# Redband Trout Spawning and Fry Emergence Study

Abundance and Year Class Strength Component

Annual Progress Report 2012

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# Abstract

The Federal Energy Regulatory Commission (FERC) issued a new license for the Spokane River Hydroelectric Project (FERC No. 2545) on 18 June 2009 (FERC 2009). This study is intended to provide information that will support the examination of redband trout year class strength, river discharge, and redband trout egg-emergence survival relationships, as required under the Washington State Department of Ecology's Water Quality 401 Certification, Amended Order No. 6702, FERC License No. 2545, Section 5.3 (D) 2. The objective of this study was to determine the abundance and year class strength of redband trout *Oncorhynchus mykiss gairdneri* in an index area of the Spokane River between Peaceful Valley (rkm 117.9) and T.J. Meenach Bridge (rkm 112.3), downstream of the Monroe Street Dam. A capture-recapture experiment coupled with scale analysis was conducted to estimate redband trout abundance and year class strength. Five sampling passes, or capture-recapture occasions, were completed using a drift boat mounted with electrofishing equipment. Abundance estimates were calculated for redband trout ≥250 mm fork length and age 1redband trout using the closed models $M_t$-Darroch and $M_t$-Chao, provided in the computer program CAPTURE. Abundance estimates of age 3 redband trout ≥250 were calculated by applying the proportion of age 3 fish to the appropriate estimate. The abundance estimates for redband trout ≥250 mm FL in the Spokane River between Peaceful Valley and T.J. Meenach Bridge were 855 (three passes) and 1,079 (five passes). The estimates of age 1 redband trout abundance were 384 for both 3 and 5 passes. The abundance estimates for age 3 redband trout ≥250 mm FL, were 259 (three passes) and 340 (five passes). The abundance estimates were considered relatively unbiased based on the evaluation of model assumptions and the use of models that account for variation in capture probabilities due to time.

# Acknowledgements

We thank Tim Vore (Avista Corporation) for administration of the joint project. We would like to thank the City of Spokane Parks and Recreation for providing access to boat launch and takeout sites. Jeff Wilson, Leslie King (WDFW), and Tim Vore assisted with fish collection. Lance Campbell and Lucinda Morrow (WDFW Fish Aging Lab) conducted the scale analysis. We thank Tim Vore (Avista), John Whalen, Chris Donley and Leslie King (WDFW) for reviewing this document.

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# Introduction

The Columbia River redband trout *Oncorhynchus mykiss gairdneri* are a subspecies of rainbow trout native to the Columbia River drainage east of the Cascade Mountains extending as far as barrier falls on the Snake, Spokane, Pend Oreille, and Kootenai rivers (Allendorf et al. 1980; Behnke 1992). Considerable variability exists in the life history of Columbia River redband trout (hereafter referred to as redband trout) including both anadromous (steelhead) and potamodromous forms (Behnke 1992). Naturally reproducing rainbow trout still occur in the Spokane River. Recent microsatellite DNA analysis conducted on wild rainbow trout in the Spokane River drainage indicated that rainbow trout populations in the Spokane River are pure redband trout and are presumed to be native (Small et al. 2007).

The Federal Energy Regulatory Commission (FERC) issued a new license for the Spokane River Hydroelectric Project (FERC No. 2545) on 18 June 2009 (FERC 2009). Ordering Paragraph E of the FERC license incorporated the Washington Department of Ecology's Certification Conditions under Section 401 of the Federal Clean Water Act (WDOE 2009). These conditions can be found in Appendix B of the License. The objective of this study was to determine the abundance and year class strength of redband trout in an index area of the lower Spokane River between Peaceful Valley (rkm 117.9) and T.J. Meenach Bridge (rkm 112.3). The study is intended to provide annual abundance estimates that will support the examination of redband trout year class strength, river discharge, and redband trout egg-emergence survival relationships, and through a 10-year effort will partially satisfy Appendix B, Section 5.3 (D) 2 (d) of the license. The Washington Department of Fish and Wildlife was contracted to assist Avista to complete the study. This report presents the results of the third year (2012) effort following the approved July 2010 – January 2013 scope of work.

## Study Area

The Spokane River originates at the outlet of Lake Coeur d'Alene in northern Idaho (rkm 178.8) and flows west 179 km through the City of Spokane to its confluence with the Columbia River in eastern Washington (Figure 1). Avista owns five hydroelectric developments (HED) (Post Falls Dam, Upper Falls Dam, Monroe Street Dam, Nine Mile Dam, and Long Lake Dam) operated under a single license from the Federal Energy Regulatory Commission (FERC No. 2545) which constitute the Spokane River Project (FERC 2009; WDOE 2009). The Monroe Street HED and the Nine Mile HED are operated as run-of-the-river, where inflow discharge equals outflow discharge (FERC 2009). The Spokane River between Monroe Street (rkm 119.1) and Nine Mile (rkm 93.5) dams was designated the lower Spokane River. The focus of our study was the upper free-flowing reach of the lower Spokane River (hereafter referred to as the lower Spokane River) from Peaceful Valley access site (rkm 117.9) to T.J. Meenach Bridge (rkm 112.3).

