EVALUATION OF FISH BEHAVIOR PASSING WEIRS WHERE ADULT PIT-TAG DETECTORS ARE INSTALLED AT BONNEVILLE DAM, 2001

by

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EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) developed an adult fish Passive Integrated Transponder (PIT) tag detection system that was installed and tested at Bonneville Dam. The Corps of Engineers Fisheries Field Unit used underwater video technologies to evaluate the detection efficiency of the orifice PIT-tag system, any effect the orifice PIT-tag detectors may have on fish passage behavior, and the proportion of fish using the weir orifices vs. weir overflows. The NMFS supplied PIT- and streamer-tagged salmonids for the evaluation.

Based upon the underwater video of PIT- and streamer-tagged salmonids, the PIT-tag detection efficiency at the Washington shore ladder was 99.2% (1552 of 1565 passage events). The detection efficiency rate in the spring was 98.6%, summer 100.0%, and fall 99.8%.

We counted 125,027 fish passing upstream and 2,522 fish passing downstream at eight weirs (4 Washington shore, 2 A-branch, 2 B-branch) in over 1600 hours of video-tape. At the Washington shore ladder (as at Cascades Island ladder in 1999 and 2000), fish did not avoid the orifices with PIT-tag detector inserts. Proportions of salmonids using the overflow sections ranged from 3.4% to 7.3% in the spring and 17.4% to 26.0% in the fall for weirs 51, 52, 53, and 56. While data for 2001 showed overall higher overflow use than seen in 2000, this was the case for the control weir (weir 51) as well as for the weirs with orifice PIT-tag detector inserts.

Average proportions of observed overflow upstream passage at four Washington shore weirs ranged from 5.0% in the spring to 19.1% in the fall. This compares to pre-PIT tag detector insert overflow proportions of upstream passage of 3.1% in the spring and 18.9% in the fall for 2000 at the Washington shore ladder. Fish passing downstream at the Washington shore accounted for 1.2% of the observations in spring, and 0.8% in the fall, mostly through the orifices. Average proportions of observed overflow upstream passage at the Bradford Island ladders in the spring were 3.5% for A-branch and 0.4% for B-branch while proportions for the fall were 12.0% for A-branch and 3.8% for B-branch. Fish passing downstream at the Bradford Island ladders in the spring accounted for 6.0% at A-branch and 14.5% at B-branch while the fall rates were 12.2% and 12.0% respectively, mostly through the orifice. These data show that there is a wide range of passage behavior at different ladders that may be related to location, season, lighting, ladder densities, species composition, or other factors.

Our data indicates high variability of overflow use within and among ladders. These data have direct implications toward the development and installation of PIT-tag detection technologies in order to detect nearly 100% of the salmonids passing these ladders. Overflow detectors or vertical slot detectors may be necessary at some sites.

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INTRODUCTION

This study is a cooperative effort with the National Marine Fisheries Service (NMFS). The NMFS has developed adult Passive Integrated Transponder (PIT) tag detection systems to monitor adult salmonid passage through submerged orifices at Columbia River hydropower project fishways. The 2000 Federal Columbia River Power System Biological Opinion (section 9.6.1.3.4 Action 50 and section 9.6.5.3.5.2 Action 192) calls for installation of adult PIT-tag detectors at selected Columbia River dams by 2002. Bonneville Dam is the first dam to have adult orifice PIT-tag detectors installed in its fishways.

In 1993, the NMFS requested that the Army Corps of Engineers investigate fish behavior at submerged orifices, overflow section, and vertical slots at Bonneville Dam. The results of this initial underwater video work at the Washington shore ladder documented "time in view" and rate of speed for teleosts and Pacific lamprey (*Lampetra tridentata*) passing through the orifices and vertical slots of the fishway (Beck, 1994). The observed mean and median "times in view" were useful for determining detection efficiencies of weir-mounted PIT-tag detectors because detection abilities are, in part, limited by the time fish are in the detectors read zone and the angle at which fish pass through an orifice. In 1999, NMFS asked the Corps of Engineers to determine if fish behavior changed when PIT-tag detectors were installed in a Cascades Island weir orifice and to determine the proportion of fish using the overflow sections of the weirs (overflow usage rates) (Stansell, et al., 2000). That work continued in 2000 (Stansell and Beck, 2001) and in 2001 the focus shifted to the Washington shore ladder.

