

Long-term Effectiveness of Flow Management and Fish Passage on the Henrys Fork Rainbow Trout Population

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Abstract—The reach of the Henrys Fork of the Snake River immediately downstream of Island Park Reservoir is a world-renowned fishery. Its productive water supports high densities of macroinvertebrates and an abundant population of quality-sized, and larger, Rainbow Trout *Oncorhynchus mykiss*. Rainbow Trout are not native to the Henrys Fork and were stocked from the early 1900s through 1977. In 1978, stocking ceased, and the Rainbow Trout population has been managed under wild trout regulations. Rainbow Trout abundance declined from 3,643 fish/km to 2,528 fish/km between 1978 and 1994 and has averaged 1,857 fish/km since then. In this study, we summarize results of ongoing research that began in 1994 to identify factors limiting recruitment to the wild Rainbow Trout population. Habitat availability for juvenile trout, particularly during winter months, was the primary factor limiting recruitment. Projects reconnecting tributary habitat and increasing river flow during winter months increased juvenile trout habitat and increased recruitment an estimated 9%. Unfortunately, lack of available water during dry years regularly limits winter flows under constraints of filling irrigation rights in the reservoir. Given hydrologic trends caused by a warming climate, the wild Henrys Fork Rainbow Trout population may not be able to attain abundances comparable to those during decades when the fishery was stocked.

Introduction

The reach of the Henrys Fork of the Snake River immediately downstream of Island Park Reservoir is a world-renowned fishery. Its productive water supports high densities of macroinvertebrates, and subsequently, an abundant population of Rainbow Trout *Oncorhynchus mykiss* (Van Kirk and Gamblin, 2000). Starting in the early 1900s to 1977, nonnative Rainbow Trout were stocked in this reach of the Henrys Fork River, and Rainbow Trout densities averaged 3,643 fish/km (Figure 1). In 1978, stocking ceased and the Rainbow Trout fishery was managed as a wild population. Rainbow Trout stocked in Island Park Reservoir regularly supplemented the river population below the dam and Rainbow Trout densities average 2,528 fish/km from 1978 to 1994. In 1994, a hydroelectric facility with fish screens was installed on the dam, greatly reducing opportunities for fish passage to the river downstream, and average Rainbow Trout densities dropped to 1,857 fish/km.

Since 1994, intensive research has been done to identify bottlenecks within the population. In the late 1990s, habitat availability for juvenile Rainbow Trout, particularly during winter months, was identified as the factor most likely limiting juvenile survival and recruitment (Meyer 1995; Gregory 2000; Mitro et al. 2003). To increase available habitat and juvenile recruitment, a fish ladder was renovated in 2005 to bolster juvenile fish passage to a major tributary of the Henrys Fork downstream of Island Park Dam (Buffalo River). Beginning in the winter of 2005-2006, a multi-stakeholder committee called the Henry's Fork Drought Management Planning Committee (DMPC) began managing winter fill of Island Park Reservoir to maximize outflow during the coldest part of the winter, December 1 through February 28, under the constraint of filling storage rights in the reservoir (Joint Committee 2005).

In this study, we quantified the benefits of the renovated Buffalo River fish ladder and increased winter flows on the Henrys Fork Rainbow Trout