Mean annual discharge in the study area, measured at the USGS gage at Spokane (USGS gage no. 12422500), for the period of record from 1892 to 2011 was 189.8 $m^3$/s, with a minimum mean daily discharge of 13.2 $m^3$/s and a maximum of 1,387.5 $m^3$/s. Mean daily discharge during the study (08 October - 27 October 2012) was 53.1$m^3$/s and ranged from 47.3 to 74.2 $m^3$/s. Latah Creek (also known as Hangman Creek) enters the Spokane River at rkm 116.5 and contributed an additional mean daily discharge of 0.6 $m^3$/s between 08 October and 27 October 2012, measured at the Hangman Creek gage at Spokane (USGS gage no. 12424000).

The study area was characterized by riffle, run, and pool sequences typical of lotic systems (Kleist 1987). Substrates in the study area consisted of medium to large cobbles and boulders (Kleist 1987), interspersed with gravel deposits identified as redband spawning habitat (Parametrix 2003, 2004).

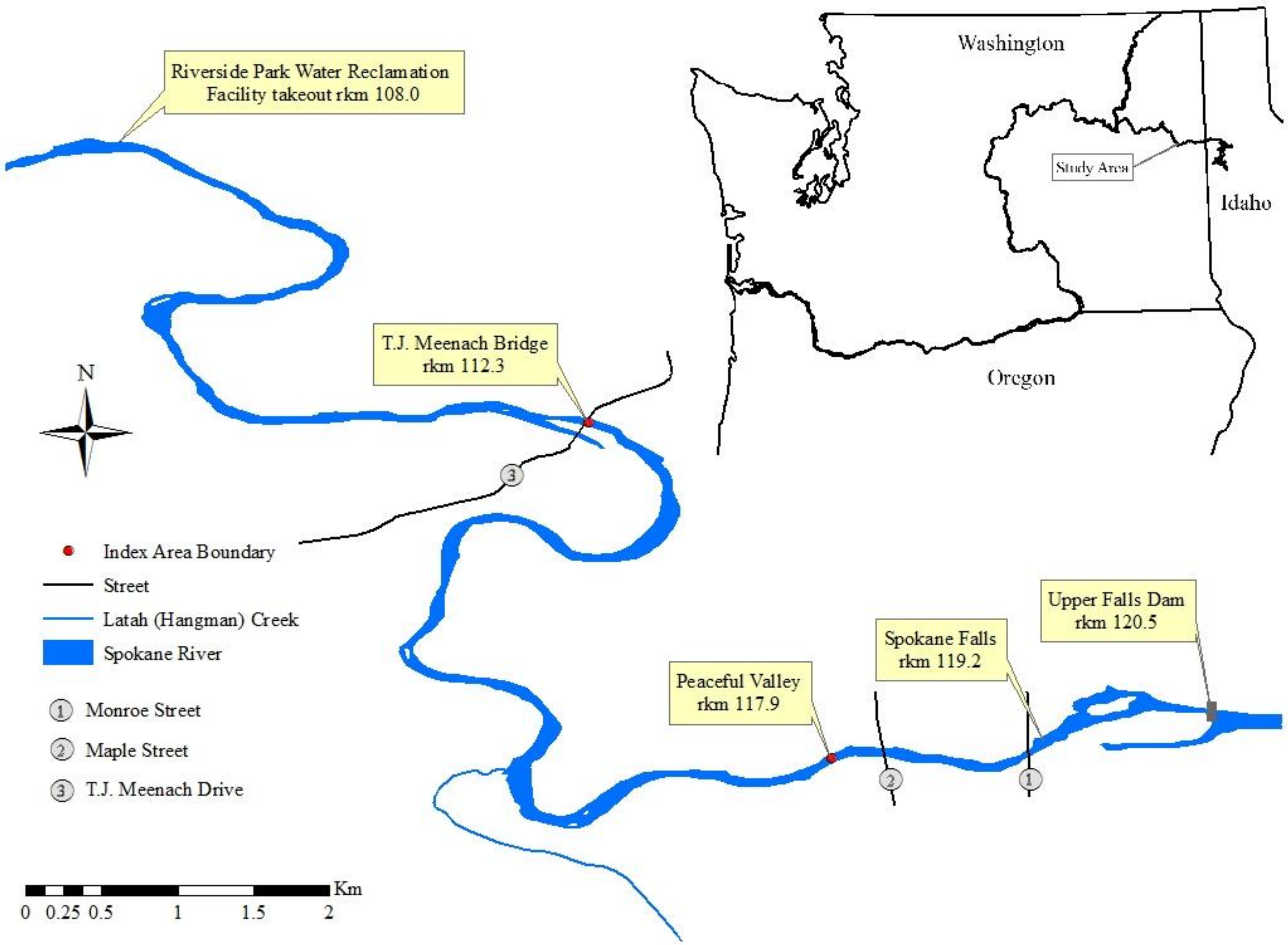


Figure 1. Lower Spokane River redband trout abundance index area (Peaceful Valley to T.J. Meenach Bridge) and the downstream reach (T.J. Meenach Bridge to Riverside Park Water Reclamation Facility [RPWRF]) sampled to evaluate the population closure assumption.