There were three objectives for our evaluation in 2001.

<u>OBJECTIVES</u>

1. Determine if an orifice PIT-tag detector insert modifies adult salmonid passage behavior.

The first objective was to evaluate the impacts of non-operational PIT-tag detector housings on adult salmonids, primarily chinook (*Onchorhynhus tshawytscha*), coho (*O. kisutch*), and steelhead (*O. mykiss*) as they pass through orifices and over weirs of a fishway. Specifically, we compared overflow usage rates of fish passing weir 51 (control, no orifice PIT-tag detector inserts) with overflow usage rates of fish passing weirs 52, 53, and 56 (with orifice PIT-tag detector inserts). The concern was that the detector housings may cause fish to reject the orifice force them to pass the overflow portion of the weir, causing a bias in PIT-tag detection efficiency, or cause passage delay or blockage. Alternative routes could be overflow sections of the weir or another fish ladder. Previous laboratory work by NMFS (Prentice et al., 1998) has already shown that fish readily pass through an orifice with an active PIT-tag detector and are not adversely affected by any electrical field generated (James Hatfield, Electromagnetic Field Exposure Concerns, 2000 PIT-Tag Workshop). In 1999 at Cascades Island, the fish did not avoid the orifice with the PIT-tag housing (Stansell, et al., 2000; Stansell and Beck 2001).

2. Determine the proportions of adult salmonids using overflow weirs vs. submerged orifices at the Washington shore and A- and B-branch (Bradford Island) ladders.

The second objective was to determine the proportion of fish using the overflow weirs at A- and B-branch ladders at Bradford Island. This was conducted both to give biologists an idea of how many fish use the overflow portions of weirs and to gather baseline data for comparison with 2002 data after orifice PIT-tag detectors are installed.

3. Determine the PIT-tag detection efficiency of adult PIT-tag orifice detectors at the Washington shore ladder using video technology and a known number of tagged fish.

The third objective was to compare observations of PIT- and streamer-tagged fish recorded by the PIT-tag detection equipment vs. underwater video cameras in order to calculate orifice PIT-tag reading efficiency. This work was conducted at the Washington shore ladder by releasing PIT and visually tagged fish from the Adult Fish Facility where they exited into the Washington shore fishway to pass weirs 50 on up.

SITE

Bonneville Dam is located at river kilometer 234 and is 64.4 km east of Portland, Oregon. It is the lower-most hydropower project on the Columbia River. It has four ladders, Bradford Island A-branch, Bradford Island B-branch, Cascades Island, and Washington shore.

A- and B-branch Ladders

Observations were made at weirs 50 and 51, each of which consisted of two submerged orifices and two overflow sections (weirs are numbered in relation to elevation above mean sea level). These weirs are two weirs below the junction to the Bradford Island main ladder where A- and B-branch ladders join. All orifices were 61.0 cm x 61.0 cm and 20.3 cm deep. The outside edge of these orifices are located about 43.2 cm from the sidewall of the fishway. Both weirs have a partial overflow section on each side about 1.8 m in width.

Washington Shore Ladder

Washington shore ladder collects fish from the tailrace of Powerhouse II (P2) and joins up with the Cascades Island ladder before the Washington shore fish count station. Our study site was at weirs 37, 51, 52, 53, and 56. Weir 56 is located 11 weirs below the junction with Cascades Island ladder. The orifices on these weirs are located 1 m from the sidewall of the fishway to the nearest edge of the orifice. All orifices are 45.7 cm x 45.7 cm. Overflow weir sections are 1.8 m wide on each side of the weir. Orifice PIT-tag detector inserts (Figure 1) conform to the dimensions of original orifice except for the addition of some PVC conduits on the downstream face of the weirs.

