ADULT STEELHEAD EVALUATIONS IN IMNAHA RIVER TRIBUTARIES

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Introduction

Significant declines in abundance resulted in the Snake River basin steelhead (*Oncorhynchus mykiss*; Héeyey in Nez Perce language) being listed as a threatened species under the United States Endangered Species Act (ESA). Although declines were apparent at the ESU level based on long-term trends at the four lower Snake River dams, the status of individual major population groups (MPG) were largely unknown. The viable salmonid population (VSP) concept outlines methods for determining the conservation status of populations and understanding the parameters used to determine viability status, both critical to the establishment of ESA delisting goals and the formulation of recovery plans (McElhany et al. 2000). The status of naturally spawning steelhead in the Imnaha River MPG was largely unknown as it related to the four VSP parameters, abundance, population growth rate, spatial structure and diversity.

In addition, the influence of the Lower Snake River Compensation Program's Endemic Little Sheep Creek Summer Steelhead program has not been determined for any spawning aggregation within the Imnaha River population except within Little Sheep Creek (USFWS, 2011). In this study we attempted to determine the status of three spawning aggregations in the lower Imnaha River and assess the presence of hatchery-origin fish in these systems.

The goal of the project is to evaluate the abundance and population composition of adult steelhead escapement in the lower Imnaha River spawning aggregates. We monitored and evaluated three natural steelhead spawning aggregates in the lower Imnaha River from 2000 – 2011. Prior to the implementation of this study the spatial and temporal spawner distribution, presence/absence of hatchery-origin steelhead and life history diversity of the natural-origin spawning aggregates in the Imnaha River were largely unknown. Results provided information directly related to VSP parameter assessments of abundance, diversity and spatial structure of the Imnaha River MPG.

The information collected by this project will be evaluated as part of a basin-wide monitoring and evaluations effort on the Imnaha River steelhead MPG. In addition to this project, two other Bonneville Power Administration funded projects have begun to evaluate adult steelhead status and trends in the upper Imnaha River (Imnaha River Adult Steelhead Monitoring Project; ISAM; http://www.cbfish.org/Project.mvc/Display/2010-032-00) and abundance in the entire basin (Integrated Status and Effectiveness Monitoring Project; ISEMP; http://www.cbfish.org/Project.mvc/Display/2003-017-00). The ISAM project operates weirs in the upper Imnaha River tributaries to describe the abundance, diversity and spatial distribution within the Imnaha River subbasin. The ISEMP project uses proportional tagging of natural-origin steelhead at Lower Granite Dam with recaptures recorded on instream passive integrated transponder (PIT) tag arrays to generate abundance estimates to the entire basin. Combined with the data collected by this project, a comprehensive assessment of the status

and viability of the entire Imnaha River subbasin will relate performance at the MPG level to status assessments of entire Snake River basin Distinct Population Segment (DPS).

Methods

Monitoring adult steelhead spawner abundance requires intensive methods, utilizing weirs and traps operated during high spring flows. For this reason, we operated 1-2 weirs per year on a rotational basis in three streams, Cow Creek, Lightning Creek and Horse Creek (Figure 1). Weirs and adult traps were placed in Cow Creek from 2001 – 2007, in Lightning Creek from 2000 to 2007 and in Horse Creek from 2008 – 2011. Rotating the placement of weirs enabled a greater number of streams to be evaluated given the limited resources. The objective was to collect 4-5 years of reliable abundance data from each tributary, understanding that high water may limit operations and data collection during some years. In addition, a resistivity counter was operated in Lightning Creek (2007) and Camp Creek (2008 – 2009; Figure 1) to evaluate the effectiveness of this technology for monitoring steelhead population abundance.

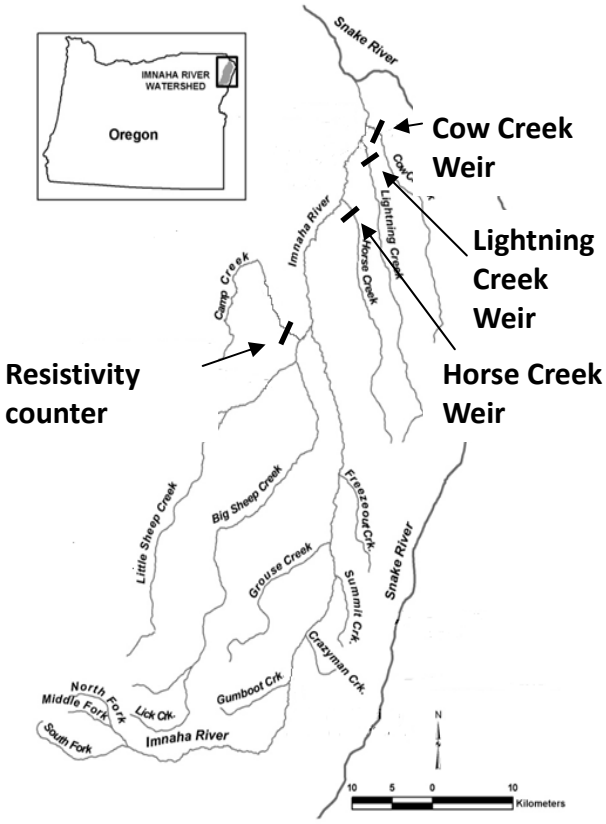

Figure 1. Map of the Imnaha River and tributaries with the locations of the Cow, Lightning and Horse Creek weirs and the resistivity counter in Camp Creek.