## Methods

*Fish Sampling* – Redband trout were captured by electrofishing using a drift boat mounted with a Smith-Root 2.5 GPP electrofishing unit. Electrofishing settings were: voltage=low (50-100), percent varied from 25-85, pulse rate 60 pulses per second direct current (DC), and amperage 2.0-2.2. A crew of three individuals, one rower and two netters, completed the electrofishing. A sampling pass, or capture-recapture occasion, consisted of sampling each shoreline of the index area, which extended from Peaceful Valley (rkm 117.9) downstream to T.J. Meenach Bridge (rkm 112.3) (Figure 1). The electrofishing transects were established prior to the initial capture effort in 2010 using a recreational grade handheld GPS. Transects in 2012 were consistent with those established in 2010. Two float trips were required to sample both shorelines during each pass. The initial sampling float started on either the north or south shoreline and alternated to the opposite shoreline at intervals of approximately 600 s (500 m). The subsequent float began on the opposite shoreline and alternated to the shoreline segments that were missed on the previous float, ensuring that the entire shoreline was sampled. This strategy was employed to avoid electrofishing over recently released trout. All float trips commenced approximately 0.5 hours after sunset and continued until all transects for that float were complete. Effort (*f*), or electrofisher "on" time, during subsequent floats varied due to river and weather conditions.

Salmonids were primarily targeted for capture during the study, although non-native game fish were collected to document their presence. All captured fish were measured for fork length (FL; mm), weighed (g), and recorded. Redband trout were examined for Floy® and passive integrated transponder (PIT) tags, as well as external marks (i.e. fin clips). Data were recorded on standardized waterproof data sheets. Untagged wild redband trout ≥65 mm FL were tagged with a full duplex (FDX) PIT tag (Destron Fearing, TX1411SST-1, 134.2 kHz). The PIT tags were injected into the coelomic cavity, just posterior to the pectoral fins (CBFWA 1999). Untagged wild redband trout ≥65 and <200 mm FL were also marked by removing the right pelvic (ventral) fin (to help distinguish from 2011 fish marked with a right pelvic fin clip), and those ≥200 mm FL were affixed with a Floy® (model FD-94) tag at the left base of the dorsal fin (Guy et al. 1996). Each Floy® tag was printed with a unique identification number and a phone number to promote angler reporting. Scales were removed from up to ten redband trout per one cm length bin for age determination.

*Abundance Estimation* – Redband trout abundance estimates within the index area were calculated using the closed models $M_t$-Darroch and $M_t$-Chao, provided in the computer program CAPTURE (Otis et al. 1978; White et al. 1982; Chao 1989; Rexstad and Burnham 1991). The model $M_t$-Darroch was selected when capture probabilities of redband trout were 10% or greater. Model $M_t$-Chao was used when the data were <10%, because it performed better when data were sparse (Chao 1989). The standard error and 95% confidence intervals for the abundance estimates were also calculated in CAPTURE. Precision of the estimates was measured by calculating a coefficient of variation (CV), which was the ratio of the standard error of the estimate to the estimate (Hightower and Gilbert 1984). Separate estimates were calculated for redband trout ≥250 mm FL and age 1 redband trout with the data from both the first three passes and all five passes. The 250 mm FL minimum size was selected due to low capture probabilities of redband trout <250 mm (see model assumptions below). The abundance of age 3 redband trout, for evaluating year class strength, was estimated by multiplying the proportions of age 3 redband trout in the catch of redband trout ≥250 mm FL in the first three and all five passes by the respective capture-recapture abundance estimates.

*Model Assumptions* -General assumptions for closed capture-recapture models are: 1) the population is closed, or there are no additions (recruitment, immigration) or losses (mortality, emigration), during the study period; 2) there is no tag loss and all tags are identified, and 3) all fish in the population have the same probability of capture on each sampling occasion (Otis et al. 1978; White et al. 1982; Pollock et al. 1990). Population closure was assumed due to the relatively short duration (18 days) of the study and Washington State angling regulations prohibited the harvest of wild redband trout in the index area. Despite our assumption, closure was evaluated by examining recaptures to determine if fish were moving into or out of the index area during study period. Redband trout upstream of the index area, in the middle Spokane River between Upper Falls and Upriver dams, were tagged in September of 2010, 2011, and 2012 using the same tagging methods prior to the start of the capture-recapture experiment (Lee and McLellan 2011; King and Lee 2012, Lee and King *in prep*). Closure was also evaluated by electrofishing downstream of the index area, between T.J. Meenach Bridge and the Riverside

Park Water Reclamation Facility (RPWRF; rkm 108.0) on two separate float trips on consecutive nights. The first was on 20 October and it was conducted in the same manner as sampling within the study area, in that, alternating shoreline sections were sampled at 600 s intervals. The second was conducted on 21 October and sampling was conducted along transects that were not electrofished on the initial float the previous night. Fish processing was conducted in the same manner as within the index area. Recaptures were analyzed to determine if tagged redband trout violated the closure assumption by moving out of the index area during the study. We assumed that a lack of recaptures of redband trout tagged upstream and downstream of the index area would support the assumption of closure.

Tag loss was essentially eliminated for redband trout ≥200 mm FL with the use of two tags. Nonetheless, we evaluated short-term tag loss for both tag types by examining for both tags on recapture. We also evaluated PIT tag retention for redband trout between 65 and 199 mm FL by examining for both the PIT tag and the secondary mark (fin clip) on recapture. Tag loss rates were reported as the proportions of redband trout recaptured that possessed only a Floy® tag, PIT tag or fin clip, versus the number of fish released with PIT and Floy® tags (≥200 mm FL) or a PIT tag and a fin clip (65-199 mm FL). We assumed all tags and marks were identified.

