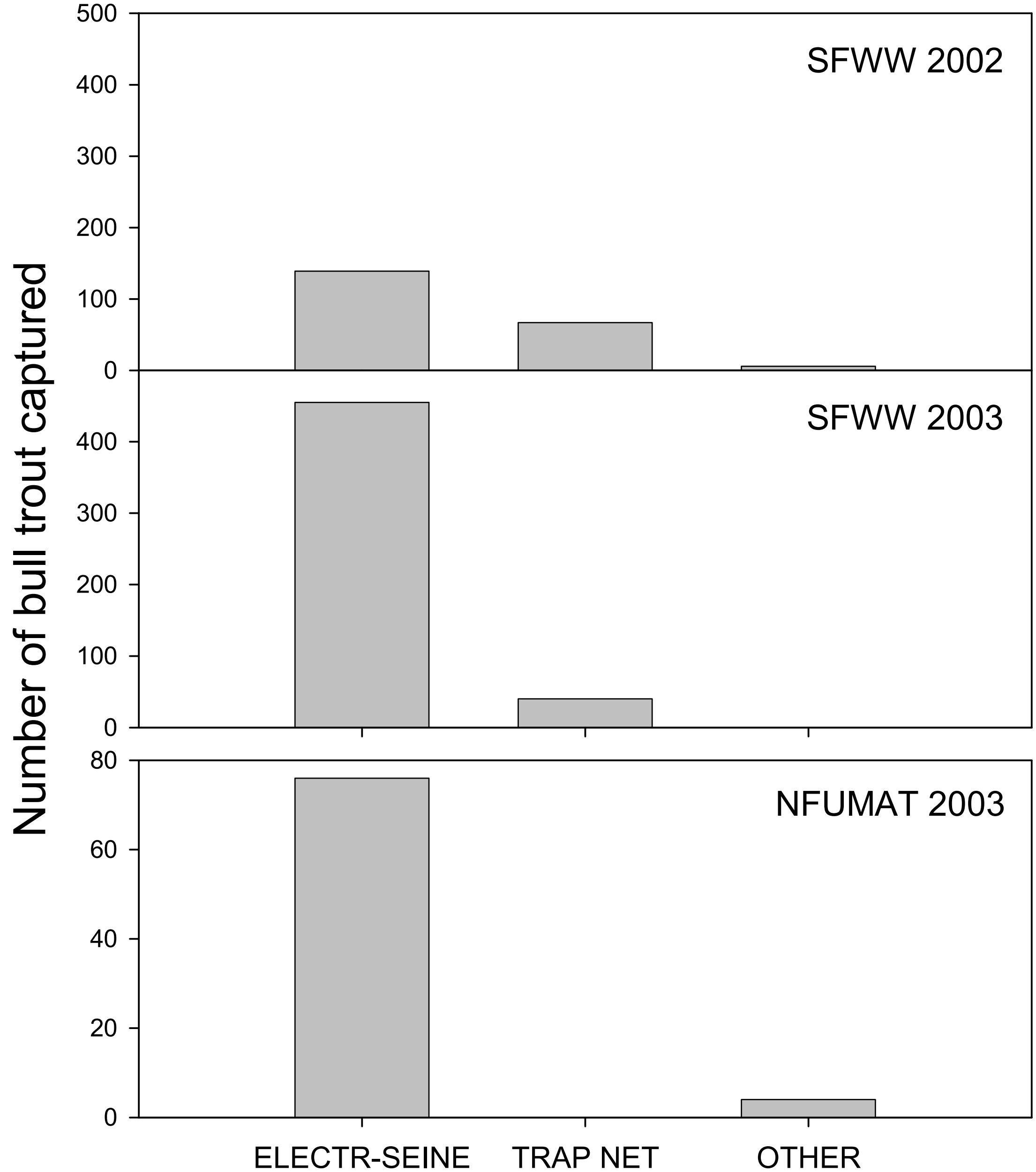


Figure 11. Number of bull trout captured by various collecting methods: trap netting, electroshocking down to a seine, and other (angling and minnow trapping) in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Note changes in y-axis scale.

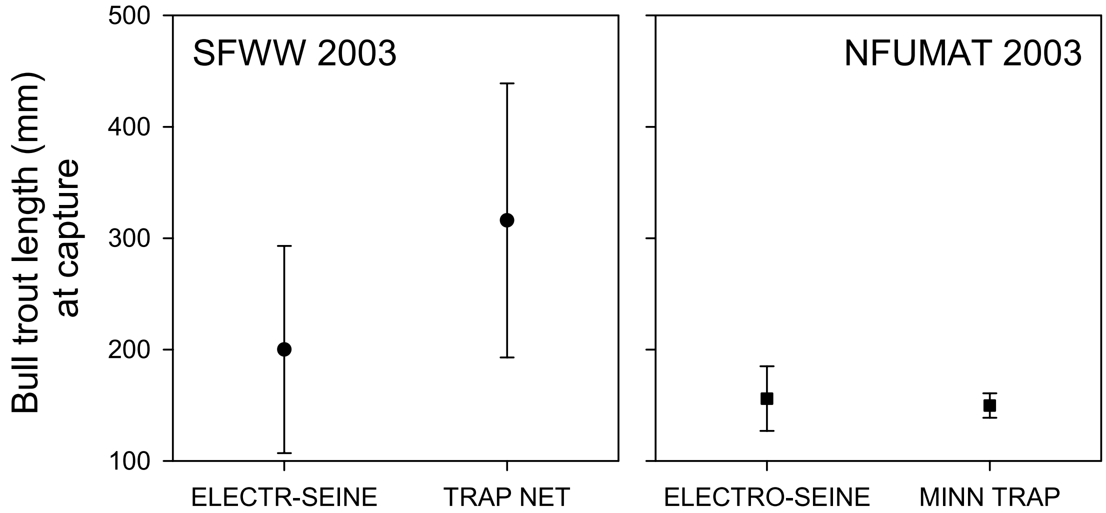


Figure 12. Bull trout length (mm TL) at capture from various collecting methods: trap netting, electroshocking down to a seine, and minnow trapping in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate + 1 standard deviation.