Temporary bi-directional weirs were operated from early March through mid June, or 10 days after the last fish was captured. Standard picket weirs were used from 2000 – 2008. Beginning 2008 a floating panel weir was used to reduce the effects of high water, safeguard equipment and provide greater safety for fish and personnel. The weir was checked daily during its period of operation, and often twice a day (mornings and evenings) during the peak migration period. The upstream and downstream trap boxes were checked and debris was removed from any points on the structure. Adult steelhead captured were released upstream if captured in the upstream trap box or released downstream if captured in the downstream trap box. Surveys looking for spawning activity (spawning fish or redds) below the weir were conducted weekly.

All captured fish were netted out of the trap box and placed in a large tote until biological data could be obtained. Biological data recorded included fork length, sex, origin, marks, and tags and scales were removed for age analysis. Fish were scanned for the presence of a coded wire tag (CWT) or passive integrated transponder (PIT) tag. Hatchery-origin fish were determined by the absence of an adipose fin or CWT the in the case that unclipped hatchery fish were captured. Fish were marked with operculum punch and the resulting tissue sample was preserved for future DNA analysis. Fish captured moving upstream or downstream that possessed an opercle punch mark were measured, observed for other tags and marks, and recorded as a recapture. Beginning in 2011, fish were marked by inserting a PIT tag in the pelvic girdle to facilitate a mark recapture study and track downstream kelt migration.

Calculations of adult monitoring performance measures were based on the biological data collected from adult steelhead trapped at the weir and estimated through adjusted Peterson mark-recapture formula expansions (*see below*). Proportional assignment of biological data (e.g., origin, sex, or length) obtained from fish that were handled provided the basis for determinations made on fish that were not handled and thus lacked the biological information needed to account for all fish estimated to have returned to the tributary. Methods of derivation and assumptions used are presented below, following those presented in Vogel (et. al 2005).

The total adult steelhead abundance was estimated by marking adult fish at the trap and then 'recapturing' the marks from downstream migrating fish captured in the downstream trap box. Total operculum-tagged and unmarked steelhead captured in the upsteam and downstream traps were tallied (assuming equal distribution and probability of recovery). We used the adjusted Petersen estimator (Chapman 1951), a commonly used mark-recapture formula (Cousens et al. 1982), to approximate an unbiased escapement estimate. Adult data was applied to the following terms:

$$A\hat{A}W_{M/R} = \frac{(M+1)(C+1)}{(R+1)} - 1$$

Where *M* is the number of marked (opercular-tagged) adults released above the weir, *C* is the total number of steelhead captured (marked and unmarked) moving downstream, and *R* is the number of marked (opercular-tagged, or lost opercular-tag with identifying staple marks) steelhead captured moving downstream. The variance for this estimate was calculated as:

$$Var_{A\hat{A}W} = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}$$

Adult Monitoring - Performance Measures

Performance measures calculated from biological data obtain from adult steelhead collected at the Cow, Lightning and Horse creek traps 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:

Spawner abundance: the raw measure of the number of adult steelhead that escaped passed the weir derived from a mark/recapture analysis plus an estimate of the number of adults that spawned below the weir. This is equivalent to adult escapement since no fishery occurred above the weir and prespawn mortality is assumed to be rare.

Hatchery fraction: calculated by dividing the total number of unique hatchery-origin steelhead captured by the total number of unique steelhead captured, assuming an equal probability of capture for hatchery- and natural-origin fish. Generally, mark/recapture point estimates for hatchery-origin fish were not reliable given the small number of hatchery-origin fish captured.

Age-at-return: the age distribution of spawning steelhead determined by scale pattern analysis. Total age and freshwater and ocean residency times were determined.

Size-at-return: the average size (fork length) and size distribution of steelhead captured in each stream, by origin. Size at return for natural-origin and hatchery-origin steelhead was compared using at t-test of means.

Adult spawner sex ratio: the proportion of female and male steelhead captured at the weir.

Return (spawn) timing: estimated using the following measures; 1) median - date that 50th percent of the total steelhead were captured and; 2) range – determined by the first and last fish and the 10th and 90th percentiles of total steelhead captures.

Resistivity counter

A Logie 2100C fish counter was installed in Lightning Creek in 2007 and in Camp Creek in 2008 and 2009 to evaluate the utility of this technology for enumerating adult steelhead abundance. This technology uses differences in resistivity that are generated when a fish passes over a electric field produced by a panel or set of panels laid across the stream bottom.

Signal processing software can determine fish size and direction of movement based on signal amplitude and signal pattern, respectively, and distinguish non-fish targets. Additional information related to the technology can be found at:http://www.aquantic.com/. The counter was installed approximately 50 meters below the Lightning Creek weir in order to document weir impedance and verify the abundance estimates determined by the mark/recapture analysis. In 2008 and 2009 the counter was operated in Camp Creek approximately one half mile above its confluence with the Imnaha River in order to estimate adult steelhead abundance.