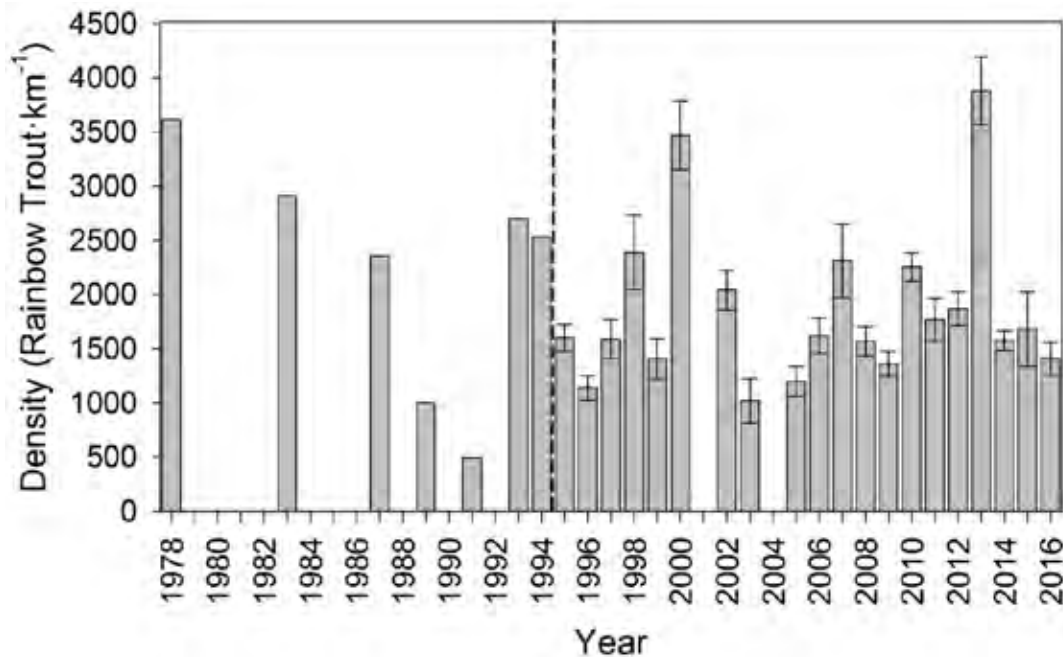


Figure 1. Rainbow Trout per kilometer with 95% confidence interval for the reach of the Henrys Fork River directly below Island Park Dam from the time wild-trout regulations were first implemented to 2016. Dashed line between years 1994 and 1995 signifies when a fish screen was installed on the hydroelectric facility at Island Park Dam and intensive monitoring of the Rainbow Trout population began.

population below Island Park Dam. We used 10 years of data from 2006 to 2016 collected at the Buffalo River fish ladder to quantify juvenile Rainbow Trout winter use of the Buffalo River and contribution back to the Henrys Fork River Rainbow Trout population. Flow data from Island Park Dam, Buffalo River, and population estimates obtained from multi-pass electrofishing in the reach below Island Park Dam from 2006 to 2016 were used to estimate trout abundances for a theoretical scenario where flows were not increased from December 1 through February 28 and compared those abundance estimates to those using actual flows during the same time period.

Study Site

The Henrys Fork of the Snake River is roughly 180 km long and located in southeastern Idaho near the Idaho, Montana, and Wyoming border (Figure 2). The most renowned section of the Henrys Fork is the 34.4-km reach immediately downstream of Island Park Dam. This reach supports high densities of macroinvertebrates (~45,000 individuals/m²), a mixture of pocket water in two canyon sections, and a

meandering flat-water section through Harriman State Park. Abundant insects and diverse habitat provides both wade fisherman and boat fisherman unique opportunities to sight-fish large, Rainbow Trout with dry flies during most of the fishing season (Lawson 2012; McDaniel 2012).

Between 1936 and 1938, Island Park dam was constructed for irrigation storage roughly 30.5 km downstream from the Henrys Fork River headwaters (Figure 2). To build Island Park Dam, a hydroelectric facility was built on the Buffalo River, a major tributary to the Henrys Fork, approximately 0.5 km downstream from Island Park Dam. These two projects severely limited access for Rainbow Trout to headwater spawning and overwinter habitat. The effects of decreased natural reproduction were mitigated by stocking trout until 1977. In 1994, a fish screen was installed on the newly constructed Island Park Dam power plant intake, limiting opportunities for downstream migration of wild and hatchery fish from the reservoir into the river. Fremont-Madison Irrigation District holds irrigation rights to all of the water stored in Island Park Reservoir, and the reservoir must be filled before irrigation season each year to

