Overwintering Summer Steelhead and Early Outmigrating Steelhead Kelts: TDA Sluiceway Operations for Downstream Passage

Until recently, relatively little was known about the wintertime distribution and behavior of overwintering steelhead and early outmigrating steelhead kelts, despite the potential importance of this period for run-year escapement. The 1997-2004 systemwide, radio-telemetry, adult salmon and steelhead studies in the Columbia River basin focused primarily on the traditional fish migration season (March 1 to 1 November at most locations)and little attention was paid to the winter period when most research ended and maintenance on equipment and dams was performed.

The majority of adult summer steelhead migrate through the lower Columbia River from May through October. Numbers of fish passing dams drops significantly in November when water temperatures are declining. Since these fish will not spawn until the following spring, many overwinter within the reservoirs and lower tributary rivers of the Columbia and Snake rivers (Keefer et al. 2008). Some fish continue to move up and downstream during winter and, at times, fall back at dams. Winter fallback numbers are difficult to estimate because previous telemetry studies focused on actively migrating fish throughout migration seasons, while overwintering fish were concentrated in later portions of the run. Estimates from previous studies suggest thousands of adult steelhead likely fall back at dams during winter (e.g., Keefer and Peery 2007). We do not yet understand completely why steelhead fall back downstream but it may be directed movement to locate downstream tributaries, a response to seasonal changes in river discharge or temperature, or random wandering as fish wait to resume migrations in spring. Typically during winter, the only fallback routes at dams are through turbines or navigation locks. Other potential routes include surface flow structures, such as the corner collector at Bonneville Powerhouse II, ice and trash sluiceways, and the RSW at McNary Dam. Fallback events appear to have direct and indirect effects on adult salmonid survival, and route-specific differences in these effects.

Fallback at monitored hydrosystem dams has consistently been linked to a reduction in systemwide escapement for migrating adult salmon and steelhead. Based on large scale telemetry studies from 96-03, a mean systemwide escapement reduction related to fallback of summer steelhead has been estimated to be about 3%, ranging from around 1-4% annually (Table 8).

The following table is excerpted from the 2005 COE Research Report, **Escapement, Harvest, and Unknown Loss of Radio-Tagged Adult Salmonids in the Columbia-Snake River Hydrosystem, 1996-2002.**

Table 8. Esc_3 estimates (*n*) for downstream-released unknown-source (Unknown) and known-source fish that either were or were not recorded falling back (FB) over a monitored hydrosystem[1] dam, with differences in Esc_3 estimates for fallback and non-fallback fish (D), proportions recorded falling back at one or more dams (FB%), and the overall Esc_3 reduction (%) associated with fallback. Fallback after hydrosystem passage (top of Lower Granite or Priest Rapids dams) and known-source groups with fewer than 10 fallback fish excluded.

Year	Stock	Esc_3 estimate (*n*) No fallback	Fallback	Esc_3 Difference (D)	System[1] FB (%)	Esc_3 Reduction (D•FB%)
Steelhead						

1996	Unknown	0.780 (600)	0.702 (124)	$0.078^{\dagger}$	17.1	1.34
1997	Unknown	0.866 (700)	0.755 (216)	0.111^{**}	23.6	2.62
2000	Unknown	0.882 (646)	0.774 (168)	0.108^{**}	20.6	2.23
2001	Unknown	0.880 (276)	0.713 (87)	0.168^{**}	24.0	4.02
2002	Unknown	0.872 (382)	0.670 (94)	0.202^{**}	19.7	3.98
2001	Upper Col.	0.906 (170)	0.923 (13)	-0.017	7.1	-0.12
2001	Snake R.	0.909 (186)	0.733 (45)	0.175^{**}	19.5	3.41
2002	Snake R.	0.897 (311)	0.809 (47)	$0.089^{\dagger}$	13.1	1.16

[1] Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose
† $P < 0.10$, * $P < 0.05$, ** $P < 0.005$ Pearson χ^2 tests

Effects of Turbine Passage on Adult Fish

Limited information is available regarding the effects on adult Pacific salmon from passing through turbines. Several studies have shown mortality rates from 22% to 57% for summer steelhead passing through Kaplan turbines at Foster and Lower Monumental Dams (Wagner and Ingram 1973, Liscom et al. 1985, Buchanan and Moring 1986). The 22% and 41% mortalities observed in 1969 and 1970 by Wagner and Ingram (1973) represented only those fish with observable injuries, indicating direct strike; as such, these estimates are minimums. Theoretical strike calculations by Chet Scott, consulting engineer in the Rock Island Settlement hearing, showed 41% and 49% mortality for 0.64- and 0.76-m fish, respectively (NOAA Hydro Division memorandum, December 5, 1985[14]).

High rates of turbine mortality are likely associated with the positive relationship between fish size and increased probability of turbine blade strike (Coutant and Whitney 2000). Bell et al. (1967, 1981) used mathematical formulas to estimate injury and mortality associated with turbine passage. In their formulas, the probability of strike increases with fish length. Mendel and Milks (1996) estimated fall Chinook fallback mortality at 26% and 14% in 1993 and 1994, respectively, for fish that fell back through one or more of the four lower Snake River dams. This higher mortality for fall Chinook occurred during periods of no spill, when the fallback was assumed to have been through turbines.

