

Buffalo River Fish Ladder 2006-2016 Comprehensive Report | August 2016

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Introduction

In the 1930s, construction of the Buffalo River Dam blocked upstream fish passage to the Buffalo River, the only large tributary to the Henry's Fork between Island Park Dam and Mesa Falls. In 1996, a working group of the Henry's Fork Watershed Council realized the goal of restoring fish migration from the Henry's Fork into the Buffalo River with the completion of a fish ladder on the Buffalo River Dam. The fish ladder was improved in 2006 to allow juvenile trout access to winter habitat and to increase the number of spawning trout migrating upstream in hopes of increasing recruitment to the Henry's Fork fishery. This report details the history of the cooperative fish ladder project, reviews reports and data from the 1996-1999 period, and provides analysis and discussion of data from the last decade of operation.

History

The Buffalo River Dam was built in 1936 to generate hydroelectric power for the construction of Island Park Dam. It was subsequently acquired by Pond's Lodge and provided power for the lodge until the powerhouse was struck by lightning and burned in 1986. Buffalo Hydro, Inc. acquired a new license for the project in 1989 and rebuilt the powerhouse, resuming hydroelectric operation in 1994. Although the Federal Energy Regulatory Commission (FERC) acknowledged that the existing fish ladder from the 1930s was ineffective, the 1989 license did not require its reconstruction, citing the need for "additional information on the need for and benefits of such a fishway."

While downstream migration had always been possible over the spillway, fish were unable to migrate upstream, except during a brief period each spring when high water spilled over the dam in sufficient quantity for fish to swim up and over. During the 1980s and 1990s, research indicated that while the Henry's Fork below Island Park Dam provides good habitat and ample food supply for growing large adult fish (Rohrer 1983; Angradi and Contor 1989), it is limited in overwintering habitat for juvenile fish (Gregory 2000; Mitro and Zale 2002). The amount of overwinter habitat available to juvenile fish is strongly and positively dependent on winter outflow from Island Park Reservoir (Gregory 2000; Mitro et al. 2003; Garren et al. 2006). Furthermore, spawning Rainbow Trout concentrate in the reach of the Henry's Fork immediately downstream of Island Park Dam (Gregory 1997; Gregory et al. 2011), making spawning success potentially dependent on flow and water quality below the dam, both of which can be highly variable from year to year. Conversely, the Buffalo River has good juvenile overwintering habitat and spawning areas, but lacks the habitat and food supply for producing large adult fish (Gregory 1997; Gregory and Van Kirk 1998). In response to recruitment declines in the Henry's Fork in the early 1980s, fisheries interests proposed that a fish ladder on the Buffalo River Dam could connect these two areas and thus provide for a wider range of trout needs.

In December 1994, The Henry's Fork Watershed Council formed a working group consisting of Buffalo Hydro, Inc. (the hydropower licensee at the time), Idaho Department of Fish and Game, the U.S. Fish and Wildlife Service, the U.S. Forest Service, and the Henry's Fork Foundation concerning fish passage at the Buffalo River Dam. A request to amend the license to mandate fish passage construction was approved in September 1996 and the fish ladder was completed in October of that year with funding provided by Buffalo Hydro, Inc. In 1997, Buffalo Hydro, Inc. sold their operation to Fall River Rural Electric Cooperative, Inc. (FRREC).

In November 2004, FRREC received a new 40-year license to continue generating power conditioned upon the installation of a fish screen and improved fish ladder capable of passing fish at least 100 mm in length. The fish ladder constructed in 1996 had a steep approach up to the concrete apron that likely prevented many fish from entering the ladder and typically passed less than 100 adult trout each spring. An improved design would allow young-of-the-year Rainbow Trout to emigrate from the Henry's Fork to overwinter in the Buffalo River as well as increase the number of spawning migrants to the Buffalo River, whose offspring could also overwinter before recruiting to the Henry's Fork population, achieving original goals for the project. The improved fish ladder was installed in 2005 and continuous monitoring began in 2006.

Monitoring of downstream migration was explored in conjunction with ladder operations shortly after each reconstruction in 1996 and 2006. A rotary screw trap was used upstream of the dam in 1997 and 1998 to study age class and migration timing of summer outmigrants, but was removed given low capture efficiency. In 2009, a downstream trap was constructed at the lip of the spillway to monitor trout moving out of the Buffalo River, but was removed in October 2015 due to its low capture efficiency and high cost of maintenance.

In 2013, research and monitoring of the Buffalo River Fish Ladder shifted from effectiveness of the ladder in passing individual fish to if and how the Buffalo River contributes to the Henry's Fork fishery. In partnership with the Idaho Department of Fish and Game, the Henry's Fork Foundation initiated a genetics study to better understand life histories of Rainbow Trout migrating between the Henry's Fork and Buffalo River. The study collected tissue for genetic testing and outfitted individuals with Passive Integrated Transponder (P.I.T) tags. A tag detector antenna was installed at the spillway to monitor downstream movement of trout out of the Buffalo River. Tagging concluded in 2015 and genetic sampling will conclude in 2017. Preliminary genetic analysis has been conducted and the results will be shared in this document, but the study is ongoing.

Fish Ladder Operation

Operation of the fish ladder has changed multiple times throughout the history of the project. A timeline is given below using information from meeting summaries, internal HFF reports (Dillinger 1999; Dillinger 2000), archived HFF newsletters, and other correspondence:

1997:

- Open the ladder on 1 December 1996.
- Begin counting trout 16 inches and longer towards the closure quota on 1 February 1997 (via video monitoring).
- Allow unhindered escapement until 1 April 1997, regardless of how many fish migrate upstream between 1 January and 1 April.

- On or after 1 April, close the ladder once 500 Rainbow Trout 16 inches and longer have migrated through the ladder, on the day the checkboards are removed¹ from the Buffalo River Dam, or 15 May 1997, whichever comes first².

1998:

- Operational criteria were the same as in 1997, with the modification that the ladder was opened on 1 October 1997 instead of 1 December 1997 as initially planned, due to anecdotal evidence that small fish had attempted to use the ladder to move upstream in October 1996.
- Video monitoring took place from 28 January to 23 April 1998.

1999:

- Operational criteria were the same as the previous year, with the modification that the ladder was opened on 1 February 2000.
- Video monitoring took place from 1 February to 2 April 1999.

2000:

- Operational criteria were the same as the previous year, with the modification that the ladder was opened on 4 February 2000.
- Video monitoring took place from 15 February 2000 to 15 May 2000.

2001: Operational criteria were the same as the previous year, with the modification that the ladder was opened and video monitoring took place from 15 February 2001 to 29 April 2001.

2002:

- The ladder remained open for fish passage throughout the year³.
- Video monitoring took place from 14 December 2001 to 25 April 2002.

2003-July 2005: No written record of ladder operations.

2005:

- Monitoring efforts suspended from August to October 2005 as construction of new fish ladder and improved screening of the turbine intake took place.

¹ Checkboards in the Buffalo River Dam are removed for approximately 30 days each spring when the water level rises to the point where it would spill over the top of the dam. Once the checkboards are removed, the number of large fish (16 inches and over) using the ladder declined immediately, presumably because the large fish were able to migrate over the dam without using the ladder.

² This operational criterion was influenced by concerns that Henry's Fork spawners in the Buffalo River would be vulnerable to harvest. The Buffalo River is managed under general regulations (six trout possession limit, no gear or size restrictions); the Henry's Fork is managed under catch-and-release regulations, with artificial lures with single barbless hooks required. Additional concerns were expressed about the potential for harvest of Henry's Fork spawners before they have spawned in the Buffalo River, and the harvest of potential Henry's Fork recruits in the Buffalo River, before they migrate to the Henry's Fork.

³ This change in operation was ordered by FERC on 22 January 2001 by a recommendation of the Henry's Fork Foundation submitted on 18 December 2000.

- The fish ladder became operational and open for fish passage in November 2005.

2006-2012

- Continuous trapping of fish moving up the ladder began in March 2006.
- The fish trap was checked at least three times per week.⁴
- All fish were measured and identified to species before being released upstream.

2013:

- Operational criteria were the same as over the 2006-2012 time period, with the modification that the trap screen was removed, allowing free passage through the ladder for July and August 2013.
- From September to December 2013, in addition to measuring and identifying all fish to species, a sample of upstream-migrating Rainbow Trout of all sizes were fitted with a P.I.T tag as part of the newly initiated life history study with IDFG.

2014:

- The fish trap screen was removed from 2 December 2013 to 25 February 2014 and 1 July to 5 September 2014, allowing free passage through the ladder. Monitoring did not occur during this time, but the fish trap was otherwise checked at least three times per week.
- All fish were measured and identified to species.
- During the spring sampling period, tissue samples were taken from all upstream-migrating spawning-sized Rainbow Trout (≥ 300 mm). These individuals were also fitted with a P.I.T tag.
- During the fall sampling period, a sample of upstream-migrating Rainbow Trout of all sizes were fitted with a P.I.T. tag.

2015:

- The fish trap screen was removed from 13 November 2014 to 22 February 2015, allowing free passage through the ladder. Monitoring did not occur during this time.
- The fish trap was operational and monitored at least three times per week between 22 February and 19 June 2015.
- The fish trap screen was removed on 19 June 2015 and only replaced once in October and once in November for two three-day trapping periods.⁵
- All fish were measured and identified to species.
- During the spring sampling period, tissue samples were taken from all upstream-migrating spawning-sized Rainbow Trout and all upstream-migrating Rainbow

⁴ The 2007, the fish trap was processed once or twice per week. In 2009 and 2012, the fish trap was not monitored in January.

⁵ Continuous fall sampling was eliminated from the Buffalo River Fish Ladder Operational Criteria at a work group meeting on 30 September 2015 due to the collection of satisfactory data demonstrating that small trout move upstream in the fall to presumably overwinter in the Buffalo River.

Trout were fitted with a P.I.T tag. Any recaptures were scanned with a tag reader and their tag code recorded.

2016:

- The fish trap screen was removed from 13 November 2015 to 18 February 2016, allowing free passage through the ladder. Monitoring did not occur during this time.
- The fish trap was operational and monitored at least three times per week between 18 February and 15 June 2016.
- The fish ladder was opened for free passage on 15 June 2016 and is anticipated to remain so until mid-February 2017 for the spring sampling season.
- All fish were measured and identified to species. Any recaptures were scanned with a tag reader and their tag code recorded.

[Review of Reports from the late 1990s](#)

Construction of the Buffalo River Fish Ladder in 1996 caused concern that spawning trout migrating from the Henry's Fork to the Buffalo River would be at risk for harvest given that the Buffalo River is managed under general regulations (six trout possession limit, no size or gear restrictions), while the Henry's Fork is managed under catch-and-release regulations. In response to this concern, the Henry's Fork Foundation conducted creel surveys in 1996-1998 to determine the composition of trout harvested in the Buffalo River and whether the Henry's Fork Rainbow Trout population is impacted by harvest of migrants into the Buffalo River via the fish ladder.

Results indicated that although there was a large increase in angling effort in 1997 and 1998 compared to a 1988 IDFG study, annual harvest of wild Rainbow Trout was lower in 1997 and 1998 after installation of the fish ladder than it was in 1988 (Van Kirk et al. 1997; Van Kirk and Giese 1999). Thus, while the data showed an increase in effort, they did not suggest any increase in the number of wild Rainbow Trout harvested in the Buffalo River after the ladder was installed. Additionally, the checkboards were removed from the Buffalo River dam on 22 April, allowing Henry's Fork spawners to migrate into the Buffalo River without the aid of the fish ladder. Thus, many of the large Henry's Fork fish harvested in the Buffalo were likely fish that would have migrated upstream after 22 April regardless of whether the ladder was present. Furthermore, migration of trout 400 mm and longer peaked in early April, six weeks before the beginning of fishing season. This allowed ample lag time for up-migrating spawners to return to the Henry's Fork before opening day.

Van Kirk et al. (1997) and Van Kirk and Giese (1999) concluded that any harvest due to the fish ladder did not appear to have a negative impact on the Box Canyon Rainbow Trout population, which increased significantly in the two years after the ladder was installed. In fact, both studies concluded that the fish ladder project likely had a net benefit on both the Henry's Fork population and the Buffalo River fishery.

In addition to the creel survey, a study was conducted in 1997 and 1998 to investigate the Buffalo River's contribution to the Henry's Fork fishery and a rotary screw trap was installed upstream of the Buffalo River dam to monitor downstream migration. Data from this study and

from the fish ladder monitoring program suggest that Henry's Fork Rainbow Trout are successfully spawning in the Buffalo River, that the majority of downstream migrants to the Henry's Fork fishery as a result of spawning activity are young-of-year (at least based on fish size), and that at least a few offspring of Henry's Fork spawners remain in the Buffalo River for one year before out-migrating (Van Kirk and Beesley 1999). The study recommended that the Buffalo River fish ladder remain open to allow Henry's Fork spawner access to the Buffalo and that monitoring activities of upstream and downstream migrants continue.

Overview of FERC License

Fall River Rural Electric Cooperative, Inc. filed an application on October 30, 2002 for a subsequent minor license to continue to operate the existing 250-kilowatt Buffalo River Hydroelectric Project. The existing license at the time was issued on March 14, 1980 and would expire on October 31, 2004. The Federal Energy Regulatory Commission issued a subsequent license for P-1413-032 on November 5, 2004.