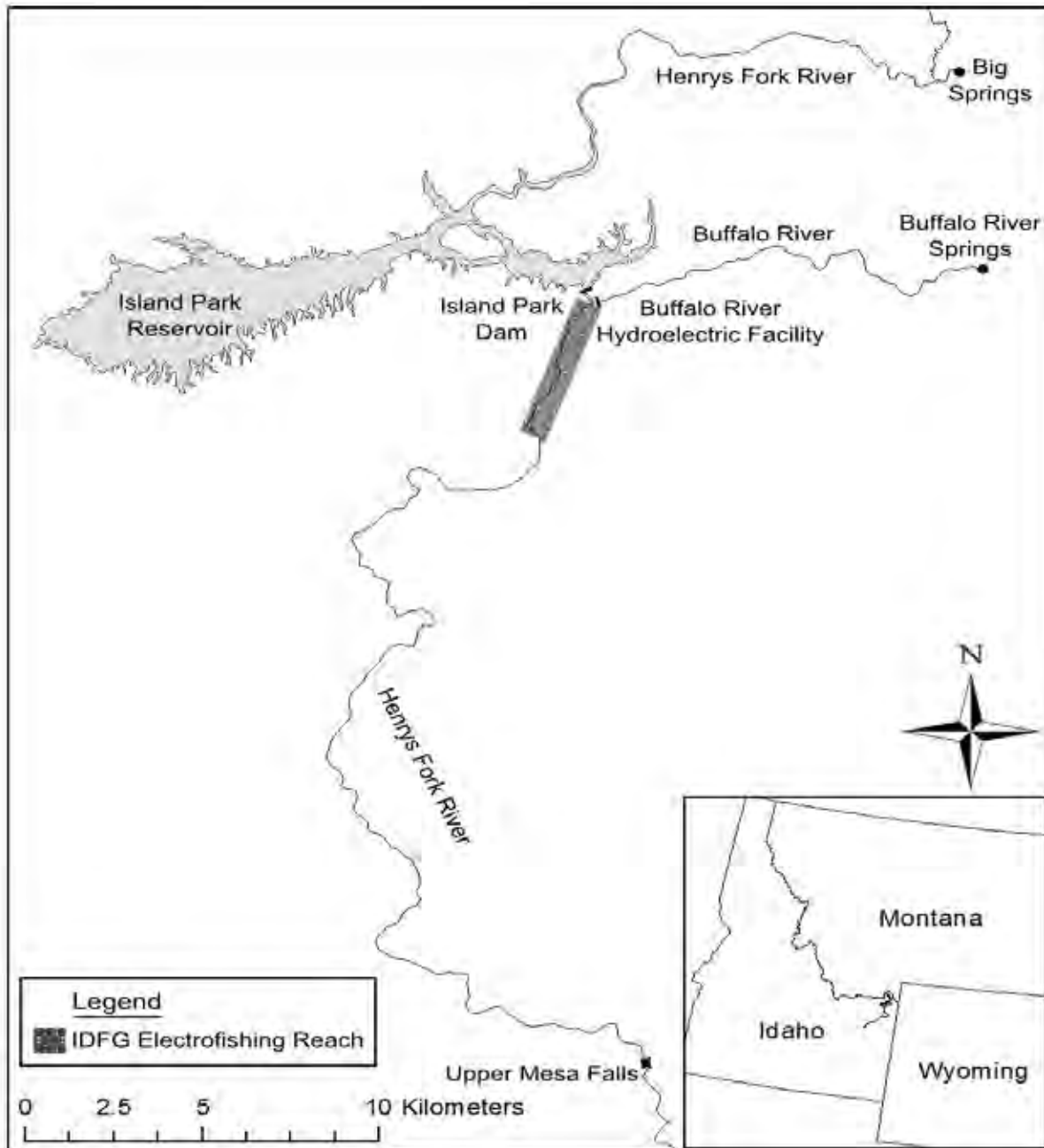


Figure 2. Map of the Henrys Fork of the Snake River downstream of Island Park Dam, Idaho.

meet these rights. Water is generally stored between October and April, and the amount of water that can be released during the storage season is primarily a function of carryover from the previous irrigation season (Benjamin and Van Kirk 1999).

Unlike Island Park Dam, the Buffalo River hydroelectric facility was built with a fish ladder that was designed to promote adult trout access to spawning habitat. Unfortunately, the gradient of

the fish ladder was too high to allow juvenile trout access to prime overwinter habitat on the Buffalo River. Due to declines in Rainbow Trout abundances in the Henrys Fork below Island Park Dam post-1994, relicensing for the Buffalo River facility in 2004 was conditional on renovating the fish ladder to accommodate juvenile trout passage. In 2006, the Buffalo River fish ladder renovation was completed and intensive Rainbow Trout monitoring began.

Methods

Juvenile Rainbow Trout Abundance Estimate

From 2006 to 2016, the Idaho Department of Fish and Game (IDFG) conducted annual multi-pass electrofishing surveys in a 4-km reach that begins 0.45 km downstream of Island Park Dam (Figure 2). This stretch was identified as the best overwinter rearing and spawning habitat below Island Park Dam and was used as an index reach to monitor trends in the Rainbow Trout population.