Based on radio-telemetry data, there is limited information concerning adult mortality associated with a specific downstream passage route at a specific dam, especially turbine passage. Linking mortality to a single event is often difficult as most effects are sublethal and may not manifest themselves until later in migration when the fish is no where near the source of the injury. About the only way to look at a direct effect from one event is to examine where fish become immediately unaccounted for after a specific suspect event. Few fish move downstream through turbine units when there are other alternatives, passing downstream via spillways and other surface flow routes when such routes are available. A 02-04 summary of fallback at BON turbines indicated that 3 of 9 steelhead were never heard again immediately after passing through a turbine unit. A similar summation of fallback at BON for fall Chinook found 5 of 7 fish disappeared after turbine passage.

Table 1. Total number of unique radio-tagged steelhead to pass Bonneville Dam in 2002-2004 with total annual fallback and total turbine fallback percentages. Included are numbers of unique fish detected by antennas mounted to traveling screens of B1 and B2 turbines, numbers of fish to fall back via turbine and the number of these fallback fish whose final fates were unknown.

	2002	2003	2004
Unique fish past dam	909	564	284

Total annual fallback %	3.8	5.6	3.5
Total turbine fallback %	0.6	0.7	0
Unique detections B1	5	0	0
Fallbacks via B1	1	0	0
Unique detections B2	19	4	1
Fallbacks via B2	4	4	0
Number unaccounted for after turbine fallback	0	3	0

06 Decisions to Operate TDA Sluiceway for Wild Steelhead Fallback in November

As a part of developing the 2006 FPP, the COE decided to operate the TDA sluiceway until NOV 30 starting in 2006 based primarily on turbine fallback concerns for overwintering wild upstream summer steelhead. Radio-tagged summer steelhead data and fallback expansion information were the basis of these decisions; estimates showed that from around 100-1000 wild fish may be falling back through turbines. From 37-51% of the fallback measured in this evaluation occurred at night. The COE recognized the cost to BPA but determined the benefits justified the operations as a part of ensuring we meet our performance standards. Witt Anderson, in his 21 Feb 2006 address in Pendleton at the Congressional Meeting on Impediments to Returning Adult Salmon in Pendleton stated, “Fallback through turbines can cause high mortality, whereas fallback over spillways is relatively benign. As an example, The Dalles Dam has an ice and trash sluiceway at the powerhouse, but no juvenile fish bypass facility. Operation of the sluiceway can be an important strategy for fallback. Based on analysis of available data, we are currently working with the region to determine the advisability of continuing to operate the sluiceway late in the adult passage season (through November) in view of steelhead passage at that time of year. Although there is a tradeoff in energy opportunity cost with water that goes through the sluiceway, there is potentially a significant benefit in terms of fallback survival.”

Following is a synopsis of the summary analyses of potential numbers of wild summer steelhead that may be passing downstream through turbines in November used to help make this decision.

Counts come from COE Fish Count Website. FB rates for 2000 and 2001 come from U of I Table 2 of fallback at TDA (see below) and used a 6.3% value for 2002 (mean of all study years);

TDA	Steelhead count (4/1 to 10/31)	(Wild)	NOV FB rate (RT based): Annual rate x %FB in NOV	# of FB Steelhead in NOV count x NOV FB rate (Wild)
2000	205,241	(53711)	.063 x .111 = .007	205,241 x 0.007 = 1437 (376)
2001	503,327	(127117)	.061 x .148 = .009	503,327 x 0.009 = 4530 (1144)
2002	387,920	(116565)	.063 x .147 = .009	387,920 x 0.009 = 3491 (1049)

TDA	Fish Counts: Total (Wild) OCT	NOV
2000	6954 (1151)	292 (67)
2001	19430 (2804)	2258 (514)
2002	21967 (4904)	2296 (241)

Discussion

First, we need to realize there was never a specific evaluation to answer this question and all of the analyses are retrospective; sample sizes are limited . Still, it appears we could potentially be eliminating a safer fallback route in November by closing the sluiceway for about .7 to .9 % of the population (400 to 1100 wild fish for the sample years).

Table 2. Percent of radio-tagged Chinook salmon and steelhead that fell back at The Dalles Dam and fallback rates at each dam during 1996-2001. NP_K = number of fish known to pass dam, FB_U = number of unique fish that fell back, FB_T = total fallback events, Fallback Percent = FB_U/ NP_K, Fallback Rate = FB_T/NP_K.

Year	Fallback Percent	Rate	NP_K	FB_U	FB_T
The Dalles Dam					
Spring–Summer Chinook					
1996	13.3	18.3	497	66	91
1997	14.4	18.6	714	103	133
1998	11.5	14.3	763	88	109
2000	9.6	12.2	844	81	103
2001	5.5	7.0	1,032	57	72
Fall Chinook					
1998	10.2	11.6	629	64	73
2000	8.5	9.6	738	63	71
2001	6.9	8.4	713	49	60
Steelhead					
1996	6.0	6.9	580	35	40
1997	6.6	7.6	683	45	52
2000	6.3	7.2	871	55	63
2001	6.1	8.8	963	59	85

% of All SH fallback at The Dalles in Oct, Nov, and Dec

20 October 2003, C. Boggs C. Peery University of Idaho

	Percentages			Sample Sizes		
YEAR	2000	2001	2002	2000	2001	2002
all fbs	72	122	163	72	122	163
% in Oct	41.7	30.3	25.8	30	37	42
% in Nov	11.1	14.8	14.7	8	18	24
% in Dec	1.4	3.3	3.1	1	4	5

96-97 and 00-03 U of Idaho Radio-telemetry Studies

In 2007 and 2008 the University of Idaho researchers undertook a thorough review of the data on nearly 6000 summer steelhead radio-tagged during 96-97 and 00-03 pertaining to this issue and presented this information at AFEP review with following research reports and publications (Keefer and Peery 2007, Keefer et al. 2008).