In the license, FERC mandated the following:

- **Article 403. Operational Compliance Monitoring Plan.** Within six months of the effective date of this license, the licensee shall file for Commission approval an operational monitoring compliance plan. The plan shall include at a minimum:
 - A description of the exact location of each gage or measuring device, the method of calibration for each gage or measuring device, the frequency of recording for each gage or measuring device, and a monitoring schedule;...
- **Article 405. Upstream Fishway.**
 - Within one year of license issuance, FRREC shall file for Commission approval detailed design drawings of proposed upstream fishway together with a schedule to construct or install, operate, and maintain the fishway.
 - The fishway shall be continuously operational and designed to pass all life history stages of Rainbow Trout of at least 100 mm in length.
- **Article 407. Fishway and Fish Screen Effectiveness Monitoring, Evaluation, and Maintenance.**
 - Within one year of license issuance, FRREC shall file for Commission approval a plan for conducting post-construction monitoring and evaluation of the fishway required by Article 405 for a period of three years and every third year thereafter for the term of the license.
 - In addition to monitoring, the plan shall include, at minimum, a provision for monitoring and documenting fishway use and effectiveness: recording the species, length, and quantity of fish found impinged on the fish screen.

FERC also mandated that the proposed fishway design and monitoring plan be prepared after consultation with the Idaho Department of Fish and Game, U.S. Forest Service, U.S. Fish and Wildlife Service, and the Henry's Fork Foundation.

Previous Reporting Under Current License

Northwest Power Services, Inc. reported data from the fishway and fish screen for the Buffalo River Hydroelectric Project for ladder monitoring conducted in 2006, 2007, 2008, and 2009, in compliance with Article 407 of the license on behalf of FRREC. Symbiotics, LCC submitted the

2011 fish ladder monitoring data. These reports satisfied the minimum reporting requirement of documenting species and length of individual fish using the fish ladder for upstream passage and may be accessed through FERC's online library for P-1413.

Examination of 2006-2016 Data

This section of the document analyzes and presents the last decade of data collected on streamflow and fish passage in compliance with articles 403, 405, and 407, as well as an update on the genetic and migration study initiated with IDFG in 2014.

Streamflow Record

The U.S. Geological Survey (USGS) established a streamflow gage on the Buffalo River in 1935 (USGS 13043000 Buffalo River at Island Park ID). The gage is located at the Highway 20 bridge near Pond's Lodge. Continuous daily streamflow was recorded at that gage from May 1, 1935 through January 2, 1941. Since that time, USGS has taken periodic field measurements at the gage location but has not recorded streamflow data on a regular basis. The operational compliance monitoring plan (Article 403), which was approved by FERC on March 2, 2007, specifies:

To update the rating curve the USGS will need to make at least three visits to the site during different flow conditions to take measurements. Once the rating curve has been updated the USGS will need to return to the site approximately twice annually to take measurements and adjust the rating curve as needed. The Licensee has agreed to reimburse the USGS for this work. The Licensee will take stage measurements of the water elevation with the current measuring gauge.

In January 2013, Northwest Power Services proposed to the stakeholders an amendment to this paragraph that would have reduced the frequency of field measurements at the gage site. However, a request for amendment was not filed with FERC, and the paragraph above remains in effect. Fall River Rural Electric began recording daily stage measurements in January 2006. Since 2007, USGS has made 29 field measurements of stage and discharge at the Buffalo River gage and maintained the rating curve.

Objective:

In the section of the FERC license entitled "Recommendations of Federal and State Fish and Wildlife Agencies," item 24 reads:

IDFG recommended that if future changes occur to the hydrology of the Buffalo River, then Fall River should provide a minimum flow of at least 50 cubic feet per second to the bypassed reach. Including a requirement for a minimum flow based on an uncertain future event is premature; however, this license includes, in standard Article 11, the Commission's reservation of authority to reopen the license to modify project structures and operations for the conservation and development of fish and wildlife resources in response to future events.

The objective of recording daily discharge measurements in the Buffalo River is to provide the long-term data needed to support this recommendation.

Methods:

The USGS has provided the current rating curve to HFF and records its field measurements and rating-curve shifts in the National Water Information System database, which is available online. Once each month, FRREC provides the daily stage measurements to HFF, which then uses the rating curve and applicable shifts to calculate discharge. The rating shift for any given day was calculated by linear interpolation between field-measured rating shifts. For days when stage data are missing, discharge was estimated by cubic-spline interpolation.

Results:

Calculated and estimated daily discharge show seasonal patterns typical of other groundwater-dominated streams in the Henry's Fork watershed (Benjamin 2000). Baseflow in the Buffalo River averages around 200 cfs; annual snowmelt peaks are short in duration, occur in late April and early May, and range between 300 cfs and 600 cfs in magnitude (Figure 1). Heavy rain in May of 2011 resulted in apparent discharge of over 2,000 cfs; however, the stage recorded during this runoff event exceeded the range of the rating curve, so the daily flows may not be accurate. Nonetheless, streamflows recorded at other gages in the watershed corroborate the data from the Buffalo River gage during that high-flow event. Regardless of the exact magnitude, flow in the Buffalo River certainly exceeded 1,000 cfs for several days in May of 2011. Otherwise, the 10-year flow record in the Buffalo River documents a generally decreasing trend, particularly from 2012 through the summer of 2016.

Discussion:

The current three-party process involving USGS, FRREC, and HFF is providing timely streamflow data of sufficient accuracy to document variability in streamflow within and across water years. The data are also of sufficient accuracy to investigate statistical responses of ecological processes to streamflow in the Buffalo River. Although sample size is still small at this point, continued compilation of streamflow data using the current process will meet the objective of collecting streamflow data, as outlined in the FERC license.

Trout Migration

With eleven sampling seasons (2006-2016) worth of data on spawning-sized Rainbow Trout up-migrating in the spring and nine sampling seasons (2006-2014) worth of data on young Rainbow Trout seeking to over-winter in the Buffalo River in the fall, we investigated if and how regulated and unregulated environmental factors in the region influence migration timing and cohort size of spawning-sized and "young" Rainbow Trout. We also considered species composition.

Objectives:

- Identify size of migration cohort and timing of peak migration for up-migrating spawning-sized Rainbow Trout in the spring and young Rainbow Trout seeking to over-winter in the Buffalo River in the fall.
- Explore how migration timing and cohort size of spring up-migrating spawning-sized Rainbow Trout and fall up-migrating young Rainbow Trout relate to streamflow and air temperature.
- Investigate if species composition of up-migrating fish changes by season and/or by year.

Methods:

UPSTREAM MIGRATION TIMING & COHORT SIZE

We compared the number of spring up-migrating spawners (≥ 300 mm) to mean daily spring runoff (1 April to 30 June) between Henry's Lake and Island Park Dam three years prior to and two years prior to mean daily spring runoff in the Buffalo River in the current year, to mean Buffalo River flow in March, April, and May, and to mean air temperature in March, April, and May. Runoff between Henry's Lake and Island Park Dam was calculated as unregulated inflow to the reach, using USGS streamflow data and Island Park Reservoir volume data from the U.S. Bureau of Reclamation Hydromet website. Air temperature data were also obtained from Reclamation's Hydromet website.

We evaluated the timing of spring up-migration by first computing the date on which half of the spawners for that year had migrated upstream (median migration date). Because temporal distribution of migration was symmetric, the median migration date represents the peak migration date. We then compared this peak migration date with mean daily spring runoff in the Buffalo River in the current year, mean temperature in March, April, and May, and the date on which half of the seven day runoff maximum in the Buffalo River occurred.

For fall up-migrants, we compared the number of fall up-migrants (≤ 150 mm) with mean temperature in September and October, mean minimum temperature in September, mean maximum temperature in September, and mean daily flow out of Island Park Dam in September and October. We evaluated the timing of fall up-migration by comparing the median migration date (again, peak migration date) of young Rainbow Trout (≤ 150 mm) with the same parameters in addition to the first and second date on which flow out of Island Park Dam was reduced.

All comparisons were first visually assessed with scatterplots. For comparisons that appeared to show a relationship between response and predictor, significance was tested with the appropriate linear regression model. All statistical tests were performed in the statistical computing environment R (R Core Team 2016).

SPECIES COMPOSITION

Species composition was calculated for each season and year. The spring season was defined as 15 February to 30 June; the fall season was defined as 1 September to 31 December. Species analyzed were Brook Trout (*Salvelinus fontinalis*), Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), and "other." The "other" category included

shiners, dace, chubs, sculpins, and suckers – species that are captured in the trap, but are too few in number to be analyzed separately.

Results:

UPSTREAM MIGRATION TIMING & COHORT SIZE – Table 1

- The median size of the spring migration cohort over the period 2006-2016 was 202 spawning-sized Rainbow Trout. The largest spawning cohort was 419 individuals, in 2013; the smallest spawning cohort was 75 individuals, in 2015.
- Median date of peak spawning over the period 2006-2016 was 6 May. The earliest peak in the last decade was during the 2016 spawning season, occurring on 18 April. The latest peak was in 2013, occurring on 20 May.
- The median size of the fall cohort migrating out of the Henry's Fork and into the Buffalo River over the period 2006-2014 was 1,800 young Rainbow Trout. The largest fall up-migrant cohort occurred in 2010 with 3,234 individuals; the smallest fall up-migrant cohort occurred in 2007 with 923 individuals.
- Median date of fall up-migration over the 2006-2014 period was 20 October. The earliest peak occurred in 2006 on 4 October. The latest peak occurred in 2007 and 2009 on 26 October.
- There appears to be a cyclic trend to the number of spawners that migrate into the Buffalo River to spawn (Figure 2), but we were unable to identify a statistically significant relationship between migration timing or migration class size for fall up-migrating young trout or spring up-migrating spawners with streamflow or air temperature data (Figures 3-6).

SPECIES COMPOSITION– Figure 7

- Brook trout and Rainbow Trout are the primary users of the fish ladder in the spring, while Rainbow Trout and Mountain Whitefish are the primary users in the fall.
- A logistic regression model identified a significant decrease in the fraction of Brook Trout migrating upstream in the spring over the 2006-2016 period.
- Species composition of fall up-migration showed a larger number of Mountain Whitefish in 2010-2012 compared to the other years.

Discussion:

We were unable to find any statistically significant relationship between migration timing or migration cohort size and regulated and unregulated environmental factors. This is likely due to a small sample size; each sampling season generates only one data point. More data are needed to identify statistically significant environmental determinants of migration timing or size of migration cohort.

However, compiling the last decade of data allowed us to learn some more general information about Rainbow Trout migration between the Henry's Fork and the Buffalo River. Peak spawning runs typically occur during the first week of May, but have occurred between mid-April and late-

May. There does not appear to be any temporal trend in timing of spawning migration over the past decade. Peak migration of young trout to overwintering habitat in the Buffalo River always occurs in October. Seasonal use of the fish ladder does not appear to be shifting towards one species or another. Species that primarily use the ladder in the spring and fall have remained consistent over the last decade. This information can help guide management actions in the region as well as provide a baseline for comparison to the next decade of data.

Genetics and Population Contribution

The migration data clearly show that a large number of fish of a variety of species successfully migrate through the Buffalo River fish ladder each spring and fall. However, evidence of successful migration is not sufficient on its own to indicate whether the fish ladder is having any effect on the Rainbow Trout population in the Henry's Fork. For example, despite fall up-migrations of around 2000 young Rainbow Trout, examination of length data of young Rainbow Trout migrating in and out of the Buffalo River indicated that the juveniles moving downstream in the spring were not the same individuals that had moved upstream during the previous autumn (Figure 8). Juveniles moving upstream in the fall were typically between 110 and 140 millimeters in length, while those moving downstream six months later were 70 to 100 millimeters in length. Given that one of the primary motivations for constructing the new fish ladder was to allow young-of-year Rainbow Trout from the Henry's Fork to winter in the Buffalo River, this discrepancy in sizes of young Rainbow Trout moving into and out of the Buffalo River raised the question of whether spawning, rather than over-wintering, is the greater contribution of the Buffalo River to the Henry's Fork fishery.

As a result, the Henry's Fork Foundation partnered with the Idaho Department of Fish and Game to investigate the life histories of Rainbow Trout migrating into and out of the Buffalo River to assess the extent to which the Buffalo River population contributes to the Henry's Fork fishery. The study was two-pronged, using genetic analysis to infer parentage of migrants and Passive Integrated Transponder (P.I.T) tags to identify migration timing as well as if individuals migrate between the Henry's Fork and Buffalo River multiple times.

Genetics

The first phase of the genetics study was completed in fall 2015 (Redfield et al. 2016). We summarize that study here.

Objectives:

- Establish the origin and diversity of the Henry's Fork population.
- Determine whether fluvial Henry's Fork adults are using the Buffalo River to spawn.
- Estimate contributions to the Henry's Fork fishery resulting from spawning activity in the Buffalo River.
- Assess the relative contribution of fluvial Henry's Fork Rainbow Trout and Buffalo River resident trout to the Henry's Fork fishery.

Methods:

Tissue was taken from 643 Rainbow Trout, assembled from four sample groups. A total of 289 samples were from trapped migrating into the Buffalo River from 2014 and 2015, 79 Buffalo

River juvenile outmigrants collected in 2015, and 275 adults and juveniles captured in electrofishing surveys from Henry's Fork in 2015.

All samples were genotyped at 186 single nucleotide polymorphisms (SNPs). Multi-locus SNP data was used to evaluate the genetic diversity among the samples and to estimate the origin of the Buffalo River and Henry's Fork populations. Analyses include:

- Percentage of polymorphic SNPs and average expected heterozygosity (H_E) for Buffalo River and Henry's Fork populations were estimated using GENALEX v6.3 (Peakall and Smouse 2006).
- We used SNPPIT (Anderson 2010) and CERVUS 3.0.3 (Kalinowski et al. 2007) to perform double- and single-parentage assignments, respectively.
- We estimated effective population size (N_E) on all populations using Colony v2.0 (Jones and Wang 2010) and assuming monogamy and random mating.
- Population structure was evaluated using Structure 2.3.4 (Pritchard 2009). Two populations were confirmed using STRUCTURE Harvester (Earl and vonHoldt 2012).

Results:

GENALEX:

- Although the study area has been stocked with *O. mykiss* from various strains, genetic assignment results continue to demonstrate that *O. mykiss* in Buffalo River and the Henry's Fork are primarily of a coastal hatchery lineage.
- Genetic diversity, measured as parentage of polymorphic SNPs and expected heterozygosity (H_E), was high for all for all of the sample groups. All four groups were polymorphic at an average of 96% of SNPs screened. The average H_E was 32%.
- We observed low, but significant genetic differentiation between Rainbow Trout samples from the Henry's Fork and Buffalo River populations.