Three rafts outfitted with electrofishing equipment were used to conduct three to four sampling events each May. 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 abundance for all trout > 150 mm using the Log-likelihood method in Fisheries Analysis+ software (Montana Fish, Wildlife, and Parks).

Flow Recruitment Model

In 2006, Garren et al. (2006) found that mean December-February flow from Island Park Dam during a cohort's first winter was the best predictor of age-2 Rainbow Trout abundances in the reach below Island Park Dam. Prior to formal establishment of DMPC, October-March outflow from Island Park Dam was generally set at the constant flow rate that would achieve a given April-1 reservoir volume (long-term average of 83% full on April 1). We considered this the "baseline" fill strategy. Starting with the winter of 2005-2006, the DMPC implemented a new fill strategy in which outflow was lowered in October and November to store water at a higher rate during this time period so that the same April-1 target could be achieved with higher outflow from December through February.

In 2016, we found that adding mean flow from the Buffalo River to the outflow of Island Park Dam increased the predictability of the earlier model (Figure 3). This updated age-2 Rainbow Trout abundance model was used to calculate expected age-2 abundance for recruitment years 2007-2016 under the actual fill strategy implemented by the DMPC over winters 2005-2006 through 2014-2015.

The same model was then used to calculate expected age-2 abundance for the same set of years under a hypothetical flow scenario that assumed application of the previous baseline fill strategy. The two recruitment estimates were then compared to obtain the expected difference in age-2 abundance between the baseline fill strategy and the new DMPC strategy.

Buffalo River Fish Ladder

Continuous trapping of fish utilizing the renovated Buffalo River fish ladder began March 2006. The trap was checked three times per week and fish were measured and identified to species before being released upstream of the Buffalo River hydroelectric facility. Due to declines in fish passage, the trap screen was removed and the trap was not operated from July 1 to August 31 and December 1 to February 28 starting in 2013.

In 2013 and 2014, a sample of juvenile Rainbow Trout migrating up the Buffalo River fish ladder in September 1 through December 31 were implanted with 12-mm long Passive Integrated Transponder (PIT) tags. These passively operating tags provide a unique 13-digit code that could be read when the tagged fish passed an electromagnetic antenna or handheld reader. A pit tag antenna was installed on the major spillway of the Buffalo River and temporal data were recorded for PIT tagged fish emigrating out of the Buffalo River that had been marked and passed upstream in 2013 and 2014.

To calculate the contribution that the renovation of the Buffalo River fish ladder had to juvenile Rainbow Trout passage and benefit to the Henrys Fork fishery, we first calculated apparent survival for individuals in 2013 and 2014. We did this by dividing the number of fish detected at the Buffalo River fish ladder PIT tag antenna in 2014 and 2015 by the number of fish passed upstream in 2013 and 2014. We then divided that rate by 50% to incorporate presumed mortality that would have taken place before the individual reached age 2 in the Henrys Fork River.

We applied the apparent survival rate to the number of juvenile Rainbow Trout passed upstream each fall from 2006 through 2014. For years 2006 and 2007, we used the mean number of juvenile Rainbow Trout passed upstream during all the other years to supplement the missing data.