Results

Weir operations

Weirs were operated in Cow, Lightning and Horse creeks (tributaries in the lower Imnaha River) from 2000 – 2011. Weir operation dates and first and last fish capture dates are presented in Figure 2. Based on the date of the first and last captures the weir operation period generally encompassed the migration and spawning period of adult steelhead in these systems. The exceptions were those years where high flows precluded weir operations later in the season. Comparing the date of last fish captured during the high flow years to that of extended weir operations demonstrated that fish were likely missed during high flow years and this impacted the resulting population estimates. A total of five years were impacted by high water (Figure 2).

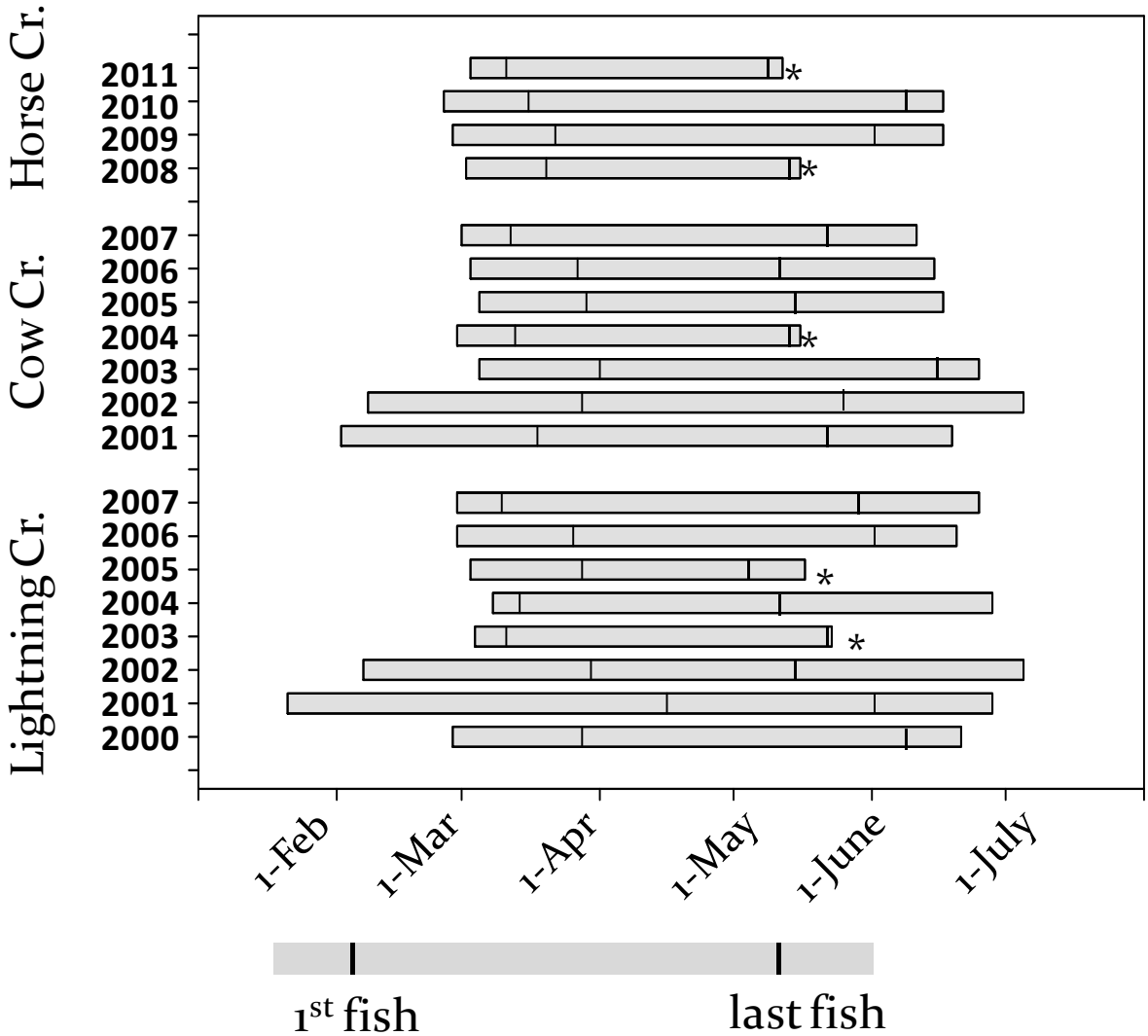

Figure 2. Annual operation dates (gray bars) for Lightning, Cow and Horse Creek weirs. First and last unique upstream migrating fish are indicated by the vertical bars. Asterisk indicates years where high water limited weir operations.