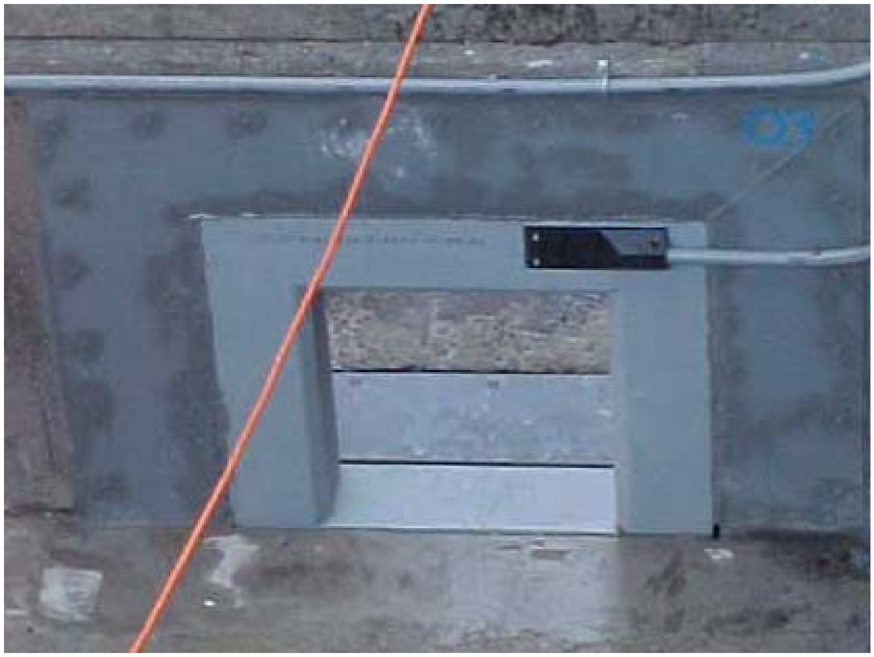

Figure 1. Orifice PIT-tag detector housing insert, downstream side of weir.

Adult Fish Facility

Also located on the Washington shore ladder is the Adult Fish Facility (AFF) that diverts fish from the main ladder into the sampling facility. The fish return to the main ladder from the north side. The AFF ladder exit section was used as a test location to release a known number of PIT-tagged and visual tagged fish for verification of the adult orifice PIT-tag detectors in the Washington shore ladder. As fish exit the AFF, they enter the Washington shore fishway between weirs 49 and 50 and can continue up the ladder.

METHODS

CAMERA INSTALLATION

Two types of underwater cameras were used. The cameras used for the submerged orifices were Kongsberg/Simrad OE1375[1]. These underwater cameras had an 88° diagonal field of view in air, 470 lines of resolution, and a sensitivity of 0.1 lux. Physical dimensions of the camera were 22.2 cm long by 5.7 cm diameter (maximum). The cameras used for viewing the overflow sections were NJM Research Corporation[1] underwater color cameras with Seamount lens and an 87° diagonal field of view in air, 470 lines of resolution, and a sensitivity of 0.45 lux. Physical dimensions of the cameras were 16.5 cm long by 5.7 cm diameter. Underwater camera mounts rode on guides that

[1] The use of a brand name does not imply endorsement by the U.S. Army Corps of Engineers.

were attached to the walls of the fishway and allowed deployment and removal of cameras without the need to de-water the fishway. Hardware to mount the cameras underwater consisted primarily of aluminum piping 3.8 cm diameter on mounts that slid up and down on guides running from the floor of the fishway along the wall to the top of the wall. Orifice cameras were not directly in the path of fish passing through the orifice, cameras were located off to one side or over the orifice or overflow section looking down (Figure 2). The underwater cameras were placed upstream of the orifices (as in 1999 and 2000), as fewer bubbles were present which tend to occlude viewing fish from downstream of the orifice. Overflow sections of monitored weirs were painted white to aid in visual (video) detection of fish passage. To avoid adverse affects on fish behavior, neither system deployed artificial lighting.