Major findings were:

1. 12.4 % of all summer steelhead that successfully survived through the FCRPS to spawning areas overwintered for some period in the main stem of the Columbia.
2. Fish migrating later in the season were much more likely to overwinter. 42.6% of summer steelhead tagged at BON in OCT overwintered in the main stem.
3. The majority of overwintering fish were from Clearwater, Salmon, or Snake River metapopulations.
4. Mean escapement rates for all overwintering summer steelhead was 82% with a 4% mean harvest rate.
5. Overwintering summer steelhead that did not survive through the FCRPS to a spawning area were nearly 3 times more likely to have fallen back through a dam than overwintering summer steelhead that did survive (60% vs.21%).
6. Estimates of relative survival impacts related to overwintering fallback found that the largest negative effects on survival over the winter occurred in months of NOV and MAR and at TDA. Based on the number of overwintering fish that became unaccounted for after falling back through a dam the estimate was up to 1-1.5% of escapement could be lost at TDA by fallback of overwintering summer steelhead.

Figure 1. Relative survival impacts of winter (November-April) fallbacks by steelhead at lower Columbia and lower Snake River dams. An index was calculated for each month-dam combination as (% of all fallback events × % unaccounted for); this is unit-less. Top: mean of index values across months for each dam, suggesting that The Dalles Dam had the largest negative effect on survival across the winter study months. Bottom: mean of index values across dams for each month, suggesting fallbacks in March and November have the largest negative effect on survival.

