# IMNAHA RIVER JUVENILE STEELHEAD EVALUATIONS

William Young, Jocelyn Hatch

Nez Perce Tribe

Department of Fisheries Resources Management

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Lower Snake River Compensation Plan

1387 South Vinnell Way, Suite 343

Boise, Idaho 83709

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# INTRODUCTION

The long-term success of the Lower Snake River Compensation Plan (LSRCP) Imnaha River endemic steelhead hatchery mitigation program relies on accurate monitoring and evaluation to inform management decisions. Understanding the performance of hatchery and natural steelhead allows the hatchery program to maximize its' success while minimizing risk to natural populations.

This project monitors the life stage performance of hatchery- and natural-origin steelhead (*Oncorhynchus mykiss*; Héeyey in Nez Perce language) emigrating from the Imnaha River. Monitoring the Lower Snake River Compensation Plan (LSRCP) steelhead program originating from the Little Sheep Creek Acclimation Facility provides information that can be used to evaluate the early life history and determine how closely the hatchery-origin fish mimic the life history characteristics of naturally produced fish in the Imnaha River. Performance measures evaluated for juvenile performance included emigrant abundance, emigration timing, size and condition factor, juvenile arrival timing at Lower Granite Dam (LGR) and juvenile survival at LGR. We also evaluated and compared hatchery- and natural-origin adult performance measures including adult arrival timing at Bonneville Dam (BON) and LGR, adult conversion rate from BON to LGR and smolt to adult return rate (SAR).

This project was funded by the LSRCP as a cost-share with the Bonneville Power Administration Imnaha River Smolt Monitoring Project (199701501) as part of the Fish Passage Center's in-season smolt performance evaluations.

# METHODS

## Fish Trapping

Emigrating juvenile steelhead were captured using a rotary screw trap (E.G. Solutions Inc., Corvallis, OR) consisting of a 2.1m diameter cone, 6.7 m long floating pontoons, a live box and debris drum. The trap was operated in the Imnaha River at river kilometer 7 (rkm), which was as close to the confluence with the Snake River as possible and while still being accessible by road (Figure 1). Both juvenile steelhead and Chinook salmon were captured and tagged. For the purpose of this report we will only focus on Imnaha River natural-origin (IRN) and hatchery-origin (IRH) juvenile steelhead monitoring. The placement of the screw trap was below 95% of the available steelhead spawning habitat in the Imnaha River, the exception being Cow Creek.

During the years 1994 through 1999 the trap operated during the peak spring outmigration period from late February through mid June. Starting in 2000 operations were expanded to include a fall trapping period, mainly targeting emigrating Chinook salmon presmolts (early October through early December). Implementation of year round trapping has occurred since 2010, except for short periods of heavy ice flows, during the winter and short periods in the summer for trap maintenance. Trapping operations during all years were affected by generally short periods of high water during spring runoff (late April through mid May).

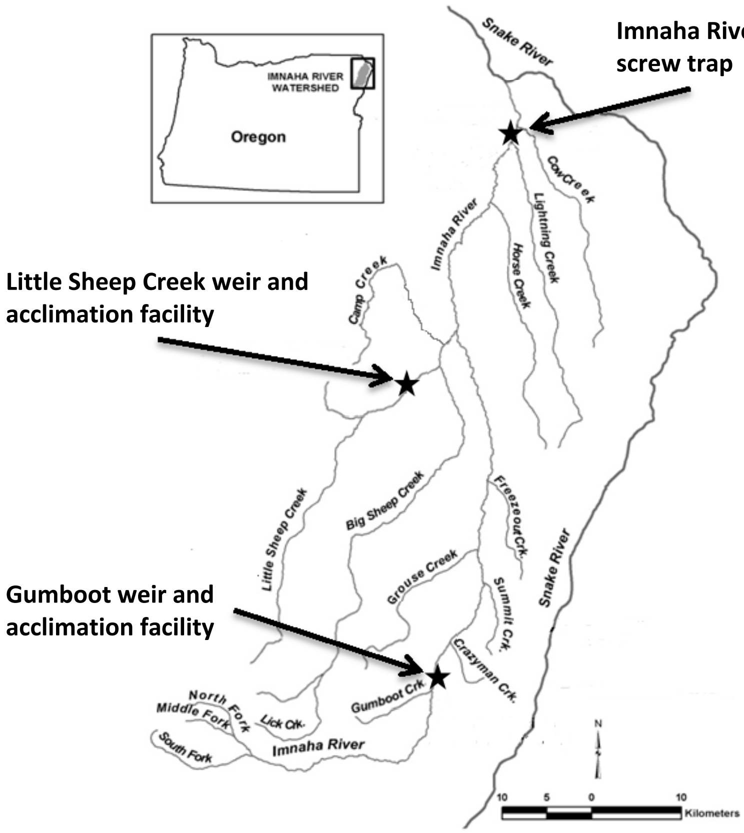



Figure 1. Map of the Imnaha River study area showing the location of the rotary screw trap, the Gumboot Chinook salmon acclimation facility and the Little Sheep Creek steelhead acclimation facility.

Fish Handling

The trap was checked early in the morning and several times throughout each night and day if warranted by large numbers of fish, high flows or excessive debris in the river. Captured juvenile steelhead were anaesthetized in a MS-222 bath (6 ml MS-222 stock solution (100 g/L) per 19 L of water) buffered with Propolyaqua. All fish were examined for existing marks (e.g. fin clips), PIT tags using a Destron Fearing FS2001F PIT tag reader, presence of all other tags, and percent descaling and general health. Non-target piscivorous fish and other non-target fish were removed from the live box first, scanned for PIT tags and then released 30-50 m downstream.

IRN and/or IRH steelhead juveniles were measured for fork length to the nearest millimeter and weighed to the nearest 0.1gram and PIT tagged using hand injector units following the methods described by Prentice et al. (1986, 1990) and Matthews et al. (1990, 1992). Hypodermic injector units and PIT tags were sterilized prior to each use in ethanol. Only fish above 80 cm were tagged because it was likely that smaller fish were not actively emigrating from the system or may represent resident rainbow trout. Tagging was discontinued when water temperatures exceeded 15° C. Mortality due to tagging was recorded. Captured steelhead juveniles were held in perforated recovery containers in the river, checked for shed tags and mortality, and released after dark.