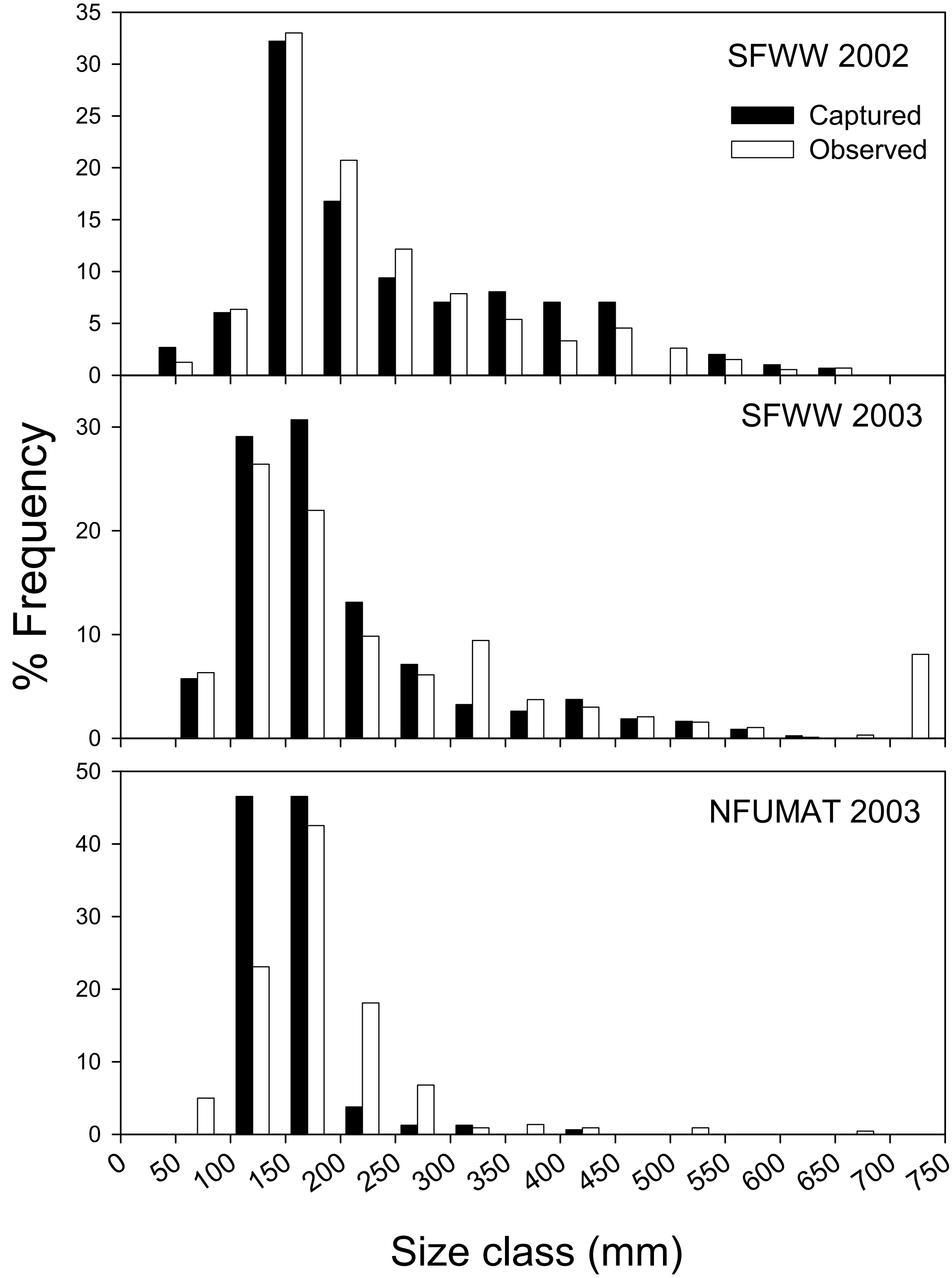


Figure 13. Length frequency distribution of bull trout sampled (captured, black bars) and observed (via snorkel counts) in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003).

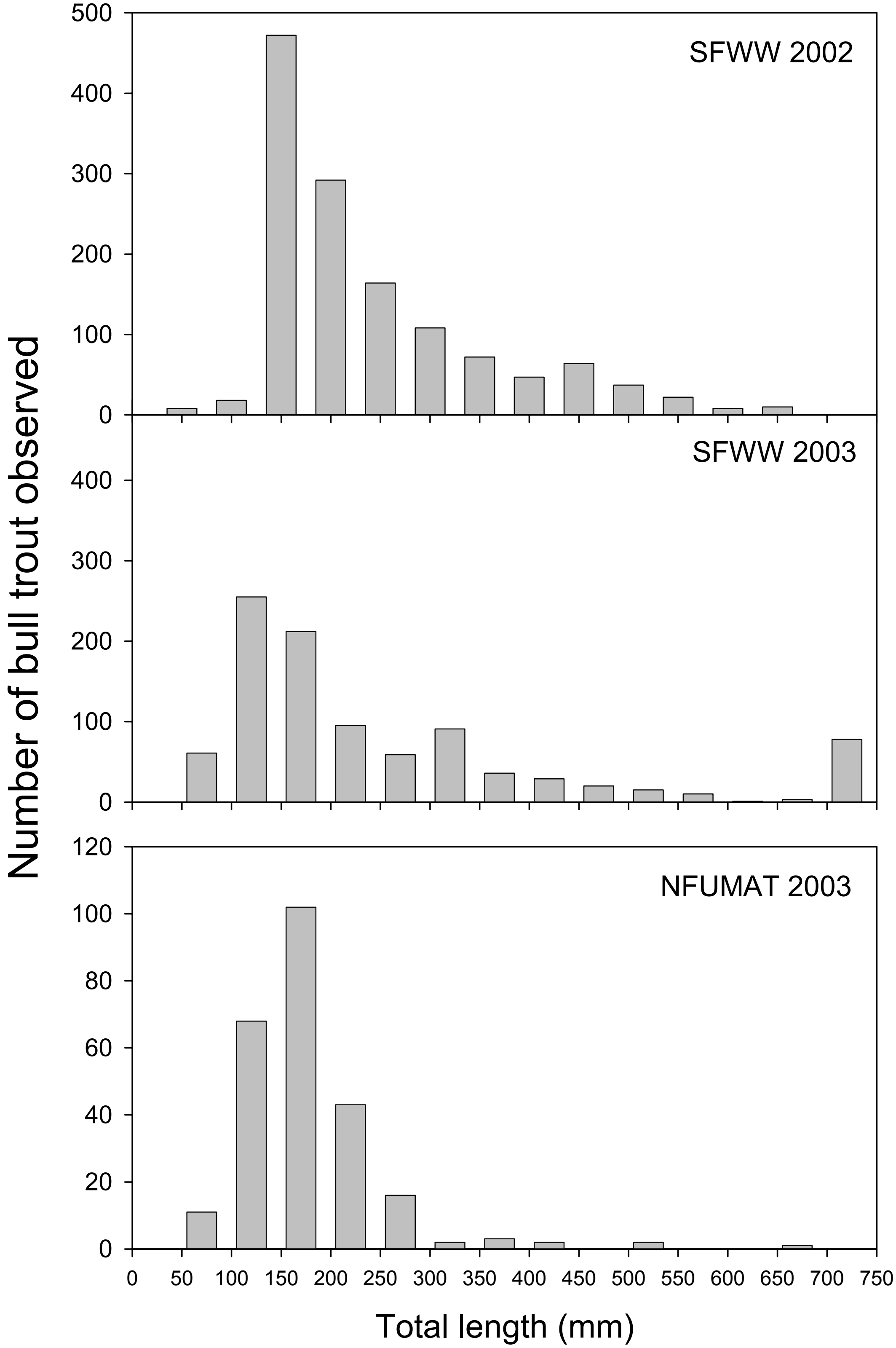


Figure 14. Number of bull trout observed during snorkel counts by size class in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Note change in y-axis scale.