Figure 2. Views of underwater orifice camera orientation (dewatered ladder) and overhead camera orientations.

A- and B-branch Ladders

Underwater camera mounts were placed upstream of weirs 50 and 51 at both A- and B-branch ladders adjacent to each orifice, giving eight underwater camera mounts, one for each orifice. Cameras were mounted so that side-views of passing fish were recorded to aid in identification of salmonid species. The cameras were located 17.8 cm to 22.9 cm off the floor, 25.4 cm from the sidewall, 35.6 cm upstream from the weir and pointed downstream to view the orifice. Cameras were mounted above each weir to monitor fish passage over the weirs. A- and B-branch weirs are partial overflow weirs

(Figure 1), so two cameras were used to cover each overflow section at each weir (eight total). Each camera was connected to a separate VCR.

Washington Shore Ladder

Underwater camera mounts were placed upstream of weirs 37, 51, 52, 53, and 56 at the Washington shore ladder, adjacent to each orifice for a total of eight underwater camera mounts, one for each orifice. The cameras were located 15.2 cm to 17.8 cm off the floor, 81.3 cm from the wall, 40.6 cm from the weir and pointed downstream to cover the upstream view of the orifice. Each overflow weir camera was located about 1 m downstream of the weir, 1 m above the water flowing over the weir and pointed upstream. The field of view for each of the eight overflow cameras covered the width of the overflow section (1.8 m). Each camera was connected to a separate VCR.

DATA COLLECTION AND ANALYSIS

Orifice PIT-tag Housing Impacts

Video-taping typically occurred between 1200 and 1800 hours for 2 hours (a few days in the spring recorded 3, 4, or 5 hours) a day at all cameras sites for the four weirs at the Washington shore. During the spring run, Washington shore ladder weirs were periodically sampled during the period April 4 through May 5 for a total of 14 days (Appendix Table A1). No taping occurred during the summer run as shad (*Alossa sapidissima*) passing the weirs are difficult to distinguish from jacks at the overflow weirs. Washington shore ladder weirs were observed during the fall from August 21 through October 18 on 14 days, 2 hours per day.

During the spring run, A- and B-branch ladder weirs 50 and 51 were video-taped from May 10 through May 12 (Appendix Table A1) for a total of 2 days for A-branch and all 3 days for B-branch. Each day taping occurred for 6 hours. During the fall run, the weirs were periodically sampled during the period August 21 through October 16 for a total of 11 days for A-branch and 10 days for B-branch, 3 hours per day.

Data recorded from video-tapes by FFU and Washington Department of Fish and Wildlife personnel included date, time, species, upstream passage number through orifices and overflow sections and the number of fish falling back through orifices and overflow sections. Unusual behaviors such as hesitation, turning around, or burst behaviors were also noted. Salmonids were recorded to species when identifiable or classed as salmonids when species was not identifiable. Fish that could not be identified to either genera or species were listed as unknown. Pacific lampreys were recorded also. In the downstream passage column, fallback fish were recorded as "headfirst", "tail-first", or "sideways", depending on their orientation as they fell back.

Several factors influenced the ability of the video-tape readers to see and identify fish. These factors include turbidity, areas of shading/light contrast on days with bright sunlight, glare caused by sunlight reflecting off the water (overflow cameras), and occasions where bubbles obscured the camera view. At times species identification was not possible at the overflow section because only the fish's back or sometimes just the dorsal or caudal fin was visible.

Orifice and overflow passage ratios were calculated for the spring and fall run sampling periods at the Washington shore and A- and B-branch ladders. Ratios were calculated separately for upstream, downstream, and net passage during each sample period. Lamprey data were collected but not analyzed for this report.