From 1994 through 2007 both natural- and hatchery-origin juvenile steelhead were PIT tagged after capture at the Imnaha River screw trap. Beginning in 2008 hatchery-origin juveniles were PIT tagged at the hatchery prior to release, and survival was evaluated from release to the screw trap using recapture/interrogation data collected at the screw trap. Arrival timing and survival to Lower Granite Dam (LGR) was determined using fish PIT tagged (pre 2008) or recaptured (2008 – present) at the screw trap.

During peak emigration periods the trap captured juvenile steelhead and Chinook salmon in numbers large enough to overload the trap box and jeopardize fish health. During these periods a subsampling procedure was used to obtain a representative sample of juveniles that was used to estimate the abundance and composition of fish passing the trap. The sub sampling procedure estimated the abundance of juveniles passing the trap by multiplying the total number of juveniles captured by an appropriate time ratio determined by the duration of sub sampling each hour. For example, if the trap was operated for 15 minutes each hour then the ratio would be 1:4 and the estimated total number of fish passing the trap would be calculated by dividing the total number of fish captured by the sample rate (in this example – ¼ = 0.25). The composition (species, origin, length, etc.) of the juveniles passing the trap was determined by expanding by the composition of the captured fish. During the subsampling procedure a partition was placed in the trap to by-pass fish around the trap box and through a PIT tag antennae to monitor for recaptures (tag efficiency or previously tagged fish).

Prior to starting the subsampling procedure the trap box was emptied, either by processing all of the fish in the trap box or by subsampling fish in the trap box. All fish were processed if the quantity of fish in the trap was determined small enough to process in a reasonable time during the beginning of the subsampling procedure. When the quantity of fish in trap box was judged to be large enough to make it impossible to process all of the fish in less than an hour then the trap box was sampled by processing one or two net-full scoops of fish and releasing the remaining net-full scoops. The released net-full scoops were released after they were passed through a separate PIT Tag antenna to interrogate any previously PIT tagged fish. The abundance and composition of the processed net-full scoops were expanded by the number of net-full scoops to determine the abundance and composition of all fish that were in the trap box.

## Trap Efficiencies

Daily trap efficiency (TE) trials were conducted using PIT tagged IRN steelhead smolts across the entire trapping period (Steinhorse, et al, 2004). Fish marked for TE trials were held in perforated containers in the river during daylight hours (up to 12 h) and then transported upstream approximately 1 km and released after dark. The daily goal was to randomly PIT tag 50 IRN steelhead for TE trials however, fish numbers during off peak periods made it impossible to achieve that goal each day. TE rates were calculated by week when at least seven marked TE fish were recaptured and flows remained relatively stable. Weeks with less than seven recaptures or when flows dramatically increased during the week were grouped with either the preceding week or the following week depending on similarity of flow conditions. Trap efficiency was determined by $E = R/M$; where E is estimated trap efficiency, R is number of marked fish recaptured, and M is number of fish marked and released. The reported 95% confidence intervals are based on a bootstrap calculation within the Gauss program (Aptech Systems Inc., Maple Valley, Washington).

## Data Management

Data collected at the screw trap were checked for errors then sent to the NPT Joseph, OR Field Office for final verification. Once verify, the compiled was uploaded to the Fish Passage Center's database within one to five days as part of the in-season smolt survival monitoring program.

## Monitoring and Evaluations Performance Measures

Performance measures calculated for juvenile steelhead (IRN and IRH independently) captured at the Imnaha River screw trap followed definitions developed by the Collaborative Systemwide Monitoring and Evaluations Project (CSMEP; web site) and adopted by the Ad Hoc Supplementation Work Group (Beasely et al. 2008).

Performance measures included:

1. **Index of juvenile emigrant abundance:** an index of the number of steelhead smolts emigrating from the Imnaha River determined through PIT tagging and trap efficiency trials. This is a minimum abundance estimate calculated from trapping operations not encompassing the entire trapping period.
2. **Juvenile emigrant timing:** the measure of the timing of smolt captures at the Imnaha River screw trap estimated using the following parameters; 1) median - date that 50$^{th}$ percent of the total juvenile steelhead were captured and; 2) range – determined by the first and last fish and the 10$^{th}$ and 90$^{th}$ percentiles of total juvenile steelhead captures.

3. **Size-at-emigration:** the length distribution of juvenile steelhead captured at the screw trap.
4. **Condition of juveniles at emigration:** a length to weight relationship (weight/length$^3$) of juvenile steelhead captured in the screw trap.
5. **Juvenile arrival timing to Lower Granite Dam:** arrival timing of juvenile steelhead smolts at Lower Granite Dam (LGR) determined by PIT tag interrogations in the juvenile by-pass system estimated using the following parameters; 1) median –date of the 50$^{th}$ percentile of the total juvenile steelhead were interrogated at LGR and; 2) range – determined by the first and last fish and the 10$^{th}$ and 90$^{th}$ percentiles of total juvenile steelhead interrogations.
6. **Juvenile survival:** survival from the screw trap to LGR and McNary Dam (MCN) determined by PIT tag interrogations.
7. **Adult arrival timing at Bonneville and Lower Granite Dams:** arrival timing of adult steelhead to Bonneville Dam (BON) and LGR determined by PIT tag interrogations in the adult fish ladders estimated using the following parameters; 1) median –date that the 50$^{th}$ percentile of the total adult steelhead were interrogated and; 2) range – determined by the first and last fish and the 10$^{th}$ and 90$^{th}$ percentiles of total adult steelhead interrogations.
8. **Adult conversion rate:** conversion rate from BON to MCN and BON to LGR determined by PIT tag interrogations in the adult fish ladders.
9. **Smolt-to-Adult return index:** number of PIT tagged adult steelhead interrogated at LGR divided by the number of PIT-tagged juveniles interrogated at LGR determined by migration year (brood year was not determined because smolts were not aged).

## RESULTS

### Screw trap operations

Over the entire study period (1994 – 2011) the median start and end dates for the spring trapping period were February 28 and June 20, respectively. Until 1999 the main objective of the project was to provide PIT tagged juvenile steelhead for the Smolt Monitoring Program (Fish Passage Center; http://www.fpc.org/about_fpc.html). Expanded trapping to include a fall period and two years of year-round trapping enabled us to define the IRN juvenile steelhead emigration period in the Imnaha River. Results indicated that approximately 95% of IRN juvenile steelhead emigrated during the spring trapping period (March 1 – June 15), with a small number of steelhead captured during the fall/winter period and approximately 5% captured during the summer. Consequently, we are confident that the trap operations prior to 2010 encompassed > 90% of juvenile steelhead emigration period in the Imnaha River.

