FISHERY MANAGEMENT INVESTIGATIONS

IDAHO DEPARTMENT OF FISH AND GAME
FISHERY MANAGEMENT ANNUAL REPORT

VIRGIL MOORE, DIRECTOR

UPPER SNAKE REGION

2015

Jon Flinders
Regional Fisheries Biologist
Brett High
Regional Fisheries Biologist
Damon Keen
Regional Fisheries Biologist
Dan Garren
Regional Fisheries Manager

July 2016
IDFG 16-111

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

HENRYS LAKE

ABSTRACT

We used 50 gill net nights of effort in the spring of 2015 to evaluate trout populations in Henrys Lake. Gill net catch rates of 9.3 trout per net night (95% CI +/- 2.2) were below the long-term trend and management target of 12.4 (95% CI +/- 2.0) and 11 fish per net night, respectively. Gill net catch rates of Brook Trout *Salvelinus fontinalis*, hybrid trout (*Oncorhynchus mykiss x Oncorhynchus clarkii bouvieri*), and Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* were below the long-term trends for each species and were 2.0, 2.2, and 5.1 fish per net night, respectively. Mean relative weight (W_r) for Brook Trout, hybrid trout, and Yellowstone Cutthroat Trout increased slightly from 2014 and were 97 (95% CI ±2.1), 99 (95% CI ±1.9), and 91 (95% CI ±1.0), respectively. Median Utah Chub *Gila atraria* catch rate decreased in 2015 to 13.0 fish per net night from the high reported in 2014 (30.5 median Utah Chub per net night). In the prior three years (2012-2014), stocking rates were reduced ~500,000 to achieve lower trout densities in an effort to improve trout condition and growth. Trout abundances as determined by gill net catch rates in 2015 were below the management objective (11 trout per net night) and as a result, fall fingerling stocking request numbers were increased by 250,000 in an effort to achieve higher trout abundances necessary to meet management objectives. Future stocking rates should continue to be determined by contributions from natural reproduction, trout relative weights and growth, and gill net catch rates and be adjusted accordingly until management goals are attained. Beginning in 2015, we stocked both Hayspur hybrid trout and Gerrard hybrid trout in Henrys Lake, and will evaluate the relative success of both strains to improve anglers catch. We monitored Yellowstone Cutthroat Trout natural reproduction on four Henrys Lake tributaries by assessing fry production in tributaries using fry traps. We also monitored tributary flows at 17 sites to determine suitability for spawning and rearing of wild produced trout. We monitored dissolved oxygen levels to assess the possibility of a winterkill event from December 14, 2014 through January 23, 2015. Based on depletion estimates, we predicted dissolved oxygen would not reach critical levels (10 g/m^2) and did not implement supplemental aeration.

Authors

Jon Flinders
Regional Fisheries Biologist

Damon Keen
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

INTRODUCTION

Henrys Lake, located in eastern Idaho in the Greater Yellowstone Ecosystem, has provided a recreational trout fishery since the late 1800s (Van Kirk and Gamblin 2000). A dam was constructed on the outflow of the natural lake in 1924 to increase storage capacity for downstream irrigation. This dam increased total surface area to 2,630 ha, with a mean depth of 4 m. The now-inundated lower portions of tributary streams historically provided spawning habitat for adfluvial Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri*, prompting concerns for recruitment limitations. To mitigate for this potential loss of recruitment, the Idaho Department of Fish and Game (IDFG) acquired a private hatchery on the shores of Henrys Lake and began a fingerling trout stocking program that continues today (Garren et al. 2008). The lake supports a robust fishery for native Yellowstone Cutthroat Trout, hybrid trout (Rainbow Trout *Oncorhynchus mykiss* x Yellowstone Cutthroat Trout) and Brook Trout *Salvelinus fontinalis*, with an average of approximately 130,000 hours of annual angling effort. Surveys of Idaho's anglers show Henrys Lake to be the most popular lentic fishery in the state (IDFG 2001). Since 1929, IDFG has stocked a total of over 77 million Yellowstone Cutthroat Trout, 9 million hybrid trout, and nearly 3 million Brook Trout. Beginning in 1998, all hybrid trout were sterilized triploids prior to release to reduce the potential for hybridization with native Yellowstone Cutthroat Trout. Although hybridization was not a concern with Brook Trout, only sterile fingerlings have been stocked since 1998 (with the exception of 50,000 fertile fish in 2003) to reduce the potential for naturally reproducing Brook Trout to compete with native salmonids.

Anglers view Henrys Lake as a trophy fishery capable of producing large trout. As early as the mid-1970s, 70% of interviewed anglers preferred the option of catching large fish even if it meant keeping fewer fish (Coon 1978). Since that time, management of Henrys Lake has emphasized restrictive harvest consistent with providing a quality fishery as opposed to liberal bag limits that are more consistent with a yield fishery. In 1984, fisheries managers created specific, quantifiable objectives to measure angling success on Henrys Lake. Based on angler catch rate information and harvest data collected during creel surveys conducted between 1950 and 1984, managers thought it was possible to maintain angler catch rates of 0.7 trout per hour, with a size objective of 10% of harvested Yellowstone Cutthroat Trout exceeding 500 mm. These objectives remain in place today, although the size objective is now measured from gill net sampling as opposed to being measured from harvested fish. To evaluate these objectives, annual gill net monitoring occurs in May, immediately after ice off and prior to the fishing season, while creel surveys are conducted on a three to five year basis.

STUDY SITE

Henrys Lake is located 1,973 m above sea level, between the Henrys Lake Mountains and the Centennial mountain range, approximately 29 km west of Yellowstone National Park. The lake is approximately 6.4 km long and 3.2 km wide, with a surface area of 2,630 ha. The outlet of Henrys Lake joins Big Springs Creek to form the headwaters of the Henrys Fork Snake River (Figure 1).

OBJECTIVES

1. Obtain current information on fish populations and limnological characteristics on Henrys Lake.
2. Develop appropriate management recommendations to benefit anglers.
3. Evaluate Gerrard strain hybrid trout to determine if growth and survival differ from the more traditional Hayspur hybrid.
4. Monitor tributary production and flow conditions to better understand and measure natural contributions of wild fish.

METHODS

Population Monitoring

As part of routine population monitoring, we set gill nets at six standardized locations in Henrys Lake from April 24 to May 5, 2015 for a total of 50 net nights (Figure 1). Gill nets consisted of either floating or sinking types measuring 46 m by 2 m, with mesh sizes of 2 cm, 2.5 cm, 3 cm, 4 cm, 5 cm, and 6 cm bar mesh. Nets were set at dusk and retrieved the following morning. We identified captured fish to species and measured to total length (TL) in mm. We calculated catch rates as fish per net night and also calculated 95% confidence intervals.

We examined all Yellowstone Cutthroat Trout handled through the year for adipose fin clips as part of our evaluation of natural reproduction. Beginning in the 1980s, 10% of all stocked Yellowstone Cutthroat Trout have been marked with an adipose fin clip prior to stocking (Appendix A). To estimate contributions to the Yellowstone Cutthroat Trout population from natural reproduction, we calculated the ratio of marked to unmarked fish collected in annual gill net surveys and trout captured ascending the fish ladder on Hatchery Creek. Since 10% of all stocked fish were marked with an adipose clip, ratios around 10% in the at-large population would be expected in the absence of additional, unmarked fish (natural reproduction). When the ratio of marked fish is less than 10%, we assume that natural reproduction is contributing to the population.

We removed the sagittal otoliths of all trout caught in our gill nets for age and growth analysis. After removal, all otoliths were cleaned on a paper towel and stored in individually-labeled envelopes. Ages were estimated using both whole otoliths and sectioned otoliths. Whole otoliths were submerged in water and annuli counted under a microscope (10x power). For sectioned otoliths we imbedded otoliths in epoxy then sectioned each one across the transverse lane. For accuracy, two independent readers examined each otolith and settled differences by re-examination. For each species, we selected size classes (10 mm) that contained more than 5 otoliths for subsampling. Otoliths were then randomly selected for the subsampling. We aged all of the fish in size classes with less than 5 otoliths. The (von Bertalanffy 1957) growth model was used to fit length:

$$l_t = L_\infty(1 - e^{-K(t-t_0)})$$

where l_t is length at time t, L_∞ is the asymptotic length, K is a growth coefficient, and t_0 is a time coefficient at which length would theoretically be 0. The model was fitted to length-at-data by using the nonlinear model (NLIN) procedure in program R. We estimated mortality rate (Z) for each trout species by catch curve analysis. Age-1 trout were excluded from the analysis due to lack of gear recruitment. We estimated Brook Trout, hybrid trout, and Yellowstone Cutthroat Trout mortality rates between the ages of 2 to 6 depending on the species.

Relative weights (W_r) were calculated by dividing the actual weight of each fish (in grams) by a standard weight (W_s) for the same length for that species multiplied by 100 (Anderson and Neumann 1996). Relative weights were then averaged for each length class (<200 mm, 200-299 mm, 300-399 mm and fish >399 mm). We used the formula, log W_s = -5.194 + 3.098 log TL (Anderson 1980) to calculate relative weights of hybrid trout, log W_s = -5.189 + 3.099 log TL for Cutthroat Trout (Kruse and Hubert 1997) and log W_s = -5.186 + 3.103 log TL for Brook Trout (Hyatt and Hubert 2001a).

We calculated proportional stock density (PSD) and relative stock density (RSD-400 and RSD-500) to describe the size structure of game fish populations in Henrys Lake. We calculated PSD for Yellowstone Cutthroat Trout, hybrid trout, and Brook Trout using the following equation:

$$\text{PSD} = \frac{\text{number} \geq 300\text{ mm}}{\text{number} \geq 200\text{ mm}} \times 100$$

We calculated RSD-400 for Yellowstone Cutthroat Trout, hybrid trout, and Brook Trout using the following equation:

$$\text{RSD-400} = \frac{\text{number} \geq 400\text{ mm}}{\text{number} \geq 200\text{ mm}} \times 100$$

The criteria used for PSD and RSD-400 values for Yellowstone Cutthroat Trout, hybrid trout, and Brook Trout populations was based on past calculations and kept consistent for comparison purposes. This methodology (and size designation) is used on other regional waters to provide comparison between lakes and reservoirs throughout the Upper Snake Region. We also calculated RSD-500, using the same equation as above, but used the number of fish greater than 500 mm as the numerator.

Hybrid Evaluation

We used fluorescent grit to mark all Hayspur and Gerrard strain fingerling hybrid trout stocked in Henrys Lake in 2015. The fish were reared and marked at Mackay and American Falls fish hatcheries. We used two different colors (orange and chartreuse) to differentiate between the two strains. Hayspur and Gerrard strain were marked with orange and chartreuse grit dye, respectively. We followed the grit marking technique described by Nielson (1990). We used a box with a screened bottom and dip nets to fill the box with fingerlings. To maintain a constant pressure of 110 psi hose pressure while continuously spraying fish, two 11 CFM portable air compressors were connected in series to one terminal hose that connected to the sand blasting gun. A sample of marked live fish of each color was held at the hatchery for a minimum of one month, post marking, to monitor short-term mark retention. After one month 200 fish from each color group at each hatchery were collected and examined under a black light to determine mark retention by color group.

Tributary Assessment

Efforts to quantify natural production from key tributaries to Henrys Lake began in 1998, but have been intermittent. In 2015, we again monitored tributaries to quantify cutthroat fry emigration. Kray-Meekin fry traps were installed in early June near the mouths of Targhee, Howard, Timber, and Duck creeks. Traps were monitored daily through late August (Howard, Timber, and Duck creeks) or mid-September (Targhee Creek). Captured fry were counted daily. When catch rates exceeded 10 fry/day, trap efficiency was estimated by marking and releasing fry 100 m above the traps. Fry were marked by immersion in a solution of Bismarck brown dye (0.75 g in 12 L water) for 20 min. Marked fry were held in aerated live cages until late afternoon to assess mortality, and then released. Recaptures were counted on subsequent days. Total fry emigration past the trap was estimated on a weekly basis (Sunday-Saturday) using the following equation:

$$N_i = (n_i / (mrecap_i / mrel_i))$$

where N_i = total number of emigrants per week, n_i = number of unmarked fish caught in trap in $week_i$, $mrecap_i$ = number of marked fish recaptured in week $_i$, and $mrel_i$ = number of marked fish released above the trap in week $_i$. The total number of fish emigrating past the trap site is then estimated by $Ntot = \sum N_i$.

To coincide with natural production monitoring, we conducted weekly flow measurements and recorded stream temperatures of the major tributaries that feed Henrys Lake; Howard Creek, Targhee Creek, Timber Creek, and Duck Creek. In addition to these tributaries, we measured the flows and temperatures of Rock Creek (tributary to Duck Creek) and lateral diversions along these same streams. We used a standard set of flow-monitoring equipment, including a Marsh-McBirney Flo-Mate Model 2000 Portable Flowmeter, a Hydrology Co. Rickly wading rod, a 200' engineering tape, and a thermometer. In order to determine the discharge, a cross-section of the stream was measured at each site and then each individual cross-section was further divided into 8-12 intervals. At each interval we used the wading rod to measure the depth and the flowmeter to measure the velocity of the water. We then multiplied the width and depth of each interval of the cross-section to give us the total cross-sectional area of the interval, which we in turn multiplied by that interval's respective flow velocity to calculate the interval's total discharge. The sum of each interval's discharge is equal to the total discharge of the stream, which is measured in cubic feet per second.

This procedure was completed every week on the main channels of all tributaries and lateral diversions. Lateral diversions were occasionally shut down by landowners, and recorded as such.

Habitat Prioritization

In 2015, the Henrys Lake Technical Team (HLTT) was formed. This group was composed of governmental agencies, NGOs, and private individuals with a focus of identifying limiting factors to major tributaries to Henrys Lake and to prioritize habitat efforts. During the first year, three organizational meetings were held. By the end of the year, a plan for future habitat rehabilitation efforts was completed.

Water Quality

We measured winter dissolved oxygen concentrations, snow depth, ice thickness, and water temperatures at four established sampling sites (Pittsburg Creek, County Boat Dock, Wild Rose, and Hatchery on Henrys Lake between December 5, 2013 and February 23, 2014 (Figure 1). Holes were drilled in the ice with a gas-powered ice auger prior to sampling. We used a YSI model Pro-20 oxygen probe to collect dissolved oxygen readings at ice bottom and at subsequent one-meter intervals until the bottom of the lake was encountered. Dissolved oxygen mass is calculated from the dissolved oxygen probe's mg/L readings converted to total mass in g/m^3. This is a direct conversion from mg/L to g/m^3 (1000 L = 1 m^3). The individual dissolved oxygen readings at each site are then summed to determine the total available oxygen within that sample site. To calculate this value, we used the following formula:

Avg (ice bottom + 1 m) + Sum (readings from 2 m to lake bottom) = total O_2 mass

The total mass of dissolved oxygen at each sample site is then expressed in g/m^2 (Barica and Mathias 1979). Data are then natural logarithm (ln*)* transformed for regression analysis. We used linear regression to estimate when oxygen levels would deplete to the critical threshold for fish survival (10.0 g/m^2).

The purpose of recording dissolved oxygen profiles is to develop a dissolved oxygen depletion model to predict the likelihood of the Henrys Lake environment reaching the critical threshold for fish survival. Upon determining the likelihood of reaching the critical dissolved oxygen threshold prior to the projected recharge date of April 1st, a determination can be made of whether or not to deploy aeration.

RESULTS

Population Monitoring

We collected 2,126 fish in 50 net nights in April and May 2015, with our standard gill net survey. Gill net catch rates for all trout species combined was 9.3 trout per net night, which was 15% below the management target (11 trout per net night) and 14 year long-term average (12.7 trout per net night; Figure 2). Catch composition in the gill nets was 5% Brook Trout, 5% hybrid trout, 12% Yellowstone Cutthroat Trout, and 78% Utah Chub. Gill net catch rates (with 95% Confidence Intervals) for trout were highest for Yellowstone Cutthroat Trout at 5.1 (±1.3) fish per net night, followed by hybrid trout at 2.2 (±0.7) and Brook Trout at 2.0 (±0.7) fish per net night (Figure 3). Yellowstone Cutthroat Trout gill net catch rate in 2015 was slightly lower than the 14 year average catch rate (5.1 vs 6.7), as were hybrid trout (2.2 vs. 3.6) and Brook Trout (2.0 vs. 2.4). The average size and range of Brook Trout was 393 mm (± 22.2; range 167-540 mm; Figure 4). The hybrid trout average size (478 mm; ±14.2) and range (320-683 mm) was higher than the Yellowstone Cutthroat Trout which had an average total length of 380 mm (±9.8) and ranged in size from to 219-574 mm. Of the Yellowstone Cutthroat Trout we collected in gill nets, we found 24 of 254 (9.4%) were adipose-clipped (Table 1). We observed a 12% fin clipped cutthroat ratio in fish that returned to the hatchery in 2015 (627 marked out of 5,211 checked for marks).

The median catch rate of Utah Chub was 13.0 fish per net night with a mean gill net catch rate of 33.2 Chubs per net night (Figure 5). Both mean and median gill net catch rates for Utah Chubs were lower than previous year, which were 36.8 and 30.5 fish per net night, respectively, in 2014. Analysis of Utah Chub length frequencies indicate several different age classes present in 2015 (Figure 6).

We analyzed 97 otoliths from Brook Trout, 106 hybrid trout otoliths, and 127 Yellowstone Cutthroat Trout otoliths. Brook Trout age ranged from 1 to 5 years old. Hybrid trout age ranged from 2 to 8 years old. Yellowstone Cutthroat Trout age ranged from 2 to 5 years old. Mean length for age-2 trout was lowest for Yellowstone Cutthroat Trout at 298 mm TL (95% CI 289-

308) and highest for hybrid trout at 347 mm TL (95% CI 323-367) (Table 2). Mean length at age two for Brook Trout was intermediate at 312 mm TL (95% CI 295-327). Yellowstone Cutthroat Trout had the slowest growth rates with a starting age of t_0 = 0.24 years (95%CI -.39 to 0.88) toward their asymptotic length of L_∞ = 581 mm (95%CI 472-689) at an instantaneous rate of K = 0.41/year (95%CI 0.16-0.66; Figure 7). Brook Trout grew from a starting age of t_0 = -0.12 years (95%CI -0.54 to 0.30) toward their asymptotic length of L_∞ = 619 mm (95%CI 504-734) at an instantaneous rate of K = 0.33/year (95%CI 0.17-0.49). Hybrid trout had the fastest growth rates and grew from a starting age of t_0 = 0.42 years (95%CI -0.50 to 0.84) toward their asymptotic length of L_∞ = 647 mm (95%CI 571-723) at an instantaneous rate of K = 0.42/year (95%CI 0.23-0.61). Catch curve analysis of Yellowstone Cutthroat Trout mortality estimates from age two to five was 36% and 47% for hybrid trout ages two to six. We were unable to successfully estimate mortality in Brook Trout from age two to five using catch curve analysis. Proportional stock density (PSD) was highest for hybrid trout (100) followed by Brook Trout (83) and Yellowstone Cutthroat Trout (77). Relative stock density (RSD-400) was highest for hybrid trout (83) followed by Brook Trout (68) and Yellowstone Cutthroat Trout (49) (Table 3). Mean relative weight (W_r) for all trout species (all sizes combined) ranged between 91 and 99 (Table 4) and W_r of Yellowstone Cutthroat Trout size classes (0 - 199 mm, 200 – 299 mm, 300 – 399 mm, and >400 mm) ranged between 88 and 94 (Figure 8). We compared the gill net catch rates (trout per night) to trends in trout mean relative weight (W_r) from 2005 to 2015 and generally found that the relative weights of trout increased or decreased inversely 1-2 years after trout abundances increased or decreased, suggesting density dependent growth (Figure 9). The highest relative weights occurred in 2005 and 2006 when trout abundances were the lowest across the 10-year analysis period.

Hybrid Evaluation

We grit marked a total of 114,576 Hayspur and 51,000 Gerrard strain hybrid trout fingerlings prior to stocking into Henrys Lake in 2015. Based on visual inspection using a black light the percent of permanently marked, stocked fish by color group was 97.4% and 96.6%, for chartreuse (Gerrard) and orange (Hayspur), respectively (Table 5). American Falls hatchery unexpectedly had a slight surplus in hybrid trout (1,801 Hayspur strain) that were stocked, but not part of the marked group. After accounting for the surplus fish unmarked, and percent unmarked after grit spraying (2.6% chartreuse and 3.4% orange) the total number of stocked fingerlings marked with grit was approximately 49,674 of the Gerrard strain and 108,941 of the Hayspur strain.

Tributary Assessment

In Howard Creek, a total of 2,200 fry were trapped from May 23 to August 30. Virtually all of the fry (97%) were trapped during the period of June 8-July 4. Trap numbers were sufficient to obtain four weekly estimates during this period. Total emigration during this period was estimated at 22,932 fry. The Targhee Creek trap was in operation from June 10 to September 15, and captured seven fry. The Duck Creek trap was in operation from May 23 to August 30, and captured 48 fry. The Timber Creek trap was in operation from May 23 to July 30, and a total of 71 fry were trapped. Fry numbers were insufficient to obtain efficiency estimates from Targhee, Duck or Timber creeks.

Howard Creek water temperature ranged from 5.0°C on May 29 to 14.0°C on July 21. Flows ranged from 3 cfs on August 7 to 6.7 cfs on June 8. Targhee Creek temperature ranged from 5.0°C on several days in mid-June to 12.0°C on August 30. Flows ranged from 9.9 cfs to 0.2 cfs on September 14, but these flows represented approximately 40% of total flow as a side channel contributed flow further down Targhee Creek. Duck Creek temperatures ranged from 4.0°C in early June to 15.0°C on July 21 and flows ranged from 0.4 cfs on July 17 to 8.6 on June 18. Timber Creek temperatures ranged from 7.0°C on May 24 to 15.5 on July 2 and flows ranged from 1.5 cfs on June 25 to 3.0 cfs on September 17.

Habitat Prioritization

The HLTT identified limiting factors on major tributaries including: Howard Creek, Targhee Creek, Timber Creek, Hope Creek, and Duck Creek. The group also discussed past habitat work on Henrys Lake and prioritized future work. Goals and objectives by tributary, with a priority ranking were identified as follows:

Duck Creek was identified as top priority for future work. Limiting factors were identified as flow and sedimentation. Future rehabilitation efforts should include:

1. Restore Rock Creek connection to Duck Creek to supplement flow and reduce temperatures.
2. Fence unfenced sections of Duck Creek to reduce sediment input and maintain stream temperatures.
3. Install beaver dam analogs to restore hyporheic exchange to improve base flows, along with reducing sediment input.
4. Replace riparian fencing where needed.
5. Restore Ingalls Creek connection to Duck Creek to supplement flow.

Howard Creek limiting factors were identified as passage and sedimentation. Future rehabilitation efforts should include:

1. Reduce size of or eliminate cattle water gaps (6) to reduce sediment input and provide improved adult passage.
2. Replace riparian fence where needed.
3. Enclose side channel below Howard Creek pond to increase rearing habitat.
4. Install flow gauges on diversions to monitor outflow.

Targhee Creek limiting factors were identified as flow and sedimentation. Future rehabilitation efforts should include:

1. Replace riparian fencing where needed.
2. Improve water gap to reduce sediment input.
3. Enclose side channel below rodeo grounds to increase rearing/spawning habitat and reduce sedimentation.
4. Install flow gauges on diversions to monitor outflow.

Timber Creek limiting factors were identified as substrate embeddedness, sedimentation, and temperature. Future rehabilitation efforts were suspended due to lack of potential for success.

Water Quality

Between December 14, 2014 and January 23, 2015, total dissolved oxygen diminished from 48.95 g/m^2 to 43.2 g/m^2 at the Pittsburgh Creek site, from 45.45 g/m^2 to 35.65 g/m^2 at the Wild Rose site, from 36.1 g/m^2 to 27.1 at the county dock site, from 42.35 g/m^2 to 33.9 g/m^2 at the hatchery site, and from 29.45 g/m^2 to 28.65 g/m^2 at the outlet site (Table 6). Depletion was less than expected at the outlet site due to winter discharge, which moved water with higher oxygen content into the outlet as winter progressed. Depletion estimates predicted dissolved oxygen would remain above the level of concern throughout the winter (Figure 11). Based on predictions of dissolved oxygen depletion rates, aeration was not necessary.

DISCUSSION

Henrys Lake is managed as a quality fishery with management goals aimed at balancing interdependent relationships between mean trout size (mm), stocking rates, and angler catch rates. Past studies have found that at high stocking levels mean trout size decreases (Garren et al. 2008). However, as trout size decreases at higher stocking rates catch rates increase. Current management goals for Henrys Lake are 11 trout per net night and catch rates of 0.7 fish per hour. Adaptive stocking strategies are aimed at achieving trying to achieve these management goals. Gill net catch rate of trout in 2015 decreased from that observed in 2014. From 2012 to 2014, we reduced stocking rates of Yellowstone Cutthroat Trout (~500,000 per year) in an effort to reduce the trout population closer to the management target of 11 trout per net night and thereby improve growth and size of the trout. In 2015, catch rates of trout in gill nets fell below the management target of 11 trout per net night and were 9.3 trout per net night. In an effort to increase the abundance of trout in the population and achieve our management objectives, stocking levels of fall fingerling trout were increased ~250,000 in 2015 from stocking levels in 2014. As such abundances of trout should increase over the next few years due to increased stocking when age-2 and age-3 trout recruit to the fishery in 2017 and 2018. The increased abundances near the management target of 11 trout per net should also improve angler catch rates towards the management target 0.7 fish per hour. Current management size goals for the fishery are for 20% of hybrid trout exceeding 500 mm, 10% of Yellowstone Cutthroat Trout exceeding 500 mm, and 5% of Brook Trout exceeding 430 mm. Based on the size goals Brook Trout were far exceeding the management target with 55% of Brook Trout larger than 430 mm in the population. Hybrid trout also exceeded management goal with 37% of hybrid trout larger than 500 mm. Yellowstone Cutthroat Trout were below the management goal with only 2% of the population larger than 500 mm. This larger sized cohort of Brook Trout in the population were age-4 and age-5 and suggests possible higher survival rates from those age class years since stocking rates have remained relatively stable over the last five years for Brook Trout (range 71,000 to 110,000). The lack of larger Yellowstone Cutthroat may be due in part to slower growth due to higher abundances observed in 2012, 2013, and 2014. Another measure of fish growth is condition and a commonly used index is relative weight (Anderson and Neumann 1996). In general trout relative weights were below desired levels. Relative weights of smaller (<400 mm) Yellowstone Cutthroat Trout have been responding to the decreased numbers of trout stocked in recent years. However, condition of the larger Yellowstone Cutthroat Trout has remained static, suggesting forage availability is lacking for this size class despite lower abundance. Alternatively, it is possible that trout that spend their early years in crowded conditions and with lower body condition do not improve body condition as quickly as those raised in less crowded conditions throughout their lives. In contrast, Brook Trout relative weight increased with size from a mean of 85 for the smaller size class (<200 mm) to 101 for larger size classes (>400 mm). This increase in relative weight suggests smaller

Brook Trout are more forage limited than larger sizes. Food availability constraints are likely due to intraspecific and interspecific competition among trout species. We expect trout condition and growth to continue to improve as trout abundances remain lower and food resources increase.

The median catch rate for Utah Chub decreased ~50% in 2015 from the highest reported catch rate in 2014 in gill net catch. The lower catch rate suggests Utah Chub abundances may have peaked in 2014. However, we have limited inferences on Utah Chub abundance due to the high variation in gill net catch and low power to detect changes based on insufficient gill net samples necessary to detect shifts in chub abundances. Despite shortcomings with current netting effort, monitoring Utah Chubs abundance as well as their growth is necessary to determine whether any biotic interactions occur between trout and chubs.

The ratio of marked to unmarked Yellowstone Cutthroat Trout collected in gill net surveys (9%) and in the spawning operation (12%) suggests that natural reproduction is currently contributing little recruitment to the Henrys Lake fishery. Past years have found inconsistent but substantial natural reproduction/recruitment in some years, likely due to the many tributary stream habitat improvement projects that have occurred over the last decade (e.g., riparian fencing, instream passage improvements, fish irrigation screening, High et al. 2014) combined with favorable environmental conditions. We currently only mark 10% of the stocked Yellowstone Cutthroat Trout with clipped adipose fins to evaluate natural recruitment. However, there is likely an unknown error associated with this ratio estimate that clouds drawing accurate conclusions about the magnitude (or lack thereof) of natural production. Developing a cost effective method that would allow for mass marking all Yellowstone Cutthroat Trout and hybrid trout we stock would remove any error associated with the ratio estimate and provide a more accurate assessment of the annual natural tributary production (Appendix A). This is particularly important as we continue to prioritize and improve spawning habitat along the lake and tributaries, which should result in higher contributions of naturally spawned Yellowstone Cutthroat Trout in future years. It is also extremely beneficial when determining adaptive stocking rates to achieve management objectives for the lake.

Natural production at Henrys Lake varies considerably from year to year. A good understanding of natural production at Henrys Lake is critical to prescribe correct stocking rates and to evaluate habitat improvement projects. A comprehensive approach to tributary assessment and natural recruitment including temperature, flow and fry enumeration, tied in with better hatchery fish marking protocol is necessary to a better understanding of natural recruitment on Henrys Lake. The 2015 tributary assessment provided a thorough evaluation of natural production within the major tributaries. Prior evaluation aimed at estimating natural production using Kray-Meekin traps (Dillon et al. 2004) indicated low numbers of emigrating fry. However, that research suggested that substantial fry movement may have occurred prior to trap installation (July). In 2015, we installed traps approximately 1 month earlier to capture earlier migrating fry. Our results indicate that fry migration does occur as early as June and supported Dillon et al. 2004 observation.

Howard Creek was the only tributary where numbers of fry were sufficient to obtain fry estimates based on trap efficiencies. Even in Howard Creek, fry numbers were low and probably had insignificant contribution to the adfluvial Henrys Lake population. Several factors likely contributed to poor recruitment in many tributaries including: low flows, high tributary temperature during egg/fry development and drought conditions throughout the year.

A poor winter snowpack during the winter of 2014-15 and early onset of warm temperatures contributed to historically low flows throughout the Henrys Fork basin. A majority of the snowpack was gone by early May and resulted in a lack of the normal spring freshet that attracts adfluvial adult Yellowstone Cutthroat Trout to tributaries and provides necessary tributary access and flows that allow easy movement through tributaries. Although adult weirs were not in place, weekly observations pointed to few adults ascending the tributaries (with the exception of Timber Creek). These observations were unusual as larger numbers of spawning adults within the major tributaries has been more common in prior years.

Low tributary flows and higher temperatures during a period of fry development and emergence may have further compromised natural production. Based on egg/fry development timing relative to stream temperature (~285 Celsius temperature units to hatch), all the tributaries had 4-8 degree fluctuations during this critical period. Although certainly temperature variation is normal, 2015 likely was an extreme. Targhee Creek especially fluctuated rapidly with a 7-degree increase in approximately 1 month. It has been hypothesized in the past that Timber Creek temperatures may be too high for fry development. We recorded a low reading of 11 degrees on June 18 and a 15-degree reading on June 25. These temperatures may be extreme and may explain lack of recruitment on that tributary even though large numbers of adults were observed spawning. Given the snowpack and resulting flows, receding stream flow may have contributed to redd exposure during this same period, namely on Targhee and Duck Creek. A low flow of 0.4 cfs on Duck Creek was especially troublesome.

Beginning in 2016, we spearheaded the formation of the Henrys Lake Technical Team (HLTT), which is a collaborative group of resource professionals with a nexus to Henrys Lake. Group members include representatives from the US Forest Service, the Nature Conservancy, the Henrys Lake Foundation, and local landowners. The primary goal of this collaborative is to address rehabilitation efforts within the Henrys Lake basin to develop comprehensive approaches to improve natural production. Incorporating input from a wide spectrum of technical and practical expertise will lead to more successful efforts at reestablishing and improving natural recruitment in tributaries, as well as organizing ongoing efforts in a strategic and prioritized approach.

RECOMMENDATIONS

1. Continue annual gill net samples at 50 net nights of effort.
2. Collect otolith samples from all trout species; use for cohort analysis and estimates of mortality/year class strength and compare to previous years.
3. Continue to monitor Utah Chub densities and evaluate potential impacts to trout.
4. Periodically conduct diet and stable isotope analysis of trout and Utah Chubs to evaluate dietary and isotopic overlap between the species
5. Collect fin rays from Utah Chubs for aging and mortality estimates.
6. Implement the HLTT plan to tributary rehabilitation to improve natural production and water quality.
7. Use most current available data and develop stocking rates.

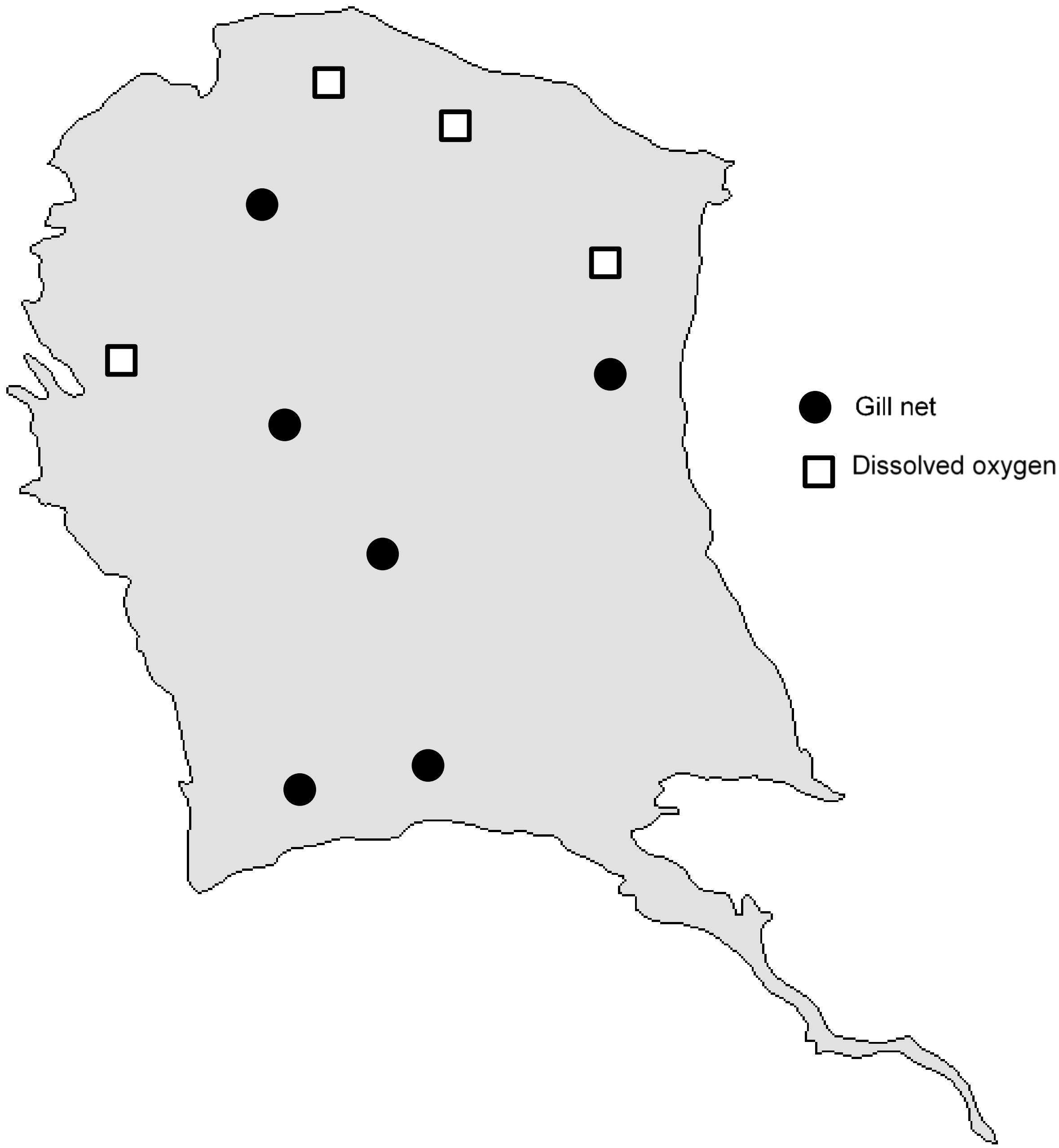

Figure 1. Spatial distribution of gill net and dissolved oxygen monitoring sites in Henrys Lake, Idaho, 2015.

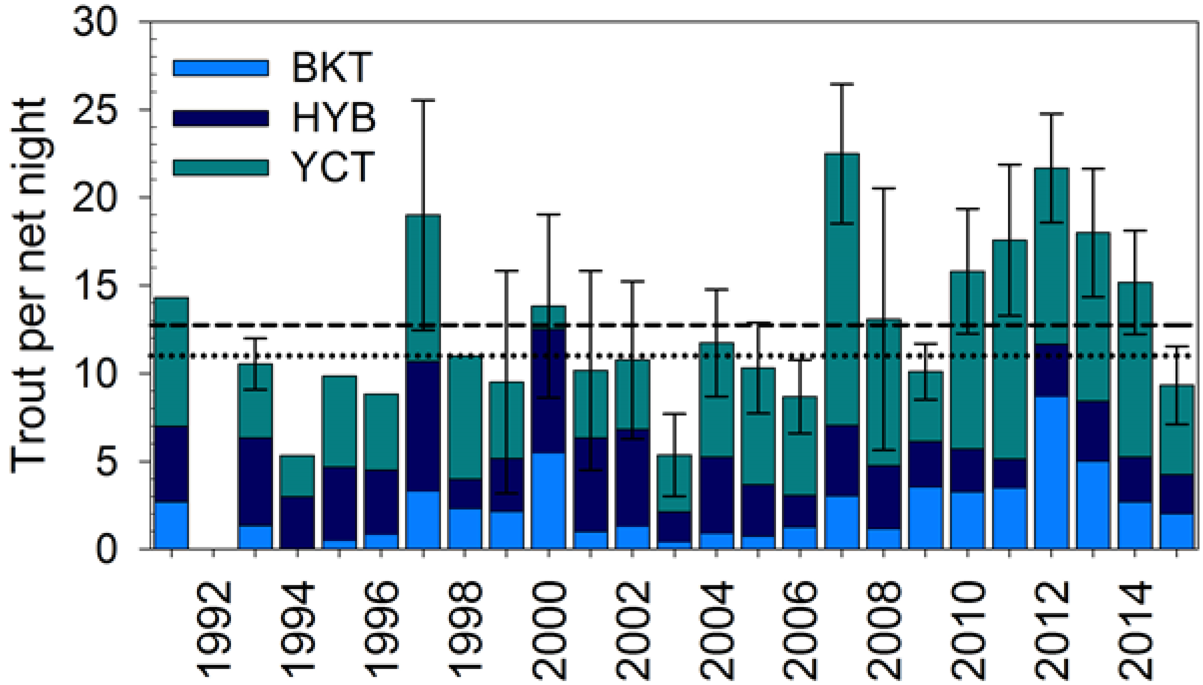

Figure 2. Catch per unit effort (CPUE) of trout per net night for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) in Henrys Lake, Idaho between 1991 and 2015. Error bars represent 95% confidence intervals. Lines represent the average gill netting CPUE from years 1991 to 2014 (dashed line) and management target of 11 trout per net night (dotted line).

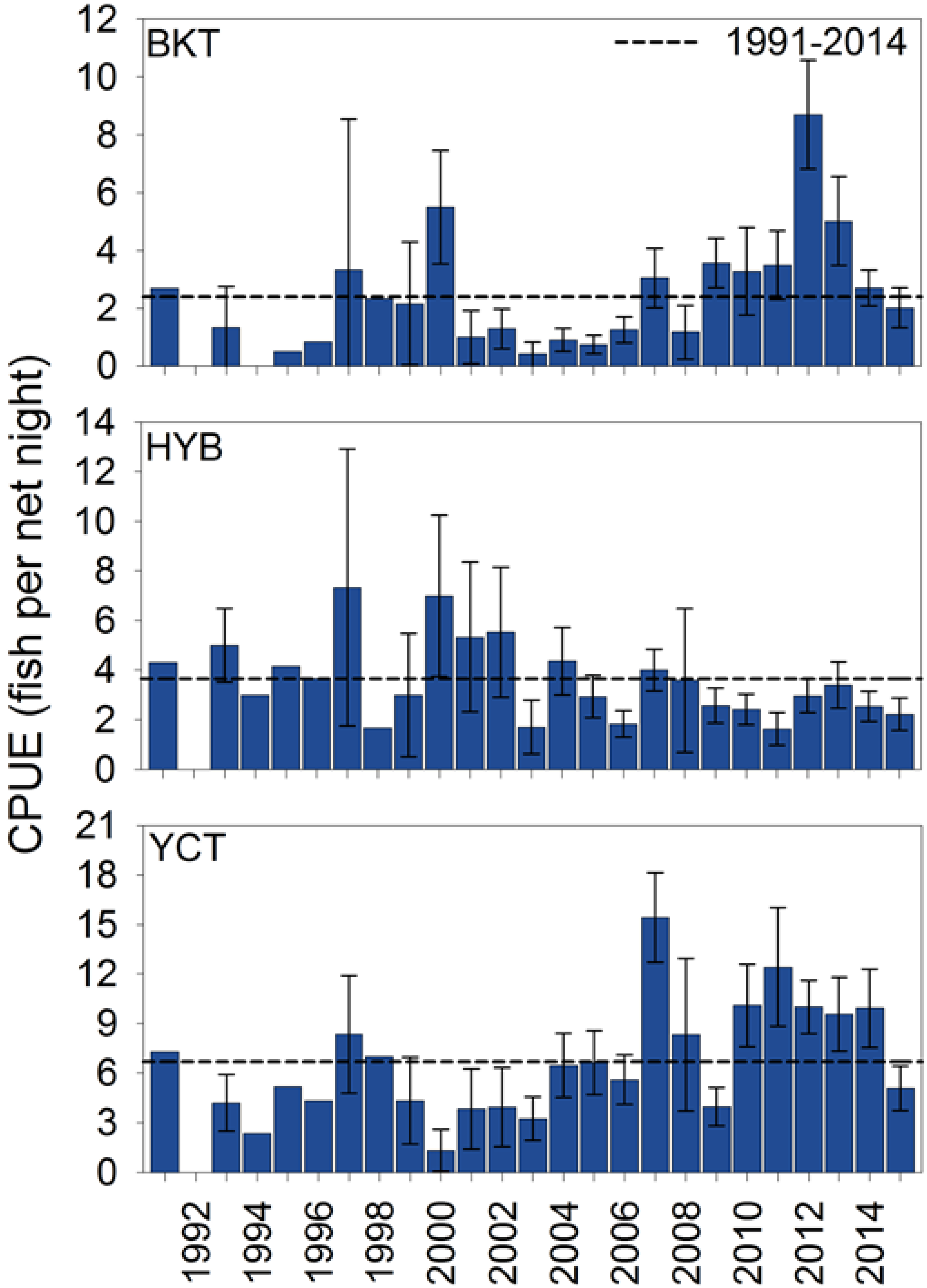

Figure 3. Catch per unit effort (CPUE) of fish per net night for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) in Henrys Lake, Idaho between 1991 and 2015. Error bars represent 95% confidence intervals. The dashed line represents the average gill netting CPUE from years 1991 to 2014.

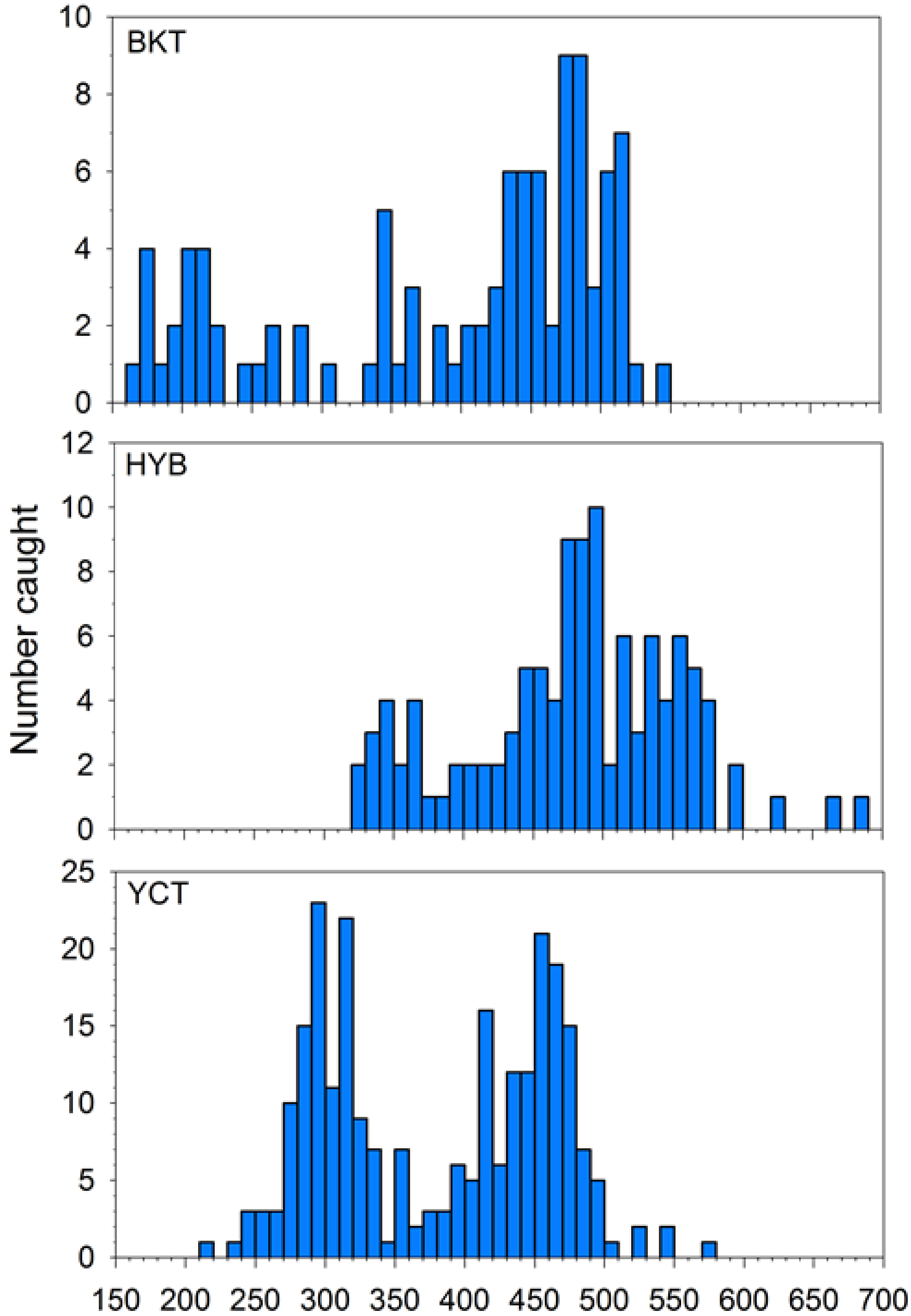

Figure 4. Brook Trout (BKT), hybrid trout (HYB) and Yellowstone Cutthroat Trout (YCT) length frequency distribution from gill nets set in Henrys Lake, Idaho, 2015.

Table 1. Fin clip data from Yellowstone Cutthroat Trout (YCT) stocked in Henrys Lake, Idaho. Annually, ten percent of stocked YCT receive an adipose fin clip. Fish returning to the Hatchery ladder and fish captured in annual gillnet surveys are examined for fin clips.

Year	No. clipped	No. checked at hatchery	No. detected	Percent clipped	No. checked in gillnets	No. detected	Percent clipped	Overall percent clipped
1996	100,290	--	--	--	--	--	--	--
1997	123,690	178	5	3%	--	--	--	3%
1998	104,740	--	--	--	--	--	--	--
1999	124,920	160	20	13%	--	--	--	13%
2000	100,000	14	1	7%	--	--	--	7%
2001	99,110	116	22	19%	--	--	--	19%
2002	110,740	38	7	18%	--	--	--	18%
2003	163,389	106	37	35%	273	47	17%	22%
2004	92,100	--	--	--	323	28	8%	9%
2005	85,124	2,138	629	29%	508[a]	55	11%	26%
2006	100,000	2,455	944	39%	269[a]	20	8%	35%
2007	139,400	--	--	--	770	70	9%	9%
2008	125,451	4,890	629	13%	100	10	10%	13%
2009	138,253	4,184	150	4%	91	9	10%	4%
2010	132,563	4,253	90	2%	505	31	6%	3%
2011	112,744	3,037	137	5%	1,097[b]	72	7%	5%
2012	75,890	2,880	215	7%	500	52	10%	8%
2013	75,600	3,360	268	8%	478	47	10%	8%
2014	72,900	6,226	651	10%	626[b]	60	10%	10%
2015	95,500	5,211	627	12%	254	24	9%	12%

[a] Includes fish from gill net samples and creel survey.

[b] Includes fish from annual spring gill net monitoring and fish collected in monthly stomach sample gill netting.

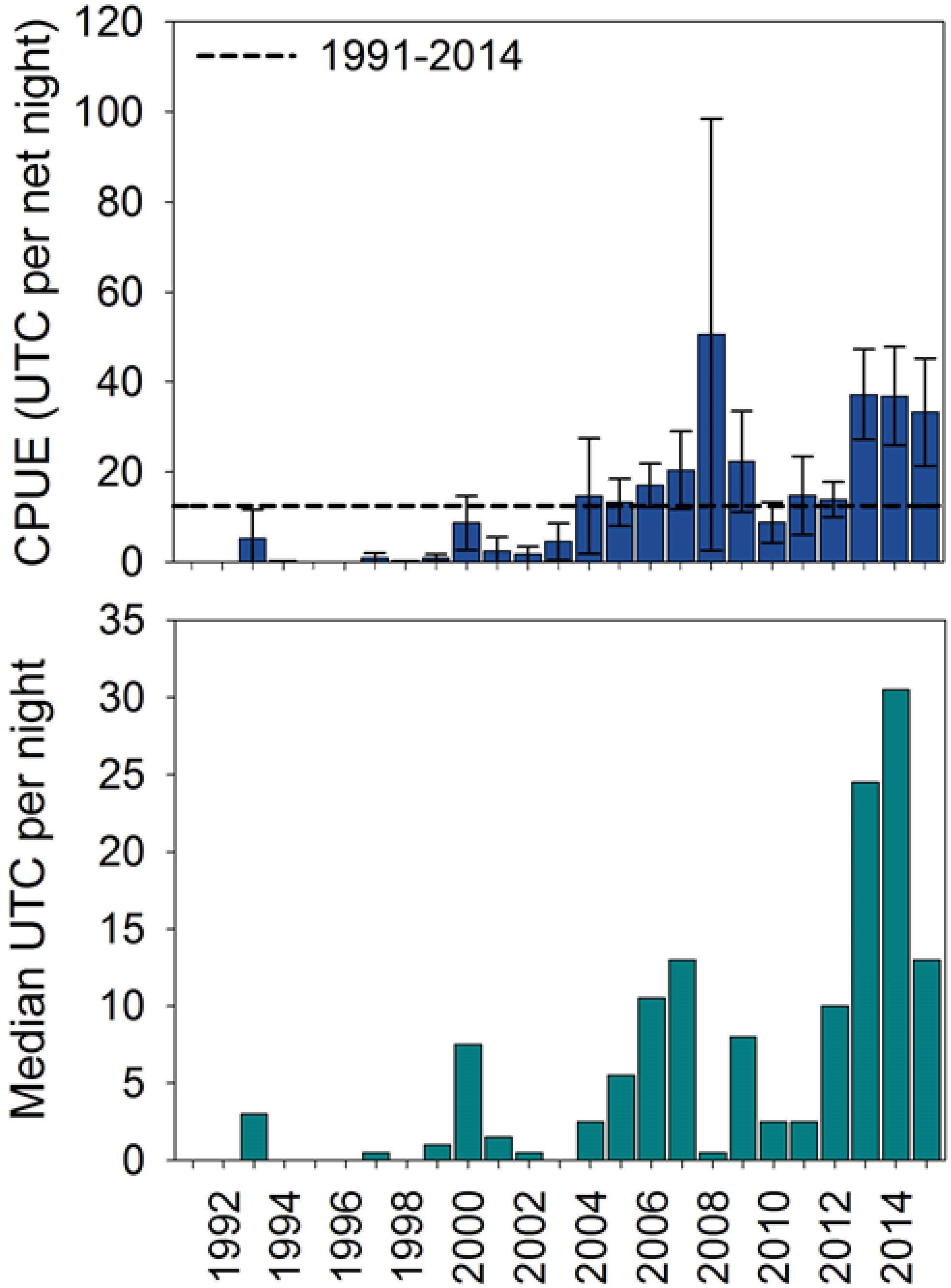

Figure 5. Catch per unit effort (CPUE) and median fish per net night and for Utah Chub in Henrys Lake, Idaho between 1991 and 2015. For the CPUE graph error bars represent 95% confidence intervals and the dashed line represents the average gill netting CPUE from years 1991 to 2015.

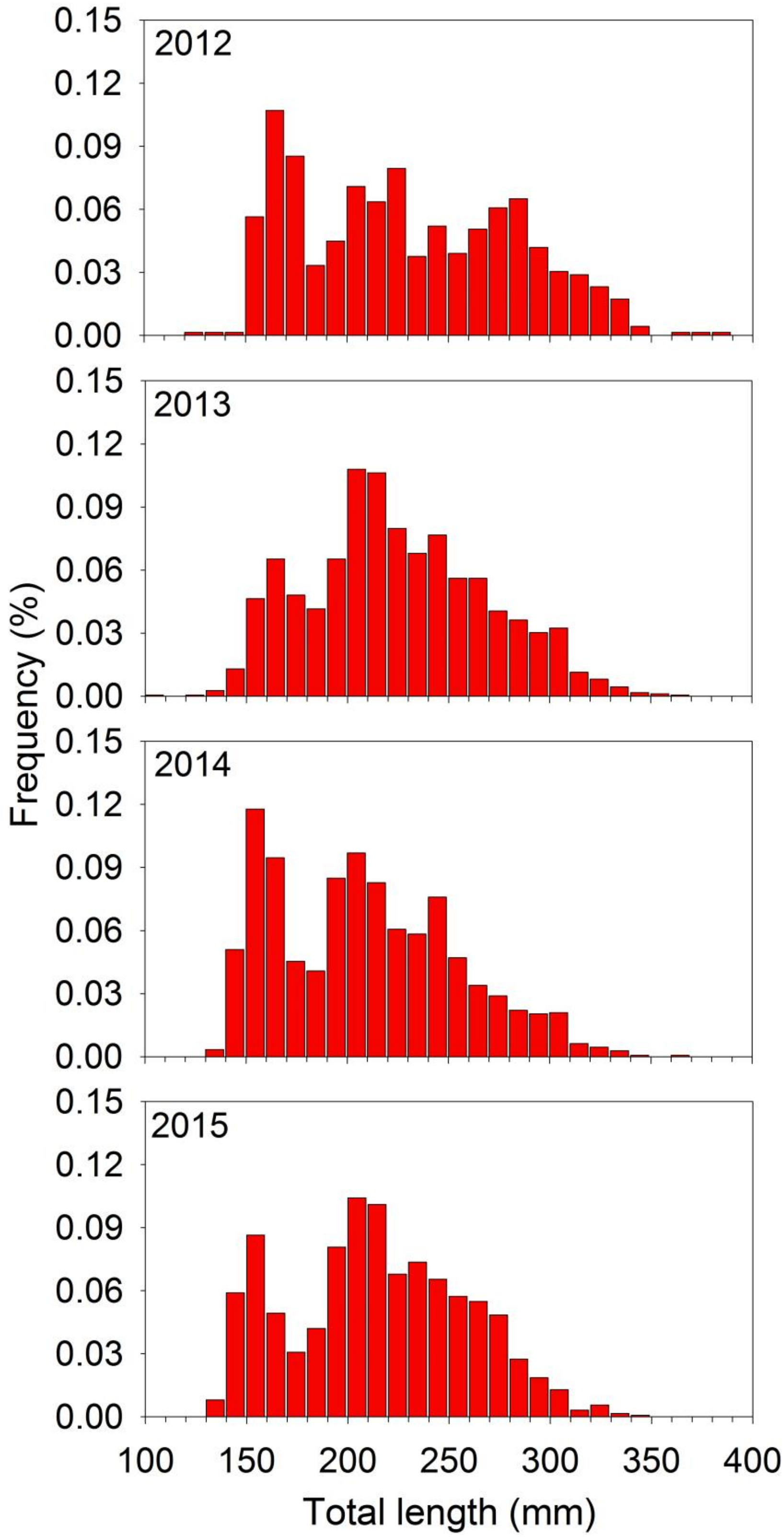

Figure 6. Utah Chub length frequency (%) from gill nets set in Henrys Lake, 2012-2015.