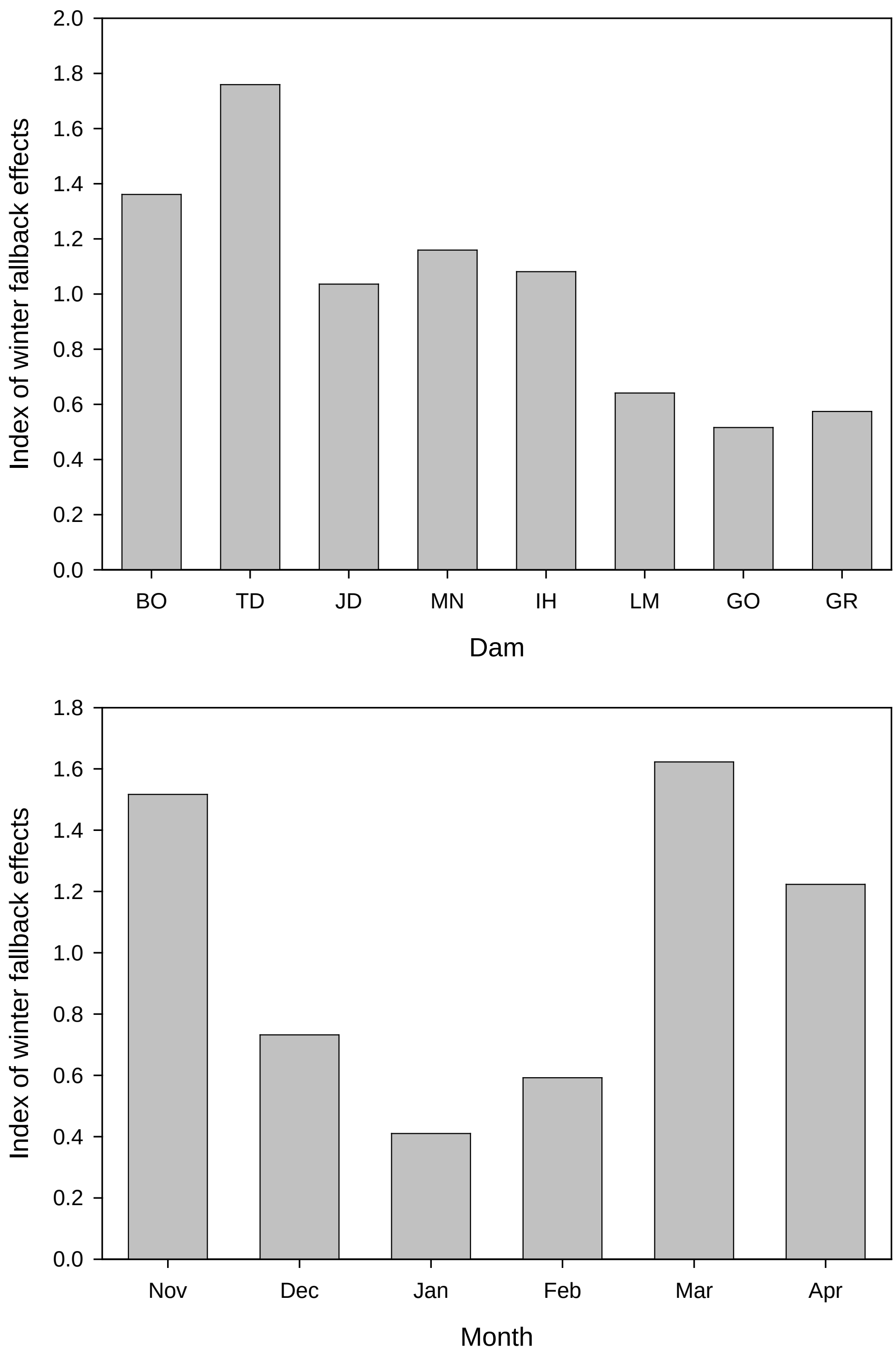
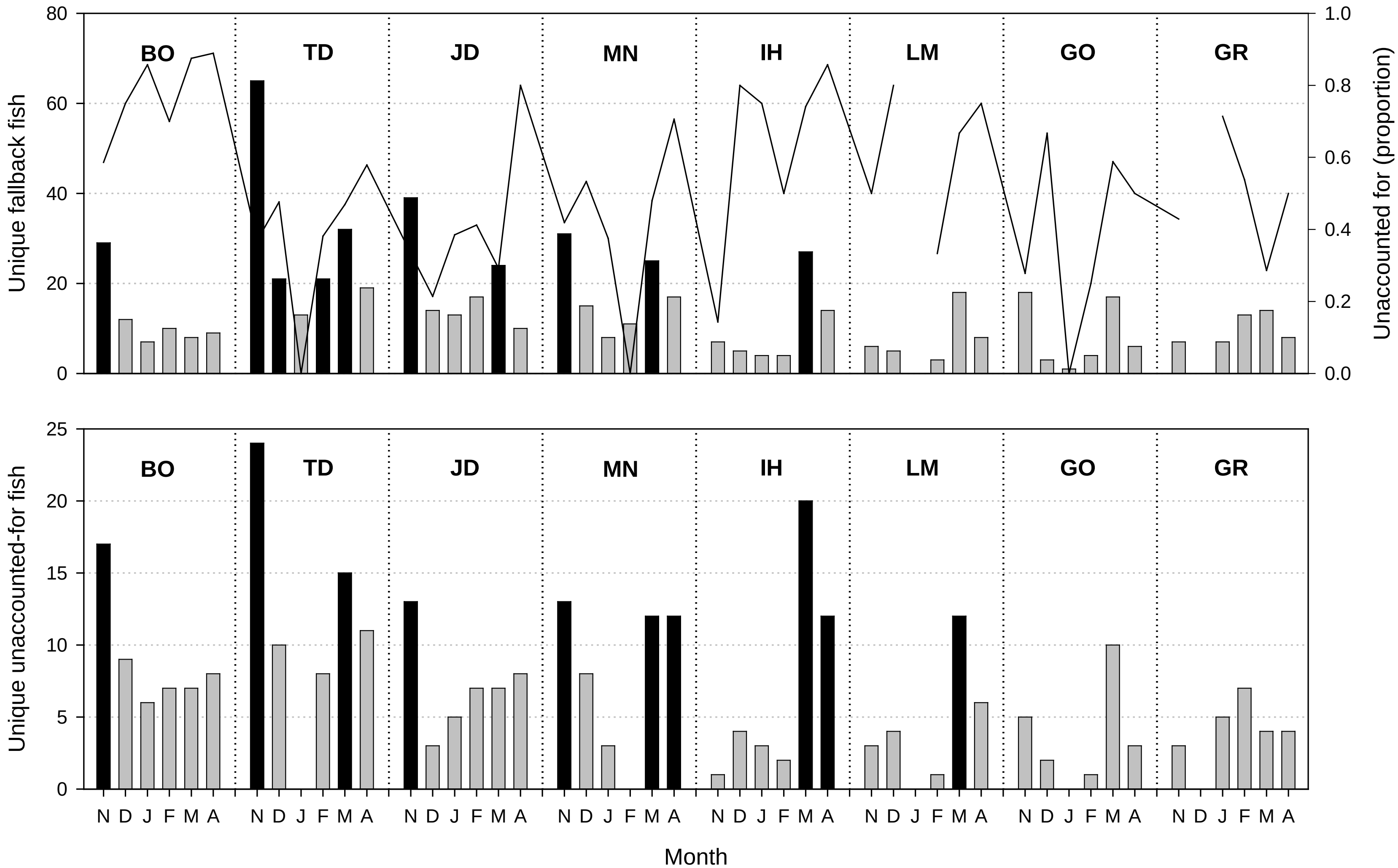


Figure 2. Top: Numbers of unique steelhead recorded falling back prior to spawning at each dam in each 'winter' study month (bars), with the proportions that were considered unaccounted for in the main stem (line). Black bars represent the 10 dam-months with the highest numbers of fallback fish. Bottom: Numbers of unique steelhead that were considered unaccounted for after falling back in each month at each dam. Black bars represent the 10 dam-months with the highest numbers and could potentially be considered higher priority for providing safer fallback routes.



Some thoughts on estimating potential mortality related to winter fallback:

- These data were not collected to address these specific questions, and there are some definite limitations. .

- Winter fallback-related mortality is almost certainly not distributed evenly among populations, with higher probable costs for later-timed populations: Clearwater, Salmon, and perhaps John Day stocks.

- Mortality almost certainly becomes increasingly composed of Snake River fish at each successive dam upstream.

- Overshoot-related winter fallback mortality may be relatively high at dams closest to home tributaries, such as for Deschutes fish at John Day Dam or John Day River fish at McNary Dam.

- We estimated a very gross measure of winter-fallback related mortality using the simple calculation: (number of unique unaccounted for fish that fell back in winter at each dam/unique number past each dam over the full migration). This can be roughly translated as the percentage of the total sample past a site that both fell back at that site in winter (Nov-April) and were ultimately unaccounted for. This does not suggest that the fallback necessarily led to the fish being unsuccessful. Estimates were:

Winter fallback site	% unaccounted for
The Dalles:	1.36%
John Day:	1.07%
McNary:	1.35%
Ice Harbor:	1.54%
Lower Monumental:	1.21%
Little Goose:	1.00%
Lower Granite:	1.00%

Keep in mind that 1% may translate to several thousand fish.