COLONY:

- We calculated the effective population size (N_E) to be 1,264 individuals for the 2014 Buffalo River adults, 1,873 for the 2015 Buffalo River adults, 462 for the 2015 Buffalo River juveniles, and 3,004 for the 2015 Henry's Fork samples.

CERVUS and SNPPIT:

- Of the 275 fish collected from the Henry's Fork in 2015, 28 were juveniles (<150 mm). Of those juveniles, only one assigned to a single parent sample from the Buffalo River in 2015.
- Of the 79 down-migrating juveniles collected from the Buffalo River in 2015, 16 (20%) assigned to either a single parent or parent pair captured in the ladder during the 2014 spawning migration. Of these 16 fish, 6 were assigned to two parents that were captured as they migrated upstream from the Henry's Fork during the spring of 2014. Nine of these 16 juveniles received single-parent assignments to Henry's Fork spawners that had migrated upstream during 2014, the other parent presumably being a Buffalo River resident fish. One juvenile captured in 2015 assigned back to an adult captured in the Henry's Fork in 2015 and an adult that had migrated upstream through the fish ladder in 2014. The other 80% were not related to any Henry's Fork spawners that we had

sampled in the spring of 2014. Presumably, these fish were offspring of resident Buffalo River fish.

STRUCTURE:

- Analysis of the four Buffalo River and Henry's Fork sample groups demonstrate differentiation between Buffalo River and Henry's Fork. Two populations were delineated, one for the Buffalo River samples and one for the Henry's Fork samples.

Discussion:

A substantial effective population size (N_E), and high expected heterozygosity (H_E) indicate that the Rainbow Trout population from the Henry's Fork is large and very genetically diverse. The Henry's Fork and Buffalo River populations exhibit low differentiation; however our STRUCTURE and GENALEX results indicate that samples from these areas were not drawn from a single randomly mating population. The parentage assignment for juveniles sampled in 2015 establish evidence of Buffalo River Rainbow Trout contributing to the Henry's Fork fishery.

To improve our baseline for parentage assignment, we recommend sampling Buffalo River residents above the trap as well as Henry's Fork spawners. To verify the source of Henry's Fork age-2 recruits, we would need to continue sampling in the Henry's Fork in 2016 and 2017. This sampling would allow us to investigate the range of Rainbow Trout life histories in these rivers. We hope to further understand how Buffalo River Rainbow Trout contribute to the Henry's Fork fishery, which continues to be one of the most important fisheries in the state.

P.I.T Tag Study

A sample of upstream- and downstream- migrating Rainbow Trout from multiple size classes were outfitted with a P.I.T tag in 2014 and 2015. Installation of a P.I.T. tag detector antenna in January 2014 allowed monitoring efforts to track downstream movement out of the Buffalo River. Although tagging was concluded in June 2015, the antenna has continued to record the downstream-migrating movement of tagged individuals into June 2016.

P.I.T tag retention has been studied extensively in juvenile fish species. In southern Idaho streams, long-term tag retention of smaller Rainbow Trout (≤ 150 mm) was high (95%), a tad lower than the general range of 98% to 100% (Bateman et al. 2009). To estimate short-term P.I.T tag retentions in juvenile trout (≤ 150 mm) for this project, HFF staff held a subsample of tagged trout in the fish ladder trap for a few days. Of 59 marked fish that were recovered from the trap several days later, 58 (98%) had retained the P.I.T tags. Although long-term retention could be lower, we assumed 98% retention rate over the study duration.

Objectives:

Young Rainbow Trout⁶

⁶ Defined as ≤ 150 mm in the fall and ≤ 180 mm in the spring to allow for growth between fall and spring, so that the same cohort could be identified in both seasons. Data from a few recaptured fish suggested that 30 mm of growth is reasonable for these fish. 150 mm was used because it is the maximum length of age-0 Rainbow Trout at the end of their first summer, based on previous age growth studies.

- Identify if “young” Rainbow Trout that migrate upstream in the fall contribute to increased over-winter success of their cohort as a whole.
- Investigate what fraction of “young” spring out-migrants is made up of upstream-migrants from the previous fall.
- Determine if “young” Rainbow Trout that migrate upstream in the fall or downstream in the spring return to migrate upstream again.

Spawning-sized Rainbow Trout⁷

- Identify how many spawners migrate downstream shortly after spawning (same spring or summer).
- Determine the frequency of repeat spawning in subsequent years.

Methods:

- February-June 2014 and 2015: tag⁸ all spawning-sized Rainbow Trout migrating upstream; tag a sample of all Rainbow Trout migrating downstream
- September-December 2013 and 2014: tag a sample of Rainbow Trout ≤ 150 mm migrating upstream
- Clip the adipose fin of all tagged individuals, and release trout in migration direction
- Scan recaptured individuals, as indicated by absence of adipose, encountered in upstream and downstream traps with tag reader to obtain tag code and track migration history
- Periodically download and erase the tag detector antenna memory
- Estimate efficiency of downstream trap:

To estimate downstream trap efficiency, HFF conducted two tests in 2014. On each of 7 April 2014 and 21 April 2014, a subsample of down-migrating fish was marked with a visible external mark and released upstream of the trap. The fraction of these marked fish subsequently recaptured in the downstream trap is an estimate of the fraction of all fish migrating downstream that are captured in the trap. Eleven of 164 fish marked on 7 April and one of 104 fish marked on 21 April were recaptured in the trap. These two data points were combined with seven observations made in 2012 and five made in 2013. The combined set of 14 efficiency tests yielded an estimated trap efficiency of 0.0386, with a 95% confidence interval of [0.0278, 0.0520]. Of the 153 P.I.T.-tagged fish that were detected by the antenna, six (3.9%) were also captured in the downstream trap, consistent with the efficiency estimated by the mark-recapture tests. Thus, the data suggest a capture efficiency of around 3.9%.

Results:

Young Rainbow Trout – Fall Up-migrants (Table 2)

- Of the 3,393 young Rainbow Trout tagged migrating upstream in the fall (September to December), 1,605 were tagged in 2013 and 1,788 were tagged in 2014.

⁷ Defined as ≥ 300 mm

⁸ Tagged trout were marked internally with a Passive Integrated Transponder (P.I.T) tag injected into the abdominal cavity.

- Of the 1,605 young Rainbow Trout tagged migrating upstream in Fall 2013, 115 were detected moving downstream. The majority of these detections occurred the subsequent spring (January to June 2014), with 105 trout detected. Seven trout were detected downstream the following summer/fall, while three were detected down-migrating in Spring 2015 after having spent a year and a half in the Buffalo River. No trout initially tagged up-migrating in Fall 2013 have been recaptured up-migrating to the Buffalo River from the Henry's Fork.
- Of the 2,806 Rainbow Trout ($\leq 180\text{mm}$) captured in the downstream out-migrant trap during Spring 2014, five were individuals initially tagged migrating upstream Fall 2013.
- Of the 1,788 young Rainbow Trout tagged migrating upstream in Fall 2014, 195 were detected moving downstream. The majority of these detections occurred in the subsequent spring (2015), with 152 detected. Nine detections from the Fall 2014 tag class occurred the following fall, while ten out-migrated the second subsequent spring (2016). Twenty-four detections occurred during the same fall as initially tagged. Zero trout initially tagged up-migrating in Fall 2014 has been recaptured moving upstream.

Young Rainbow Trout – Spring Out-migrants (Table 3)

- Of the 618 young Rainbow Trout tagged out-migrating in the Spring (January – June), three were tagged in 2014 and 615 were tagged in 2015.
- None of the three out-migrating young Rainbow Trout tagged in Spring 2014 were recaptured moving upstream or detected moving downstream.
- Three of the 615 young out-migrating Rainbow Trout were recaptured moving upstream. Two were recaptured the same spring with no later detections, while one was recaptured returning upstream the following fall (2015) and detected moving downstream the subsequent spring (2016).
- Seven other young out-migrating Rainbow Trout tagged in 2015 were detected moving downstream the subsequent spring (2016). These individuals presumably migrated upstream when the ladder was open for free passage during Fall 2015 as they were not recaptured in the upstream trap.

Spawning-sized Rainbow Trout – Spring Up-migrants (Table 4)

- Of the 202 spawning-sized Rainbow Trout tagged migrating upstream in the spring, 130 were tagged in 2014 and 72 were tagged in 2015.
- Of the 130 spawners initially tagged in 2014, 33 were detected moving downstream. Thirty of these detections occurred during the same spring or summer, while three of these detections occurred much later – one the following fall and two the subsequent spring/summer. The median amount of time spawning-sized Rainbow Trout spent in the Buffalo River was 34 days in 2014.
- Four of the 2014 tagged spawning-class were recaptured moving downstream the same spring. One was recaptured moving upstream the same spring. One was recaptured moving upstream in a subsequent spring.

- Of the 72 spawners initially tagged in 2015, 20 were detected moving downstream. Nineteen of these detections occurred during the same spring or summer, while one occurred the subsequent spring. The median amount of time spawning-sized Rainbow Trout spent in the Buffalo River was 31 days in 2015.
- Two of the 2015 tagged spawning-class were recaptured moving downstream the same spring. Four were recaptured moving upstream the subsequent spring.

Discussion:

Although overwintering habitat between Island Park Dam and Harriman State Park is cited as a limiting factor for juvenile Rainbow Trout populations in the upper Henry's Fork (Mitro and Zale 2002) and was a motivating factor in improving the Buffalo River Fish Ladder in 2005, it does not appear as if juvenile trout migrating into the Buffalo River to overwinter substantially contribute to increased over-winter success of their cohort as a whole. P.I.T tag data revealed that 6.5% and 8.5% of young trout up-migrating in the fall of 2013 and 2014, respectively, were detected migrating back downstream the subsequent spring, whereas apparent autumn-to-spring survival of age-0 Rainbow Trout between Island Park Dam and Harriman State Park is around 10% (Mitro and Zale 2002). Trout that overwinter in the Buffalo River contribute approximately 150 individuals annually to the Henry's Fork. At average annual survival for trout in the Henry's Fork, only half of these would be expected to contribute to the cohort of two-year old fish that recruit to the fishable population in the subsequent year. This is in comparison to the mean two-year old recruit-class size of 3,200 fish. This small addition demonstrates that while young trout do use the Buffalo River for overwintering habitat, the Henry's Fork provides the majority of overwintering habitat for young fish. Thus, maintaining high winter flows in Box Canyon remains the most important practice for improving natural recruitment.

Young fall up-migrants (≤ 150 mm) tagged in 2013 and 2014 made up 0.18% and 1.42% of out-migrants (≤ 180 mm) caught in the downstream trap the subsequent spring, respectively. This information, combined with length information demonstrating that fall up-migrants are larger than spring out-migrants (Figure X), indicate that spring out-migrants are primarily "new" fish to the Henry's Fork system – individuals born to resident Buffalo River and migrating Henry's Fork spawners that have spent nine to twelve months in the Buffalo River before migrating downstream. Results from the genetics study further support this conclusion. Based on numbers of spawners migrating upstream from the Henry's Fork and on typical sex ratios and fecundities, this spawning run produces 8,000 to 30,000 fry annually, providing recruitment insurance in years with low spawning success in the Henry's Fork. These results imply that the Buffalo River is a very important spawning tributary and that habitat enhancement activities in the Buffalo River and its tributaries focus on spawning and rearing habitat rather than strictly on winter habitat.

P.I.T tag analysis of spawning-sized Rainbow Trout indicate that at least 23.1% and 26.4% of spawners migrated back to the Henry's Fork after about 30 days in the Buffalo River in 2014 and 2015, respectively. Of those that return to the Henry's Fork, at least 3% of the 2014 spawning tag class and 20% of the 2015 spawning class returned to spawn in the Buffalo for at least the second time. Percentages of out-migration and spawning-return may be greater given that tag retention

in mature Rainbow Trout may be negatively affected by spawning (Bateman et al. 2009; Meyer et al. 2011). The presence of dual return to the Buffalo River to spawn indicates that these migrants were likely born in the Buffalo River and are returning to their natal grounds to spawn (Scott and Crossman 1973).

Conclusion

Through cooperation of multiple partners, fish passage has been successfully restored between the Henry's Fork and Buffalo Rivers. Examination of the last decade of data in combination with the genetics and tagging study has demonstrated the following:

- Young-of-year sized trout migrate from the Henry's Fork to the Buffalo River in the fall, but only a small number appear to out-migrate the following spring.
- The vast majority of out-migrants appear to have been born in the Buffalo River, and the vast majority of those are offspring of resident Buffalo River fish.
- There is a relatively stable annual run of approximately 200 spawners from the Henry's Fork into the Buffalo River. It appears as if 20% of young fish in the Henry's Fork are related to these spawners. Thus, primary contribution of the Buffalo River to the Henry's Fork fishery appears to be spawning and not overwintering habitat, although spring outmigrants have spent a winter in the Buffalo River. Improving spawning and rearing habitat in the Buffalo River and its tributaries is important to the Henry's Fork fishery.
- Given that trout recruitment is dependent on winter flow and that the young fish that recruit to the Henry's Fork fishery primarily overwinter in the Henry's Fork and not the Buffalo River, winter flows out of Island Park Dam remain important for increasing overwinter survival of young fish, regardless of their origin.

Recommendations

The partners listed below have reviewed this document and agree on the following recommendations:

- Continue monitoring springtime (February-June) migration according to the monitoring schedule in Article 407.
- Amend Article 407 to eliminate the requirement of monitoring upstream migration during the remainder of the year (July-January).
- Complete the genetics study prior to making any additional management and monitoring recommendations.