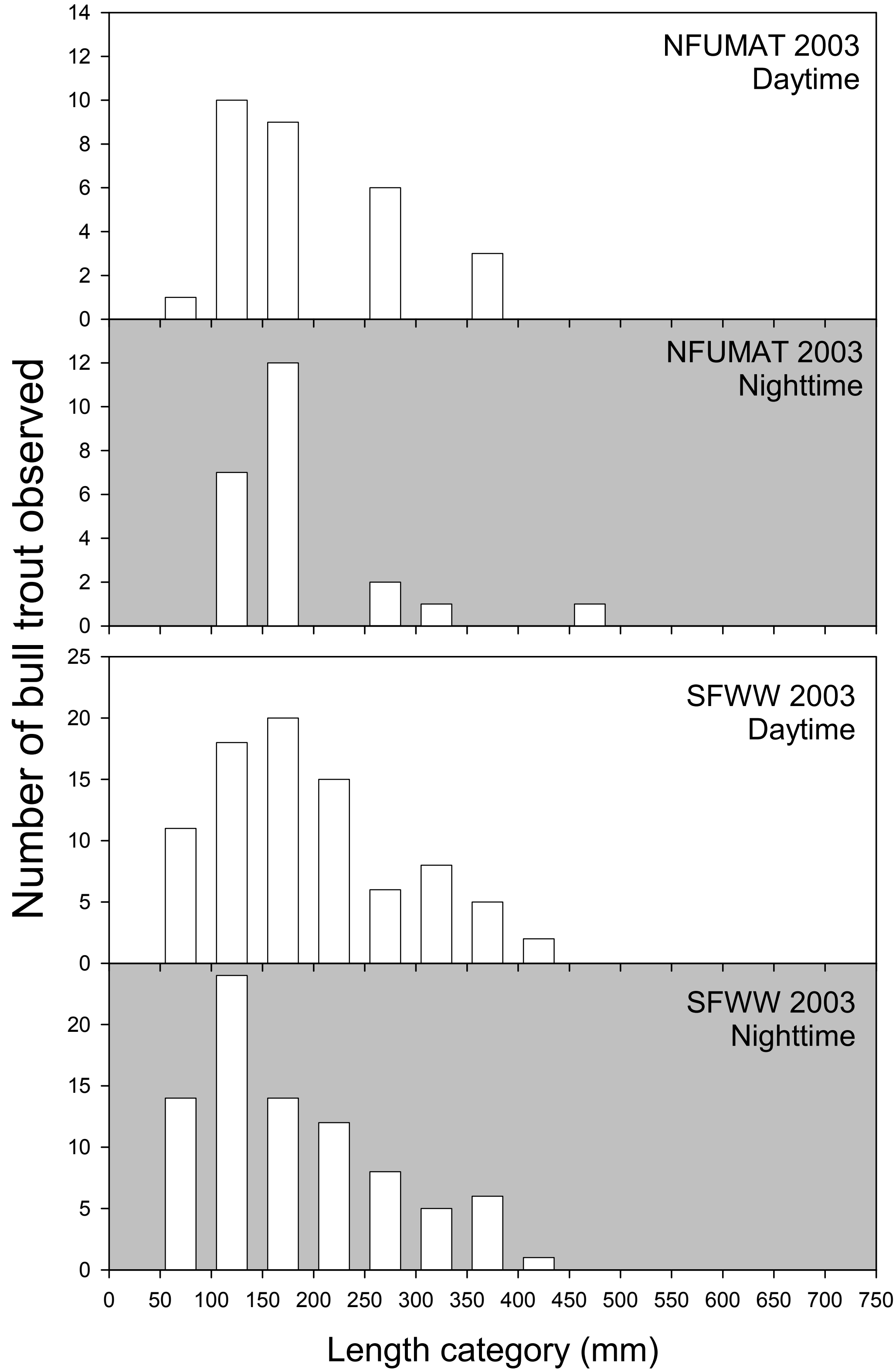


Figure 15. Number of bull trout observed during snorkel counts by size class in selected reaches in the North Fork Umatilla River (daytime versus nighttime surveys in 2003) and the South Fork Walla Walla River (daytime versus nighttime surveys in 2002 and 2003). Note changes in y-axis scale.

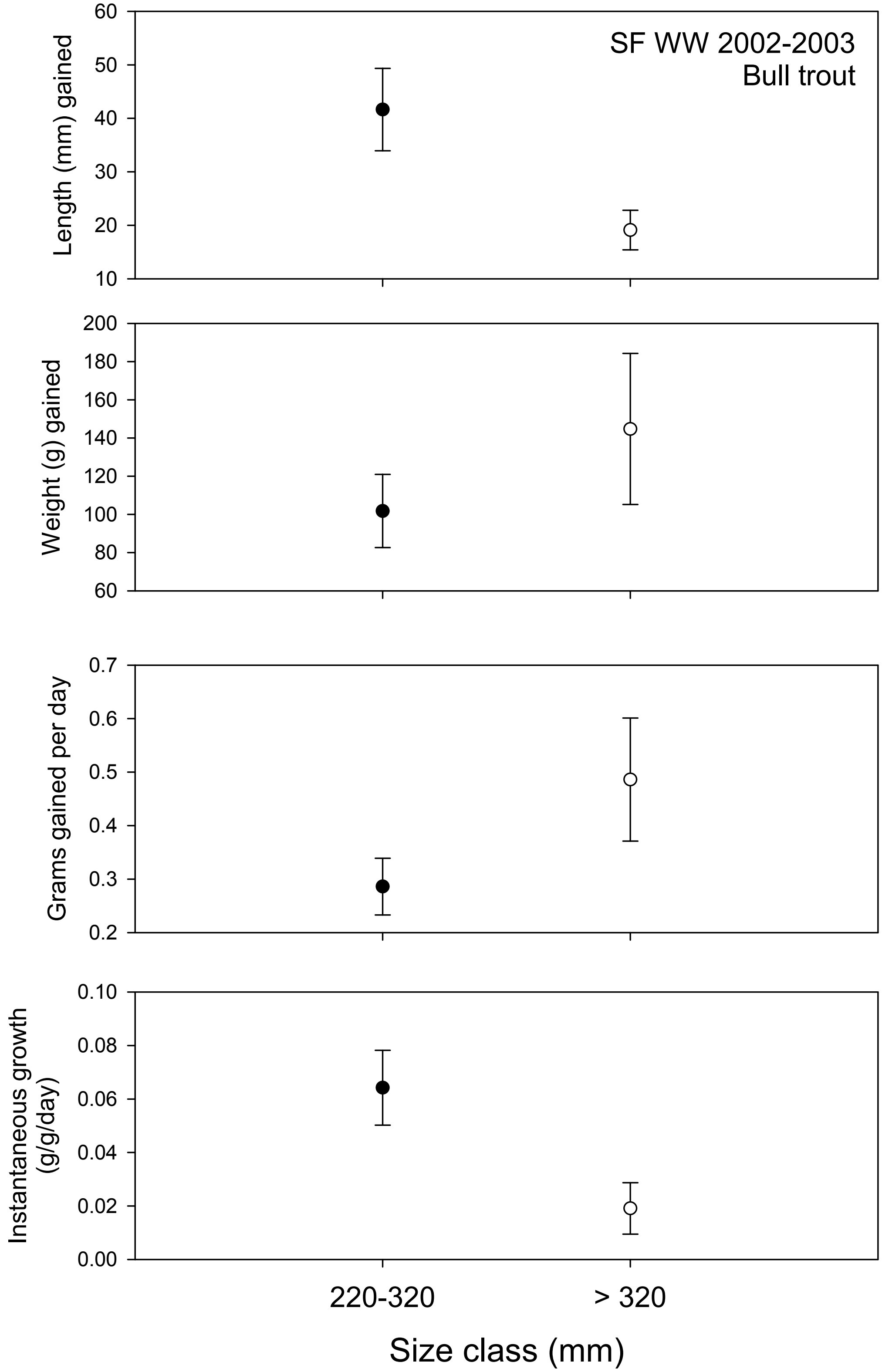


Figure 16. Growth of two size classes of bull trout in the South Fork Walla Walla River (2002 and 2003) expressed as length and weight gained between tagging date and recapture date (usually one year), grams per day, and instantaneous growth.