For analysis to determine statistical differences between weirs with the orifice PIT-tag detectors both in 2001 and between 2000 and 2001, we use Statistical Analytical Systems (SAS) software to run logistic regression using year, julian day, weir, and weir/year as our variables. All values for zero fish were given a 0.5 for our analysis.

Detection Efficiency of the PIT-tag Detectors

On April 11, 16, 17, 18, 24, 25, June 13, and September 18, 19, 24, and 25 underwater video technology was used at the Washington shore ladder in determining the PIT-tag reading efficiency of the adult orifice PIT-tag detectors in-situ with live PIT-tagged salmonids. NMFS personnel tagged 646 (316 spring, 52 summer, and 278 fall) salmonids with bright neon-colored orange, red or pink fabric streamer-tags attached to the base of the dorsal fin with a cotton string (Figure 3). The string would decay and release the streamer-tag over time. The streamer-tags were about 2.5 cm wide by 15 cm long and readily visible by our cameras, both underwater and passing overflow weirs, under all but the worst conditions of turbidity, bubbles, or sun glare (overflows). In addition, PIT-tags were inserted into the body cavity. Fish were observed passing through both the orifices and overflow sections. Adult orifice PIT-tag detection efficiency was determined by dividing the number of PIT-tagged fish detected by the orifice detectors by the number of visually confirmed PIT- and streamer-tagged fish passing through the orifices of the weirs.

Figure 3. View of a brightly colored, reflective streamer tag attached to the dorsal fin of PIT-tagged salmonids released from the AFF into the Washington shore ladder.

RESULTS

During the 2001 fish passage season at the Washington shore and A- and B-branch ladders, we video-taped over 1600 hours of fish passing submerged orifices and overflow weirs. At the Washington shore and A- and B-branch ladders, we recorded 123,629 fish passing upstream and 2,321 passing downstream (Appendix Table B1). All the following results are for known salmonids and unknown teleosts combined, and exclude miscellaneous other fish unless otherwise stated.

ORIFICE PIT-TAG IMPACTS (WASHINGTON SHORE)

In the spring at the Washington shore ladder, sampling occurred 14 days at each weir (Appendix Table A1). In the fall, sampling occurred 9 days at weir 51, 10 days at weir 52, 11 days at weir 53, and 9 days at weir 56.

In the spring, observed upstream overflow usage averaged from a low of 3.4% at weir 51 to a high of 7.3% at weir 53 (Appendix Table C1). In the fall, observed upstream passage overflow usage averaged from a low of 19.2% at weir 53 to a high of 26.0% at weir 51 (the control weir).

Results compared to 2000 data can be seen in Table 1. Overall, spring overflow rates were higher in 2001 than in 2000. Only weir 56 in the spring had an increase in overflow use that was of concern (greater than 2%), but in the fall, the control weir (51) actually had the highest increase in overflow use in 2001 and weir 53 had a drop in overflow use.

Table 1. Mean daily overflow usage rates for fish passing upstream at the Washington shore ladder weirs in 2000 and 2001 (weir 51 is the control weir with no orifice PIT-tag detector either year).

	Weir 51 Mean	Weir 51 SE	Weir 52 Mean	Weir 52 SE	Weir 53 Mean	Weir 53 SE	Weir 56 Mean	Weir 56 SE
Spring 2000	**2.4%**	0.6%	**2.6%**	0.6%	**6.1%**	1.1%	**2.4%**	0.6%
Spring 2001	**3.4%**	1.3%	**3.6%**	1.5%	**7.3%**	2.6%	**5.8%**	2.4%
Fall 2000	**17.0%**	0.9%	**11.3%**	0.2%	**22.2%**	3.3%	**20.6%**	5.7%
Fall 2001	**26.0%**	6.7%	**21.1%**	6.0%	**19.2%**	6.2%	**23.3%**	7.3%

Plots of daily overflow rates between the years can be seen in Appendix G. Results of performing a logistics regression with year, julian day, weir, and weir/year can be seen in Table 2. It is evident that there was a consistently significant difference between the years (mostly an increase in overflow use in 2001 compared to 2000) and with julian day (indicating more overflow use when fish numbers are high). However, the results are more mixed for differences between weirs. This may be due to having only two sample days for the fall of 2000 for comparison. Yet when taking both the weir and year into account, the results tend to indicate that there was no difference between the weirs, although again, the small sample size in the fall of 2000 has to be taken into account.