Partners

- Caribou-Targhee National Forest: owner/manager of land on which the fish passage facility sits and manager of most of the land in the Buffalo River watershed. Forest personnel are involved in monitoring and study design, provide permission for work on Forest land, and incorporate information gained from the project into management actions.

- Fall River Rural Electric Cooperative and its contractors: owner of hydroelectric plant, dam, and fish passage facilities. Fall River Electric permits access to the facility, collects stream flow data, maintains functionality of attractant flow pipe and crowder when trap is not in operation, and provides electricity to power the P.I.T-tag detection antenna.
- Henry's Fork Foundation: non-profit fisheries conservation organization. Foundation personnel monitor fish migration, compile and analyze flow and fisheries data, and maintains functionality of attractant flow pipe and crowder when trap is in operation.
- Idaho Department of Fish and Game: sole authority for managing recreational fisheries in State. Department personnel help design monitoring and study procedures, incorporate information gained from the project into their management, and issue the permit that allows us to handle fish at the facility.

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Tables

Table 1. Summary information on the number of spawning-sized Rainbow Trout (≥ 300 mm) to up-migrate in the spring and the number of age-0 trout (≤ 150 mm) to up-migrate in the fall with their associated dates of peak migration.

Year	Number of spring up-migrating spawners	Date of peak spring spawning migration	Number of young fall up-migrants	Date of peak fall migration
2006	90	15-May	1095	4-Oct
2007	145	27-Apr	928	26-Oct
2008	356	7-May	2444	20-Oct
2009	152	13-May	1032	26-Oct
2010	386	13-May	3234	8-Oct
2011	213	2-May	1749	18-Oct
2012	264	27-Apr	3016	20-Oct
2013	419	20-May	1792	21-Oct
2014	142	5-May	1796	8-Oct
2015	75	6-May	NA	NA
2016	202	18-Apr	NA	NA
Median	202	6-May	1792	20-Oct

Table 2. Summary information on young Rainbow Trout ($\leq 150\text{mm}$) tagged migrating upstream in the fall of 2013 and 2014 and their detections in subsequent seasons.

Upstream Trap – “Young” Rainbow Trout Up-migrants								
Sampling period	Tagged	Detected downstream				Recaptured in downstream trap subsequent spring	Total RBT $\leq 180\text{mm}$ captured in downstream trap subsequent spring	Recaptured moving upstream
		Same fall	Subsequent spring	Subsequent fall	Second subsequent spring			
Fall 2013	1605	0	105	7	3	5	2806	0
Fall 2014	1788	24	152	9	10	9	635	0

Table 3. Summary information on young Rainbow Trout ($\leq 180\text{mm}$) tagged migrating downstream in the spring of 2014 and 2015 and their detections in subsequent seasons.

Downstream Trap – “Young” Rainbow Trout Out-migrants				
Sampling period	Tagged	Recaptured moving upstream		Detected moving downstream subsequent spring
		Same spring	Subsequent fall	
Spring 2014	3	0	0	0
Spring 2015	615	2	1	8

Table 4. Summary information on spawning-sized Rainbow Trout ($\geq 300\text{mm}$) tagged migrating upstream in the spring of 2014 and 2015 and their detections in subsequent seasons.

Upstream Trap – “Spawning-sized” Rainbow Trout Up-Migrants							
Season	Year	Tagged	Detected moving downstream		Median time spent in Buffalo River	Recaptured moving downstream	Recaptured moving upstream
			Same spring/summer	Other			
Spring	2014	130	30	3	34 days	4	2*
Spring	2015	72	19	1	31 days	2	4

*One spawner was recaptured moving upstream the same spring.

Figures

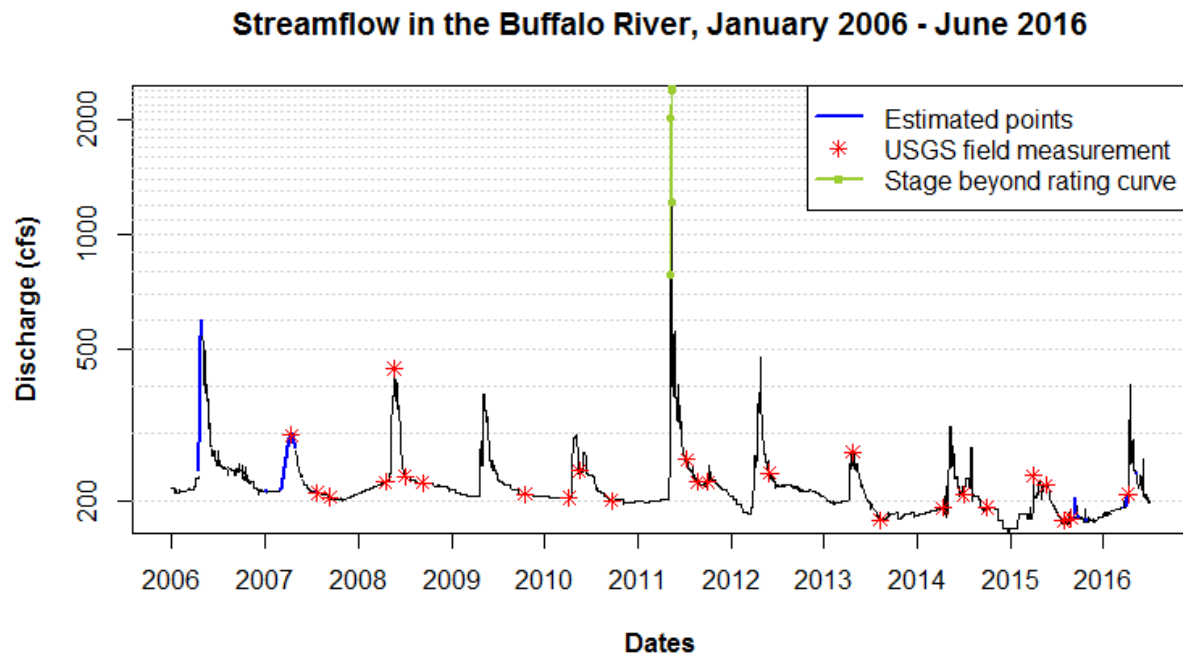


Figure 1. Streamflow record plotted using daily stage measurements collected by FRREC and the rating curve provided by USGS.

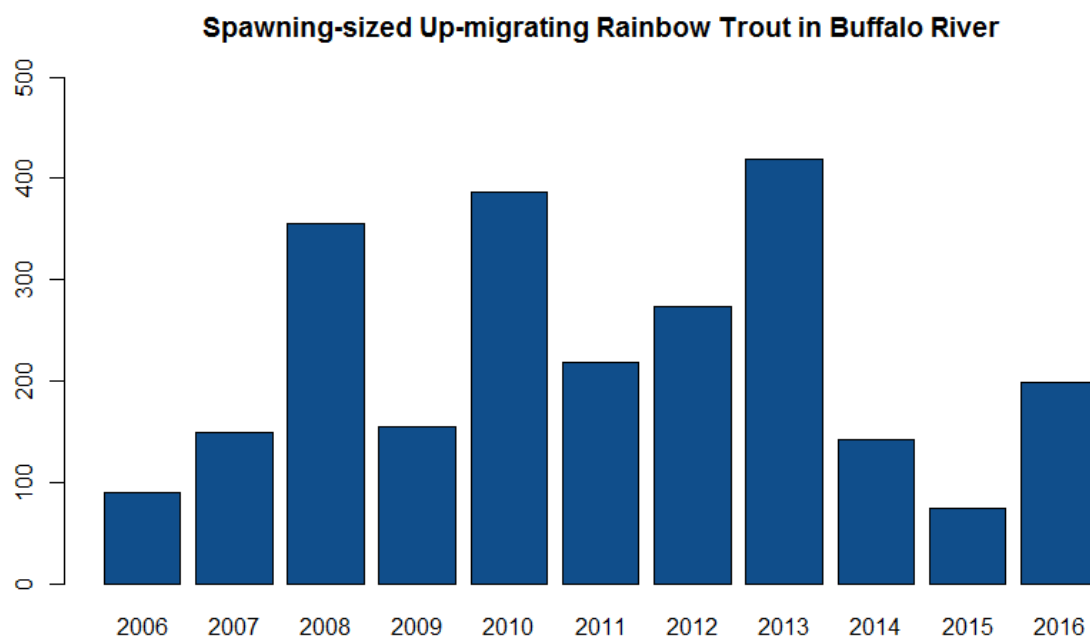


Figure 2. The number of spawning-sized Rainbow Trout ($\geq 300\text{mm}$) to migrate from the Henry's Fork to the Buffalo River between 15 February and 30 June.

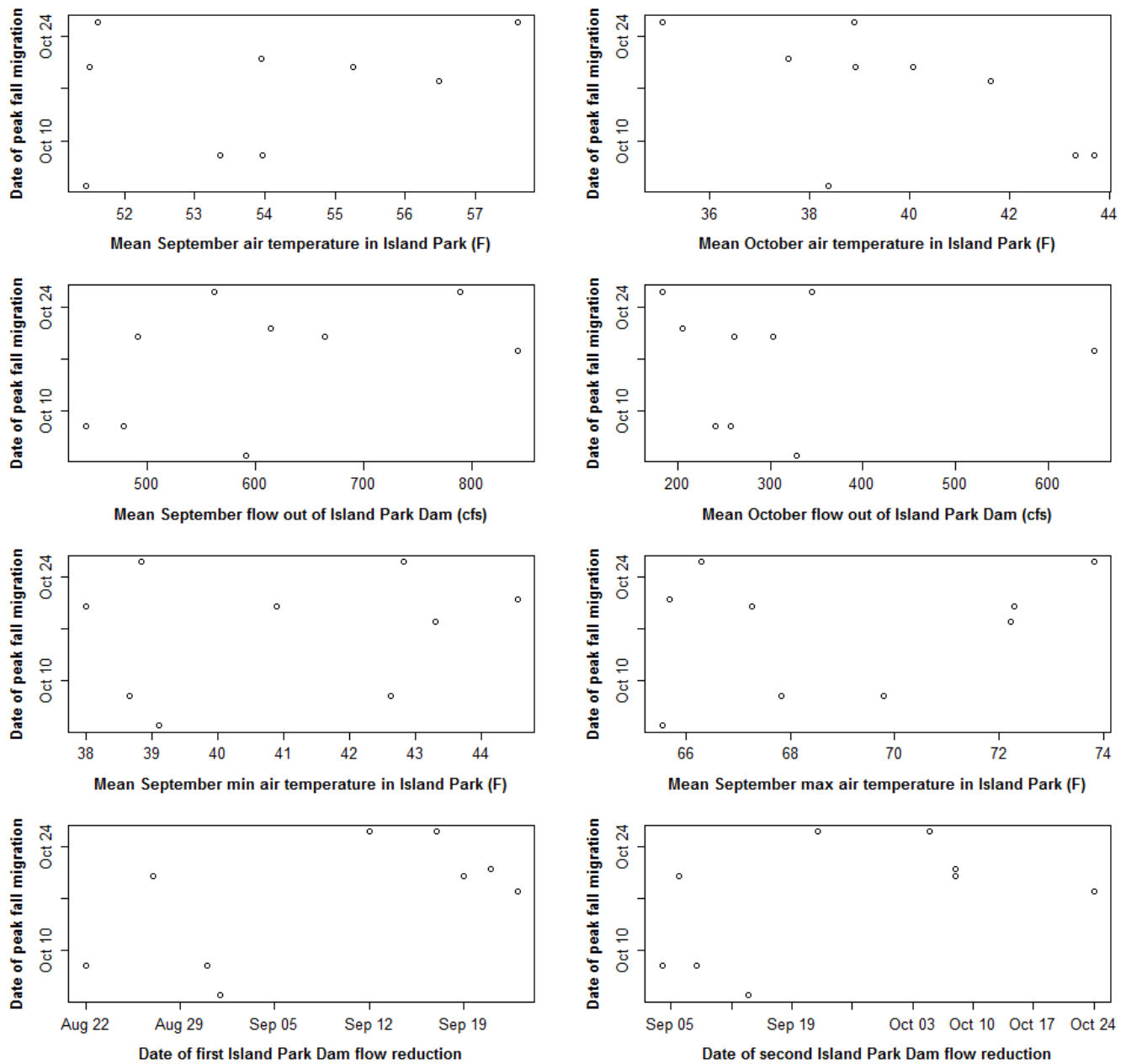


Figure 3. Scatterplots showing relationship the date a peak fall migration of age-0 Rainbow Trout ($\leq 150\text{mm}$) from the Henry's Fork to the Buffalo River as a response along with several other regulated and unregulated predictors.