Spawner escapement

Steelhead returns were highly variable over the study period. Average abundance estimates (coefficient of variation – C.V.) were 77 (10.8) for Cow Creek, 126 (13.6) for Lightning Creek and 228 (17.5) for Horse Creek (Figure 3; Table 1). Overall C.V.'s were low, suggesting moderate to high precision around the estimates, even during high flow years when weir operations were curtailed and capture probabilities approached zero. Relatively low C.V. estimates during high flow years indicated high precision around the population estimate and raise a concern with inaccuracy of mark/recapture models in high flow years when using weirs

for steelhead spawner escapement estimates. Steelhead return and spawn over a two to three month period, with early fish spawning and leaving the system to migrate back to the ocean. Early in the season when the water was low, a high proportion of the adults were captured and marked, then recaptured as they migrated downstream after spawning. This provided an adequate number of mark and recapture events to derive a low standard error around the estimate for the entire year. Consequently, violations of mark/recapture model assumptions that all fish have an equal probability of being marked and recaptured was not met during high flow years, making abundance estimates likely inaccurate (biased low) in high flow years.

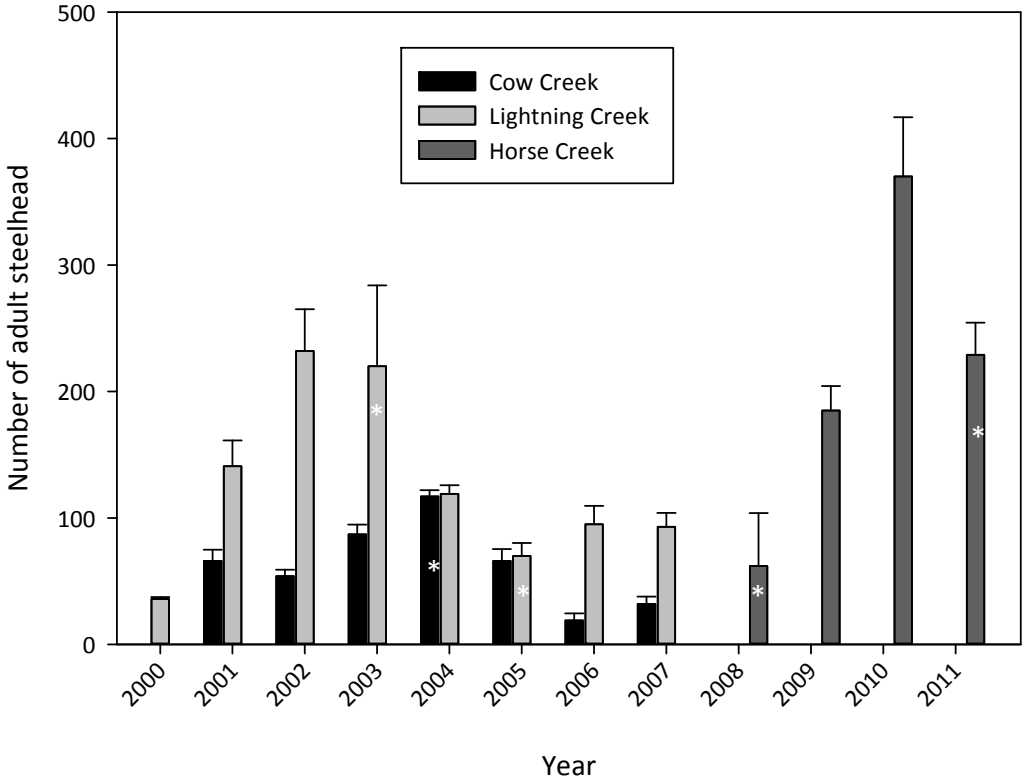

Figure 3. Annual spawner abundance for Cow, Lightning and Horse creeks. Asterisk indicated years where high water limited weir operations.

Table 1. Adult steelhead capture data for Cow (a), Lightning (b) and Horse (c) creeks, including year, number of unique captures, number marked passing upstream (marked upstream), number captured passing downstream (captured downstream), number of marked steelhead recaptured passing downstream (recaptured downstream), mark/recapture point estimate, lower and upper 95% confidence interval (CI) and the coefficient of variation (CV%).

a. Cow Creek

Year	Unique captures	Marked upstream	Captured downstream	Recaptured downstream	Point estimate	Lower 95% CI	Upper 95% CI	CV%
2001	66	46	42	22	87	69	104	10.1
2002	54	37	40	23	64	54	74	7.9
2003	87	42	75	30	104	89	120	7.3
2004	117	103	71	57	128	118	138	3.9
2005	66	51	35	20	88	69	107	10.7
2006	19	10	14	5	27	16	37	20.5
2007	32	30	8	6	39	27	51	15
				Mean	77			10.8
				S.E.	35.7			

b. Lightning Creek

Year	Unique captures	Marked upstream	Captured downstream	Recaptured downstream	Point estimate	Lower 95% CI	Upper 95% CI	CV%
2000	35	33	23	21	36	33	39	3.7
2001	84	52	50	18	141	101	182	14.3
2002	125	54	92	21	232	166	297	14.2
2003	73	30	49	6	220	93	348	29.0
2004	103	90	53	40	119	105	132	5.7
2005	55	52	11	8	70	49	90	14.6
2006	60	37	37	14	95	66	124	15.3
2007	66	46	39	19	93	71	115	11.8
				Mean	126			13.6
				S.E.	69.3			

c. Horse Creek

Year	Unique captures	Marked upstream	Captured downstream	Recaptured downstream	Point estimate	Lower 95% CI	Upper 95% CI	CV%
2008	38	22	19	3	114	30	198	36.6
2009	142	132	30	21	186	148	225	10.3
2010	184	103	110	30	371	278	465	12.6
2011	147	108	72	33	233	185	281	10.3
				Mean	226			17.5
				S.E.	108.3			

