Comparing effort bias and precision between three methods to estimate steelhead smolt abundance in two Skagit River tributaries.

Michael LeMoine and Katie Rayfield
Upper Skagit Indian Tribe, Sedro Woolley, WA, mikel@upperskagit.com

Introduction

Smolt traps (inclined plane screen traps and rotary screw traps) are commonly used to estimate abundances of out migrating juvenile salmon by pairing catches with simple mark-recapture techniques that release a portion of the marked fish upstream of the smolt trap. Recaptures are used to estimate capture efficiency, which is applied to the overall catch to estimate total abundance. This approach generally assumes individuals are migrating in one direction at a specific period of time. *O. mykiss* however, have conditional life history strategies that can lead to anadromous smolts being intermixed with freshwater migrants or dispersing resident rainbow trout (Boughton 2010). Visual assessments of smoltification or direct measure of Na+,K+-ATPase activity levels can be employed to partition anadromous smolts from other life strategies. Anadromous steelhead smolts with elevated ATPase can return to freshwater to rear for another year (Hayes et al. 2011). In addition, natural residualization after initial out migration is observed in juvenile steelhead; and maybe influenced by handling, marking, and releasing of migrating smolts (Ward et al.1989).

Over the past 5 years, we operated a screw trap paired downstream PIT antennas arrays (PIA) in Hansen and Illabot Creeks, two Skagit River tributaries, we have seen high residualization rates in our marked fish that are released upstream for recapture. In addition, some smolts return to the tributary after smolt trapping (June-September). We have identified that visual characteristics of smolts (shape, color and rigidity) did not explain patterns of residualization (unpublished data).

We are evaluating alternative methods to estimate steelhead smolt abundances using detections of PIT tagged individuals at the screw trap, PIT antenna and within the stream (via electrofishing and mobile PIT antenna), including:

1) Traditional screw trap mark/recapture: Utilize smolts capture at the smolt trap marked with PIT tags and released upstream for recapture, during the migratory period (April to mid June).

2) Hybrid method: PIT antenna detections downstream of the smolt trap are used to augment detections at the smolt trap, during the migratory period.

3) Tagging Juveniles and Monitoring Migrants (T-JAMM): We adapted a method described by Boughton (2010) to include freshwater phase. O. mykiss abundances are estimated in each tributary using mark/recapture techniques and proportion of migrants from PIT detections are applied to the tributary abundance.

Methods

Summer 2016, we conducted mark-recapture abundance estimates via backpack electrofishing in 5-400m reaches in Hansen Creek (3rd order) and 4-400 meter reaches in Ilalbot Creek (4th order). All collected *O.mykiss* >65mm FL were tagged with 12.5mm FDX PIT tag. We operated 1.5 m diameter rotary screw traps from April 2, 2017 to June 12, 2017, encompassing the known migratory window. We visually assessed O.mykiss for degree of smoltification, PIT tagged unmarked fish and released upstream. Two channel spanning (PIA) were located within one kilometer downstream of each trap so to assess detection efficiency and direction of movement. PIA's operated all year with a detection efficiency of 92% for Hansen Creek and 89% for Illabot Creek. Mobile PIT surveys throughout the stream and backpack electrofishing surveys in same reaches as 2016 were conducted during the summer 2017 (after smolt trapping) to detect residual fish in streams. With these data, we estimated abundance and variance using three methods:

Traditional Method: Number of recaptures did not allow for stratified estimate

$$\widehat{N_{migrant}} = \frac{(M_s+1)(C_s+1)}{(R_s+1)} - 1$$

C_s: total fish captured at smolt trap
M_s: total fish marked at trap and released upstream
R_s: total recaptures from mark group (M_s)

Hybrid Method:

$$\widehat{N_{migrant}} = \left(\frac{(M_p+1)(C_s+1)}{(R_s+1)} - 1\right) * \left(1 - \frac{I_p}{M_p}\right)$$

C_s: total fish captured at smolt trap
M_p: total fish detected at PIA
R_s: total captured fish with PIT tag at smolt trap and detected at PIA ($R_s|M_p$) from April 2 to June 15, 2017
I_p: Proportion of fish detected at the PIA from June 16 to December 30, 2017 that were detected in M_p ($I_p|M_p$)

T-JAMM Method: Using freshwater phase of Boughton (2010) in WinBUGS

(1) $N_{migrant} = \sum_{j \in J} Ri_{+j,t}$
(2) $+\sum_{j \in J} Binomial\,[Vi_j, s_1(1-d_3)(1-d_4)]$
(3) $+\sum_{j \in J} Binomial(U_j, s_1)$
(4) $+\sum_{j \in J} Binomial(N_j, s_1)$

(1) Tagged smolts detected at PIA, during migratory period minus-tagged smolts detected at PIA outside migratory period
(2) Estimated tagged smolts not detected by PIA minus-tagged those outside migratory period
(3) Estimated number of untagged smolts from sampled reaches
(4) an estimate of migrants from unsampled reaches.