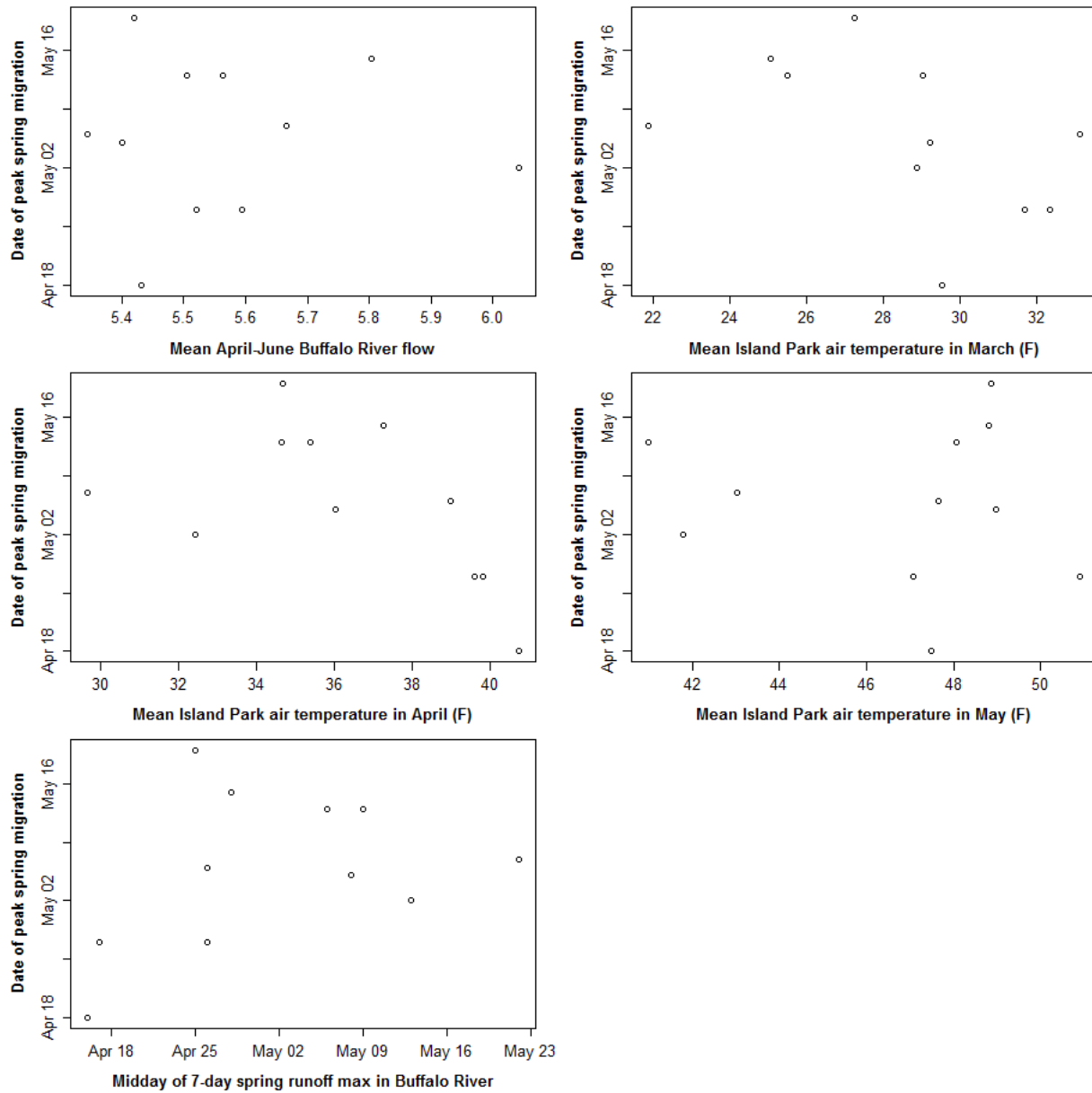


Figure 4. Scatterplots showing relationship between date of peak spring migration of spawning-sized Rainbow Trout ($\geq 300\text{mm}$) as a response and along with several other predictors.

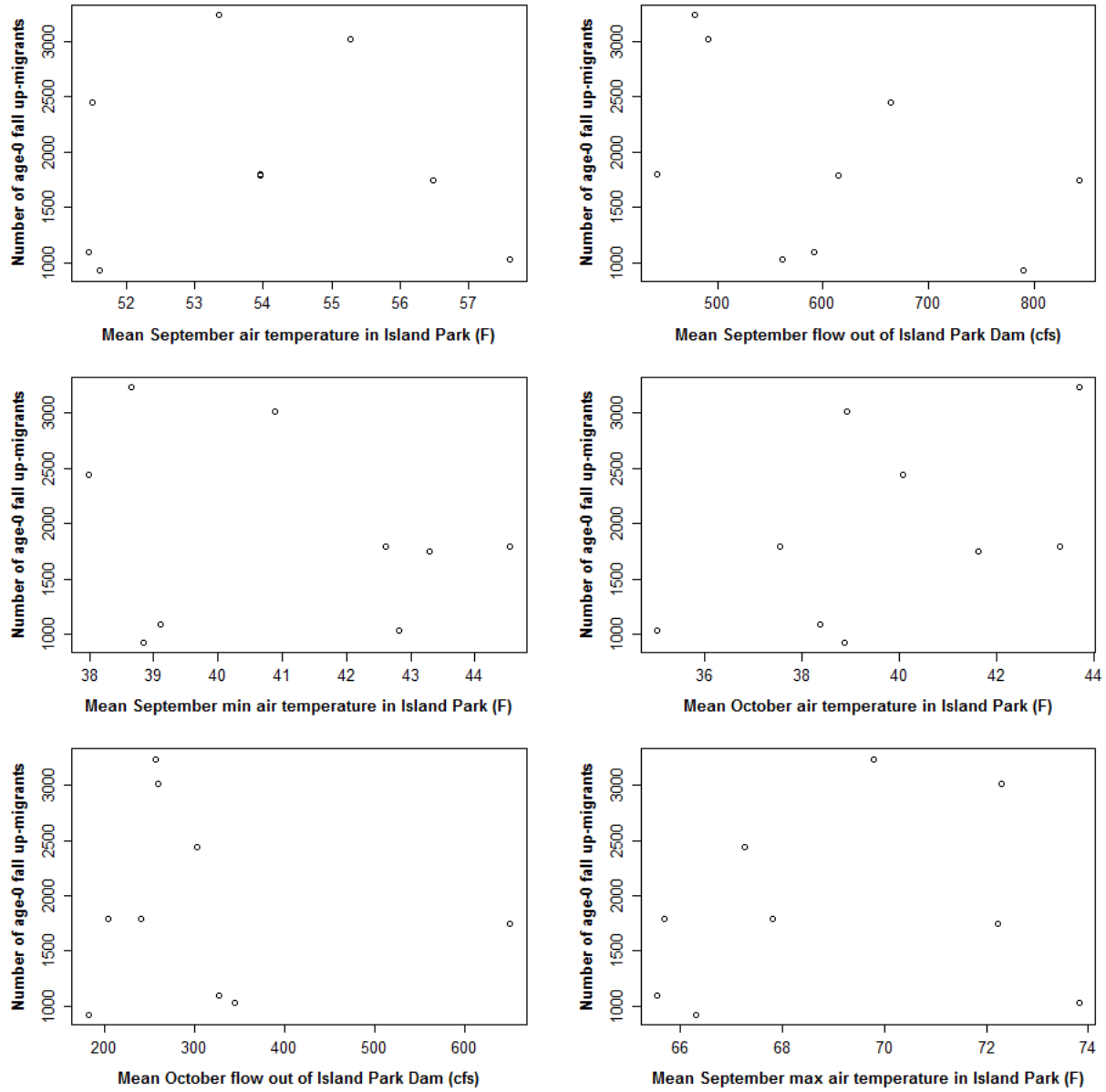


Figure 5. Scatterplots showing relationship between the number of age-0 up-migrating Rainbow Trout ($\leq 150\text{mm}$) in the fall as a response and along with several other predictors.

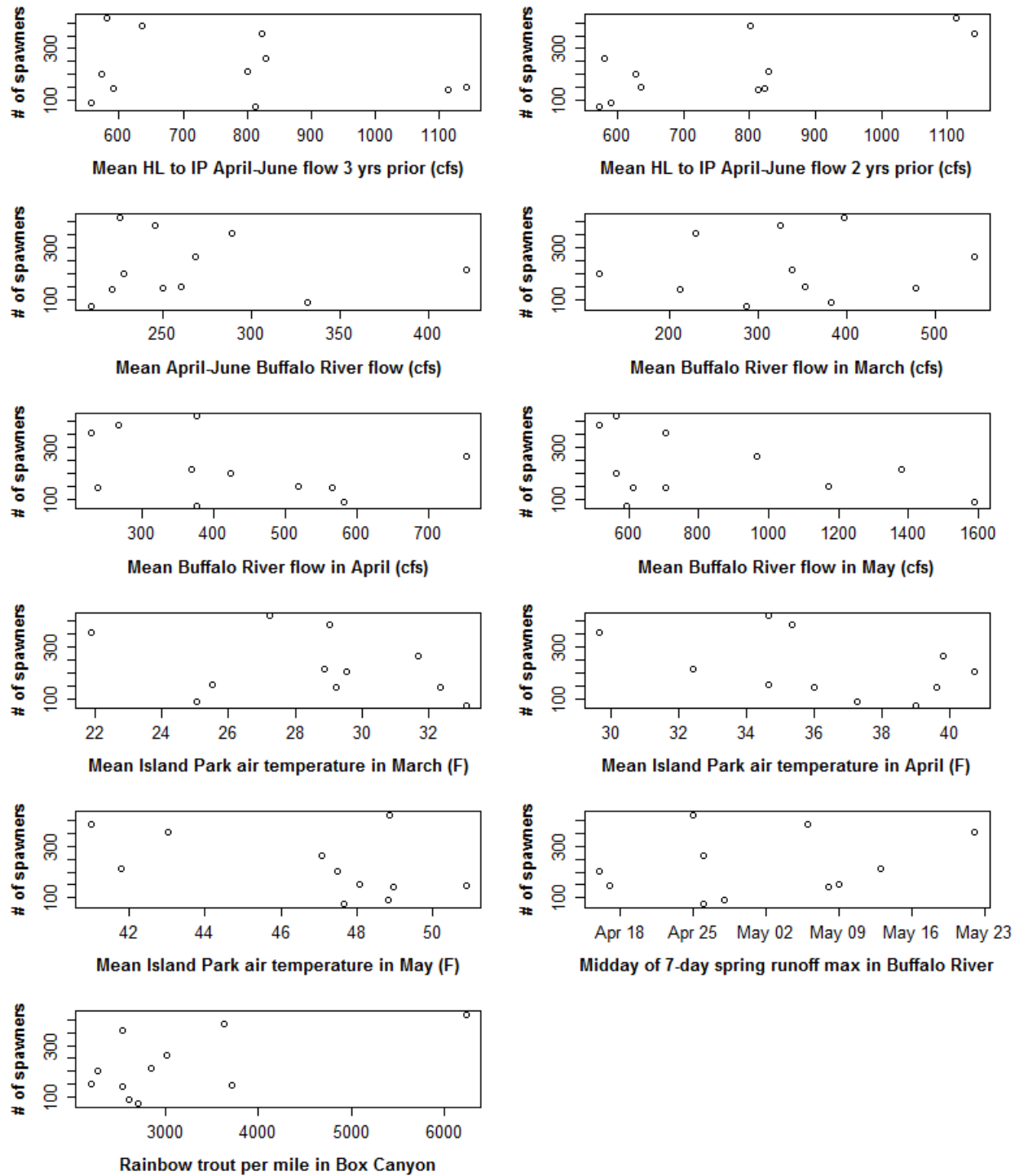


Figure 6. Scatterplot showing relationship between the number of spawning-sized Rainbow Trout migrating from the Henry's Fork to the Buffalo River ($\geq 300\text{mm}$) as a response and along with several other predictors.

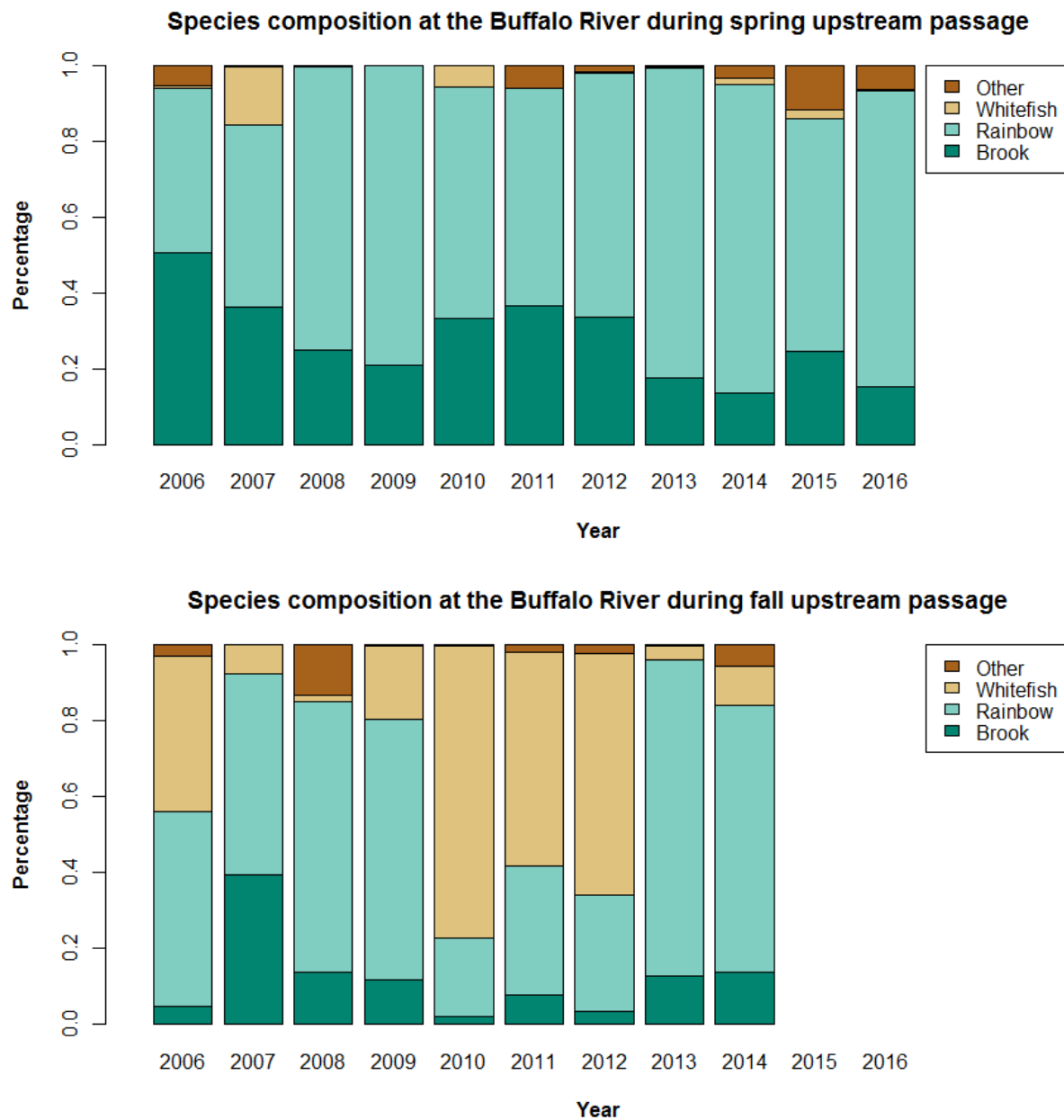


Figure 7. Species composition of up-migration into the Buffalo River in the spring (15 February – 30 June) and the fall (1 September to 30 December).