Hatchery Fraction

The average hatchery fraction measured by the percent hatchery-origin fish captured at the weirs was highest in Cow Creek and lowest in Horse Creek (Figure 4). Variation was high, ranging from a low of 2.2% in Horse Creek in 2009 and 2010 to a high of 29.6% in Cow Creek in 2002. In general only two to eight hatchery steelhead were captured at each trap in any given year (Table 2). However, the small size of the spawning aggregates, especially Cow Creek, resulted in a relatively high hatchery fraction. For example, in 2006 and 2007 only 3 hatchery fish were captured in Cow Creek, but this generated a hatchery fraction estimate of 15.8% and 9.4%, respectively. Consequently, even a small number of dispersing hatchery fish has the potential to significantly influence a small spawning aggregation. Total returns of Imnaha River hatchery steelhead above Lower Granite Dam averaged greater than 2,000 fish per year (Warren, et al. 2011), making the number of hatchery fish that dispersed to these streams small relative to the total number of hatchery fish in the Imnaha River subbasin. Their influence to these small populations could not be determined.

Table 2. Annual number of hatchery steelhead captured and percent hatchery fraction for Cow, Lightning and Horse creeks.

	Cow Creek		Lightning Creek		Horse Creek	
	# of hatchery fish	hatchery fraction %	# of hatchery fish	hatchery fraction %	# of hatchery fish	hatchery fraction %
2000			2	5.4		
2001	4	6.1	2	2.4		
2002	16	29.6	8	6.4		
2003	5	5.7	7	9.6		
2004	21	17.9	8	7.8		
2005	5	7.6	3	5.5		
2006	3	15.8	3	5.4		
2007	3	9.4	5	7.6		
2008					10	26.3
2009					3	2.2
2010					4	2.2
2011					7	4.7

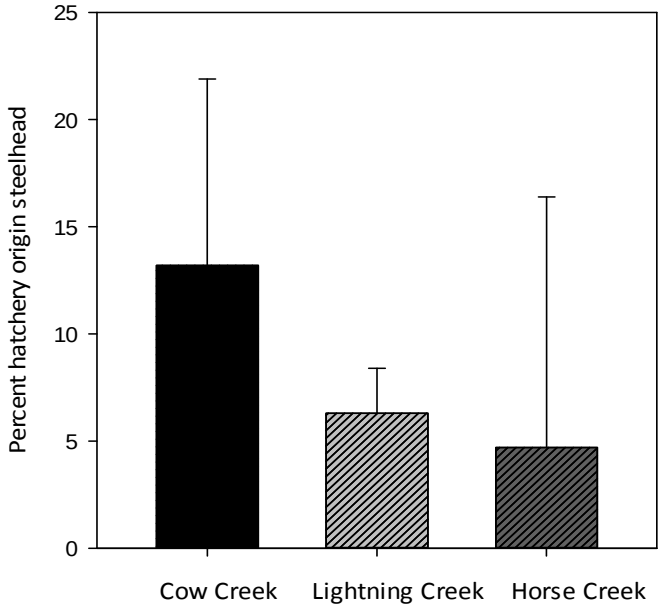

Figure 4. Average percent hatchery-origin steelhead trapped at Cow, Lightning and Horse creeks.

Age at return

Scale pattern analysis resolved total and European ages (freshwater age.ocean age) for steelhead captured from Cow and lightning Creeks. Fish returned predominantly as total age 3 for both streams, with a significantly higher proportion of age 4 in Lightning Creek compared to Cow Creek (chi-square - 2 d.f., $P < 0.01$; Figure 5). European ages distinguishing freshwater and ocean residency times indicated predominantly 2.1 and 2.2 aged fish, with a small number of age 3.2 adults (Figure 5 and Figure 6). The total age differences observed between the two streams was explained by a greater proportion of 2-ocean steelhead in Lightning Creek compared to Cow Creek. A small number of 0-ocean fish were documented, suggesting a contribution of resident rainbow trout in the population.

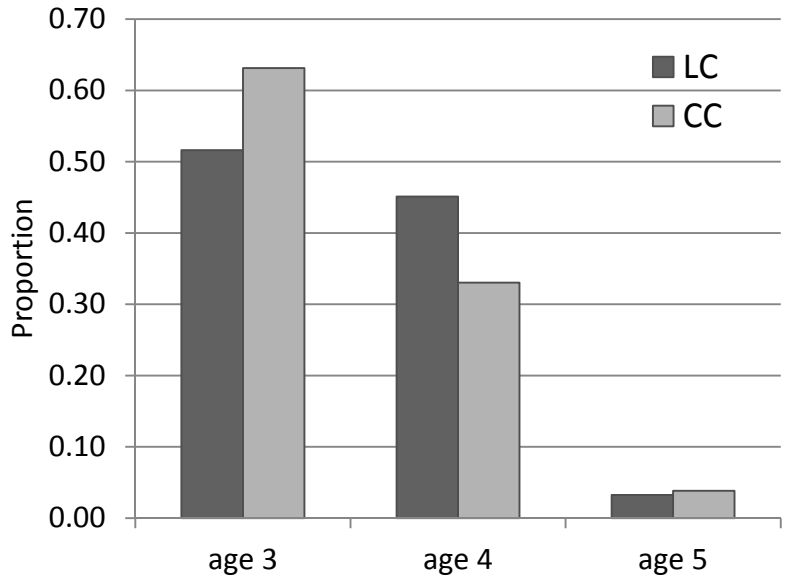

Figure 5. Proportions of age 3, age 4 and age 5 steelhead captured in Lightning Creek (LC) and Cow Creek (CC).