Results

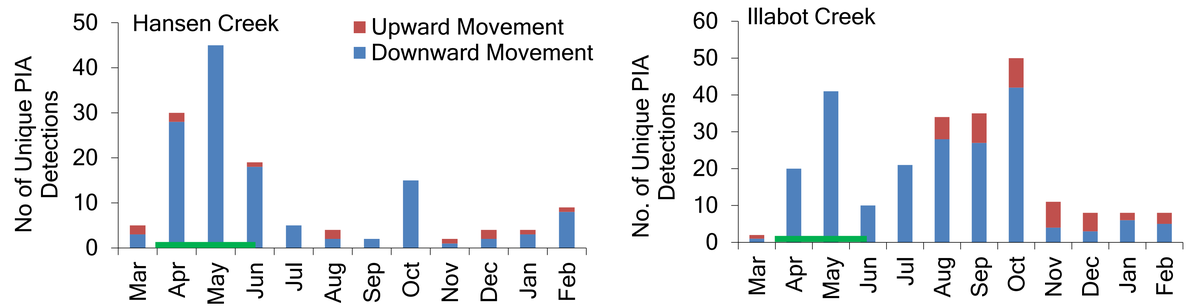

Figure 1. Unique PIT detections at PIA's with direction for Hansen Creek (left) and Illabot Creek (right) . Migratory window is consider April 1st to June 15th (green line). Fish are documented across the PIA's through out the year. In 2017, five smolts in Hansen creek and 16 smolts in Illabot Creek were detected at PIA's moving upstream from July to December.

Table 1. Number of O. mykiss captured, marked and release upstream for traditional smolt trap estimates.

	Marked and release upstream	Smolt trap recapture
Hansen Creek	89	1
Illabot Creek	55	2

Table 2. Number of O. mykiss detected at the PIA and captured at the smolt trap for hybrid estimates. Detections during migratory period (April 2 to June 15) were consider migrants, however fish moving upstream after that period were removed from the analysis.

	Detected at PIA (Apr 2-Jun 15)	Smolt trap capture	Detected at PIA moving downstream (Apr 2- Jun 15) and then upstream (Jun 16-Dec 31)
Hansen Creek	91	3	5
Illabot Creek	71	3	16

Table 3. Detection and collection information used for T-JAMM estimation.

	Marked instream (2016)	Recaptured instream (2016)	Estimated stream abundance	Detected at PIA (Apr 2-Jun 15)	Detected at PIA moving downstream (Apr 2- Jun 15) and then upstream (Jun 16-Dec 31)
Hansen Creek	542	208	6,617	91	5
Illabot Creek	553	153	14,422	71	16

Illabot Creek smolt trap

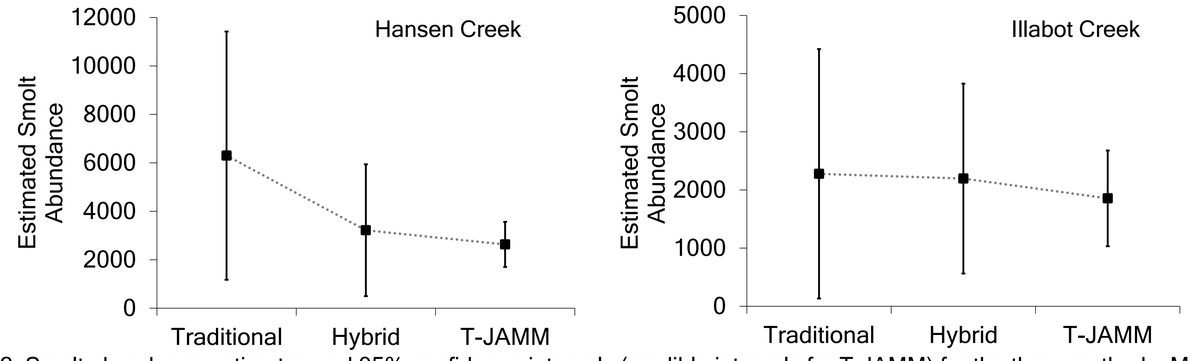

Figure 2. Smolt abundance estimates and 95% confidence intervals (credible intervals for T-JAMM) for the three methods. Methods the account for potential residualization had lower estimates than traditional method. T-JAMM provided for the most precision for the abundance estimate.

Conclusions

- Traditional mark/recapture abundance estimates tend to be variable and potentially biased, 27 marked fish that were released upstream in Hansen Creek and 23 fish from Illabot Creek residualized (either never left or re-entered the tributary).
- Using PIA's to augment catch data at the smolt trap can improve smolt abundance estimates and proved more information regarding annual movement.
- The T-JAMM method seem to produce the most reliable estimates that can account for potential residualization and less field intensive. Normal operation of a smolt trap takes 120 person days to implement. The T-JAMM method took about 92 person days.
- We plan to continue these comparisons for two more years and include a third tributary

References

Boughton, D.A., 2010. Estimating the size of steelhead runs by tagging juveniles and monitoring migrants. North American Journal of Fisheries Management, 30(1), pp.89-101.

Hayes, S.A., Bond, M.H., Hanson, C.V., Jones, A.W., Ammann, A.J., Harding, J.A., Collins, A.L., Perez, J. and MacFarlane, R.B., 2011. Down, up, down and "smolting" twice? Seasonal movement patterns by juvenile steelhead (Oncorhynchus mykiss) in a coastal watershed with a bar closing estuary. Canadian Journal of Fisheries and Aquatic Sciences, 68(8), pp.1341-1350.

Ward, B. R., P. A. Slaney, A. R. Facchin, and R. W. Land. 1989. Size-biased survival in steelhead trout (Oncorhynchus mykiss)–back-calculated lengths from adult scales compared to migrating smolts at the Keogh River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1853-1858.

In Collaboration with:

Seattle City Light