Although the trap operated during the peak emigration period, the trap was removed during periods of excessively high water in most years. High water created unsafe conditions for the crew or choked the trap with debris, potentially compromising fish health. Operations were non-continuous in 17 of 18 years, with non-operational periods ranging from 0 to 73 days per year with a median of 22 days (Table 1). Since 2000 an effort was made to operate the trap as much as possible, and this reduced the median number of days that the trap was not operational to 13 days, with a range of 0 to 23 days. In spite of these efforts it was likely that significant numbers of fish were missed. Annual total numbers of juvenile steelhead captured are presented in Table 1.

Table 1. Annual trapping operations at the Imnaha River screw trap including year, total days per season, days not fish, trapping start date, trapping end date and total natural-origin steelhead captured.

| Year | Days Per Season | Days Not Fished | Trapping Start Date | Trapping End Date | Natural steelhead captured |
|---|---|---|---|---|---|
| 1994 | 107 | 15 | 3/1/94 | 6/15/94 | 5332 |
| 1995 | 135 | 73 | 2/6/95 | 6/20/95 | 789 |
| 1996 | 123 | 44 | 2/23/96 | 6/24/96 | 3786 |
| 1997 | 110 | 40 | 3/9/97 | 6/27/97 | 877 |
| 1998 | 112 | 43 | 2/26/98 | 6/16/98 | 3569 |
| 1999 | 115 | 28 | 3/1/99 | 6/25/99 | 2748 |
| 2000 | 110 | 18 | 2/26/00 | 6/15/00 | 5041 |
| 2001 | 120 | 23 | 2/22/01 | 6/20/01 | 6462 |
| 2002 | 102 | 16 | 3/4/02 | 6/12/02 | 6956 |
| 2003 | 112 | 5 | 3/7/03 | 6/24/03 | 8771 |
| 2004 | 123 | 8 | 2/25/04 | 6/27/04 | 8204 |
| 2005 | 111 | 13 | 3/2/05 | 6/21/05 | 5374 |
| 2006 | 111 | 15 | 3/1/06 | 6/20/06 | 2334 |
| 2007 | 113 | 0 | 3/1/07 | 6/21/07 | 10323 |
| 2008 | 111 | 22 | 2/28/08 | 6/18/08 | 4247 |
| 2009 | 112 | 10 | 2/25/09 | 6/17/09 | 5703 |
| 2010 | 116 | 11 | 2/24/10 | 6/20/10 | 7247 |
| 2011 | 112 | 19 | 2/28/11 | 6/20/11 | 3883 |

Juvenile Performance Measures

Index of Juvenile emigrant abundance

Imnaha River natural-origin steelhead juvenile emigrant abundance was estimated from 2004 -2009. Trap efficiencies trials were not conducted prior to 2004. Results revealed that other than 2006, minimum estimates of IRN steelhead juvenile abundance ranged from 50,000 to 75,000 emigrants per year (Table 2). Estimates from 2006 were significantly greater than those of other years and the low number of recaptured TE fish and wide confidence intervals suggested that the total estimate was less accurate than the other years (Table 2). The similar emigrant abundance estimates from the other years suggest that the Imnaha River consistently produces a minimum of 50,000 IRN juvenile steelhead smolts per year. This should be considered a minimum abundance because we did not include an estimate of emigrants passing the site during periods of high water and/or debris. Although methods are available to extrapolate fish passage during times when the screw trap was not operational, we have not completed those analyses. We plan to go back and determining total juvenile abundance estimates using alternative methods that account for non-operational periods in a future report.

Table 2. Annual Imnaha River natural-origin (IRN) juvenile steelhead abundance estimates determined by mark/recapture analysis at the Imnaha River juvenile screw trap including the upper and lower 95% confidence interval (C.I.), Standard Error (SE), number captured, number marked, number recaptured and the average annual trap efficiency.

| Year | Abundance Estimate | Upper 95% C.I. | lower 95% C.I. | SE | Number Captured | Number Marked | Number Recaptured | Average Trap efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| 2004 | 76,678 | 98,640 | 61,537 | 9,508 | 8,204 | 1,820 | 156 | 9.0 |
| 2005 | 51,991 | 65,339 | 43,331 | 5,828 | 5,374 | 1,976 | 218 | 11.4 |
| 2006[1] | 172,605 | 287,537 | 108,852 | 48,897 | 2,334 | 1,482 | 17 | 9.0 |
| 2007 | 59,504 | 65,001 | 54,695 | 2,698 | 10,323 | 2,412 | 419 | 17.8 |
| 2008 | 50,311 | 64,576 | 39,688 | 2,909 | 4,247 | 954 | 87 | 11.3 |
| 2009 | 56,298 | 74,595 | 45,378 | 6,661 | 5,703 | 1,362 | 146 | 10.1 |

[1]imprecise estimate resulting from few recaptures and low trap efficiencies

Juvenile steelhead arrival timing at the screw trap

Combining arrival timing data from 2008 – 2011 indicated that the median arrival timing at the screw trap for the Big Sheep Creek direct released fish was April 13 compared to May 7 for both the natural population and the Little Sheep Creek acclimated group. Cumulative arrival timing graph revealed that the Little Sheep Creek group closely mimicked the natural population and both of these groups were significantly later than the Big Sheep Creek group (Figure 2; Kolmogorov-Smirnov two-sample test, $P < 0.01$). Results suggest that the Big Sheep Creek direct released fish rapidly moved down stream and entered the Snake River whereas the acclimated/volitionally released group from Little Sheep Creek emigrated similarly to that of the natural population. Only 2008 – 2011 data were used for this analysis because prior to 2008 only 1,000 fish were PIT tagged from each hatchery group to estimate survival to Lower Granite Dam, resulting in relatively few PIT tag recaptures at the screw trap (ranging from 9 to 59) and relatively imprecise estimates of arrival timing at the screw trap. Since 2008, greater than 10,000 IRH juveniles were PIT tagged from each group, resulting in high numbers of IRH PIT tag recaptures at the screw trap.

Significantly different arrival timing results in IRH compared to IRN indicate emigration patterns influenced by the timing and release strategy rather than natural environmental cues. Assuming that IRN juveniles emigrate at the optimal time and speed, significant differences may limit survival of the hatchery groups. Hatchery releases have varied over the years, but in general there were two hatchery groups that utilized acclimated (Little Sheep Creek) and a direct (Big Sheep Creek) release strategies (for example, see Lower Snake River Compensation Plan, 2011). Combining recapture data from both releases revealed a protracted emigration period from release to the screw trap that did not represent emigration patterns of the individual IRH groups. Consequently, we analyzed the groups separately to get a more accurate representation of the emigration patterns of the two distinct release groups and allow for the evaluation of the two release strategies. Our results suggested that the emigration timing of Big Sheep direct release was significantly different than that of the Little Sheep Creek acclimated release and the natural population, which were similar. A closer examination of juvenile survival and adult returns should be conducted to determine if the Big Sheep Creek release have decreased survival, and if the release strategy could have affected hatchery steelhead performance.