Table 2. Mean length at age data based on otoliths of Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) caught with gill nets in Henrys Lake, Idaho 2015. Mean length at ages were estimated using non-linear regression.

		Age					
Species	**Summary statistic**	**1**	**2**	**3**	**4**	**5**	**6**
BKT	Mean TL (mm)	192	312	398	460	505	537
	Lower 95% CI	168	295	383	448	487	507
	Upper 95% CI	214	327	411	471	524	572
	No. Analyzed	14	13	22	29	18	--
HYB	Mean TL (mm)	190	347	450	517	562	591
	Lower 95% CI	101	323	441	509	547	568
	Upper 95% CI	250	367	459	526	576	616
	No. Analyzed	--	11	46	38	10	1
YCT	Mean TL (mm)	155	298	393	456	498	526
	Lower 95% CI	79	289	383	448	480	496
	Upper 95% CI	203	308	403	464	518	565
	No. Analyzed	--	48	30	39	10	--

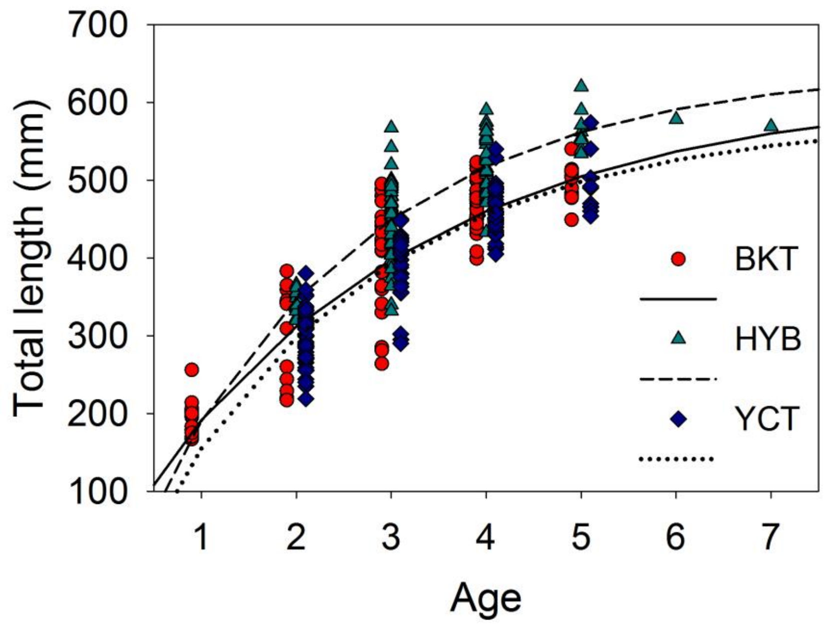

Figure 7. Length-at-age based on non-linear regression for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout from spring gill netting in Henrys Lake, 2015. Growth is described by the fitted von Bertalanffy growth (VBG) model (solid line, dashed line, dotted line) for each species.

Table 3. Stock density indices (PSD, RSD-400, and RSD-500) and relative weights (W_r) with 95% confidence intervals in parenthesis for all trout species collected with gill nets in Henrys Lake, Idaho 2015.

	Brook Trout	**Hybrid trout**	**Yellowstone Cutthroat Trout**
PSD	83	100	77
RSD-400	68	83	49
RSD-500	14	37	2
W_r			
<200 mm	85 (6.9)	--	--
200 – 299 mm	90 (4.4)	--	92 (1.7)
300 – 399 mm	99 (6.2)	99 (6.8)	94 (1.5)
>399 mm	101 (2.4)	99 (1.9)	88 (1.5)

Table 4. Summary statistics of total length (mm), weight (g), and relative weights (W_R) for Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chubs (UTC) collected in the spring gillnetting at Henrys Lake, 2015.

	BKT			**HYB**			**YCT**			**UTC**	
Summary statistic	**TL (mm)**	**WT (g)**	**W_R**	**TL (mm)**	**WT (g)**	**W_R**	**TL (mm)**	**WT (g)**	**W_R**	**TL (mm)**	**WT (g)**
Mean	393	908	97	478	1,362	99	380	649	91	217	143
Confidence Level (95.0%)	22.2	110.3	2.1	14.2	116.2	1.0	9.8	44.9	1.0	2.2	4.1
Median	438	1,083	97	485	1,336	100	395	671	91	216	125
Minimum	167	42	75	320	286	69	219	106	70	94	29
Maximum	540	1,850	129	683	3,489	132	574	1,823	115	447	539
Count	101	101	101	111	111	111	254	254	254	1,660	1,660

Table 5. Short-term (30 d) mark retention rates for hybrid trout fingerlings marked with fluorescent grit dye at Mackey and American Falls fish hatcheries, based on black light observations at each hatchery.

	Mackay		American Falls
Grit Dye	**Hayspur**	**Gerrard**	**Hayspur**
Present	189	195	198
Absent	11	5	2
Percent marked	94.2	97.4	99.0

Table 6. Dissolved oxygen (DO) (mg/l) levels recorded in Henrys Lake, Idaho winter monitoring 2014-2015.

Location	Date	DO Ice bottom	DO 1 meters	DO 2 meters	DO 3 meters	DO 4 meters	DO 5 meters	Total g/m^2
Pittsburgh Creek	15-Dec-14	12.4	11.3	11.4	10	8.8	6.9	48.95
	22-Dec-14	13.4	12.9	10.9	8.9	6.1	--	52.35
	1-Jan-15	12.8	11.8	11.1	9.4	8	6.8	47.6
	8-Jan-15	11.8	11.7	11.1	8.9	7.5	5.8	45.05
	23-Jan-15	12.7	12.3	10.8	8.5	6.3	5.1	43.2
County Ramp	15-Dec-14	10.4	9.8	8.7	6.2	--	--	36.1
	22-Dec-14	12.5	11.9	11.3	10.3	6.8	--	40.6
	1-Jan-15	11.5	10.8	9.9	8.6	5	--	34.65
	8-Jan-15	12.3	11.5	10.4	9.1	6.4	--	37.8
	23-Jan-15	12.6	10.4	9.4	6.2	--	--	27.1
Wild Rose	15-Dec-14	11.1	10.7	9.7	7.8	5.8	--	45.45
	22-Dec-14	12.8	12.1	11.8	10.3	7.7	5.8	48.05
	1-Jan-15	11.7	11.2	10.7	9	6.8	5.8	43.75
	23-Jan-15	13.3	12	10.3	7.7	5	--	35.65
Hatchery	15-Dec-14	12.5	11.6	11.7	10	8.6	--	42.35
	22-Dec-14	14.3	12.5	10.8	9.7	7.9	--	41.8
	1-Jan-15	13.4	12.4	11.2	10.2	8.8	--	43.1
	8-Jan-15	12.7	11.1	9.1	7.5	6.4	--	34.9
	23-Jan-15	12.8	11	8.9	8.2	4.9	--	33.9
Outlet	15-Dec-14	12.2	10.7	9.8	8.2	--	--	29.45
	22-Dec-14	11.6	11.2	10.2	8.7	--	--	30.3
	1-Jan-15	12	11.3	9.7	8.1	--	--	29.45
	8-Jan-15	10.9	10.5	8.8	7.5	--	--	27
	23-Jan-15	13.2	11.9	9.1	7	--	--	28.65

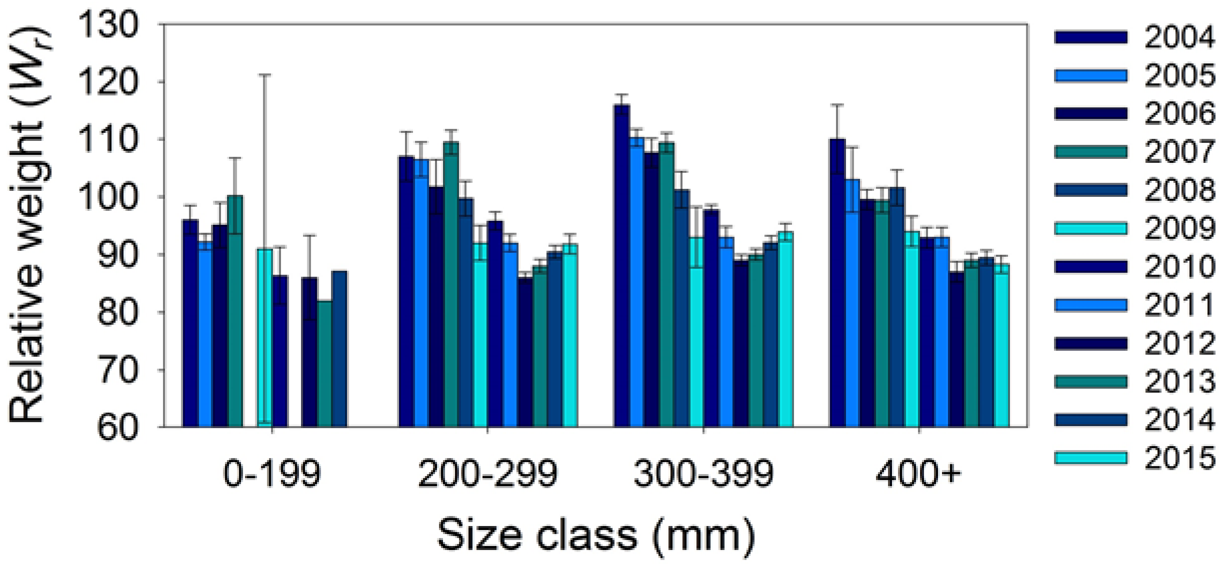

Figure 8. Relative weights (W_r) for four size classes (0 – 199 mm, 200 – 299 mm, 300 – 399 mm, and 400+ mm) of Yellowstone Cutthroat Trout from spring gill netting in Henrys Lake, Idaho 2004-2015. Error bars represent 95% confidence intervals.

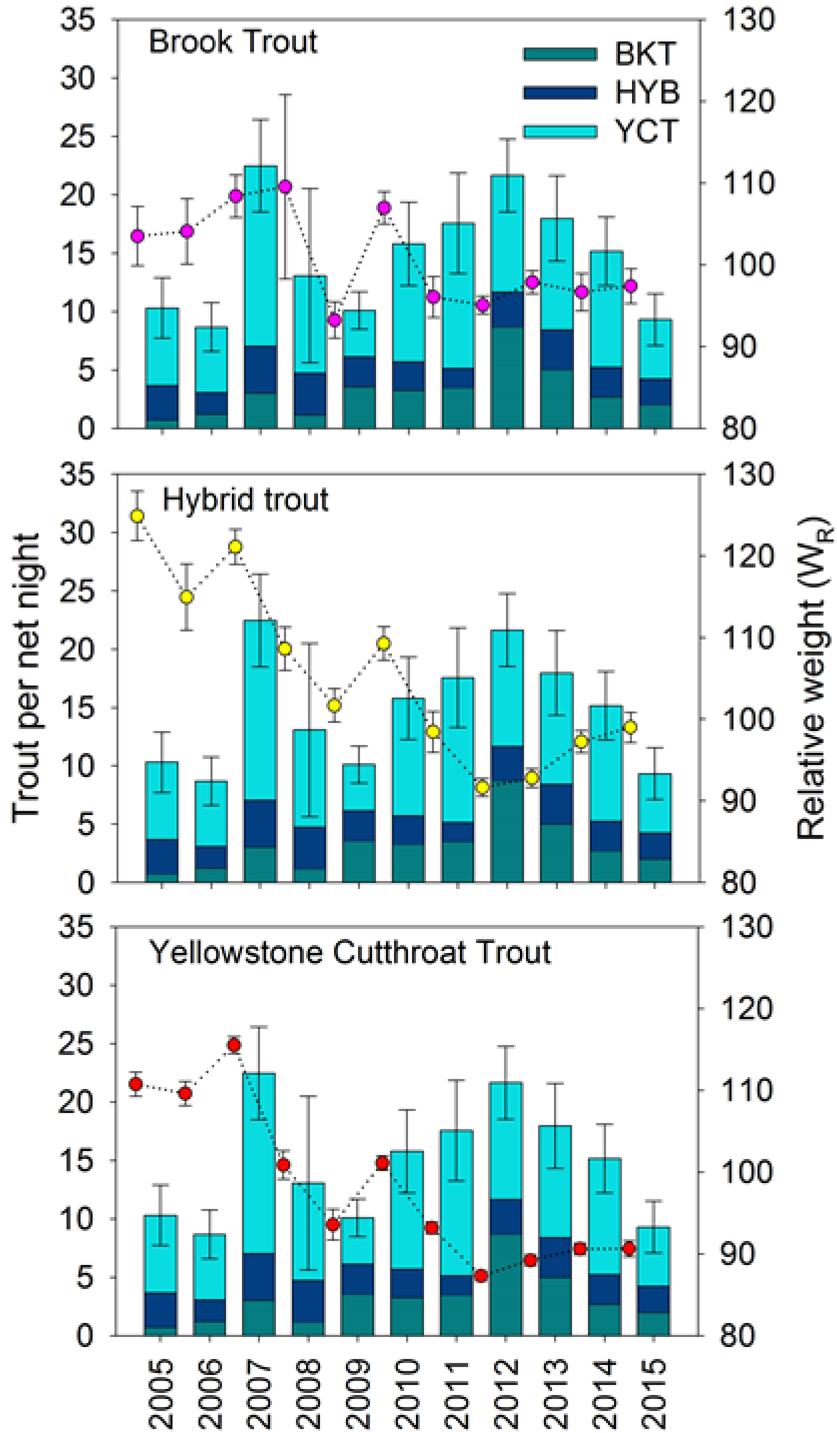

Figure 9. Bar stack plot of trout per night from spring gill netting (left-axis) with 95% confidence intervals for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) from 2005-2015, Henrys Lake. Line-scatter plot of relative weights (right-axis) with 95% confidence intervals by Brook Trout (Pink), hybrid trout (Yellow), and Yellowstone Cutthroat Trout (Red).

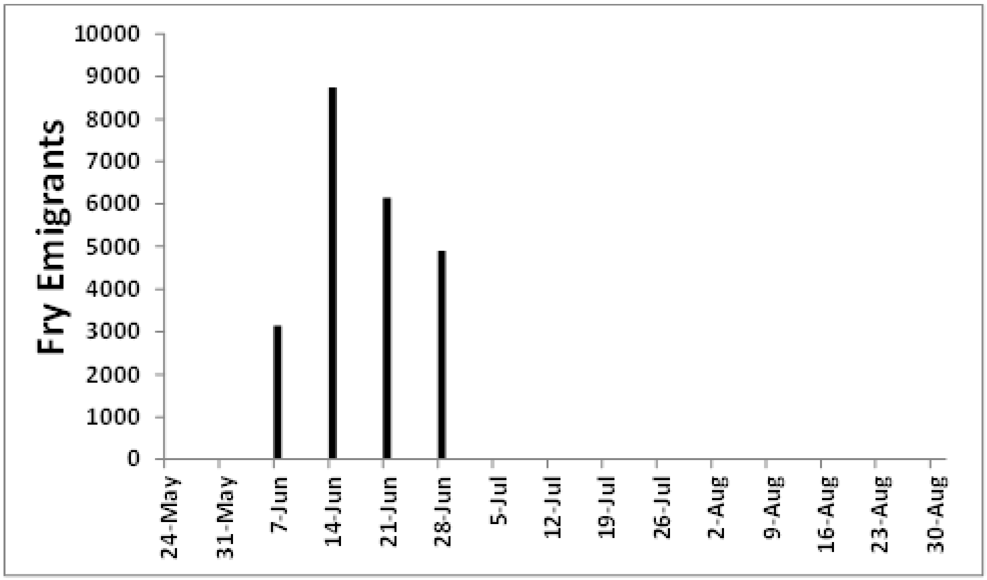

Figure 10. Number of Cutthroat fry emigrants on Howard Creek, tributary to Henrys Lake from May 24-August 31, 2015.

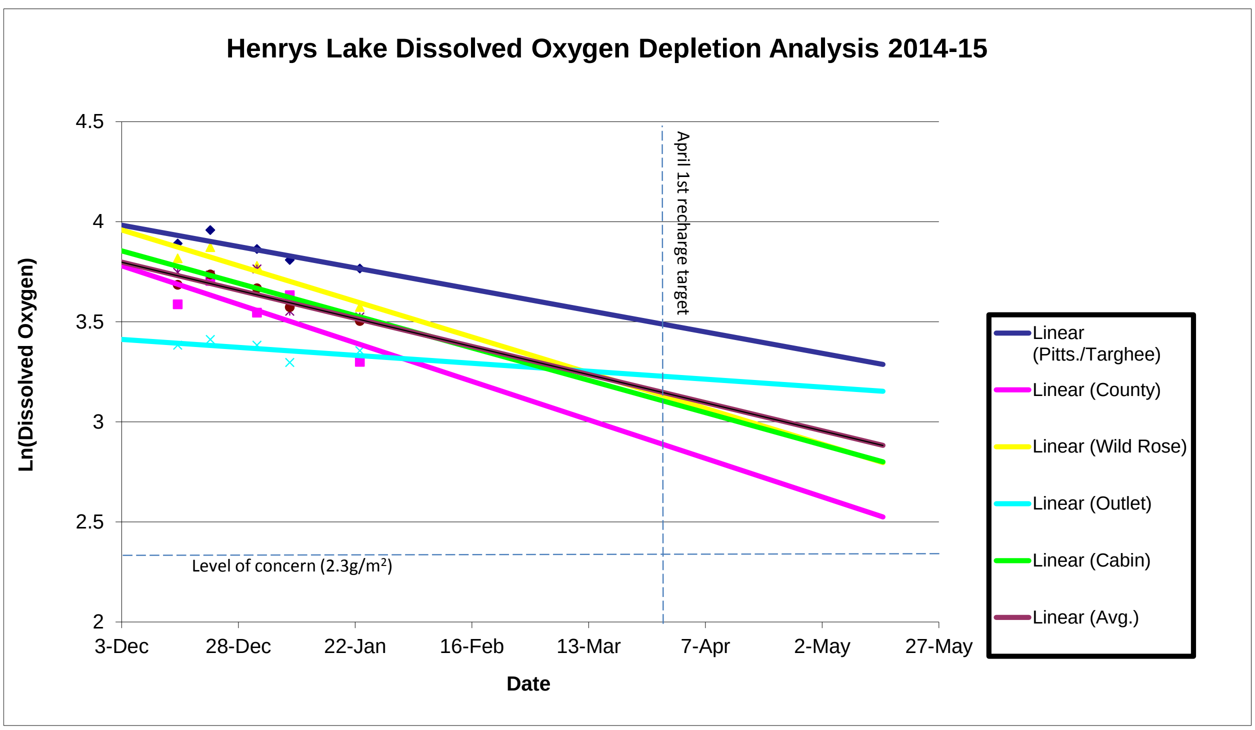

Figure 11. Dissolved oxygen depletion estimates from Henrys Lake, Idaho, 2014-2015.

EVALUATION OF MARKING PROCEDURES TO ESTIMATE NATURAL REPRODUCTION OF YELLOWSTONE CUTTHROAT TROUT IN HENRYS LAKE, IDAHO

ABSTRACT

Henrys Lake is primarily supported by annual stocking of fingerling trout. However, adfluvial Yellowstone Cutthroat Trout spawning occurs in all major tributaries during the spring. Recruitment of naturally-produced YellowstoneCutthroat Trout into the fishery likely varies yearly based on biotic and abiotic factors in both the tributaries and lake. Assessing the natural component in the lake is important when determining adaptive stocking rates to achieve management objectives and to evaluate the effects of habitat improvement projects. Currently 10% of the stocked Yellowstone Cutthroat Trout are marked with clipped adipose fins to evaluate natural recruitment. However, there is likely an unknown error associated with this ratio estimate that makes the magnitude (or lack thereof) of natural production difficult to assess. I conducted a literature review to assess the advantages and disadvantages of various mass marking options that could be used for fingerling salmonids and found nine different techniques suitable for mass marking. The possible options available were: high pressure application of fluorescent grit, fin clipping, phototonic paint marks, visible implant fluorescent and visible implant elastomer tags, otolith thermal marking, passive integrated transponder tags, coded wire tags, fluorescent marking by bath immersion in oxytetracycline, calcein, or alizarin, stable isotope (SI) marking, and parental-based tagging (PBT) by annual genotyping of hatchery broodstock. After review of the techniques available, I found that thermal marking and possibly SI marking are the most promising and likely effective tool for mass marking Yellowstone Cutthroat Trout in Henrys Lake. Both marks provide a permanent mark that is relatively easy to apply and inexpensive. Although a potentially viable marking method, the relatively high cost of analysis for PBT may be a limiting factor until costs recede in the future. PBT may become a more viable tool in the future for evaluating mass marking in Henrys Lake and would be a more powerful method than thermal or stable isotopic marking given each fish is individually genetically tagged.

Author:

Jon Flinders
Regional Fisheries Biologist

INTRODUCTION

Henrys Lake is a stronghold for native Yellowstone Cutthroat Trout and has provided a recreational fishery since the late 1800s (Van Kirk and Gamblin 2000). In 1924, a dam was constructed on the outflow to increase storage capacity for irrigation demand. The increased storage water inundated lower sections of the tributaries that were critical spawning areas for adfluvial Yellowstone Cutthroat Trout. In an effort to mitigate for the losses of reduced recruitment, Idaho Department of Fish and Game (IDFG) acquired a private hatchery on the shores of Henrys Lake and began stocking fingerling trout in 1929. Since 1929, IDFG has stocked over 86 million Yellowstone Cutthroat Trout, 10 million hybrid trout (Rainbow Trout x Yellowstone Cutthroat Trout) and nearly 4 million Brook Trout. Stocking ratios have averaged 85% Yellowstone Cutthroat Trout, 11% hybrid trout, and 4% Brook Trout from 1966 to 2014. Beginning in 1998, all hybrid trout were sterilized prior to release to reduce the potential for hybridization with native Yellowstone Cutthroat Trout. Although hybridization was not a concern with Brook Trout, only sterile fingerlings have been stocked since 1998 (with the exception of 50,000 fertile fish in 2003) to reduce the potential for naturally reproducing Brook Trout to compete with native salmonids.

Currently, IDFG marks 10% of the stocked Yellowstone Cutthroat Trout in Henrys Lake with an adipose fin clip. The ratio of marked to unmarked Yellowstone Cutthroat Trout collected in gill nets and spawning operations allows fisheries managers to assess the contribution of natural recruitment of Yellowstone Cutthroat Trout. The advantage with using a ratio approach is the marking cost is much lower than marking all fish stocked (~1,000,000 per year). The potential drawback with using a ratio estimate is there is likely an unknown error associated with that estimate. In recent years, IDFG has begun habitat restoration in the tributaries in an effort to increase natural recruitment for Yellowstone Cutthroat Trout. As tributary habitat improvement projects continue to be completed, understanding the level of natural recruitment will become more critical to evaluating ultimate success or failure of these habitat restoration efforts. Developing a cost effective method for mass marking all Yellowstone Cutthroat Trout and hybrid trout stocked would provide a more robust assessment of natural recruitment contributing to this important fishery. A variety of methods for mass marking are currently available, including fin-clipping (e.g. adipose, pectoral), tagging (e.g. coded wire tags, PIT tags), genetics (e.g. parentage based tagging), and chemicals (e.g. oxytetracycline). Various marking techniques are often inadequate for a variety reasons that may affect fish behavior or survival, require excessive handling, costs associated with marking or processing, and a reduction in retention rates over time. Thus, the objective of this chapter was to use a literature review to evaluate marking programs and procedures for salmonids and suggest complementary or alternative methods for marking individuals Yellowstone Cutthroat Trout stocked in Henrys Lake.

METHODS

I conducted a literature review and personal communications with subject matter experts on different marking procedures. Articles that I found particularly pertinent I used Science Citation Index to check references to find additional articles that have cited the previous research. I also used web search engines to find grey literature from various agencies using different mass-marking techniques. I generally focused my attention to research on salmonids, but occasionally added information from other species when deemed appropriate. Given the vast amount of research on the subject of fish mass marking, I restricted my analysis in a few ways. I tried to hone in methods I found to be most promising and limited my literature review on methods less likely to be implemented. I tended to focus on the techniques suitable for mass marking groups of fish instead of individuals in large part due to costs, effects on mortality and growth, and the size of fish at tagging (~75 mm TL).

RESULTS

External Marks

Fluorescent Grit Mark

High-pressure application of fluorescent grit that forces fluorescent pigment into the dermal tissue of fish was first reported to be used in the late 1950s (Jackson 1959). Evaluations of the effectiveness of florescent grit marking salmonids began in late 1960s and into the 1970s (Phinney et al. 1967; Phinney and Mattews 1969). The major advantages with grit marking are the low costs ($30/lb), relative ease of marking (50,000 fingerlings/hour), high marking efficiency, and often low marking mortality. However, high marking efficiency and low mortality occurs only if proper application of pressure and techniques are used and varies based on species and fish size (Schumann et al. 2013). A few disadvantages with grit are the identifications of the mark require a black light, mark identification on live fish is difficult unless anesthetized, the inability to mark individual fish, and mark retention decreases over time. Marking mortality, efficiency, and retention (short-term and long-term) can vary with marking pressure, size, and species. Schumann et al. (2013) evaluated retention on six species (Orange Throat Darter, Bluegill, Plains Topminnow, Grass Carp, Black Bullhead, and Channel Catfish) and found after five months, fluorescent mark retention decreased below 75% for all six species. Previous studies with salmonids found retention ranged from 75% to 98% for up two years (Leskelä 1999; Phinney and Mathews 1973; Phinney 1974; Strange and Kennedy 1982; Evenson and Ewing 1985; Hennick and Tyler 1970). Past studies have used larger sized pigments that are no longer commercially available, which may influence retention. Marking mortality percentages for salmonids with grit has ranged from 0 to 97 percent (Phinney 1974; Bartow 1987; Strange and Kennedy 1982; Hennick and Tyler 1970).

Fin clipping

Fin clipping is among the oldest and simplest methods for marking fish where a fin (e.g., adipose) is partially or entirely removed (i.e. clipped) for subsequent identification with a group of fish. Coble (1967) and McNeil and Crossman (1979) developed and evaluated techniques for fin clipping. Armstrong (1949) and Shetter (1951) addressed issues of fin regeneration among salmonids. Fin clipping is suitable for mass marking small fish (~50 mm TL). A limitation with fin clips is there are limited numbers of fin clip combinations possible. All fins with the exception of the adipose fin will regenerate unless cut back to the bone. However, occasionally an adipose fin will regenerate or become clipped in the wild creating a false mark (McFarlane et al. 1990). Clipping rates can be high (800 fish/hr) and costs are relatively low ($0.05 per fish) compared to other marking methods.

Phototonic Paint Marks

Photonic paint can be used to mark a fish using paint injections of Poly(methyl methacrylate) fluorescent pigment encapsulated in latex to their fins. The paint is often visible in regular light. Hayes et al. (2000) evaluated photonic paint on adult Chinook Salmon *Oncorhynchus tshawytscha* (701-956 mm TL) on the pectoral fin, pectoral girdle, and dorsal fin.

They found that only pink marks in the pectoral girdle were classified as good marks and yellow was difficult to detect because the skin of salmon often became yellowish as the spawning season progressed. Retention time of the mark was only evaluated for 52 days (Hayes et al. 2000). Thus, little is known regarding long-term retention (>1 year) and this technique may be only suitable for mass marking for short-term studies. Marking time averaged 30 seconds and average cost was $0.24 per fish (Hayes et al. 2000). A study examining swimming performance of Sacramento Splittail *Pogonichthys macrolepidotus* subcutaneous injections of fluorescent latex found that they were unaffected by the marking technique (Sutphin et al. 2007). To date limited studies have been conducted on juvenile salmonids using this method. Also, marking fish with a visible mark may make them more susceptible to visual predators and would need to be evaluated to ensure adequate survival of fish after stocking.

Visible implant fluorescent and elastomer tags

Visible implant fluorescent (VIF) tags are a small plastic strip coded with a three-digit alphanumeric code, whereas visible implant elastomer (VIE) tags comprise a two-part, mixed component of a biologically-inert silicon polymer that fluoresces under UV light that is injected and is actually an internal mark that is visible under ambient or ultraviolet light (Close 2000). In salmonids, tags can be implanted in a few body locations, such as the transparent adipose eye tissue or between fin rays (Bailey et al. 1998). Morgan and Paveley (1996) marked presmolt brown trout *Salmo trutta* (100-170 mm TL) in the postocular adipose tissue and reported a tagging rate average around 300 fish/hr. They monitored brown trout for 4 months and found tag loss rate (partial and complete) of 23.8%. Bailey et al. (1998) evaluated VIE marking in coho salmon (mean 108 mm TL) and found detectable marks in 73% of adults when viewed under UV light. Hale and Gray (1998) conducted a short term study (30 d) and found detection rates of 94-96% for Rainbow Trout *O. mykiss* (range 80-314 mm TL) tagged in eye adipose tissue, but detectability declined with time. Close (2000) evaluated a green and yellow VIE tagged in the postocular adipose tissue of fingerling Rainbow Trout (range 50-160 mm TL) for detection and retention for 195 d. Close found a mortality rate of 5.6% (range 3.3-8.1 per day) within 16 h of marking and that mark detectability decreased as the fish grew. He also found that VIE marks in the Rainbow Trout fingerlings under UV light were low (range 57-87% after 195 d) and suggested VIE may be only useful for short-term marking of fingerling Rainbow Trout. The advantages of VIF and VIE tags is that fish are not required to be sacrificed to assess the tag and no open wounds are created after tagging.

Internal Marks

Thermal Marks

Thermal marks are distinct, nonrandom patterns created in the otoliths of fish by exposing embryos or fry to temperature changes. Different patterns can be used to distinguish year-classes or different lots of fish. Otolith thermal marking is such that short-term temperature manipulations modify the appearance of one or more otolith increments, producing an obvious pattern that can be recognized at any life stage (e.g. fry, fingerling, adult). Depending on the mean ambient water temperature, water may be heated or chilled to produce the desired mark. The magnitude of the change in temperature is primarily governed by the hatchery capacity in producing chilled or heated water (general range 2-5°C) with larger changes producing a more pronounced effect (Volk and Hagen 2001). Elevated temperatures shorter than 24 hours are less effective at producing obvious marks, as well as steady temperature increases and decreases (Volk et al. 1999). Letcher and Terrick (1998) found strong thermal marks on Atlantic salmon otoliths when at a premark temperature of 5°C for 4 days and a marking temperature of 1°C for at least 24 hours.

Error recognition and misclassification rates of otolith thermal marks may arise from poor otolith marks, natural mimics of induced patterns, and poor preparations (Volk et al. 1999). Volk et al. (1999) evaluated misclassified errors of known marked and non-marked otoliths of Chinook and Coho Salmon *O. kisutch* (n=1,852) and found an overall mean error rate for known marked fish of 2% and a much higher error rate when classifying known unmarked of 6 to 11%. Bergstedt et al. (1990) estimated classifications rates of 85-98% in marked and unmarked fish. In pink salmon *O. gorbuscha*, Hagen et al. (1995) accurately identified 64-100% of known marked and unmarked otoliths.

Thermal marks work particularly well for hatchery-incubated salmonids due to protracted incubation and yolk absorption stages, high numbers of fish are concentrated in hatchery incubators, and otoliths begin growing in embryos (Volk et al. 1990). Thermal marking is a relatively inexpensive technique that is accomplished without handling individual fish (Brothers 1990; Volk et al. 1990). However, mark retrieval is more labor-intensive and time-consuming and requires the sacrifice of the fish for otolith extraction, preparation, and examination. For a long-lived slow growing species occupying cold temperatures, such as lake trout in the Great Lakes, thermal mark application and identification can be difficult (Negus 1999). Advantages of thermal marks is it can be accomplished without handling individual fish, occurs at life stage at hatcheries when concentrated in small areas, no chemicals are used, little or no mortality, and a reliable permanent mark. Duration of thermal marks on lake trout sac fry lasted for at least seven years with 100% mark recognition (Negus 1999). Developing an effective thermal mark using density, spacing, and regularity will increase mark recognition and decreases preparation (e.g. grinding) time (Negus 1999). Marking can be conducted according to the water temperature sources available (e.g., spring, well, lake) and if different water sources are not available then heating and cooling systems must be purchased. Major disadvantages to thermal marking are the initial and subsequent costs of heating or cooling water, fish must be sacrificed to obtain the mark, relatively few combinations of marks can be used, and processing time and expertise are required to read marks. In some systems, environmental fluctuations can mimic hatchery reared marks in wild stock fish (Volk et al. 1999). Hammer and Blankenship (2001) estimated otolith thermal marks cost US $0.001 per alevin and costing US $8-10 per otolith for processing and mark detection.

Passive Integrated Transponder tags

Passive Integrated Transponder (PIT) tags have gained considerable interest as a tagging method since the 1980s. PIT tags consist of an integrated microchip bonded to the antenna coil encapsulated in a glass tube that can vary in size with the most common a 12.0 mm x 2.1 mm and 0.1-g sized tag. The PIT tag allows for 34 million unique code combinations. For smaller salmonids (<200 mm TL) PIT tags are injected into the peritoneal cavity just posterior to the pectoral fin between the pyloric caeca and pelvic girdle using a 12-gauge injector needle (Prentice et al. 1990). PIT tags small size, light weight, long life span, internal location, and near unlimited code combinations make them ideal for small fish. PIT tags with resident spawning salmonids may result in significant tag loss as tags may be expelled during spawning. For example, Peterson et al. (2004) discontinued using PIT tags in cutthroat trout over concerns of spawning females shedding tags. Subcutaneous placement into the musculature rather than body cavity may increase tag retention (Dieterman and Hoxmeier 2009). However, PIT tags inserted into the dorsal musculature of harvested fish could be consumed by anglers. The relatively slow tagging rate (~200 fish per hr), cost per tag (US $2-5), and tag loss in resident spawning salmonids make them more suited for small scale tagging studies rather than mass marking.

Coded Wire Tags

Coded wire tags (CWT) are made of magnetized stainless steel wire (1 mm) injected into the snout of fish anterior to the eyes (Elliott and Pascho 2001). Coded wire tags have binary codes that allow for 250,047 different codes or blank wire with no code. Elliott and Pascho (2001) found increased infection rates of Renibacterium salmoninarum, which causes Bacterial Kidney Disease (BKD), in salmon injected with CWT. Factors that may influence lower success rates with CWT may be hatchery conditions and untrained tagging personal. Kaill et al. (1990) evaluated retention rates in pink salmon and found retention rates exceeded 93% over the short-term (40 d) and become lower over a long term (2 years) which ranged from 49-84%. Automated marking trailers for CWT can increase retention and provide a means to allow for mass marking that does not require handling or anesthetizing of the fish. However, the cost of an automated trailer (US $1.3 million) makes this option cost prohibitive.

Fluorescent markers

Fluorescent marking occurs when fish are immersed in oxytetracycline (OTC), calcein, or alizarin creating a visible band of color in the otolith, scales, or fin rays. OTC is an antibiotic that produces a fluorescent mark on bony structures. Calcein is a chemical marker that produces a bright blue marker similar to OTC. Alizarin chemicals, most commonly alizarin complexone and alizarin-red S, produce scarlet bands on otoliths. Fish can be mass marked using injections, dietary transmission, or solution immersion. Immersion is generally the most commonly reported method for marking given it is the least time consuming.

Fluorescent markers are effective for batch marking large numbers of fish with a single identification mark. However, oxytetracycline mark success is not always 100%, may result in bone deformities (Toften and Jobling 1996), and mark retention decreases with age (Reinert et al. 1998). Studies have varied on the recommended structure to examine for marks such as vertebrae (Trojnar 1973), lapillae otoliths (Peterson and Carline 1996), or pelvic bones (Scidmore and Olson 1969). Most studies suggest sagittal otoliths are the most consistent structure for fluorescent marks. To ensure 100% mark with alizarin and calcein, high concentrations can be used. However, higher concentrations increase mortality in some species such as Walleye *Sanders vitreus* (Brooks et al. 1994), Striped Bass *Morone saxatilis* (Bumguardner and King 1996), and Golden Perch *Macquaria ambigua* (Crook et al. 2009).

Stable isotopes

Stable isotope (SI) marking is typically done with barium (Ba) or strontium (Sr) isotopes. Direct uptake from the water rather than through the diet is the principal route by which strontium and barium are incorporated into hard structures in fishes (Walther and Thorrold 2006). Stable isotopes may be administered via maternal transfer (Thorrold et al. 2006; Munro et al. 2009), dietary transmission (Woodcock et al. 2013), immersion of eggs, larval, or juvenile fish (Braux et al. 2014; Smith and Whitledge 2011; Warren-Myers et al. 2015) or direct injection during vaccination (Warren-Myers et al. 2014). Concentrations of enriched isotopes vary markedly among the different techniques to achieve a 100% mass mark. For example, immersion time can vary from 1 h (Braux et al. 2014) to 70 days (Walther and Thorrold 2006). The immersion times can affect the costs (i.e. increased costs with increased time) and mortality (Walther and Thorrold 2006). In an effort to decrease immersion time, Warren-Meyers et al.

(2015) evaluated the feasibility of isotopic otolith marking via immersion at the egg swelling stage (period immediately following fertilization when eggs are left in the water to swell before being transferred to the hatchery) in Atlantic Salmon *Salmo salar*. In Atlantic salmon only ^{135}Ba, ^{136}Ba, ^{137}Ba were successful in marking 100%, whereas ^{134}Ba, ^{86}Sr, ^{87}Sr, and ^{26}Mg were not successful in achieving mark success despite much higher concentrations (Warren-Meyers et al. 2015).

The SI marking technique requires isotopic analysis which is relatively costly (approximately $15 US per fish for analysis) compared with other marking methods. Also, only a relatively few laboratories are equipped for such an analysis. The cost of enriched $^{86}SrCO_3$ is relatively expensive (US $11 mg^{-1}). However, the cost of producing stable strontium isotope marks in fish is comparable to other chemical marking methods for small fishes due to the small amount of $^{86}SrCO_3$ required to mark otoliths (Munro et al. 2008). Smith and Whitledge (2011) estimated the cost associated with marking 100 Lake Sturgeon *Acipenser fulvescens* fin rays with 100 µg L^{-1} $^{86}SrCO_3$ over a 10-day immersion period was approximately US $350. However, sturgeon were larger fish (>150 mm TL) and costs would be expected to be lower with smaller fish. Marking costs for eggs during swelling ranged from US $0.0001 to 0.0017 per egg. Isotopic analysis per fish costs US $15 per otolith for larval fish (Warren-Meyers et al. 2015). Additional costs would be incurred with larger older fish otoliths due to increased time required for sectioning and polishing prior to laser ablation.

Parental-based tagging

Parental-based tagging (PBT) is a molecular technique that involves the annual genotyping of hatchery broodstock, creating a database of parental genotype of the hatchery. The genetic mark passes transgenerationally and would permanently and noninvasively mark all offspring. Progeny can also be nonlethally sampled (e.g. genetic fin clip) at any life stage (e.g., fingerling, adult) and assigned back to brood year (i.e. age). An advantage with PBT is the ability to tag every juvenile when its two parents are genotyped. Steele et al. (2013) conducted a large-scale PBT study in the Snake River basin for tracking hatchery salmonids and found PBT to be an effective tool in marking millions of smolts. The relatively high cost of analysis for PBT may be a limiting factor at present, although costs are declining as genetic analysis technology improves (Estoup et al. 1998; Castro et al. 2004). At the time of writing this report, the estimated cost per sample is US $15 per fish for genotyping parents and assigning the offspring to broodstock (M. Campbell, IDFG, personal communication).

DISCUSSION

A variety of methods exist for mass-marking salmonids in Henrys Lake (Table 7). As mentioned previously the major factors considered were the potential effects on fish behavior or survival, handling time, costs associated with marking, mark retention rates, and mark readability. Based on my analysis I placed a mark into four likely groups: impractical, candidate, viable, and powerful. Impractical represent those marks with the least amount of promise. Candidate represents marks that could work, but are less than ideal. Viable represents marks with promise and appear to be best suited for mass marking. Powerful represents a mark with the ability to address more specific management questions.

Impractical

Despite relatively low costs and minimal handling, OTC, calcein, alizarin, and fluorescent grits, all have marks that will decrease over time (i.e. lower retention rates); thereby limiting their effectiveness. PIT tags are impractical due to their high costs and shed tags in spawning female fish. VIE and VIF have slow marking rates and unacceptable tag detection loss rates (e.g. cloudiness in adipose tissue).

Candidate

Fin clipping and CWT have high mark success, permanent mark retention, and high mark readability. However, the cost of fin clipping and CWT is similar to other marks, such as PBT, or more expensive than a few other marking techniques with similar abilities, such as otolith thermal and isotopic marking. A potential benefit with fin clipping (e.g., adipose) is that it would allow for an external mark that anglers could readily verify and allow for harvest of clipped fish only (i.e. only hatchery fish harvested), if fish managers deemed appropriate and necessary.

Viable

Given the lower costs, mark effectiveness (100%), permanent mark retention, and high mark readability, otolith thermal marks and isotopic marking at egg swelling stage are likely the most viable methods for ascertaining wild contribution levels. The advantage with otolith thermal marking is different thermal bands can be applied each year to track cohorts (i.e. age). However, the initial setup costs for a heating or cooling water source would need to be explored to determine the feasibility of implementing such a mark. Stable isotope markers using the egg swelling stage is a relatively new method and has not been evaluated in Yellowstone Cutthroat Trout. Therefore, methodologies for SI in Yellowstone Cutthroat Trout would need to be developed and evaluated prior to large-scale implementation. The advantage that SI has compared to thermal marks is that correct mark identification rates of Atlantic salmon eggs immersed in stable isotopes was nearly 100% (Warren-Myers et al. 2015) whereas estimated rates with otolith thermal marking rates have ranged from 65 to 95% (Hagen et al. 1995; Volk et al. 1999).

Powerful

The most powerful method for mass marking would be PBT since every fish is noninvasively marked when the parents are genotyped. PBT would provide a means to address specific management questions such as evaluations of growth and survival of stocking strategies (spring vs. fall fingerlings) or hatchery performance (American Falls hatchery vs. Mackay Hatchery). Currently, PBT is likely too cost prohibitive. However, as genetic analysis technology improves and costs decline, PBT may become a more viable tool in the future for evaluating mass marking in Henrys Lake.

CONCLUSION

This study was completed to evaluate possible methods for mass marking Yellowstone Cutthroat Trout to estimate their natural production in Henrys Lake. After review of the methods available, I found that thermal marking and possibly stable isotopic marking are the most promising and likely effective tool for mass marking Yellowstone Cutthroat Trout. Both methods provide a permanent mark that is relatively easy to apply and inexpensive. Implementation of thermal marking will require additional expenditures at the Henrys Lake or Mackay hatchery for heating or cooling as well as additional research and training in correctly identifying the marks. Isotopic marking will require research projects aimed at developing correct protocols for standardized egg immersion techniques. As costs decrease, Parental Based Tagging may well become a method with direct applications to Henrys Lake and our efforts to better understand the fishery there. Ultimately results should prove beneficial in providing insight into the contributions of naturally produced Yellowstone Cutthroat Trout into the economically important and renowned fishery at Henrys Lake.

Table 7. Estimated costs (US dollar) of mass marking Yellowstone Cutthroat Trout and hybrid trout in Henrys Lake, Idaho. Costs were calculated for marking, sampling, and detecting marks.

	Mark		Detection	Total
Method	**Cost per fish**	**Cost per million**	**Cost per fish**	**Cost per 1,000 sampled per million marked**
GRIT	0.001	1,000	0.00	1,000
Fin Clip	0.05	50,000	0.00	50,000
Phototonic	0.24	240,000	0.00	240,000
VIE	0.40	400,000	0.00	400,000
Thermal	0.001	1,000	10.00	11,000
PIT	3.00	3,000,000	0.00	3,000,000
CWT	0.092	92,000	3.00	95,000
OTC	0.062	62,000	3.00	65,000
Isotopic	0.0017	1,700	15.00	16,700
PBT	15.00	34,500[a]	15.00	49,500

[a] PBT mark cost is for analysis of 1,300 females and 1,000 males collected from spawning operations at the Henrys Lake hatchery.

PALISADES RESERVOIR

ABSTRACT

Palisades Reservoir is a 27 km reservoir on the South Fork Snake River near the Idaho and Wyoming border that supports a fishery for Yellowstone Cutthroat Trout, Brown Trout *Salmo trutta*, kokanee salmon *O. nerka*, and Lake Trout *Salvelinus namaycush*. All of these species have self-reproducing populations in Palisades Reservoir and its tributaries, but Yellowstone Cutthroat Trout are also stocked by Jackson National Fish Hatchery to augment fishing opportunity. In 2015, the Idaho Department of Fish and Game conducted a creel survey, a gillnet survey, and initiated a kokanee salmon enhancement project. The creel survey was conducted May through August when an estimated 44,623 h were spent fishing and 3,814 trout and salmon were caught of which 2,141 of them were harvested. The overall catch rate was 0.09 fish/h. The majority of anglers surveyed rated the fishery in Palisades Reservoir as poor. Using 24 net nights of gillnetting, we captured 1,075 fish that included 62 wild trout. No hatchery Yellowstone Cutthroat Trout were observed, although all stocked fish have been marked with a fin clip since 2013. The average length for Yellowstone Cutthroat Trout was 316 mm and their average relative weight was 88. The average length of Brown Trout caught was 405 mm and their average relative weight was 72. We transplanted 50 male and 50 female kokanee salmon from Big Elk Creek to Bear Creek in August and stocked these fish upstream of a picket weir to enhance natural production of kokanee to Palisades Reservoir. Several redds were documented above the picket weir and water temperatures from Bear Creek suggest emergence timing of the fry should have occurred around March 1.

Brett High
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

INTRODUCTION

Palisades Reservoir is an impoundment on the South Fork Snake River, near the Idaho and Wyoming border in eastern Idaho (Figure 12). Palisades Dam is located at a constricting point in the valley near Calamity Point and the reservoir inundated what was formerly Grand Valley (Figure 13). Palisades Dam construction was authorized in 1941, but initiation of the project was delayed until 1951 because of World War II. At the time of construction it was the largest earthen dam in the world at 82 m (270') high and 640 m (2,100') wide (USBR 2015). Construction was completed in the fall of 1956 and the reservoir first reached full pool in 1957 (USBOR 1978). At full pool, the reservoir holds 1,401,000 acre feet of water (USBOR 2015). Palisades Reservoir is 6,458 hectares (15,958 acres) at full pool, and is 26.6 km long and relatively narrow, ranging from 0.43 to 4.1 km wide. It has a maximum depth of 86 m (248') and a mean depth of 23 m (76') at full pool. The reservoir was commissioned primarily for irrigation storage and secondarily for flood control and power generation (USBOR 1978). Water stored in Palisades Reservoir is managed by Idaho's Water District 1 as part of the Minidoka Project. As part of the Minidoka Project and due to its location relatively high in the drainage, water managers attempt to fill the reservoir each spring. Irrigation demand for water from Palisades Reservoir drastically reduces pool elevations by fall with water levels reaching the lowest level typically by the first part of October (Figure 14). Over the last 25 years, the average of the low pool level is 206,326 acre feet or 15% full. Over the same time period, the average annual highest pool level was 1,052,654 acre feet or 75% full. Although capacity is over 1.4 million acre feet, managers do not fill Palisades Reservoir over 1.2 million acre feet for flood control purposes. Over the last 25 years, Palisades Reservoir has reached 1.2 million acre feet ten times or 40% of the time (Figure 14).

Jackson National Fish Hatchery stocks Yellowstone Cutthroat Trout (YCT) in Palisades Reservoir. The number, size, and time of stocking of fish has varied through time. Beginning in 2013, all trout stocked from JNFH have been marked with a fin clip prior to stocking, to allow for assessments of fish survival and to evaluate the effectiveness of different stocking strategies.

Kokanee Salmon *O. nerka* have also been stocked in Palisades Reservoir. Nearly 4 million kokanee eggs and fry were stocked into Palisades Reservoir and tributaries between October 1963 and January 1965 (Jeppson et al. 1965). Jeppson et al. (1965) note that 2 million kokanee eggs were stocked in gravel beds at the mouth of Big Elk Creek, where they had good survival. Development was slow with sac fry observed on March 14. Kokanee fry were stocked in Palisades Reservoir in October 1963 and January 1965 (totaling 1.5 million). An additional 2 million eggs were stocked in October 1963 in McCoy and Big Elk creeks (Jeppson et al. 1965). The first documented returns from these efforts were from Big Elk Cr in 1980 (Moore et al. 1981). Kokanee salmon have not been stocked in Palisades Reservoir since 1965, but a wild reproducing population of kokanee salmon that spawn in Big Elk Creek persists and supports a popular fishery.

In 2015, the Idaho Department of Fish and Game (IDFG) conducted a creel survey to assess angler effort, catch and harvest; a gillnet survey to assess species composition, sizes, and relative contributions by hatchery YCT; and initiated a kokanee salmon enhancement research study to determine if translocating kokanee salmon to another Palisades Reservoir tributary could be an effective way to establish another reproducing group of kokanee for the reservoir. This report summarizes these efforts.

METHODS

Creel Survey

We conducted a creel survey on Palisade Reservoir from May through August of 2015 to estimate annual effort, catch, and harvest. Estimates were generated using an Access – Access design with completed trip data (Pollock et al. 1994). Estimates for total catch, effort, and harvest were the sum of the daily completed trip estimates and the daily incomplete trip estimates by month.

We divided the study period into two-week intervals. Creel clerks interviewed anglers at boat ramps four times during each two-week time interval - two weekdays and two weekend days or holidays. Interview days were selected randomly using a random number generator. Creel interviews were conducted during daylight hours, and days were divided into three periods, the AM period from sunrise to 11:00 AM, the noon period from 11:00 AM to 4:00 PM, and the PM period from 4:00 PM to sunset. These three time periods were weighted with equal sampling probabilities. Creel clerks were instructed to be at the designated boat ramp throughout the creel shift. There were two designated access sites (boat ramps) where clerks conducted interviews: the Blowout and Calamity boat ramps. We assigned the boat ramp with different probability based on expected use. Blowout was weighted with a 70% probability and the Calamity Boat ramp location was weighted with a 30% probability. The primary goal was to collect completed trip data from anglers leaving the access sites, but clerks also collected incomplete trip data from anglers who were still fishing when the survey period ended, when possible.

Effort was estimated by counting anglers on the reservoir from a fixed-winged aircraft to collect instantaneous counts of anglers. Counts were done on two weekdays and two weekends/holiday during each two-week interval. The days and flight start times were selected randomly using a random number generator.

Creel clerks also asked anglers five questions during interviews (Appendix B). One question pertained to angler satisfaction in relation to the number and size of fish caught. The second question asked the angler to rate the quality of the fishery. The third question asked anglers what was more important in their opinion, number of fish caught versus size. The fourth question asked anglers to indicate which species they would prefer fish management was geared towards, and the final question was an open-ended question allowing for the angler to provide comments and feedback.

Gill Net Survey

We set pairs of floating and sinking gill nets at 12 randomly assigned locations in Palisades Reservoir from July 7-10, 2015 for a total of 24 net nights (Figure 15). Net locations were determined using 500 m^2 sections of shoreline. All possible sections on the reservoir were numbered and six of the 500 m^2 were randomly selected in the northern half of the reservoir and the other six were randomly selected from the southern half of the reservoir. Gillnets consisted of either floating or sinking types measuring 46 m by 2 m, with mesh sizes of 2 cm, 2.5 cm, 3 cm, 4 cm, 5 cm, and 6 cm bar mesh. Nets were set at dusk and retrieved the following morning. We identified captured fish to species and recorded total lengths (TL) and weights (g). We calculated catch rates as fish per net night and also calculated 95% confidence intervals. We examined all YCT handled for adipose fin clips as part of our evaluation of hatchery fish performance, as all hatchery YCT had been ad-clipped prior to stocking.

Relative weights (W_r) were calculated by dividing the actual weight of each fish (in grams) by a standard weight (W_s) for the same length for that species (Anderson and Neumann 1996). Relative weights were then averaged for each length class (<150 mm, 150-249 mm, 250-349 mm, 350-449, and fish >449 mm). We used the formula:

$$\log W_s = -5.189 + 3.099 \log TL$$ (Kruse and Hubert 1997)

to calculate relative weights of YCT and

$$\log W_s = -5.422 + 3.194 \log TL$$

for Brown Trout (Hyatt and Hubert 2001b).

Kokanee Salmon Translocation

We captured kokanee salmon from Big Elk Creek and transplanted them in Bear Creek. We used backpack electrofishing units to capture kokanee and hauled these fish to Bear Creek in a slide-in truck hauling tank outfitted with a fresh flow and oxygen diffusers. Prior to transplanting these fish, we installed a picket weir near the mouth of Bear Creek to prevent transferred kokanee salmon from migrating back to Palisades Reservoir. We also installed a temperature logger to monitor water temperatures during egg incubation. During the second transplanting event, we surgically implanted three radio-transmitters in three of the male kokanee salmon and relocated these tagged fish twice each week until fish died.

RESULTS

Creel Survey

Anglers fished for an estimated 44,623 h on Palisades Reservoir from May through August. The duration of the 2015 creel survey was shorter than previous surveys (Table 11). Boat anglers accounted for 64% of the effort while bank anglers accounted for 36% of the fishing effort. The total number of angler trips during the survey period was 5,814 with an average trip duration of 3.6 h.

Anglers caught 1,389 YCT, 1,977 Brown Trout, 208 kokanee salmon, 154 Rainbow Trout, 86 Lake Trout, 410 Utah Chub, and 32 Utah Sucker *Catostomus ardens*. Combining all trout and salmon caught during the survey and dividing by total angler effort indicates an overall catch rate of 0.08 fish/h.

Anglers harvested 449 Yellowstone Cutthroat Trout, 1,394 Brown Trout, 77 kokanee salmon, 135 Rainbow Trout, and all 86 Lake Trout. Release rates were highest for YCT (68%) and kokanee salmon (63%) and lowest for Lake Trout (0%) and Rainbow Trout (12%).

Most of the Palisades Reservoir anglers rated the quality of the fishing in Palisades Reservoir as poor (Table 8). In addition to this overall rating, anglers placed more importance on the size of fish caught over the number of fish caught in order to experience a quality trip (Table 9). When asked which species was preferred among those present, there were not clear indications of a “favorite fish.” All species ranked out evenly, in terms of angler preference. Angler satisfaction on a scale from one to ten averaged 3.3 relative to the number of fish caught and averaged 3.6 for the size of fish caught. Anglers rated their fishing experience higher than satisfaction levels for both the number of fish caught (6.0) and the size of fish caught (6.8).

A few anglers provided comments to an open-ended question at the conclusion of the survey (n = 18). The three most common themes of these comments were: stock more fish (28%), stock rainbows (28%), and frustration over fluctuating reservoir levels (11%). The other 33% of the responses were about random topics including parking conditions, dock conditions, more boat inspections, and fishing regulation concerns.

Gill Net Survey

We caught 1,075 fish during 24 net nights of gill net surveys in Palisades Reservoir, including ten YCT, 51 Brown Trout, one Mountain Whitefish *Prosopium williamsoni*, 261 Utah Sucker, and 752 Utah Chub. Utah Chub and Utah Sucker were the most abundant species caught during gillnet surveys with chubs being the dominant fish caught during the most recent surveys (Table 11). We caught an average of 2.8 trout per net night using floating nets (Figure 16) and 2.3 trout per net night using sinking nets (Figure 17). The species with the highest catch per unit effort for both net types was for Utah Chub. The average total length for Yellowstone Cutthroat Trout was 316 mm and the average W_r was 88% (Figure 18). None of the YCT captured in gillnets had adipose fin clips. Brown Trout captured in gillnets averaged 405 mm and their overall average W_r was 72% (Figure 19).

Kokanee Salmon Translocation

We captured and transplanted kokanee salmon on August 21 and 28, 2015, hauling 50 fish each day (25 males and 25 females). We transplanted a total of 100 kokanee salmon into Bear Creek. We stocked the fish near the Bear Creek trailhead, approximately 1.6 km upstream of the picket weir.

The weir was effective at keeping kokanee in Bear Creek, and we observed many kokanee salmon after release moving downstream to the weir, but did not observe fish escaping past the weir. All three of the radio-tagged male salmon stayed within Bear Creek. After three weeks, all three of these males had died and washed up against the weir. Many of the spawned out female salmon were also picked off the weir or observed along the margins of Bear Creek. All of the dead females we observed were spawned out. We counted more than 25 redds, with most of these within 200 m of the picket weir.