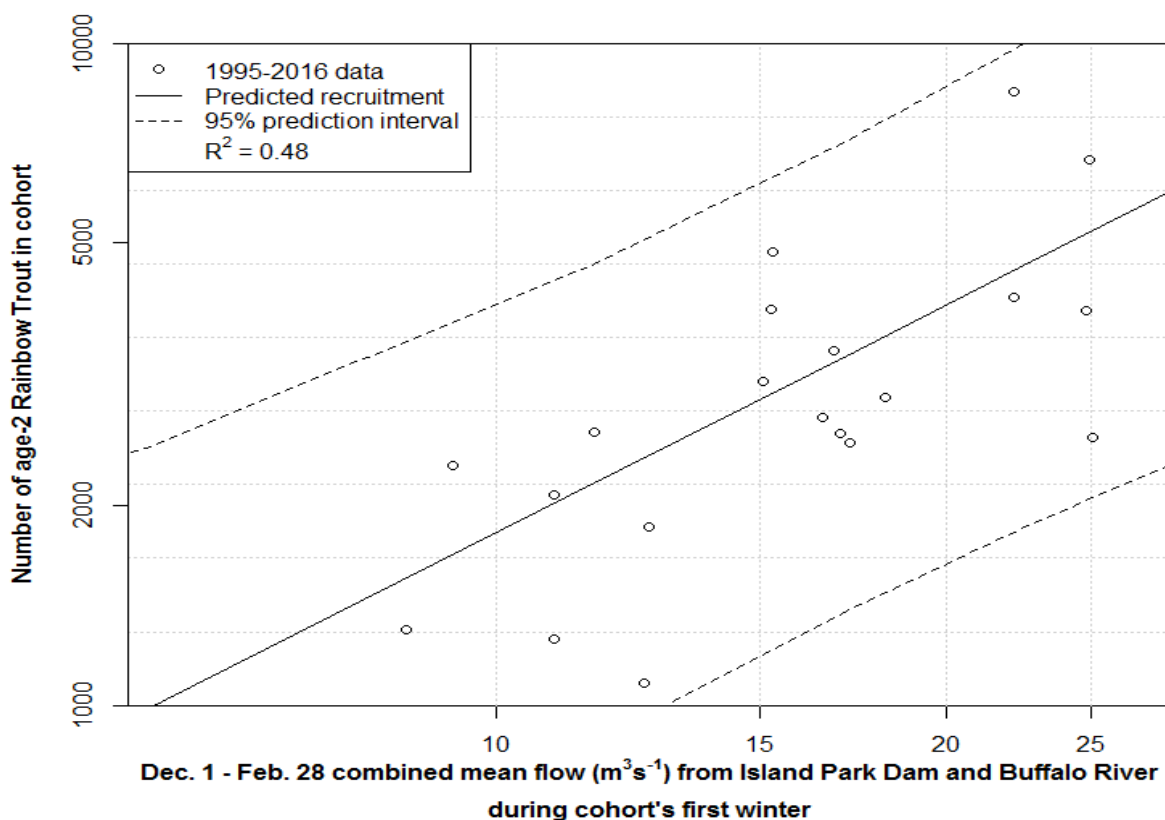


Figure 3. December 1 through February 28 mean flow (m^3s^{-1}) from Island Park Dam and Buffalo River during a cohorts first winter and corresponding abundance of that cohort at two years of age, 1995-2016.

Results

From 2006 to 2016, between 639 and 1532 Rainbow Trout were marked, and electrofishing efficiencies were between 0.09 and 0.28. Mean abundance of age-2 Rainbow Trout was 3,329. Maximum age-2 abundance was 8,747 in 2012 and minimum age-2 abundance was 1,078 in 2015.

Implementing the management practice of increasing flows from December 1 through February 28 increased flows an average of $0.679 \text{ m}^3\text{s}^{-1}$ (5% flow increase) from 2006 to 2016 compared to the baseline scenario in which flows remained constant throughout the storage season. Using the age-2 abundance estimate model with combined mean flows from Buffalo River and Island Park Dam from December 1 through February 28 as the sole predictor variable, increasing flows during December 1 through February 28 added an average of 140 Rainbow Trout, or 5.7%, annually to the total population (Figure 4).

From 2006 to 2016, an average of 1,898 juvenile Rainbow Trout migrated up the Buffalo River fish ladder annually from September 1 through December 1. In 2013 and 2014, 1,605 and 1,788 juvenile Rainbow Trout were implanted with PIT tags as they were passed upstream of the Buffalo River hydroelectric facility. In 2014 and 2015, 105 and 152 PIT tagged fish were detected emigrating from the Buffalo River to the Henrys Fork in the spring. After applying a 50% mortality rate to account for the time between emigrating from the Buffalo River to becoming two years of age in the Henrys Fork River, apparent survival for juvenile Rainbow Trout migrating up the Buffalo River in the fall and returning to the Henrys Fork to reach age 2 was 3.8%. Expanding this rate to the mean number of juvenile Rainbow Trout that migrate up the Buffalo River fish ladder in the fall, the Buffalo River fish ladder contributed 72 fish, or 3%, annually to the total Henrys