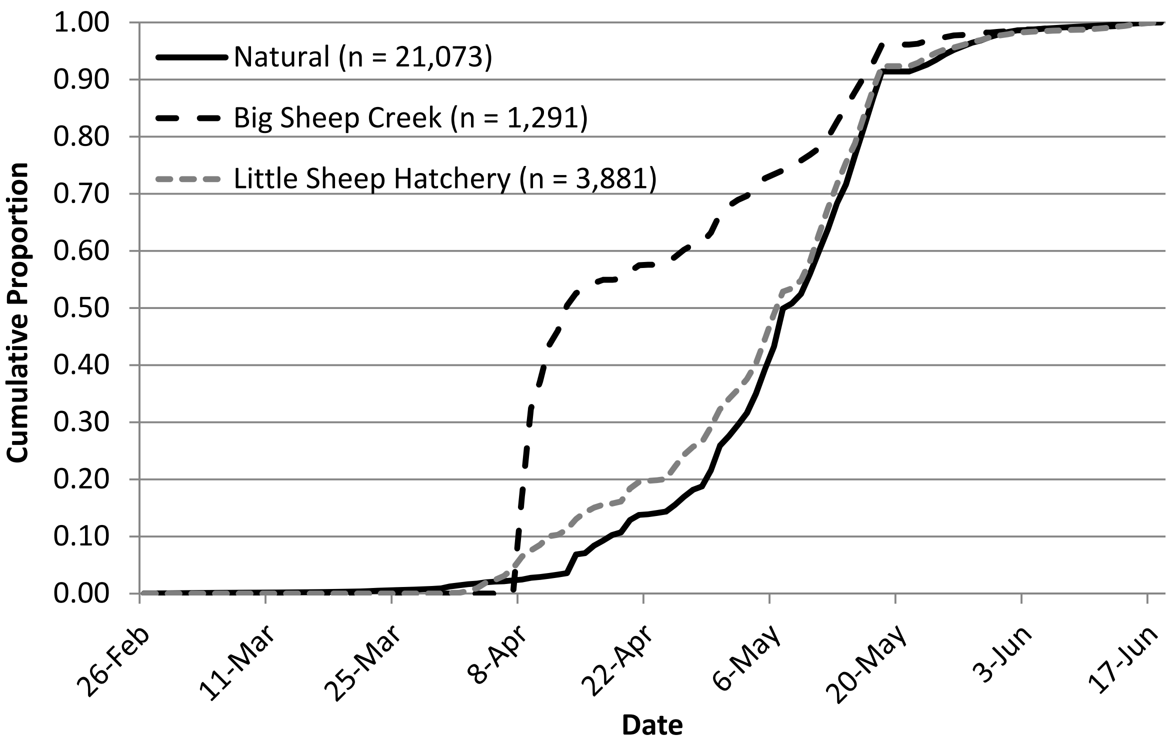



Figure 2. Line graph showing cumulative arrival timing (n = sample size) at the Imnaha River screw trap for natural-origin, Big Sheep Creek hatchery and Little Sheep Creek hatchery juvenile steelhead from 2008 – 2011.

Size at emigration

Imnaha River hatchery-origin juveniles were significantly larger than IRN juveniles for both fork length and weight (Table 3; t-test, $P < 0.001$). We only presented data from 2009, but this was representative of fish captured in the other years. The lower C.V. for fork length compared to weight suggested that length was more uniform than weight for both IRH and IRN juveniles.

Condition of juveniles at emigration

Condition factor measures a species length to weight relationship as an index of growth and is calculated as weight/length$^3$. Table 3 presents mean condition factor for IRH and IRN juvenile steelhead captured in 2009 and is representative of data from other years. Although the fork lengths and weights were significantly greater in hatchery fish compared to naturals, equivalent condition factors indicated that growth and body conditions were similar.

Table 3. Size-at-emigration of natural- (IRN) and hatchery-origin (IRH) juvenile steelhead captured at the Imnaha River screw trap in 2009, including sample size (n), mean length (centimeters – mm) and mean weight (grams – g) and standard deviation (S.D.), coefficient of variation (C.V.), minimum and maximum for both measures.

| | IRN | IRH |
|---|---|---|
| Mean length (mm) | 172.9 | 218.6 |
| Sample (n) | 5,171 | 1,987 |
| S.D. | 17.6 | 23.4 |
| C.V. | 10.2% | 10.7% |
| Minimum | 120 | 130 |
| Maximum | 257 | 315 |
| | | |
| Mean weight (g) | 54.5 | 110.3 |
| Sample (n) | 5,169 | 1,928 |
| S.D. | 16.9 | 38.6 |
| C.V. | 31.0% | 35.0% |
| Minimum | 14.9 | 20.2 |
| Maximum | 174.7 | 376.3 |
| | | |
| Mean condition ($W/L^3$) | 1.03 | 1.02 |
| Sample (n) | 5,163 | 1,923 |
| S.D. | 0.08 | 0.08 |
| C.V. | 7.8% | 7.8% |
| Minimum | 0.64 | 0.76 |
| Maximum | 1.52 | 1.42 |

Juvenile arrival timing at Lower Granite Dam

Arrival timing at Lower Granite Dam was determined by detections of IRH and IRN juvenile steelhead that were PIT tagged or recaptured at the Imnaha River screw trap. The median, 10$^{th}$ and 90$^{th}$ percentile arrival times for Imnaha River IRH, IRN and Snake River aggregate (SRA; an aggregate of PIT tag detections from juvenile steelhead tagged throughout the Snake River basin, data provided by the Fish Passage Center) are presented in Table 4. The median arrival timing date of SRA was May 8, four days earlier than IRN and seven days earlier than IRH. Cumulative arrival timing distributions (Figure 3) indicated that both IRN and IRH initially arrived later than the SRA, but by the end of the emigration period the cumulative arrival of IRN was similar to that of SRA (same 90% arrival timing date). A Kolmogorov-Smirnov two-sample test measuring the maximum difference (max D) in the distributions revealed that the arrival timing distribution of the SRA was significantly earlier than that of IRH (Max D = 0.222; $P < 0.05$; occurring on May 7), but not IRN steelhead (Max D = 0.152; $P > 0.05$). The arrival timing of IRH steelhead was not significantly different than that of IRN steelhead (Max D = 0.140; $P > 0.05$).