The assumption of equal capture probability was addressed by estimating abundance using models $M_t$-Darroch and $M_t$-Chao, which accounted for unequal capture probabilities due time effects (Otis et al. 1978; Chao 1989), as previously described. In addition, the assumption of equal capture probability was evaluated by examining recapture rates for 50 mm size classes of tagged redband trout. Most sampling techniques are size selective (Ricker 1975), which result in unequal capture probabilities for fish over a range of sizes. In cases where size selectivity is evident, capture-recapture data are often stratified into size groups and several abundance estimates are generated (Ricker 1975) or size-specific capture efficiencies are estimated and used to correct an abundance estimate (Vincent 1983); however, stratification of capture-recapture data into length groups results in reduced precision (Seber 1982).

*Age Determination and Analysis* – Fish scales were mounted on cards, pressed in acetate, and magnified to identify annuli and spawning checks. Ages were determined by counting annuli. Ages were assigned to redband trout from which scales were not analyzed by constructing an age-length key for each year (Iserman and Knight 2005). The age-length keys were developed using the FSA (Fish Stock Assessment Methods) and NC Stats packages (available at http://www.rforge.net/FSA/files/; accessed 18 January 2013) in program R with the semi-random assignment method (documentation available at http://www.ncfaculty.net/dogle/fishR/gnrlex/gnrlex.html; accessed 21 December, 2012).

## Results

Throughout the study period, we conducted a total of five sampling passes. The initial pass was conducted between 08 and 09 October, the second pass was conducted between 12 and 13 October, third pass was conducted between 16 and 17 October, fourth pass was conducted between 22 and 23 October, and the fifth pass was conducted between 26 and 27 October. Two passes were conducted downstream of the index area on 20 and 21 October. The study period encompassed the 20 days between 08 October and 27 October 2012.

A total of 750 fish were captured from the Spokane River between Peaceful Valley and the RPWRF during the study. The total catch was comprised of 692 redband trout, eight brown trout *Salmo trutta*, two westslope cutthroat trout *O. clarkii lewisi*, 21 hatchery origin rainbow trout, 26 smallmouth bass *Micropterus dolomieu* and one yellow perch *Perca flavescens*. The 692 redband trout consisted of 607 individuals. A total of 455 individual redband trout were captured within the lower Spokane River index area (Peaceful Valley to T.J. Meenach Bridge). The 455 redband trout within the index area consisted of 391 that were captured only once, 57 that were captured twice, six that were captured three times and one fish was captured four times. No individual redband trout was captured on more than four occasions. There were a total of 290 individual redband trout ≥250 mm FL captured during the first three passes, and of those 36 were captured on more than one occasion (Table 1). We captured 340 individual redband trout ≥250 mm FL during all five passes, of which 48 were captured on more than one occasion (Table 1). There were a total of 114 individual age 1 redband trout captured during the first three passes, of which 12 were captured on more than one occasion. A total of 132 individual age 1 redband trout were captured during all five passes and of those 20 were captured on more than one occasion (Table 1). All potential capture histories were represented in the first three passes for redband trout ≥250 mm FL and age 1fish. Three age 1 fish were captured three times and none were captured more than three times in the five pass data set. Capture histories with greater than four captures were absent from the five pass dataset.

Short term tag loss within the study period was low (3.1%). A total of 64 redband were captured on more than one occasion within and downstream of the study area, two of which had lost their PIT tag. Both fish that had lost their PIT tag possessed an intact Floy® tag. All recaptured fish that possessed a PIT tag also had either a fin clip or a Floy® tag. None of the untagged fish had a tag wound where a PIT tag or Floy® tag would have been applied. Tag loss did not affect the abundance estimates due to double marking all redband captured.

The abundance estimates for redband trout ≥250 mm FL in the index area of the lower Spokane River between Peaceful Valley and T.J. Meenach Bridge were 855 (three passes) and 1,079 (five passes) (Table 2). The estimates of age 1 redband trout abundance were 384 (three passes and five passes). The CV values for all estimates were ≤25.1% and were lower for the five pass estimates. The estimates of age 3 redband trout abundance were 259 (three passes) and 340 (five passes).

Based on the evaluation of model assumptions and the use of models that account for variation in capture probabilities due to time, the abundance estimates were considered unbiased. The population was considered closed since current Washington State angling regulations prohibit harvest of wild redband trout within the study area, no tagged redband trout immigrated from upstream of the study area, and there were no reports of anglers catching tagged redband trout downstream of the study area within the study period. A single redband trout initially tagged within the index area was captured downstream of the index area. The emigration of a single redband violated the closure assumption; however, we believe the effects of the emigration on the estimates were likely negligible.

Unequal capture probabilities due to length were accounted for by removing fish <250 mm FL from the analysis other than the age 1 estimates, due to smaller sample size and lower proportions of tagged fish recaptured (Table 3).