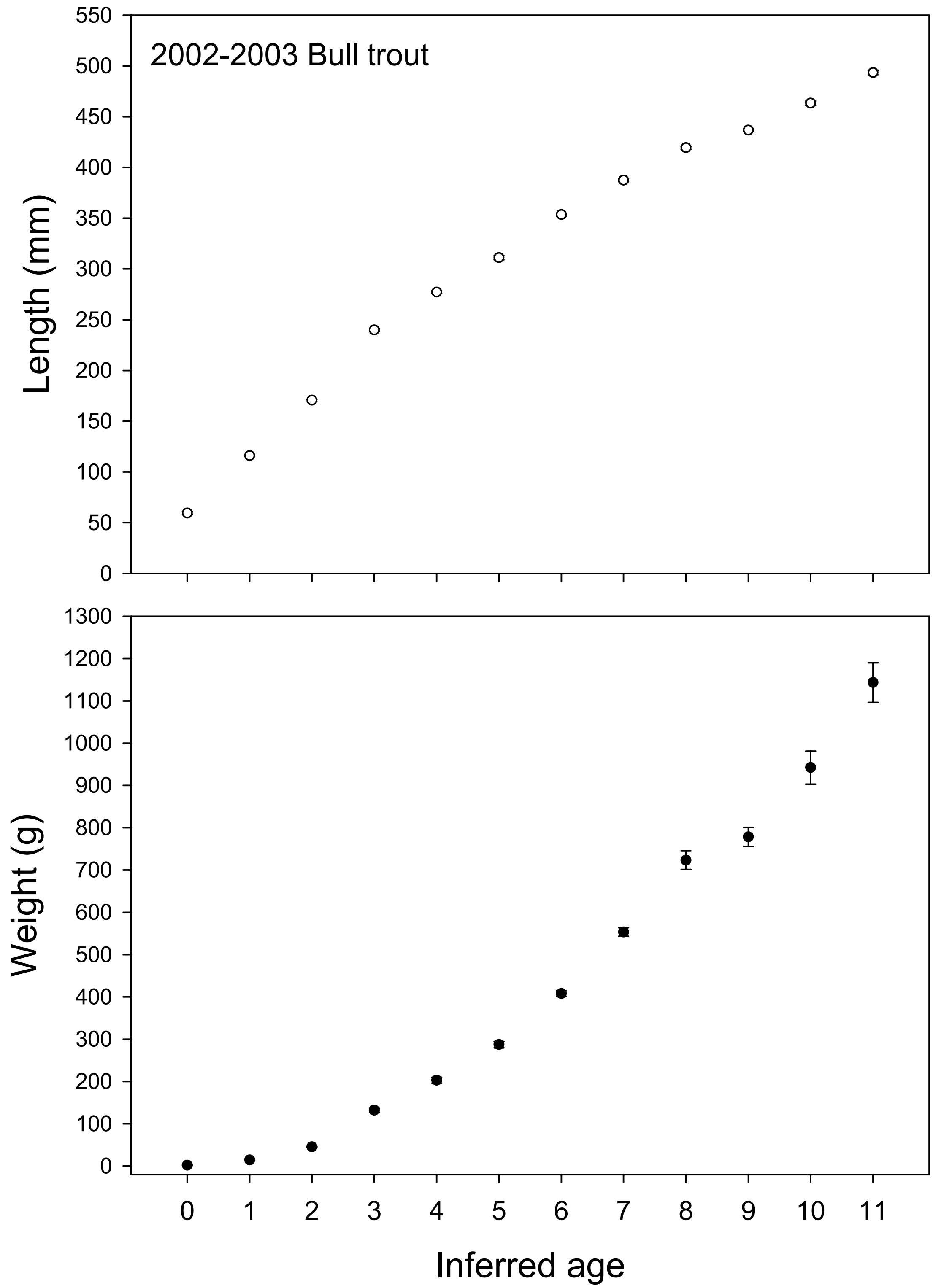


Figure 17. Bull trout length-at-age and weight-at-age inferred from length-frequency analysis for fish captured in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate + 1 standard error.

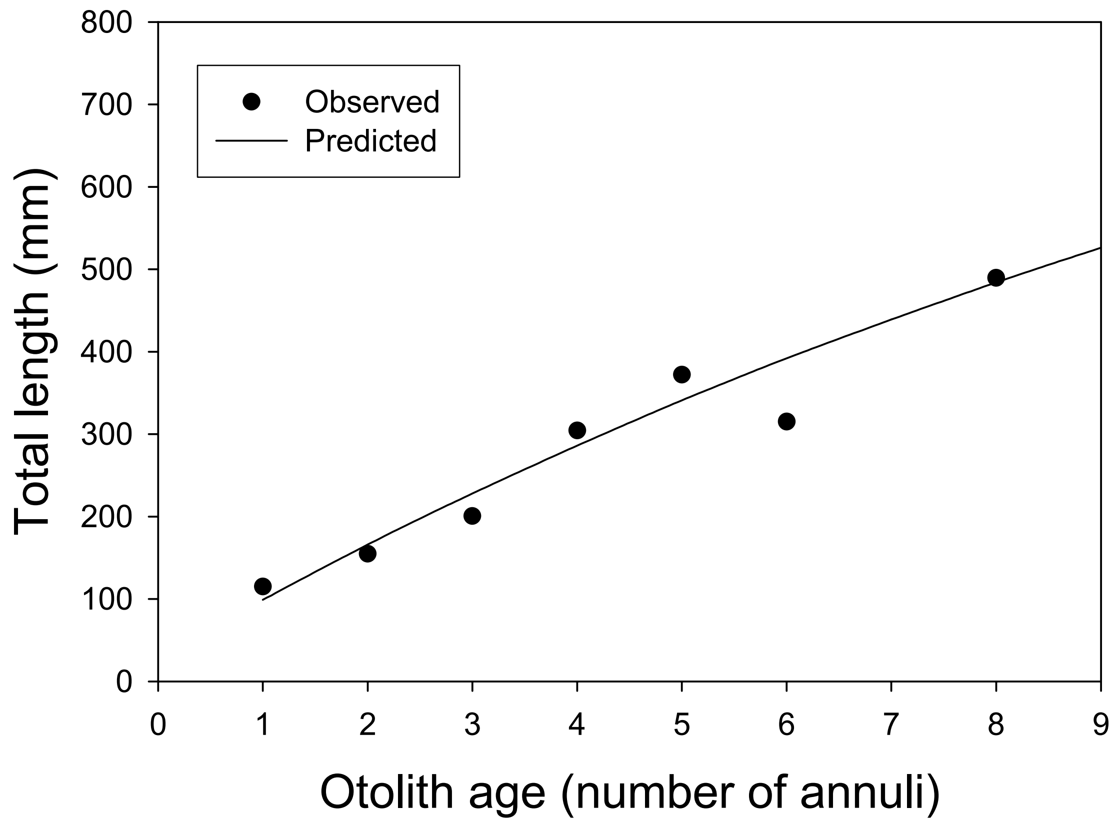


Figure 18. Observed bull trout length-at-age (black circles) obtained from otolith-analysis of bull trout captured in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003) compared to bull trout length-at-age predicted by a Von Bertalanffy growth model (solid line).