DISCUSSION

Angler effort, catch, and harvest were lower in 2015 than in previous surveys. Despite the shorter survey period, anglers reported drastically lower catch rates than previous years. On average in 2015, anglers fished 11 hours per fish caught in 2015. Estimates of both angler effort and catch rates for creel surveys conducted in seven previous years between 1963 and 1985 were two to seven times higher than estimated fishing effort and catch rates in 2015. These low catch rates likely negatively affected fishing pressure.

Angler satisfaction with Palisades Reservoir was low, but anglers ranked their fishing experiences with moderate scores. Given the low catch rates, low angler satisfaction ratings was not surprising. However, when asked to rank their fishing experience on the same scale, anglers ranked their fishing experience, in terms of fish numbers and size, double what they ranked their satisfaction for fish numbers and size. In relation to having a quality experience fishing Palisades Reservoir, the majority of anglers indicated the size of fish caught was the more important than the number of fish caught. Currently, both the size of fish caught and their average sizes could be improved on Palisades Reservoir. When given an opportunity to comment on the Palisades Reservoir fishery, most anglers requested more fish be stocked in Palisades Reservoir, and many anglers would like to see Rainbow Trout stocked in the reservoir.

Although sample sizes were low for YCT in gill nets, it appears that hatchery fish did not recruit to the fishery in high numbers. No marked hatchery fish were captured, although 100% of hatchery fish were marked prior to stocking. In 2014, over 101,000 YCT that averaged 190 mm were stocked in September in Palisades Reservoir. In 2015, hatchery YCT were stocked in both spring and fall. In the spring, 18,630 YCT excess fish that averaged 132 mm were stocked in May, and more than 103,000 YCT that averaged 203 mm were stocked in September. Current stocking requests are for 100,000 6-8" YCT stocked in September. Due to stocking size and timing, hatchery fish from 2015 were not catchable in our gillnet surveys. Historically, the timing of stocking events are bimodal with peaks in spring and fall. Over the last 30 years, Jackson National Fish Hatchery has stocked roughly three size groups of fish including catchables, juveniles, and fingerlings. The timing of stocking has occurred anywhere from March 29 through November 18, but 75% of the stocking occurred between May 1 and September 18. Historical reports indicate poor returns of YCT stocked as fry (over 1.4 million) between 1959 and 1963. Contributions of these stocking efforts to angler harvest were low enough that the stocking of fry was discontinued by managers in 1964 when a transition was made to stocking yearlings in May (Jeppson et al. 1965). After yearlings were stocked, Jeppson et al. (1965) documented a substantial change in return to creel. The YCT stocked as yearlings comprised 72% of the harvest and returned to the creel at an estimated rate of 14%. Managers continued to favor stocking yearling YCT over fingerlings as stocking evaluations continued to document higher return to creel rates for yearlings than fingerlings (Jeppson et al. 1965; Jeppson 1966). Moore et al. (1981) also recommended stocking YCT larger than 200 mm to achieve better return to creel. Fingerlings were again stocked in the mid-1980s despite recommendations for stocking larger fish and return to creel rates were again believed to be low as evidenced by lack of observed harvest during the 1985 creel survey (Corsi and Elle 1986). From 1985 to 2013, fingerlings were the most commonly stocked hatchery product and were stocked in 22 of these 29 years. Currently, stocking practices are being altered to stock larger fish, and different brood stock are being used to improve survival rates. We expect hatchery YCT contributions to the fishery in Palisades Reservoir to increase.

Floating and sinking gill nets during summer sampling may not be the most effect survey tool for Palisades Reservoir. Only 6% of the fish caught in 2015 gill nets were salmonids. Summer gill net surveys allow for more consistent water level conditions during sampling among different years, but may render floating and sinking gill nets less effective due to stratification and fish behavior relative to the thermocline which is located between the two nets. An alternative to floating and sinking nets would be curtain nets, which can be deployed on the thermocline where salmonids tend to occur during summer. Curtain nets have been used successfully to sample kokanee Salmon which strongly orient to thermoclines in stratified water bodies (Beauchamp et al. 2009: Schoen et al. 2012). If effective in Palisades Reservoir, curtain nets may prove a useful tool to monitor hatchery YCT and kokanee salmon abundance instead of using traditional floating and sinking gill nets.

Gillnet surveys have been inconsistent in Palisades Reservoir, with six years of data available since the dam was constructed well over 50 years ago. While too small to be captured using gillnets, Jeppson et al. (1965) noted that Redside Shiner *Richardsonius balteatus* were the most abundant species in Palisades Reservoir in terms of numerical abundance based on their fisheries surveys using dynamite. During the early 1960s YCT were more abundant in Palisades Reservoir than they currently are, with the most recent gill net survey indicating the lowest composition of YCT in the gill net catch to date. Despite the drop in YCT catch during gill net surveys, the composition of wild Brown Trout and Lake Trout has remained relatively stable. This suggests that the drop in YCT catch is likely associated with hatchery trout abundance. Stocking practices were changed in 2015 after a joint meeting between Wyoming Game and Fish, IDFG, and the US Fish and Wildlife Service/JNFH. Brood stock used for hatchery production were switched to a source provided by WGF, and progeny from this new source will be stocked in 2016. Rainbow Trout have also been observed during gill net surveys, both historical and recent, but at low abundance (i.e. fewer than 6 fish or less than 1%). Moore et al. (1981) documented wild Rainbow Trout presence in Trout Creek, adjacent to McCoy Creek, but could not find stocking records for Rainbow Trout in that system. Rainbow trout presence in Palisades is a concern, particularly in light of YCT conservation efforts downstream. Source populations of Rainbow Trout upstream of Palisades should be identified in conjunction with WGF personnel.

It is too early to determine if kokanee salmon transplant efforts into Bear Creek will be successful at starting a new run, but we learned through this first year of transplanting kokanee Salmon that the picket weir was necessary to keep fish in Bear Creek and when fry could be emerging from gravels. Most of the redds observed were downstream of the stocking location and immediately upstream of the weir. This suggests that kokanee Salmon transplanted in Bear Creek may have left the stream in an effort to return to Big Elk Creek and not spawned if the weir was not installed and maintained. In a laboratory setting, Hendry et al. (1998) observed emergence of Sockeye Salmon fry 815 thermal units after fertilization. With the first redds in Bear Creek observed on August 24, 2015, and based on water temperature data from Bear Creek, we would expect fry emergence occurred around March 1, 2016. If future efforts to document kokanee salmon spawning in Bear Creek with fry trapping are pursued in future years, early March should be the time when trapping efforts are made. Otherwise, we expect to observe adult kokanee return to Bear Creek in the fall of 2018.

RECOMMENDATIONS

1. Continue working to improve hatchery Yellowstone Cutthroat Trout survival and return to anglers in Palisades Reservoir.

2. Monitor hatchery Yellowstone Cutthroat Trout contributions to the fishery using gill net surveys to determine if hatchery fish survival and occurrence increases with modifications of stocking sizes and brood source.

3. Survey Idaho tributaries to Palisades Reservoir to determine distribution and abundance of Rainbow Trout.

4. Continue transplanting kokanee salmon in Bear Creek from Big Elk Creek.

5. Begin monitoring kokanee salmon abundance in the reservoir using curtain nets.

Table 8. Angler responses to ranking the quality of the fishery at Palisades Reservoir, 2015.

Ranking	Percent of responses
Excellent	12.2
Good	25.6
Fair	14.6
Poor	47.6

Table 9. The importance of the number of fish caught versus the size of fish caught for a quality fishing trip ranked on a scale of 1 to 10 by anglers with 1 being not important at all and 10 being extremely important. The table includes the sample size, mean ranking, and standard deviation of the ranking.

Question	n	mean	sd
Importance of number of fish caught	82	6.0	2.6
Importance of size of fish caught	82	6.8	2.8

Table 10. Summary of creel surveys from 1963 through 2015 including estimates for total fishing effort, harvest, and catch rates. Species composition observed in the creel is also reported for Yellowstone Cutthroat Trout both wild (WCT) and hatchery (HCT), Brown Trout (BNT), and Lake Trout (LKT).

					% Composition of catch			
Year	Months	Effort (h)	Harvest	Catch rate (fish/h)	WCT	HCT	BNT	LKT
1963	June - Oct	52,315	23,650	0.45	33	66	0.5	0.1
1964	May - Nov	80,242	43,347	0.54	27	72	1.2	0.02
1965	May - Nov	125,956	58,072	0.52	29	68	2.5	0.02
1970	Jan - Dec	80,414	19,712	0.25	88		9.5	0.4
1975	Jan - Nov	67,575	9,601	0.14	52	32	14.5	1.2
1980	Jan - Dec	197,575	59,163	0.30	5	85	5.8	3.5
1985	June - Oct	71,349	23,157	0.33	15	80	5	1
2015	May - Aug	28,347	2,141	0.08	36		52	2.3

Note: No differentiation was made between hatchery or wild Yellowstone Cutthroat Trout in 1970 and 2015.

Table 11. Species composition and catch of Yellowstone Cutthroat Trout (YCT), Brown Trout (BNT), Lake Trout (LKT), Utah Chub (UTC), and Utah Sucker (UTS) in Palisades Reservoir during gillnet surveys from 1963 through 2015.

	YCT	BNT	LKT	UTC	UTS
1963	37	7	1	104	78
1964	125	13	1	269	125
1975	14	34	7	358	268
1985	16	16	0	55	266
2010	61	195	4	1354	363
2015	10	51	0	752	221

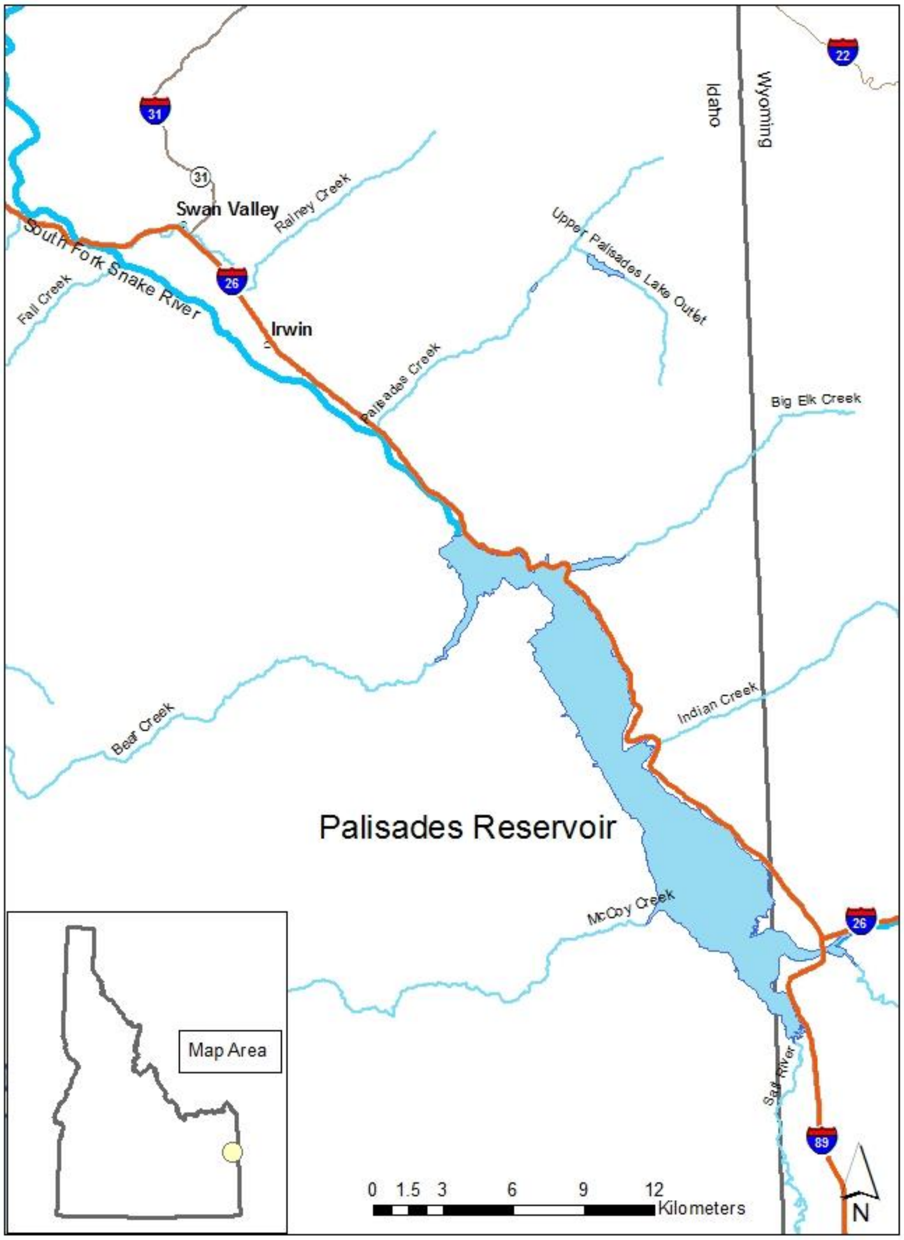

Figure 12. Palisades Reservoir in eastern Idaho.

Figure 13. The site of Palisades Dam prior to construction. This photo was taken in 1911 and shows Calamity Point, the north end of Grand Valley, and Swan Valley in the background.

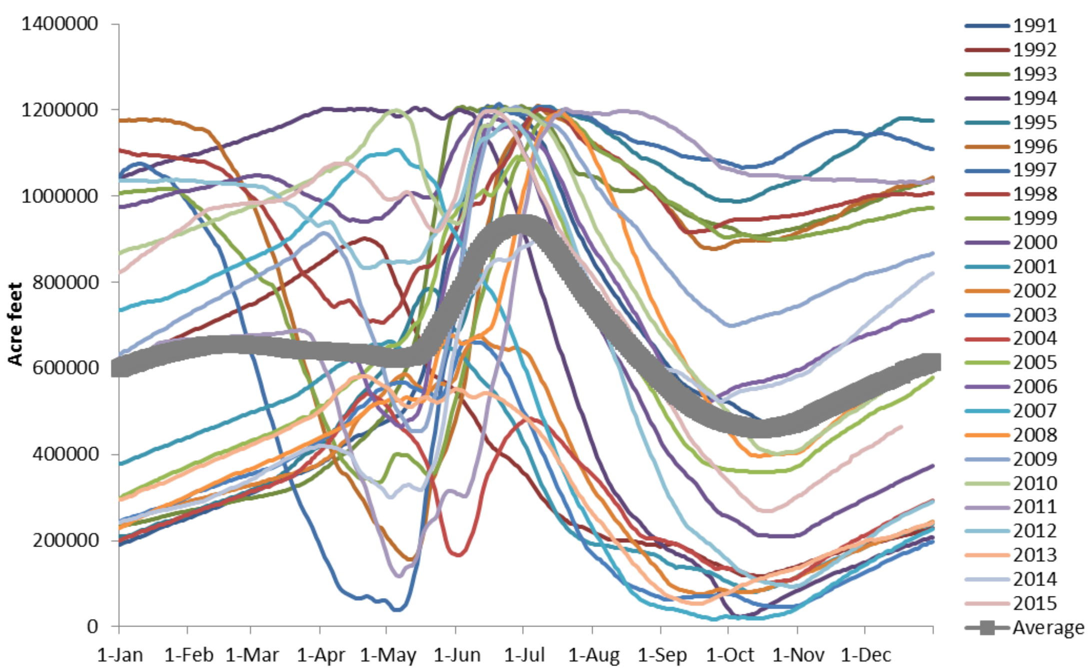

Figure 14. Annual storage of water (acre-ft) in Palisades Reservoir from 1991 through 2015.

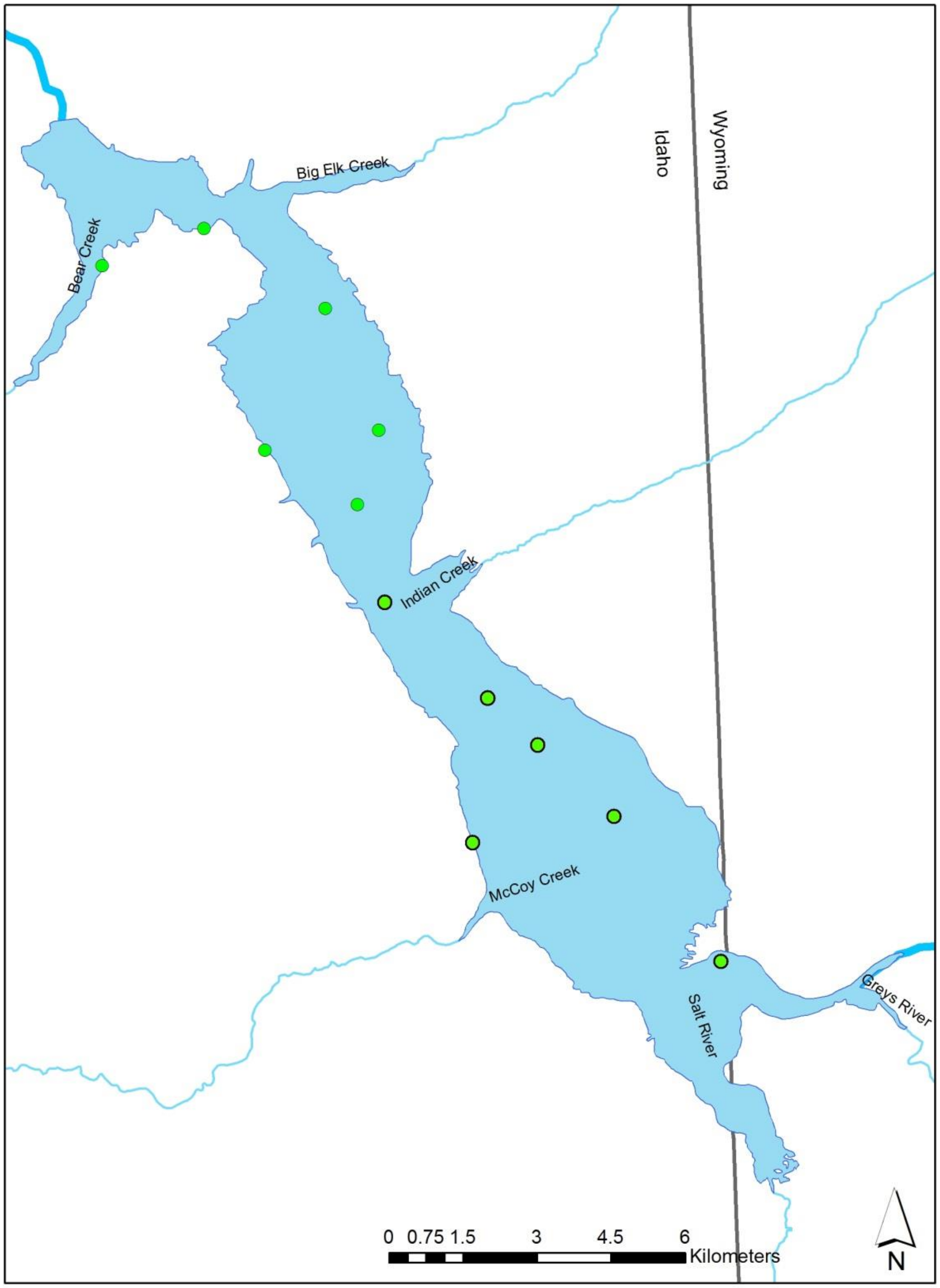

Figure 15. Gillnet locations in Palisades Reservoir 2015 survey.

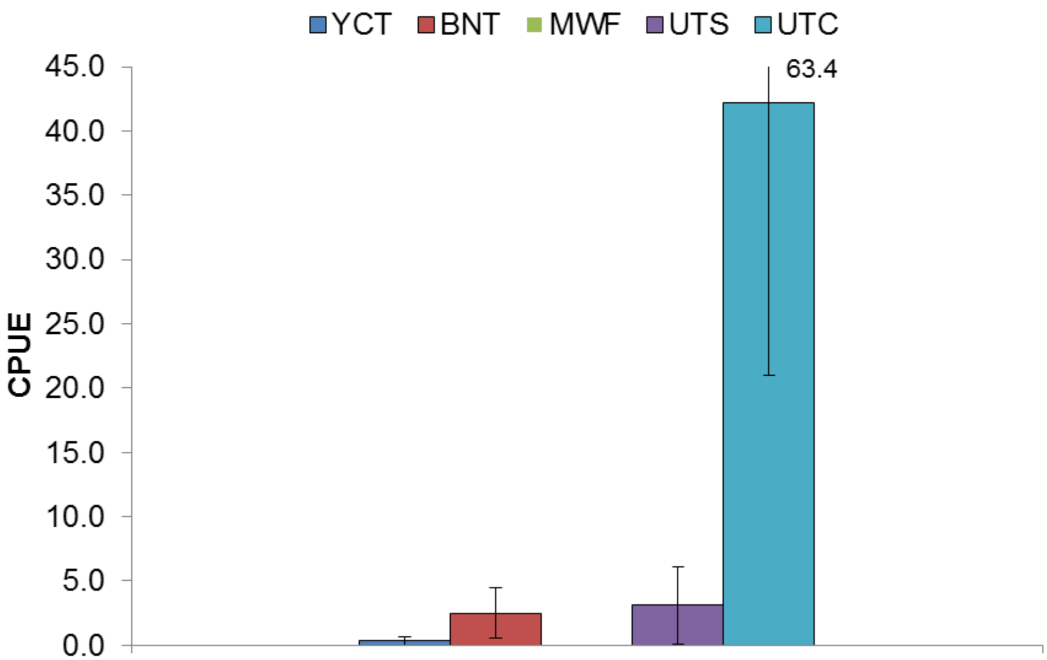

Figure 16. Catch per unit effort (CPUE) for Yellowstone Cutthroat Trout (YCT), Brown Trout (BNT), Mountain Whitefish (MWF), Utah Sucker (UTS), and Utah Chub (UTC) sampled in Palisades Reservoir with floating gill nets in 2015.

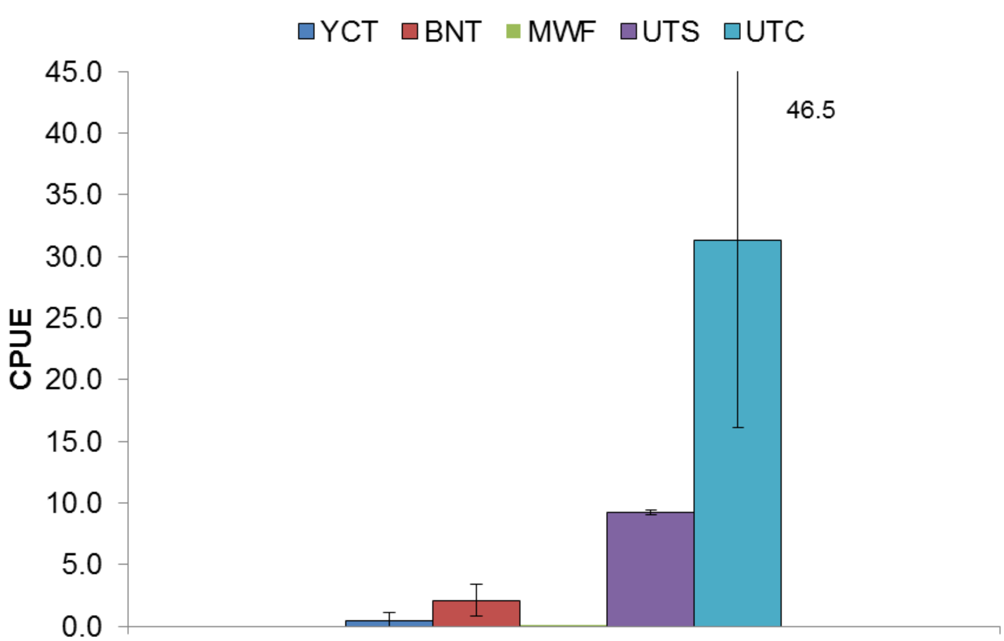

Figure 17. Catch per unit effort (CPUE) for Yellowstone Cutthroat Trout (YCT), Brown Trout (BNT), Mountain Whitefish (MWF), Utah Sucker (UTS), and Utah Chub (UTC) sampled in Palisades Reservoir with sinking gillnets in 2015.

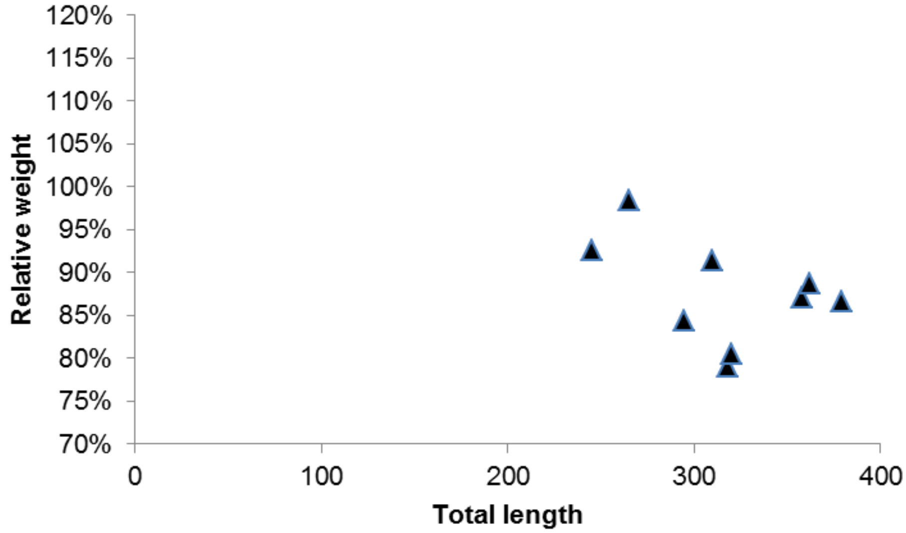

Figure 18. Relative weights for Yellowstone Cutthroat Trout captured in Palisades Reservoir during gill net surveys in 2015.

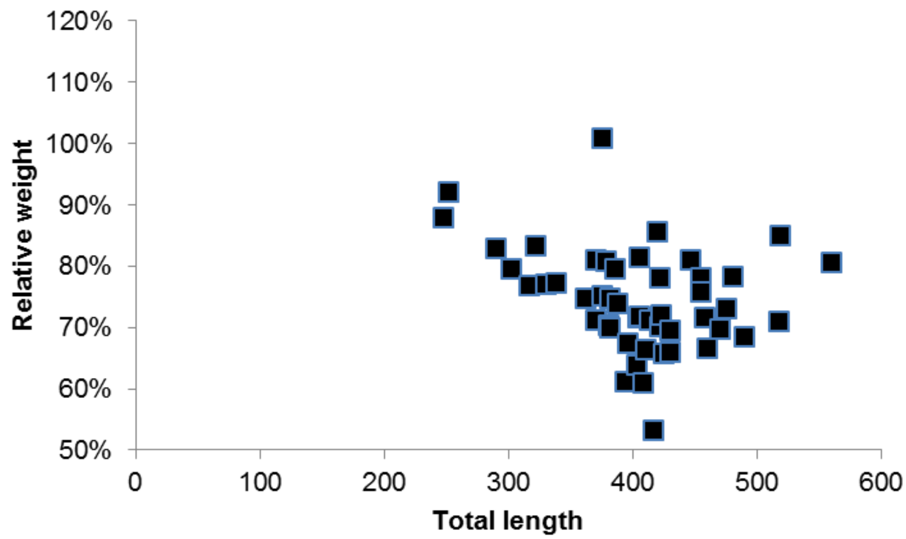

Figure 19. Relative weights for Brown Trout captured in Palisades Reservoir during gill net surveys in 2015.

RIRIE RESERVOIR

ABSTRACT

We conducted our sixth annual fall Walleye index netting (FWIN) in Ririe Reservoir, and captured 13 Walleye, ranging from 203 mm to 720 mm TL. Average Walleye per net night (± 95% CI) was 0.7 ± 0.5, which was similar to the low abundances of Walleye per net night from 2010-2014 (0.4 per net night). Walleye otoliths were read and ages estimated to range from two to nine, with four different age classes represented, suggesting yearly recruitment likely occurs albeit at low levels. Walleye only comprised a small proportion of the overall species composition (0.5%) with the majority of gill net catch being dominated by Yellow Perch *Perca flavescens* (71%) and Utah Sucker (22%). Continued annual monitoring of the Walleye population is necessary to evaluate population expansion and to evaluate predatory effects (i.e. trophic cascade) on the other fish populations, particularly stocked salmonids in Ririe Reservoir. We conducted curtain netting in July and August with 6 net nights of effort to assess the kokanee salmon population. Average kokanee per net night (± 95% CI) was 29.4 ± 50.0. Kokanee ranged in size and age from 121 to 346 mm TL and zero to two, respectively. We examined kokanee otoliths (N = 82) for thermal marks and found 12% and 88% were of natural/wild and hatchery origins, respectively. Power analysis to determine appropriate sampling effort for kokanee monitoring found at least 47 net nights are required to obtain CPUEs that are within 80% confidence limits and ±25% of the population mean. Developing an effective monitoring program for the kokanee population will allow managers to adjust stocking rates when appropriate in effort to produce a quality fishery with adequate catch rates.

Authors:

Jon Flinders
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

INTRODUCTION

Ririe Reservoir is located on Willow Creek, approximately 20 km east of Idaho Falls (Figure 20). Ririe Dam was constructed in 1977, with the reservoir being filled to capacity for the first time in 1978. Ririe Reservoir is fed by approximately 153 km of streams in the Willow Creek drainage, and has a total storage capacity of 100,541 acre-feet. Ririe Reservoir is approximately 17 km long, and is less than 1.5 km wide along the entire length, with a surface area of approximately 1,560 acres and mean depth of 19.5 m. The US Bureau of Reclamation manages Ririe Reservoir primarily for flood control and irrigation storage (USBR 2001).

Ririe Reservoir supports a popular fishery for kokanee salmon, Yellowstone Cutthroat Trout, Smallmouth Bass *Micropterus dolomieu*, and Yellow Perch. Utah Chub and Utah Sucker are also found in Ririe Reservoir in relatively high abundance. In 2013, creel surveys showed angler use was approximately 43,000 hours and has averaged 47,000 hours of angler use over the last 20 years (High et al. 2015). Beginning in 1990, 70,000 juvenile kokanee were stocked annually, with an increase to 210,000 annually in 2004 to improve catch rates and meet increased angler demand. In 2013, juvenile kokanee stockings increased again annually to approximately 300,000 to 400,000. Increasing the kokanee stocking numbers will increase the density of kokanee. However, high densities may also limit growth. Managing for high catch rates of desirable sized kokanee is the management goal. Up until 2012, approximately 18,000 catchable Yellowstone Cutthroat Trout were stocked annually to provide angler opportunity. Following relatively poor performance of those fish, they were replaced by similar numbers of sterile Rainbow Trout. Based on creel results in 2013, anglers caught an estimated 14,128 of the 18,000 (78%) Rainbow Trout stocked (High et al. 2015). The high angler use of Rainbow Trout observed in 2013 suggests that hatchery Rainbow Trout are providing a diverse angling opportunity as well as meeting angler expectations. A Yellow Perch fishery also exists in Ririe Reservoir and has become more popular over the past several years as spring reservoir levels have remained high with a resultant increase in condition and size of perch (Schoby et al. 2010). A self-sustaining population of Smallmouth Bass has developed from introductions into Ririe Reservoir from 1984-1986. Although limited by the short growing season at this latitude and altitude, Smallmouth Bass provide a diverse and popular angling opportunity for fishermen in the Upper Snake Region.

Walleye were first documented in Ririe Reservoir in 2008 (Schoby et al. 2010), which prompted further investigations by IDFG fisheries personnel. Gill netting effort increased in 2008, followed by a walleye telemetry study in 2009 and 2010 (Schoby et al. 2014). Fall Walleye index netting (FWIN, Morgan 2002) was initiated in 2010 as an annual monitoring tool to document trends in the Walleye population in Ririe Reservoir. No Walleye were captured in 18 gill net nights of effort during 2010, and only small numbers of Walleye are encountered in annual netting to date. Low catch rates suggest a low abundance population, but the potential for population expansion exists. The impact Walleye may have on the existing fishery is unknown. Managing an apex predator such as Walleye can be difficult because they have the potential to alter fish communities (Knight and Vondracek 1993). In Lake Roosevelt, Washington predation by introduced Walleye accounted for a 31-39% loss of stocked kokanee (Baldwin and Polacek 2002). There are also concerns that the Walleye in Ririe Reservoir may provide a source population for future illegal introductions in the surrounding waters (McMahon and Bennett 1996) and the possibility exists for them to spread downstream of the reservoir. In Washington, personnel with the Department of Fish and Wildlife have cited irrigation canals as the mechanism for Walleye expansion from Banks Lake throughout the Columbia River basin. Additionally, in a study conducted to assess the potential for Walleye introductions in Idaho (IDFG 1982), Ririe Reservoir was identified as having the biological suitability to sustain a healthy Walleye population, but conflicts with maintaining the existing trout fishery were cited as the main reason for not introducing Walleye into Ririe Reservoir.

OBJECTIVES

1. Use annual fall gill netting to describe population characteristics of Walleye in Ririe Reservoir as a long-term monitoring tool and to monitor changes in abundances of other species in the presence of a new apex predator.

2. Monitor kokanee populations in Ririe Reservoir in an effort to develop appropriate stocking rates that balance angler catch rates with a desirable fish size.

METHODS

The fall of 2014 marked the fifth year of FWIN to monitor trends in the Walleye population in Ririe Reservoir. From October 27-29, we set six gill nets per night, for a total of 18 gill net nights of effort. Netting effort was based on FWIN protocol recommendations for water body size (Morgan 2002). Gill nets were 61 m long x 1.8 m deep, and consist of eight panels (7.6 m long) containing 25 mm, 38 mm, 51 mm, 64 mm, 76 mm, 102 mm, 127 mm, and 152 mm stretched mesh. The reservoir was divided into three strata (Upper, Middle. Lower), with six nets set at previously established sites in each stratum (Figure 21). FWIN protocol recommends stratifying net sets between two depth strata (shallow: 2-5 m; deep: 5-15 m). Steep shoreline topography limits the amount of shallow water habitat in Ririe Reservoir; therefore we set a combination of floating and sinking gill nets over a variety of depths (Appendix C).

We identified all fish collected with gill nets to species and recorded total length (mm) and weight (g). Additionally, we recorded sex and maturity of all Walleye captured, and collected otoliths and stomach samples for aging and diet analysis. We calculated proportional stock density (PSD) and relative stock density of preferred sized fish (RSD-P) for all game fish (Anderson and Neumann 1996).

We targeted the kokanee population from July 29 – August 11 using experimental curtain nets with a neutrally buoyant design suspended at the thermocline. Experimental curtain nets measured 37 m long by 6 m deep with 12 panels that were 3 m in length with two panels for each mesh size randomly positioned throughout the length of the net. The mesh sizes of the panel were 25, 38, 51, 64, 76, and 102 mm bar mesh monofilament. We excluded smaller meshes (13 and 19 mm) typically found in statewide standardized kokanee nets in an effort to minimize capture of Yellow Perch, which have been found in high abundance in recent years. We set nets at dusk and retrieved them the following morning. Sites were randomly selected by overlaying a grid system (100 X 100 m) in mapping software (IDFG staff 2012). For site selection, Ririe Reservoir was stratified into three strata (Upper, Middle, Lower). The nets were set in depth range of 9 to 15 m to ensure adequate coverage in the thermocline. All fish captured were identified, measured for total length to the nearest millimeter, and weighed to the nearest gram. We calculated CPUE of for each species as fish per net night.

We estimated the number of sites required to monitor kokanee CPUE within certain bounds (e.g. 80% confidence limits, ±25% of the mean) based on Willis (1998):

$$n = \frac{(t^2)(s^2)}{[(a)(x)]^2}$$

Where n = sample size required, t = t value from t-table, s^2 = variance, x = mean CPUE, a = precision in describing the mean as a proportion.

We also examined length-at-maturity for kokanee. For females, each ovary was assigned a maturity stage of either immature (small, translucent) or mature (large, orange, opaque). Logistic regression was used to fit sigmoid curves to the proportion mature by length in the form, $p_{x1} = e^{(b_0+b_1+x_1)}/(1+e^{(b_0+b_1+x_1)})$ where, p is the probability that a fish is mature in a given length (mm) interval x_1, and b_0 and b_1 are parameters that define the shape and location of the fitted sigmoid curve. The predicated length of 50% maturity was calculated as, $L_{50} = -b_0/b_1$.

We removed the sagittal otoliths from kokanee collected from curtain netting for age and growth analysis. We also evaluated success of the kokanee stocking program via otolith thermal mass-marking (Volk et al. 1990). Prior to stocking, kokanee were reared at Cabinet Gorge Hatchery where all kokanee fry received a thermally induced otolith pattern at the swim-up stage of development. Differential temperature was approximately 5°C. We examined otolith growth rings for distinctive thermal bands for each year class. After removal, all otoliths were cleaned on a paper towel and stored in individually-labeled envelopes. We sectioned, polished, and read otoliths in cross-section view with transmitted light when the annuli were not distinct in whole view. The von Bertalanffy (1938) growth model was used to fit length:

$$l_t = L_\infty(1 - e^{-K(t-t_0)})$$

where l_t is length at time t, L_∞ is the asymptotic length, K is a growth coefficient, and t_0 is a time coefficient at which length would theoretically be 0. The model was fitted to length-at-date by using the nonlinear model (NLIN) procedure in program R.

RESULTS

FWIN

We collected 2,396 fish in 21 FWIN net nights of effort in Ririe Reservoir, including 13 Walleye. Mean gill net catch (± 90% CI) in 2015 was dominated by Yellow Perch (70.5% ±7.8) and non-game fish, mainly Utah Sucker (22.4 ± 8.4) and Utah Chub (4.5% ±2.4). Walleye only comprised 0.5% ± 0.4) of the relative abundance of our gill net catch. Walleye catch per net night (± 95% CI) was 0.7 ± 0.5 (Figure 22), which was similar to low number of Walleye per net night from 2010-2014 (0.4 per net night). Walleye ranged in length from 203 to 720 mm with a mean TL (± 95% CI) of 361 mm ± 106.6 (Figure 23, Table 12). Relative weights of Walleye ranged from 73 to 109 with a mean of 93 ± 6.1 (Figure 24). Walleye PSD and RSD-P were 83 and 50. Aged Walleye grew from a starting age of t_0 = -0.289 years (95% CI -0.64 to -0.06) toward their asymptotic length of L_∞ = 731 mm (95% CI 698-764) at an instantaneous rate of growth (K) = 0.46/year (95% CI 0.36-0.57) and their length-at-age in 2015 was higher than the North American average developed by Quist (2003) (Figure 25).

We analyzed diet of all Walleye captured; 6 stomachs were empty, 5 stomachs contained unknown fish, 1 stomach contained Yellow Perch (TL = 51 mm) and the last stomach sample contained a partially digested crayfish. Total weight of stomach contents ranged from 0 g to 17.1 g (mean: 1.9 g; 95% CI 2.8). We captured 94 Yellow Perch per net night (n = 1,690) that ranged from 81 mm to 293 mm with a mean TL (± 95% CI) of 208 mm ± 1.0 in FWIN nets (Figure 26). Yellow Perch PSD was 73, while mean relative weights (± 95% CI) were 83 ± 1.4 (Figure 27). Mean CPUE (± 95% CI) of kokanee was 1.5 ± 0.9 fish per net night, ranging in TL from 162 mm to 346 mm with a mean TL of 263 mm ± 16.5. Kokanee PSD and RSD-P values were 82 and 7, respectively. Kokanee mean relative weights were 84 ±3.0. We only captured one Yellowstone Cutthroat Trout (TL = 362 mm) which represents 0.1 Yellowstone Cutthroat Trout per net night. We captured 0.6 Smallmouth Bass per net night. Smallmouth Bass were 145 mm and 358 mm in length. Smallmouth Bass mean relative weight was 90 ± 7.9. We captured 0.6 ± 0.7 Rainbow Trout per net night that ranged from 280 mm to 374 mm with a mean TL of 328 ± 16.8 mm. Mean relative weights for Rainbow Trout were low at 78 ± 4.6.

Curtain Netting

We collected 147 Kokanee, 16 Yellow Perch, 8 Rainbow Trout, 1 Utah Chub, 44 Utah Sucker, and 16 Yellowstone Cutthroat Trout from five curtain nets deployed at the thermocline in July and August. We set one curtain net at the surface to ensure that we were targeting kokaneein the thermocline. The net at the surface only contained one kokanee. Thus, we excluded the net in the estimating mean fish per net night due to its ineffectiveness in targeting kokanee. Kokanee captured per net night (± 95% CI) in curtain nets was 29.4 ± 50 (Figure 28). Kokanee ranged in size from 121 to 412 mm with a mean of 275 ± 15.0 mm (Figure 29) and their mean relative weight was 87 ± 1.1 and ranged from 70 to 103 and exhibited no increase in condition with size (R^2 = 0.08; Figure 30). Fish captured per net night (± 95% CI) in curtain nets varied drastically for the remaining species and was 1.2 ±1.0 for Rainbow Trout, 0.2 ±0.6 for Utah Chub, 7.2 ± 9.6 for Utah Sucker, 3.2 ± 8.2 for Yellowstone Cutthroat Trout, and 84 ± 77.7 for Yellow Perch. Based on power analysis from 2015 with five curtain nets, at least 47 net nights are required to obtain kokanee CPUEs that are within 80% confidence limits and ±25% of the population mean.

We examined 82 otoliths for thermal marks of which 12% were of natural/wild origin and the remaining 88% were of hatchery origin. We used the distinct thermal marks to assign the fish to age class (i.e. aged kokanee). We aged 72 kokanee otoliths of hatchery origin and had ages that ranged from 0 to 2 years between the lengths of 140 to 408 TL mm (Figure 31). Mean length at age (± 95% CI) was 142 ± 2 mm for age-0, 301 ± 7 mm for age-1, and 388 ± 81 mm for age-2. We examined 72 kokanee for maturity analysis, which ranged in size from 140 to 408 mm. Of the 72 fish, 5 were unknown sexes due to immature stage of their ovaries or testes. We examined 19 females of which 3 were mature and 16 were immature based on inspection of the ovaries. For males we examined 48, of which 9 were immature and 39 were mature based on the testes. The logistic regression curve (Female maturity proportion = $1 + e^{(-(-40.23 + 0.132 \times TL))}$) found that female kokanee were 1% mature (L_1) at approximately 270 mm TL and 50% mature (L_{50}) at approximately 306 mm TL and would be approximately age-1 (Figure 32). For male kokanee the logistic regression curve (Male maturity proportion = $1 + e^{(-(-36.09 + 0.127 \times TL))}$) found that 1% mature ($L_1$) at approximately 248 mm TL, which would be between age-0 and age-1, and 50% mature (L_{50}) at approximately 285 mm TL.

DISCUSSION

Similar to years past (2010-2014), Walleye continue to comprise only a small proportion of the overall species composition (<1.0%) in the gill net catch, and are a minor portion of the fishery in Ririe Reservoir. Walleye gill net catch per unit effort was similar to the average number of Walleye per net night from 2010-2014 (0.4 per net night). Low and stable catch rates suggest the Walleye population is persisting at low abundance levels, and that the population is not rapidly expanding. Over half of the Walleye collected in 2015 were age-0 suggesting decent recruitment for this age class. Fry survival may have been due to better spring spawning conditions in 2015. A telemetry study conducted in 2009-2010 found that the majority of Walleye spawning activity likely occurred within the lower 2 km of Willow Creek between mid-April and mid-May (Schoby et al. 2014). Population expansion of Walleye may be limited by adequate availability of spawning habitat in some years or perhaps other abiotic and biotic factors. The high growth rates of Walleye compared to North American average estimated by Quist et al. (2003) along with the good relative weights (mean 93; 95% CI 6.1), indicates a readily available prey base exists for Walleye. Currently we stock kokanee and Rainbow Trout annually into Ririe Reservoir. If the Walleye population expands, this may result in losses of valuable stocked salmonids with such a top predator (Lepak et al. 2014). The salmonid fishery is an important component in Ririe Reservoir with angler catch rates for salmonids comprising 49% of the total catch in creel surveys from 2013 (High et al. 2015). Additional predation and consequent reduction in salmonid abundances has the potential to impact angler catch rates and success. Stocking larger catchable salmonids in reservoirs with top predators has been shown to be more effective in reducing predation (Flinders and Bonar 2008), but places additional financial and spatial demands on the limited resources available at IDFG hatcheries. Currently, Rainbow Trout are stocked as catchables and kokanee as fingerlings. Limited hatchery capacities and associated higher feed costs in producing catchable kokanee instead of fingerlings make this highly unrealistic as a stocking strategy. It is more likely that if Walleye populations expand drastically, and they continue to prey on salmonids, stocking of these salmonids may become impractical. Continued yearly monitoring of the Walleye population is necessary to determine factors that drive Walleye populations, and to monitor impacts to valuable sportfish populations.

Curtain nets suspended near the thermocline were found to be an effective method for sampling the kokanee population in Ririe Reservoir. Kokanee comprised 22% of the species composition in the curtain nets, whereas kokanee only comprised 1% of the species composition in the more traditional approach of gillnets that were used for FWIN. Kokanee are a pelagic species and targeting their known summer habitat (thermocline) should provide more reliable abundance estimates. Also, curtain netting in Ririe Reservoir minimized the number of non-target species (e.g. Yellow Perch, Utah Chub, Utah Sucker, etc.) and reduced net processing time. A few of the curtain nets may have been placed a little higher or lower than the thermocline resulting in lower catch rates. In the future ensuring proper placement of the nets near the thermocline should reduce the variance associated with the catch rates and reduce the number of nets in an effort to increase precision around the abundance estimates.

RECOMMENDATIONS

1. Continue annual gill net monitoring (FWIN) to continue monitoring abundance, growth, mortality, reproduction, and foraging behavior of Walleye.

2. Collect biological information on all fish (including non-game species) captured during FWIN monitoring to determine impacts from Walleye establishment.

3. Evaluate stocking rates of kokanee to provide maximum benefits to anglers.

4. Continue stocking sterile Rainbow Trout to meet angler expectations.

5. Implementing standardized sampling protocols for monitoring kokanee population trends over time.

Table 12. Summary statistics for Walleye captured during 2015 FWIN in Ririe Reservoir.

Date	Net type	Net (#)	FL (mm)	TL (mm)	Weight (g)	Sex	Maturity	Age	Visceral fat (g)	Gonad (g)
October 27	Sinking	17	452	475	1,164	F	Mature	2	57.79	63.6
October 27	Sinking	17	546	577	2,206	F	Mature	3	101.94	142.83
October 27	Floating	18	522	555	1,901	F	Mature	N/A[b]	113.17	109.03
October 28	Sinking	12	168	203	56	UNK[a]	Immature	0	0.13	0
October 28	Floating	8	193	230	98	UNK	Immature	0	0.73	0
October 28	Sinking	9	186	222	99	UNK	Immature	0	0.95	0
October 28	Sinking	12	194	234	103	UNK	Immature	0	0.58	0
October 28	Sinking	9	182	219	88	UNK	Immature	0	0.47	0
October 28	Sinking	12	194	233	98	UNK	Immature	0	0.37	0
October 29	Sinking	4	183	219	91	UNK	Immature	0	0.46	0
October 29	Sinking	4	279	330	391	M	Immature	1	15.59	0
October 29	Floating	2	394	471	963	M	Mature	2	35.08	31.12
October 29	Floating	3	623	720	4,242	F	Mature	9	177.78	373

[a] UNK: Unknown sex
[b] N/A: Otoliths were broken and unreadable

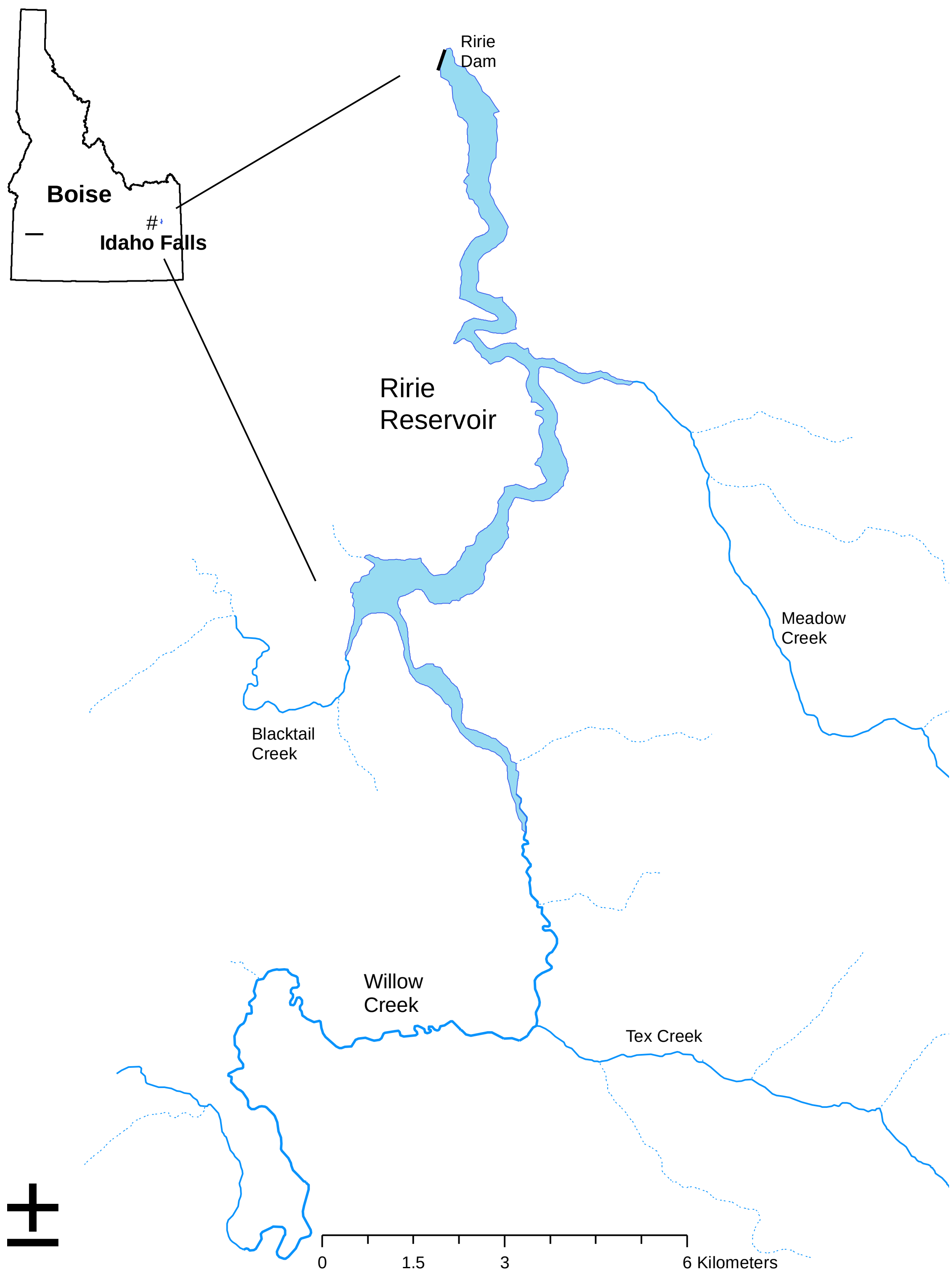

Figure 20. Location of Ririe Reservoir and major tributaries.

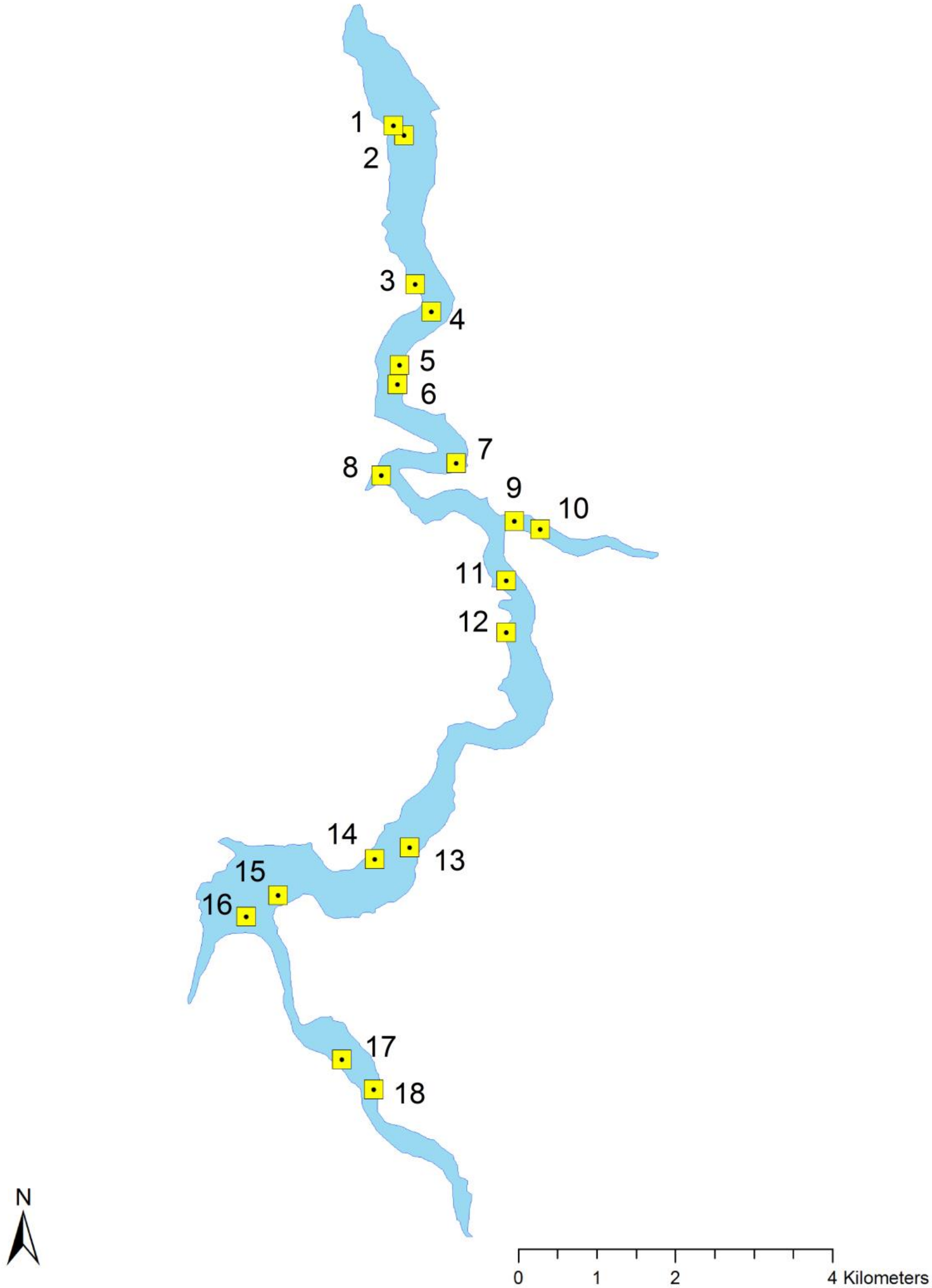

Figure 21. Location of 2015 fall Walleye index netting (FWIN) in Ririe Reservoir.