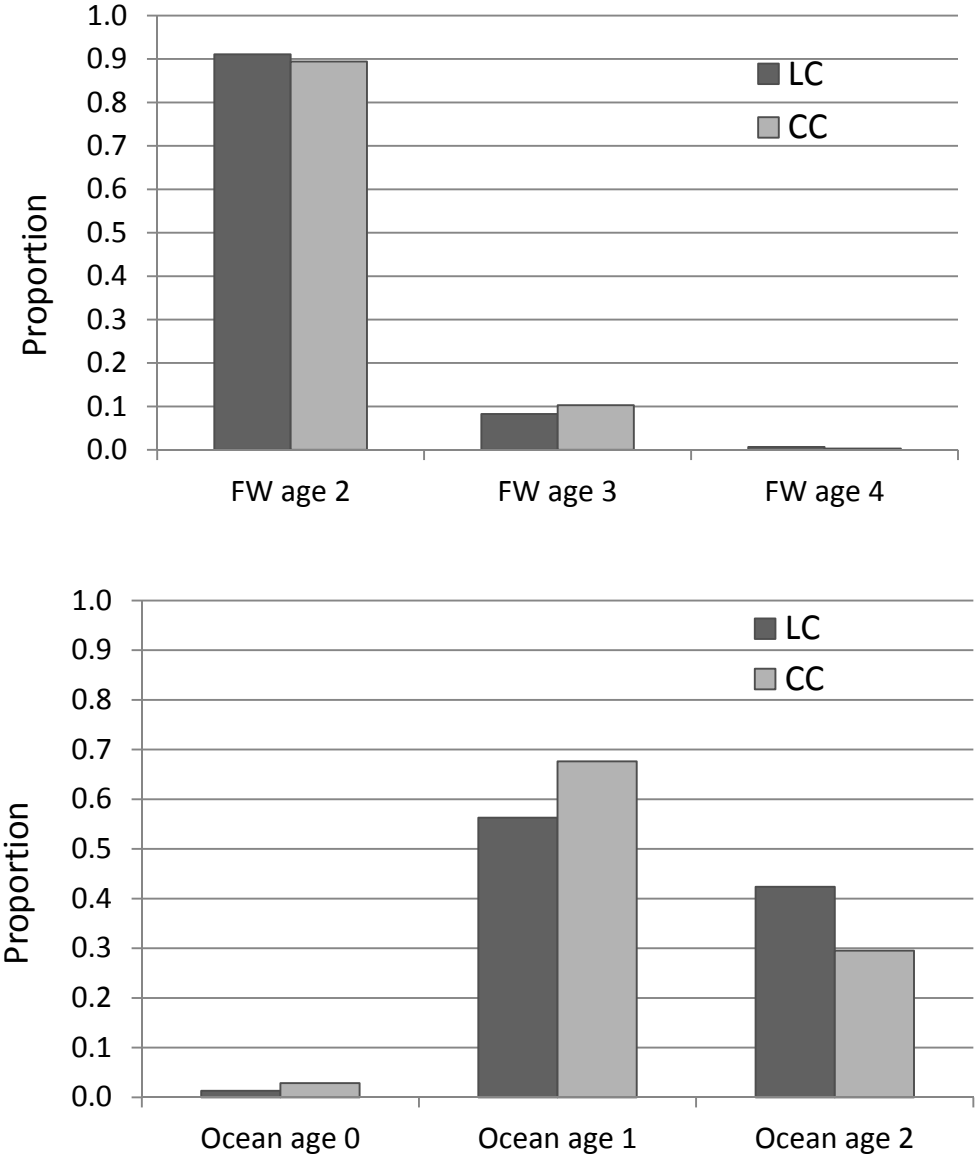

Figure 6. Proportions of adult steelhead by freshwater (FW; top graph) and ocean (bottom graph) ages captured at the Lightning Creek (LC) and Cow Creek (CC) weirs.

Size at Return

Mean fork lengths of female and male adult steelhead captured in Cow, Lightning and Horse creeks are presented in Table 3. No significant differences in length were observed between steelhead captured from Cow and Lightning creeks or between males and females within Cow and Lightning creeks, but females were significantly larger than males in Horse Creek (t-test – P = 0.002). Length comparisons were not performed between Horse Creek and the other two streams because of the potential for annual size variation to affect the results. There was no significant difference in mean length between natural- and hatchery-origin fish.