- The above estimates make no adjustments for the composition of fish falling back, for potential sample biases, for straying, or for harvest. They apply to the runs overall from our full samples.

- The estimate for fallback at "any dam" would be several times higher than at the individual projects, but would not be a sum of the above figures because some fish fell back at multiple sites.

- Estimates for individual months at individual dams would obviously be smaller.

- Estimates for individual populations would require some additional information: 1) knowing the origins of unaccounted for winter fallback fish, and 2) knowing the total sample size for each population passing each dam. We really do not know these numbers. However, given the patterns of increased FCRPS overwintering for Snake River populations and relatively large proportions of fallbacks at the lower river dams by successful Snake River fish, we would expect the estimates above to be at least slightly higher for the Snake River population at Columbia River dams. Estimates for Snake River fish at the lower Snake River dams would perhaps be slightly lower given overshoot by lower Columbia stocks, especially at Ice Harbor Dam.

- Finally, if providing alternative fallback routes at dams during winter can improve overall survival, those improvements would be some percentage of the estimates above because some mortality was likely unrelated to fallback.

08-09 PNNL Hydroacoustics and Didson Camera Studies

As a result of these findings additional research was prioritized and funded to evaluate downstream passage at TDA sluiceway (NOV-DEC 08 and MAR-Spill 09) and the BON B2 corner collector (MAR 07 and 08) using hydroacoustics and didson cameras.

Preliminary Data Report

Evaluation of Adult Salmon Fallback and Steelhead Downstream Passage at the Sluiceway and Turbines at The Dalles Dam, Winter 2008 and Early Spring 2009

AFEP Study Code ADS-00-1

Prepared for USACE, Portland District

Prepared by Fenton Khan, Gary Johnson, and Mark Weiland (Pacific Northwest National Laboratory)

June 1, 2009

Introduction

This report presents *preliminary* data for fisheries managers and engineers to use in decision-making for sluiceway operations at The Dalles Dam (TDA). The goal of this study was to characterize adult salmonid spatial and temporal distributions, passage rates, and movement in front of the sluiceways at TDA during November/December 2008 and March/April 2009. The objectives were to 1) estimate the number and distribution of adult salmon and kelt-sized acoustic targets passing into the sluiceway and turbines at TDA during the study periods, and 2) assess the behavior of these fish in front of sluiceway entrances.

For Objective 1, we conducted a full powerhouse hydroacoustic study where a transducer was randomly deployed in one of the three intakes of each turbine unit and paired transducers were deployed in each of the six operating sluice entrances (1-1, 1-2, 1-3, 5-2, 18-1, and 18-2). For Objective 2, an acoustic camera was deployed at the entrance to the sluiceway above Main Unit 1-1 and aimed across the entrances of 1-1 and 1-2. We collected data 24 hr/d, 7d/wk for the course of two study periods (85 days total); November 1 – December 15, 2008 for adult salmon fallback and March 1 – April 9, 2009 for steelhead kelt downstream passage. Observational data were obtained from a subset of the DIDSON data. Because of the large amount of data collected, we randomly selected four hours (one hour from each 6-hr block) for each day of the study and reviewed each hour in the subset for fish behavior.

This report contains separate sections for each study periods. We present data on fish behavior, passage rates, run timing, and horizontal distribution. The data are preliminary and subject to change.

Results for Fall/Winter 2008 – Adult Salmon Fallback

Fish Behavior Observations at Sluice 1-1 and 1-2 (DIDSON acoustic camera).

We observed the following fish behaviors:

- Adult salmonids in front of the sluice entrance were oriented into the flow in the sluice near field, milling just upstream of the sill, falling back into the sluiceway, or swimming upstream out into the forebay. They also moved along the face of the dam from SL1-2 to SL1-1 and vice versa.
- Juvenile shad were present from the beginning of the sampling period on November 1, 2008 until mid-November. Adult salmonid behavior did not change in the presence of thousands of juvenile shad.
- From late November to the end of the sampling period on December 15, schools of yearling-sized salmonids were observed. These fish were present in large schools at times and they used the sluiceway to pass downstream.

Adult Salmon Fallback Results (hydroacoustics).

The main findings included:

- A total of 1,790 ±250 (95% confidence interval) adult size salmon targets passed through the powerhouse intakes and operating sluiceways from November 1 – December 15, 2008. A daily average of 40 adult size salmon targets passed (fallback) the dam during the 45 day study period.
- Of the 1,790 total adult size targets, 1,704 passed through the sluiceways (95%) and 86 passed through the powerhouse intake units (5%).
- Run timing peaked in late November (Figure 1). Adult size salmon targets fallback occurred, but at relatively low rates (10-25 fish/d), during the first and last days of the study period
- Total fish passage was highest at Sluice 1 (1,453 targets). Sluice 18 had the second highest number of fish passing (211). A small number passed through Sluice 5 (40 fish) and powerhouse Main Units 7, 8 and 18 (23, 51, and 12 fish, respectively) (Figure 2).
- Fish passage peaked at 0900 h and was lowest at 1000 h and 2300 h. Passage was also high during mid afternoon hours and nighttime (2000 h and 2200 h), except for a dip at 2100 h, and low during the early morning (0300 – 0500 h)and late afternoon hours (1600 – 1800 h) (Figure 3).