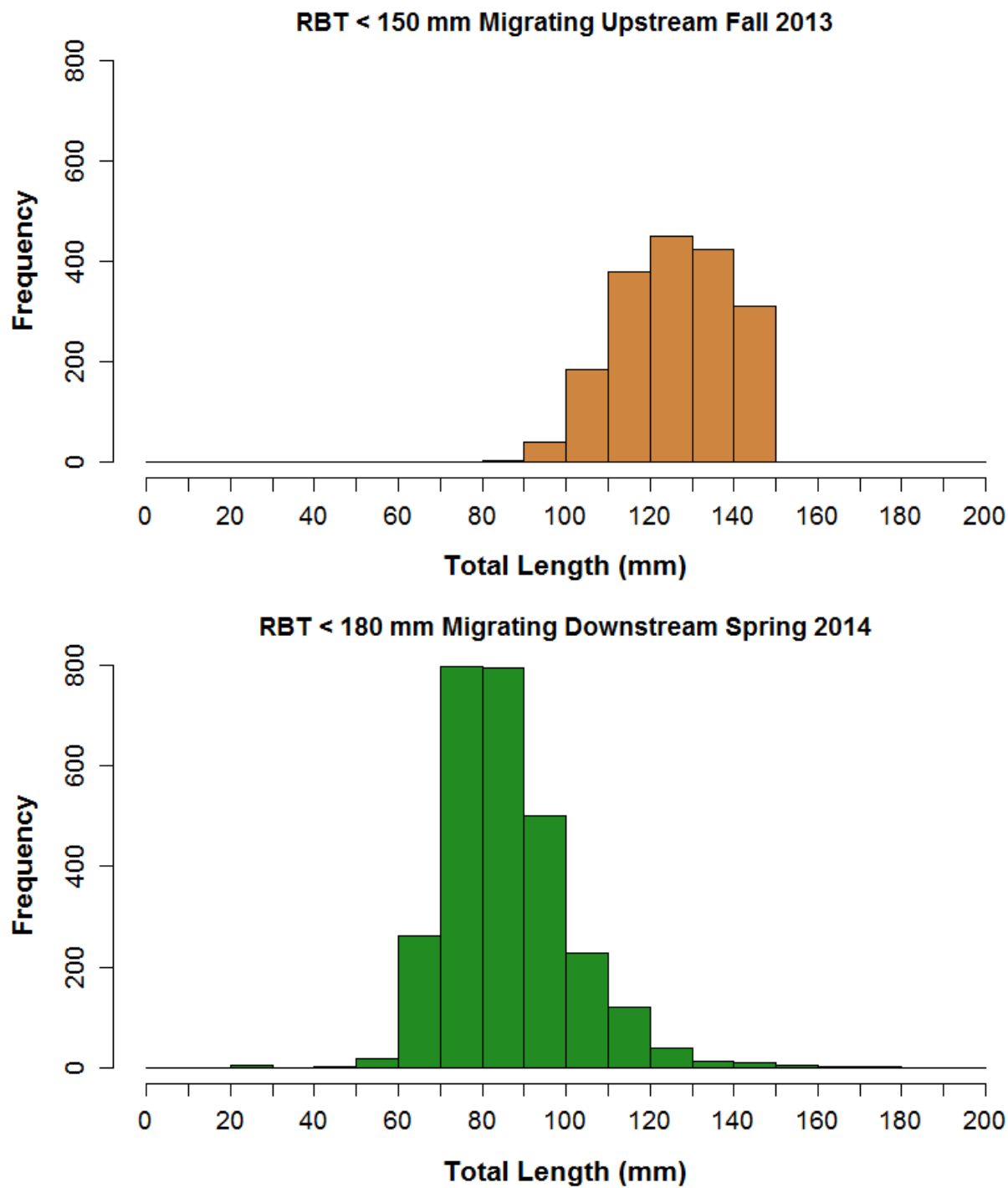
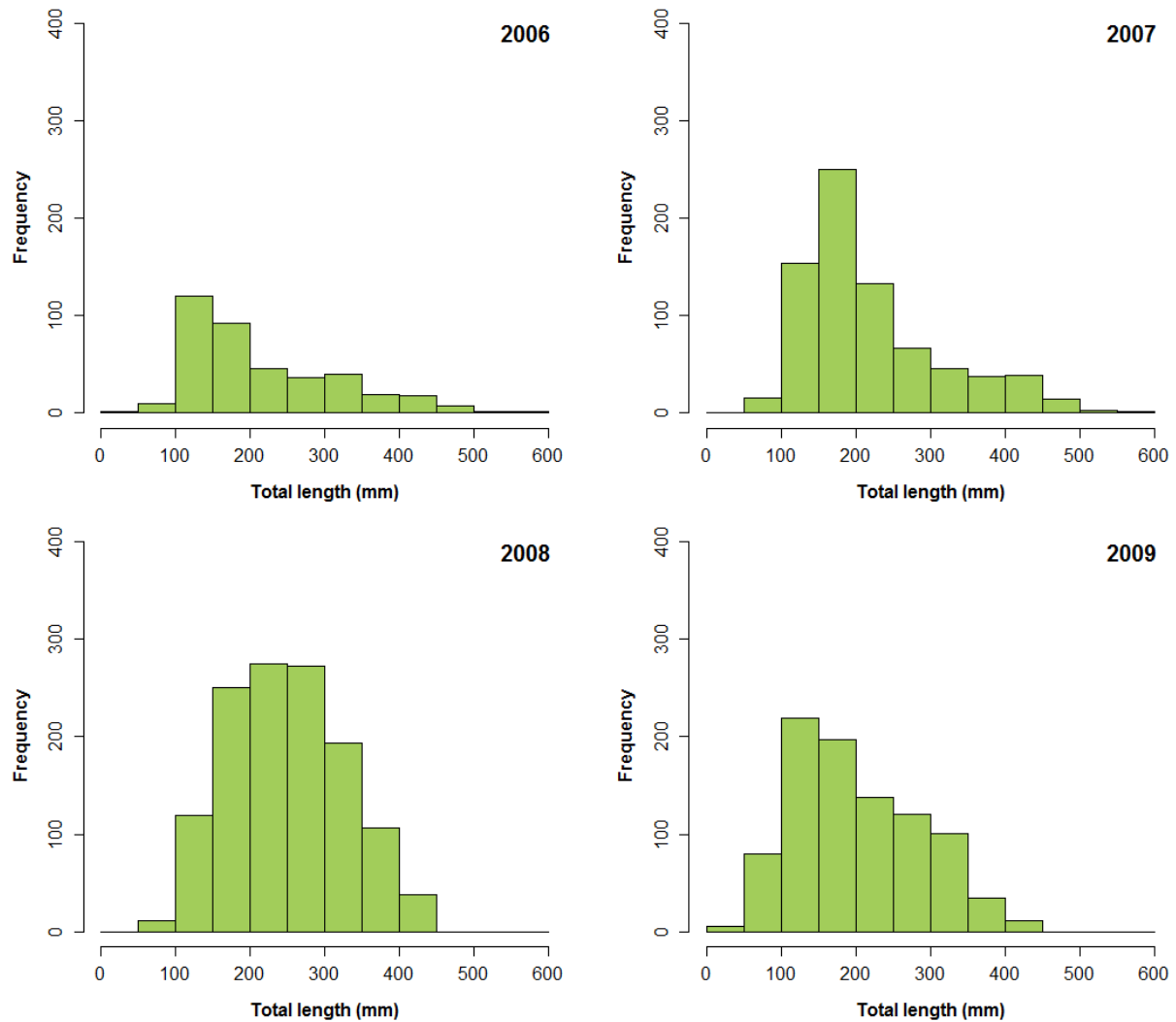


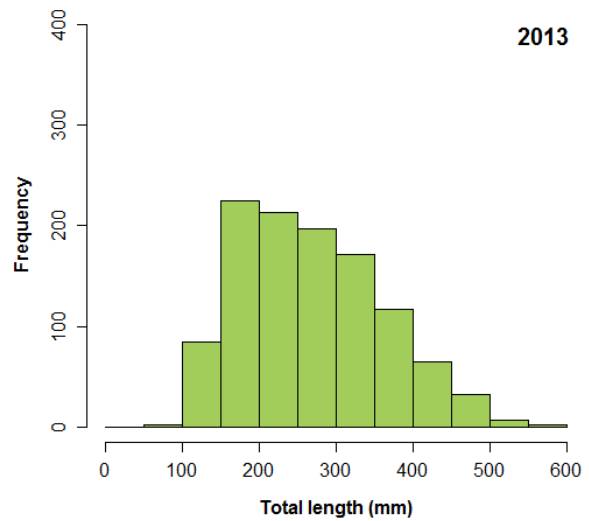
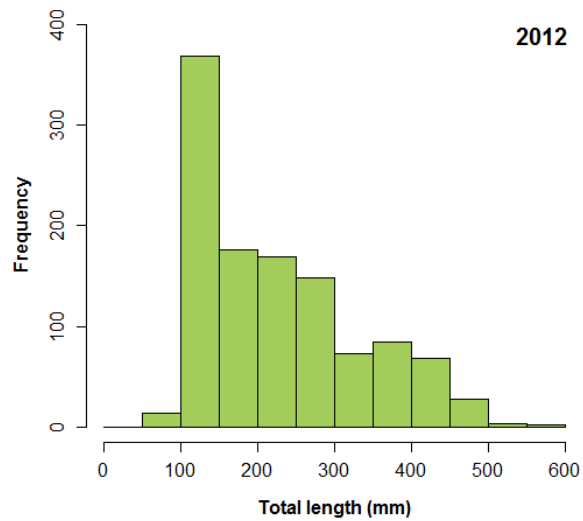
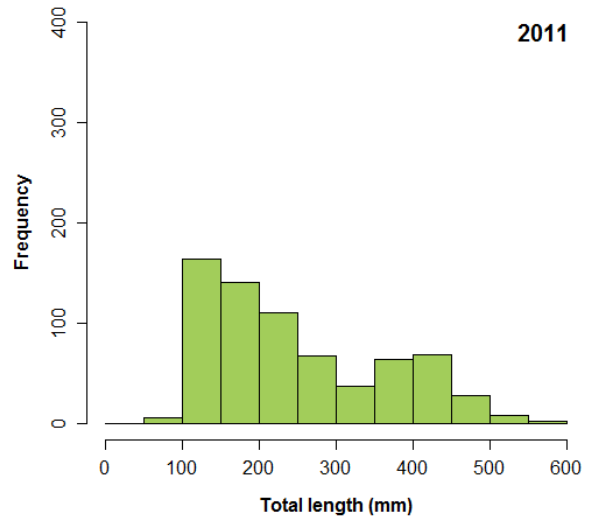
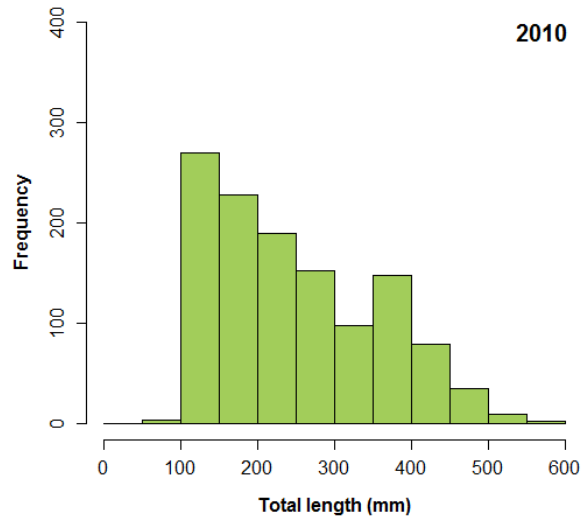
Figure 8. An example of how young trout migrating upstream in the fall are not the same cohort of young trout migrating downstream in the spring.