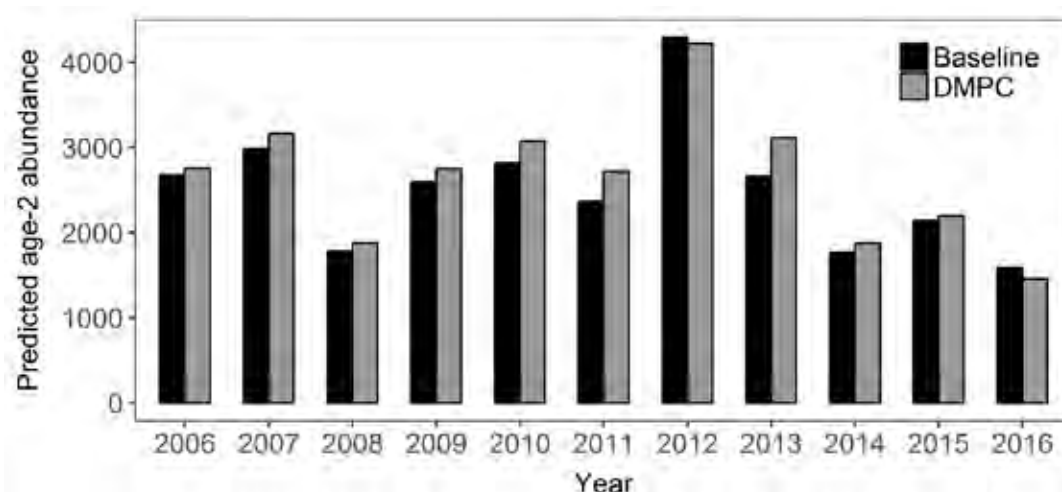


Figure 4. Predicted age-2 Rainbow Trout abundances below Island Park Dam for a hypothetical baseline fill strategy (Baseline) where flows from Island Park Dam, Idaho, were not increased during a portion of the winter compared to predicted age-2 Rainbow Trout abundances using observed flows implemented by the Drought Management Planning Committee (DMPC), 2006-2016.

Fork River Rainbow Trout population below Island Park Dam.

Discussion

Increased flows from Island Park Dam from December 1 through February 28 provided slight increases to the Henrys Fork fishery. The amount of water available to increase flows during the winter was largely restricted by the previous year's snowpack, runoff timing, and irrigation demand. If natural river flows were able to satisfy irrigation rights and demand, surplus water stored at Island Park during the summer and fall could be released during the winter to increase juvenile Rainbow Trout survival. Unfortunately, springtime temperatures in the Henrys Fork watershed have increased an average of 2.48 °C from 1989-2016 (Van Kirk 2017). This has led to earlier peak runoff, requiring increased use of storage water out of Island Park Dam during the summer, and decreasing the amount of storage water available for winter flows. In addition, the variability of snowpack and runoff timing has increased since the 1980s and it is unlikely that there will be a series of consecutive years of increased winter flows needed to achieve Rainbow Trout abundances comparable to those during the mid-1900s when the fishery was stocked.

Renovating the Buffalo River fish ladder to increase juvenile Rainbow Trout access to overwinter

habitat provided only modest increases to the Henrys Fork fishery. The renovation allowed juvenile Rainbow Trout access to overwinter habitat and a 3% increase of Rainbow Trout in the Henrys Fork population. The 3% increase to the population is likely a conservative estimate due to the 50% mortality rate used to account for the time between emigrating out of the Buffalo River and turning two years of age in the Henrys Fork River. Trout survival is highly variable between systems and seasons but typically increases substantially after age-1 (Rieman and Apperson 1989; Carlson and Letcher 2003). We chose to use the 50% survival rate as to not overestimate the Buffalo River juvenile Rainbow Trout contribution.

The renovated Buffalo River fish ladder had additional benefits to the Henrys Fork Rainbow Trout population outside of increased access to overwinter habitat. The lower gradient of the renovated fish ladder increased passage of adult Rainbow Trout migrating to spawn in Buffalo River (Morrisett 2016). In addition, preliminary genetic analysis shows that some offspring of Henrys Fork Rainbow Trout that spawn with Buffalo River Rainbow Trout emigrate and contribute to the Henrys Fork population. Upon completion of the genetic analysis, we hope to be able to quantify the total benefit that the Buffalo River fish ladder, and Buffalo River Rainbow Trout population, have to the Henrys Fork Rainbow Trout population.

In summary, these two projects were successful at increasing the Henrys Fork Rainbow Trout population below Island Park Dam. Unfortunately, the combined total effect of the two management actions was only a 9% increase in the Rainbow Trout population with an interannual coefficient of variation of 38% over the 1995-2016 time period. With increasing regional temperatures, and without substantial decreases in irrigation demand, it is unlikely that the iconic Henrys Fork fishery below Island Park Dam will be able to attain Rainbow Trout abundances comparable to those during decades when the fishery was stocked.

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