The emigration timing of Imnaha River juvenile steelhead reflects a localized ecological pattern as it relates to the Snake River aggregate, and similar timing by the hatchery component generally corresponds with a later pattern of outmigration of Imnaha River steelhead smolts. Similar to emigrant arrival timing at the screw trap, significant differences may signify non-adaptive patterns in emigration of the hatchery release groups with the potential to reduce juvenile survival and adult returns. Our data showing similar arrival timing at LGR for IRN and IRH indicate a localized pattern of emigration persists in the hatchery release groups.

Table 4. Juvenile steelhead median, 10$^{th}$ and 90$^{th}$ percentile arrival time dates to Lower Granite Dam for Imnaha River natural-origin (IRN), Imnaha River hatchery-origin (IRH) and Snake River aggregate (SRA).

| | Date | | |
|---|---|---|---|
| | 10th % | median | 90th % |
| IRN | 24-Apr | 12-May | 25-May |
| IRH | 26-Apr | 15-May | 31-May |
| SRA | 23-Apr | 8-May | 25-May |

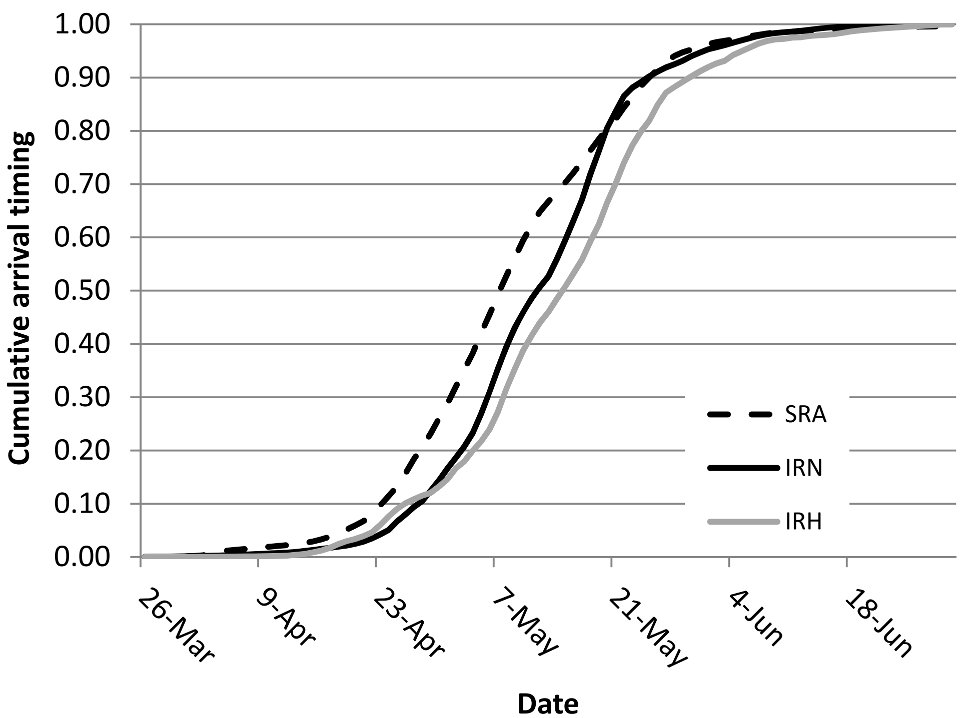



Figure 3. Cumulative distribution of arrival time at Lower Granite Dam for Imnaha River hatchery-origin (IRH), Imnaha River natural-origin (IRN) and Snake River aggregate (SNA) from 1998 – 2010.

Juvenile survival

Juvenile survival from the screw trap to LGR and MCN were determined for IRN and IRH steelhead using juveniles PIT tagged or recaptured (hatchery-origin juveniles) at the Imnaha River screw trap and PIT tag interrogations at the juvenile bypass facilities. From 1995 – 2011 survival from the Imnaha River screw trap to LGR was high for both IRN and IRH averaging 84.7% (4.0) and 84.4% (10.3), respectively. In contrast to the relatively consistent survival to LGR, survival from the screw trap to MCN was highly variable for both IRN an IRH juveniles (Figure 4), averaging 52.9 (14.3) and 52.1 (17.9), respectively. Survival of IRN compared to IRH juveniles was not significantly different to LGR ($t = 0.668$; $P = 0.510$) or MCN ($t = 0.112$; $P = 0.913$) indicating that hatchery- and natural-origin steelhead survived at the similar rate from the screw trap to MCN.