Supplemental information

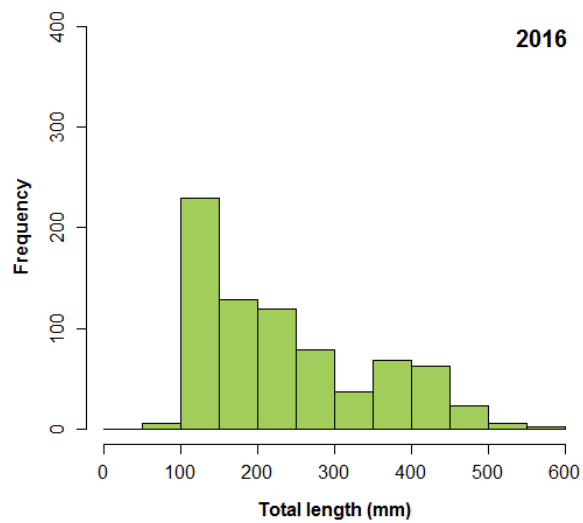
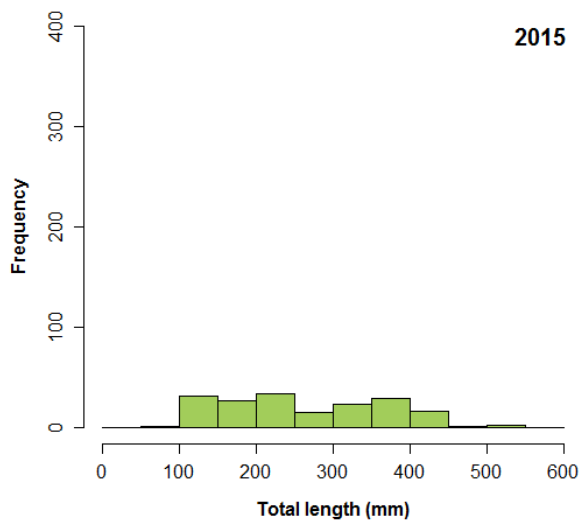
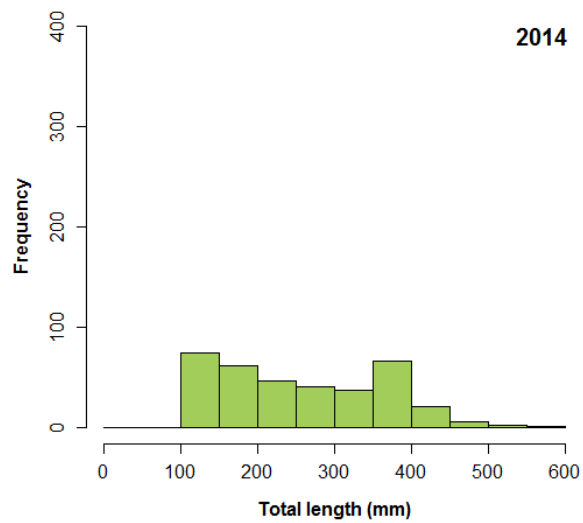
This section shares plots not otherwise discussed in the document to accompany those submitted in previous reports to FERC as well as infographics to demonstrate tables 2-4 from the P.I.T. tag study.



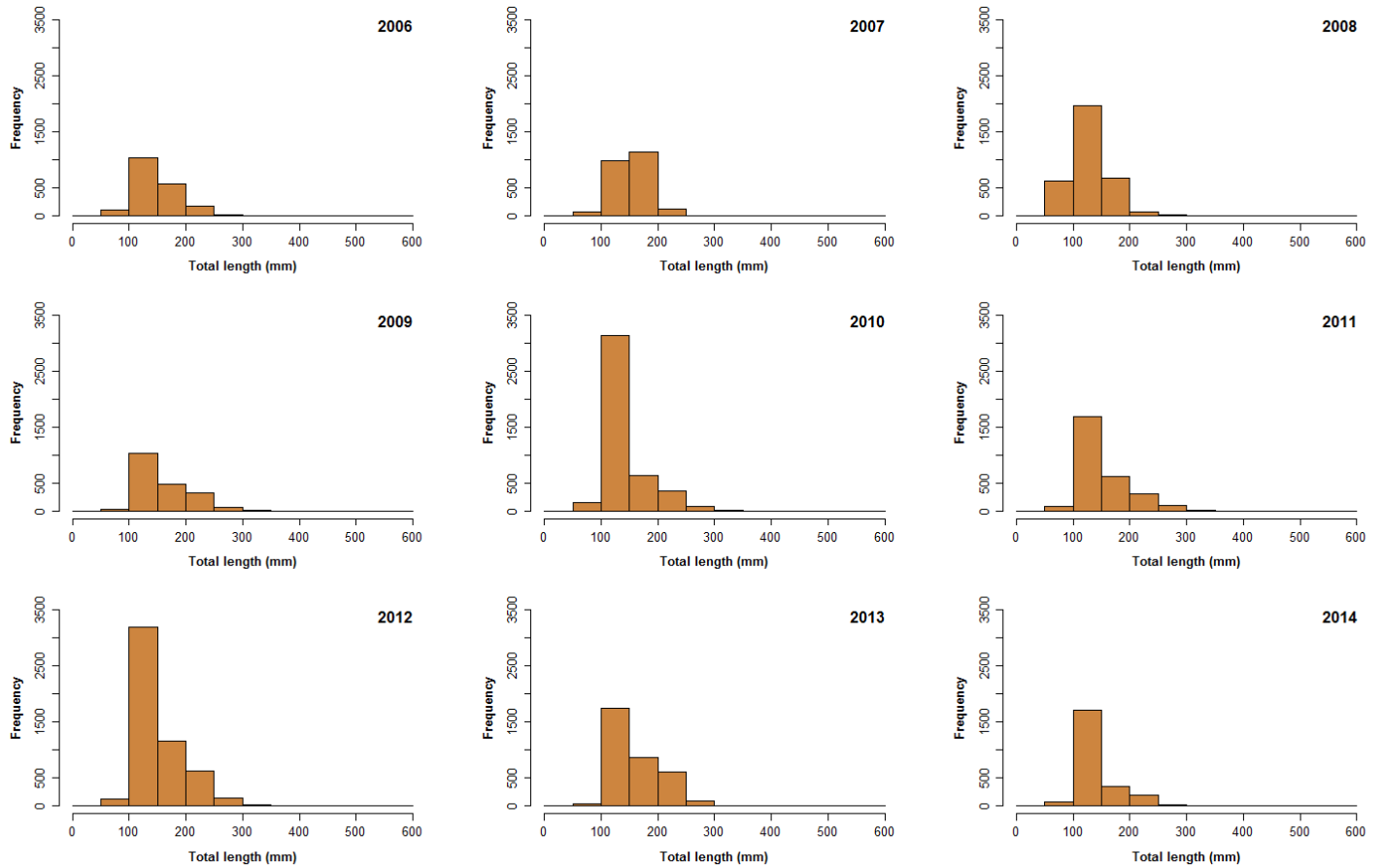
Supplement 1. Size distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2006-2009.



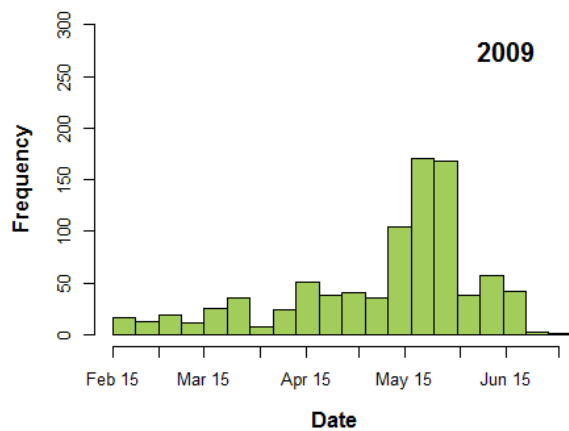
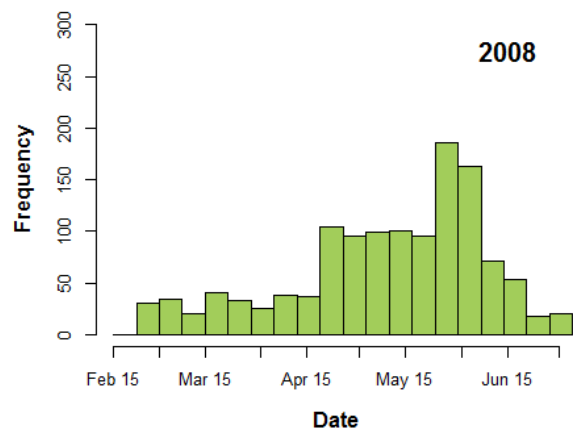
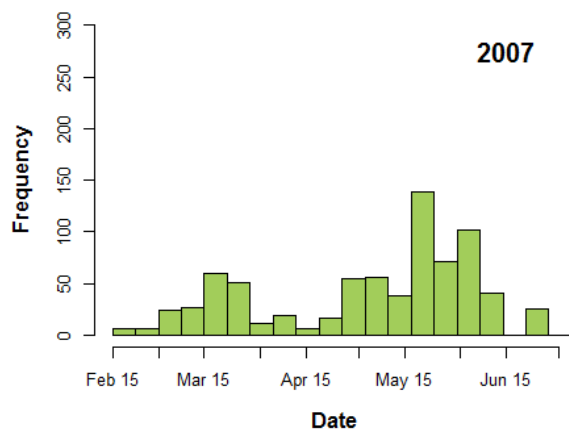
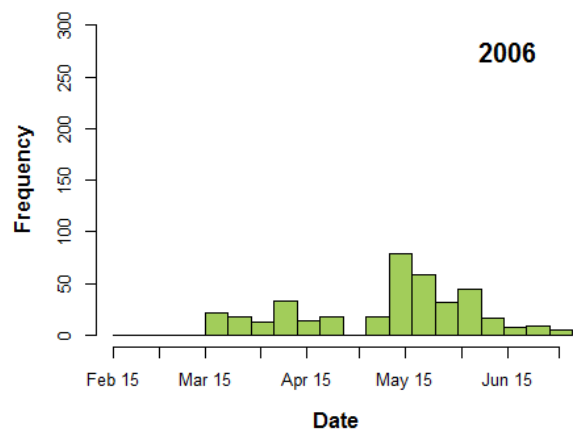
Supplement 2. Size distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2010-2013.



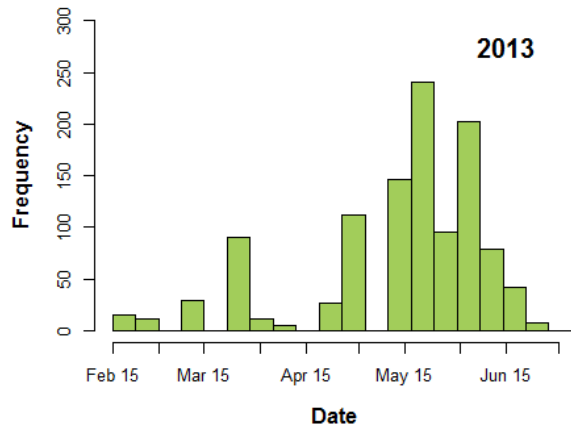
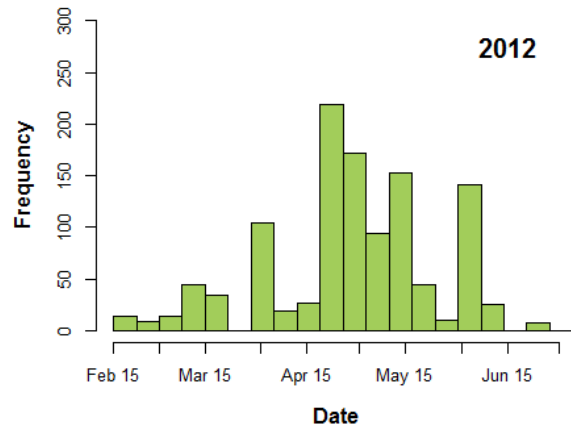
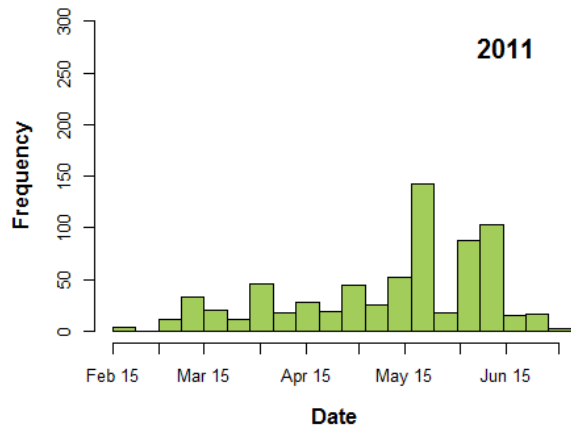
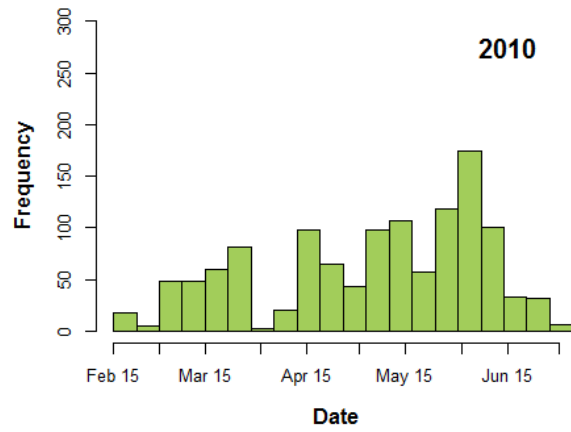
Supplement 3. Size distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2014-2016.



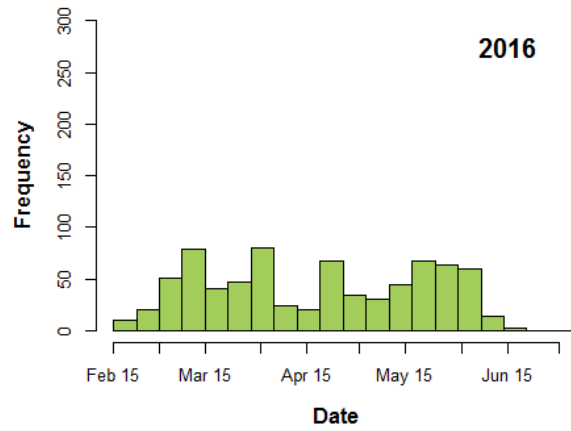
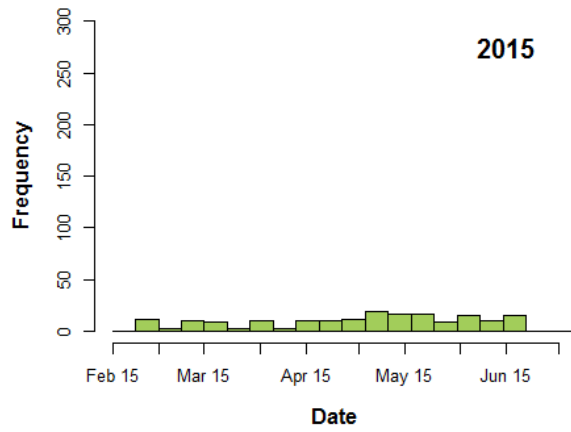
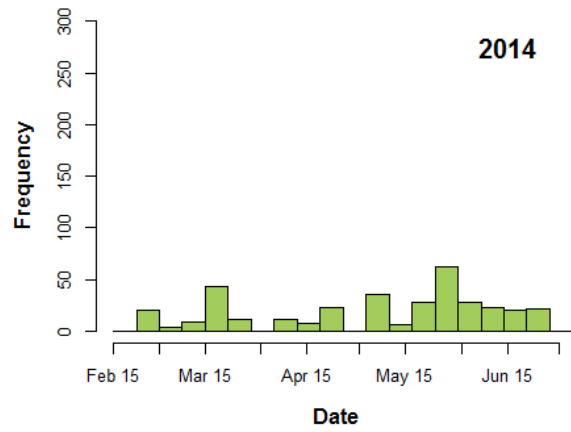
Supplement 4. Size distribution of Rainbow Trout migrating upstream in the fall (1 September to 31 December).