Scale samples were collected and aged from 271 redband. Resorption limited the ability to collect scales from several of the larger fish. Ages were assigned to the additional 336 redband trout captured between Peaceful Valley and RPWRF that did not have ages determined from scales. Ages of redband trout captured ranged from 0 to 6 years. There was substantial overlap in the lengths of redband trout older than age 1 (Figure 2). The proportions of redband trout age 1 (30.0%), age 2 (28.3%), and age 3 (24.4%) were similar and made up the majority of the catch (Figure 3). Age 2 redband accounted for 39.4% of the fish ≥250 mm FL in the index area during all five passes. Age 3 redband trout comprised 24.4% of the total catch of redband trout ≥250 mm FL (Peaceful Valley – RPWRF) and 31.4% in the index area during all five passes (Figure 3).

Table 1. Count of redband trout capture histories within the lower Spokane River index area during the first three and all five capture-recapture passes (October 2012). In capture history notation a 1 indicated a fish was encountered during a specific pass and a 0 indicated it was not. For example, a fish with a capture history of 001 was only captured during the third sampling occasion (or pass). The capture history data was used to calculate the capture-recapture abundance estimates.

| 3 Passes | | | 5 Passes | | |
|---|---|---|---|---|---|
| Capture History | n (≥250 mm FL) | n (age 1) | Capture History | n (≥250 mm FL) | n (age 1) |
| 100 | 124 | 51 | 10000 | 119 | 46 |
| 010 | 69 | 29 | 01000 | 66 | 28 |
| 001 | 61 | 22 | 00100 | 58 | 20 |
| 110 | 15 | 8 | 00010 | 31 | 9 |
| 101 | 13 | 2 | 00001 | 18 | 9 |
| 011 | 7 | 1 | 11000 | 14 | 7 |
| 111 | 1 | 1 | 10100 | 11 | 2 |
| | | | 10010 | 4 | 3 |
| | | | 10001 | 0 | 1 |
| | | | 01100 | 5 | 1 |
| | | | 01010 | 3 | 0 |
| | | | 00110 | 1 | 2 |
| | | | 01001 | 0 | 1 |
| | | | 00101 | 2 | 0 |
| | | | 00011 | 1 | 1 |
| | | | 11100 | 1 | 1 |
| | | | 11010 | 1 | 0 |
| | | | 10110 | 2 | 0 |
| | | | 10011 | 1 | 1 |
| | | | 01101 | 1 | 0 |
| | | | 01111 | 1 | 0 |

Table 2. Estimated abundance, standard errors (SE), 95% confidence intervals (CI), and coefficient of variation (CV) values, of redband trout ≥250 mm fork length (FL), age 1, and age 3 in the lower Spokane River index area between Peaceful Valley and T.J. Meenach Bridge calculated with capture-recapture data from the first three and all five sampling passes (October 2012).

| Model | Passes | Fork Length (mm) or Age | N | SE | Lower 95% CI | Upper 95%CI | CV |
|---|---|---|---|---|---|---|---|
| $M_t$-Chao | 3 | ≥250 | 855 | 120.8919 | 663 | 1145 | 0.141 |
| $M_t$-Chao | 5 | ≥250 | 1079 | 146.441 | 844 | 1425 | 0.136 |
| | | | | | | | |
| $M_t$-Chao | 3 | age 1 | 384 | 96.5056 | 251 | 646 | 0.251 |
| $M_t$-Chao | 5 | age 1 | 384 | 78.2824 | 272 | 589 | 0.204 |
| | | | | | | | |
| Proportional[a] | 3 | ≥250/age 3 | 259 | - | 201 | 347 | - |
| Proportional[a] | 5 | ≥250/age 3 | 340 | - | 266 | 448 | - |

[a]The estimated abundance of age 3 redband trout was calculated by multiplying the estimated proportion of age 3 redband trout in the catch of redband trout ≥250 mm FL during the first three and all five passes by the respective capture-recapture abundance estimate of redband trout ≥250 mm FL.

Table 3. Proportions of tagged redband trout within 50 mm length groups that were recaptured during the first three and all five capture-recapture passes conducted on the lower Spokane River index area between Peaceful Valley and T.J. Meenach Bridge (October 2012).

| 3 Passes | | | | 5 Passes | | | |
|---|---|---|---|---|---|---|---|
| Length Bin (FL; mm) | No. Tagged | No. Recaptured | Proportion Recaptured (%) | Length Bin (FL; mm) | No. Tagged | No. Recaptured | Proportion Recaptured (%) |
| 55-99 | 6 | 0 | 0.00 | 55-99 | 11 | 0 | 0.00 |
| 100-149 | 27 | 2 | 7.41 | 100-149 | 47 | 5 | 10.64 |
| 150-199 | 1 | 1 | 100.00 | 150-199 | 2 | 1 | 50.00 |
| 200-249 | 44 | 4 | 9.09 | 200-249 | 53 | 9 | 16.98 |
| 250-299 | 71 | 9 | 12.68 | 250-299 | 79 | 13 | 16.46 |
| 300-349 | 107 | 8 | 7.48 | 300-349 | 125 | 14 | 11.20 |
| 350-399 | 85 | 17 | 20.00 | 350-399 | 105 | 20 | 19.05 |
| 400-449 | 27 | 2 | 7.41 | 400-449 | 31 | 2 | 6.45 |
| 450-499 | 2 | 0 | 0.00 | 450-499 | 2 | 0 | 0.00 |
| Grand Total | 370 | 43 | 11.62 | Grand Total | 455 | 64 | 14.07 |