Length distributions from all captured steelhead indicated that although a majority of steelhead were less than 78 cm, representing the management criteria for Snake River A-run steelhead, a small number (1.3%) fish greater than 78 cm were captured in these streams and would be categorized as B-run as they migrate through the hydrosystem (Figure 7).

Table 3. Mean fork length (Mean FL), standard deviation (S.D.) and sample size (n) of adult steelhead captured in Cow, Lightning and Horse creeks.

	Cow Creek		Lightning Creek		Horse Creek	
	Female	Male	Female	Male	Female	Male
Mean FL	61.6	61.0	62.0	61.2	63.7	61.8
S.D.	6.2	6.0	6.7	7.2	6.5	6.2
n	243	141	398	159	319	188

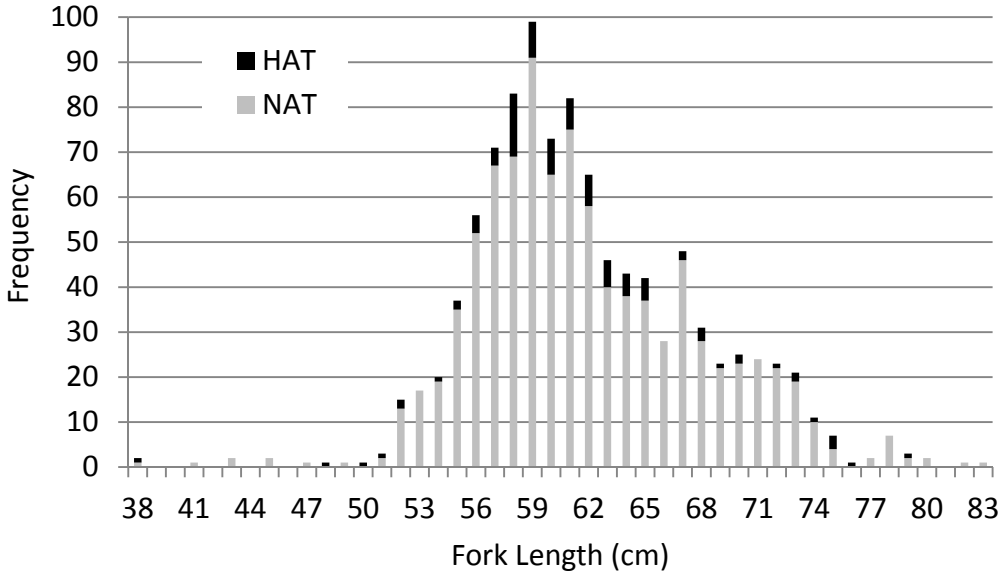

Figure 7. Fork length distribution of hatchery-origin (HAT) and natural-origin (NAT) adult steelhead captured in Cow, Lightning and Horse creeks.

Sex Composition

Sex composition of adult steelhead returning to the study streams were predominantly female. Females comprised an average of 0.64 female (0.11), from Cow Creek, 0.70 (0.11) from Lightning Creek and 0.63 (0.02) from Horse Creek. The higher proportion of females in the anadromous population suggests a contribution of resident males to the spawning population. A small number of fish that appeared to be resident rainbow trout based on coloration and size were captured and their external phenotype suggested that they were males.

Adult run timing

The adult steelhead return encompassed a period from early April through mid May (Table 4; Figure 8). Median return dates and cumulative adult run timing was not significantly different among the three streams and likely represented travel times associated with distance from the mouth of the Imnaha River.

Table 4. Median, 10th and 90th percent return dates of adult steelhead captured in Cow, Lightning and Horse creeks.

Section	Median	10th percentile	90th percentile
Cow Creek	4/19	3/25	5/19
Lightning Creek	4/24	4/1	5/18
Horse Creek	4/25	4/6	5/14

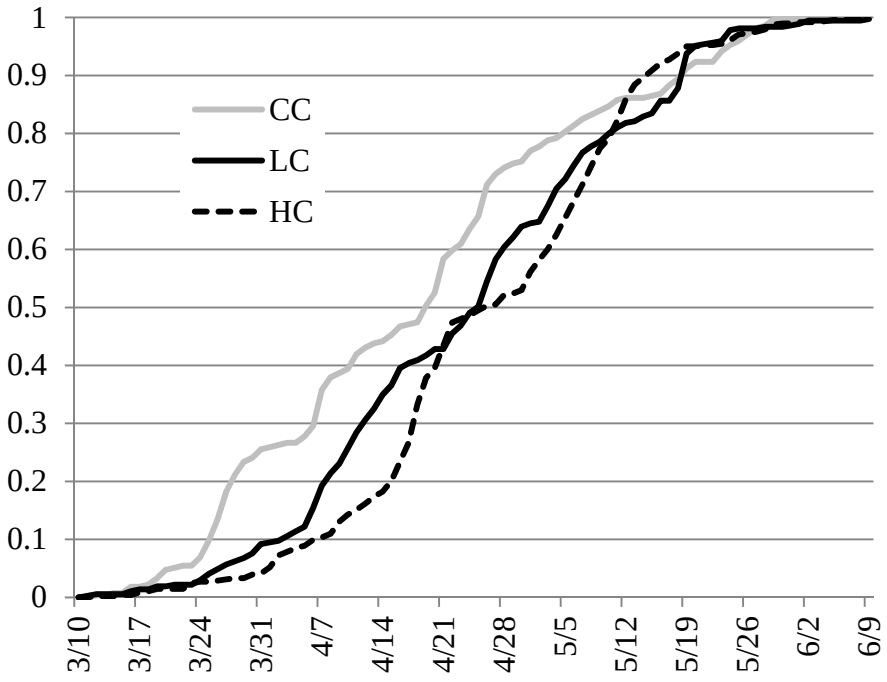

Figure 8. Cumulative run timing of steelhead captured at the Cow Creek (CC), Lightning Creek (LC) and Horse Creek (HC) weirs.