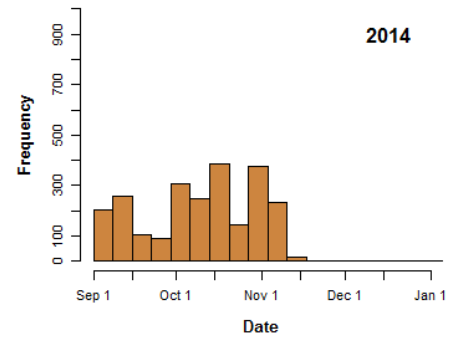
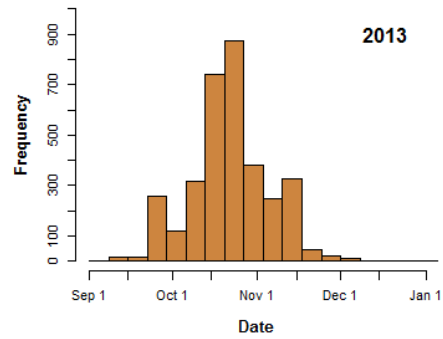
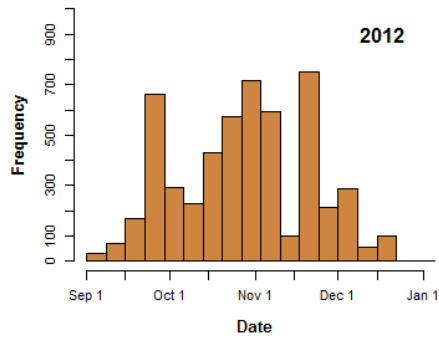
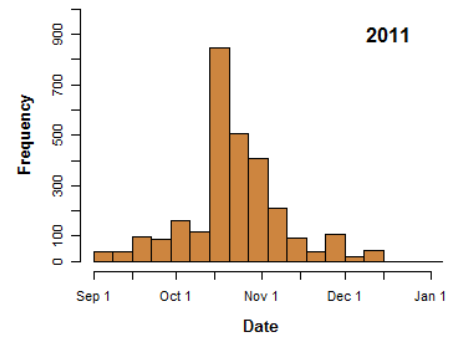
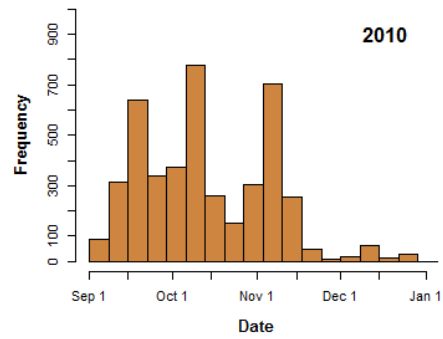
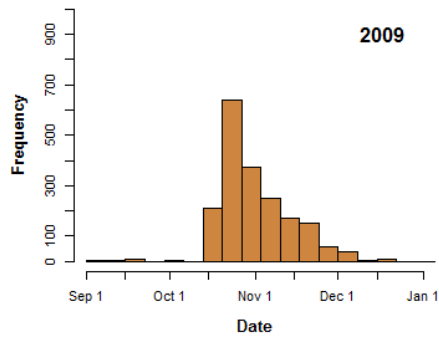
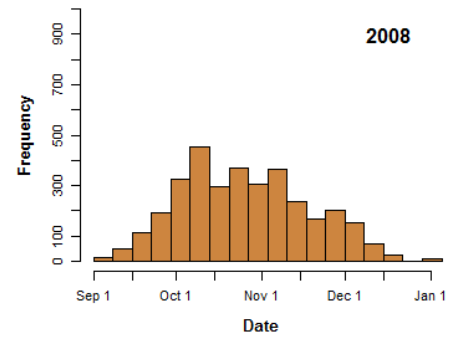
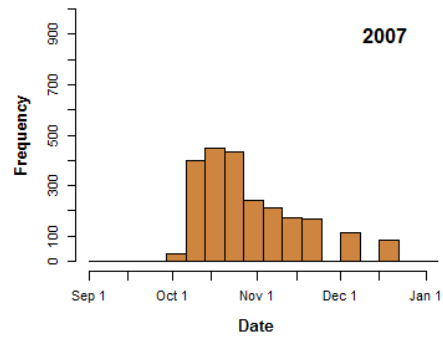
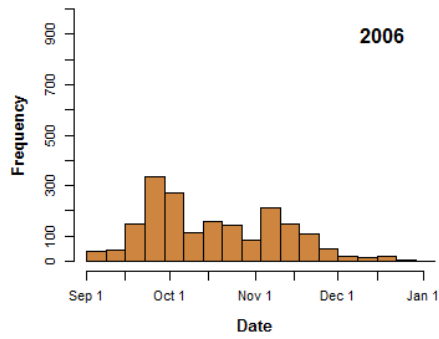
Supplement 5. Temporal distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2006-2009.



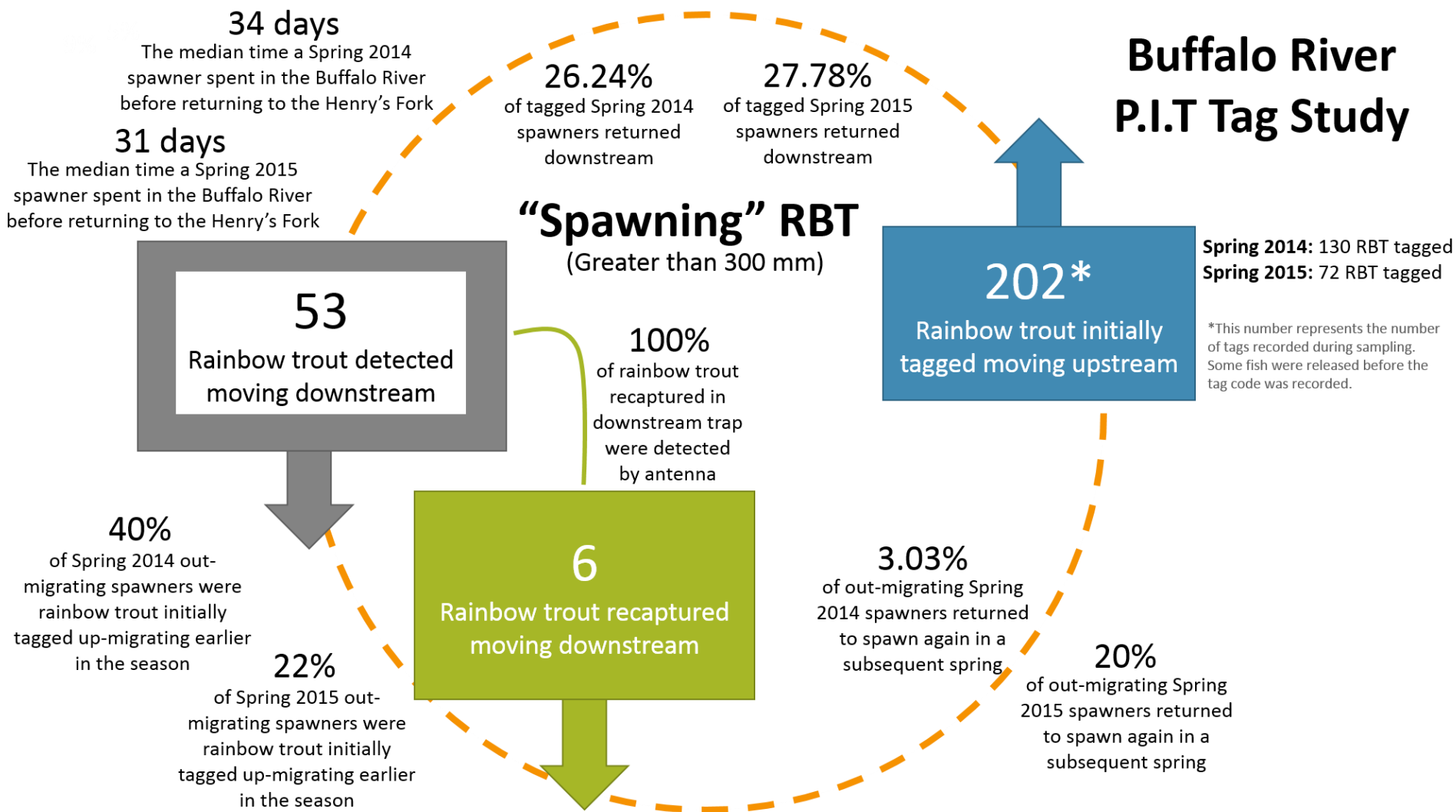
Supplement 6. Temporal distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2010-2013.



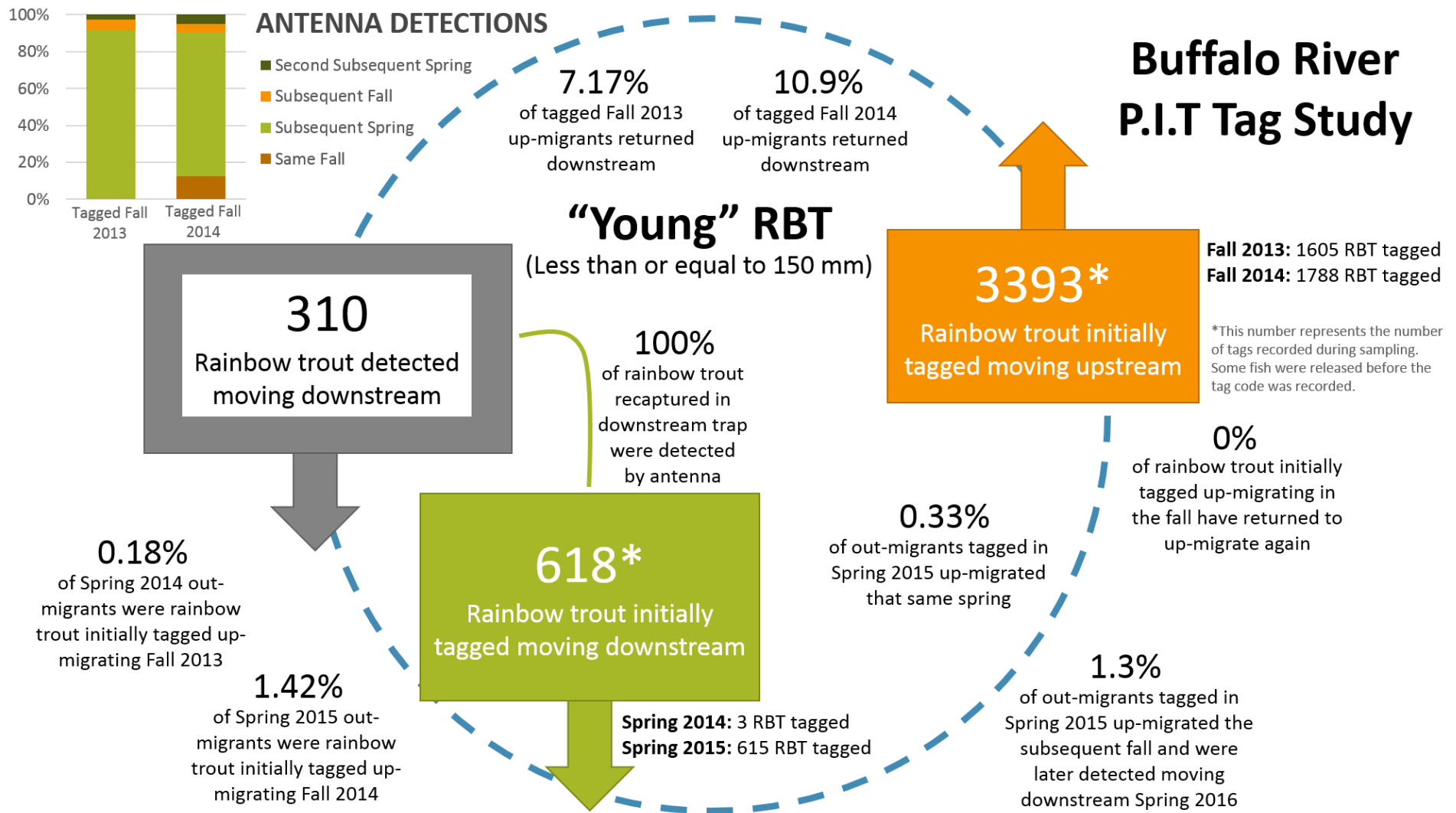
Supplement 7. Temporal distribution of Rainbow Trout migrating upstream in the spring (15 February to 30 June) from 2014-2016.



Supplement 8. Temporal distribution of Rainbow Trout migrating upstream in the fall (1 September to 31 December).



Supplement 9. Infographic demonstrating how many spawning-sized Rainbow Trout were tagged in the spring of 2014 and 2015, how many returned, how long they spent in the Buffalo River before returning, and how many have returned to spawn a second time.



Supplement 10. Infographic demonstrating how many young Rainbow Trout were tagged migrating upstream in the fall of 2013 and 2014, how many returned downstream, when they returned downstream, the fall up-migrant contribution to spring out-migrant cohort, and if they have since returned.