Figure 1. Total number of adult size salmon targets passing daily at each route of the powerhouse and sluiceway from November 1 – December 15, 2008 (95% CI).

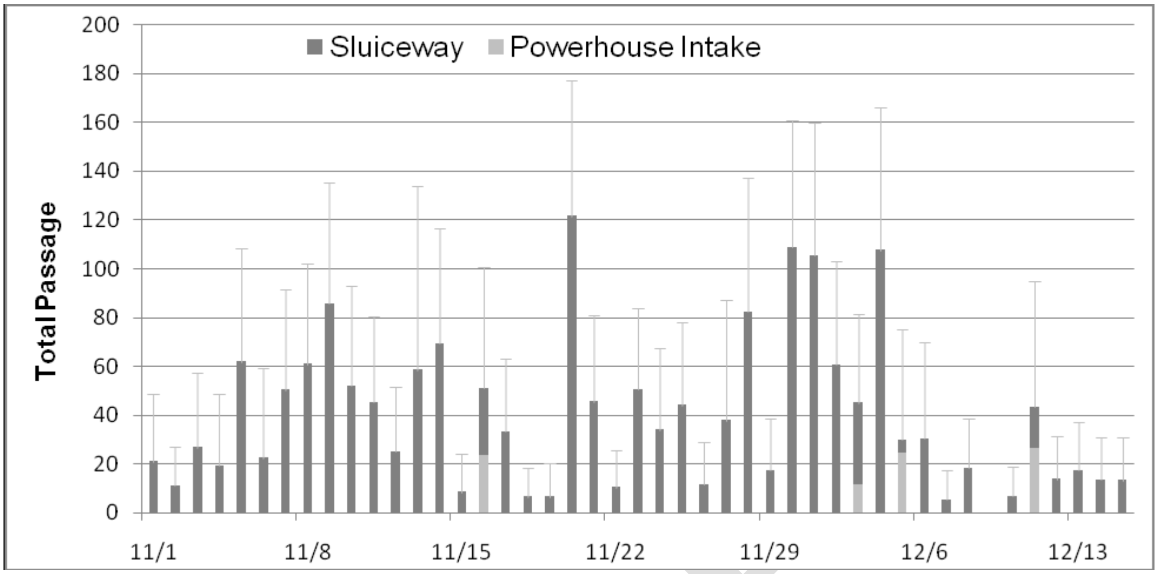


Figure 2. Horizontal distribution of total adult size salmon targets passage at each route of the powerhouse and sluiceway, with corresponding powerhouse intake unit discharge, from November 1 – December 15, 2008.

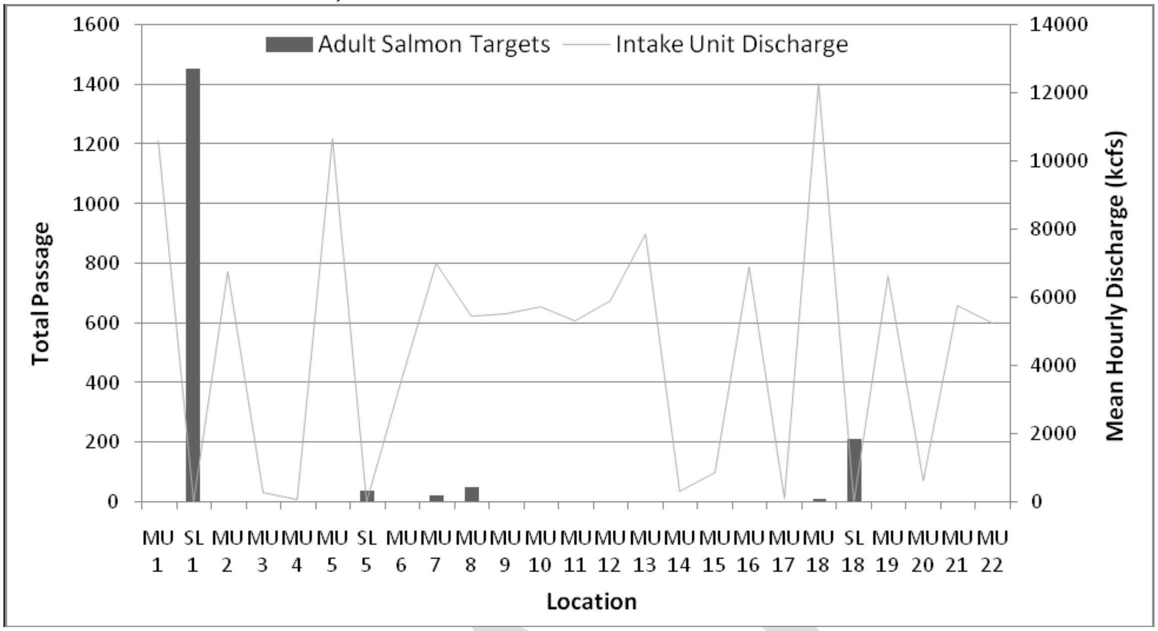
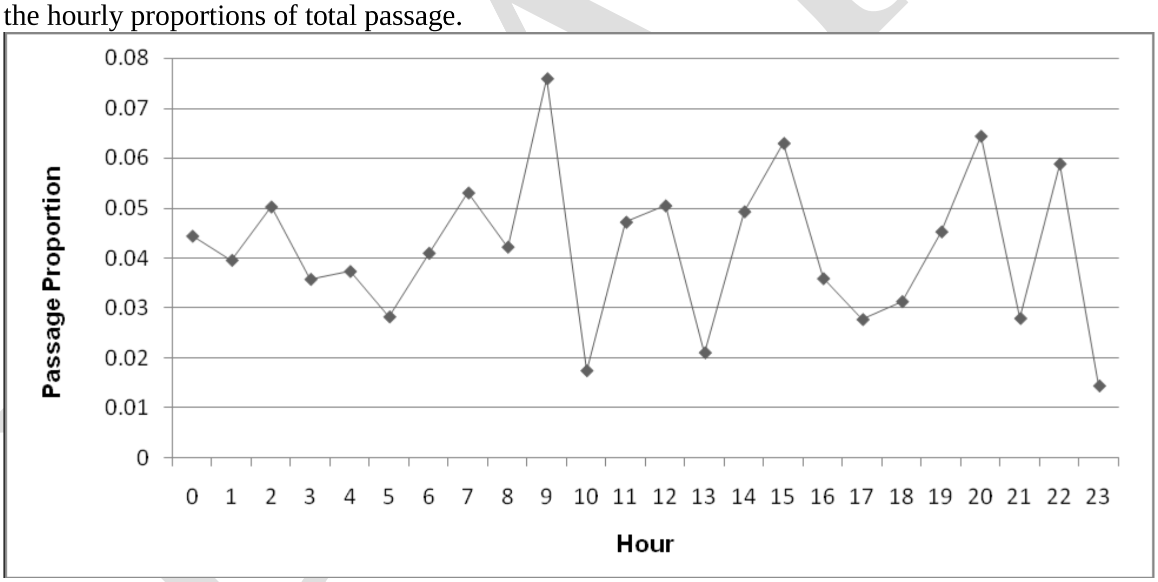