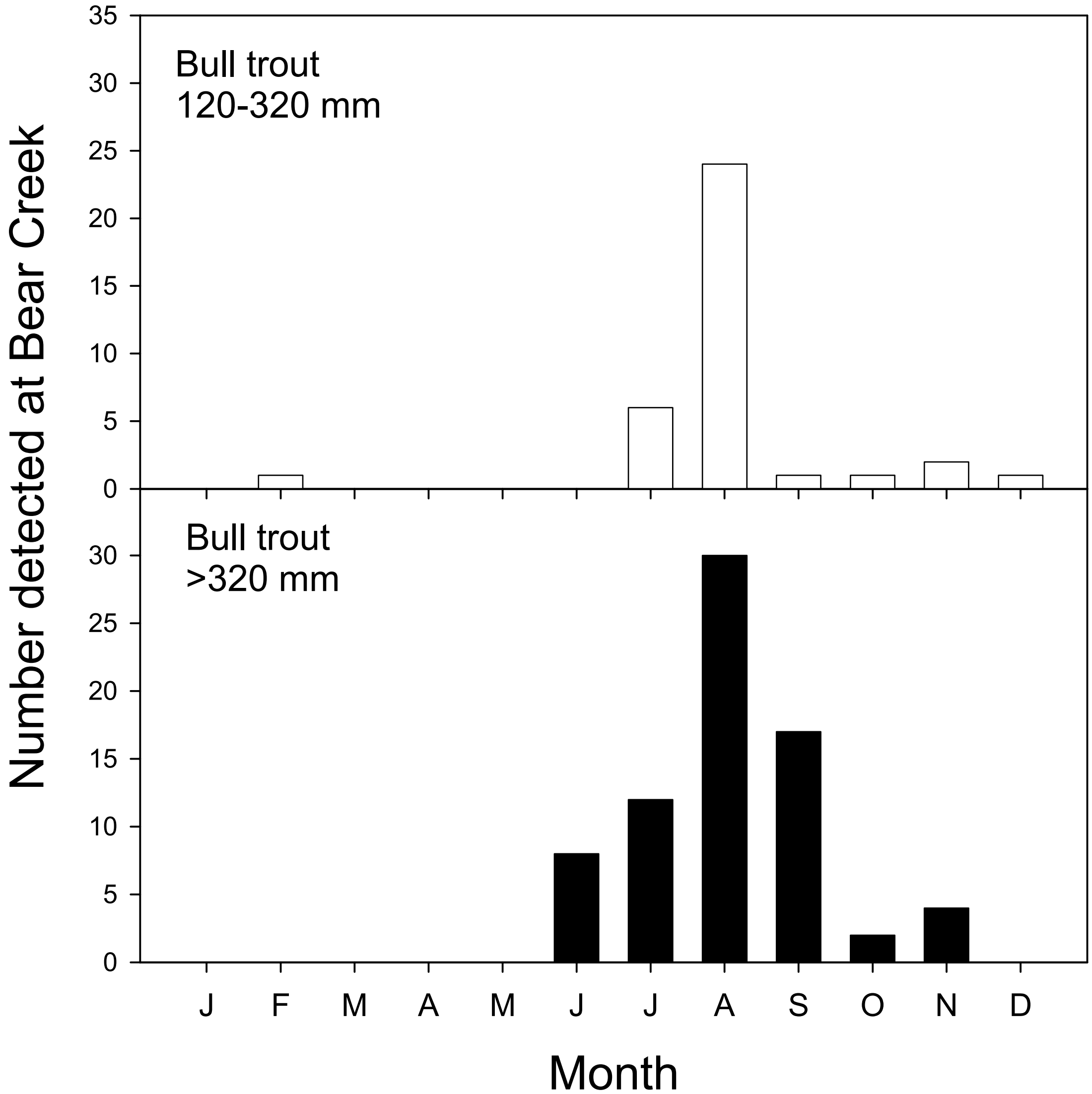


Figure 19. Monthly PIT-tag detections (recaptures) of small (120-320 mm; top panel) and large (> 320 mm; bottom panel) bull trout made at the Bear Creek antennae array, 2003.

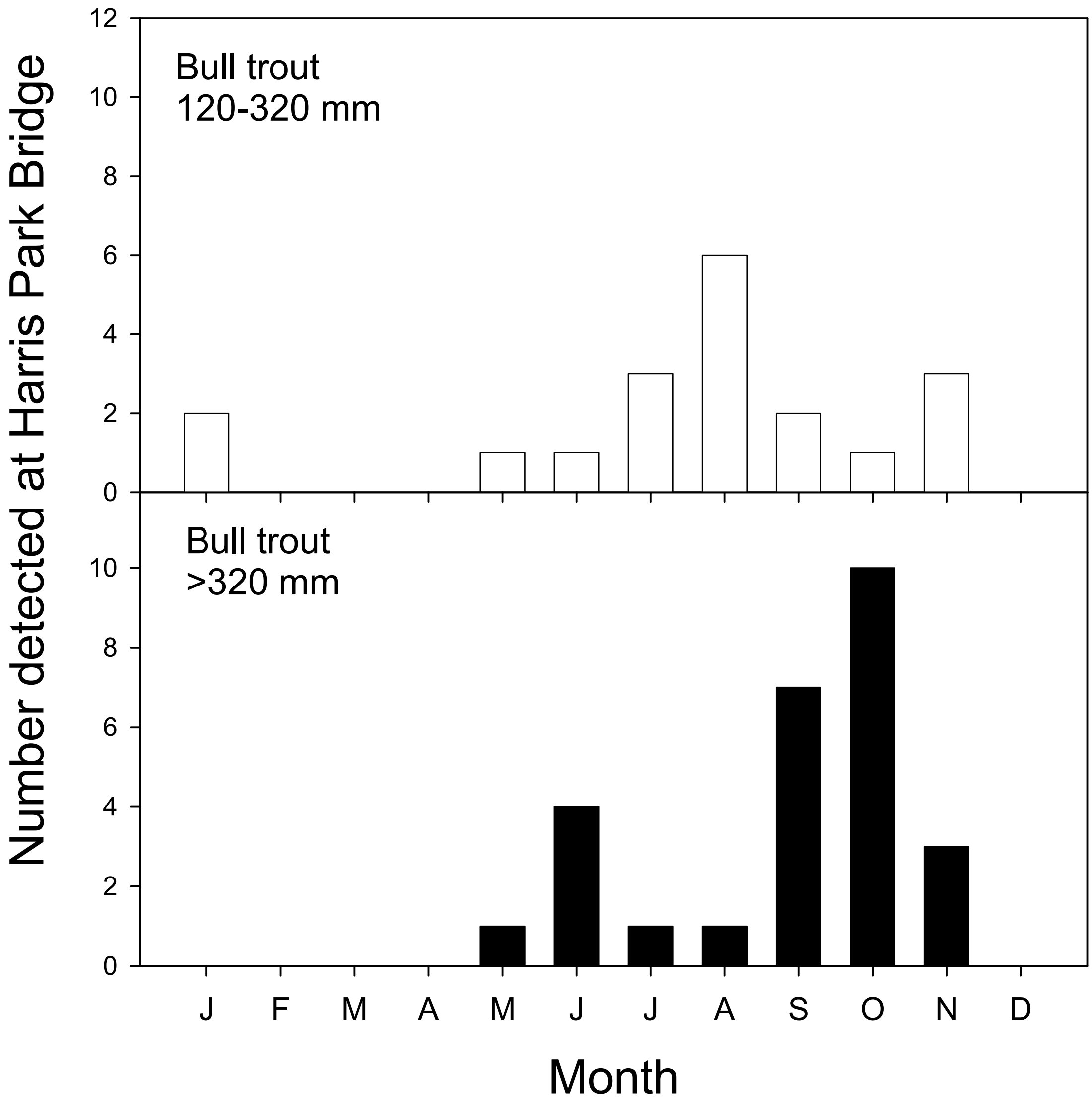


Figure 20. Monthly PIT-tag detections (recaptures) of small (120-320 mm; top panel) and large (> 320 mm; bottom panel) bull trout made at the Harris Park Bridge antennae array, 2003.