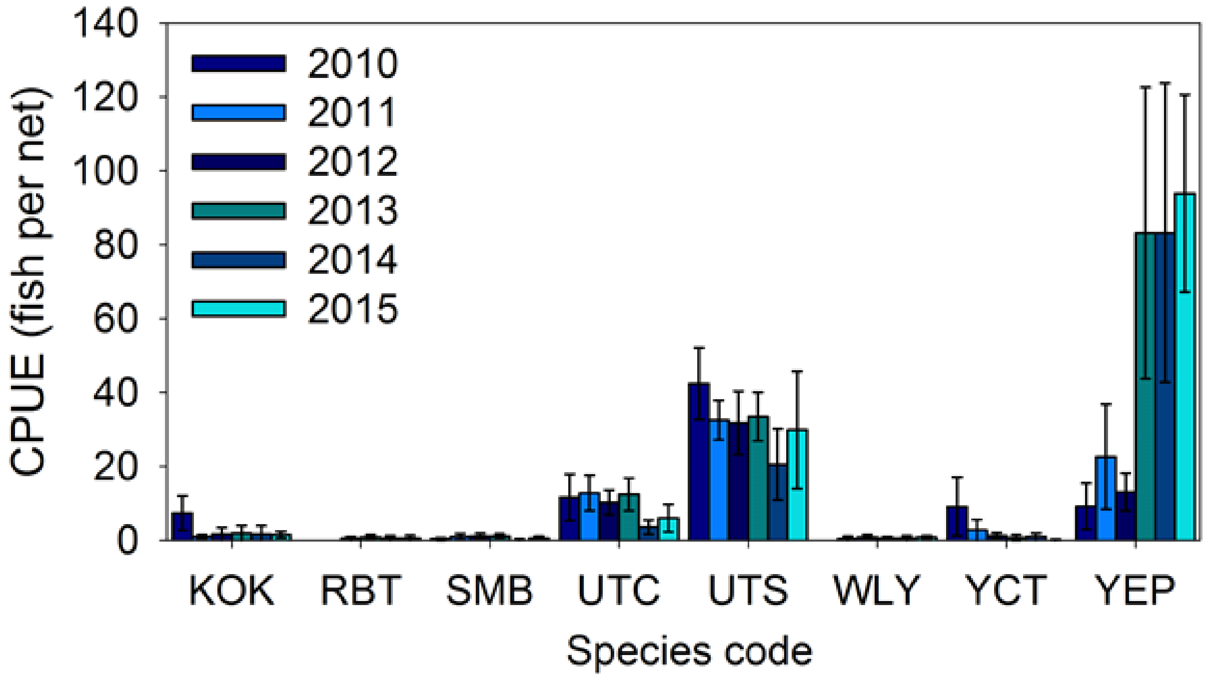

Figure 22. Catch per unit effort (fish per net night), for 18 net nights of FWIN in Ririe Reservoir, during 2010-2015. Error bars represent 95% confidence intervals.

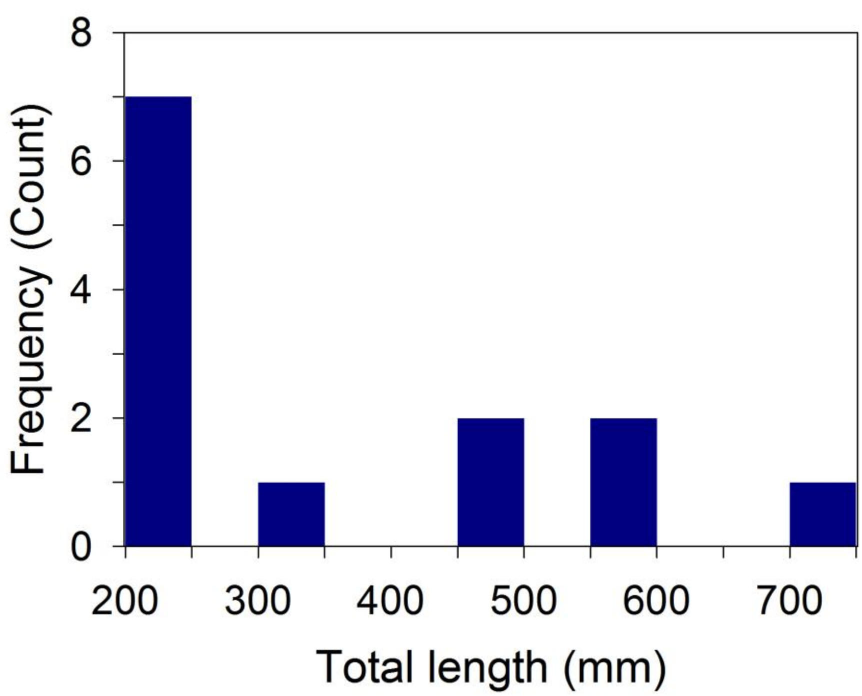

Figure 23. Frequency by count by length group of Walleye captured in gill nets during 2015 FWIN in Ririe Reservoir.

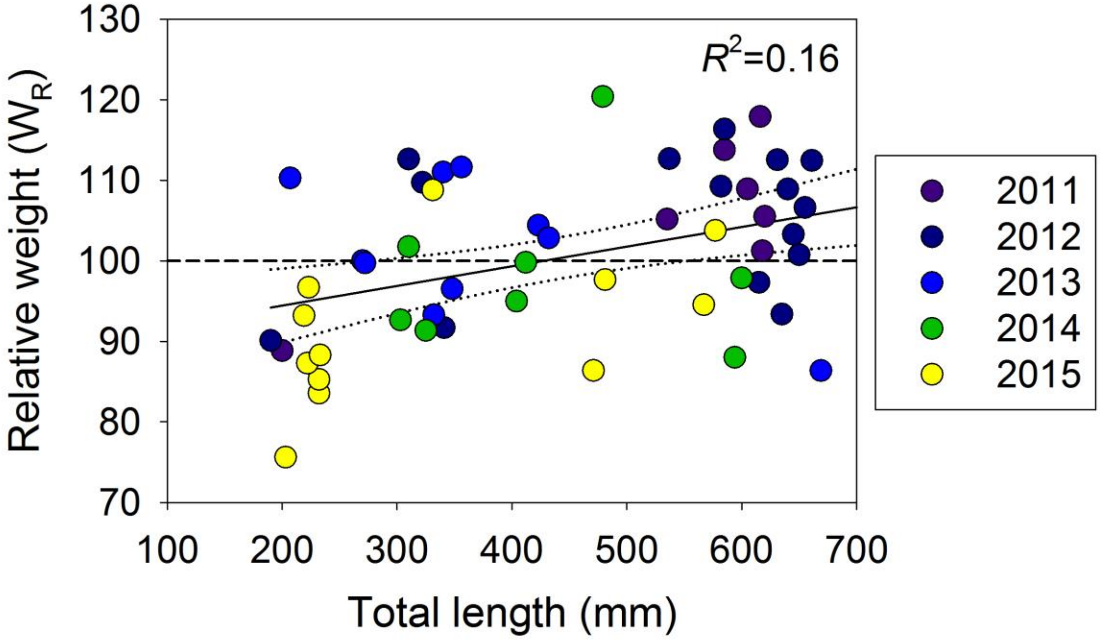

Figure 24. Relative weight of Walleye in Ririe Reservoir by total length collected in gill nets from FWIN surveys by year. Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively.

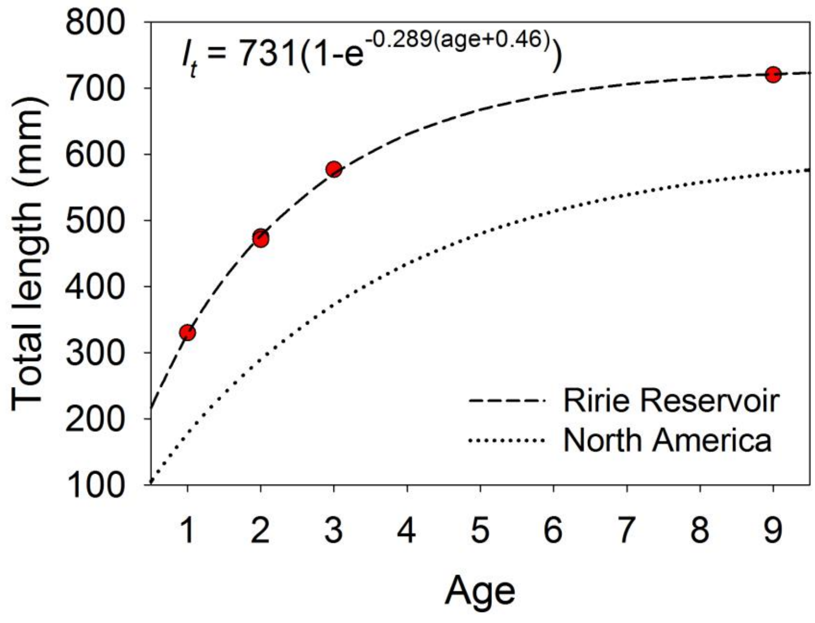

Figure 25. Walleye length-at-age based on non-linear regression captured from FWIN in Ririe Reservoir, 2014. Walleye growth in Ririe Reservoir represents the fitted von Bertalanffy growth model (dashed line) compared to the North America average of both male and female Walleye ($l_t = 610(1\text{-}e^{-0.300(age+0.148)})$) developed in Quist et al. (2003).

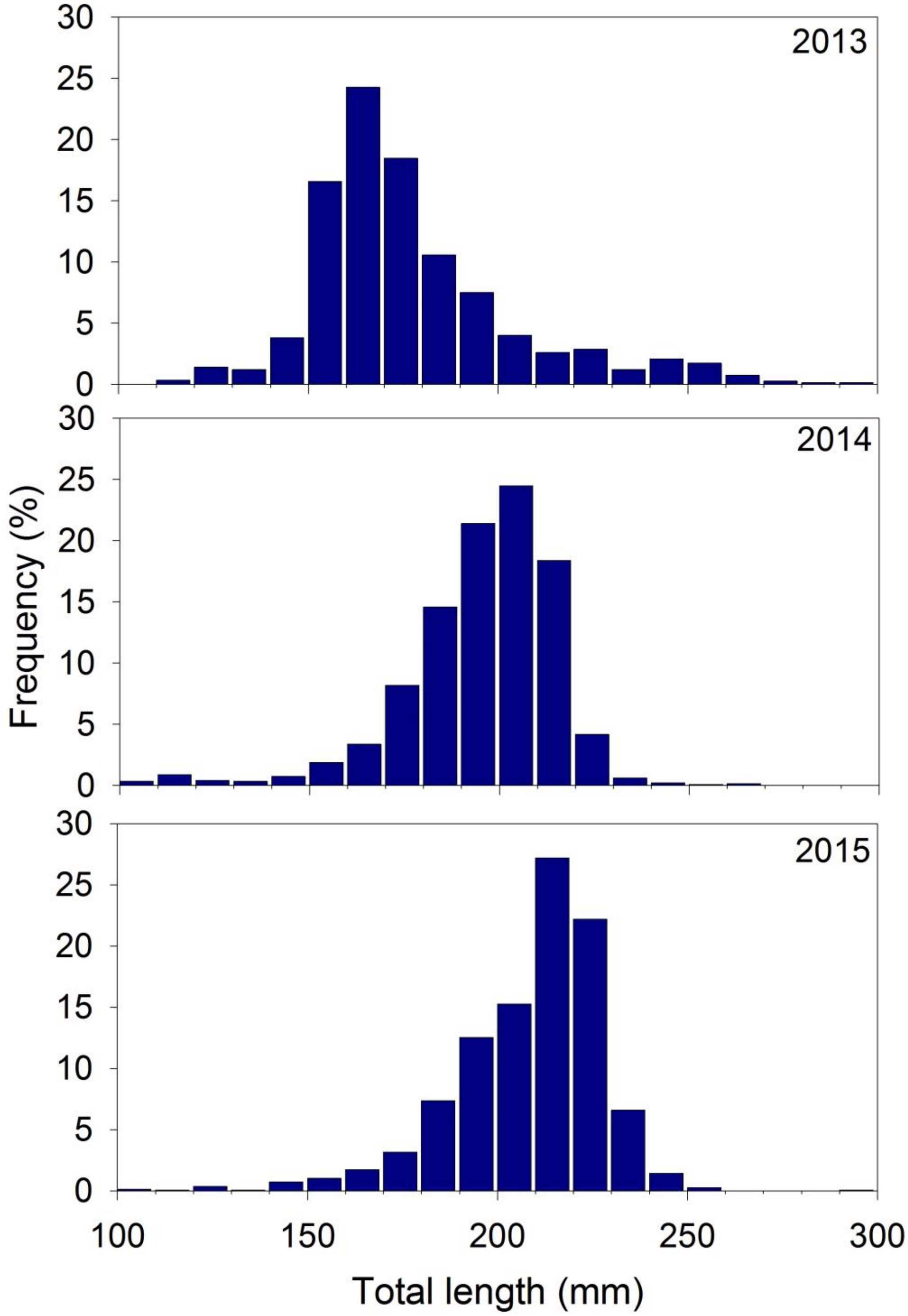

Figure 26. Length frequency of Yellow Perch captured during 2013-2015 FWIN in Ririe Reservoir.

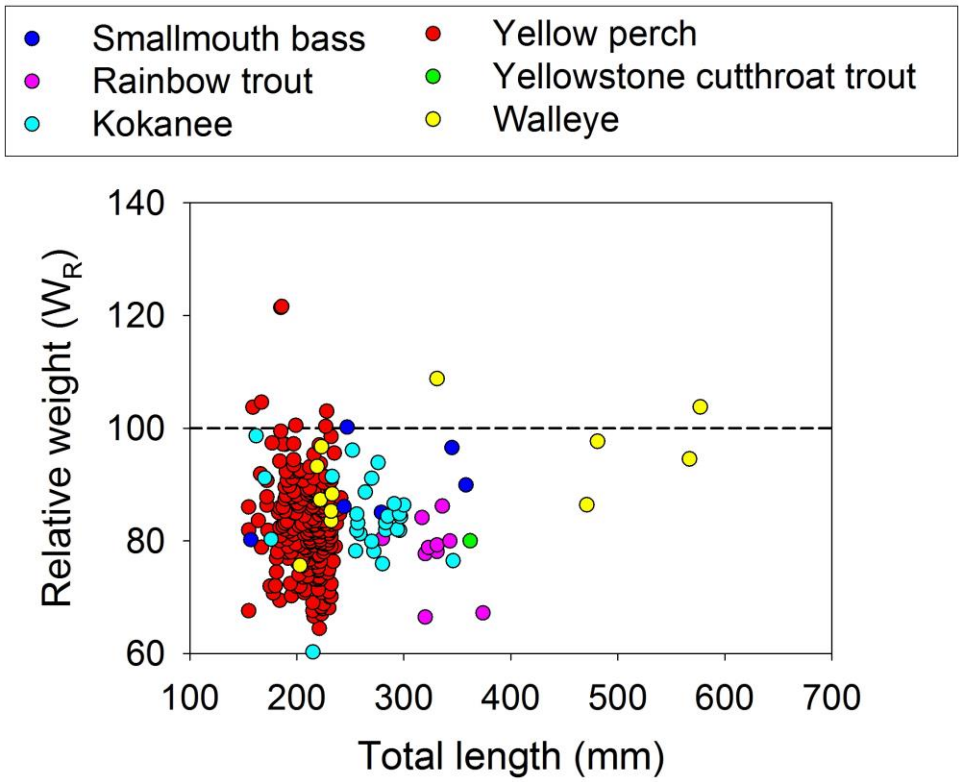

Figure 27. Relative weights by total length of kokanee, Rainbow Trout, Smallmouth Bass, Walleye, Yellowstone Cutthroat Trout, and Yellow Perch collected in gill nets from FWIN surveys, 2015.

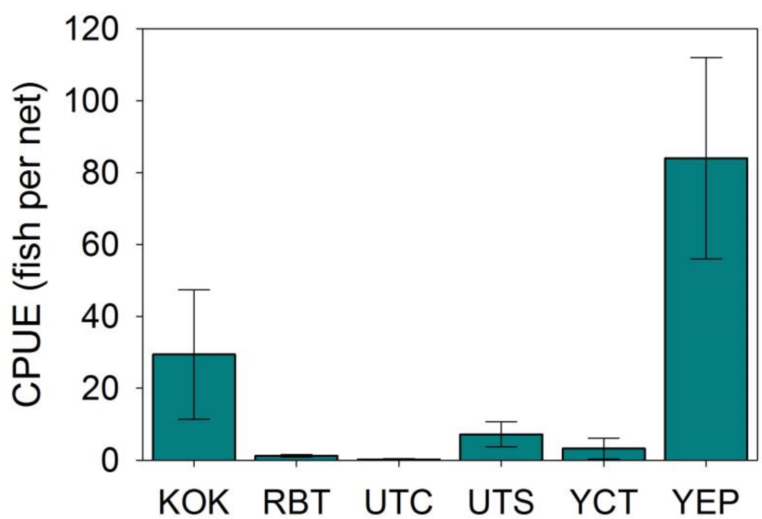

Figure 28. Catch per unit effort (fish per net) from five net nights of curtain netting in Ririe Reservoir during 2015. Error bars represent standard error.

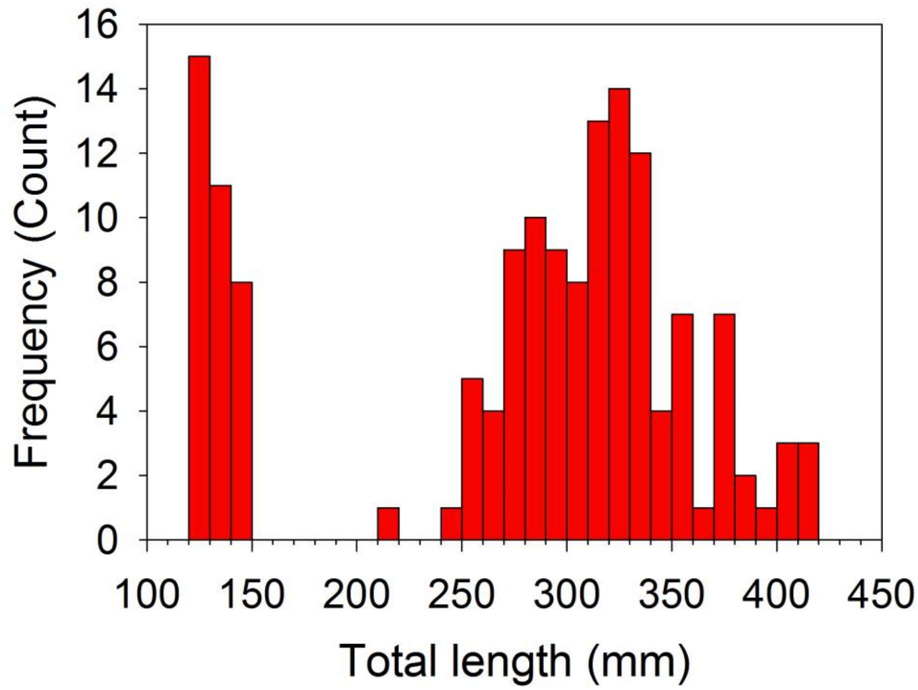

Figure 29. Length frequency by count of kokanee captured in curtain nets in Ririe Reservoir during the summer of 2015.

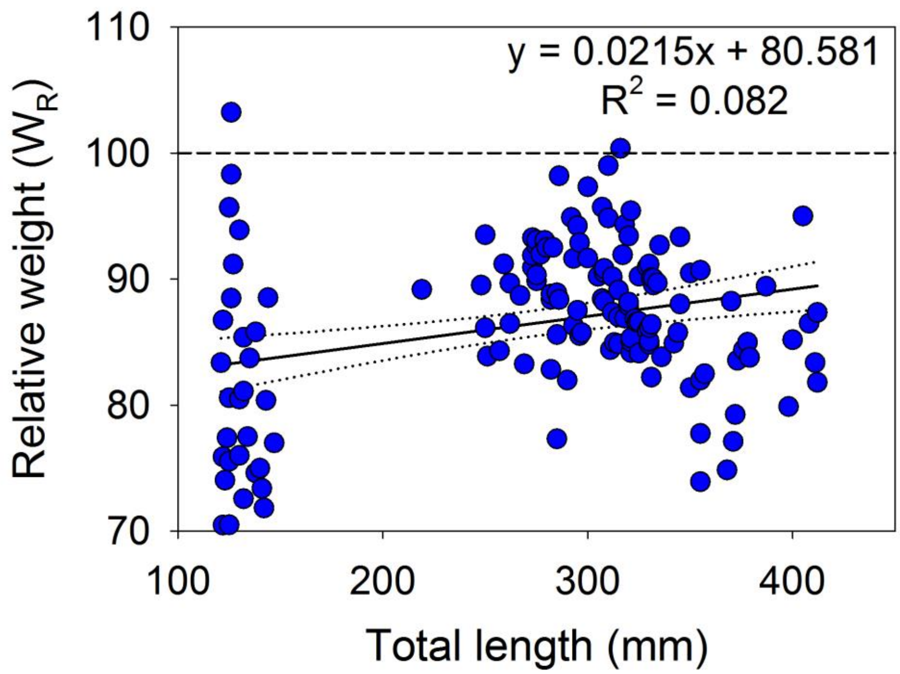

Figure 30. Kokanee relative weights (W_R) by total length from summer curtain netting surveys in Ririe Reservoir, 2015. Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively. Dashed line represents mean W_R of 100, which are based on 75th percentile of weight at a given length.

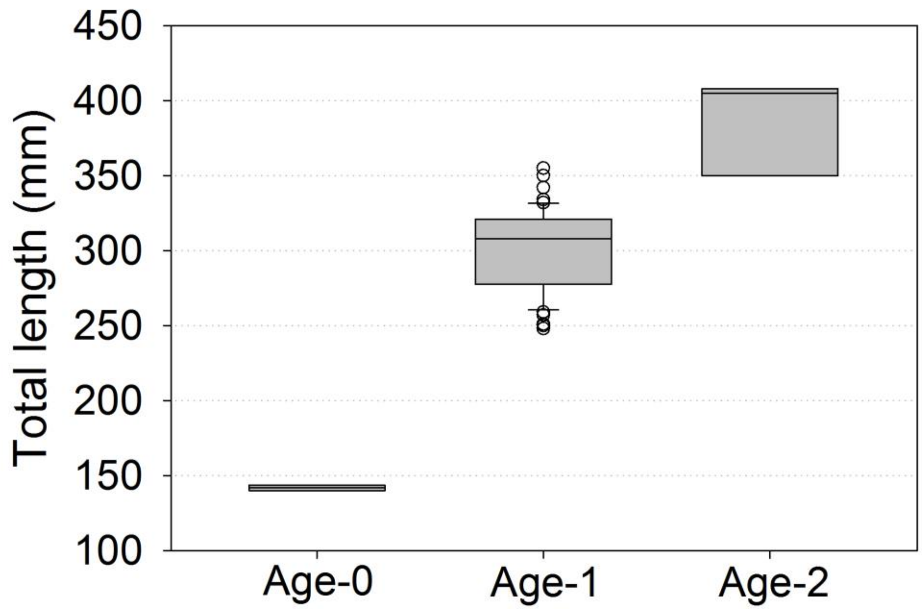

Figure 31. Boxplot of kokanee total length (mm) by age in Ririe Reservoir during 2015. The box is the interquartile range. The whiskers are the high and low values excluding outliers. The line across the box is the median.

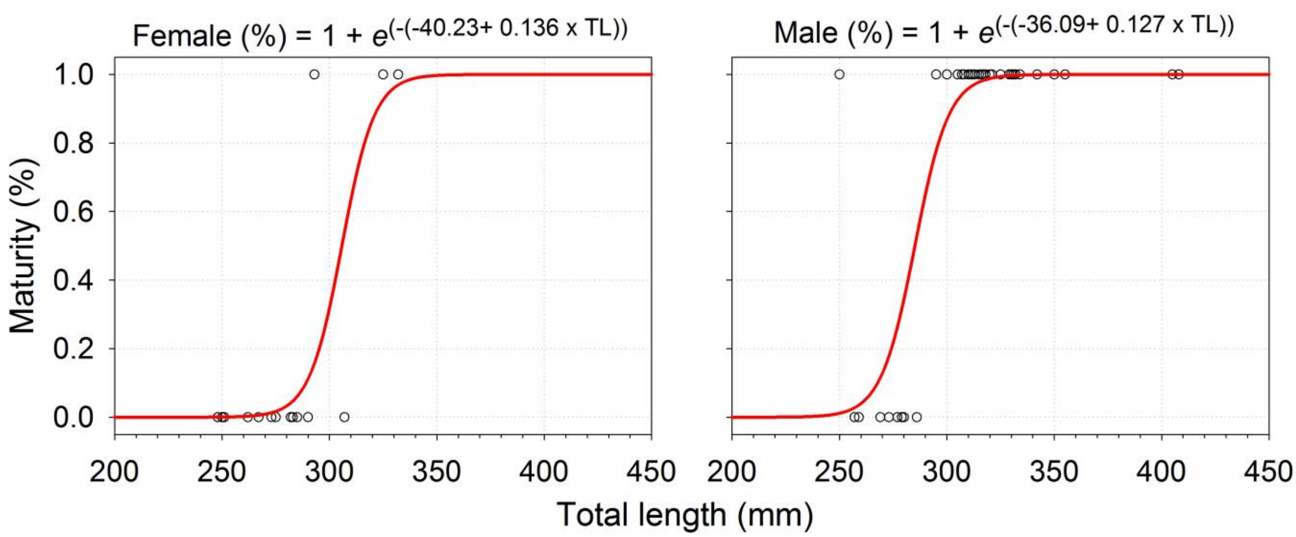

Figure 32. Proportion mature (1 = mature, 0 = immature) by total length with a fitted logistic regression curve of female and male kokanee collected in curtain nets at Ririe Reservoir in the summer of 2015.

HENRYS FORK

ABSTRACT

We used boat mounted electrofishing equipment to assess fish populations in the Box Canyon, Vernon, and Chester reaches of the Henrys Fork Snake River during 2015. In Box Canyon, Rainbow Trout densities (± 95% CI) were 1,681 ± 343 fish per km , which were near densities observed in 2014 (1,575 ± 91 fish per km), and slightly lower (13%) than the 21 year average of 1,926 trout per km. The effects of winter flows on Rainbow Trout first-winter survival continue to be significantly related to year class strength two years later. Age-2 trout abundances were predicted by the flow model to be 2,220, and we estimated abundances at 1,257 based on mark-recapture. Factors in addition to winter flows likely influenced the lower than expected age-2 trout in the population. We observed a strong year class of age-1 Rainbow Trout recruiting into the population in 2015 which should contribute significantly to the fishery in 2016 as age-2s. The large percentage of larger rainbow trout (>350 mm) currently in the Box Canyon reach should provide excellent angling opportunities for larger fish in 2015. In the Vernon reach, we estimated 433 ± 146 trout per km with a species composition of 27% Brown Trout and 71% Rainbow Trout in our spring survey. Trout densities in the Vernon Reach decreased slightly (12%) when compared to the average density of 615 ± 140 trout per km (2005-2012). We estimated 962 ± 159 trout per km in our spring survey in the Chester reach. Species composition was 32% Brown Trout and 68% Rainbow Trout. Trout densities increased in the Chester reach 78% in 2015 when compared to the average density of 538 ± 95 trout per km from previous surveys from 2003 to 2012. We continued to observe a slight shift in species composition in the HFSR downstream reaches below Mesa Falls, with Brown Trout increasing in species composition 2.4% and 1.9% per year in the Vernon and Chester reaches, respectively, since the early 2000s. Similar to past evaluations we found a significant proportion of the population was comprised of larger trout (>500 mm) in the Vernon reach and to a lesser extent in the Chester reach suggesting anglers should encounter large fish through the coming year.

Authors:

Jon Flinders
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

INTRODUCTION

The Henrys Fork Snake River is a popular fishery that attracts anglers from throughout the nation and across the globe. An economic survey conducted in 2003 showed that Fremont County, which encompasses a large portion of the Henrys Fork drainage, ranked first out of the 44 counties in Idaho in terms of angler spending, and generated nearly $51 million for the local economy (Grunder et al. 2008). Similarly, an IDFG economic survey in 2011 estimated that anglers fished 165,236 days in Fremont County and spent nearly $62 million during angling trips (IDFG, unpublished data).

The Henrys Fork Snake River forms at the confluence of Big Springs Creek and the Henrys Lake Outlet, and flows approximately 25 km before reaching Island Park Dam. Below Island Park Dam, the Henrys Fork flows 147 km and through two dams and four irrigation check structures before joining the South Fork Snake River to form the Snake River. The Henrys Fork above Island Park Reservoir provides a family fishery primarily supported by stocked trout. The fishery is also supported by trout that move out of Henrys Lake or Island Park Reservoir. Management of the Henrys Fork downstream of Island Park Dam emphasizes wild, natural populations without hatchery supplementation. The Henrys Fork below Island Park Dam, particularly the Box Canyon, Harriman Ranch, and Pinehaven reaches, support world famous wild Rainbow Trout fisheries. Downstream of the Harriman Ranch, the Henrys Fork flows over Mesa Falls and is joined by the Warm River, before it is impounded by Ashton Dam. Brown Trout are present in the Henrys Fork downstream of Mesa Falls, and increase in numbers in downstream reaches, eventually dominating the species composition (>80%) in and around the town of St. Anthony and below.

Previous research has emphasized the importance of winter river flows to the survival of age-0 Rainbow Trout in the Box Canyon reach (Garren et al. 2006a, Mitro 1999). Higher winter flows in this reach result in significantly higher overwinter survival of juvenile trout and subsequent recruitment to the fishery below Island Park Reservoir. Implementation of a congressionally-mandated Drought Management Plan has improved communications among interested parties and planning regarding winter discharges. We will continue to work cooperatively with stakeholders to maximize wild trout survival, based on timing and magnitude of winter releases from Island Park Dam.

STUDY SITE

During 2015, we sampled the Box Canyon, Chester, and Vernon reaches of the Henrys Fork Snake River (Figure 33). The Box Canyon reach is sampled on an annual basis as part of our long-term monitoring program for the Henrys Fork Snake River. The Box Canyon reach started below Island Park Dam at the confluence with the Buffalo River and extended downstream 3.7 km to the bottom of a large pool. The Vernon reach started at the Vernon boat ramp and continued downstream 4.4 km to the Chester backwaters. The Chester reach started just below Chester Dam and extended downstream 5.7 km to the backwaters above the Fun Farm Bridge. Coordinates for all mark-recapture transect boundaries are presented in Appendix D.

OBJECTIVES

To obtain current information on fish population characteristics for fishery management decisions on the Henrys Fork Snake River, and to develop appropriate management recommendations.

METHODS

During 2015, we sampled all survey reaches using three electrofishing rafts. In the Box Canyon reach, we marked fish on May 11 and 12, and recaptured fish on May 18. Two passes per boat were made on each marking and recapture day for a total of 6 passes per day for both marking and recaptures. In the Vernon reach, we marked fish on May 6, and recaptured fish on May 14. In the Chester reach, fish were marked on May 7 and recaptured on May 15. Two passes per boat were made on each marking and recapture day in Vernon and Chester. All trout collected during mark-recapture surveys were identified to species and measured for total length (TL, mm). Those exceeding 150 mm were marked with a hole punch in the caudal fin prior to release.

In all reaches, we estimated densities for all trout >150 mm using the Log-likelihood method in Fisheries Analysis+ software (FA+; Montana Fish, Wildlife, and Parks 2004). Proportional stock densities (PSD) were calculated as the number of individuals (by species) ≥300 mm / by the number ≥200 mm. Similarly, relative stock densities (RSD-400) used the same formula, with the numerator replaced by the number of fish > 400 mm (Anderson and Neumann 1996).

We removed the sagittal otoliths from a subsample of Rainbow Trout collected for age structure analysis. Otoliths were cleaned on a paper towel and stored in individually-labeled envelopes. Ages were estimated by counting annuli under a microscope. Otoliths were submerged in water and read in whole view when clear, distinct growth rings were present. We sectioned, polished, and read otoliths in cross-section view with transmitted light when the annuli were not distinct in whole view. The von Bertalanffy (1938) growth model was used to fit length:

$$l_t = L_\infty(1 - e^{-K(t-t_0)})$$

where l_t is length at time t, L_∞ is the asymptotic length, K is a growth coefficient, and t_0 is a time coefficient at which length would theoretically be 0. The model was fitted to length-at-age data by using the nonlinear model (NLIN) procedure in program R.

We also evaluated year class strength in Box Canyon using linear regression to examine the relationship between age-2 Rainbow Trout abundance and mean winter (Dec 1 – Feb 28) stream flow (cubic feet per second [cfs]) as described by Garren et al (2006a). We log-transformed age-2 Rainbow Trout abundance and mean winter flow data from the past 15 surveys to establish the following relationship:

$$\log_{10} \text{ age-2 Rainbow Trout abundance} = 0.0.6601 \log_{10} \text{ winter stream flow} + 1.8002$$

Using this equation we predicted the expected abundance of age-2 Rainbow Trout in our 2015 sampling based on mean winter stream flows observed during 2014 (December 2013 - February 2014). To validate this relationship, we determined age-2 Rainbow Trout abundance during the 2015 electrofishing surveys by estimating the number of fish between 230 and 329 mm, which corresponds to the length distribution of age-2 trout in past surveys. Age-2 Rainbow Trout were determined to be the first year class fully recruited to the electrofishing gear (Garren 2006a). We then compared predicted and observed age-2 Rainbow Trout abundance in Box Canyon to evaluate the equation above in predicting year class strength based on winter flow. Data from 2014 was added to the flow vs. age-2 abundance regression model and this model will continue to be used in management of winter flow releases from Island Park Dam.

RESULTS

Box Canyon

We collected 1,219 trout during two days of electrofishing in Box Canyon. Confidence intervals shown in parenthesis are 95% intervals unless otherwise specified. Species composition of trout collected was 99% Rainbow Trout and 1% Brook Trout. Rainbow Trout ranged in size from 90 mm to 509 mm, with a mean and median total length of 296 ± 6 mm and 346 mm, respectively (Figure 34; Appendix E). Rainbow Trout PSD and RSD-400 were 83 and 25, respectively (Table 13). We used the Log-likelihood Method (LLM) to estimate Rainbow Trout >150 mm (± 95% CI) in the reach to be 6,220 ± 1,270 (Table 14, Appendix F), which equates to 1,681 fish per km (Figure 35). Our efficiency rate (ratio of marked fish during the recapture runs [R] to total fish captured on the recapture run [C]), unadjusted for size selectivity was 19% (Appendix F). Rainbow Trout mean relative weights were 96 ± 3.4. We found a decrease in relative weights with an increase in length (linear regression, $r^2 = 0.30$, F (1,61) = 26.42, P <0.001; Figure 36). We aged 53 Rainbow Trout from the Box Canyon reach of the Henrys Fork. Rainbow Trout grew from a starting age of $t_0 = -0.14$ years (95%CI -0.88 to 0.60) toward their asymptotic length of $L_\infty = 528 + 156$ mm at an instantaneous rate of K = 0.30 + 0.20 /year (Figure 37). Mean length at age-2 based on non-linear regression was 235 mm (± 25.2) (Table 15).

The regression model between winter flow predicted 2,220 age-2 Rainbow Trout in the 2015 survey based on winter flows that averaged 200 cfs. However, based on the length-based estimates of abundance from our Log Likelihood model, we estimated age-2 Rainbow Trout abundance at 1,257 fish in the Box Canyon reach during 2014 (Figure 38). Across most years, the regression model accurately estimates the relative year class strength of Rainbow Trout using mean winter stream flow ($r^2 = 0.51$, F(1,17) = 17.993, P <0.001) and is a useful tool to evaluate the effects of variable winter flows on trout populations.

Vernon

We collected 245 trout during two days of electrofishing in the Vernon reach of the Henrys Fork. Species composition of trout collected was 27% Brown Trout, 71% Rainbow Trout, and 2% Brook Trout. Rainbow Trout ranged between 107 mm and 585 mm (Figure 39), with a mean and median total length of 383 mm (± 18 mm) and 419 mm, respectively. Rainbow Trout PSD and RSD-400 values were 88 and 70, respectively. Length frequency distribution of Rainbow Trout captured electrofishing in the Vernon reach of the Henrys Fork Snake River during the spring of 2015 were similar to the average distributions from 2005, 2006, 2007, 2009, and 2012 (Figure 40). We estimated 2,688 ± 1,577 Rainbow Trout >150 mm for the reach, which equates to 358 Rainbow Trout per km (Figure 41). Our efficiency rate (unadjusted for size selectivity) was 7%. Brown Trout ranged between 130 mm and 615 mm with a mean and median total length of 368 mm (± 34 mm) and 423 mm, respectively. Brown Trout PSD and RSD-400 values were 86 and 75, respectively. Brown trout in 2015 exhibited two pronounced peaks in length frequency distribution at ~450 and ~525 mm when compared to the average distribution from 2005, 2006, 2007, 2009, and 2012. We estimated 192 ± 104 Brown Trout >150 mm for the reach, which equates to 44 Brown Trout per km. Our efficiency rate (unadjusted for size selectivity) for Brown Trout was 15%. Based on regression analysis of Brown Trout species composition across time, Brown Trout have increased 2.4% percent composition per year since 2005 ($r^2 = 0.86$, $F(1,4) = 24.019$, $P < 0.01$ Figure 42).

Chester

We collected 245 trout during two days of electrofishing in the Vernon reach of the Henrys Fork. Species composition of trout collected was 33% Brown Trout, 67% Rainbow Trout, <1% Brook Trout, and <1% Yellowstone Cutthroat Trout. Rainbow Trout ranged between 91 mm and 532 mm (Figure 43), with a mean and median total length of 367 mm (± 10 mm) and 400 mm, respectively. Rainbow Trout PSD and RSD-400 values were 89 and 59, respectively. We estimated 4,135 ± 809 Rainbow Trout >150 mm for the reach, which equates to 725 Rainbow Trout per km. Our efficiency rate (unadjusted for size selectivity) was 9%. Brown Trout ranged between 126 mm and 645 mm with a mean and median total length of 337 mm (± 15 mm) and 373 mm, respectively. Brown Trout PSD and RSD-400 values were 94 and 62, respectively. Length frequency distribution of Rainbow Trout and Brown Trout captured electrofishing in the Chester reach of the Henrys Fork Snake River during the spring of 2015 were similar to the average distributions from 2003, 2007, 2009, and 2012 (Figure 44). We estimated 1,449 ± 558 Brown Trout >150 mm for the reach, which equates to 254 Brown Trout per km. Our efficiency rate (unadjusted for size selectivity) for Brown Trout was 12%. Based on regression analysis of Brown Trout species composition across time, Brown Trout have increased 1.9% percent composition per year since 2003 ($r^2 = 0.72$, $F(1,3) = 7.579$, $P = 0.072$; Figure 45).

DISCUSSION

Estimates of trout densities in Box Canyon in 2015 were similar to trout densities in 2014 and only slightly below (13%) the 21-year average of 1,926 trout per km. Based on densities it appears the trout population in Box Canyon has stabilized following the strong rainbow trout year class produced in 2011. Length frequency distribution in 2014 indicated a strong year class of age-3 trout with limited recruitment of age-1 and age-2 trout in the population. We observed a strong year class of age-1 Rainbow Trout recruiting into the population in 2015 that should be contributing substantially to the fishery in 2016 as age-2s. The large number of larger Rainbow Trout (>350 mm) currently in the population should provide excellent fishing opportunities during the angling season.

Winter stream flows continue to be the main factor in driving Rainbow Trout abundances within the Box Canyon section (Garren et al. 2006a). Observed age-2 abundance (1,257) in 2014 was outside of the 95% CIs predicted from our regression model (2,220). Flows during the winter of 2013-2014 would have affected age-2 fish in the 2015 survey. Fausch et al. (2001) found Rainbow Trout recruitment was higher in tailwaters exhibiting high winter and/or low spring flows. High spring flows can reduce year class strength due to substrate scouring displacing eggs and fish larvae. Low winter flows may reduce survival through redd desiccation. Spring flows may also play a limited role in reducing/increasing year class strength in Henrys Fork and subsequently cause slight divergences in predictions of the winter flow model. In past five years (2010-2015) average spring flows have ranged from 468-1,057 cfs. Past studies in the Henrys Fork have found winter flows are the primary driver regulating the survival of young-of-year (YOY) due to the reduction of complex habitat along the river margins (Meyer and Griffith 1997; Mitro et al. 2003). Incorporating spring flows into the winter flow model may make regression model predications more robust, if spring flows indeed regulate recruitment to a varying degree in Rainbow Trout population in Box Canyon.

Trout densities in the Chester reach have increased approximately 78% compared to past spring surveys. In the last several years the Crosscut and Last Chance Canal fish screens below Chester Dam have been operated throughout the irrigation season. Fish screening may have contributed to the observed increase in trout abundance in the Chester section by reducing fish entrainment and allowing those fish to persist in the fishery. In an unscreened diversion, fish will enter the irrigation system and likely be lost to the recreational fishery. If the diversion is screened, fish are bypassed and returned to the main channel and fishery. In 2014 IDFG conducted an evaluation of the bypass tubes at the canals to determine whether fish were bypassed effectively and with minimal mortality. We found the bypass tubes and fish screens were functioning properly and as designed with minimal fish mortality. Waters et al. (2012) evaluated fish screens in the Lemhi River, Idaho and found that under median streamflow conditions with unscreened diversions, the estimated cumulative effect of diversions (41-71 water diversions) was a loss of 71.1% of out-migrating Chinook salmon *O. tshawytscha* smolts due to entrainment. A single diversion can also have considerable effects on the population in some cases. For example, a diversion in the Yellowstone River was found to contribute more than half of all non-fishing mortality in saugers *Sander Canadensis* (Jaeger et al. 2005). Currently we do not have data on the encounter rates of salmonids on the Crosscut and Last Chance canals, but their locations may be such that there are high fish encounter rates. Quantifying diversion entrainment and setting screening priorities when funding is available and deemed appropriate should be considered in other regional waters.

We continued to observe a shift in species composition in the HFSR downstream of Mesa Falls from a Rainbow Trout dominated system to an increasing abundance of Brown Trout (High et al. 2011). In the Vernon reach, Brown Trout comprised 4% of the species composition in 2005 and increased to 28% in 2015. Similarly, in the Chester reach, Brown Trout comprised 9% of the species composition in 2003 and increased to 32% in 2015. The shift towards a more Brown Trout dominated system may be due to both abiotic (e.g., temperature) and biotic factors (e.g., competition). Brown Trout often displace Rainbow Trout from their preferred habitat in sympatric populations owing to their larger size and higher innate aggression (Gatz et al. 1987). Brown Trout are often a less desirable species when compared to Rainbow Trout for anglers because they can be more difficult to catch. Stemming the increasing trend in Brown Trout may require increased removal of browns to reduce competition and displacement of Rainbow Trout. Anglers could play a pivotal role in shifting species composition if they value Rainbow Trout over Brown Trout. However, angler behavior has shifted towards more catch-and-release angling than harvest. In the South Fork Snake River, an Angler Incentive Program was developed to encourage anglers to harvest Rainbow Trout to protect the Yellowstone Cutthroat Trout population (High et al. 2015). This program has motivated some anglers to harvest the targeted species, but it has failed to create large-scale harvest. Over the past several decades, angler behaviors have shifted towards catch-and-release, particularly in rivers and streams, and particularly for trout. Over the coming years, angler input will be critical to informing management decisions about what direction to take with regards to selective harvest and attempts to shift species composition.

Similar to past evaluations we found a significant proportion of the population was comprised of larger trout (>500 mm) in the Vernon reach and to a lesser extent in the Chester reach (Garren et al. 2006). Average size of trout tends to be much higher in Vernon and Chester reaches (~360 mm) when compared to other reaches in the HFSR due to the lack of younger trout. Past surveys have documented similar population characteristics of high densities of larger trout and apparent recruitment failures (Garren et al. 2006). Despite the trend of large trout dominating and the apparent lack of juvenile fish in the Vernon and Chester reaches, adult abundance has remained relatively stable since the early 2000s. Recruitment of juvenile fish into the system is likely coming from tributaries (e.g., Fall River) and/or mainstem HFSR. Future research should focus on identifying juvenile source population areas. Identifying juvenile rearing habitats will allow managers to develop appropriate protective measures to ensure these unique fisheries continue to produce trophy angling opportunities.

RECOMMENDATIONS

1. Continue annual population surveys in the Box Canyon reach to quantify population response to changes in the flow regime over time. Collect trout otoliths annually for age distribution and morality estimates.

2. Continue to collaborate with the irrigation community, Bureau of Reclamation, and other agencies to increase winter flows from Island Park Dam to benefit trout recruitment, stressing the importance of early winter flows (December, January, and February) to age-0 trout survival.

3. Investigate the potential of flows outside of winter (e.g., spring) to improve the winter flow model and increase predicted estimates.

4. Develop and implement creel surveys in the Henrys Fork to monitor angler use, preferences, and harvest in areas where allowed.

Table 13. Trout population index summaries (±95% confidence intervals) for the Henrys Fork Snake River, Idaho 2015.

River Reach	Species	Mean TL (mm)	Median TL (mm)	PSD	RSD-400	RSD-500	Density (No./km)	Species Composition (%)
Box Canyon	Rainbow Trout	296 (±6.2)	346	83	25	0	1,681 (±343)	100
Vernon	Rainbow Trout	383 (±18.5)	419	88	70	24	313 (±106)	72
	Brown Trout	368 (±33.9)	423	86	75	28	120 (±41)	28
Chester	Rainbow Trout	367 (±9.3)	400	89	59	4	658(±109)	68
	Brown Trout	337 (±15.3)	373	94	62	6	304(±50)	32

Table 14. Log-Likelihood Method (LLM) population estimates of trout (≥150 mm) from the Henrys Fork Snake River, Idaho during 2015.

River reach	Species	No. marked	No. captured	No. recaptured	Population Estimate	Confidence Interval (± 95%)	Density (No./km)	Discharge[1] (ft^3/s)
Box Canyon[2]	Rainbow Trout	765	351	67	6,220	1,270	1,681	709
	Brook Trout	1	0	0	--	--	--	
Vernon[3]	Rainbow Trout	81	96	7	2,688	1,577	358	1,432
	Brown Trout	28	40	6	192	104	44	
	Brook Trout	5	0	0	--	--	--	
Chester[3]	Rainbow Trout	304	228	20	4,135	809	725	1,447
	Brown Trout	130	130	15	1,449	558	254	
	Brook Trout	2	0	0	--	--	--	
	Cutthroat Trout	1	0	0	--	--	--	

[1] Represents the mean discharge value between marking and recapture events.
[2] Data obtained from USGS gauge (13042500) near Island Park Dam.
[3] Data obtained from USGS gauge (13046000) below Ashton Dam.

Figure 33. Map of the Henrys Fork Snake River watershed and electrofishing sample sites (Box Canyon, Chester, and Vernon) during 2015.

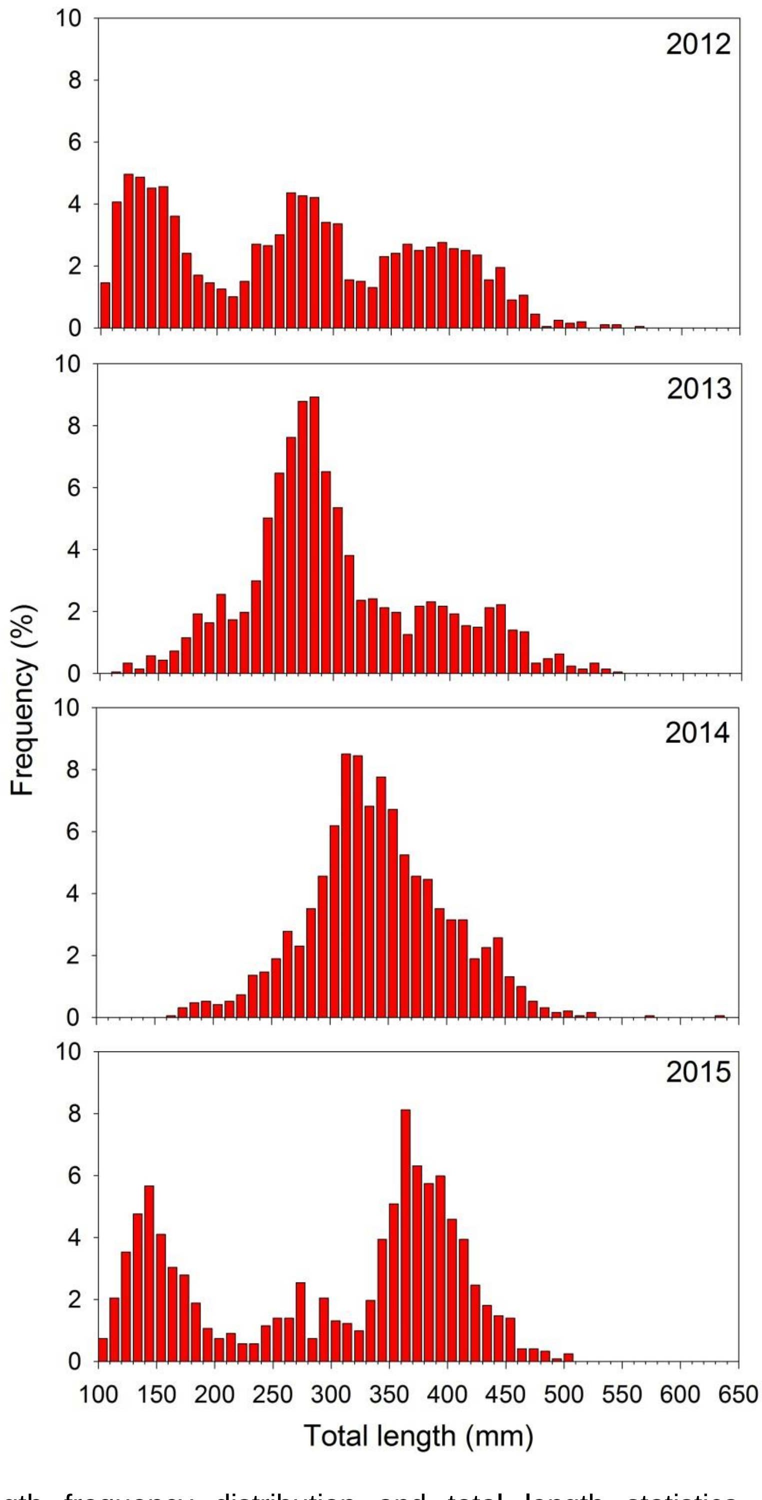

Figure 34. Length frequency distribution and total length statistics of Rainbow Trout collected by electrofishing in the Box Canyon reach of the Henrys Fork Snake River, Idaho, 2012 - 2015.

Table 15. Mean length at age data based on otoliths of trout collected electrofishing in Box Canyon of Henrys Fork, Idaho in 2005, 2011, 2013, 2014, and 2015.

		Summary statistic					
Year	**Age**	**Mean**	**95% CI**	**Median**	**Min**	**Max**	**Count**
2015	1	168	51.2	169	130	204	4
	2	235	25.2	244	152	303	14
	3	334	23.4	341	271	380	12
	4	377	24.1	374	285	445	15
	5	405	38.1	413	338	446	6
	6	441	146.1	441	429	452	2
2014	1	255	64.3	265	226	275	3
	2	329	6.4	330	229	390	83
	3	391	8.3	387	322	470	56
	4	433	26.6	426	402	470	6
	5	--	--	--	--	--	0
	6	459	69.9	459	453	464	2
2013	1	170	8.0	168	130	205	35
	2	278	10.8	268	185	424	90
	3	390	10.8	390	305	460	53
	4	449	32.5	436	375	516	9
	5	484	--	--	--	--	1
	6	475	--	--	--	--	1
2011	1	260	19.3	263	170	305	15
	2	324	15.6	323	234	404	31
	3	389	16.1	396	333	450	20
	4	421	24.8	413	382	460	8
2005	1	122	23.6	134	92	142	6
	2	296	9.4	301	239	337	28
	3	348	19.7	365	290	394	14
	4	432	16.0	435	310	497	25
	5	422	28.9	428	300	479	13
	6	458	13.0	459	418	495	15
	7	494	--	--	--	--	1

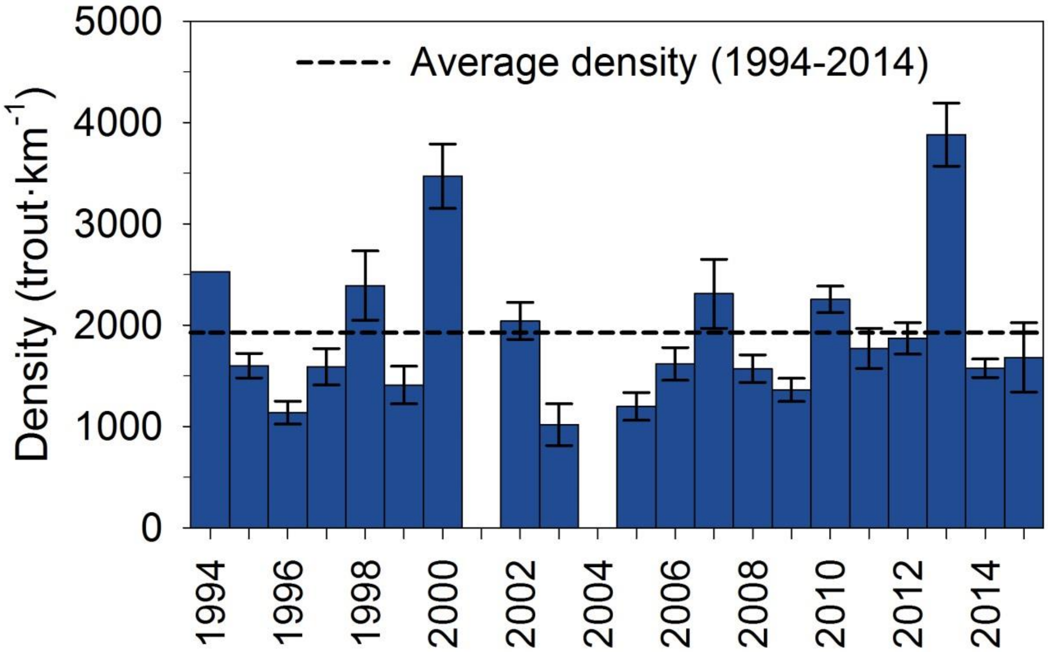

Figure 35. Rainbow Trout density estimates (fish per km) for the Box Canyon reach of the Henrys Fork Snake River, Idaho 1994-2015. Error bars represent 95% confidence intervals. The dashed lines represent the long-term average Rainbow Trout density, excluding the current year's survey.

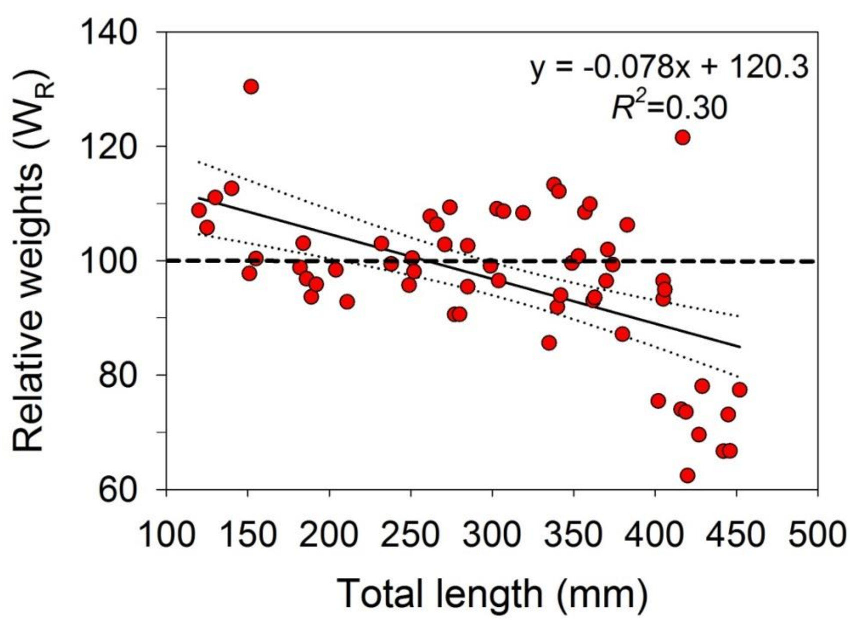

Figure 36. Rainbow Trout relative weights (W_R) by total length from spring electrofishing surveys in the Box Canyon reach of Henrys Fork, 2015. Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively. Dashed line represents mean W_R of 100, which are based on 75th percentile of weight at a given length.

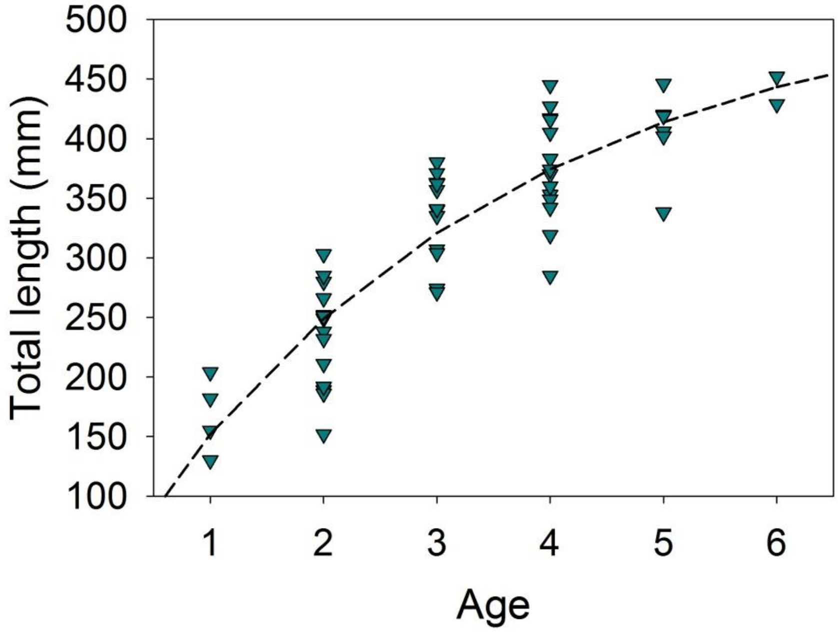

Figure 37. Length-at-age based on non-linear regression for Rainbow Trout from spring electrofishing in the Box Canyon reach of the Henrys Fork, 2015. Growth is described by the fitted von Bertalanffy growth (VBG) model with a dashed line.