Figure 3. Diel distribution of adult size salmon from November 1 – December 15, 2008. Data are the hourly proportions of total passage.



Results for Spring 2009 – Steelhead Kelt Passage

<u>Fish Behavior Observations at Sluice 1-1 and 1-2 (DIDSON acoustic camera).</u>

We observed the following fish behaviors:

- Steelhead kelt behavior was typical for salmonids in front of a sluiceway entrance – tail-first orientation downstream, milling, traversing along the face of the dam, moving over the sill and into the sluiceway.
- Interestingly, some kelt approached SL 1-1 from the west moving around the large pier between SL1-1 and Fish Unit 2-2 and into the sluiceway, or they would make an abrupt U-turn and swim upstream into the forebay or over to SL 1-2.

Fish Fallback Results (hydroacoustics).

The main findings were as follows:

- A total of 1,766 ±277 steelhead kelt size targets passed through the powerhouse intakes and operating sluiceways from March 1 – April 9, 2009. A daily average of 44 kelt size targets passed The Dalles dam during the 40 day study period.
- Run timing peaked in late March (Figure 4). However, very large numbers of kelt size targets passed the dam on March 2nd and March 6th.
- 1,673 kelt size targets passed into the sluiceway (95%) and 93 passed through the powerhouse intake units (5%).
- Total fish passage was highest at Sluice 1 (1,091 targets). Sluice 18 had the second highest number of fish passing (454). At Sluice 5, 128 targets passed. A small number of kelt size targets passed through the powerhouse Main Units 8, 21 and 22 (24, 23, and 46 fish, respectively) (Figure 5).
- Fish passage peaked at 2100 h and was lowest at 0500 h, 0700 h and 1100 h. Passage was also high during mid morning hours and late afternoon/nighttime, except for a dip at 2200 h (Figure 6).

Figure 4. Total number of Steelhead kelt size targets passing daily at each route of the powerhouse and sluiceway from March 1 – April 9, 2009 (95% CI).

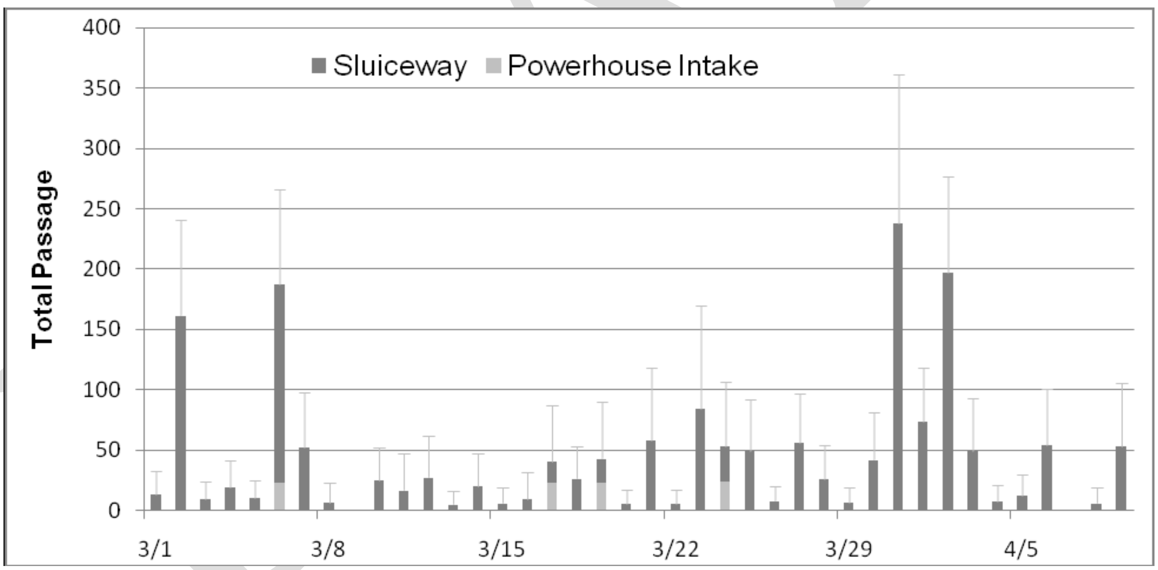


Figure 5. Horizontal distribution of total Steelhead kelt size targets passage at each route of the powerhouse and sluiceway, with corresponding powerhouse intake unit discharge, from March 1 – April 9, 2009.