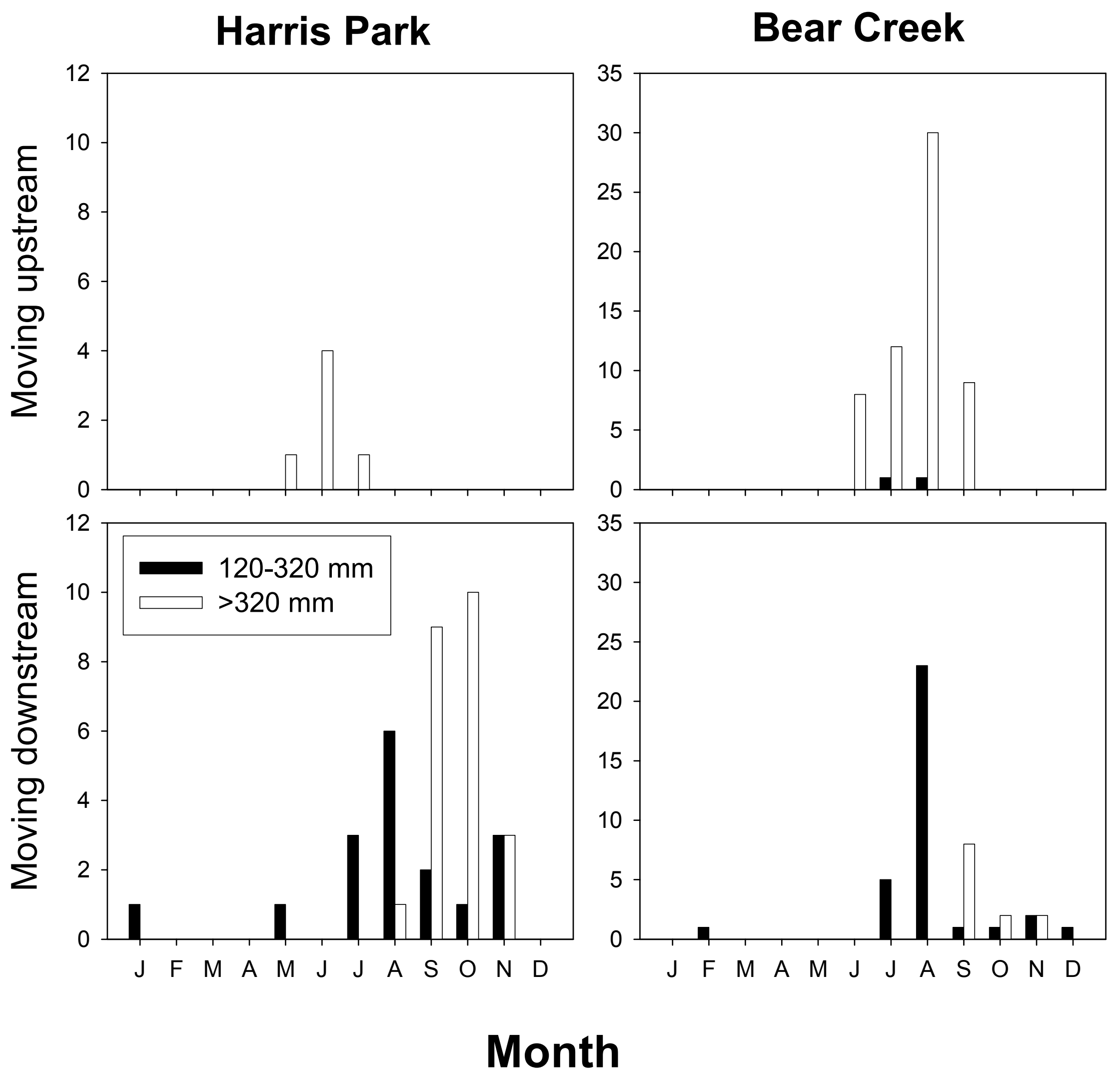


Figure 21. Movement of small (120-320 mm; top panel) and large (> 320 mm; bottom panel) bull trout based on PIT-tag directional-detections (recaptures) of made at the Bear Creek and Harris Park antennae arrays, 2003.

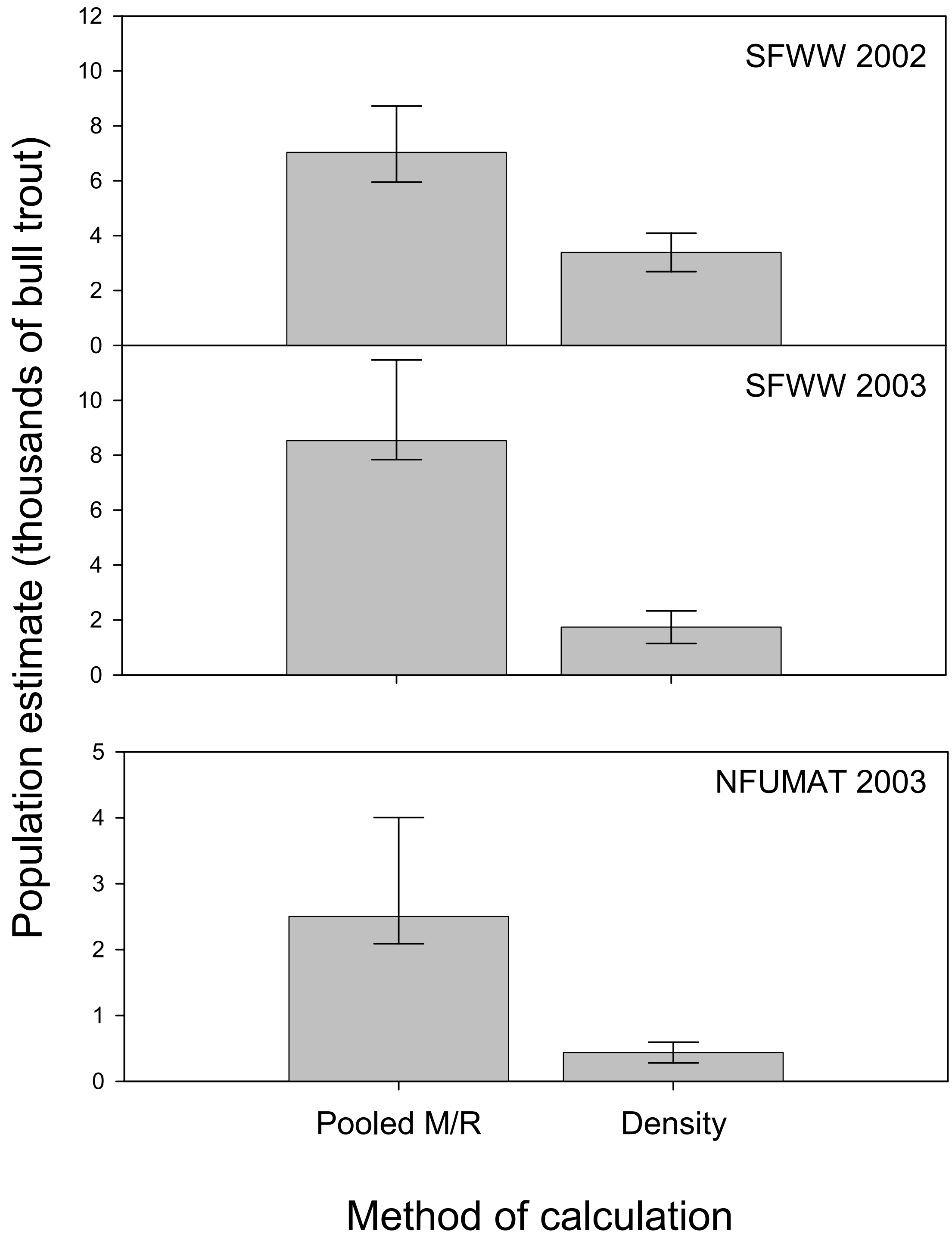


Figure 22. Population estimates (in thousands) of bull trout calculated by various methods (*see Methods*) in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate 95% confidence intervals around mean. Note changes in y-axis scales.