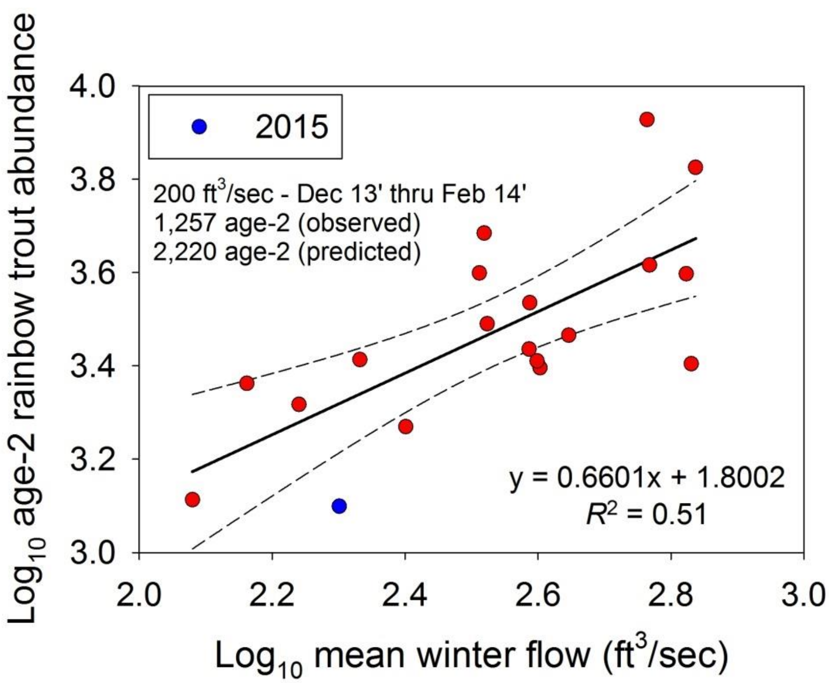

Figure 38. The relationship between age-2 Rainbow Trout abundance and mean winter flow (cfs) during the first winter of a fish's life from 1995 - 2014; $\log_{10}$ age-2 trout abundance = 0.5995 $\log_{10}$ flow (cfs) + 1.9668, (r^2=0.49, F(1,16)=15.3, p=0.00 1). Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively.

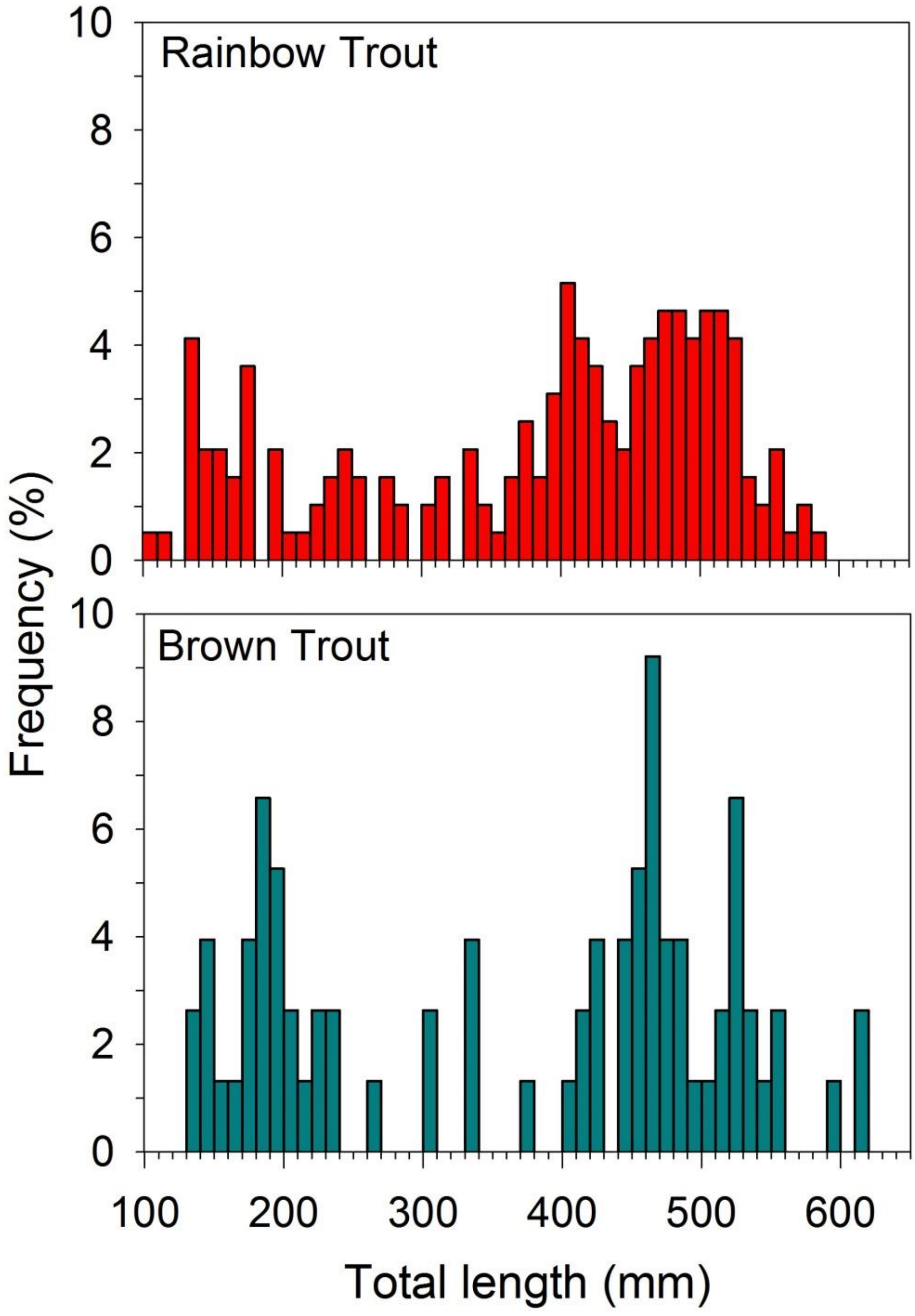

Figure 39. Length frequency of Rainbow Trout and Brown Trout captured by electrofishing in the Vernon reach of the Henrys Fork Snake River during the spring of 2015.

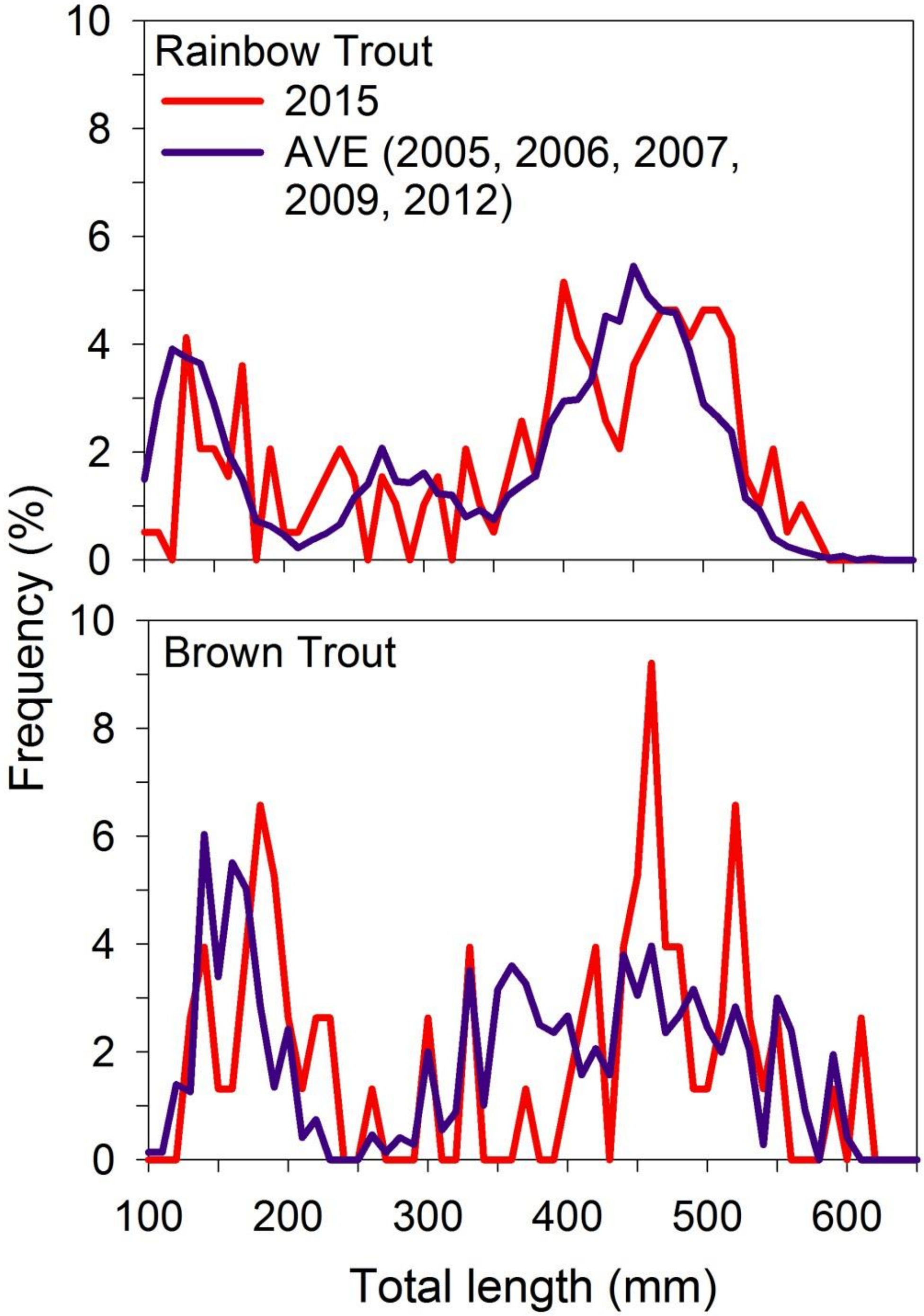

Figure 40. Length frequency distribution of Rainbow Trout and Brown Trout captured electrofishing in the Vernon reach of the Henrys Fork Snake River during the spring of 2015 compared to the average distribution from 2005, 2006, 2007, 2009, and 2012.

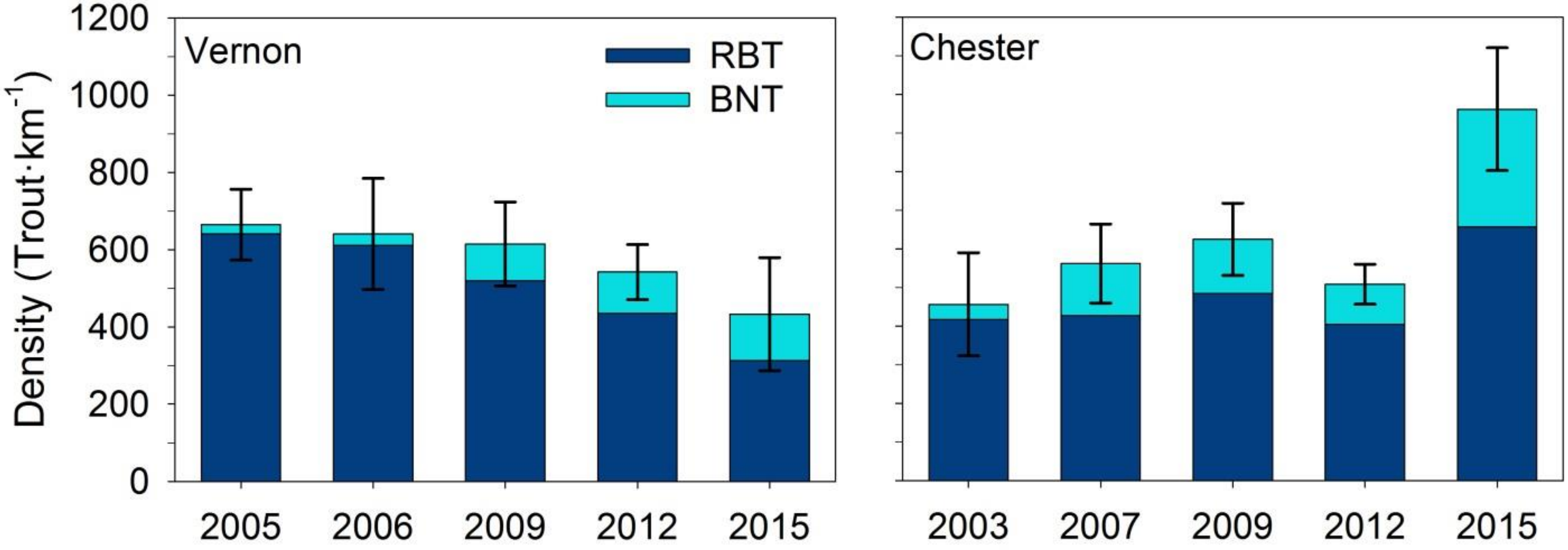

Figure 41. Rainbow Trout (RBT) and Brown Trout (BNT) density estimates (fish per km) from spring electrofishing surveys in the Vernon and Chester reach of the Henrys Fork Snake River, Idaho by year (2003-2015). Error bars represent 95% confidence intervals.

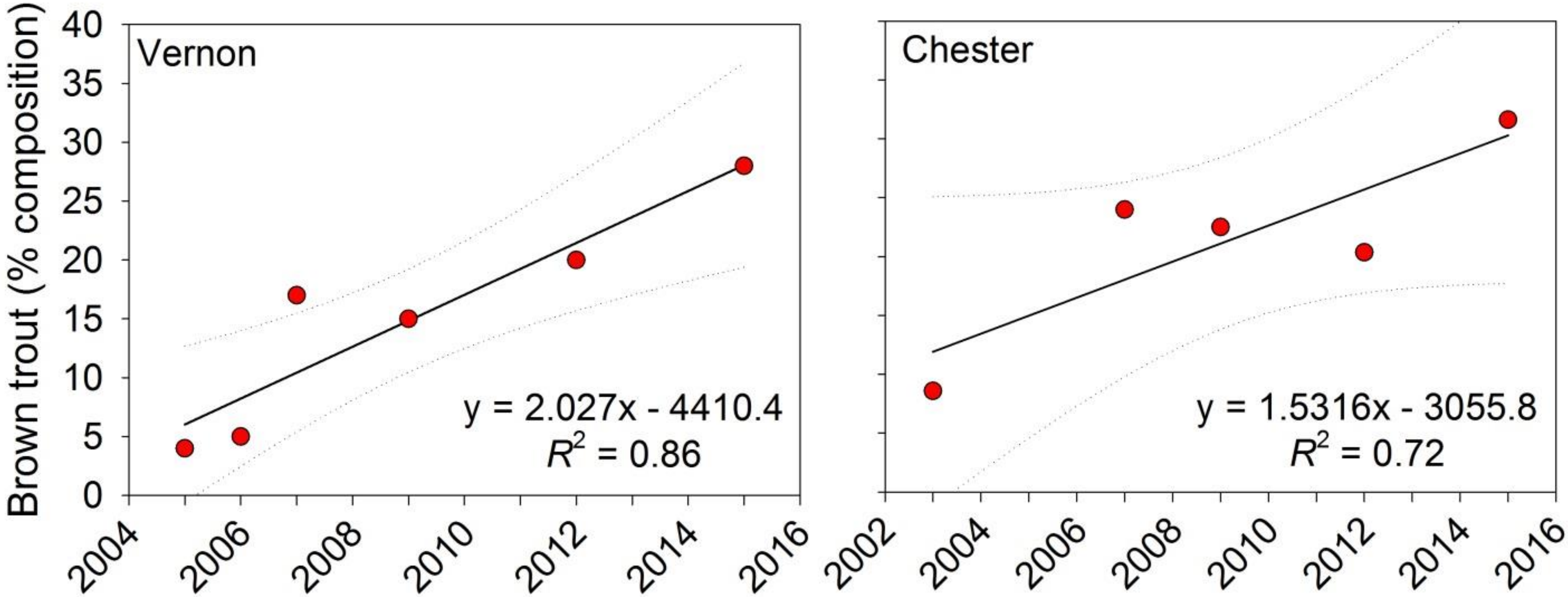

Figure 42. Species composition (%) of Brown Trout in the Vernon and Chester reach of the Henrys Fork Snake River, Idaho collected from electrofishing surveys from 2003 to 2015. Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively.

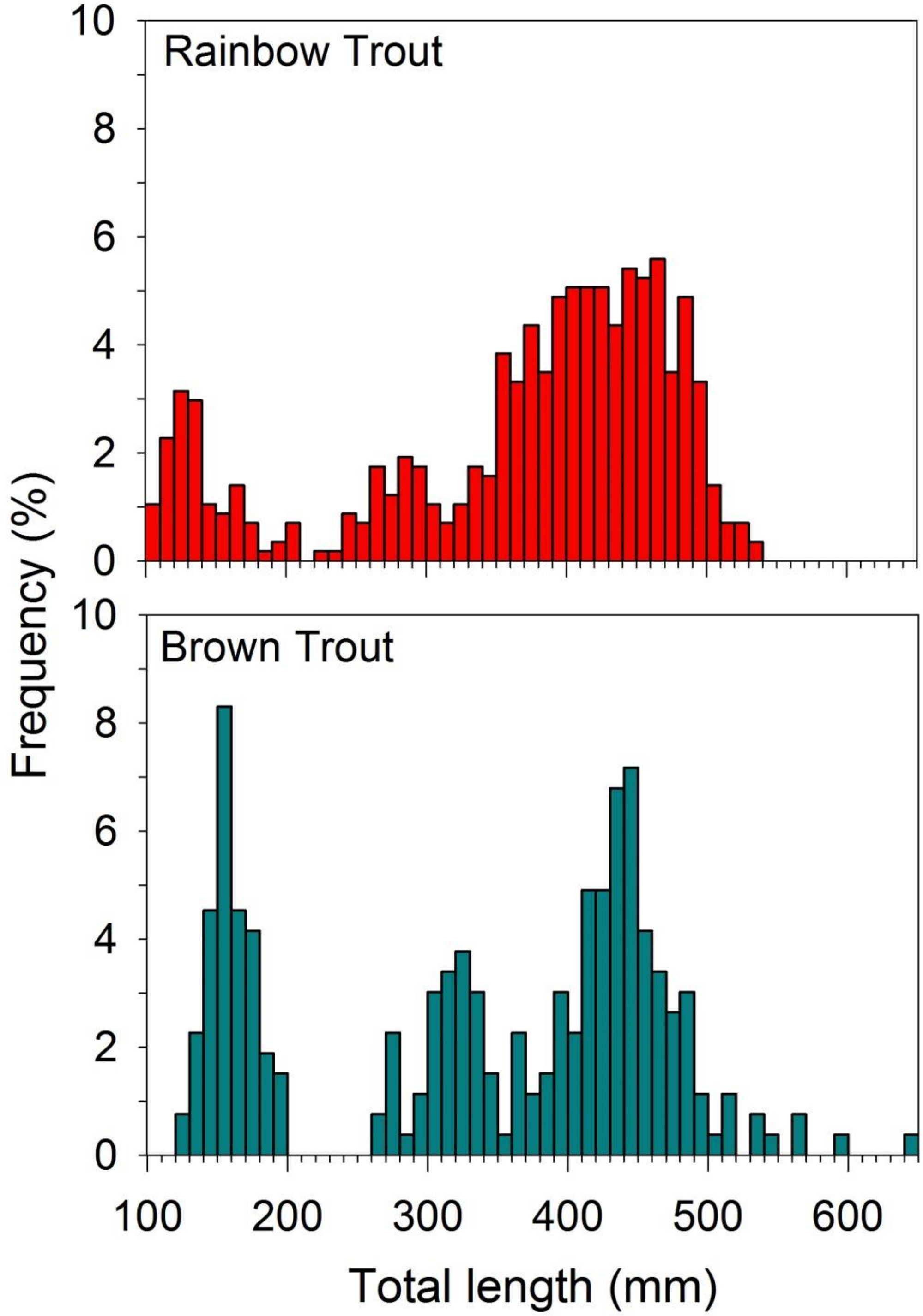

Figure 43. Length frequency of Rainbow Trout and Brown Trout captured by electrofishing in the Chester reach of the Henrys Fork Snake River during the spring of 2015.

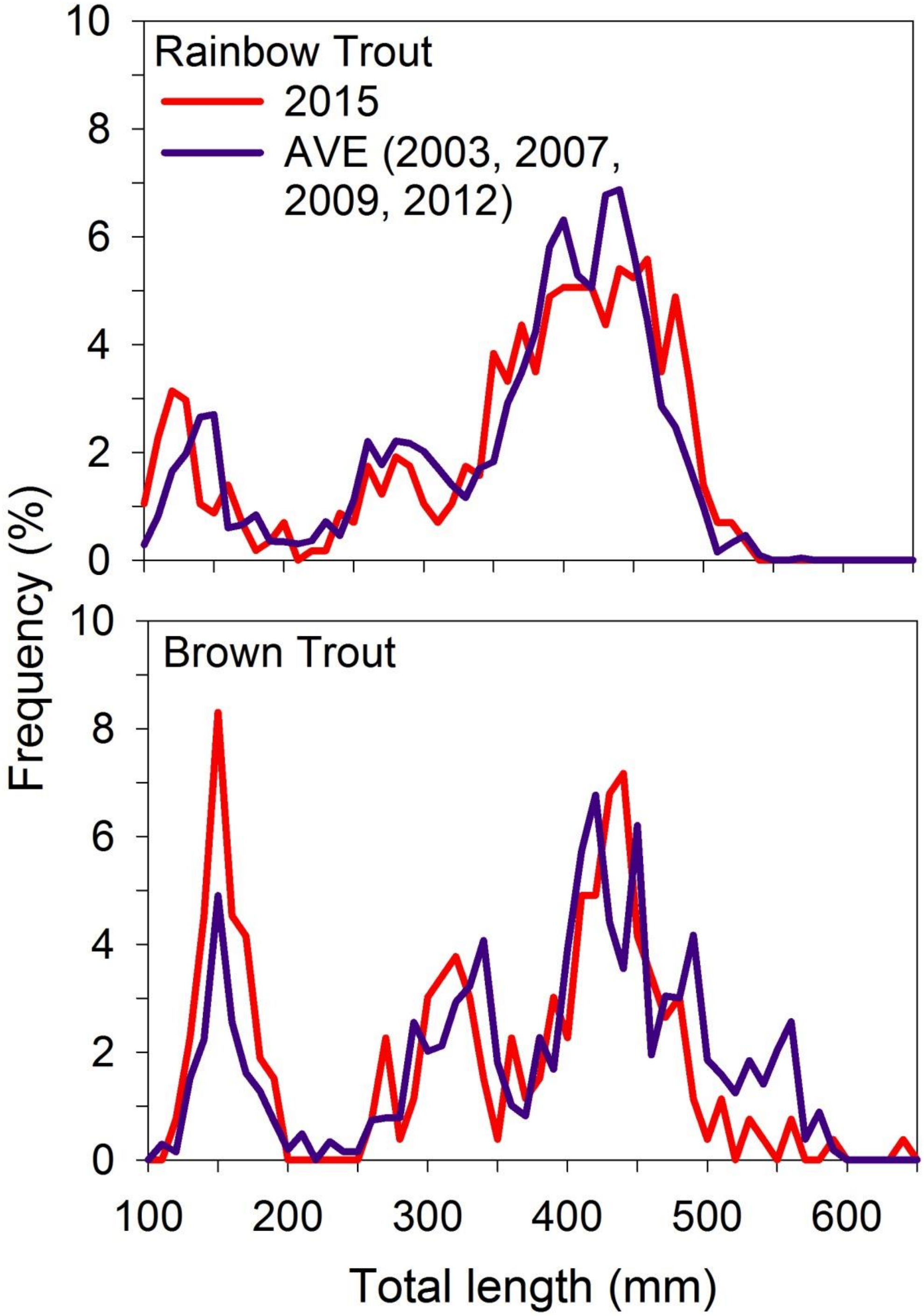

Figure 44. Length frequency distribution of Rainbow Trout and Brown Trout captured electrofishing in the Chester reach of the Henrys Fork Snake River during the spring of 2015 compared to the average distribution from 2003, 2007, 2009, and 2012.

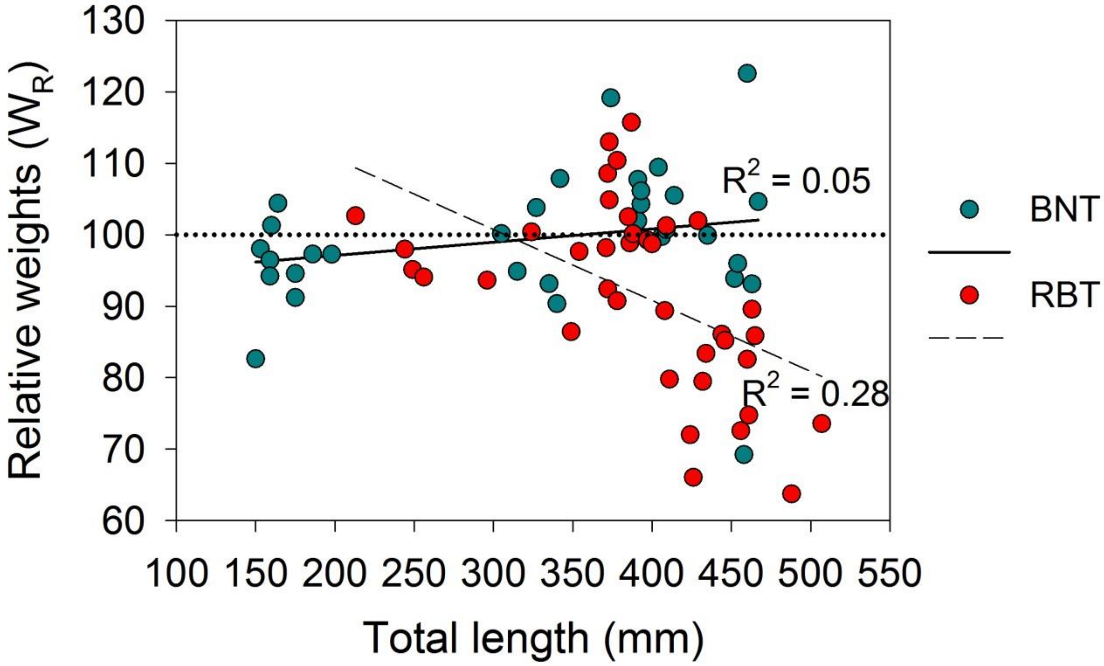

Figure 45. Brown Trout (BNT) and Rainbow Trout (RBT) relative weights (W_R) by total length from spring electrofishing surveys in the Chester reach of Henrys Fork, 2015. Linear regression for Brown Trout and Rainbow Trout are represented with a solid and dashed line, respectively. Dotted line represents mean W_R of 100, which are based on 75th percentile of weight at a given length.

TETON RIVER

ABSTRACT

The Teton River supports an important population of native Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* (YCT) which the Idaho Department of Fish and Game regularly monitors at two electrofishing sites in Teton Valley. The Nickerson reach represents the upper Teton Valley and Breckenridge the lower Teton Valley. In addition to these monitoring reaches, IDFG surveyed the Parkinson reach in Teton Canyon and the South Fork Teton River reach on the lower end of the drainage. Trout abundances were stable or increasing at all sites surveyed in 2015. The largest changes of abundance were observed for nonnative trout species. The intrinsic rates of population growth (r) were not significantly different than zero for YCT in the Nickerson or Breckenridge monitoring reaches, but abundance of YCT was much higher in the Nickerson reach (441 YCT/km) than in the Breckenridge reach (18 YCT/km). The trend for the intrinsic rate of population growth for Rainbow Trout *O. mykiss* was significantly positive at both the Nickerson (r = 0.20; P = 0.006) and Breckenridge monitoring reaches (r = 0.15; P<0.001). The trend of abundance for Brook Trout *Salvelinus fontinalis* was significantly positive at Nickerson (r = 0.17; P<0.001), but not significantly different than zero at Breckenridge (r = 0.12; P=0.27). We observed four times more Brown Trout *Salmo trutta* in the Breckenridge monitoring reach in 2015 (n = 28) than ever before, including some smaller Brown Trout for the first time, suggesting some recruitment has taken place. Yellowstone Cutthroat Trout continue to dominate the Parkinson reach where we estimated abundance at 242 YCT/km, but did not recapture enough Rainbow Trout to calculate a population estimate. In the South Fork Teton River, YCT were significantly lower in abundance in 2015 (48 YCT/km) relative to the previous two surveys in 2006 and 2011.

Brett High
Regional Fisheries Biologist

INTRODUCTION

The Teton River, a tributary of the Henrys Fork Snake River in Eastern Idaho, supports a robust population of wild trout including an important population of native Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* (YCT). Other trout present include Rainbow Trout *O. mykiss* (RBT), Brook Trout *Salvelinus fontinalis* (BKT), and Brown Trout *Salmo trutta* (BNT). Since 1987, two reaches in the upper Teton River have been routinely sampled to monitor fish population trends. This report summarizes the 2015 Teton River monitoring surveys. For a broader description of the Teton River fish assemblage and factors contributing to observed trends in abundance and species composition see Schoby et al. (2013).

METHODS

We estimated trout abundance by species using mark/recapture techniques at the Nickerson and Breckenridge monitoring reaches in Teton Valley, the Parkinson's reach in lower Teton Canyon, and the South Fork Teton River near the river's confluence with the Henrys Fork Snake River (Figure 46). Electrofishing sampling was conducted using raft-mounted gear in the fall when river flows reached base levels. Two electrofishing passes at each reach were completed with approximately one week between passes. We attempted to capture all trout encountered. All fish were measured to the nearest mm (total length), and identified to species. A representative sample of fish for each species was weighed to the nearest gram. During the first pass, fish were marked using a hole punch in the caudal fin, and this mark was used to identify previously captured fish in subsequent runs. At each site, genetic samples were collected from a minimum of 30 YCT and stored on Whatman data sheets. Many YCT and RBT were also marked with half-duplex Passive Integrated Transponder (PIT) tags as part of an ongoing general movement study in the drainage. During the second pass, captured fish were again measured, identified to species, and inspected for caudal fin marks. After calculating population estimates for each species as described in Schoby et al. (2013), we assessed population trends at Nickerson and Breckenridge since 1995 using an exponential model and the intrinsic rate of population change (r) as explained by Maxell (1999) using $\alpha = 0.10$ to have more power to assess trends in these populations (Peterman 1990). Hatchery Trout were last stocked into the Teton River in 1994. Since 1995 the Teton River has been managed under Wild Trout regulations, thus we assessed population trends since 1995.

Relative weights (W_r) were calculated by dividing the actual weight of each fish (in grams) by a standard weight (W_s) for the same length for that species multiplied by 100 (Anderson and Neumann 1996). Relative weights were then averaged for each length class (<150 mm, 150-249 mm, 250-349 mm, 350-449, and fish >449 mm). We used the formula

$$\log W_s = -5.192 + 3.086 \log TL$$ (Kruse and Hubert 1997)

to calculate relative weights of YCT,

$$\log W_s = -5.023 + 3.024 \log TL$$

for Rainbow Trout (Simpkins and Hubert 1996),

$$\log W_s = -5.186 + 3.103 \log TL$$

for Brook Trout (Hyatt and Hubert 2001a), and

$$\log W_s = -4.867 + 2.96 \log TL$$

for Brown Trout (Milewski and Brown 1994). We compared relative weights among size groups using 95% confidence intervals.

RESULTS

We sampled the Nickerson monitoring reach on September 14 and 22, 2015 and caught 2,035 trout (Figure 47). We captured 358 YCT, 691 RBT, and 986 BKT. We estimated (± 95% CI) there were 441 ± 90 YCT/km, 726 ± 94 RBT/km, and 1,411 ± 286 BKT/km (Figure 48). The average length of YCT was 285 mm and their average relative weight was 101% (Figure 49). Rainbow Trout averaged 296 mm and had an average relative weight of 103%. The Brook Trout average length at Nickerson was 217 mm with an average relative weight of 101%. Population trends for trout at Nickerson since 1995 have been increasing, but the increase in abundance was not significant for YCT (F = 1.946, df = 9 P = 0.20). However, increasing trends of RBT have been significant (F = 17.590, df = 7, P = 0.006) as has the trend for BKT (F = 81.662, df = 8, P <0.001).

We sampled the Breckenridge monitoring reach on September 15 and 21, 2015 and caught a total of 1,451 trout (Figure 50). This included 37 YCT, 1,027 RBT, 359 BKT, and 28 BNT. We estimated the abundance (± 95% CI) of these species to be 18 ± 12 YCT/km, 1,126 ± 152, RBT/km and 302 ± 95BKT/km; (Figure 51). The average length of YCT at Breckenridge was 309 mm and they had an average W_r = 103%. The average length of RBT was 297 mm with an average W_r = 94. Brook Trout were on average 201 mm in length with a W_r = 96. Brown Trout were observed in two size groups with 27 BNT ranging in size from 197 mm to 398 mm and one BNT 544 mm in length. The average relative weight for BNT was 108% (Figure 52). Since 1995 the intrinsic rate of population growth for YCT has been slightly negative (r = -0.07), but r was not significant indicating a stable trend (F = 0.912, df = 8, P = 0.37). Rainbow Trout at Breckenridge since 1995 have exhibited an increasing trend in abundance (r = 0.15) which was significant (F = 43.230, df = 9, P <0.001). The trend of abundance for BKT at Breckenridge since 1995 has been stable with r = 0.12 that was not significantly different than 0 (F = 1.639, df = 5, P = 0.27).

We sampled the Parkinson reach of the Teton River on September 17 and 25, 2015. We captured trout including 299 YCT and 38 RBT (Figure 53). We estimated there to be 242 ± 51 YCT/km (Figure 54). We did not recapture enough RBT to calculate an estimate. The average length for YCT at Parkinson was 337 mm and their average W_r = 102. For RBT, their average length was 334 mm with an average W_r = 96 (Figure 55).

We sampled the South Fork Teton River on September 23 and 30, 2015. We captured 351 trout, including 89 YCT, 15 RBT, 55 BNT, and 192 Mountain Whitefish (Figure 56). There were an estimated 48 ± 11, YCT/km, 4 ± 2 RBT/km, 36 ± 14 BNT/km, and 210 ± 102 Mountain Whitefish/km; (Figure 57). The average length for YCT in the South Fork Teton River was 342 mm and they had an average W_r = 92. Rainbow Trout had an average total length of 341 mm with an average W_r = 97, while BNT was 337 mm with an average W_r = 100 (Figure 58).

DISCUSSION

Populations of all trout in Teton Valley are stable or increasing in both monitoring reaches. However, the strongest trends in population change have been observed for non-native salmonids, including Rainbow Trout at both Nickerson and Breckenridge, Brook Trout at Nickerson, and an apparent increase in BNT at Breckenridge. With 28 BNT captured at Breckenridge, which is four times higher than the previous record number of BNT observed at Breckenridge, it appears BNT may be in the early stages of establishing a population in the Teton River. This is also the first year we have observed Brown Trout less than 250 mm, indicating some BNT have recruited to the population, and suggesting reproduction may be occurring. While stable population trends for YCT in the valley are encouraging, the increasing abundance of nonnative RBT, BKT, and BNT may result in increased risks to the long-term persistence of YCT in the Teton River due to competition and hybridization (Allendorf and Leary 1988; Wang and White 1994; Hitt et al. 2003).

There is a larger discrepancy in YCT distribution in the upper portion of the Teton River in Teton Valley than the lower portion of the valley. The abundance of YCT in the upper Teton River (Nickerson Reach) was 25 times greater than in the lower river. Despite generally good habitat throughout the Teton River in Teton Valley, Yellowstone Cutthroat Trout are not evenly distributed through this well-connected system. Interestingly, previous radio-telemetry studies have documented Yellowstone Cutthroat Trout in Teton Valley move throughout this section of river (Schrader and Jones 2004). The cause of this discrepancy in density across the Valley is unknown, but future work should assess factors that may be contributing to this oddity.

Trout populations in the Parkinson reach (Teton Canyon) and the South Fork Teton River (lower river) appear to be stable. The dominant species of trout in the Teton Canyon continues to be YCT. This spawning aggregation is the largest group of YCT in the Teton River, and this may be tied to the more natural hydrograph in this reach. Bitch Creek is the largest tributary to the Teton River below the Valley, and remains unaffected by diversions and dams. As such, the river through the Teton Canyon is subject to widely fluctuating flows, particularly during spring snowmelt. Yellowstone Cutthroat Trout in the SF Teton River appear to be spatially segregated spawners from YCT in Teton Canyon, and this lack of mixing is similar to the separation of Teton Valley from the Teton Canyon (Schrader and Jones 2004). The abundance of YCT in the South Fork Teton reach was significantly lower in 2015 than in the previous survey (2011). However, this variation may simply be inter-annual variability, or it could be tied to flow management resulting from upstream irrigation delivery. Additional surveys should be conducted in coming years to better monitor the trend of this population and to get a better understanding of the effects of flow management on fish.

RECOMMENDATIONS

1. Continue to monitor the abundance of trout in the Teton River.
2. Identify factors limiting Yellowstone Cutthroat Trout abundance in the Breckenridge reach.
3. Continue to monitor trout abundance in the South Fork Teton River.

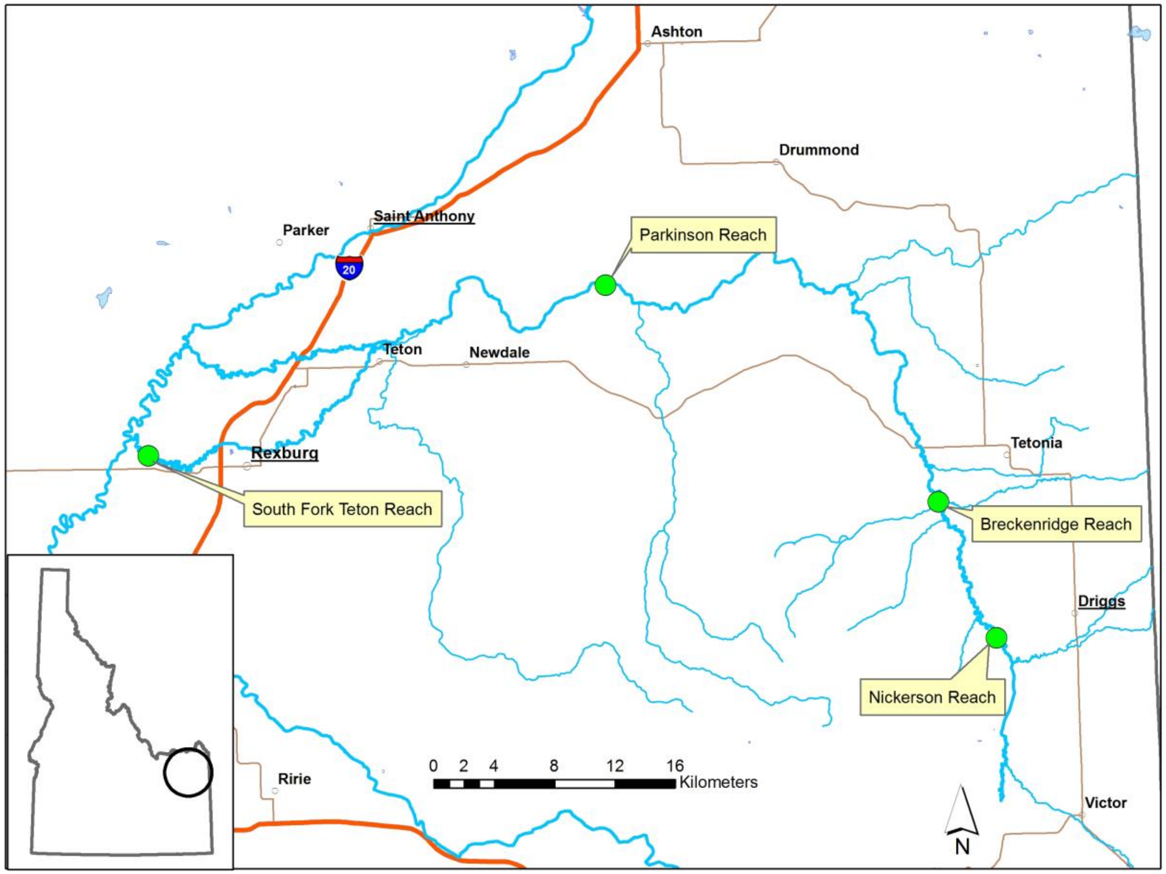

Figure 46. Electrofishing reaches sampled in the Teton River in 2015.

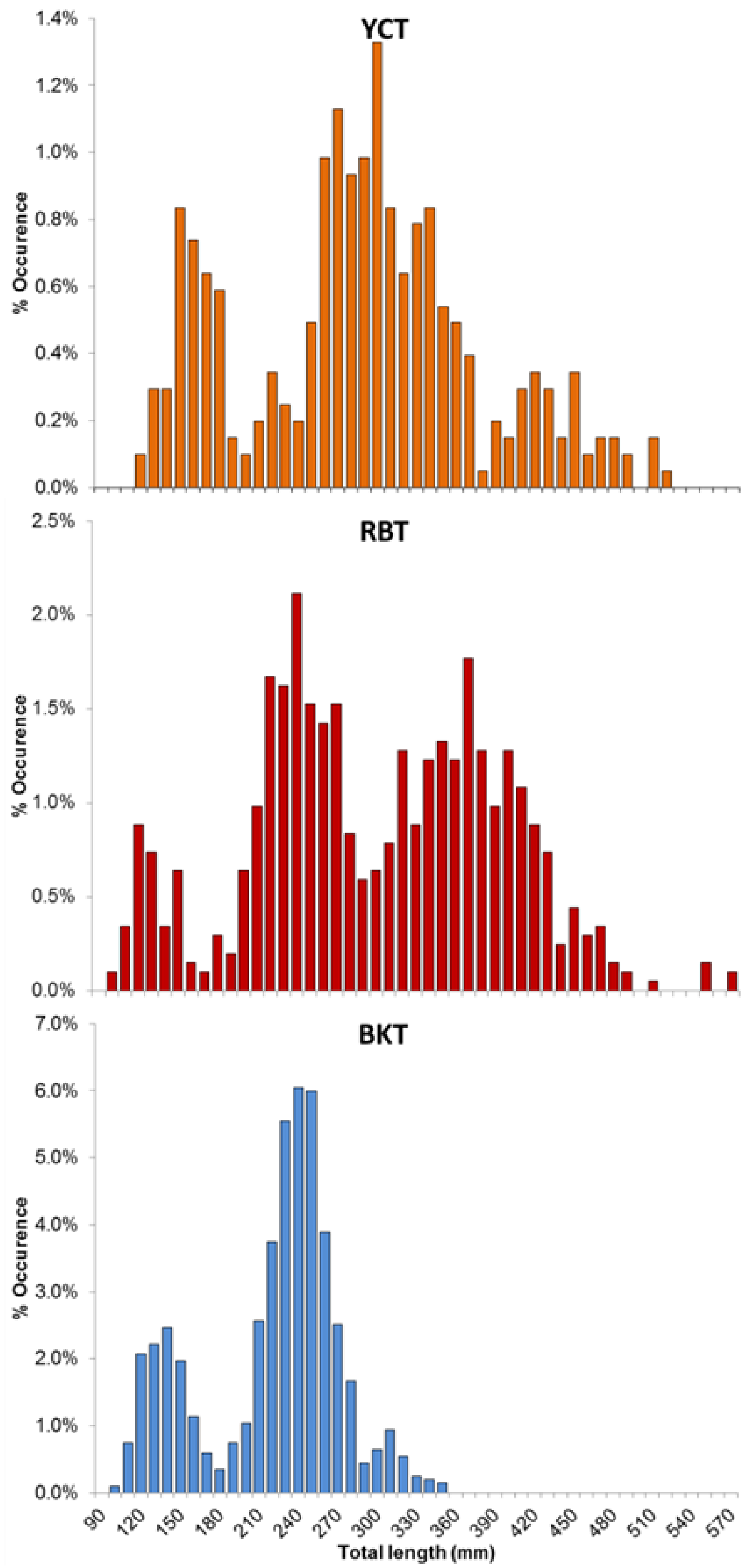

Figure 47. Length frequency distribution for trout at the Nickerson monitoring reach of the Teton River, 2015.

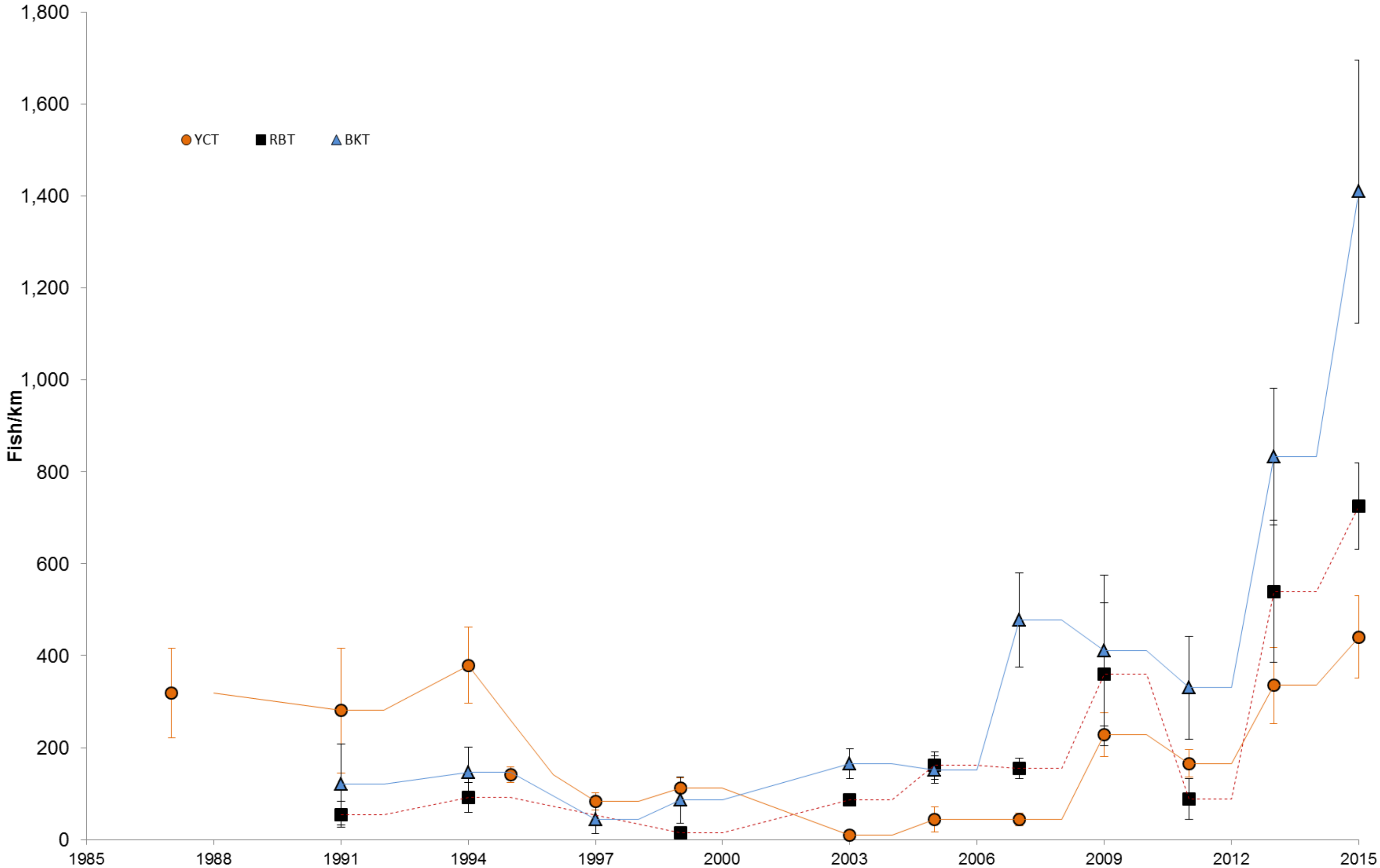

Figure 48. Estimates and associated 95% confidence intervals of the abundance of Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), and Brook Trout (BKT) in the Teton River at the Nickerson monitoring reach from 1987 through 2015.

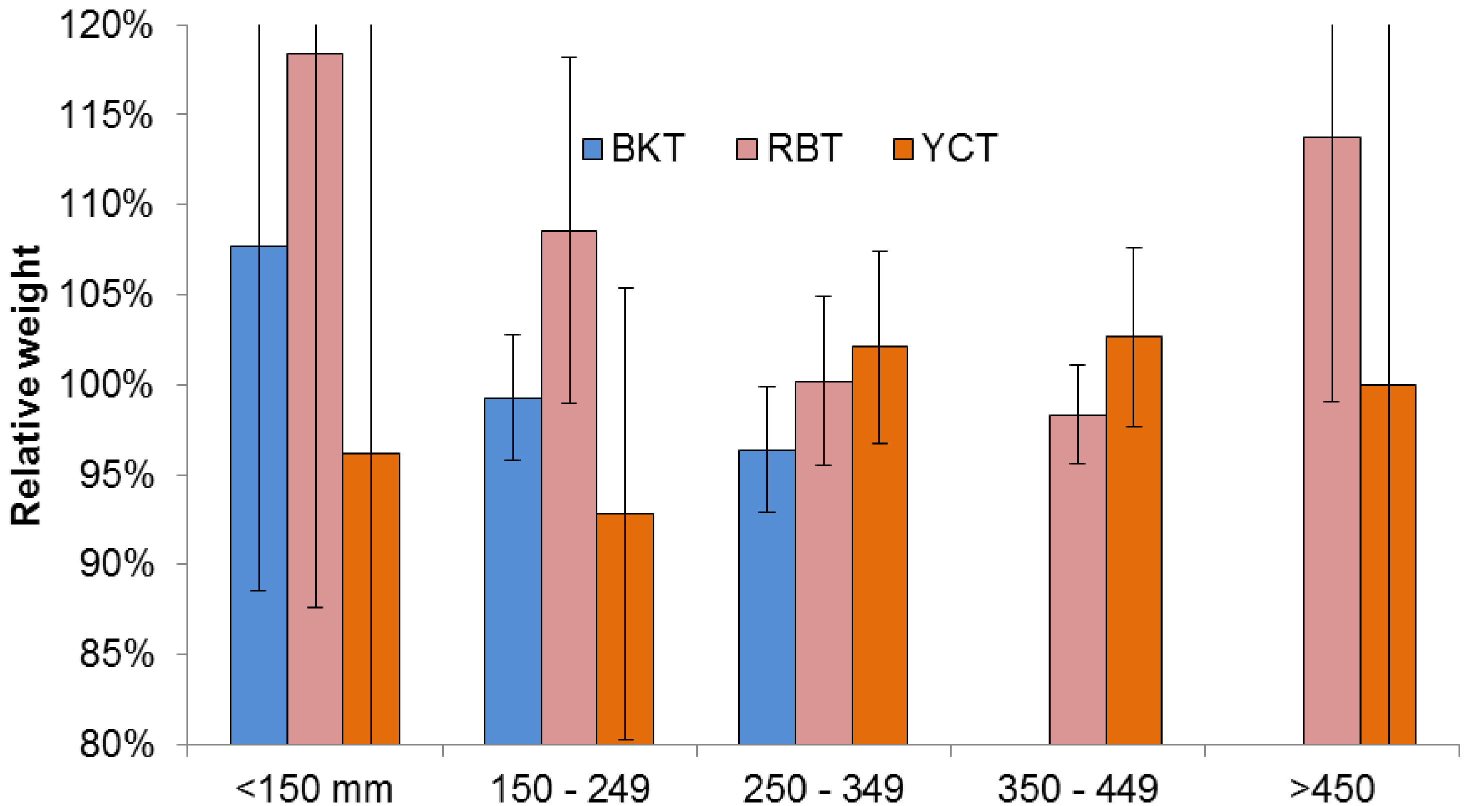

Figure 49. Mean relative weights and 95% confidence intervals of Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), and Brook Trout (BKT) in the Teton River at the Nickerson monitoring reach in 2015.

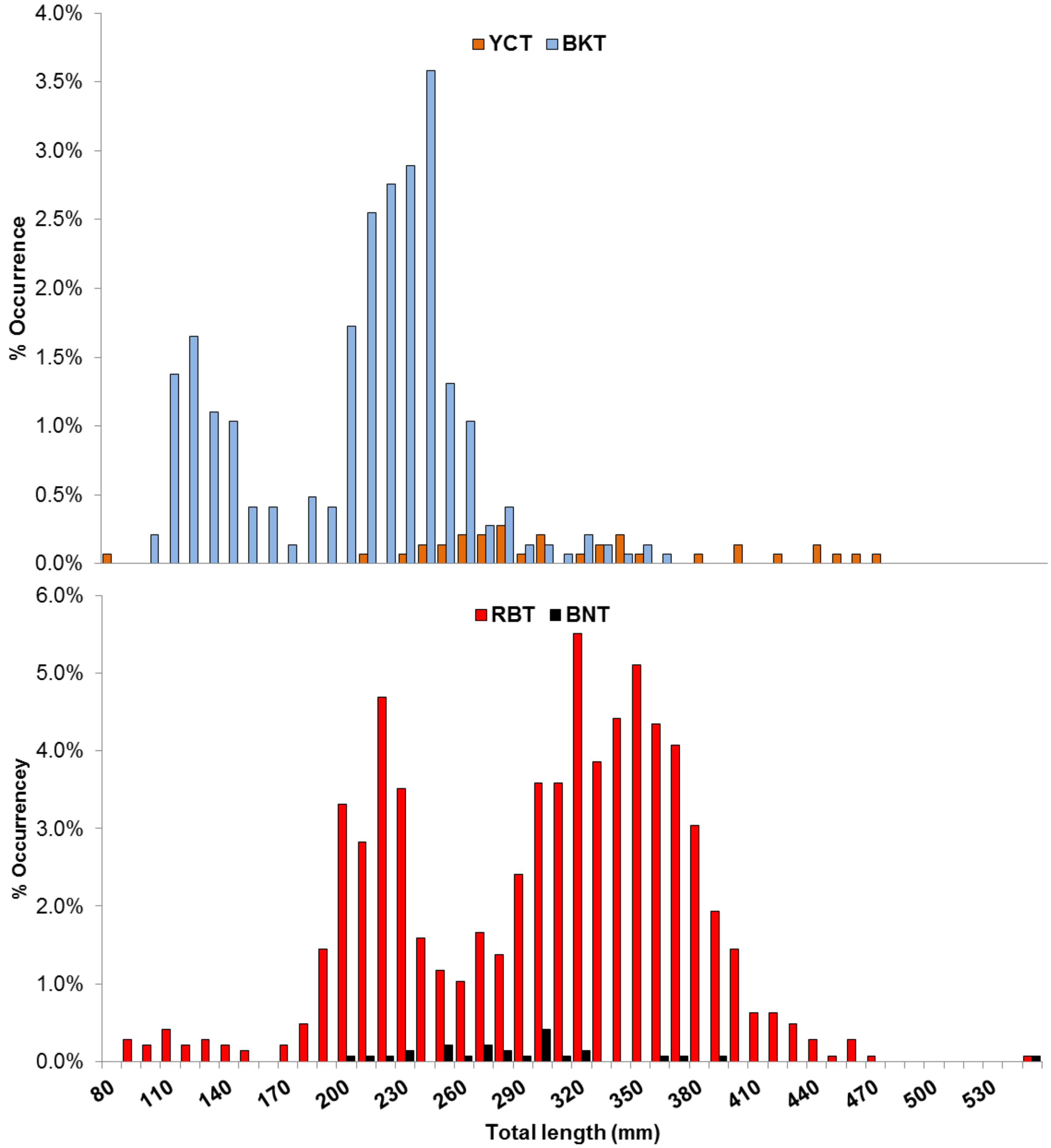

Figure 50. Length frequency distribution for trout at the Breckenridge monitoring reach of the Teton River, 2015.