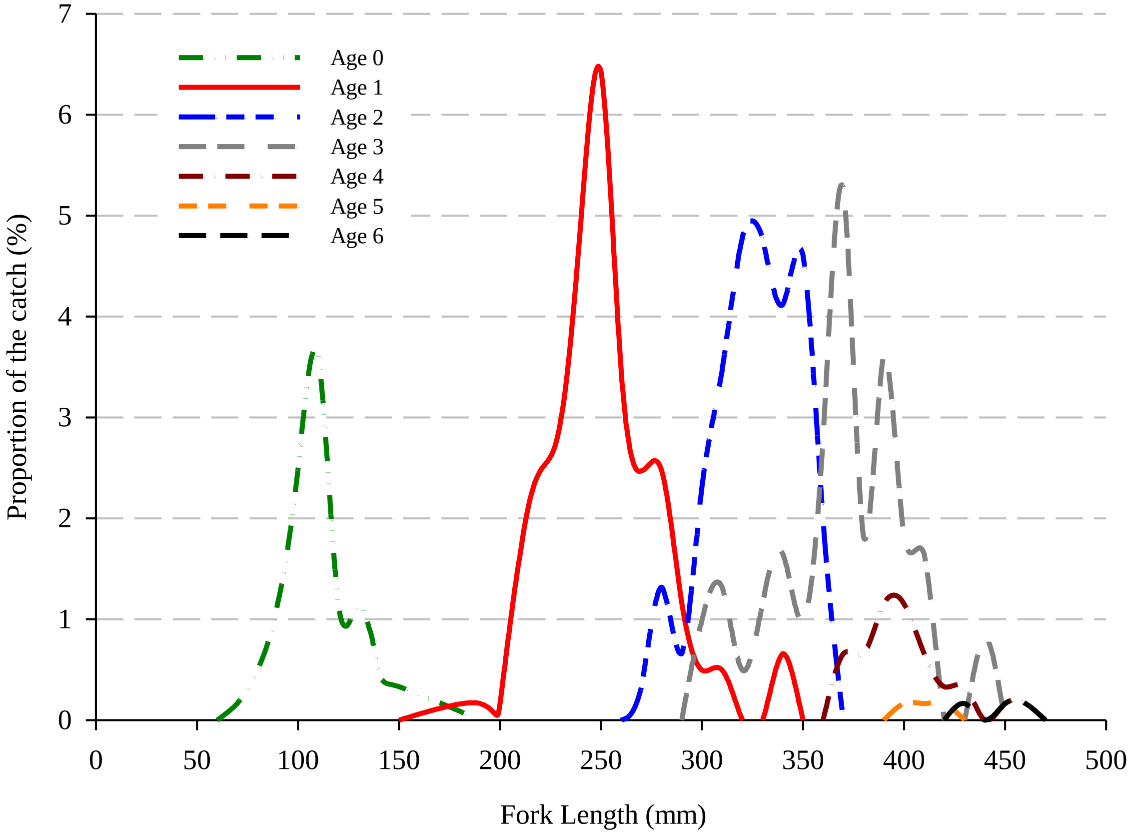


Figure 2. Length- and age-frequency distribution of all redband trout (n=607) captured between Peaceful Valley and the Riverside Park Water Reclamation Facility (RPWRF)(October 2012).