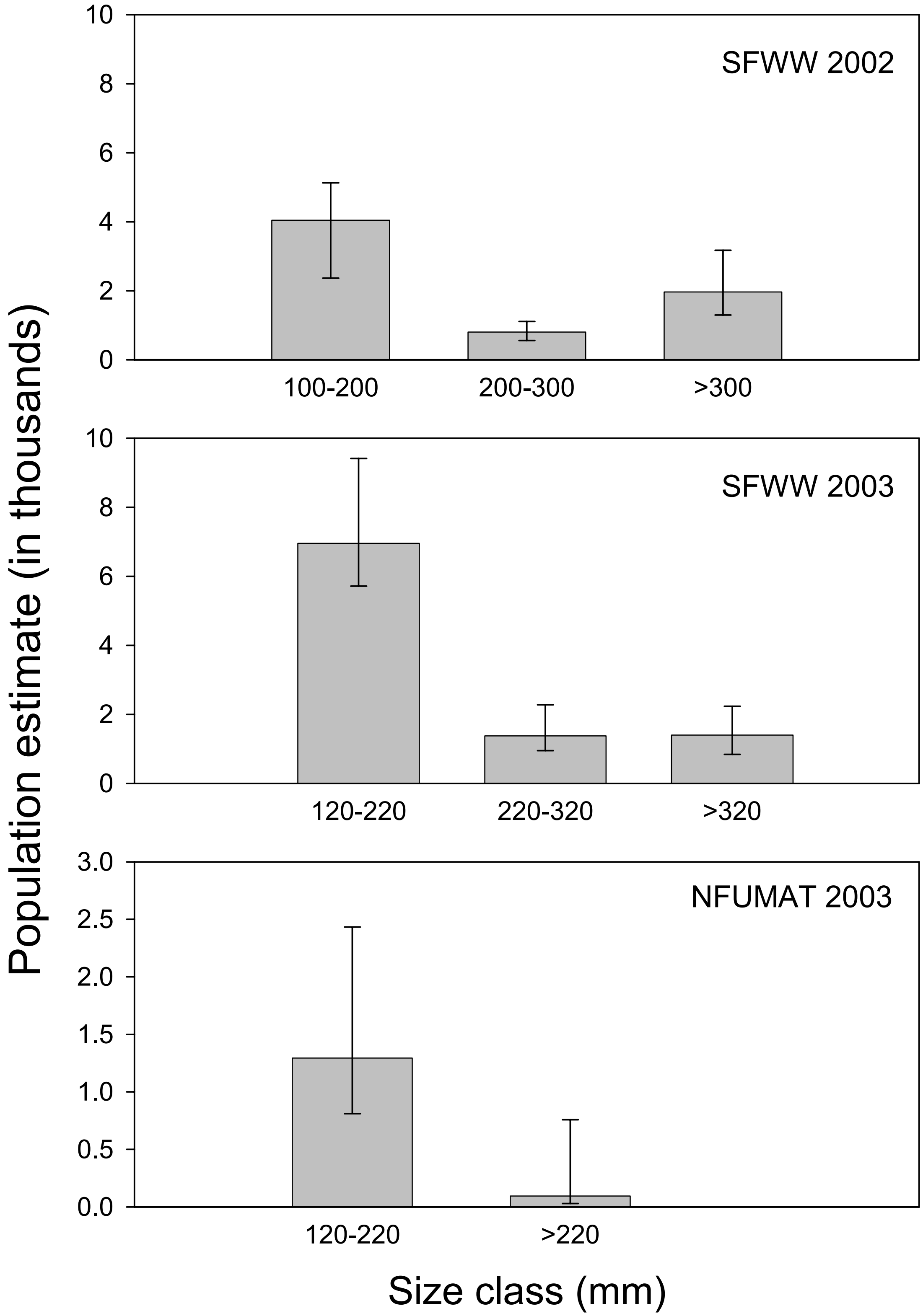


Figure 23. Population estimates (in thousands; calculated by pooled mark-recapture, M/R, method) for various size classes of bull trout in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003). Error bars indicate 95% confidence intervals around mean. Note changes in y-axis scales.

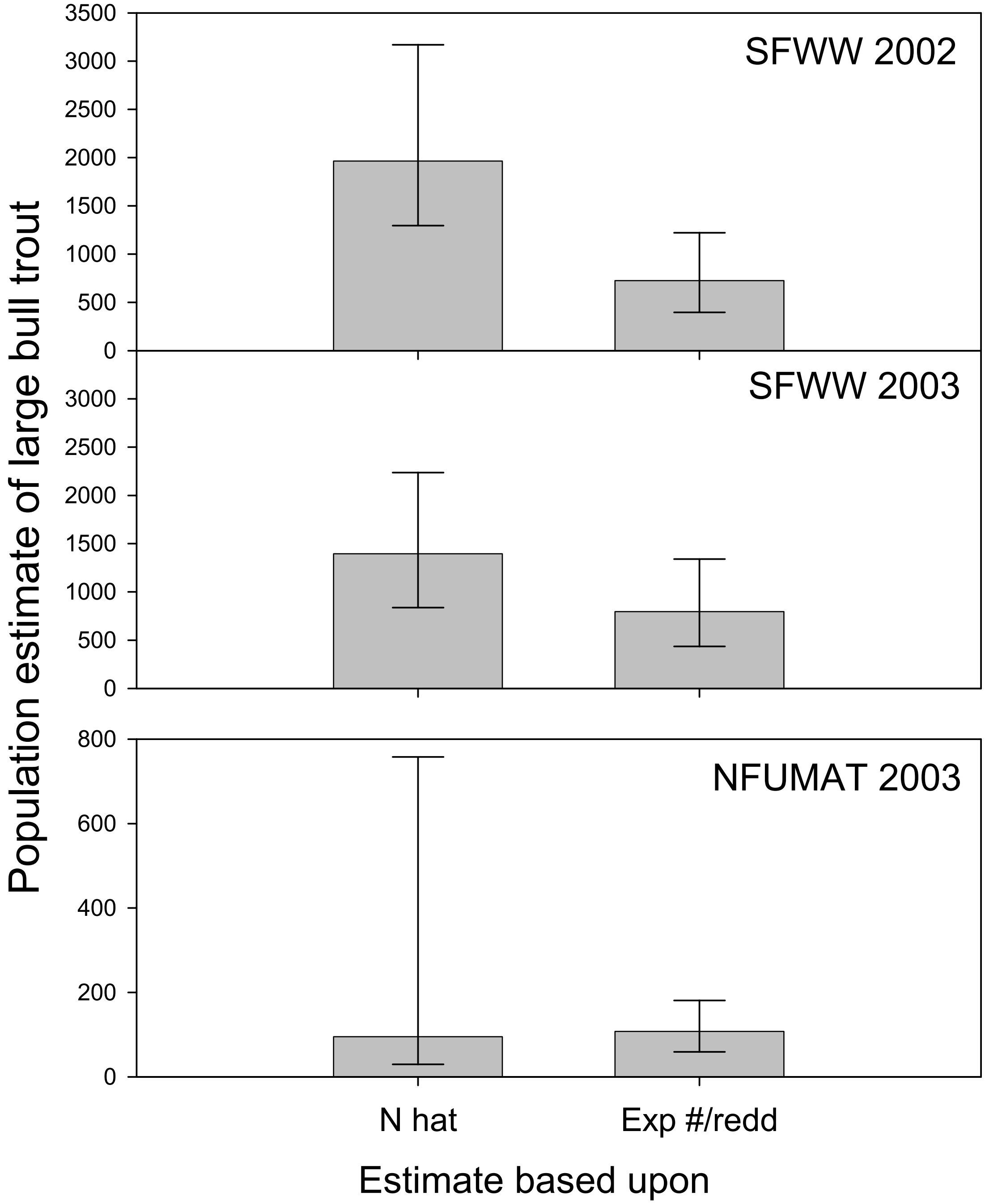
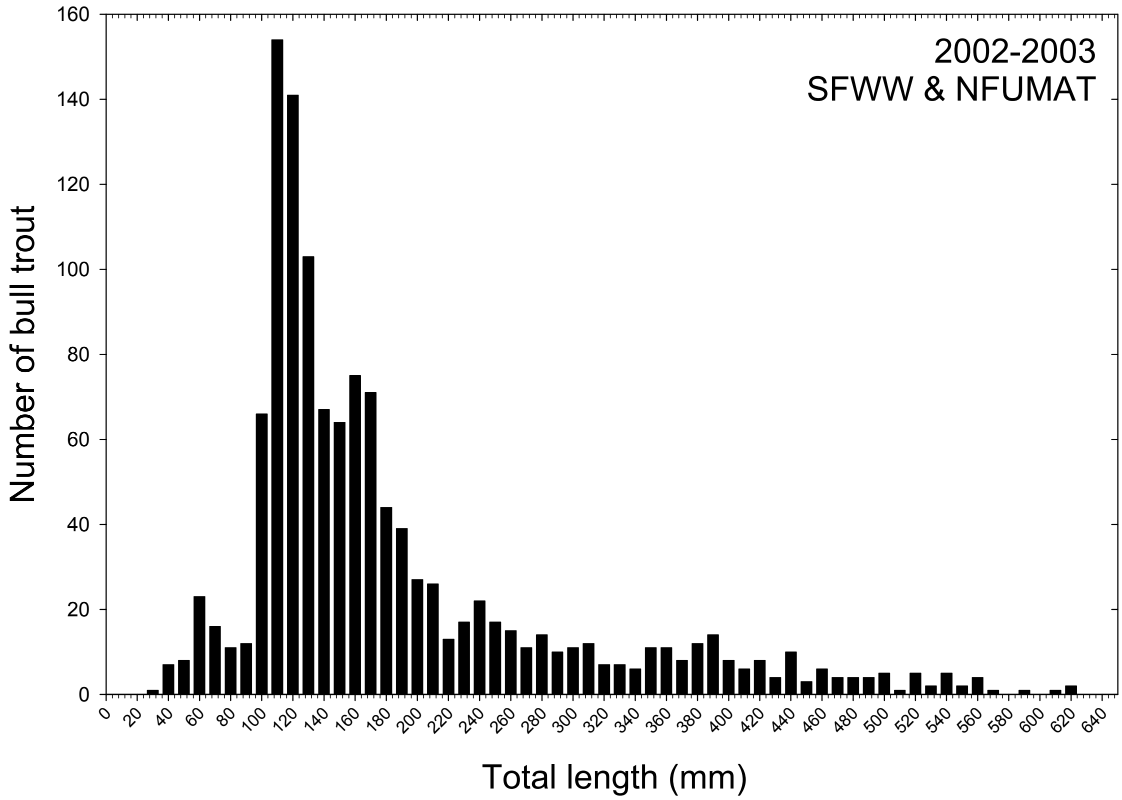