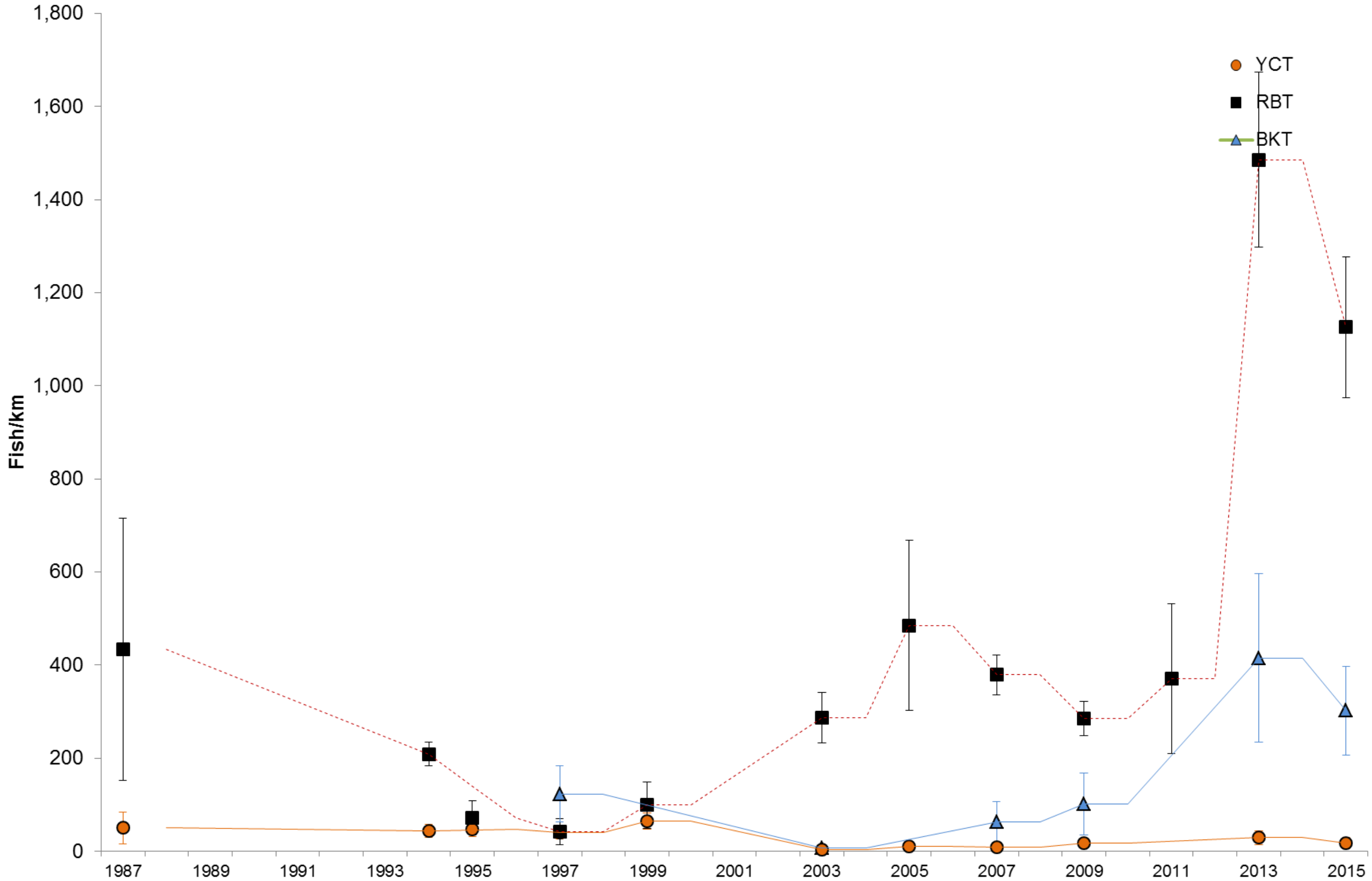

Figure 51. Estimated abundance (with 95% confidence intervals) of Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), and Brook Trout (BKT) in the Teton River at the Breckenridge monitoring reach from 1987 through 2015.

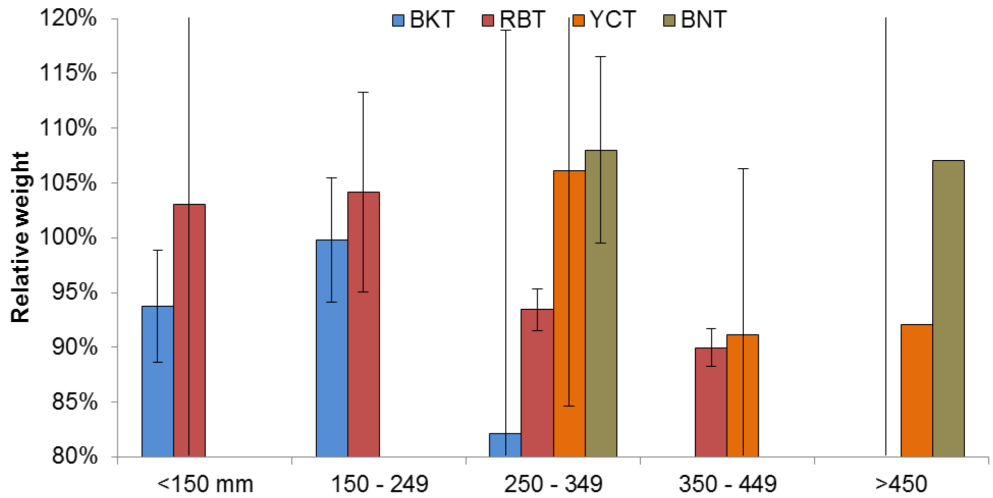

Figure 52. Mean relative weights and 95% confidence intervals of Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brook Trout (BKT), and Brown Trout (BNT) in the Teton River at the Breckenridge monitoring reach in 2015.

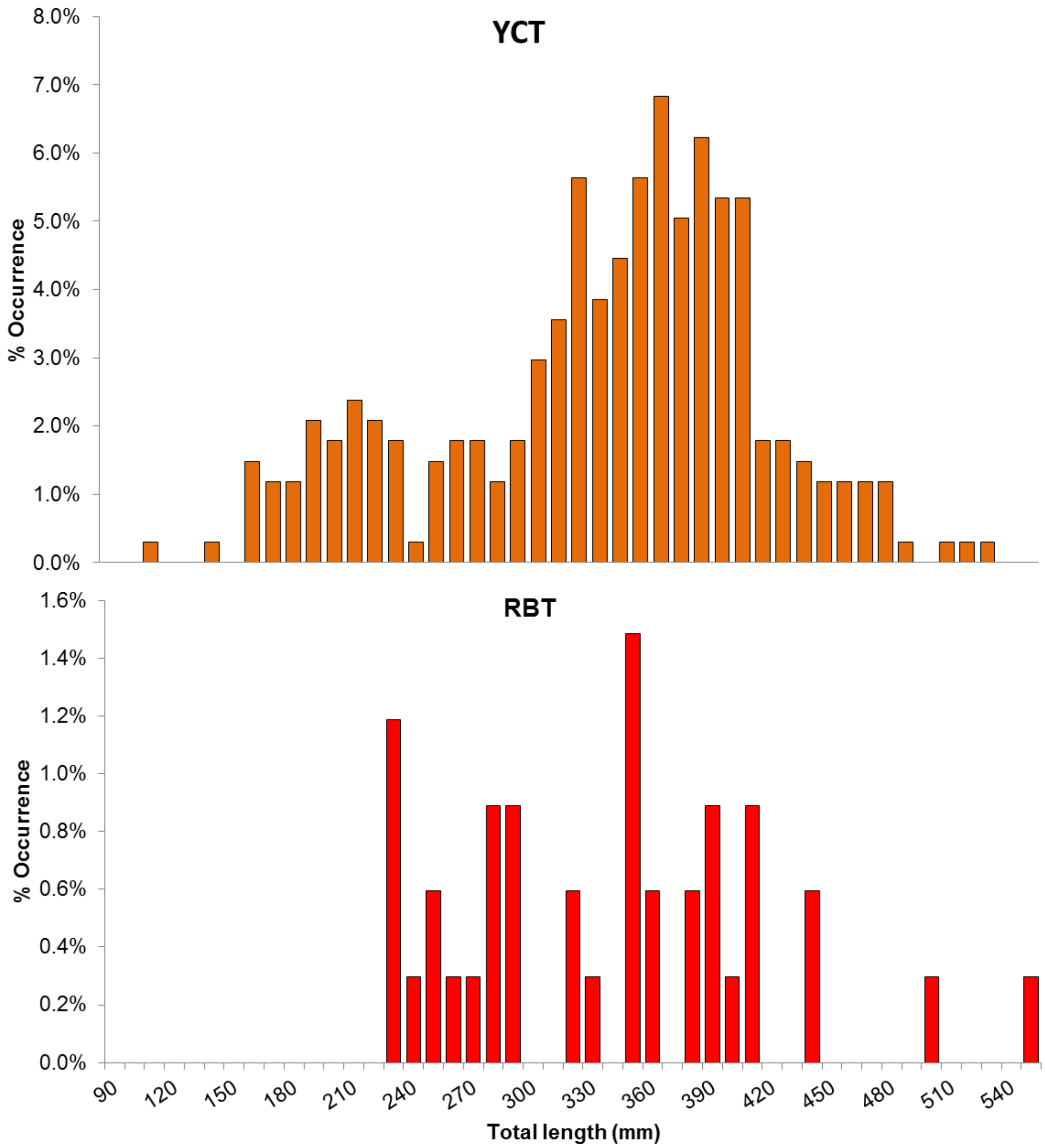

Figure 53. Length frequency distribution of trout at the Parkinson reach of the Teton River, 2015.

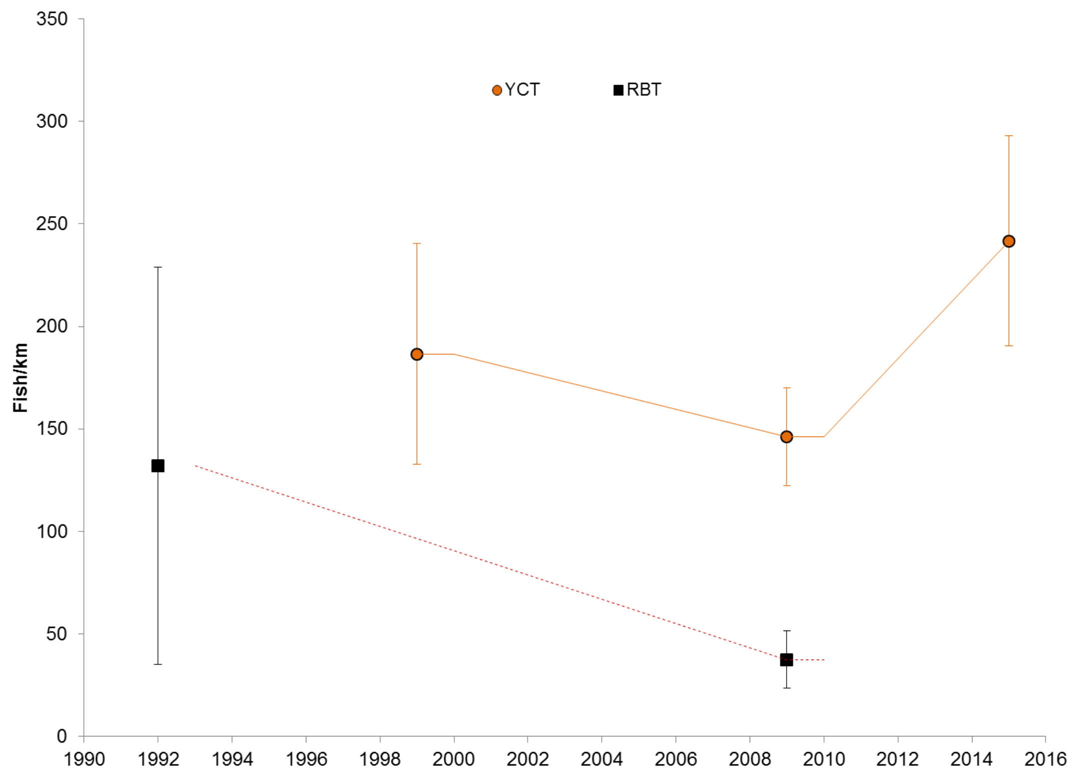

Figure 54. Estimated abundance (with 95% confidence intervals) of Yellowstone Cutthroat Trout (YCT) and Rainbow Trout (RBT) in the Teton River at the Parkinson reach from 1992 through 2015.

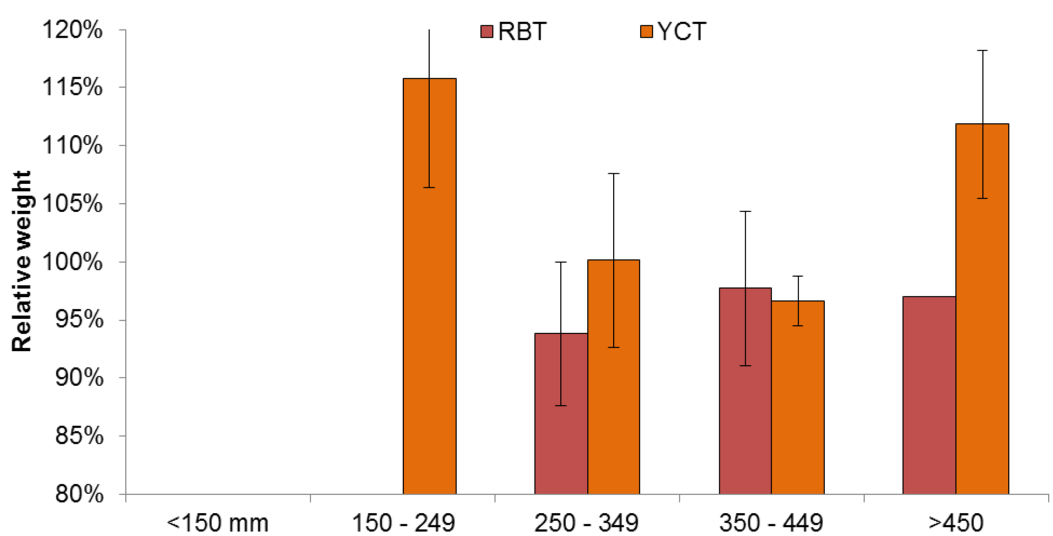

Figure 55. Mean relative weight and 95% confidence intervals of Yellowstone Cutthroat Trout (YCT) and Rainbow Trout (RBT) in the Teton River at the Parkinson reach in 2015.

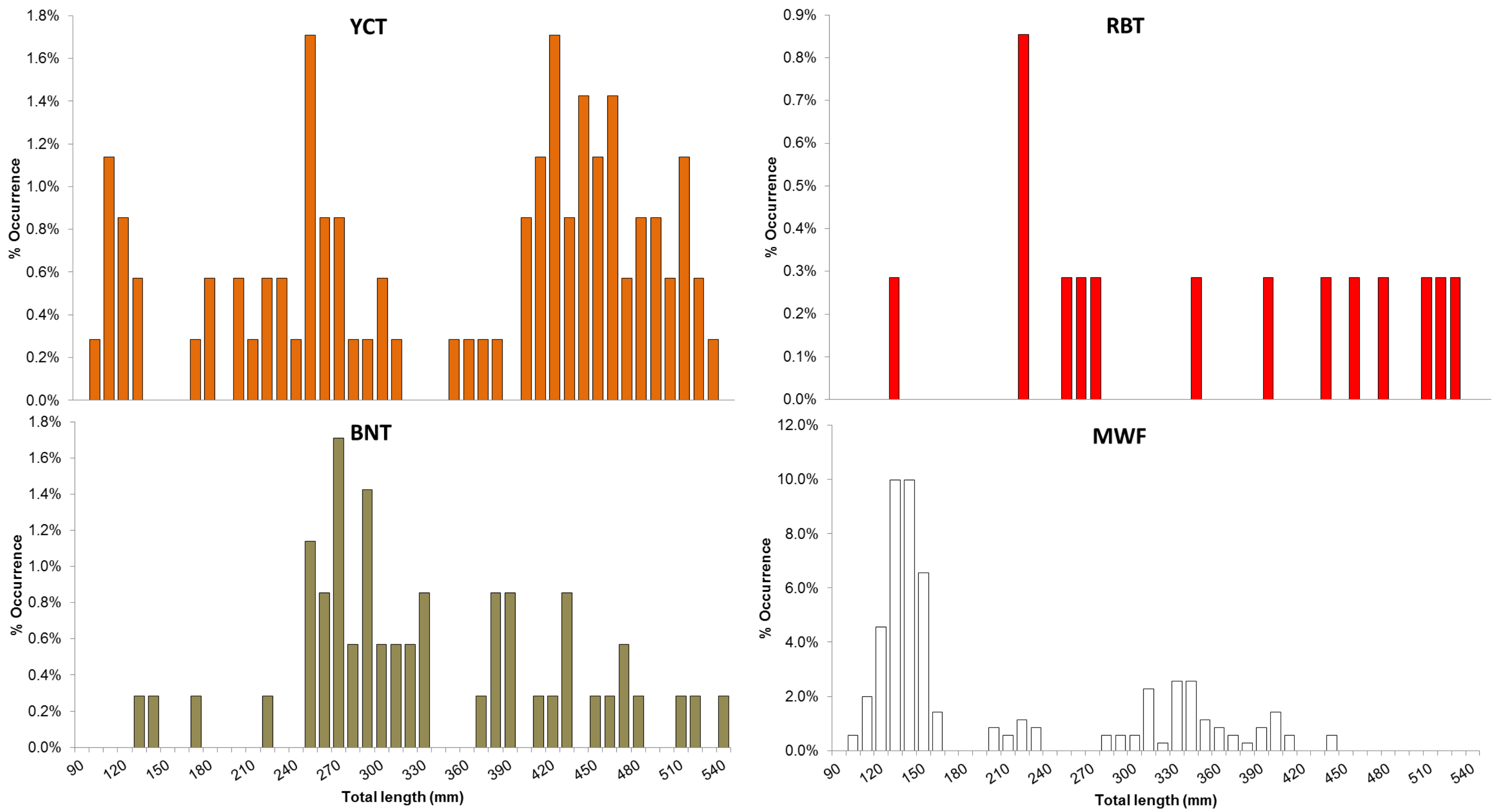

Figure 56. Length frequency distribution for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brown Trout (BNT) and Mountain Whitefish (MWF) at the South Fork Teton reach of the Teton River, 2015.

Figure 57. Estimated abundance and associated 95% confidence intervals of Yellowstone Cutthroat Trout (YCT) and Rainbow Trout (RBT) in the Teton River at the South Fork Teton reach from 1993 through 2015.

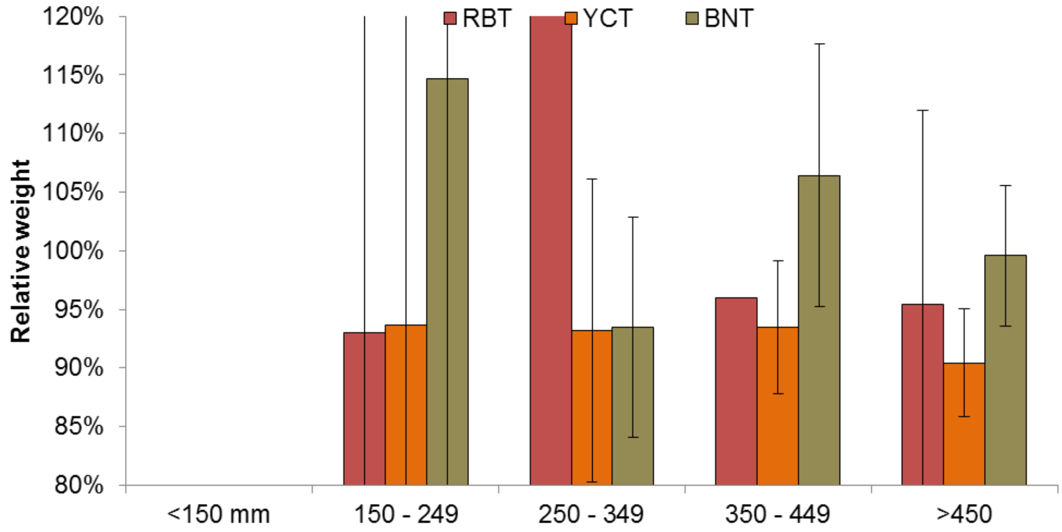

Figure 58. Mean relative weight and 95% confidence intervals of Rainbow Trout (RBT), Yellowstone Cutthroat Trout (YCT) and Brown Trout (BNT) in the South Fork Teton River reach in 2015.

SOUTH FORK SNAKE RIVER

ABSTRACT

Monitoring surveys on the Lorenzo reach of the South Fork Snake River indicated stable abundance and relative weights (W_r) for Yellowstone Cutthroat Trout (YCT) and Brown Trout (BNT), while at the Conant reach, YCT, BNT, and rainbow trout (RBT) have increased in abundance with stable W_r (93 to 99%). We continued assessing irrigation canal entrainment rates of YCT, BNT, and RBT using radio telemetry. We marked 182 YCT, 42 BNT, and 17 RBT in the lower, canyon, and upper strata of the South Fork in 2015. Entrainment rates averaged 7% overall, with higher entrainment for lower strata trout (12%) where the canals are located, than in the canyon strata (7%) or upper strata (2%). Entrainment rates were higher for YCT than for BNT or RBT, which mirrored the ranking of migration distances observed for each species. Locations of fish during spawning seasons were mostly in the main river for all species, but 24% of radio tagged YCT spawned in tributaries. Increases in spring flows are positively correlated with age-1 YCT abundance the following year, but no such relationship has been observed between RBT and spring flows. The Angler Incentive Program (AIP) remains an important tool for educating anglers about nonnative trout impacts on native YCT. More harvested RBT have been turned in during 2015, but the number of participants remains static. Participants are mostly local anglers, half of which use bait as opposed to other methods. Non-resident fly anglers are not proportionally represented in the AIP based on ratios obtained from creel surveys. We assessed the spawning stream fidelity of YCT as well as the spawning frequency of these tributary spawners using PIT tag data. We observed high fidelity rates (98%) and spawning frequencies representative of annual spawners for both male and female YCT. Threats to YCT populations remain in the South Fork, but consistent and adaptive management can continue to help YCT to increase in abundance and maintain population viability.

Authors:

Brett High
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

INTRODUCTION

The South Fork Snake River (henceforth South Fork) in Eastern Idaho supports a robust population of wild trout including an important population of native Yellowstone Cutthroat Trout (YCT). Other trout present in the South Fork include Rainbow Trout and Rainbow x Cutthroat Trout hybrids (RBT) and Brown Trout (BNT). Since 2004, a three-pronged management approach has been used to accomplish the objectives outlined in the state fish management plan including preserving the genetic integrity and population viability of native Yellowstone Cutthroat Trout and limiting RBT to less than 10% of the species composition of the catch at the Conant monitoring reach during annual fall electrofishing surveys (IDFG 2013). This report summarizes management and research activities on the South Fork Snake River in 2015. For a broader description of the South Fork Snake River and additional background information see Schoby et al. (2013).

METHODS

South Fork Population Monitoring

The methodology for annually monitoring fish abundances and trends in the South Fork, operating and evaluating the tributary weirs, assessing the effects of spring flows on YCT and RBT recruitment, implementation and analysis of the South Fork Angler Incentive Program, and analyses using PIT tag data, can be found in detail in Schoby et al. (2013). Methods used in 2015 were identical to those outlined in the referenced report.

In addition to methods used during previous years, we compared length-weight relationships for each trout species caught at the Lorenzo and Conant monitoring reaches of the South Fork. During the electrofishing surveys we weighed a subsample of each species at each of the electrofishing reaches. We then compared these observed weights with standard weights calculated for each species. We used the standard published by Kruse and Hubert (1997) for YCT, the standard published by Simpkins and Hubert (1996) for RBT, and the standard published by Milewski and Brown (1994) for BNT. We calculated relative weights (*Wr*) for each of the sampled trout that were weighed and compared these with relative weights from 2002, 2003, 2012, 2013, and 2014 for trout at the Lorenzo Reach and with relative weights from 2002, 2012, 2013, and 2014 for trout at the Conant Reach. Comparisons were based on 100 mm length groups and were compared among years using 95% confidence intervals where non-overlapping intervals were considered statistically significant at the $\alpha = 0.05$ level.

Radio Telemetry

We initiated a five-year telemetry study to determine trout movements in the South Fork starting in the summer of 2013. In 2015, we continued this telemetry study. In the lower portion of the South Fork there are seven large, unscreened irrigation canals. These include the Anderson Canal, Eagle Rock Canal, Enterprise Canal, Farmer’s Friend Canal, Dry Bed Canal, Sunnydell Canal, and Reid Canal. As in 2013, we stratified the study area into three sections, the lower section, canyon section, and upper section. The lower section is 38.6 river kilometers in length and is located from the confluence upstream to near the Wolf boat ramp. The canyon section is 32.2 river kilometers in length and extends from near the Wolf boat ramp upstream to near the mouth of Pine Creek. The upper section is 29.0 river kilometers in length and is located from near the mouth of Pine Creek upstream to Palisades Dam. We marked YCT, RBT, and

BNT with two sizes of coded VHF radio transmitters. The larger transmitters were 12 x 53 mm, weighed 10 g in the air, and are expected to have a 528 d battery life with a 5 s burst rate for the signal. The small tags we used measured 9.5 x 32 mm, weighed 4.5 g, and are expected to have a 196 d batter life. Both sizes of radio transmitters included motion sensors which caused a different unique code to be transmitted if the tag sat idle for 24 h. We placed 80% of the available transmitters in YCT, 15% in BNT, and 5% in RBT.

We used boat-mounted electrofishing gear to capture trout for tagging from March 16 to May 5. After radio tags were implanted, fish were held overnight in cages, and released the following day in the same river section they were captured. We surgically implanted radio transmitters into the body cavities of trout. Fish were measured to the nearest mm (total length) and weighed to the nearest g before being placed in an anesthetic bath. We weighed fish to ensure the transmitter used did not exceed 3% of the body weight of the fish (Brown et al. 1999). We anesthetized fish and placed them belly up in a tray mounted above the cooler once equilibrium was lost. We used a small battery-powered bilge pump attached to an adjustable hand-held sprinkler to keep the gills flooded with water during the surgery. With one worker constantly flushing the gills with water, a second would make a short 2-3 cm incision in through the body wall of the belly anterior to the pelvic fins. We then inserted a grooved director through the incision and back near the vent to shield internal organs from damage. We then inserted a catheter needle through the body wall near the vent onto the groove director which we used to guide the point of the needle out through the incision anterior to the pelvic fins. Next we inserted the transmitter's antenna through the catheter needle and then removed the needle leaving the antenna trailing out of the fish. We used the antenna to gently pull the tag into the fish's body cavity. We also placed a PIT tag in the body cavity with the radio transmitter. Next, we used 3-0 nylon suture material to seal the incision using three to four sutures. We treated the incision and antenna wound with iodine and placed the fish in a bucket of fresh water for recovery. We recorded time to loss of equilibrium, surgery time, and recovery time (time to regain equilibrium) during each surgery. Once fish recovered equilibrium, we placed them in a PVC tube holding cage secured in calm water, and held tagged fish until the following day when they were released.

We monitored fish locations weekly through October, and then monthly in November and December, as fish movements subsided. Fish locations were recorded using a hand-held GPS device during mobile tracking efforts. Proximity to a fish was estimated when power readings on the receiver exceeded 200 with the gain level at or below 50. When we were confident in the nearby location of a radio-tagged fish, we recorded the GPS location. We used jet boats, rafts, and trucks to track along the river and adjacent canals. We also used fixed receiver stations to monitor tagged fish movements throughout the system and to help fill in information gaps between mobile tracking surveys. Fixed receivers stations were placed in seven locations: downstream of the Menan boat ramp, downstream of the Lorenzo boat ramp, at the Great Feeder irrigation diversion, at the Eagle Rock Canal diversion, at the Anderson Canal diversion, at Reid Canal, and near the mouth of Mud Creek. Fixed stations all had two or three antennas searching either a combination of canals and main river directions (two antenna set up) or a combination of main river upstream, main river downstream, and down canals for radio signals.

We recorded fish locations in an Access database which we used to summarize fish movements and final locations for 2015. We summarized fish movements by describing distance moved (river km) from the tagging location through December 2015 and the percentage of tagged fish entrained in the irrigation canal system.

We calculated entrainment rates into canals separately for 2013, 2014, and 2015. For 2013, entrainment rates were left uncorrected for natural mortality by simply dividing the number of radio-tagged fish entrained into canals by the total number of fish marked with radio-tags. For 2014 and 2015, entrainment rates were based on the number of fish we determined were alive through the entire summer irrigation season (May-September). Only radio tagged fish that were alive through the entirety of this period were included in the entrainment estimate – fish that died due to other causes during the timeframe were excluded from this analysis. These included fish that were marked in 2013 that were still alive (as evident by movement between location events) as well as those new fish marked in March of 2014 and 2015 with radio tags. Fish marked in 2013 were deemed still alive if they had moved more than one river mile between October 2013 and April 2014 and the same for fish marked in 2014. Entrainment rates for 2015 were calculated separately for each species by study strata (lower river, canyon, and upper river). We used linear regression to assess the effect of canal flow on the number of fish entrained using the June flow values listed in Table 16 as the predictor value. We also summarized the location and the timing of entrainment where sufficient data was available, as well.

We mapped the locations of radio-tagged trout during their respective spawning seasons. We inferred general spawning locations based on prior movements and “proximity” relocations assigned during the peak of spawning season and marked these on a map. The map included only one spawning location per individual fish. We also described the migratory behavior of each species by calculating the average distance in river miles from the tagging location to the spawning location as well as the minimum and maximum observed migrations.

PIT Tags

We used PIT Tag recapture information to assess spawning stream fidelity and factors that affect it such as tributary location, inter-annual variability, and gender. We used Program R and analyzed ‘subsequent’ spawning data over a period of six continuous years, from 2009-2014. Only a single recapture of YCT occurred at Rainey Creek where spawning runs are small. This one record was removed from the analyses to reduce bias in summations of straying rates. In the fidelity analysis, the response variable was fidelity, which we defined as repeated spawning in the same tributary fish were marked in, and the predictor variables included tributary, year, and gender. We summarized data in R. Due to the low number of strays (PIT-tagged fish observed in two or more tributaries during different spawning season) especially for female YCT, we could not construct meaningful models with interactions that included year or interactions between tributary and sex. We then constructed all possible logistic regression models using the glm function in R, and calculated Akaike’s information criteria corrected for small sample sizes (AICc) to select the best model. We then used the coefficients of the best model to interpret model results to assess direction and degree of influence for each of the variables.

We also used PIT tag data to assess the frequency of YCT spawning in South Fork tributaries. We used logistic regression in Program R to assess spawning frequency of South Fork YCT with the observed probability of spawning each year as the response variable and year and gender as predictor variables. By using the observed probability of spawning each year as the observed variable, more weight was given to YCT with greater number of years they were recaptured during spawning runs. We used the glm function in R to perform the logistic regression analysis. First, however, we fit the full model using a dispersion parameter to test for overdispersion. With overdispersion not evident, we proceeded by fitting all available models using the predictor variables and then used AICc scores to choose the best model. Once the best model was selected, we then used coefficients to interpret model results and then calculated the probabilities for YCT spawning in each of the tributaries.

RESULTS

South Fork Population Monitoring

We captured 1,496 trout at the Lorenzo monitoring reach, including 183 YCT, 29 RBT, and 1,284 BNT. Our density estimates (± 95% CI) include age-1 and older YCT (≥102 mm) and BNT (≥178 mm). We estimated YCT densities at 298 (± 206) fish/km (Figure 59). The trend for YCT density estimates at Lorenzo from 1987 through 2003 was stable as indicated by an intrinsic rate of change (*r*) of -0.01 which was significantly different than zero at the α = 0.10 level (*F* = 0.153, df = 9, *P* = 0.71). In 2005, the abundance of YCT at Lorenzo did decrease below the long-term average to a low of 76 YCT/km. Since 2005, YCT abundance has increased, but this trend is not statistically significant at α = 0.10, with an intrinsic rate of growth of 0.06 (*F* = 10.66, df = 8, *P* = 0.33). Mean relative weight for YCT at Lorenzo was similar to recent years (Figure 60). We estimated BNT densities to be 730 (± 131) BNT per kilometer at Lorenzo (Table 17; Figure 59). The BNT estimates of abundance at Lorenzo had a significantly increasing trend over the 1987 through 2003 time period with *r* = 0.09 (*F* = 17.488, df = 9, *P* = 0.003). Since the start of the three-pronged management approach on the South Fork, BNT abundance at Lorenzo has had a stable trend with r = -0.02 which was not significantly different than zero (*F* = 0.466, df = 10, *P* = 0.51). Brown Trout had similar relative weights in 2015 as in previous years (Figure 61). We captured too few RBT to generate a population estimate using mark recapture techniques, but RBT did comprise 1.9% of the catch. Extrapolating 1.9% with the total trout estimate (1,028 trout/km) indicates RBT density is around 19 RBT/km at Lorenzo. Relative weights for RBT at Lorenzo averaged 95%, and were similar to previous years (Figure 62).

We captured a total of 2,964 trout at the Conant monitoring reach. This included 1,056 YCT, 959 RBT, and 949 BNT. We estimated the total trout density at 3,168 (± 210) trout/km with 1,069 age-1 and older YCT/km (± 127) (Table 18; Figure 63). Prior to the three-pronged management approach on the South Fork (1982-2003), YCT at the Conant monitoring reach experienced a statistically significant decrease in abundance, with an intrinsic rate of growth *of* -0.04 (*F* = 11.697, df = 13, P = 0.005). Since management changed to the three-pronged management approach in 2004, YCT at Conant have experienced a significantly increasing trend in abundance with *r* = 0.06 (*F* = 6.202, df = 11, *P* = 0.03). Relative weights for YCT at Conant were similar among years with YCT >350 mm general having lower relative weights than smaller YCT (Figure 64). The average relative weight was 99. We estimated there to be 779 age-1 and older BNT/km (± 196) at Conant. Brown Trout abundance prior to the three-pronged management approach (1982 – 2003) was stable (*r* = 0.01, *F* = 0.542, df = 13, *P* = 0.48). Since 2004, BNT abundance has increased at Conant with an intrinsic rate of population growth rate of 0.09 (*F* = 11.784, df = 11, *P* = 0.006). Brown Trout relative weights were stable among years and averaged 106% (Figure 65). We estimated there to be 653 age-1 and older RBT/km (± 84) in the Conant monitoring reach in 2015. Between 1982 and 2003, RBT abundance has increased (*r* = 0.18, *F* = 85.489, df = 11, *P* = <0.001). From 2004 through 2015, RBT abundance continued to increase, but with a lower intrinsic rate of growth at *r* = 0.06 (*F* = 4.056, df = 11, *P* = 0.07). Relative weights for RBT at Conant were consistent across the size groups among recent years and averaged 100 (Figure 66).

At Lufkin reach, we captured a total of 1,659 trout. This included 689 YCT, 406 RBT, and 458 BNT. For age-1 and older trout, we estimated there were 1,065 YCT/km (± 165), 439 BNT/km (± 95), and 616 RBT/km (± 152) (Table 19). The average relative weight for YCT was 100%, 93% for BNT, and 96% for RBT at Lufkin.

Weirs

From April 6 through July 3 we captured 1,358 migrating trout at the Burns Creek weir, including 1 male RBT and 1,357 YCT (627 males and 729 females). At Burns Creek, 23% of the male YCT captured at the trap fell back over the weir and were recaptured at the fish trap during the same spawning season. Female YCT at Burns Creek fell back at a rate of 12%. We captured 53 fluvial-sized YCT upstream of the Burns Creek weir using backpack electrofishing gear, and found 50 of 53 were marked indicating they were handled at the fish weir. Thus, the 2015 trapping efficiency estimate for the Burns Creek weir was 94% (Table 20).

We operated the Pine Creek weir from April 1 through June 25, capturing a total of 1,867 fish of which three were RBT (all females). The 1,864 YCT included 787 males and 1,077 females. The fallback rates were 4% for male and 2% for female YCT. Upstream of the weir, we again used backpack electrofishing units to collect a sample of fluvial-sized fish and caught a total of 37 YCT, of which 29 had marks, so the 2015 efficiency estimate for the Pine Creek weir was 78%.

At the Palisades Creek weir, we caught a total of 846 migrating trout between April 2 and July 18. These included 14 RBT: 6 males and 8 females. The remainder were YCT, and included 323 male YCT and 509 female YCT in the trap. Fallback rates for male YCT were 6% and 3% for females. A screened irrigation diversion near the Palisades Creek weir was used to generate a weir efficiency estimate. Most of these fish (56 of 59) had marks indicating they were captured at the weir during their upstream migration, so the 2015 Palisades Creek electric weir efficiency estimate was 95%.

We operated the Rainey Creek weir from April 1 through June 21, capturing a total of 75 trout, including two RBT (one male and one female). The remaining 73 fish included 29 male YCT and 44 female YCT. We had a single YCT that fell back through the Rainey Cr weir in 2015, so fall back rates were 0% for male YCT and 2% for female YCT.

Radio Telemetry

We marked a total of 241 trout with radio transmitters in 2015. We placed 25% of these tags (59) in the lower section, 46% (113) in the canyon section, and the remaining 29% of the tags (69) in the upper section. Tags were allocated based on YCT densities in the different sections with sections with higher YCT densities receiving more tags. We placed 80% of the available radio tags for each section in YCT, 15% in BNT, and 5% in RBT. In the lower section we marked 47 YCT, nine BNT, and three RBT. In the canyon section we marked 90 YCT, 18 BNT, and five RBT. In the upper section, we marked 45 YCT, 15 BNT, and nine RBT. The overall average surgery time was 3:36 from start to finish. We did not observe any mortalities when returning the following day to release fish.

There were 209 active (live) trout with radio tags during the 2015 irrigation season, and 14 (7%) were entrained into a canal between April 1 and the close of irrigation season on October 1. The entrainment rates for each study strata were 12% for radio-tagged fish in the lower river strata (7 out 57 trout), 7% for the canyon strata (6 out of 91 trout), and 2% for the upper river strata (one out of 61 trout). Entrainments rates were variable for each species (Table 21). In the lower strata, where all the canals are located, entrainment rates were 17% for YCT (7 of 41 trout) and 19% for BNT (three out of 16 trout). We were unable to estimate entrainment rates in 2015 for RBT in the lower strata as none of the three RBT marked in 2015 with radio tags persisted through the irrigation season nor did any RBT survive through the irrigation seasons in either 2013 or 2014. In the Canyon strata, entrainment rates were 9% for YCT (six out of 64 trout), 0% for RBT (none out of six trout), and 0% for BNT (none out of 21 trout). In the upper river strata, entrainment rates were 3% for YCT (one out of 14 trout), 0% for RBT (none out of eight), and 0% for BNT (none out of 14 trout). Entrainment was only documented in two canals in 2015, including 12 radio-tagged fish entrained in the Dry Bed Canal, and two fish entrained into the Sunnydell Canal (Table 22). These two canals are the largest and smallest canals in the South Fork, respectively (Table 16).

We identified locations for 96 YCT during the spawning season (Figure 67). The average migration distance from the site of tagging was 10.6 river km in the downstream direction. The range of YCT migrations from the initial capture location was -50.9 km downstream to 73.4 km upstream. Of the 96 YCT we observed during the spawning season, five YCT migrated into Burns Creek, 16 YCT entered Pine Creek, and two entered Palisades Creek. We observed 24% of the radio-tagged YCT in 2015 in spawning tributaries during spawning season.

We relocated 22 BNT during their spawning season, and assessed their migration distances and direction from their summer locations (Figure 68). The average migration distance was 7.2 km in an upstream direction, and ranged from -37.7 river km downstream to 59.1 river km upstream.

We identified general fish locations for nine RBT during spawning season in 2015 (Figure 69). The average migration distance for these RBT was -0.3 river km in the downstream direction, and ranged from -9.5 river km downstream to 5.0 river km upstream. The locations of these nine RBT during spawning season was dispersed throughout the river instead of clustered in a few areas, and YCT were present in these areas during spawning season (Figure 70).

Spring Flows

Higher spring flows in the South Fork were significantly correlated with increased abundance of age 1 YCT the following year. Maximum spring flows released from Palisades Dam were positively related with increased age-1 YCT abundance (F = 6.185, df = 9, P = 0.04). Analysis of residuals indicated data were distributed normally.

The abundance of age-1 RBT was not correlated with spring flows the previous year. Analysis of residuals indicated age-1 RBT data were not normally distributed, so we log-transformed age-1 RBT abundance and regressed these with log-transformed maximum spring flow values for the prior year. Log transformations normalized the data. However, age-1 RBT was not correlated with maximum spring flows (F = 1.418, df = 10, P = 0.26).

South Fork Angler Incentive Program

In 2015, we marked 628 RBT with coded wire tags (CWT) between Palisades Dam and Heise for the Angler Incentive Program. We tagged 352 RBT with $50 tags, 200 with $100 tags, 50 with $200 tags, 20 with $500 tags, and 6 fish with $1,000 tags. A total of 177 anglers turned in 2,543 RBT in 2015 (Figure 71). Based on the 17% compliance rate for turning in harvested Rainbow Trout estimated in 2012 (High et al. 2014), these Rainbow Trout likely represent

14,959 harvested rainbows in total. Overall, anglers turned in a median of six RBT and an average of 15 RBT. Of the 2,543 RBT brought in to IDFG there were 72 tagged fish. The tag values and number that were turned in were $50 (44), $100 (17), and $200 (11) for a total of $6,100. The tags that were turned in during 2015 were originally placed in RBT in the South Fork over multiple years (Table 23). Just over half of the marked RBT turned in (38 or 53%) were turned in by anglers who did not use bait. The remaining 34 winning RBT (47%) were caught using bait. Overall, roughly half (57%) of the anglers who participated in the angler incentive program used bait.

PIT Tags

We observed high fidelity for spawning streams in the South Fork exhibited by fluvial YCT. We documented 1,052 individual PIT tagged YCT over a six year period that spawned on two or more occasions. More than 98% of these recaptured YCT were observed in the same spawning tributary. Of the 13 YCT that strayed among tributaries, eight strayed from Palisades Creek (two female and six male), three strayed from Pine Creek (one female and two male), and two male YCT strayed from Burns Creek. Logistic regression analysis and AICc scores indicated tributary was the most important predictor, occurring in the top four models, and the best model predicting spawning stream fidelity included all three predictor variables (Table 24). With Burns Creek, 2009, and female YCT set as the reference group, the exponentiated coefficients of the log (odds) indicated straying was not significantly different between Burns Creek and Pine Creek, but had 112% higher odds of straying from Palisades Creek than Burns Creek. Also, the odds of straying was 3.5 times higher for males than female YCT, and straying odds were 6.25 times greater in 2009 than either 2012 or 2013 (when straying was documented).

Most Fluvial YCT in the South Fork that spawn in tributaries spawn annually. We included records from the same YCT used in the fidelity analysis when we investigated if tributary or gender affected spawning frequency. It was clear that tributary was the most important predictor variable, and we chose the model with tributary as the only predictor variable to be the best model (Table 25). We observed 62% of the YCT In Burns Creek spawned annually while 55% of YCT in Pine Creek, 46% of YCT in Palisades Creek spawned annually.

DISCUSSION

South Fork Population Monitoring

Trout abundances in the Lorenzo reach of the South Fork were similar in 2015 to most of the recent five years. Trout populations vary annually because of a variety of factors including flows (Moller and Van Kirk 2003), temperature (Isaak and Hubert 2004), disease (Hedrick et al. 1998), genetics (Guinand et al. 2003), variable recruitment, angler harvest (but not in our case), and various other natural and anthropomorphic factors. Overall, trend analysis from electrofishing data suggest trends are stable for BNT and YCT at Lorenzo since the three-pronged management approach was initiated in 2004.

At the Conant monitoring reach, both RBT and YCT abundances have significantly increased since 2004, but it is possible that these trends - particularly for RBT - may change in coming years. A scatterplot of the density estimates for RBT since 2004 resembles a bell curve, with the peak of the bell in 2009. In 2009, fall surveys documented a doubling of the RBT abundance at Conant with over half the abundance comprised of age-1 fish (High et al. 2011), suggesting a strong year class of RBT entered the fishery. Rainbow Trout have a short four to five year life span in the South Fork (DeVita 2014). Thus, the large year class spawned in 2008 have likely been harvested or died of natural causes. The lingering effects of the strong 2008 RBT year class in terms of increased recruits produced by mature individuals are likely diminishing as they too are either harvested or dying of natural causes. Post analysis of intrinsic rates of population change using age-1 RBT data since 2008, indicated the abundance of age-1 RBT recruits have significantly decreased over the 2009 through 2015 time period. These trends will likely result in less RBT in the next year or two of sampling.

In addition to the trends mentioned above, management efforts have likely further limited the RBT population growth rate, but efforts to cause a decrease in RBT abundance to mid-1990 levels (no more than 10% species composition) as stated in the state fisheries management plan (IDFG 2013) have not yet been successful. Currently, RBT represent 32% of the species composition at the Conant monitoring site, a virtual three-way tie with BNT (32%) and YCT (36%). Across their native range, YCT have not persisted as strong populations when RBT are abundant (Allendorf and Leary 1988; Hitt et al. 2003; Gunnell et al. 2008; Muhlfeld et al. 2009; Seiler and Keeley 2007a; Seiler and Keeley 2007b). Yellowstone Cutthroat Trout are still abundant in the South Fork at the Conant monitoring site, but RBT continue to pose a threat to their persistence.

The increasing abundance of BNT at the Conant monitoring reach warrants continued monitoring. Brown Trout are the dominant species in the lower South Fork, but used to be a minor component in the Conant reach. Prior to 2004, BNT species composition ranged from 7 to 21% and exhibited a stable trend, but since that time, BNT abundance has significantly increased similar to BNT trends in the Henrys Fork Snake River (see above). Because this is a trend being observed across the Upper Snake Region and elsewhere, it is likely that the increase in brown trout abundance is related to large-scale environmental changes as opposed to a specific driving force within the South Fork Snake.

Relative weights for all trout species in the Lorenzo and Conant monitoring reaches were similar among years, with average relative weights ranging from 93 to 99. Relative weights close to 100 indicate the fish population is in balance with their food supply whereas relative weights below 85 would suggest fish are underweight and may be too abundant for available food (Flickinger and Bulow 1993). Relative weights for all trout species in the South Fork throughout the length of the river near 100 indicate food supply is not lacking for trout. The South Fork is a productive river and relative weights for all species suggest that it is a conducive environment for growing healthy trout. Although trout abundances commonly exceed 3,000 or more trout per mile, the food supply in the South Fork appears adequate to support this density of fish.

Weirs

This was the second consecutive year since 2010 that we were able to effectively operate weirs and traps on all four major spawning tributaries of the South Fork and we observed relatively strong spawning runs of YCT in three of the tributaries compared to the previous five years. The total number of YCT captured at all of the weirs in 2015 was second only to 2010, when record runs were observed at all tributaries except Burns Creek. The high number of YCT captured at the weirs was aided by high trapping efficiencies, especially at Burns and Palisades creeks which were near 100%.

Trapping efficiencies at Pine Creek have yet to exceed 90% with the electric weir. This is despite efforts to maximize electric weir settings (see Larson et al. 2014) and efforts to exclude migratory fish from the side channel that skirts around the weir. We have always installed a picket weir to exclude fish in the side channel, but since 2013, the side channel picket weir has been reinforced with more sturdy supports and maintained during all flow levels. Despite increasing electrical settings to a point where spinal compressions and injuries are occasionally observed (Larson et al. 2014) and ensuring passage through the side channel is blocked, we have continued to observe efficiencies at Pine Creek in the 70 to 80% range.

Adding an obstacle, such as a submerged check board across the width of the channel to the Pine Creek weir may increase efficiencies. Pine Creek flows can be high, similar to Palisades Creek. However, we do have high trapping efficiencies at Palisades Creek. The main difference between the two sites during the bulk of the spawning run are check boards, which are placed in Palisades Creek once flows begin to recede in order to divert water into the Palisades Canal. There is no diversion associated with Pine Creek, so check boards have only been placed in the weir structure during low flows to increase water velocities through the trap. When flows are high at Pine Creek, we have observed YCT challenging the weir with some individuals fighting through the electrical field most of the way. It may be possible that trapping efficiencies have been negatively affected by some YCT that have pushed through the electric barrier during high flows. Thus, we may increase trapping efficiencies at Pine Creek by placing stop logs in Pine Creek such that fish would need to jump to pass over them.

Radio Telemetry

This was the third year of a five-year study investigating the occurrence and effect of entrainment of South Fork trout into large unscreened diversions. In 2015, we documented lower overall entrainment rates than in 2014 with a 2015 entrainment estimate of 7% compared to 12% in 2014 (Flinders et al. 2018). Additionally, we observed higher entrainment rates for trout marked with radio tags that were initially captured closer in proximity to the middle portion of the South Fork where the large canals are located versus trout that were captured and tagged further away, especially upstream.

Entrainment rates varied by species, and were higher for species that migrated further distances for spawning. Yellowstone Cutthroat Trout had the highest average migration distance and the highest rates of entrainment, followed by BNT, and then RBT. Thus, it appears that the risk of entrainment is correlated with distance traveled. This likely results in disproportional risks of entrainment for YCT which move great distances in the South Fork versus RBT which are more sedentary.

The location of entrainment was different in 2015 than in previous years. Previously, we documented entrainment occurring in all of the major unscreened canals off the South Fork. In 2015, we observed entrainment occurring only in two canals, the Dry Bed Canal and Sunnydell Canal. There is no apparent explanation for this outcome other than random chance. Radio-tagged fish were scattered throughout the entire length of the South Fork and the canals diverted water in a similar fashion during all years. One constant is the fact that the Dry Bed Canal entrains relatively more fish than the other large canals. This seems intuitive because it is also the canal that diverts the largest amount of water. However, other factors such as the location and angle of the headgates relative to the river's thalweg are known to affect entrainment rates (Bahn 2007). In the case of the Dry Bed Canal, where the thalweg is directed to the headgates at a near 90 degree angle and the fact that there is a sharp bend in the river at the headgate bringing the thalweg close to the gates, it is likely these attributes increase entrainment of trout at this location.

The majority of radio-tagged trout in the South Fork appear to spawn in the main river. This is especially true for BNT and RBT which were all documented in the main river during spawning season. We observed more radio-tagged YCT in spawning tributaries in 2015 than in previous years (Flinders et al. In Review). However, tributary spawners still only comprised 24% of the fish relocated accurately during spawning season. This suggests that main river spawning is significant for YCT in the South Fork. The biggest threat to YCT in the South Fork is hybridization and competition with RBT (IDFG 2013). We documented that there is spatial overlap in RBT and mainstem spawning YCT in the South Fork, which has the potential to impact hybridization rates. Temporal overlap in spawn timing has been documented previously in the South Fork (Henderson et al. 2000). Previous modeling exercises investigating the population viability of YCT in the South Fork were performed assuming half of the YCT population spawned in tributaries where trapping and culling efforts at the weirs could effectively limit the impact of hybridization and competition with RBT (Van Kirk et al. 2010). These models highlighted the importance of the weir program in the South Fork relative to the long-term persistence of YCT. If the assumptions the models were based on were inaccurate, which may be the case given these most recent telemetry data, the effective operation of tributary weirs and increased RBT harvest efforts may be even more important to the viability and genetic integrity of the South Fork YCT population which appear to spawn primarily in the main channel where RBT are present.

Spring Flows

Increases in spring flows benefit YCT recruitment, but are not necessarily correlated with reduced RBT recruitment at the magnitude, timing, and duration observed over the past decade. Since 2004, increases in maximum spring flows are correlated with increasing abundance of age 1 YCT the following year. Flows during the past decade ranged from 396 to 668 m^3/s. The relationship between higher maximum spring flows and higher age-1 YCT recruitment are likely related to the fact that YCT use decreasing spring flows as a spawning cue (Thurow and King 1994; Henderson et al. 2000). Tributary flow variations are also likely related to snowpack levels. Increased tributary flows, often associated with high snowpack years, benefit YCT recruitment in spawning tributaries (Varley and Gresswell 1988). The abundance of age-1 RBT was not significantly correlated with flows, suggesting maximum flows did not reach levels sufficient to disturb developing embryos or displace newly emerging fry. This finding corroborates previous studies on the South Fork that indicated spring flows in 2005 peaking at 422 m^3/s were not sufficient to move small radio transmitters placed in RBT redds (Schrader and Fredericks 2006) and that South Fork riverbed material is not mobilized until flow reach 736 m^3/s (Hauer et al. 2004). Previous studies performed on the South Fork indicate flows in excess of 708 m^3/s are required for geomorphic processes to start altering stream channels (Hauer et al. 2004) or providing the most benefit to YCT (Moller and Van Kirk 2003). While we could not detect a statistically significant correlation between maximum spring river flows and age 1 RBT abundance the following year, our dataset does not include maximum flows that are near the range suggested by Hauer et al. (2004).

South Fork Angler Incentive Study

The South Fork Angler Incentive Program plays an important role in IDFG's management of YCT in the South Fork. This program provides a tool for outreach and education about the importance of Yellowstone Cutthroat Trout conservation in the South Fork. This of itself may be enough justification for how much benefit is derived given the program's low operational costs. However, recent population modeling efforts for how YCT populations respond to different levels of harvest and different scenarios of spring flows indicate the Angler Incentive Program as part of the three-pronged management efforts on the South Fork is one of the key factors that is limiting the rate of RBT population growth, and has the potential to cause a population decline, particularly if harvest levels are increased (De Vita et al. 2015).

Anglers participating in the Angler Incentive Program are not representative of anglers on the South Fork as a whole. More than half of the anglers participating in the Angler Incentive Program are bait anglers. While bait fishing is allowed on the South Fork, the most recent creel survey indicated bait anglers comprised only 13% of South Fork anglers (High et al. 2014). Bait anglers are typically residents. In 2015, the majority (86%) of the anglers that participated in the Angler Incentive Program that did not use bait were also Idaho residents. Thus, the largest group of anglers not participating proportionally in the Angler Incentive Program are non-resident fly anglers. Angler participation in the Angler Incentive Program on the South Fork would likely benefit by more participation of clients of local guides and outfitters. As such, increasing guide and outfitter participation should be prioritized in the coming years.

PIT Tags

Previous research has demonstrated that adfluvial (McCleave 1967) and fluvial YCT (Jeppson 1970, Moore and Schill 1984, Schoby et al. 2014) display patterns of tributary fidelity during spawning season. We attempted to identify the drivers of fidelity based on home tributary, gender, and year. Results from our analysis demonstrate strong patterns of tributary fidelity (98.7%). Such high fidelity rates to spawning tributaries in a connected drainage such as the South Fork could lead to the genetic structuring and maintenance of that structure, observed by Cegelski et al. (2006).

While straying rates were extremely low, our models indicated the source tributary was the most important predictor affecting YCT when straying occurred. In our study, YCT from Palisades Creek were more likely to stray than YCT from the other tributaries. To the best of our knowledge, similar findings have not been documented in resident or anadromous trout. A potential explanation for this result may be that fish that strayed from Palisades Creek were not originally from Palisades Creek, and thus did not have a strong homing tendency to return there. Palisades Creek is the first tributary downstream of Palisades Dam. It is possible that YCT from Palisades Reservoir that are entrained through Palisades Dam could migrate into Palisades Creek during spawning season, and consequently be marked with a PIT tag and mistakenly identified as a returning Palisades Creek fish. Regardless of the cause of straying, the overall rate of YCT straying among South Fork tributaries was low causing us to conclude that spawning stream fidelity is high. Secondary variables influencing fidelity include the gender of the fish as well as annual variability. We documented male YCT having more potential to stray from spawning tributaries they were observed in during previous spawning runs. Male biased dispersal among polygamous and promiscuous mammals has been documented (Dobson 1982). Additionally, male biased dispersal among fish, including a brook trout population in Freshwater River Newfoundland, Canada has been documented as well (Hutchings and Gerber 2002). This brook trout population displayed a pattern of movement similar to the YCT of our study. While straying was not the focus of the brook trout study, dispersal distances, with a focus on spawning dispersal of males vs. females were. In the population, male brook trout dispersed significantly further distances during the spawning period than did females (Hutchings and Gerber 2002). However, it should be noted that the population studied was a closed, resident population and the scale of movement was much smaller than that of our study. In another movement study, male brook trout in an adfluvial population in Mistassini Lake, Québec, Canada demonstrated a higher rate of straying than did females among three neighboring tributaries. Conversely, in a fourth tributary approximately 90 to 100 km in distance from the three neighboring tributaries, females were more likely to stray (Fraser et. al 2004).