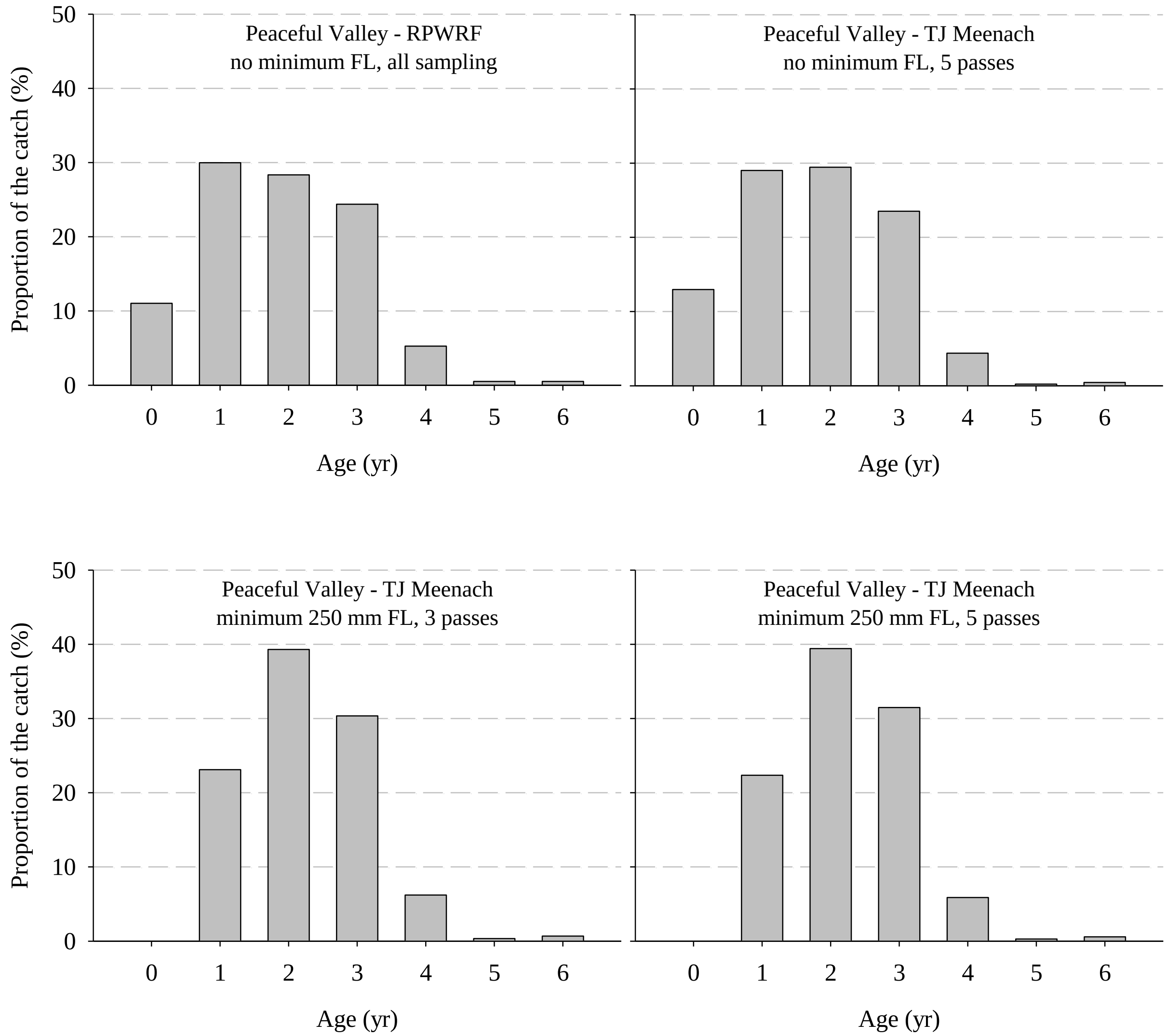


Figure 3. Age-frequency distribution of all redband trout (n=607) captured between Peaceful Valley and the Riverside Park Water Reclamation Facility (RPWRF) (upper left), all redband trout (n=527) captured within the index area (upper right), redband trout ≥250 mm FL (n=252) captured within the index area during the first three passes (lower left), and redband trout ≥250 mm FL (n=399) captured within the index area during all five passes (lower right) (October 2012).

## Discussion

The abundance estimates for redband trout ≥250 mm FL calculated using the data from the first three and all five passes exhibited considerable variation. The estimate generated from the five pass dataset (n=1,079 redband trout ≥250 mm) was greater than the 3 pass and exhibited greater precision evident by the lower CV value. The difference between the 3 pass and 5 pass estimates for redband trout ≥250 mm was likely due to the larger proportion of older (larger) redband captured during the last two passes. The estimate of age 1 redband trout abundance generated from the first three and all five passes were equal; however, precision of the 5 pass estimate was greater. The 5 pass estimate for age 3 fish using the proportional method was greater than the 3 pass estimate as a result of a greater proportion of age three fish in the last two passes. Capture probabilities decreased on each pass throughout the study for redband ≥250 mm and age 1 redband trout, which resulted in reduced precision of the estimates. Sampling five passes resulted in greater precision of the estimates and would have fulfilled the requirements to use an open model if violations of closure were substantial.

Abundance estimates conducted since 2010 have identified relatively strong 2009 and 2010 year classes (McLellan and Lee 2011, Lee 2012). The strength of the 2009 and 2010 cohorts is evident in the age 3 abundance estimates and age frequency distribution (Table 2, Figure 3). Five pass abundance estimates in 2012 for redband trout ≥250 mm (1,079) were substantially lower than 2010 (1,337) and 2011 (1,420). Coincidentally, five pass abundance estimates of age 1 redband trout (384) were also much lower than 2010 (1,379) and 2011 (634). Age 1abundance estimates appear to be a good representation of redband trout year class strength in the lower Spokane River and can be verified through the age frequency distribution and age 3 abundance estimates.

We believe the capture-recapture estimates were relatively unbiased despite the violation of the closure assumption. Only one of the 455 redband trout handled during the present study was captured downstream of the index area; therefore, emigration was minimal and the effect on the estimates was likely negligible. Under certain conditions the assumption of closure can be relaxed and met approximately (Otis et al. 1978).We did experience decreases in capture probabilities throughout the study for all redband trout groups that abundance estimates were conducted. However, the models we used to estimate abundance allow for unequal capture probabilities due to time. In a closed population, the abundance estimate describes the number of individuals in the population at any point during the study period within the study area. However, if during the study period fish leave the study area (mortality and/or emigration) and none enter (recruitment and/or immigration) the study area, and the losses were equal for both the marked (tagged) and unmarked portions of the population, then the abundance estimate was the number of individuals in the population at the beginning of the study (Otis et al. 1978; Pollock et al. 1990). If both losses and gains to the study population occurred then the estimates were biased high (Otis et al. 1978). There was no indication of mortality or immigration from above or below the index area during the study period. Additionally, the timing of the study eliminated the possibility of recruitment. One fish was captured downstream of the study area; assuming emigration was equal for both tagged and untagged fish, our estimates provided the number of redband trout within the index area at the beginning of the study.