Resistivity counter

Operating the resistivity counter below the Lightning Creek weir indicated little or no weir impedance, although it did detect significant milling behavior in the vicinity of the counter panels (up and down movement). This behavior made it difficult to estimate abundance due to a high rate misclassification of up or down passages as “non-fish” events.

Operation of the resistivity counter in Camp Creek provided imprecise adult steelhead abundance estimates. Placement of the counter in the middle of the spawning region resulted in a large number of up and down movement across the counting panels that, similar to above, resulted in high rates of signal misclassifications. Video evidence indicated that as fish moved downstream accross the counter they were often higher in the water column and turned sideways, resulting in the misclassification of a true “fish” signal as a random or “non target” event. This negatively impacted the ability to get a reliable estimate of the total net number of steelhead moving up stream. In spite of these issues, the data from the counter and a video camera operated at the site confirmed the presence of a relatively large adult steelhead spawning population in Camp Creek, with abundance estimates greater than 200 adults per year.

Both of these trials demonstrated the challenges associated with passive technologies such as the resistivity counter and highlight the importance of site location. In both studies the counter was placed in an area were steelhead were likely to pass up and down across the panels multiple times as opposed to a location further downstream where single upstream passages were more likely. Our recommendation is to locate this type of equipment in areas well downstream from weirs or spawning habitat so as to minimize multiple passage events.

Discussion

Knowledge of population status, including percentage of hatchery origin spawners (pHOS), is central to the monitoring and evaluation of hatchery programs (Beasley et al. 2008). Intensive research and evaluation of the endemic Little Sheep Creek steelhead hatchery program has been focused within the Little Sheep Creek spawning aggregate of Imnaha River Steelhead population/MPG. The performance measures evaluated here provide important information for the other spawning aggregates within the Imnaha River population/MPG. Significant results included: 1) although small, Cow, Lightning and Horse creeks make significant contributions to the total steelhead escapement in the Imnaha River subbasin. In addition, being at low elevation close to the Imnaha River mouth, they contribute significantly to the spatial distribution and diversity of steelhead in the entire MPG. 2) Observed hatchery fractions generally ranged from 2% – 10%, and exceeded 20% during some years, suggesting a potential for benefit/risk to the natural population. However, the relatively high hatchery fraction was disproportionately affected by high returns from three years, with a low overall number of hatchery steelhead captured in most years. Given that as many as 2,000 hatchery

steelhead per year returned to the basin during some years of the study (Warren et al. 2011), these represented a small number of hatchery fish dispersing to these steams. However, preliminary results from the ISAM (Jim Harbeck, personal communication) and ISEMP (Rick Orme, personal communication) projects suggest that a significant proportion of the steelhead production from the Imnaha River result from spawning in smaller tributary streams. Consequently, small numbers of dispersing hatchery fish at levels similar to that observed by this study could have significant influence to these spawning aggregations. 3) Adult steelhead size at return was similar among the streams with no difference between males and females. Overall steelhead from these spawning aggregate were predominantly less than 78 cm size, with approximately 1.3% of the fish being greater than 78 cm (B-run characterization threshold for mainstem Columbia management purposes). 4) Steelhead captured in Cow and Lightning creeks were 60% age 3 and 40% age 4. Over 90% spent 2 years in freshwater, with a small number that resided for 3 years in freshwater. Ocean age varied between the streams with a significantly higher proportion of 2 ocean fish returning to Lightning Creek. Overall an estimate 37% of the returning adults to Cow and Lightning creeks were spent 2 years in the ocean. It was unclear whether the age differences observed between Cow and Lightning creeks resulted from differences in population dynamics, hatchery fish introgression or was just random. However, age composition differences in spatially close spawning aggregates suggested that the small population size and high hatchery fractions observed in Cow Creek may be influencing age at return in that stream. 5) Adult sex composition indicated greater than 60% of the returning adult steelhead were female. Presence of resident O. mykiss males was documented. 6) The starting and ending and duration of the migration period was similar for all three streams, beginning in early April, peaking in late April and ending in mid May. Upstream migrating fish were captured as early as late March and as late as late May. Unique fish returning in late May apparently spawned after a majority of the earlier spawning fish had migrated downstream past the weir, suggesting a long duration spawning period for steelhead in these streams. Comparisons with spawning aggregates in the upper Imnaha River (ISAM project) will provide important information on the level of run timing diversity in the entire MPG.

Citations

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