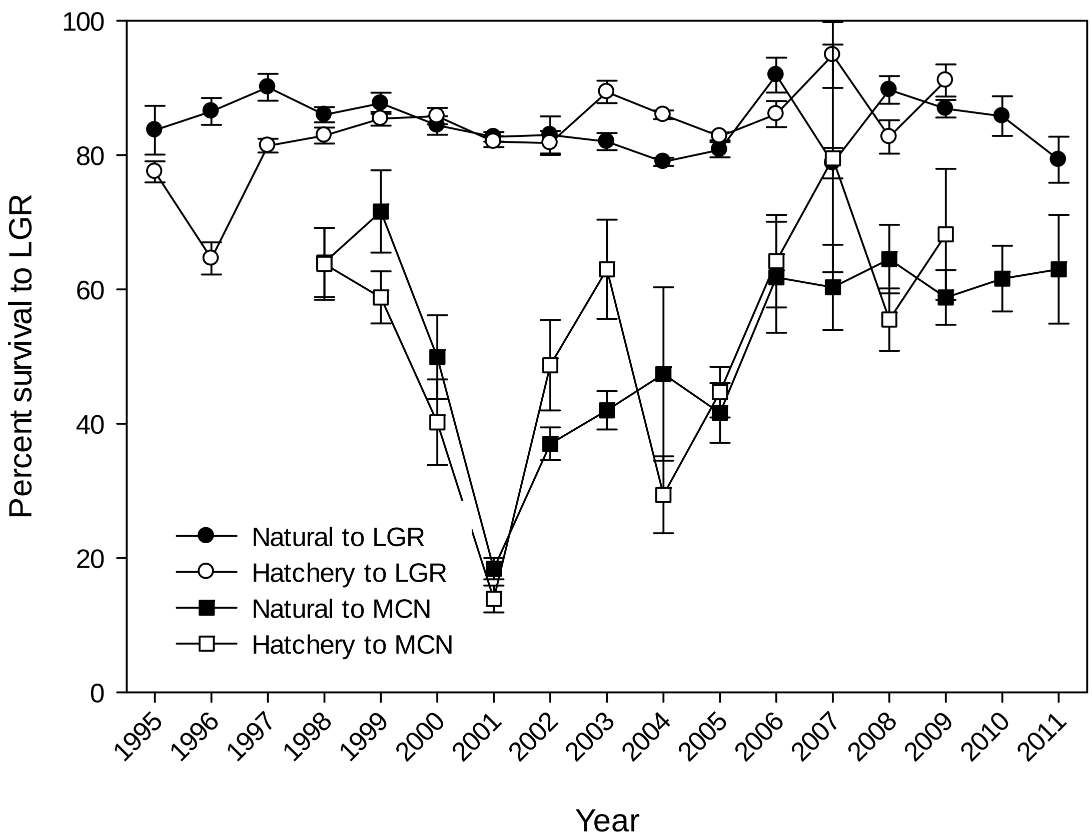



Figure 4. Natural-origin (IRN) and hatchery-origin (IRH) juvenile steelhead survival from the Imnaha River screw trap to Lower Granite Dam (LGR; 1995 – 2011) and McNary Dam (MCN, 1998 – 2011).

Our report focused on the effects of Imnaha and Snake River conditions above LGR. A more comprehensive review of the effects of environmental conditions on juvenile survival through the hydrosystem can be found in the CSS report (http://www.fpc.org/documents/CSS.html). An analysis of the relationship between Snake River flow and surivival to LGR revealed that Snake River flow was positively related to juvenile survival to LGR for IRN ($R^2$ = 0.298, P = 0.023), but not IRH ($R^2$ = 0.066, P = 0.353; Figure 5). The lack of relationship between higher flow and IRH survival suggests that hatchery fish were less influenced by annual variations in river flow compared to natural-origin juveniles. The larger juvenile size, later release and migratory behavior may enable hatchery steelhead to rapidly migrate to LGR under variable conditions, whereas the emigration timing of natural-origin steehead was determined by environmental cues, such as flow, that were advantageous to survival.

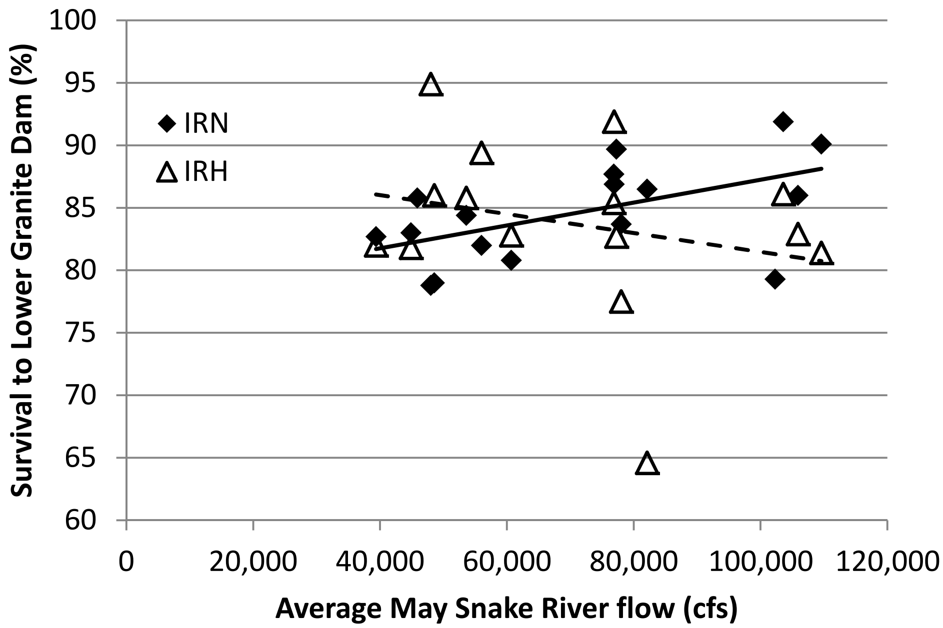



Figure 5. Relationship between average May Snake River flow and survival from the Imnaha River screw trap to Lower Granite Dam (LGR) for Natural-origin (IRN) and hatchery-origin (IRH). Solid line represents the IRN trend and dashed line represents the IRH trend. Snake River flow in cubic feet per second (cfs).

Adult arrival timing

Imnaha River adult steelhead arrival timing to BON and LGR were estimated from PIT tag interrogations at the adult fishways. Both IRH and IRN adults were first detected at BON in late June with the last detections occurring in mid September. The median arrival timing at BON was July 31 for IRN and August 7 for IRH (Table 5). Adults were first detected at LGR in early – mid July, with the last detections occurring the following May. The median arrival timing at LRG was September 25 for IRN and September 21 for IRH (Table 5). Approximately, 5% of IRN adults pass LGR the following spring, compared to 1% of IRH.

Table 5. Adult arrival timing at Bonneville Dam (BON; a) and Lower Granite Dam (LGR; b) for natural-origin (IRN) and hatchery-origin (IRH) steelhead PIT tagged in the Imnaha River from 2000 – 2011. Data includes medial arrival date, 10$^{th}$ percentile date (10$^{th}$), 90$^{th}$ percentile date (90$^{th}$) and date of first and last fish.

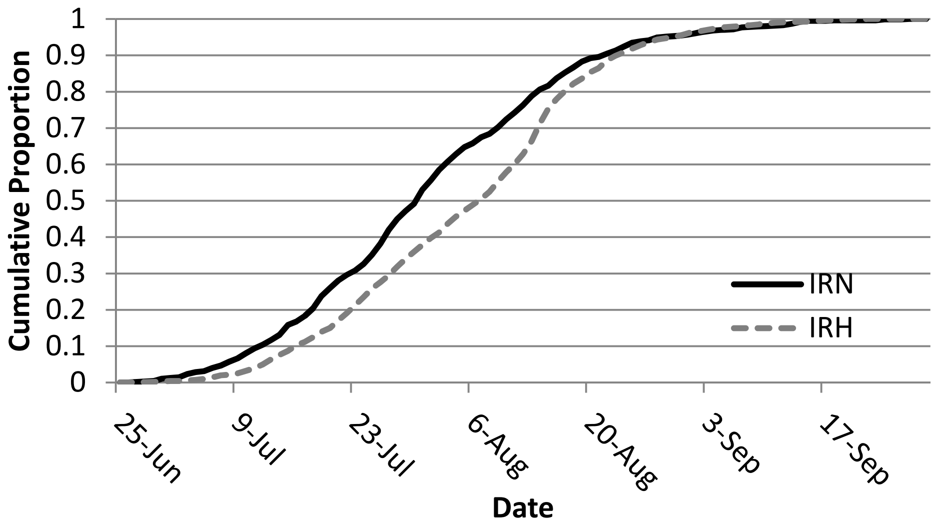
a. Arrival timing at BON

| | median | 10th | 90th | First | Last |
|---|---|---|---|---|---|
| IRN | 31-Jul | 12-Jul | 21-Aug | 27-Jun | 27-Sep |
| IRH | 7-Aug | 16-Jul | 23-Aug | 27-Jun | 22-Sep |