Different models for capture- recapture abundance estimates have been developed to account bias associated with unequal capture probabilities due to the affects of time, behavior, and individual heterogeneity (Otis et al. 1978, White et al. 1982). The models we used to calculate the abundance estimates accounted for differences in capture probabilities due to time effects. We employed an active sampling technique to reduce behavioral (gear avoidance or attraction) effects that could bias the abundance estimates. If a negative capture response was exhibited by redband trout that had been previously captured; the estimates would have been biased high. A positive capture response would have resulted in estimates that were biased low. Additionally, we addressed the affects of unequal capture probabilities due to individual heterogeneity by stratifying the data into age/length groups with relatively similar recapture proportions. Although capture probabilities of redband trout <250 mm (200-249 mm length group) were higher than in previous years, the stratification for abundance estimates was kept consistent for comparison among years.

We used an age-length key to assign ages to fish not aged by scale analysis. There is error inherent in aging with fish scales that cannot be accounted for in the abundance estimate. We calculated the age 1 estimate as an indication of year class strength. The benefits of the age 1 estimate for monitoring year class strength are that it is an actual capture-recapture estimate with measures of precision (SE, confidence interval, and CV). Additionally, using age 1 fish may reduce the error associated with misidentification of annuli in older fish associated with spawning and environmental factors. Sampling five passes generally results in a larger proportion of the population being marked, greater precision, and thus greater confidence in the estimates. Additionally, sampling 5 passes allows a better evaluation of the closure assumptions. Consequently, we suggest the continued use of the age 1 abundance estimate as the indicator of year class strength and the five pass sampling strategy in future modeling efforts associated with the larger Redband Trout Spawning and Fry Emergence Study.

## Literature Cited

Allendorf, F. W., D. M. Espeland, D. T. Scow, and S. Phelps. 1980. Coexistence of native and introduced rainbow trout in the Kootenai River drainage. Proceedings of the Montana Academy of Science 39:28-36.

Behnke, R. J. 1992. Native trout of western North America. Monograph 6, American Fisheries Society, Bethesda, Maryland.

CBFWA (Columbia Basin Fish and Wildlife Authority). 1999. Pit tagging procedures manual, version 2.0. Portland, Oregon. Available at: http://www.ptagis.org/ptagis/frame.jsp?menu=3&main=main.jsp?menu=3. Accessed 01/16/2013.

Chao, A. 1989. Estimating population size for sparse data in capture-recapture experiments. Biometrics 45:427-438.

FERC. 2009. Order Issuing New License and Approving Annual Charges for Use of Reservation Lands. FERC Project Nos. 2454-091 and 12606-000. FERC DC. Available at: http://www.avistautilities.com/resources/relicensing/spokane/. Accessed 1/6/2012.

Guy, C. S., H. L. Blankenship, and L. A. Nielsen. 1996. Tagging and marking. Pages 353-383 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hightower, J. E., and R. J. Gilbert. 1984. Using the Jolly-Seber model to estimate population size, mortality, and recruitment for a reservoir fish population. Transactions of the American Fisheries Society 113:633-641.

Iserman, D. A., and C. T. Knight. 2005. A computer program for age-length keys incorporating age assignment to individual fish. North American Journal of Fisheries Management 25:1153-1160.

King L. C. and C. D. Lee. 2012. Middle Spokane River baseline fish population assessment, annual progress report 2011. Annual report prepared for Avista Corporation, Spokane, Washington.

Kleist, T. R. 1987. An evaluation of the fisheries potential of the lower Spokane River:Monroe Street Dam to Nine Mile Falls Dam. The Washington Water Power Company, Spokane, Washington.

Lee, C. D. and L. C. King. *In prep*. Middle Spokane River baseline fish population assessment, annual progress report 2012. Annual report prepared for Avista Corporation, Spokane, Washington.

Lee, C. D., and J. G. McLellan. 2011. Middle Spokane River baseline fish population assessment, annual progress report 2010. Report prepared for Avista Corporation, Spokane, Washington.

McLellan, J. G. and C. D. Lee. 2011. Redband trout spawning and fry emergence study: abundance and year class strength component, annual progress report 2010. Report prepared for Avista Corporation, Spokane, Washington.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife monographs 62:24-28.

Parametrix. 2003. Rainbow trout spawning survey, 2003 final report. Document No. 2003-0590. Avista Corporation, Spokane, Washington.

Parametrix. 2004. Rainbow trout radio tracking survey 2004 – final draft report. Document No. 2004-0341. Avista Corporation, Spokane, Washington.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs, No. 107.

Rexstad, E. A., and K. P. Burnham. 1991. User's guide for interactive program CAPTURE: abundance estimation of closed animal populations. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191. Fisheries Research Board of Canada, Department of the Environment, Ottawa.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company, Ltd., London.

Small, M. P., J. G. McLellan, J. Loxterman, J. Von Bargen, A. Frye, and C. Bowman. 2007. Fine-scale population structure of rainbow trout in the Spokane River drainage in relation to hatchery stocking and barriers. Transactions of the American Fisheries Society 136(2):301-317.

Vincent, R. 1983. Fish population estimation techniques in Montana. Proceedings of the Western Association of Fish and Wildlife Agencies and the Western Division, American Fisheries Society 63:109-115.

WDOE (Washington Department of Ecology). 2009. 401 Certification-Order. Spokane River Hydroelectric Project Certification, Amended Order No. 6702, FERC License No, 2545, May 8, 2009.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory Report LA-8787-NERP.