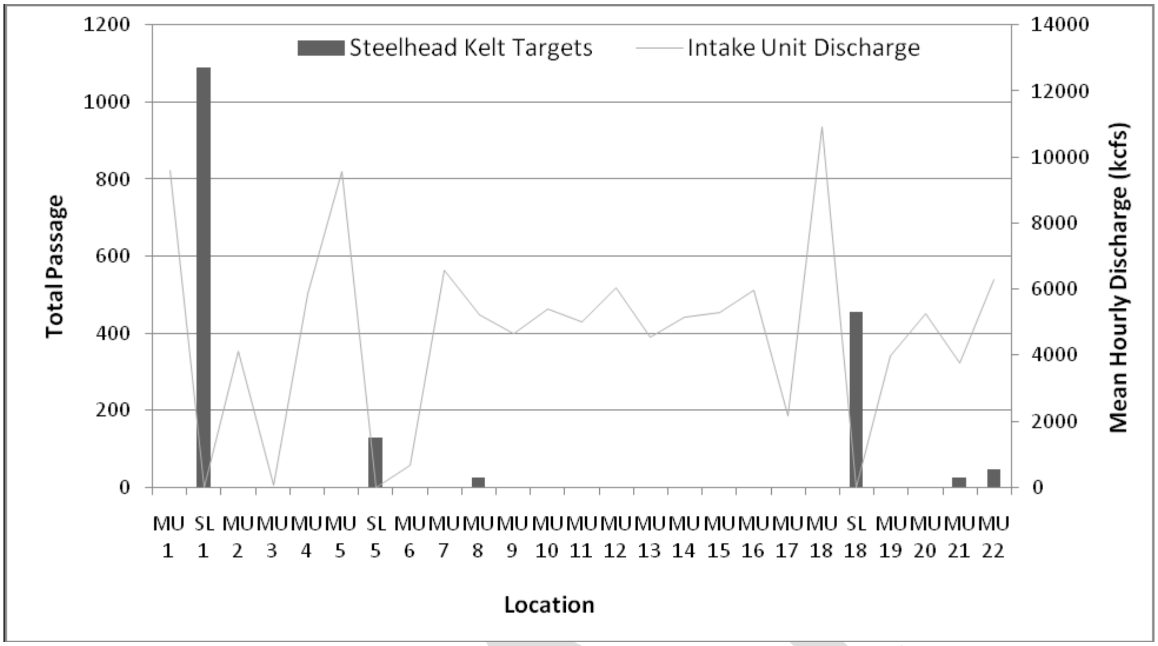
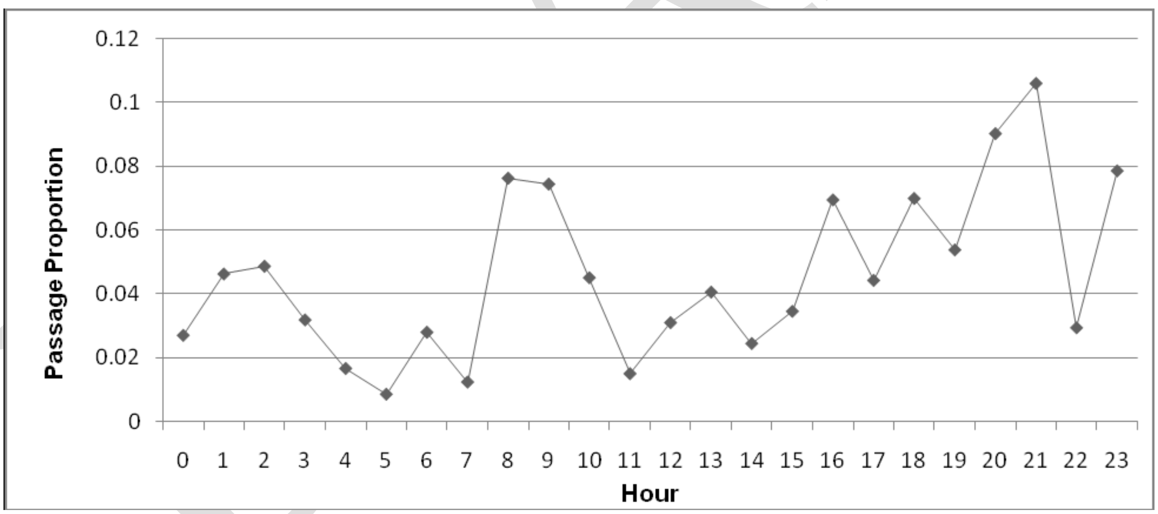


Figure 6. Diel distribution of Steelhead kelt size targets from March 1 – April 9, 2009. Data are the hourly proportions of total passage.



Next Step

• Prepare draft final report for submittal on July 31, 2009.

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