b. Arrival timing at LGR

| | median | 10th | 90th | First | Last |
|---|---|---|---|---|---|
| IRN | 25-Sep | 21-Aug | 5-Nov | 12-Jul | 16-Jun |
| IRH | 21-Sep | 2-Sep | 19-Oct | 19-Jul | 15-Jun |

Cumulative arrival timing to BON and LGR (Figure 6) demonstrated that IRN arrived earlier at BON compared to IRH. The relationship was reversed at LGR, with IRH arriving earlier than IRN. Kolmogorov-Smirnov two-sample test (K-S test) for differences in arrival timing between IRN and IRH revealed that the maximum difference in cumulative arrival timing at BON (Max D = 0.175; $P > 0.05$) was not have significantly different for IRN compared to IRH adults. In contrast, arrival timing at LGR was significantly earlier for IRH compared to IRN (Max D = 0.117, $P < 0.05$; occurring on September 30) indicating that the cumulative arrival timing distribution of IRH was significantly earlier than that of IRN.



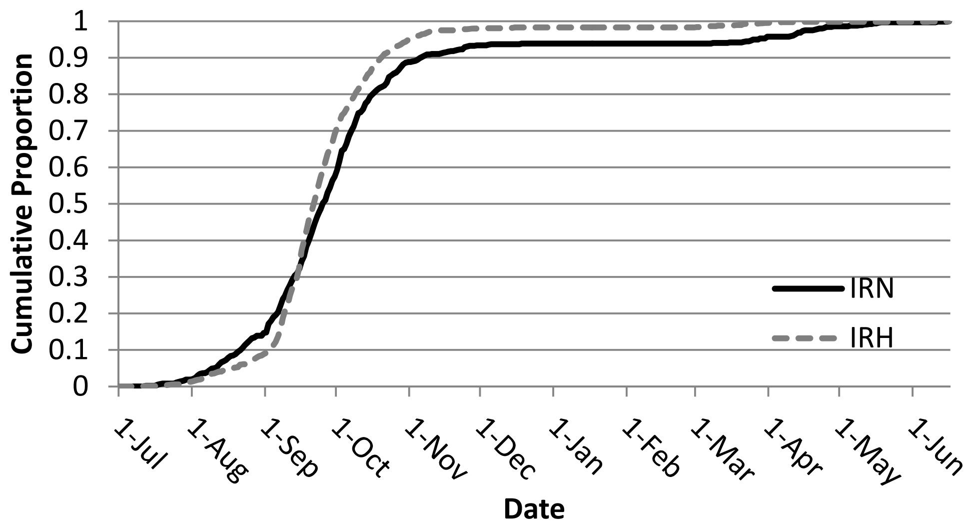




Figure 6. Adult arrival timing at Bonneville Dam (top) and Lower Granite Dam (bottom) for Imnaha River natural-origin (IRN) and hatchery-origin (IRH) steelhead determined from PIT tag interrogations.

Adult conversion rates

IRN and IRH adult conversion rates from BON to LGR were compared using PIT tag interrogations at the adult fishways. The average conversion rate from 2002 through 2010 was 0.75 (0.06) and 0.78 (0.10) for IRN and IRH, respectively. The rates were relatively consistent (Figure 7), with no difference in average conversion between IRN and IRH (T-test; $P > 0.05$). Most of the loss occurred between BON and MCN, conversions from MCN to LGR averaged greater than 95% for both IRN and IRH (data not shown). Similar conversion rates between adipose fin-clipped hatchery fish and unmarked natural fish was surprising and suggested that the mark-selective sport fishery in the mid Columbia River had little or no effect on conversion rate of Imnaha River adipose fin clipped hatchery steelhead between BON and LGR.

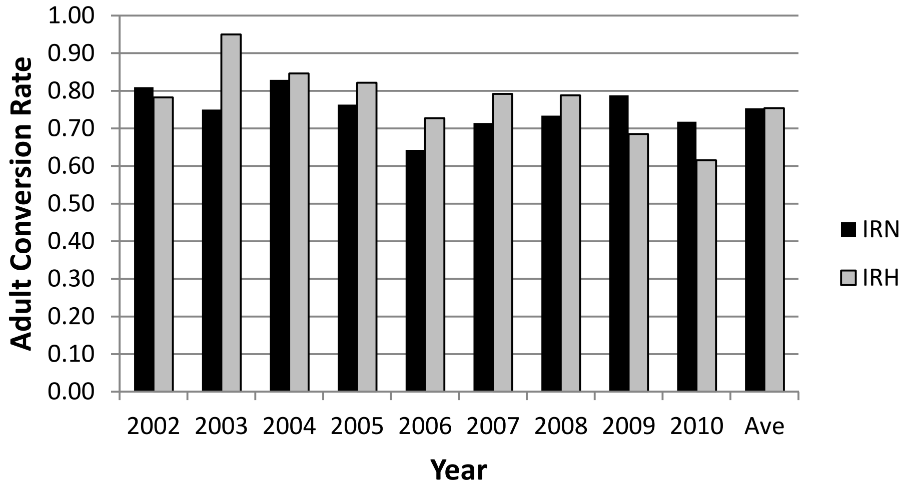



Figure 7. Natural-origin (IRN) and hatchery-origin (IRH) adult steelhead conversions from Bonneville Dam (BON) to Lower Granite Dam (LGR) from 2002 – 2010. Ave – average conversion rate across all years.