Fluvial YCT spawning in South Fork tributaries spawn annually in most years. In both Young and Hungry creeks in Montana, repeat spawning occurs on an annual basis by fluvial Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi* (WCT; Huston 1972; Huston 1973 in Likens and Graham 1988). However in other drainages in Montana, alternate year spawning tends to predominate in repeat spawning behavior of WCT (Liknes and Graham 1988). An adfluvial resident RBT population in Loon Lake, British Columbia was observed to spawn both annually and in alternate years (Lindsey et al 1959). The most important predictor affecting spawning frequency in our models was tributary. This may be the result of one of the limitations of our study. We relied on recapture events of PIT-tagged YCT at each of the spawning tributaries in order to compile data for our analyses. In order for the analysis of spawning frequency to be truly comparable among tributaries, we would need capture efficiencies to be equal at all of the streams. This was not the case. Trapping efficiencies at Burns Creek are generally higher than at Pine Creek or Palisades Creek (High et al. 2015). This was especially true in 2011, when damage caused by high flows at Palisades Creek forced us to shut down trapping efforts and let fish go up the creek without interference. Trapping efforts in 2011 were suspended early enough that the run had not peaked. Therefore, the fact that tributary, particularly Palisades Creek, was the most influential variable affecting stray rates and the fact that annual spawning frequencies were higher in streams where we generally had higher trapping efficiencies, we could assume that trapping efficiencies were potentially the cause of these results. Despite this potential limitation, spawning frequencies we estimated using our models, yielded similar results and we interpret these as evidence that fluvial YCT in the South Fork tributaries are annual spawners similar to YCT in Yellowstone Lake (Jones et al. 1985 in Varley and Gresswell 1988).

In our study, YCT spawned annually, or nearly so, and both male and female fish followed this trend. There are a number of studies that document repeat spawning periodicity of varying resident salmonid species; adfluvial RBT (Lindsey et al. 1959), fluvial YCT (Moore and Schill 1984), fluvial WCT (Schmetterling 2001). However, to the best of our knowledge, the frequency of male vs. female spawning has not been documented until now.

RECOMMENDATIONS

1. Continue to monitor effects of spring freshets, the operation of tributary weirs, and angler harvest of RBT on South Fork Snake River RBT, YCT, and BNT populations and adjust management actions accordingly.

2. Continue to use tributary weirs to protect spawning YCT in South Fork tributaries from risks of hybridization and competition.

3. Continue efforts to boost harvest of RBT through the Angler Incentive Program.

4. Manually remove RBT from Palisades Creek between the weir and Lower Palisades Lake.

5. Assess trout distribution and densities in the entire Pine Creek drainage.

6. Continue to use PIT tags to monitor YCT movements, spawning locations, periodicity, duration, recruitment, and survival.

Table 16. Rankings of South Fork Snake River canals based on average June 2015 volumes (IDWR 2015).

Canal	m^3/s
Dry Bed Canal	1160
Eagle Rock Canal	213
Farmer's Friend Canal	123
Anderson Canal	117
Market Lake Canal	79
Enterprise Canal	58
Reid Canal	51
Sunnydell Canal	42

Table 17. Summary statistics from the Lorenzo monitoring site between 1987 and 2015 on the South Fork Snake River.

	Yellowstone cutthroat trout							Rainbow trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
1987	146	63	6	9.5	422	207	0.25	2	0	0					65
1988	133	88	13	14.8	187	47	0.13	3	2	0					33
1989	119	74	13	17.6	248	98	0.20	1	2	0					25
1990	208	91	12	13.2	308	145	0.24	2	0	0					68
1991	199	175	17	9.7	445	146	0.17	0	6	0					72
1992															
1993	144	201	18	9.0	487	155	0.16	6	8	0					57
1994															
1995	264	196	22	11.2	568	116	0.10	4	5	0					36
1996															
1997															
1998															
1999	194	163	26	16.0	335	81	0.12	3	4	0					67

	Brown trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
1987	225	102	12	11.8	531	160	0.15	380	168	18	0.1	970	97	0.10	65
1988	241	130	23	17.7	300	88	0.15	386	225	36	0.2	529	49	0.09	33
1989	199	97	22	22.7	185	38	0.10	377	204	35	0.2	677	59	0.09	25
1990	260	93	23	24.7	272	99	0.18	549	240	35	0.1	949	73	0.08	68
1991	319	234	47	20.1	369	56	0.08	560	474	64	0.1	953	65	0.07	72
1992															
1993	238	270	27	10.0	555	105	0.10	420	531	45	0.1	1,213	73	0.06	57
1994															
1995	325	341	41	12.0		101	0.08	677	731	66	0.1	1,587	72	0.05	36
1996															
1997															
1998															
1999	500	588	55	9.4	1,150	161	0.07	711	798	82	0.1	1,485	73	0.05	67

Table 17 continued.

Year	Yellowstone cutthroat trout M	C	R	R/C	YCT/km	SD	CV	Rainbow trout M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2000															
2001															
2002	108	138	14	10.1	246	65	0.13	4	3	1					98
2003	90	81	11	13.6	237	133	0.29	2	2	0					81
2004															
2005	37	47	4	8.5	76	54	0.36	5	2	0					78
2006	112	71	14	19.7	116	25	0.11	10	12	1					
2007	90	41	2	4.9				17	6	0					131
2008	30	34	0	0.0				2	2	0					157
2009	77	110	10	9.1	218	93	0.22	13	10	1					92
2010	110	91	10	11.0	233	83	0.18	8	11	1					91
2011	134	126	12	9.5	279	132	0.24	12	17	0					107
2012	134	106	10	9.4	321	93	0.15	5	11	0					93
2013	150	167	25	15.0	299	72	0.12	17	27	0					66
2014	97	98	21	21.4	117	27	0.12	20	14	1					93
2015	77	109	5	4.6	298	206	0.35	8	21	0					110

Year	Brown trout M	C	R	R/C	BNT/km	SD	CV	Total trout M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2000															
2001															
2002	457	579	61	10.5	1,030	117	0.06	582	750	76	0.1	1,385	65	0.05	98
2003	557	432	61	14.1	926	110	0.06	668	593	72	0.1	1,184	60	0.05	81
2004															
2005	440	486	67	13.8	771	91	0.06	641	569	71	0.1	2,030	155	0.08	78
2006	1,154	933	140	15.0	1,761	148	0.04	1,326	1,064	155	0.1	2,116	76	0.04	
2007	764	446	67	15.0	1,125	110	0.05	888	525	69	0.1	1,504	69	0.05	131
2008	373	365	40	11.0	778	132	0.09	415	418	40	0.1	988	76	0.08	157
2009	603	739	104	14.1	915	90	0.05	718	916	117	0.1	1,236	52	0.04	92
2010	600	545	110	20.2	653	49	0.04	735	709	121	0.2	956	33	0.03	91
2011	323	365	27	7.4	1,058	241	0.12	495	544	39	0.1	1,770	150	0.08	107
2012	437	435	51	11.7	784	99	0.06	607	642	61	0.1	1,329	64	0.05	93
2013	838	714	108	15.1	1,200	121	0.05	1,094	1,041	140	0.1	1,826	68	0.04	66
2014	589	481	72	15	854	90	0.05	761	624	95	0.2	1,203	47	0.04	93
2015	423	558	70	12.5	730	131	0.09	571	986	80	0.1	1,326	70	0.05	110

Table 18. Summary statistics from the Conant monitoring site between 1982 and 2015 on the South Fork Snake River.

	Yellowstone cutthroat trout							Rainbow trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
1982					1,899							16			
1983															
1984															
1985															
1986	1,170	546	70	12.8	2,890	402	0.07	32	16	2	12.5				102
1987	281							5							26
1988	1,100	561	98	17.5	1,491	148	0.05	41	18	1	5.6				103
1989	1,416	1,050	200	19.0	1,610	108	0.03	57	55	10	18.2	102	42	0.21	86
1990	1,733	1,522	317	20.8	2,330	173	0.04	113	109	14	12.8	330	104	0.16	101
1991	1,145	625	140	22.4	1,399	136	0.05	98	54	9	16.7	216	87	0.20	132
1992	595							34							60
1993	972	623	100	16.1	1,512	150	0.05	74	41	6	14.6	177	82	0.24	91
1994	853							87							52
1995	631	542	77	14.2	1,230	147	0.06	130	140	17	12.1	436	116	0.14	93
1996	707	548	72	13.1	1,502	225	0.08	155	111	5	4.5	958	677	0.36	107
1997	910	895	164	18.3	1,145	76	0.03	429	467	72	15.4	974	118	0.06	85
1998	674	682	61	8.9	1,691	204	0.06	216	247	26	10.5	743	127	0.09	110
1999	1,019	883	117	13.3	1,847	163	0.04	345	241	29	12.0	1,055	204	0.10	110

	Brown trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
1982					412										
1983															
1984															
1985															
1986	183	105	8	7.6	641	253	0.20	1,385	667	80	0.12	2,351	236	0.10	102
1987	26							312							26
1988	113	46	4	8.7	340	310	0.47	1,254	625	103	0.16	1,836	88	0.05	103
1989	92	76	11	14.5	191	162	0.43	1,565	1,181	221	0.19	1,791	54	0.03	86
1990	173	117	12	10.3	369	133	0.18	2,019	1,748	343	0.20	2,984	89	0.03	101
1991	150	119	19	16.0	195	52	0.14	1,393	798	168	0.21	1,616	58	0.04	132
1992	76							705							60
1993	101	64	10	15.6	135	78	0.29	1,147	728	116	0.16	1,643	66	0.04	91
1994	110							1,050							52
1995	150	108	13	12.0	294	176	0.31	911	790	107	0.14	1,696	79	0.05	93
1996	212	124	18	14.5	314	78	0.13	1,074	783	95	0.12	2,292	131	0.06	107
1997	344	281	82	29.2	369	203	0.28	1,683	1,643	318	0.19	1,969	48	0.02	85
1998	257	216	49	22.7	249	36	0.07	1,147	1,145	136	0.12	2,191	79	0.04	110
1999	293	241	31	12.9	512	169	0.17	1,657	1,365	177	0.13	2,827	90	0.03	110

Table 18 continued.

	Yellowstone cutthroat trout							Rainbow trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2000	797							260							91
2001	776							321							117
2002	495	394	50	12.7	841	119	0.07	295	257	24	9.3	1,265	314	0.13	72
2003	422	571	72	12.6	840	119	0.07	272	360	29	8.1	1,501	364	0.12	108
2004	315	379	51	13.5	478	61	0.07	227	304	29	9.5	854	168	0.10	114
2005	391	254	30	11.8	658	205	0.16	172	142	11	7.7	678	340	0.26	106
2006	423	365	54	14.8	749	104	0.07	289	251	23	9.2	1,092	287	0.13	89
2007	784	568	72	12.7	1,380	142	0.05	565	361	52	14.4	1,329	182	0.07	116
2008	377	554	51	9.2	1,065	156	0.07	187	318	25	7.9	925	174	0.10	170
2009	623	489	90	18.4	826	87	0.05	475	425	34	8.0	2,270	486	0.11	98
2010	389	307	27	8.8	1,211	284	0.12	286	139	7	5.0	1,893	1,073	0.29	127
2011	609	429	70	16.3	1,225	221	0.09	448	311	28	9.0	1,190	256	0.11	99
2012	721	601	102	17.0	1,059	104	0.05	445	518	44	8.49	1,198	177	0.08	105
2013	784	536	73	13.6	1,401	159	0.06	578	393	52	13.2	1,180	334	0.14	62
2014	488	415	50	12.1	923	132	0.07	350	265	28	10.6	880	172	0.10	77
2015	613	496	63	12.7	1,069	127	0.06	447	330	49	14.9	653	84	0.07	85

	Brown trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2000	133							1,190							91
2001	208							1,305							117
2002	111	104	9	8.7	288	122	0.22	901	755	83	0.11	1,803	81	0.05	72
2003	143	165	27	16.4	240	99	0.21	837	1,096	128	0.12	1,821	67	0.04	108
2004	169	202	22	10.9	383	204	0.27	711	885	102	0.12	1,441	62	0.04	114
2005	115	95	10	10.5	206	105	0.26	678	491	51	0.10	1,588	200	0.13	106
2006	215	223	31	13.9	329	70	0.11	927	839	108	0.13	1,938	80	0.04	89
2007	404	289	50	17.3	530	117	0.11	1,753	1,218	174	0.14	2,713	87	0.03	116
2008	205	253	29	11.5	380	57	0.08	769	1,125	105	0.09	1,882	74	0.04	170
2009	261	219	42	19.2	307	48	0.08	1,359	1,133	166	0.15	2,276	80	0.04	98
2010	178	154	14	9.1	479	136	0.15	853	600	48	0.08	2,295	297	0.13	127
2011	357	300	29	9.7	796	166	0.11	1,414	1,040	127	0.12	3,002	142	0.05	99
2012	561	573	75	13.1	892	111	0.06	1,827	1,776	221	0.12	3,543	95	0.03	105
2013	538	314	52	16.6	752	212	0.14	1,947	1,319	179	0.14	3,136	123	0.04	62
2014	382	273	46	16.9	475	60	0.06	1,276	981	124	0.13	2,473	92	0.04	77
2015	440	295	37	12.5	779	196	0.13	1,670	1,313	156	0.12	3,168	107	0.03	85

Table 19. Summary statistics from the Lufkin site of the South Fork Snake River, 2014 and 2015.

	Yellowstone cutthroat trout							Rainbow trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2014	264	215	15	7.0	1,497	441	0.15	147	107	13	12.2	364	122	0.17	161
2015	376	365	54	14.8	1,065	165	0.08	242	169	25	14.8	616	152	0.13	165

	Brown trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2014	245	191	18	9.4	820	211	0.13	665	520	46	8.8	2,428	104	0.04	161
2015	191	201	27	13.4	439	95	0.11	848	797	108	13.6	2,285	66	0.03	165

Table 20. South Fork Snake River tributary weir summary statistics from 2001 through 2015.

Location and year	Weir type	Operation dates	Estimated weir efficiency (%)[a]	Catch: Cutthroat trout	Catch: Rainbow trout	Catch: Total
Burns Creek						
2001[b]	Floating panel	March 7 - July 20	16	3,156	3	3,159
2002[b]	Floating panel	March 23 - July 5	NE[c]	1,898	46	1,944
2003[d]	Floating panel	March 28 - June 23	17-36	1,350	1	1,351
2004	ND[e]	ND	ND	ND	ND	ND
2005	ND	ND	ND	ND	ND	ND
2006	Mitsubishi	April 14 - June 30	NE	1,539		
2007	ND	ND	ND	ND	ND	ND
2008	ND	ND	ND	ND	ND	ND
2009	Fall/velocity	Apirl 9 - July 22	98	1,491	2	1,493
2010	Fall/velocity	March 26 - July 14	100	1,550	2	1,552
2011	Fall/velocity	March 23 - July 12	90	891	5	896
2012	Fall/velocity	March 24 - July 11	90	496	0	496
2013	Fall/velocity	April 4 - July 2	98	888	6	894
2014	Fall/velocity	April 1 - July 3	90	833	12	845
2015	Fall/velocity	April 6 - July 3	94	1,357	1	1,358
Pine Creek						
2001[b]	ND	ND	ND	ND	ND	ND
2002[b]	Floating panel	April 2 - July 5	NE	202	14	216
2003[f]	Floating panel	March 27 - June 12	40	328	7	335
2004	Hard picket	March 25 - June 28	98	2,143	27	2,170
2005	Hard picket	April 6 - June 30	NE	2,817	40	2,857
2006[g]	Mitsubishi	April 14 - April 18	NE	NE	NE	NE
2007	Mitsubishi	March 24 - June 30	20	481	2	483
2008	Hard picket	April 21 - July 8	NE	115	0	115
2009	Hard picket	Apirl 6 - July 15	49	1,356	1	1,357
2010	Electric	April 13 - July 6	NE	2,972	3	2,975
2011	Electric	April 11 - July 9	49	1,509	1	1,510
2012	Electric	March 28 - July 1	NE	1,427	3	1,430
2013	Electric	April 5 - June 22	89	1,908	1	1,909
2014	Electric	April 7- June 30	70	899	7	906
2015	Electric	April 1 - June 25	78	1,864	3	1,867
Rainey Creek						
2001[b]	Floating panel	March 7 - July 6	NE	0	0	0
2002[b]	Floating panel	March 26 - June 27	NE	1	0	1
2003	ND	ND	ND	ND	ND	ND
2004	ND	ND	ND	ND	ND	ND
2005	Hard picket	April 7 - June 29	NE	25	0	25
2006	Hard picket	April 5 - June 30	NE	69	3	72
2007	Hard picket	March 19 - June 30	NE	14	0	14
2008	Hard picket	June 19 - July 11	NE	14	0	14
2009	Hard picket	April 7 - July 6	NE	23	0	23
2010	Hard picket	April 13 - June 29	NE	145	1	146
2011	Electric	March 28 - June 28	NE	0	0	0
2012	Electric	April 18 - June 23	NE	7	0	7
2013	Electric	ND	ND	ND	ND	ND
2014	Electric	April 29 - June 25	NE	56	2	58
2015	Electric	April 2 - June 21	NE	73	2	75

Table 20 continued.

Location and year	Weir type	Operation dates	Estimated weir efficiency (%)[a]	Catch: Cutthroat trout	Rainbow trout	Total
Palisades Creek						
2001[b]	Floating panel	March 7 - July 20	10	491	160	651
2002[b]	Floating panel	March 22 - July 7	NE	967	310	1,277
2003	Floating panel	March 24 - June 24	21 - 47	529	181	710
2004	ND	ND	ND	ND	ND	ND
2005	Mitsubishi	March 18 - June 30	91	1,071	301	1,372
2006	Mitsubishi	April 4 - June 30	13	336	52	388
2007	Electric	May 1 - July 28	98	737	20	757
2008	ND	ND	NE	ND	ND	ND
2009	Electric	May 12 - July 20	26	202	4	206
2010	Electric	March 19 - July 18	86	545	50	595
2011	Electric	April 7 - June 15	NE	30	13	43
2012	Electric	March 24 - July 2	88	232	20	252
2013	Electric	April 5 - July 8	96	619	23	642
2014	Electric	April 2 - July 18	98	734	63	797
2015	Electric	April 2 - July 18	95	832	14	846
Total by year						
2001				3,647	163	3,810
2002				3,068	370	3,438
2003				2,207	189	2,396
2004				2,143	27	2,170
2005				3,913	341	4,254
2006				1,944	55	460
2007				1,232	22	1,254
2008				129	0	129
2009				3,072	7	3,079
2010				5,212	56	5,268
2011				2,430	19	2,449
2012				2,162	23	2,185
2013				3,415	30	3,445
2014				2,522	84	2,606
2015				4,126	20	4,146
Grand Total				41,222	1,406	41,089

[a]Weir efficiency was estimated using several different methods
[b]From Host (2003)
[c]NE = no estimate
[d]Weir was shut down on June 10, but the trap was operated until June 23
[e]ND = no data; weir either not built or not operated
[f]Weir was shut down early due to high cutthroat trout mortality
[g]Weir was destroyed during high runoff

Table 21. Summary table for fish entrainment of radio-tagged trout into large South Fork Snake River irrigation canals during 2015 summarized by river strata and species. Species marked with radio tags included Yellowstone Cutthroat Trout (YCT), Brown Trout (BNT), and Rainbow Trout (RBT).

Strata	Species	Fish entrained	Fish alive through irrigation season	% Entrainment
Lower	YCT	4	41	9.8%
	BNT	3	16	18.8%
	RBT	0	0	
	Total	**7**	**57**	**12.3%**
Canyon	YCT	6	64	9.4%
	BNT	0	21	
	RBT	0	6	
	Total	**6**	**91**	**6.6%**
Upper	YCT	1	39	2.6%
	BNT	0	14	0.0%
	RBT	0	8	0.0%
	Total	**1**	**61**	**1.6%**

Table 22. Summary table for locations of entrainment of radio-tagged trout into large South Fork Snake River irrigation canals during 2015 summarized by river strata and species. Species marked with radio tags included Yellowstone Cutthroat Trout (YCT), Brown Trout (BNT), and Rainbow Trout (RBT).

Strata	Species	Canal	Timing of entrainment	Fish ID	Year tagged
Lower	YCT	Sunnydell Canal	Prior to May 22	2.137	2013
Lower	YCT	Dry Bed Canal	Prior to Oct. 20	2.123	2013
Lower	YCT	Sunnydell Canal	Prior to July 17	5.014	2015
Lower	YCT	Dry Bed Canal	Prior to Oct. 20	6.007	2015
Lower	BNT	Dry Bed Canal	Prior to May 5	1.129	2013
Lower	BNT	Dry Bed Canal	Prior to Oct. 28	5.001	2015
Lower	BNT	Dry Bed Canal	Prior to Oct. 28	6.005	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 20	6.010	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 28	7.016	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 30	7.014	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 28	7.035	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 29	7.048	2015
Canyon	YCT	Dry Bed Canal	Prior to Oct. 20	7.058	2015
Upper	YCT	Dry Bed Canal	Prior to July 1	3.212	2014

Table 23. Summary table for when the winning Rainbow Trout turned in for the South Fork Snake River's Angler Incentive Program were originally marked with Coded Wire Tags, based on the six digit numbers associated with the different dollar amounts. These six digit codes changed every two years, except for the $200 value where the same code was used four years (2010 through 2013).

Years used	$ 50	$ 100	$ 200
2010-2011	18	6	5
2012-2013	10	0	
2014-2015	15	7	4

Table 24. AIC table for Yellowstone Cutthroat Trout spawning tributary fidelity analysis in the South Fork Snake River from 2009 through 2014 with fidelity as the response variable and spawning tributary, year, and gender as predictor variables.

Model	Parameters	LogL	AICc	ΔAICc	Weight	Cumulative weight
Full model	9	-48.37	114.9	0.0	0.7	0.7
Tributary and year	8	-50.21	116.6	1.7	0.3	1.0
Tributary and gender	4	-57.45	122.9	8.0	0.0	1.0
Tributary	3	-59.01	124.0	9.1	0.0	1.0
Gender	2	-68.55	141.1	26.2	0.0	1.0
Null	1	-70.03	142.1	27.2	0.0	1.0
Year and gender	7	-64.94	144.0	29.1	0.0	1.0
Year	6	-66.41	144.9	30.0	0.0	1.0

Table 25. AIC table for YCT spawning frequency analysis in the South Fork Snake River from 2009 through 2014 with the observed probability of spawning as the response variable and spawning tributary and gender as predictor variables.

Model	Parameters	LogL	AICc	ΔAICc	Weight	Cumulative weight
Tributary	3	-954.66	1915.3	0.0	0.5	0.5
Tributary and gender	4	-954.20	1916.4	1.1	0.3	0.8
Full	6	-952.39	1916.9	1.5	0.2	1.0
Gender	2	-972.76	1949.5	34.2	0.0	1.0
Null	1	-974.51	1951.0	35.7	0.0	1.0

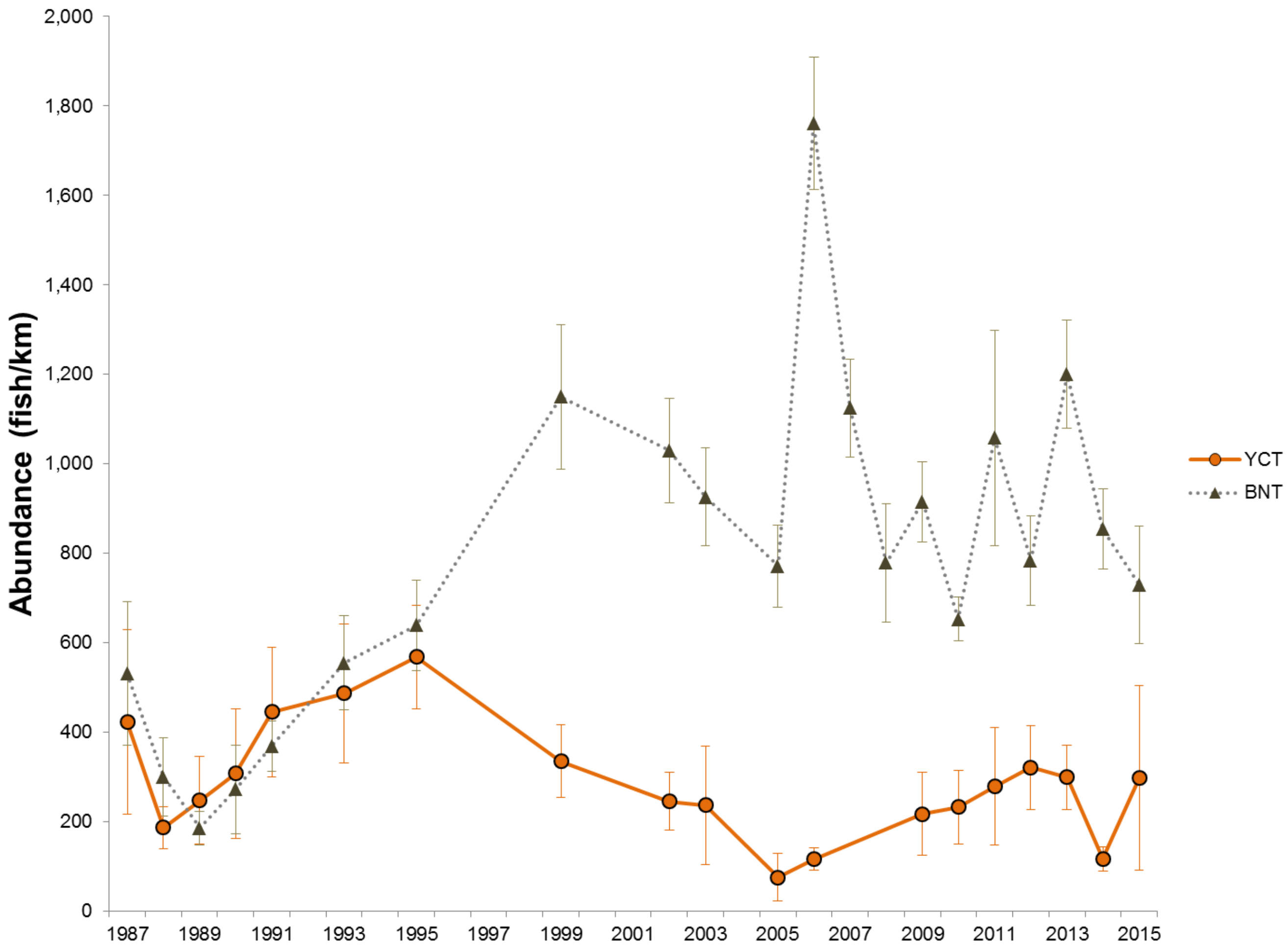

Figure 59. Abundance estimates and 95% confidence intervals for Yellowstone Cutthroat Trout (YCT) and Brown Trout (BNT) at the Lorenzo monitoring reach on the South Fork Snake River from 1987 through 2015.

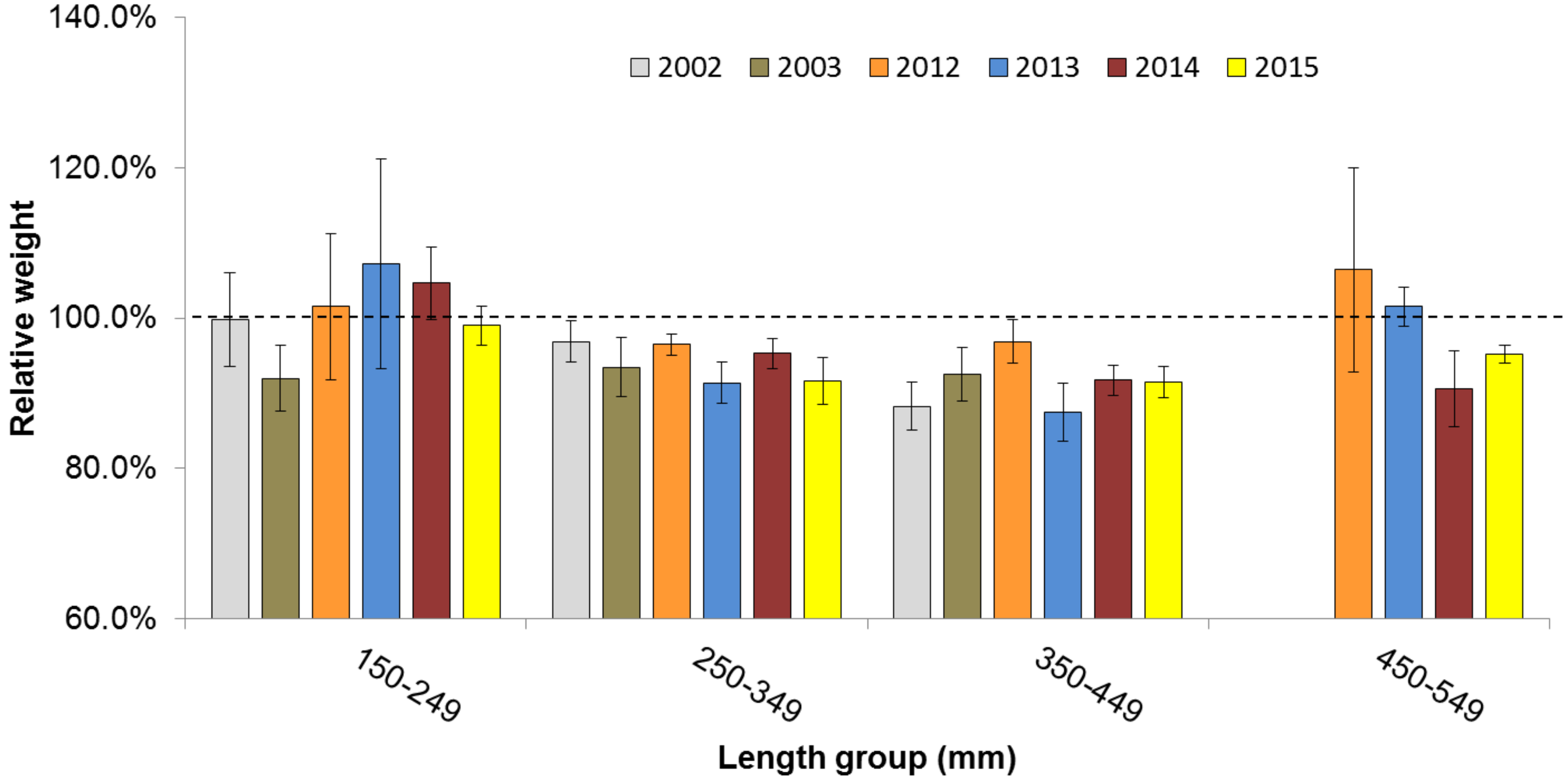

Figure 60. Mean relative weights and 95% confidence intervals for Yellowstone Cutthroat Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2002 through 2015.

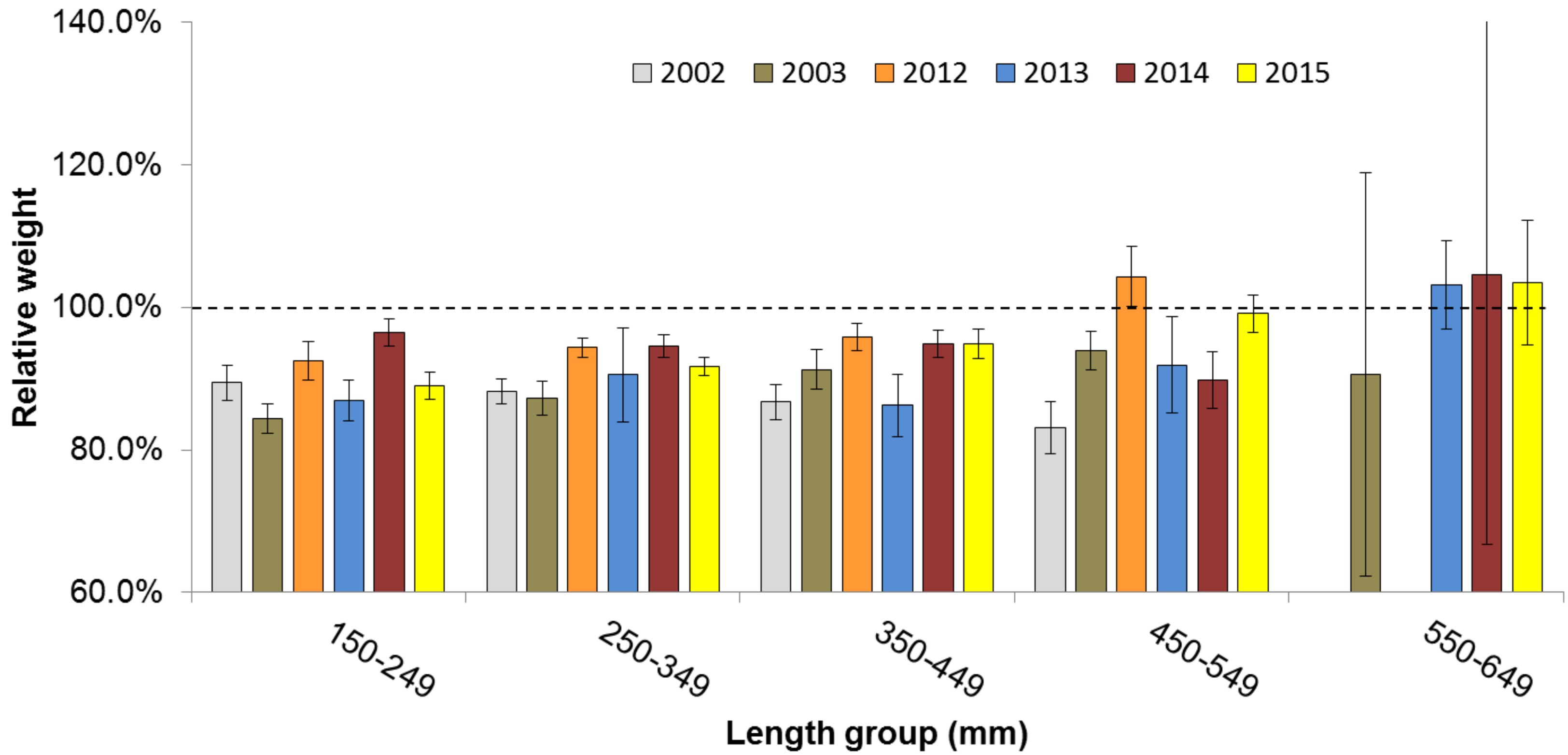

Figure 61. Mean relative weights and 95% confidence intervals for Brown Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2002 through 2015.

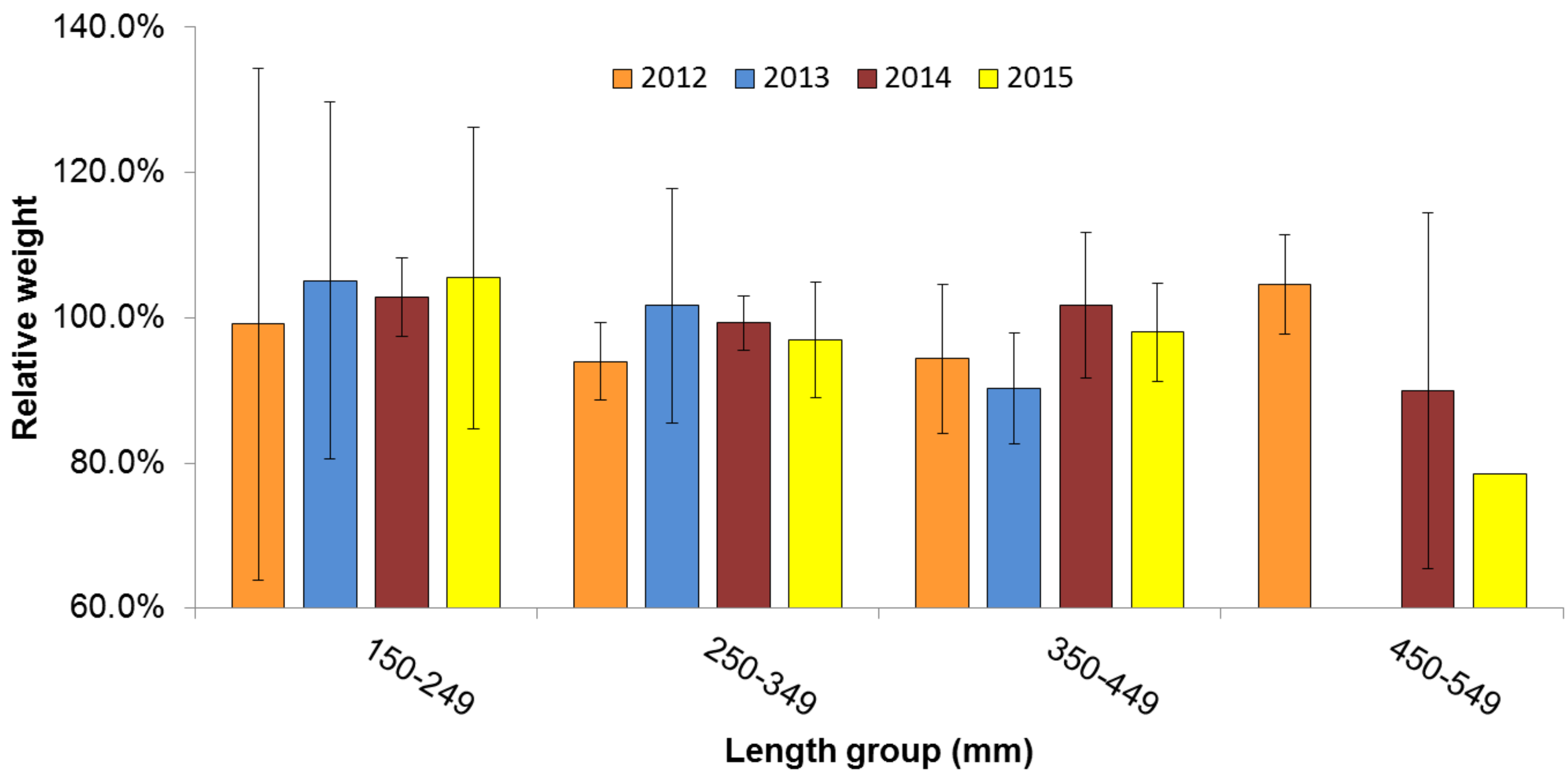

Figure 62. Mean relative weights and 95% confidence intervals for Rainbow Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2012 through 2015.

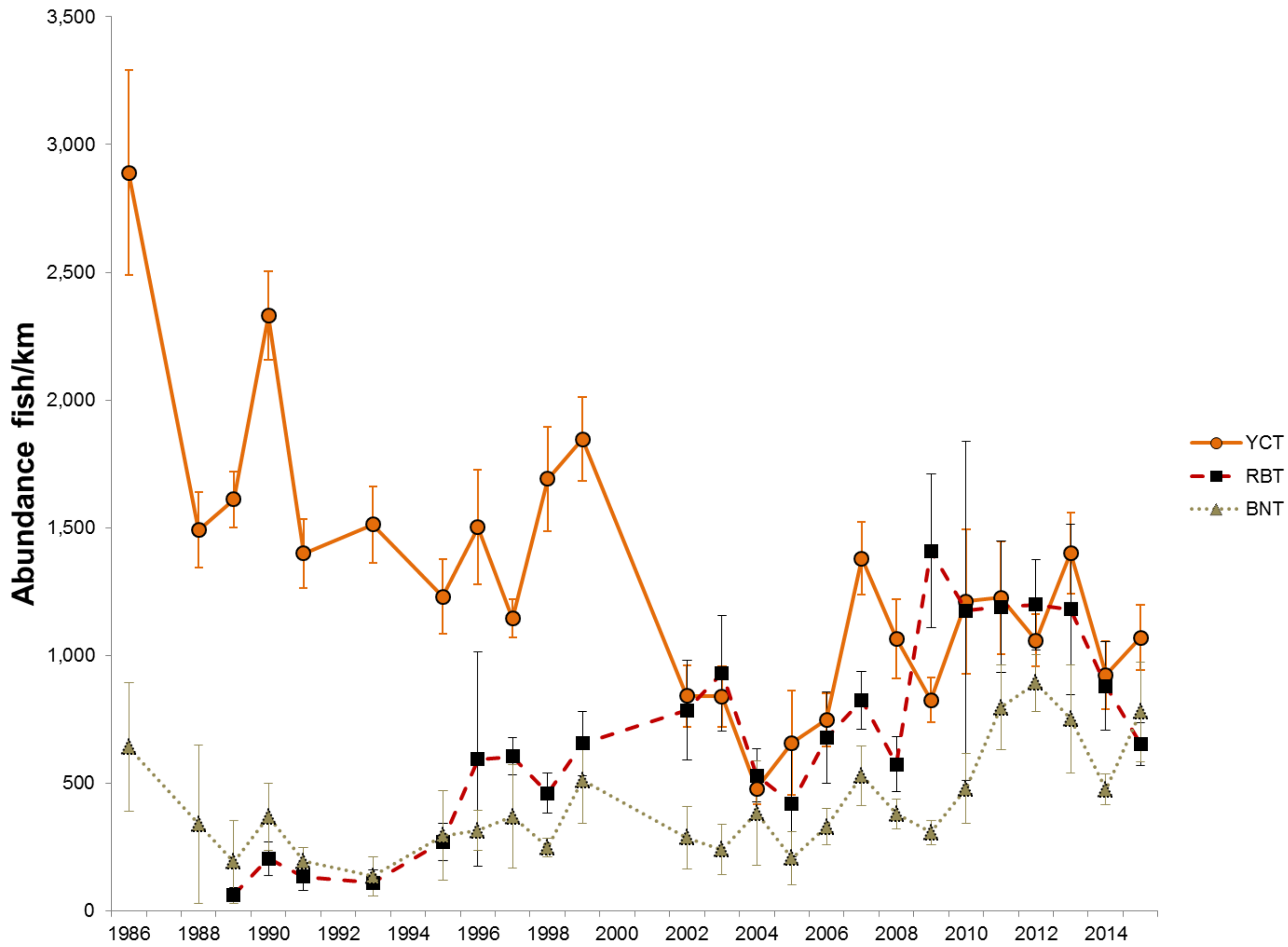

Figure 63. Abundance estimates and 95% confidence intervals for Yellowstone Cutthroat Trout (YCT) and Brown Trout (BNT) at the Conant monitoring reach on the South Fork Snake River from 1982 through 2015.

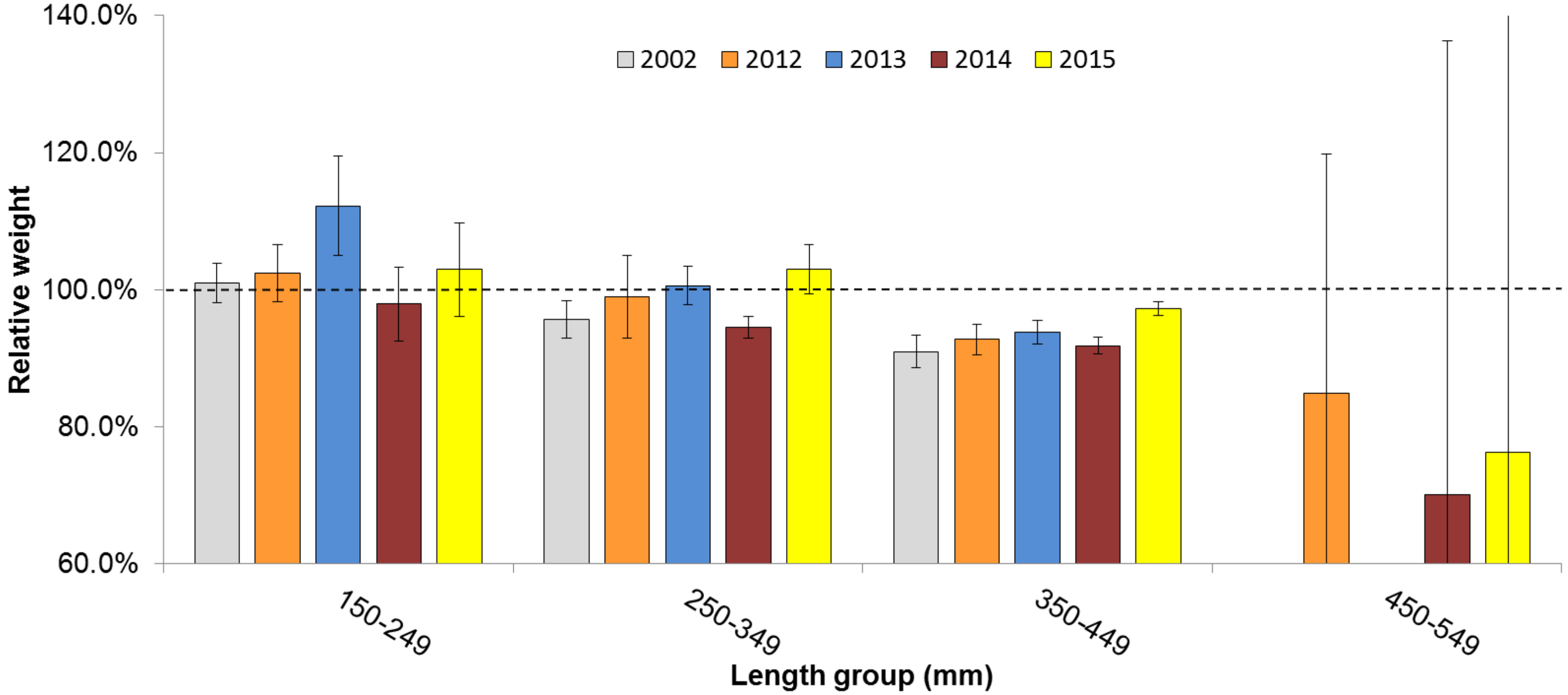

Figure 64. Mean relative weights and 95% confidence intervals for Yellowstone Cutthroat Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2015.

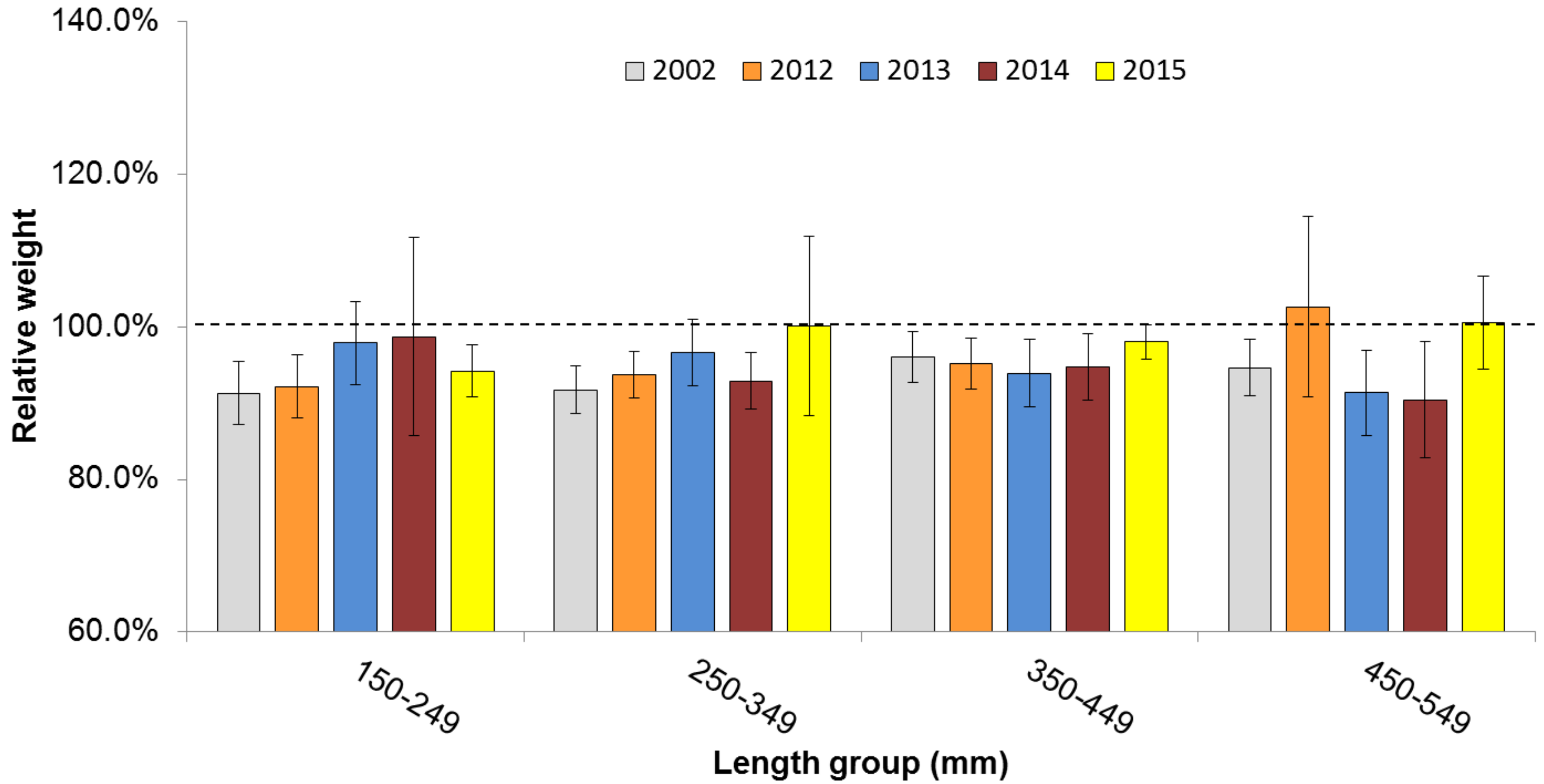

Figure 65. Mean relative weights and 95% confidence intervals for Brown Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2015.

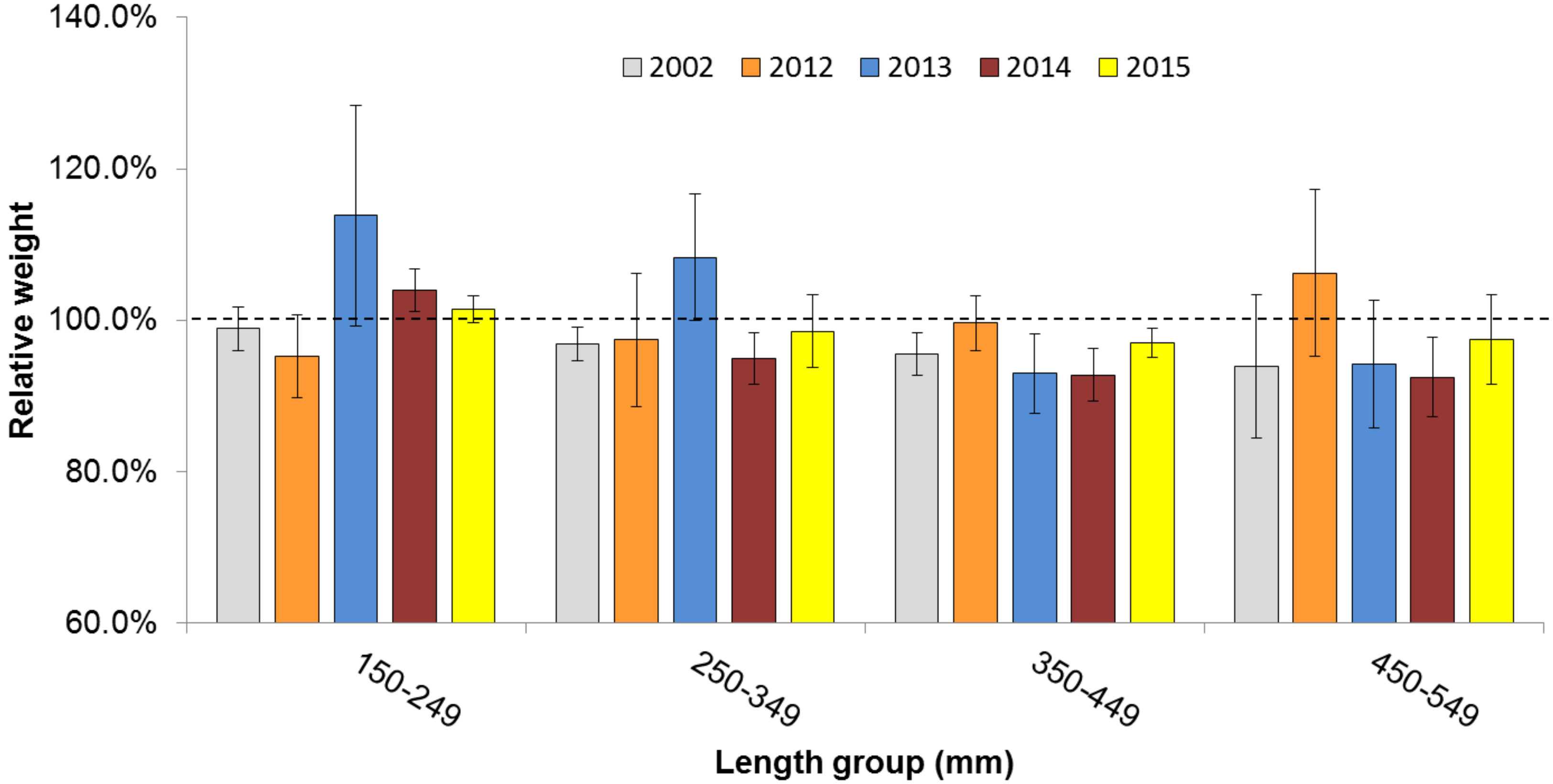

Figure 66. Mean relative weights and 95% confidence intervals for Rainbow Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2015.

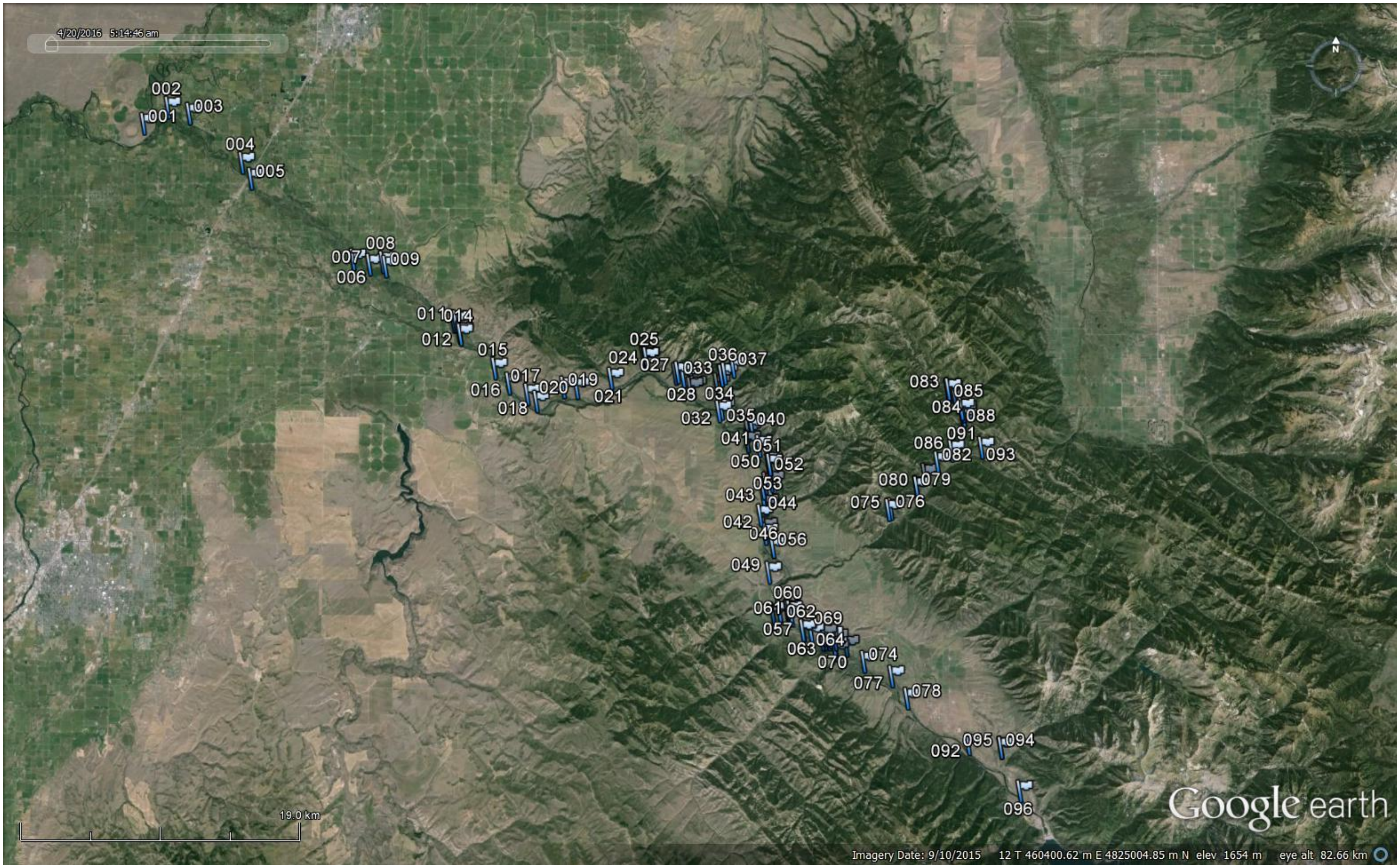

Figure 67. The locations of 96 Yellowstone Cutthroat Trout during the 2015 spawning season, based on radio-telemetry data.