Figure 24. Comparison of population estimates (with 95% confidence intervals) of adult bull trout calculated from mark-recapture estimation (N hat) and from expanded redd count estimation (Exp #/redd). N hat includes bull trout > 300 mm in the South Fork Walla Walla River and bull trout > 220 mm in the North Fork Umatilla River. Redd counts are from respective streams and years (T. Bailey, ODFW, unpublished data). Expanded redd count estimates assume a mean of 2.2 fish/redd with upper error bar limit at 3.7 fish/redd (Taylor & Reasoner 1999) and lower error bar limit at 1.2 fish/redd (Baxter & Westover 2000).

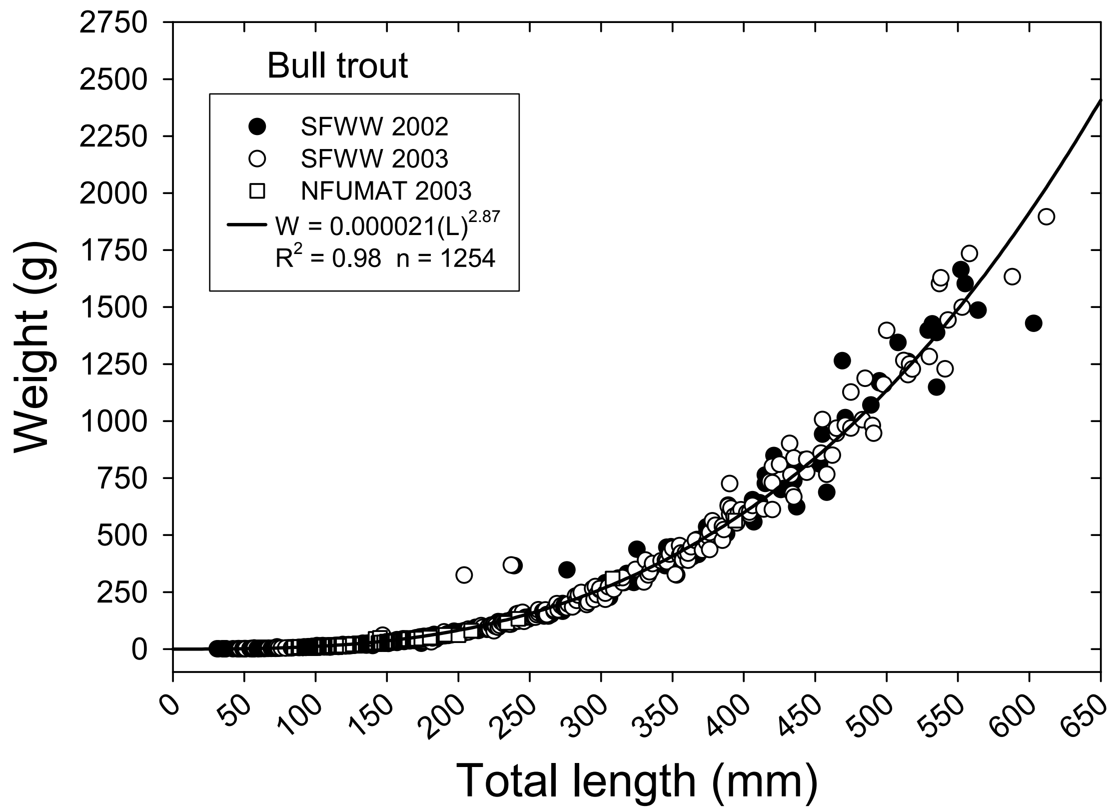
APPENDIX I

Appendix Table 1. Summary of all fish captured, tagged, and counted (sighted during snorkeling surveys) in sampled reaches of the South Fork Walla Walla and North Fork Umatilla rivers, summer 2003.

Species sampled	Activity	SF Walla Walla	NF Umatilla
Bull trout			
	Captured	743	152
	Tagged	383	78
	Counted	849	231
O. mykiss spp.			
	Captured	165	166
	Counted	1,777	4,996
Chinook salmon			
	Captured	45	38
	Counted	810	1,130
Mountain whitefish			
	Captured	8	7
	Counted	75	342
Lamprey			
	Counted	2	0



Appendix Figure 1. Length frequency distribution of bull trout captured in the South Fork Walla Walla River (2002 and 2003) and North Fork Umatilla River (2003); both streams, two years combined.



Appendix Figure 2. Combined length-weight relationship for bull trout captured in the South Fork Walla Walla and North Fork Umatilla rivers, 2002 and 2003. Regression equation, R^2-value, and sample size are given.

APPENDIX II

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.