Smolt-to-adult return Index

Smolt-to-adult (SAR) return index rates were estimated from juveniles PIT tagged at the Imnaha River trap and subsequent PIT tag interrogations at LGD as juveniles and adults. In the early years of the study the main objective was to analyze in-river juvenile migration, resulting in a majority of the tagged fish being bypassed back to the river. Consequently, SAR index results presented here do not represent the run-at-large and have limited management utility. They are presented mainly as a comparison between natural- and hatchery-origin fish under similar conditions. Results demonstrated that SAR index rates from LGR to LGR were slightly higher for IRH compared to IRN (Table 6).

Table 6. Hatchery- and natural-origin steelhead smolt-to-adult return index (SAR) from the Imnaha River screw trap to Lower Granite Dam (LGR) and from LGR to LGR determined from fish PIT tagged and/or captured and released at the Imnaha River screw trap. All fish were designated in river survival mode as they passed through the hydrosystem and don't represent the run-at-large.

| Migration Year | Number PIT Tagged | Estimated Smolts at LGR | Number of Adult detections at LGR | 1 Ocean[1] | 2 Ocean[2] | SAR Index Imnaha R. to LGR % | SAR Index LGR to LGR (%) |
|---|---|---|---|---|---|---|---|
| Hatchery-origin | | | | | | | |
| 2000 | 5,846 | 5,016 | 65 | 49 | 16 | 1.11 | 1.30 |
| 2001 | 3,463 | 2,840 | 3 | 3 | 0 | 0.09 | 0.11 |
| 2002 | 2,153 | 1,787 | 25 | 18 | 7 | 1.16 | 1.40 |
| 2003 | 5,227 | 4,673 | 38 | 26 | 12 | 0.73 | 0.81 |
| 2004 | 4,487 | 3,854 | 16 | 11 | 5 | 0.36 | 0.42 |
| 2005 | 6,570 | 5,440 | 21 | 19 | 2 | 0.32 | 0.39 |
| 2006 | 1,494 | 1,286 | 20 | 17 | 3 | 1.34 | 1.55 |
| 2007 | 1,492 | 1,416 | 22 | 17 | 5 | 1.47 | 1.55 |
| Natural-origin | | | | | | | |
| 2000 | 4,737 | 3,998 | 69 | 51 | 18 | 1.46 | 1.73 |
| 2001 | 3,680 | 3,043 | 10 | 1 | 9 | 0.27 | 0.33 |
| 2002 | 4,809 | 3,934 | 37 | 21 | 16 | 0.77 | 0.94 |
| 2003 | 6,302 | 5,168 | 34 | 18 | 16 | 0.54 | 0.66 |
| 2004 | 1,506 | 1,190 | 1 | 0 | 1 | 0.07 | 0.08 |
| 2005 | 4,400 | 3,555 | 5 | 3 | 2 | 0.11 | 0.14 |
| 2006 | 2,063 | 1,896 | 26 | 21 | 5 | 1.26 | 1.37 |
| 2007 | 3,238 | 2,552 | 32 | 18 | 14 | 0.99 | 1.25 |

## Conclusions

The performance measures evaluated here provide important information for the entire Imnaha River population/Major Population Group (MPG). Significant results included: 1) natural-origin juvenile steelhead index of abundance emigrating from the Imnaha River averaged greater than 50,000 per year. Combined with the estimated juvenile survival to LGR, an estimated 40,000 natural-origin juvenile steelhead from the Imnaha River survive to LGR. 2) Emigration from the Imnaha River peaks in April/May, with greater than 95% of the total Imnaha River juvenile steelhead leaving during this peak migration period. The emigration timing of the volitionally-released hatchery juveniles from the Little Sheep Creek Acclimation Facility closely mimicked the timing of the natural-origin population as measured by arrival timing at the screw trap. In contrast, the direct release from Big Sheep Creek was significantly earlier with a more compressed migration period. There were not enough PIT tagged steelhead that originated from the Big Sheep Creek release to evaluate the effects of the different emigration pattern on juvenile survival through the hydrosystem or subsequent adult returns. 3) Hatchery-origin juveniles had significantly larger average fork length and weight, but condition factor was not significantly different compared to natural-origin fish. Larger size did not appear to positively affect survival to LGR or MCN, but may have positively affected SAR rates. 4) Arrival timing at LGR for hatchery-origin juveniles was slightly later than that of natural-origin juveniles. Both hatchery- and natural-origin Imnaha River juvenile steelhead arrived at LGR later compared to the Snake River aggregate. This was likely a localized adaptation of Imnaha River steelhead that has been retained in the hatchery population. 5) Juvenile survival to LGR was relatively consistent, averaging approximately 80% for both hatchery- and natural-origin juveniles. In contrast, juvenile survival to MCN was highly variable, suggesting that environmental conditions had a much greater effect on survival below compared to above LGR. 6) Adult arrival timing patterns were not significantly different. Natural-origin adult steelhead arrived at BON earlier than hatchery-origin adults, with the relationship reversed at LGR. A higher proportion of natural-origin adults arrive at LGR the following spring compared to hatchery-origin adults. 7) Adult conversion rates from BON to LGR averaged 75%, with similar rates for hatchery- and natural-origin steelhead. Conversion rates from MCN to LGR were > 95% indicating that most of the loss occurred between BON and MCN. Slightly different migration patterns indicated by different arrival timing at BON and LGR did not significantly affect conversion rates to LGR. 8) Smolt-to-adult return index rates were slightly higher for hatchery- compared to natural-origin steelhead. However, the analysis measured bypassed in river juveniles only and did not represent the run at-large.

Naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, behavior, growth and other biological characteristics (NPCC, 2009). These results indicated that the post release performance of the LSRCP hatchery program fish was similar to that of the natural population for survival to LGR, migration timing (arrival timing at the screw trap and at LGR), adult arrival timing to BON, adult BON to LGR conversion rate and SAR rate. The major differences observed were juvenile size. However, hatchery juvenile growth rates were purposely increased in order to produce larger juveniles at time of release. The significantly larger juvenile size likely conferred a survival advantage as juveniles, and this translated to increase survival to adult. Hatchery programs that mimicked the life history of the natural population also reduces risk factors associated with supplementation fish mating with the natural-origin fish. The Imnaha River supports an integrated hatchery program that allows for and encourages hatchery/natural interaction (Little Sheep and Big Sheep Creek outplants). Thus it is important that the hatchery fish are as similar as possible, in genetics and behavior, to the natural population (NPCC, 2009). This study provides information critical to addressing these objectives.  Juvenile abundance estimates and survival provide an important data for assessing productivity and diversity, both of which are important to population viability (McElhany et al. 2000).

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