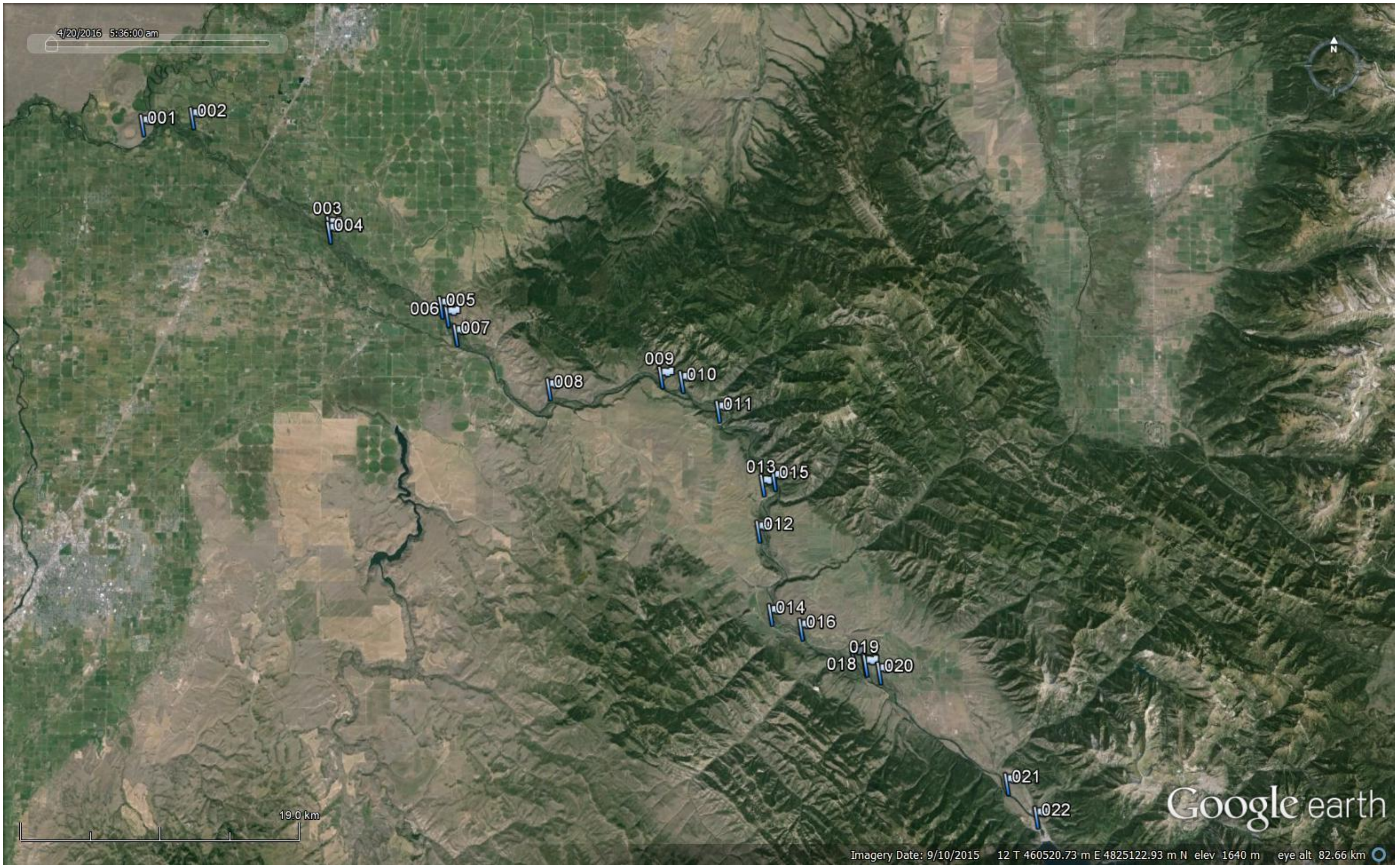

Figure 68. The locations of 22 Brown Trout during the 2015 spawning season, based on radio-telemetry data.

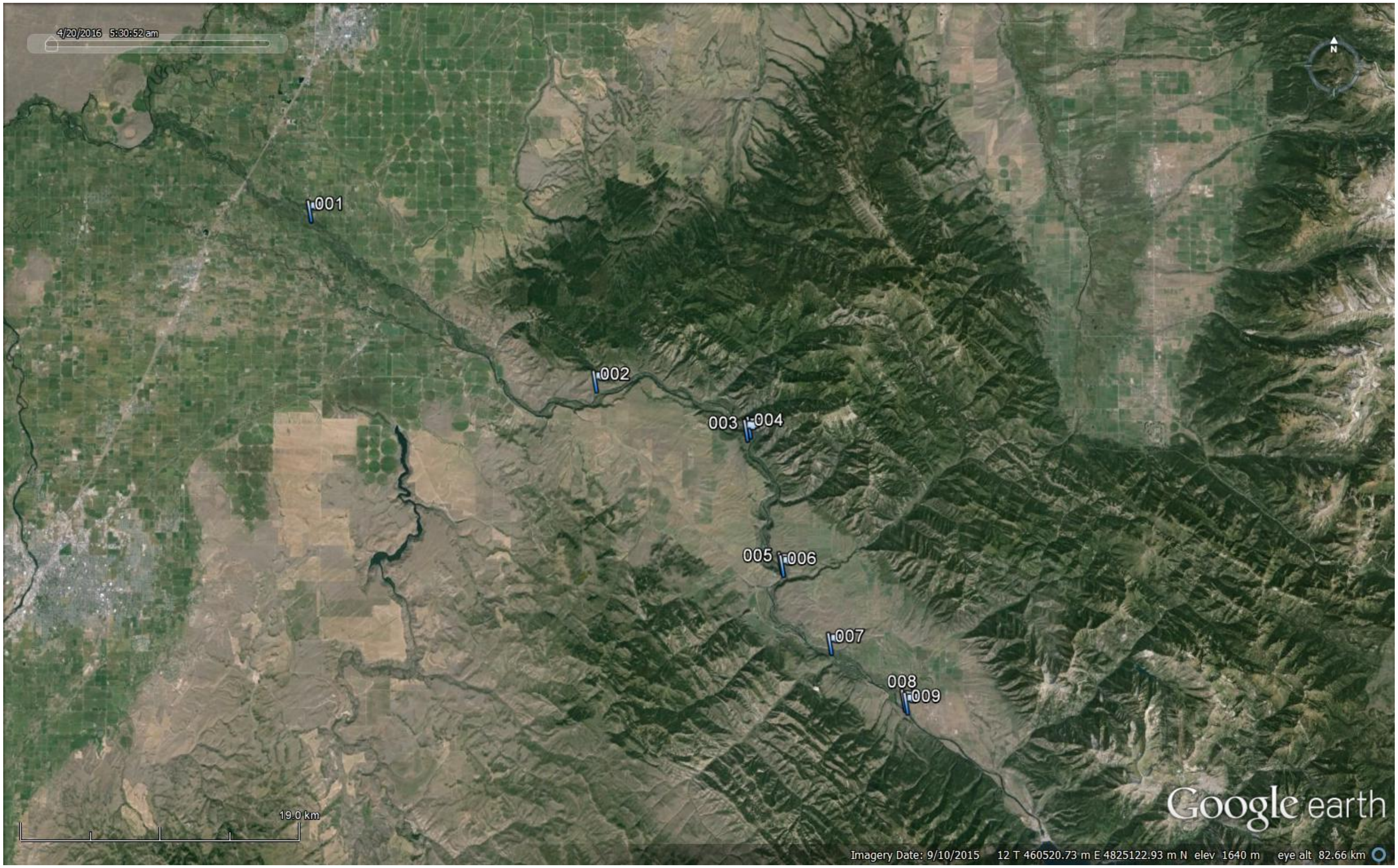

Figure 69. The locations of nine Rainbow Trout during the 2015 spawning season, based on radio-telemetry data.

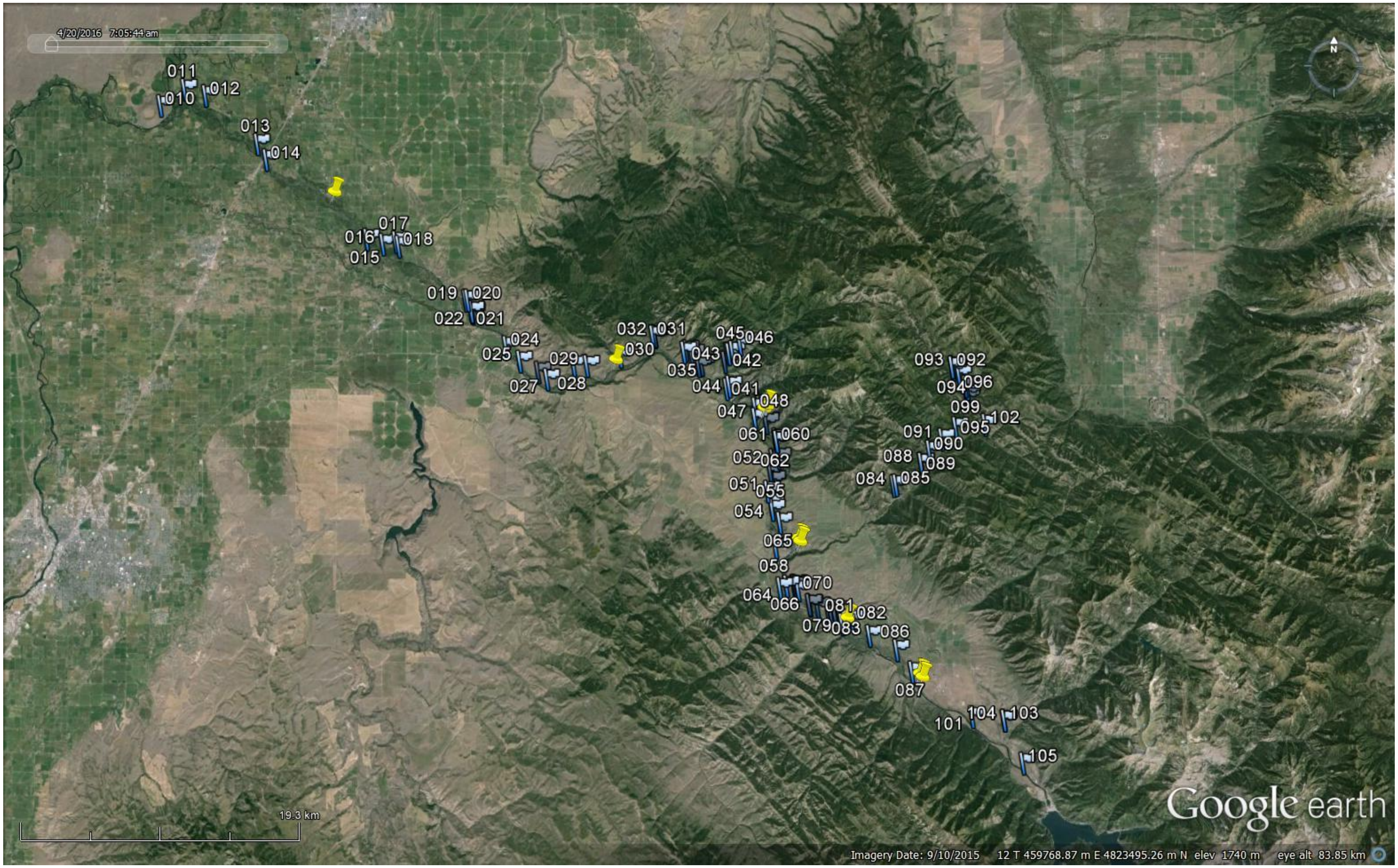

Figure 70. The locations of 96 Yellowstone Cutthroat Trout (flags) and nine Rainbow Trout (yellow pins) during the 2015 spawning season, based on radio-telemetry data.

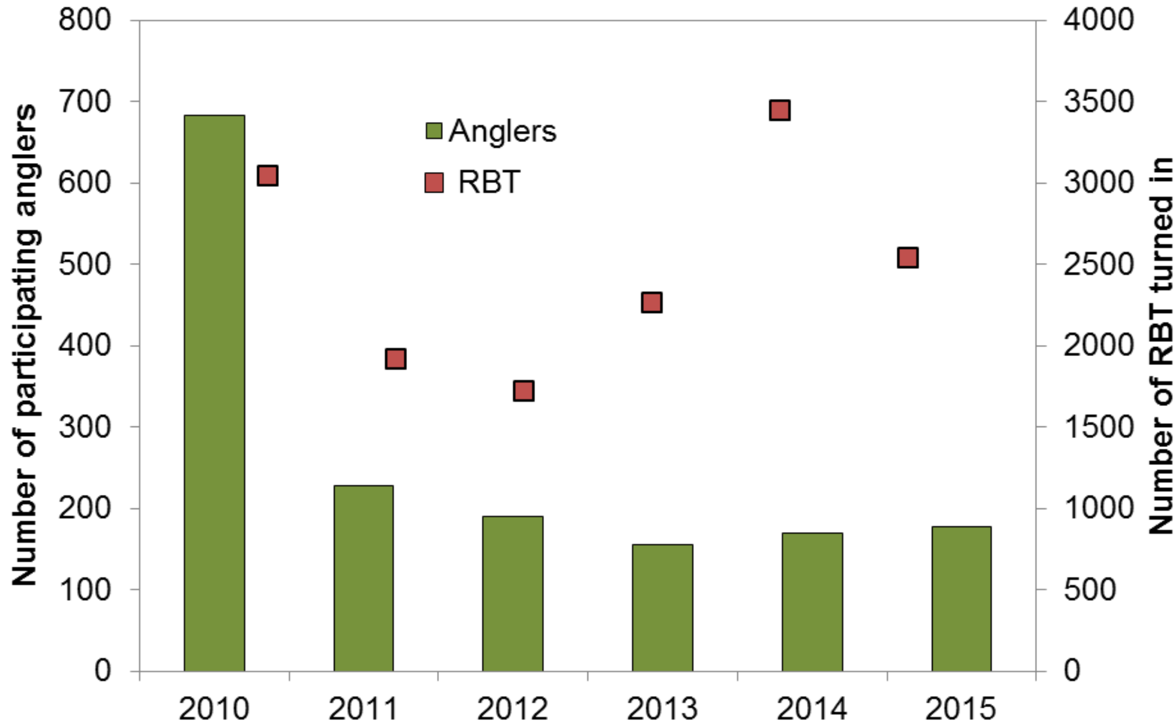

Figure 71. The annual number of anglers participating in the South Fork Snake River angler incentive program and the number or Rainbow Trout turned in since the program started in 2010.

LITERATURE CITED

Allendorf, F. W., and R. F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the Cutthroat Trout. Conservation biology 2:170-184.

Anderson, R.O. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive indices for fish populations and communities. Pages 27-33 in S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980s. American Fisheries Society, New York Chapter, Ithaca, New York.

Anderson, R.O., and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 in B.R. Murphy and D. W. Willis, ed. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Armstrong, G.C. 1949. Mortality, rate of growth, and fin regeneration of marked and unmarked lake trout fingerlings at the provincial fish hatchery, Port Arthur, Ontario. Transactions of the American Fisheries Society 77:129–131.

Bahn, L. 2007. An assessment of losses of native fish to irrigation diversions on selected tributaries of the Bitterroot River, Montana. Master’s Thesis. Montana State University. Bozeman.

Bailey, R.E., J.R. Irvine, F.C. Dalziel, and T.C. Nelson. 1998. Evaluations of visible implant fluorescent tags for marking coho salmon smolts. North American Journal of Fisheries Management 18:191–196.

Baldwin, C., and M. Polacek. 2002. Evaluation of limiting factors of stocked kokanee and rainbow trout in Lake Roosevelt, Washington. Inland Fish Investigations, Washington Department of Fish and Wildlife.

Barica, J., and J.A. Mathias. 1979. Oxygen depletion and winterkill risk in small prairie lakes under extended ice cover. Journal of Fisheries Research Board of Canada 36: 980-986.

Bartow, F. 1987. Fluorescent pigment marking of seven Minnesota fish species. Investigational Report No. 393. Minneapolis, Minnesota Department of Fisheries.

Beauchamp, D.A., D.L. Parrish, and R.A. Whaley. 2009. Coldwater fishes in large standing waters. Pages 97-117 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Bergstedt, R.A., R.L. Eshenroder, C. Bowen, J.G. Seelye, and J.C. Locke. 1990. Mass-marking of otoliths of lake trout sac fry by temperature manipulation. American Fisheries Society Symposium. 7:216–223.

Braux, E., F. Warren-Myers, T. Dempster, P.G. Fjelldal, T. Hansen, and S.E. Swearer. 2014. Osmotic induction improves batch marking of larval fish otoliths with enriched stable isotopes. Journal of Marine Science 71:2530-25389.

Brooks, R.C., R.C. Heidinger, and C.C. Kohler. 1994. Mass-marking otoliths of larval and juvenile walleyes by immersion in oxytetracycline, calcein, or calcein blue. North American Journal of Fisheries Management. 14:143-150.

Brothers, E.B. 1990. Otolith Marking. American Fisheries Society Symposium. 7:183–202.

Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge the “2% Rule” for biotelemetry. North American Journal of Fisheries Management 19:867-871.

Bumguardner, B.W., and T.L. King. 1996. Toxicity of oxytetracycline and calcein to juvenile striped bass. Transactions of the American Fisheries Society. 125:143-145.

Castro, J., C. Bouza, P. Presa, A. Pino-Querido, A. Riaza, I. Ferreiro, L. Sanchez, and P. Martinez. 2004. Potential sources of error in parentage assessment of turbot (Scophthalmus maximus) using microsatellite loci. Aquaculture 242:119-135.

Cegelski, C.C., M.R. Campbell, K.A. Meyer, and M.S. Powell. 2006. Multiscale genetic structure of Yellowstone cutthroat trout in the Upper Snake River basin. Transactions of the American Fisheries Society 135(3):711-726.

Close, T.L. 2000. Detection and retention of postocular visible implant elastomer in fingerling rainbow trout. North American Journal of Fisheries Management 20:542-545.

Coble, D.W. 1967 Effects of fin-clipping on mortality and growth of yellow perch with a review of similar investigations. Journal of Wildlife Management 31:173–180.

Crook, D.A., D.J. O'Mahony, A.C. Sanger, A.R. Munro, B.M. Gillanders, and S. Thurstan. 2009. Development and evaluation of methods for osmotic induction marking of golden perch Macquaria ambigua with calcein and alizarin red S. North American Journal of Fisheries Management 29:279-287.

Coon, J.C. 1978. Lake and reservoir investigations. Federal aid to fish and wildlife restoration 1978 Annual Performance Report program F-53-R-12. Idaho Department of Fish and Game, Boise.

Corsi, C., and S. Elle. 1986. Regional fisheries management investigations. Job Performance Report F-71-R-10. Idaho Department of Fish and Game. Boise.

DeVita, EvaLinda. 2014. Modeling population interactions between native Yellowstone Cutthroat Trout and invasive Rainbow Trout in the South Fork Snake River. Master's Thesis. Humboldt State University. Arcata, California.

Dieterman, D.J., and R.J.H. Hoxmeier. 2009. Instream evaluation of passive integrated transponder retention in brook trout and brown trout: effects of season, anatomical placement, and fish length. North American Journal of Fisheries Management 29:109-115.

Dillon, J., M. Gamblin, and W.C. Schrader. 2004. Regional Fisheries Management Investigations, Upper Snake Region (Subprojects I-G, II-G, III-G, IV-G). Report No. 04-09. Idaho Department of Fish and Game, Boise.

Dobson, F.S. 1982. Competition for mates and predominant juvenile dispersal in mammals. Animal Behavior 30:1183-1192

Elliott, D.G., and Pascho, R.J. 2001. Evidence that Coded-Wire-Tagging Procedures can enhance transmission of Renibacterium salmoninarum in Chinook Salmon. Journal of Aquatic Animal Health. 13:181–193.

Estoup, A., K. Gharbi, M. SanCristobal, C. Chevalet, P. Haffray, and R. Guyomard. 1998. Parentage assignment using microsatellites in turbot (Scophthalmus maximus) and rainbow trout (Oncorhynchus mykiss) hatchery populations. Canadian Journal of Fisheries and Aquatic Sciences 55:715-725.

Evenson M.D., and R.D. Ewing. 1985. Long-term retention of fluorescent pigment marks by spring Chinook salmon and summer steelhead. North American Journal of Fisheries Management 5:26-32.

Fausch, K.D., Y. Taniguchi, S. Nakano, G.D. Grossman, and C.R. Townsend. 2001. Flood disturbance regimes influence rainbow trout invasion success among five Holarctic regions. Ecological Applications 11:1438-1455.

Flickinger, S.A., and F.J Bulow. 1993. Small impoundments. Pages 469 – 492 in C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Flinders, J.M., and S.A. Bonar. 2008. Growth, condition, diet, and consumption rates of northern pike in three Arizona reservoirs. Lake and Reservoir Management 24:99-111.

Flinders, J., D. Keen, B. High, and D. Garren. 2018. Fishery Management Annual Report, Upper Snake Region 2014. Report #16-108. Idaho Department of Fish and Game, Boise.

Fraser, D.J., C. Lippé, and L. Bernatchez. 2004. Consequences of unequal population size, asymmetric gene flow and sex-biased dispersal on population structure in brook char (Salvelinus fontinalis). Molecular Ecology 13:67-80.

Garren, D., J. Fredericks, R. Van Kirk, and D. Keen. 2008. Evaluating the success of fingerling trout stocking in Henrys Lake, Idaho. Pages 427-437 in M.S. Allen, S. Sammons, and M.J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society, Symposium 62, Bethesda, Maryland.

Garren, D., W.C. Schrader, D. Keen, and J. Fredericks. 2006. Fishery management annual report, Upper Snake Region 2004. Report No. 05-15. Idaho Department of Fish and Game, Boise.

Garren, D., W.C. Schrader, D. Keen, and J. Fredericks. 2006a. Regional fisheries management investigations. 2003 Annual Performance Report, Project F-71-R-28. Report #04-25. Idaho Department of Fish and Game, Boise.

Garren, D., W.C. Schrader, D. Keen, and J. Fredericks. 2008. Fishery management annual report, Upper Snake Region 2006. Report No. 08-102. Idaho Department of Fish and Game, Boise.

Gatz, A.J., M.J. Sale, and J.M. Loar. 1987. Habitat shifts in rainbow trout: competitive influences of brown trout. Oecologia 74:7-19.

Grunder, S.A., T.J. McArthur, S. Clark, and V.K. Moore. 2008. Idaho Department of Fish and Game 2003 Economic Survey Report. Report #08-129. Idaho Department of Fish and Game, Boise.

Guinand, B., K.T. Scribner, and K.S. Page. 2003. Genetic variation over space and time: analyses of extinct and remnant lake trout populations in the upper Great Lakes. The Royal Society 270.

Gunnell, K., M.K. Tada, F.A. Hawthorne, E.R. Keeley, and M.B. Ptacek. 2008. Geographic patterns of introgressive hybridization between Yellowstone Cutthroat Trout (Oncorhynchus clarkia bouvieri) and introduced Rainbow Trout (O. mykiss) in the South Fork of the Snake River watershed, Idaho. Conservation Genetics 9:49-64.

Hagen, P., K. Munk, B. Van Alen, and B. White. 1995. Thermal mark technology for inseason fisheries management: a case study. Alaska Fisheries Research Bulletin 2:143-155.

Hale, R.S., and S.H. Gray. 1998. Retention and detection of coded wire tags and elastomer tags in trout. North American Journal of Fisheries Management 18:197–201.

Hammer, S.A., and H.L. Blankenship. 2001. Cost comparison of marks, tags, and mark-with-tag combinations used in salmonid research. North American Journal of Aquaculture 63:171-178.

Hauer, F.R., M.S. Lorang, D. Whited, and P. Matson. 2004. Ecologically Based Systems Management (EBSM) The Snake River – Palisades Dam to Henrys Fork. Final Report to the US Bureau of Reclamation, Boise, Idaho. Flathead Lake Biological Station, Division of Biological Sciences, The University of Montana, Polson. pp. 133.

Hayes, M.C., S.M. Focher, and C.R. Conto. 2000. High-pressure injection of photonic paint to mark adult chinook salmon. North American Journal of Aquaculture 62:319-322.

Hedrick, R.P., M.A. Adkison, M. El-Matbouli, and E. MacConnell. 1998. Whirling disease: re-emergence among wild trout. Immunological Reviews 166:365-376.

Henderson, R., J.L. Kershner, and C.A. Toline. 2000. Timing and location of spawning by nonnative wild Rainbow Trout and native Cutthroat Trout in the South Fork Snake River, Idaho, with implications for hybridization. North American Journal of Fisheries Management 20:584-596.

Hendry, A.P., J.E. Hensleigh, and R.R. Reisenbichler. 1998. Incubation temperature, developmental biology, and the divergence of sockeye salmon (Oncorhynchus nerka) within Lake Washington. Canadian Journal of Fisheries and Aquatic Sciences 55:1387-1394.

Hennick, D.P., and R.W. Tyler. 1970. Experimental marking of emergent pink salmon (Oncorhynchus gorbuscha) fry with sprayed fluorescent pigment. Transactions of the American Fisheries Society 99:397-400

High, B., D. Garren, G. Schoby, and J. Buelow. 2015. Fishery Management Annual Report, Upper Snake Region 2013. Report No. 15-108. Idaho Department of Fish and Game, Boise.

High, B., G. Schoby, D. Keen, and D. Garren. 2011. Fishery Management Annual Report, Upper Snake Region 2009. Report #11-107. Idaho Department of Fish and Game, Boise.

High, B., G. Schoby, J. Buelow, and D. Garren. 2014. Fishery management annual report, Upper Snake Region, 2012. Report No. 14-104. Idaho Department of Fish and Game, Boise.

Hitt, N.P., C.A. Frissell, C.C. Muhlfeld, F.W. Allendorf. 2003. Spread of hybridization between native Westslope Cutthroat Trout Oncorhynchus clarkii lewisi, and nonnative Rainbow Trout, Oncorhynchus mykiss. Canadian Journal of Fisheries and Aquatic Sciences 60:1440-1451.

Huston, J. E. 1972. Reservoir Investigations. Life history studies of Westslope Cutthroat Trout and Mountain Whitefish. Montana Fish and Game Department, Job Completion Report, Projecdt F-7-R-5, Job III, Helena.

Huston, J. E. 1973. Reservoir Investigations. Montana Fish and Game Department, Job Completion Report, Project F-34-R-6, Job III, Helena.

Hutchings, J.A., and L. Gerber. 2002. Sex-biased dispersal in a salmonid fish. Proceedings of the Royal Society B 269:2487 -2493.

Hyatt, M.W., and W.A. Hubert. 2001a. Proposed standard-weight equations for brook trout. North American Journal of Fisheries Management 21:253-254.

Hyatt, M.H., and W.A. Hubert. 2001b. Proposed standard-weight (Ws) equation and length-categorization standards for brown trout (Salmo trutta) in lentic habitats. Journal of Freshwater Ecology 16:53-56.

IDFG (Idaho Department of Fish and Game). 2013. Fisheries management plan. 2013 – 2018. Boise.

IDFG (Idaho Department of Fish and Game). 2001. 2001-2006 Fisheries Management Plan. Idaho Department of Fish and Game, Boise.

IDFG (Idaho Department of Fish and Game). 2012. Standard fish sampling protocol for lowland lakes and reservoirs in Idaho. Report No. 12-10. Idaho Department of Fish and Game, Boise.

IDFG (Idaho Department of Fish and Game). 1982. Evaluation of walleye for an expanded distribution in Idaho. Idaho Department of Fish and Game, Boise.

Isaak, D.J., and W.A. Hubert. 2004. Nonlinear response of trout abundance to summer stream temperatures across a thermally diverse montane landscape. Transactions of the American Fisheries Society 133:1254-1259.

Jackson, C.F. 1959. A technique for mass-marking fish by means of compressed air. New Hampshire Fish and Game Department , Technical Circular No. 17.

Jaeger, M.E., A.V. Zale, T.E. McMahon, and B.J. Schmitz. 2005. Seasonal movements, habitat use, aggregation, exploitation, and entrainment of saugers in the Lower Yellowstone River: an empirical assessment of factors affecting population recovery. North American Journal of Fisheries Management 25:1550-1568.

Jeppson, P. 1970. Job completion report, F-32-R-12. South Fork of Snake River investigations. Test for increasing the returns of hatchery trout. Idaho Department of Fish and Game, Boise.

Jeppson, P., O.E. Casey, W.S. Platts, J. Mallet, and D.R. Corley. 1965. Tests for increasing the returns of hatchery trout 1964. Project completion report F-32-R-7. Idaho Department of Fish and Game. Boise.

Jones, R. D., D. G. Carty, R. E. Gresswell, C. J. Hudson, L. D. Lentsch, and D. L. Mahony. 1986. Fishery and aquatic management program in Yellowstone National Park. U.S. Fish and Wildlife Service, Technical Report for 1985, Yellowstone National Park, Wyoming.

Kaill, M.W., K. Rawson, and T. Joyce. 1990. Retention rates of half-length coded wire tags implanted in emergent pink salmon. American Fisheries Society, American Fisheries Symposium 7:253–258.

Knight, R.L., and B. Vondracek. 1993. Changes in prey fish populations in western Lake Erie, 1969-88, as related to walleye, Stizostedion vitreum, predation. Canadian Journal of Fisheries and Aquatic Sciences 50:1289-1298.

Kruse, C.G., and W.A. Hubert. 1997. Proposed standard weight (W_s) equations for interior cutthroat trout. North American Journal of Fisheries Management 17:784-790.

Larson, E.I., K.A. Meyer, and B. High. 2014. Incidence of spinal injuries in migratory Yellowstone cutthroat trout captured at electric and waterfall-velocity weirs. Fisheries Management and Ecology 21:509-514.

Lepak, J.M., C.N. Cathcart, and W.L. Stacy. 2014. Tiger muskellunge predation on stocked salmonids intended for recreational fisheries. Lake and Reservoir Management 30:250-257.

Leskelä, A. 1999. Prolonged retention of fluorescent pigment spray marks in European whitefish, Coregonus lavaretus (L.). Fisheries Management and Ecology 6:255-257.

Letcher, B.A., and T.D. Terrick. 1998. Thermal marking of Atlantic salmon otoliths. North American Journal of Fisheries Management. 18:406-410.

Liknes, G.A., and P.J. Graham. 1988. Westslope cutthroat trout in Montana: life history, status, and management. American Fisheries Society, Symposium 4, Bethesda, Maryland.

Lindsey, C.C., T.G. Northcote, and G.F. Hartman. 1959. Homing of rainbow trout to inlet and outlet spawning streams at Loon lake, British Columbia. Journal of Fisheries Research Board of Canada. 16(5):695-719.

Maxell, B. A. 1999. A power analysis on the monitoring of bull trout stocks using red counts. North American Journal of Fisheries Management 19:860-866.

McCleave, J.D. 1967. Homing and orientation of cutthroat trout (salmo clarki) in Yellowstone lake with special reference to olfaction and vision. Journal of the Fisheries Research Board of Canada 24:2011-2044.

McFarlane, G.A., R.S. Wydoski, and E.D. Prince. 1990. Historical review of the development of external tags and marks. American Fisheries Society Symposium 7:9-29.

McMahon, T.E., and D.H. Bennett. 1996. walleye and northern pike: boost or bane to Northwest fisheries? Fisheries 21:6-13.

McNeil, F.I., and E.J. Crossman. 1979. Fin clips in the evaluation of stocking programs for muskellunge, Esox masquinongy. Transactions of the American Fisheries Society 108: 335–343.

Meyer, K.A., and J.S. Griffith. 1997. First-winter survival of rainbow trout and brook trout in the Henrys Fork of the Snake River, Idaho. Canadian Journal of Zoology 75:59-63.

Milewski, C.L., and M.L. Brown. 1994. Proposed standard weight (Ws) equation and length-categorization standards for stream-dwelling brown trout (Salmo trutta). Journal of Freshwater Ecology 9:111-116.

Mitro, M.G. 1999. Sampling and analysis techniques and their applications for estimating recruitment of juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. PhD thesis, Montana State University, Bozeman.

Mitro, M.G., A.V. Zale, and B.A. Rich. 2003. The relation between age-0 Rainbow Trout (Oncorhynchus mykiss) abundance and winter discharge in a regulated river. Canadian Journal of Fisheries and Aquatic Sciences 60:135-139.

Moller, S., and R. Van Kirk. 2003. Hydrologic alteration and its effect on trout recruitment in the South Fork Snake River. Project Completion Report for Idaho Department of Fish and Game, Idaho State University, Pocatello.

Montana Department of Fish, Wildlife, and Parks. 1997. Mark recapture for Windows, version 5.0. Montana Department of Fish, Wildlife, and Parks, Helena.

Moore, V., and D. Schill. 1984. Job Completion Report, Project F-73-R-5. Fish distribution and abundance in the South Fork Snake River. Idaho Department of Fish and Game, Boise.

Moore, V., K. Aslett, and C. Corsi. 1981. South Fork Snake River Fishery Investigations. Job Performance Report F-73-R-3. Idaho Department of Fish and Game. Boise.

Morgan, G.E. 2002. Manual of Instructions – Fall walleye Index Netting (FWIN). Percid Community Synthesis Diagnostics and Sampling Standards Working Group. Ontario Ministry of Natural Resources, Peterborough.

Morgan, R.I.G., and D.S. Paveley. 1996. A simple batch mark for fish studies using injected elastomer. Aquaculture Research 27:631–633.

Muhlfeld, C.C., S.T. Kalinowski, T.E. McMahon, M.L. Taper, S. Painter, R.F. Leary, and F.W. Allendorf. 2009. Hybridization rapidly reduces fitness of a native trout in the wild. Biology letters 5:328-331.

Munro, A.R., B.M. Gillanders, T.S. Elsdon, D.A. Crook, and A.C. Sanger, A.C. 2008. Enriched stable isotope marking of juvenile golden perch (Macquaria ambigua) otoliths. Canadian Journal of Fisheries and Aquatic Sciences 65:276–285.

Munro, A.R., B.M. Gillanders, S. Thurstan, D.A. Crook, and A.C. Sanger. 2009. Transgenerational marking of freshwater fishes with enriched stable isotopes: a tool for fisheries management and research. Journal of Fish Biology 75:668-684.

Negus, M.T. 1999. Thermal marking of otoliths in lake trout sac fry. North American Journal of Fisheries Management 19:127-140.

Nielson, B.R. 1990. Twelve-Year overview of fluorescent grit marking of Cutthroat Trout in Bear Lake, Utah-Idaho. American Fisheries Society Symposium 7:42-46.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47:2-15

Peterson, D.L., and R.F. Carline. 1996. Effects of tetracycline marking, transport density, and transport time on short-term survival of walleye fry. Progressive Fish-Culturist. 58:29-31.

Peterson, D.P., K.D. Fausch, and G.C. White. 2004. Population ecology of an invasion: effects of brook trout on native cutthroat trout. Ecological Monographs 14:754–772.

Phinney D.E., and S.B. Mathews. 1969. Field test of fluorescent pigment marking and finclipping of coho salmon. Journal of the Fisheries Research Board of Canada 26:1619-24.

Phinney, D.E., D.M. Miller, and M.L. Dahlberg. 1967. Mass marking young salmonids with fluorescent pigment. Transactions of American Fisheries Society 96:157-162.

Phinney, D.E. 1974. Growth and survival of fluorescent pigment marked and fin clipped salmon. Journal of Wildlife Management 38:132-137.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Prentice, E.F., T.A. Flagg, and C.S. McCutcheon. 1990. Feasibility of using implantable passive integrated transponder PIT tags in salmonids. American Fisheries Society Symposium 7:317-322.

Quist, M.C., C.S. Guy, R.D. Schultz, and J.L Stephen. 2003. Latitudinal comparisons of walleye growth in North America and factors influencing growth of walleyes in Kansas reservoirs. North American Journal of Fisheries Management 23:677-692.

Quist, M.C., C.S. Guy, R.D. Schultz, and J.L Stephen. 2003. Latitudinal comparisons of walleye growth in North America and factors influencing growth of walleyes in Kansas reservoirs. North American Journal of Fisheries Management 23:677-692.

Reinert, T.R., J. Wallin, M.C. Griffin, M.J. Conroy, and M.J. Van Den Avyle. 1998. Long-term retention and detection of oxytetracycline marks applied to hatchery-reared striped bass, Morone saxatilis. Canadian Journal of Fisheries and Aquatic Sciences 55:539-543.

Schmetterling, D.A. 2001. Seasonal movements of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21(3):507-520.

Schoby, G., B. High, D. Garren, and J. Fry. 2013. Fishery management annual report, Upper Snake Region 2009. Idaho Department of Fish and Game Report 13-117, Boise.

Schoby, G., B. High, D. Keen, and D. Garren. 2010. Fishery Management Annual Report, Upper Snake Region 2008. Report No. 10-107. Idaho Department of Fish and Game, Boise.

Schoby, G., B. High, J. Buelow, and D. Garren. 2014. Fishery Management Annual Report, Upper Snake Region 2010. Report No. 14-101. Idaho Department of Fish and Game, Boise.

Schoen, E.R., D.A. Beauchamp, and N.C. Overman. 2012. Quantifying latent impacts of an introduced piscivore: Pulsed predatory inertia of Lake Trout and decline of kokanee. Transactions of the American Fisheries Society 141:1191-1206.

Schrader, W.C., and J. Fredericks. 2006. South Fork Snake River investigations. 2005 Annual Job Performance Report 06-50. Idaho Department of Fish and Game. Boise.

Schrader, W. C. and M. D. Jones. 2004. Teton River investigations – Part II: Fish movements and life history 25 years after Teton Dam. Idaho Department of Fish and Game Report #04-45, Boise.

Schuman, D.A., K.D. Koupal, W.W. Hoback, and C.W. Schoenebeck. 2013. Evaluation of sprayed fluorescent pigment as a method to mass-mark fish species. The Open Fish Science Journal 6:41-47

Scidmore, W.J., and D.E. Olson. 1969. Marking walleye fingerlings with oxytetracycline antibiotic. Progressive Fish-Culturist 31:213-216

Seiler, S.M., and E.R. Keeley. 2007a. A comparison of aggressive and foraging behavior between juvenile Cutthroat Trout, Rainbow Trout, and F1 hybrids. Animal Behaviour 74:1805-1812.

Seiler, S.M., and E.R. Keeley. 2007b. Morphological and swimming stamina differences between Yellowstone Cutthroat Trout (Oncorhynchus clarkia bouvieri), Rainbow Trout (Oncorhynchus mykiss), and their hybrids. Canadian Journal of Fisheries and Aquatic Sciences 64:127-135).

Shetter, D.S. 1951. The effect of fin removal on fingerling lake trout (Cristivomer namaycush). Transactions of the American Fisheries Society 80: 260–277.

Simpkins, D.G., and W.A. Hubert. 1996. Proposed revision of the standard-weight equation for rainbow trout. Journal of Freshwater Ecology 11:319-325.

Smith, K.T., and G.W. Whitledge. 2011. Evaluation of stable-isotope labelling technique for mass marking fin rays of age-0 lake sturgeon. Fisheries Management and Ecology 18:168-175.

Steele, C.A., E.C. Anderson, M.W. Ackerman, M.A. Hess, N.R. Campbell, S.R. Narum, and M.R. Campbell. 2013 A validation of parentage-based tagging using hatchery steelhead in the Snake River basin. Canadian Journal of Fisheries and Aquatic Sciences 70:1046-1054.

Strange, C.D. and J.A. Kennedy. 1982. Evaluation of fluorescent pigment marking of brown trout (Salmo trutta L.) Fisheries Management 13:89-95.

Sutphin, Z.A., C.A. Myrick, and M.M. Brandt. 2007. Swimming performance of Sacramento splittail injected with subcutaneous marking agents. North American Journal of Fisheries Management 27:1378-1382.

Thorrold, S.R., G.P. Jones, S. Planes, and J.A. Hare. 2006. Transgenerational marking of embryonic otoliths in marine fishes using barium stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 63:1193-1197.

Thurow, R.F., and J.G. King. 1994. Attributes of Yellowstone Cutthroat Trout redds in a tributary of the Snake River, Idaho. Transactions of the American Fisheries Society 123:37-50.

Toften, H., and M. Jobling. 1996. Development of spinal deformities in Atlantic salmon and Artic charr fed diets supplemented with oxytetracycline. Journal of Fish Biology 49:668-677.

Trojnar, J.R. 1973. Marking rainbow trout fry with tetracycline. Progressive Fish-Culturist 35:52-54.

USBR (United States Bureau of Reclamation). 1978. Palisades power plant enlargement. Idaho Palisades Project. Idaho-Wyoming. USBR, Pacific Northwest Region. 61 pp.

USBR (United States Bureau of Reclamation). 2015. http://www.usbr.gov/projects/Facility.jsp?fac_Name=Palisades+Dam

USBR (Bureau of Reclamation). 2001. Ririe Reservoir Resource Management Plan. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Snake River Area Office, Boise, Idaho.

Van Kirk, R. W,L. Battle, and W.C. Schrader. 2010. Modelling competition and hybridization between native Cutthroat Trout and nonnative Rainbow and hybrid Trout. Journal of Biological Dynamics 4:158-175.

Van Kirk, R.W., and M. Gamblin. 2000. History of fisheries management in the upper Henry's Fork watershed. Intermountain Journal of Sciences 6:263-284.

Varley, J.D., and R.E. Gresswell. 1988. Ecology, status, and management of the Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Volk, E.C., and P. Hagen. 2001. An overview of thermal marking. North Pacific Anadromous Fish Commission Technical Report. 3:1-2.

Volk, E.C., S.L. Schroder, and J.J. Grimm. 1999. Otolith thermal marking. Fisheries Research 43:205-219.

Volk, E.C., S.L. Schroder, and K.L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific salmon. American Fisheries Society Symposium 7:203-215.

Von Bertalanffy, L. 1957. Quantitative laws in metabolism and growth. The Quarterly Review of Biology 32:217-231.

Walther, B.D., and S.R. Thorrold. 2006. Water, not food, contributes the majority of strontium and barium deposited in the otoliths of a marine fish. Marine Ecology Progress Series 311:125-130.

Wang, L., and R.J. White. 1994. Competition between wild brown trout and hatchery greenback cutthroat trout of largely wild parentage. North American Journal of Fisheries Management 14:475-487.

Warren-Meyers, F., T. Dempster, P.G. Fjelldal, T. Hansen, and S.E. Swearer. 2015. Immersion during egg swelling results in the rapid uptake of stable isotope markers in salmonid otoliths. Canadian Journal of Fisheries and Aquatic Sciences 72:722-727.

Warren-Meyers, F., T. Dempster, P.G. Fjelldal, T. Hanson, A.J. Jensen, and S.E. Swearer. 2014. Stable isotope marking of otoliths during vaccination: a novel method for mass-marking fish. Aquaculture Environment Interactions 5:143-154.

Waters, A.W., D.M. Holzer, J.R. Faulkner, C.D. Warren, P.D. Murphy, and M.M. McClure. 2012. Quantifying cumulative entrainment effects for Chinook Salmon in a heavily irrigated watershed. Transactions of the American Fisheries Society 123:1180-1190.

Willis, D.W. 1998. Warmwater fisheries sampling, assessment, and management. U.S. Fish and Wildlife Service National Conservation Training Center Course. August 3-6, 1998. Olympia, Washington.

Woodcock, S.H., C.A. Grieshaber, and B.D. Walther. 2013. Dietary transfer of enriched stable isotopes to mark otoliths, fin rays, and scales. Canadian Journal of Fisheries and Aquatic Sciences 70:1-4.

APPENDICES

Appendix A. Historic annual stocking (*1,000) of Henrys Lake, Idaho, 1925 -2015.

Year	Yellowstone Cutthroat Trout	Hybrid trout	Brook Trout	Total trout
1923	40	0	0	40
1924	0	0	0	0
1925	1	0	1	2
1926	140	0	0	140
1927	222	0	0	222
1928	116	0	0	116
1929	0	0	0	0
1930	0	0	0	0
1931	634	0	0	634
1932	170	0	0	170
1933	50	0	0	50
1934	980	0	0	980
1935	632	0	3	635
1936	0	0	0	0
1937	719	0	0	719
1938	753	0	0	753
1939	370	0	0	370
1940	750	0	0	750
1941	0	0	0	0
1942	1589	0	0	1589
1943	1665	0	0	1665
1944	1537	0	0	1537
1945	818	0	0	818
1946	1670	0	0	1670
1947	238	0	0	238
1948	584	0	0	584
1949	684	0	2	686
1950	779	5	6	790
1951	2070	0	0	2070
1952	610	8	0	618
1953	600	0	0	600
1954	1223	0	0	1223
1955	1243	0	0	1243
1956	985	0	0	985
1957	640	0	0	640
1958	534	0	0	534
1959	454	0	0	454
1960	1024	138	0	1162
1961	1570	390	0	1960
1962	1366	385	0	1751
1963	1300	565	0	1865
1964	1455	0	0	1455
1965	1755	0	0	1755
1966	1481	563	0	2044

Year	Yellowstone Cutthroat Trout	Hybrid trout	Brook Trout	Total trout
1967	1159	448	0	1607
1968	847	132	0	979
1969	111	476	0	587
1970	391	133	0	524
1971	763	184	0	947
1972	834	0	0	834
1973	1145	0	0	1145
1974	1105	0	0	1105
1975	1024	0	101	1125
1976	862	200	167	1229
1977	825	200	137	1162
1978	946	179	89	1214
1979	1134	125	96	1355
1980	1040	32	91	1163
1981	2251	146	20	2417
1982	2442	242	18	2702
1983	2179	229	22	2429
1984	2041	135	0	2175
1985	995	33	111	1139
1986	989	292	0	1281
1987	663	256	0	919
1988	1011	312	0	1323
1989	1090	251	95	1436
1990	1001	200	157	1358
1991	1326	201	129	1656
1992	943	203	189	1336
1993	1060	217	112	1388
1994	1048	201	115	1363
1995	1381	144	136	1662
1996	661	200	196	1057
1997	1237	180	204	1621
1998	1047	204	207	1459
1999	1249	204	0	1453
2000	978	0	0	978
2001	991	135	0	1126
2002	1107	331	0	1438
2003	1634	264	99	1996
2004	921	38	117	1077
2005	851	201	152	1204
2006	1124	150	107	1381
2007	1394	146	104	1644
2008	1254	196	198	1648
2009	1382	220	171	1773
2010	1326	138	93	1557
2011	1127	205	100	1432
2012	768	221	101	1090

Year	Yellowstone Cutthroat Trout	Hybrid trout	Brook Trout	Total trout
2013	756	213	110	1079
2014	729	167	83	979
2015	955	167	71	1193

Appendix B. Satisfaction questions used by creel clerks during the 2015 creel survey.

Palisades Reservoir – Interview Questions 2015

Hi, I am ___________ and I am conducting an angler survey on behalf of Idaho Department of Fish and Game. The purpose of the survey is to determine the factors that affect anglers satisfaction. Are you willing to answer five quick questions? (*If yes, proceed. If no, say thank you and move on*)

Date _________________ Time _______________ Clerk name___________________

1) On a scale of 1-10, where 1 is very dissatisfied and 10 is very satisfied, how satisfied were you with each of the following aspects of your fishing experience on Palisades Reservoir today?

	Very dissatisfied ... Very Satisfied
(A) The number of fish you caught	1 2 3 4 5 6 7 8 9 10
(B) The size of the fish you caught	1 2 3 4 5 6 7 8 9 10

2) Overall, how would you rate the quality of fishing on Palisades Reservoir today?

☐ Excellent ☐ Good ☐ Fair ☐ Poor

3) On a scale of 1-10, where 1 is not at all important and 10 is extremely important, how important is each of the following factors in determining whether you have a high quality fishing experience on Palisades Reservoir?

	Not at all important ... Extremely Important
(A) The number of fish you caught	1 2 3 4 5 6 7 8 9 10
(B) The size of the fish you caught	1 2 3 4 5 6 7 8 9 10

4) What fish species would you like to see managed for in Palisades Reservoir with 1 as the most important species and 4 the least important species? (*Fill the numbers out in the order listed below. For example, if they prefer lake trout as the second most important species (2), kokanee the most important (1), and cutthroat third most important (3) and brown trout the least important (4), put 2,1,3,4 in the Question 4 column*)

Lake trout _______ Kokanee _______ Cutthroat trout _______ Brown trout _______

5) Is there anything additional you would like us to know about your fishing trip today?

Appendix C. Location of Ririe Reservoir fall Walleye index netting (FWIN) net locations during the fall of 2015. All coordinates are Zone 12, and WGS 84 datum.

Date	Net	Lake Strata	Latitude	Longitude	Net Type
October 29	1	Lower	43.57389	-111.73896	Sinking
October 29	2	Lower	43.57190	-111.73730	Floating
October 29	3	Lower	43.55865	-111.73516	Sinking
October 29	4	Lower	43.55458	-111.73408	Floating
October 29	5	Lower	43.55152	-111.73736	Floating
October 29	6	Lower	43.54914	-111.73777	Sinking
October 28	7	Middle	43.54118	-111.73067	Sinking
October 28	8	Middle	43.54018	-111.73941	Floating
October 28	9	Middle	43.53589	-111.72381	Sinking
October 28	10	Middle	43.53430	-111.71858	Floating
October 28	11	Middle	43.53075	-111.72564	Floating
October 28	12	Middle	43.52612	-111.72368	Sinking
October 27	13	Upper	43.50336	-111.73889	Sinking
October 27	14	Upper	43.50400	-111.74468	Floating
October 27	15	Upper	43.50239	-111.75437	Sinking
October 27	16	Upper	43.50046	-111.76001	Floating
October 27	17	Upper	43.48119	-111.74784	Sinking
October 27	18	Upper	43.48669	-111.74451	Floating

Appendix D. Locations used in population surveys on the Henrys Fork Snake River, Idaho 2015. All locations used NAD27 and are in Zone 12.

	Start		Stop	
Reach	Easting	Northing	Easting	Northing
Box Canyon	468677	4917703	467701	4914352
Vernon	457092	4878151	454184	4875043
Chester	453182	4873986	451042	4871020

Appendix E. Mean total length, length range, proportional stock density (PSD), and relative stock density (RSD-400 and RSD-500) of Rainbow Trout captured in the Box Canyon electrofishing reach, Henrys Fork Snake River, Idaho, 1991-2015. RSD-400 = (number ≥400 mm/ number ≥200 mm) x 100. RSD-500 = (number ≥500 mm/ number ≥200 mm) x 100.

Year	Number	Mean TL (mm)	Length range (mm)	PSD	RSD-400	RSD-500
1991	711	293	71 – 675	65	46	9
1994	1,226	313	46 - 555	90	46	3
1995	1,590	316	35 – 630	61	30	1
1996	1,049	300	31 – 574	66	20	1
1997	1,272	307	72 – 630	47	14	1
1998	1,187	269	92 – 532	45	13	0
1999	874	330	80 – 573	63	16	1
2000	1,887	293	150 – 593	45	11	1
2002	1,111	352	100 – 600	75	28	0
2003	599	365	100 – 520	86	42	1
2005	1,064	347	93 – 595	76	44	2
2006	1,200	320	95 – 648	64	26	2
2007	1,092	307	91 – 555	58	21	2
2008	1,417	341	92 – 536	73	20	1
2009	1,371	350	80 – 587	79	27	1
2010	2,700	307	75 - 527	51	23	1
2011	1,224	348	111 - 550	74	27	1
2012	1,583	302	77 – 560	57	22	1
2013	2,072	295	110 - 535	39	14	1
2014	1,916	341	106 - 635	80	17	1
2015	1,219	296	90 - 509	83	25	0

Appendix F. Electrofishing mark-recapture statistics, efficiency (R/C), coefficient of variation (CV), Modified Peterson Method (MPM), and Log-Likelihood Method (LLM) population estimates (N) of age 1 and older Rainbow Trout (≥150 mm), and mean stream discharge (ft^3/s) during the sample period for the Box Canyon reach, Henrys Fork Snake River, Idaho, 1995-2014. Confidence intervals (±95%) for population estimates are in parentheses.

Year	M[a]	C[a]	R[a]	R/C (%)	CV	N/reach MPM	N/reach LLM	N/km LLM	Discharge (ft^3/s)
1995	982	644	104	16	0.04	6,037 (5,043-7,031)	5,922 (5,473-6,371)	1,601 (1,479-1,722)	2,330
1996	626	384	69	18	0.05	3,456 (2,770-4,142)	4,206 (3,789-4,623)	1,137 (1,024-1,250)	1,930
1997	859	424	68	16	0.06	5,296 (4,202-6,390)	5,881 (5,217-6,545)	1,589 (1,410-1,769)	1,810
1998	683	425	42	10	0.07	6,775 (4,937-8,613)	8,846 (7,580-10,112)	2,391 (2,049-2,733)	1,880
1999	595	315	38	12	0.07	4,844 (3,484-6,204)	5,215 (4,529-5,901)	1,409 (1,224-1,595)	1,920
2000	1,269	692	74	11	0.05	11,734 (9,317-14,151)	12,841 (11,665-14,017)	3,471 (3,153-3,788)	915
2002	1,050	511	81	16	0.05	6,574 (5,329-7,819)	7,556 (6,882-8,230)	2,042 (1,860-2,224	820
2003	427	167	20	12	0.10	3,472 (2,147-4,797)	3,767 (3,005-4,529)	1,018 (812-1,224)	339
2005	735	401	90	22	0.06	3,250 (2,703-3,797)	4,430 (3,922-4,938)	1,197 (1,060-1,334)	507
2006	887	356	61	17	0.05	5,112 (4,005-6,219)	5,986 (5,387-6,585)	1,618 (1,456-1,779)	1,783
2007	737	332	51	15	0.08	4,725 (3,598-5,852)	8,549 (7,288-9,810)	2,311 (1,970-2,652)	542
2008	887	615	93	15	0.04	5,818 (4,842–7,089)	5,812 (5,312-6,312)	1,571 (1,436–1,706)	894
2009	673	775	112	14	0.04	4,628 (3,910-5,540)	5,034 (4,610-5,458)	1,361 (1,246-1,476)	1,377
2010	1,309	1,292	262	20	0.03	6,439 (5,820-7,058)	8,341 (7,857-8,825)	2,254 (2,123-2,385)	626

Year	M[a]	C[a]	R[a]	R/C (%)	CV	N/reach MPM	N/reach LLM	N/km LLM	Discharge (ft^3/s)
2011	639	652	74	11	0.06	5,571 (4,516-6,988)	6,548 (5,816-7,280)	1,770 (1,572-1,968)	1,159
2012	793	901	116	13	0.04	6,120 (5,178-7,313)	6,915 (6,339-7,491)	1,869 (1,713-2,025)	911
2013	1,115	1,301	120	9	0.04	12,008 (10,148-14,349)	14,358 (13,207-15,509)	3,881 (3,570-4,129)	648
2014	1,532	636	175	28	0.06	5,547 (4,901-6,335)	5,828 (5,491-6,165)	1,575 (1,484-1,666)	971
2015	765	351	67	19	0.11	3,964 (3,216-4,989)	6,220 (4,950-7,490)	1,681 (1,338-2,024)	709

[a] M = number of fish marked on marking run; C = total number of fish captured on recapture run; R = number of recaptured fish on recapture run.

Prepared by:

Jon Flinders
Reginoal Fisheries Biologist

Damon Keen
Regional Fisheries Biologist

Brett High
Regional Fisheries Biologist

Dan Garren
Regional Fisheries Manager

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Jeff C. Dillon
State Fishery Manager

James P. Fredericks, Chief
Bureau of Fisheries