Plots of the log of the odds ratio comparing weirs 52, 53, and 56 to weir 51 (spring and fall) showed roughly an even number of days above and below zero, except for weir 53 in the spring. This tends to show that overflow use for the weirs with orifice PIT-tag detectors was greater on some days and less on others. Weir 53 in the spring, however, was consistently above zero, indicating that overflow use of weir 53 was consistently higher than the control weir. However, this was also the case for weir 53 in 2000, when no orifice PIT-tag detectors were installed.

The fallback (downstream passage) rate at the Washington shore was 1.2% in the spring and 0.8% in the fall. The numbers and percentages of observed overflow use for each day, upstream and downstream passage, can be seen in Appendix Table E1. In the spring, 1,019 fish were observed passing downstream, 214 in the fall. These figures are very close to 2000 data at the Washington shore (Appendix Table B1).

Table 2. Probability values from a logistics regression using year, julian day, weir, and weir/year as variables. Data are from 2000 and 2001 at the Bonneville Washington shore.

SPRING	WEIR 51 vs. 52	WEIR 51 vs. 53	WEIR 51 vs. 56
YEAR	<0.0001	<0.0001	<0.0001
JULIAN DAY	<0.0001	<0.0001	<0.0001
WEIR	0.06	<0.0001	<0.0001
WEIR/YEAR	0.46	0.94	0.15
FALL	WEIR 51 vs. 52	WEIR 51 vs. 53	WEIR 51 vs. 56
YEAR	<0.0001	<0.0001	<0.0001
JULIAN DAY	<0.0001	<0.0001	<0.0001
WEIR	<0.0001	0.22	0.74
WEIR YEAR	0.08	0.03	0.77

Note: Fall data for 2000 were from two sample days only.

OVERFLOW USAGE PROPORTIONS

A- and B-branch Ladders

Overflow usage of fish observed passing upstream in the spring in averaged less than 5.2% for both ladders (Table 3). Observed upstream overflow usage in the fall varied more from an average of 2.9% at B-branch for weir 50 to 13.7% for A-branch for weir 50. The numbers and percentages of observed overflow use for each day, upstream, downstream, and net passage, can be seen in Appendix Tables D1-D2.

Table 3. Mean daily sample percentages of upstream passage overflow use by fish at A- and B-branch ladders, weirs 50 and 51 in 2001.

		% UP	% UP	% UP	% UP	% UP	% UP
		A W50	A W51	A TOTAL	B W50	B W51	B TOTAL
	# DAYS	2	2	2	2	3	3
SPRG	MEAN	5.2%	1.8%	3.5%	0.0%	0.6%	0.4%
	SE	3.6%	1.1%		0.0%	0.6%	
	# DAYS	11	11	11	10	10	10
FALL	MEAN	13.7%	10.3%	12.0%	2.9%	4.6%	3.8%
	SE	2.8%	1.5%		0.8%	1.2%	

The fallback rate (number of fish passing downstream/number of fish passing upstream) at A-branch was 6.0% in the spring, and 12.2% in the fall (Appendix Table B1). The fallback rate at B-branch was 14.5% in the spring and 12.0% in the fall. In the spring for both ladders, 206 fish were observed passing downstream, and 1,122 in the fall.

Washington Shore Ladder

The results for the Washington shore ladder overflow use in 2001 are reported in Table 3, Appendix Tables D3 through D6, and in the previous section, Orifice PIT-tag Impacts.

All Bonneville Ladders, All Years

Figure 4 shows the mean percentage of fish using overflow sections for all weirs monitored per ladder, per year. Additional data including medians and ranges can be seen in Appendix Tables C1 and C2.

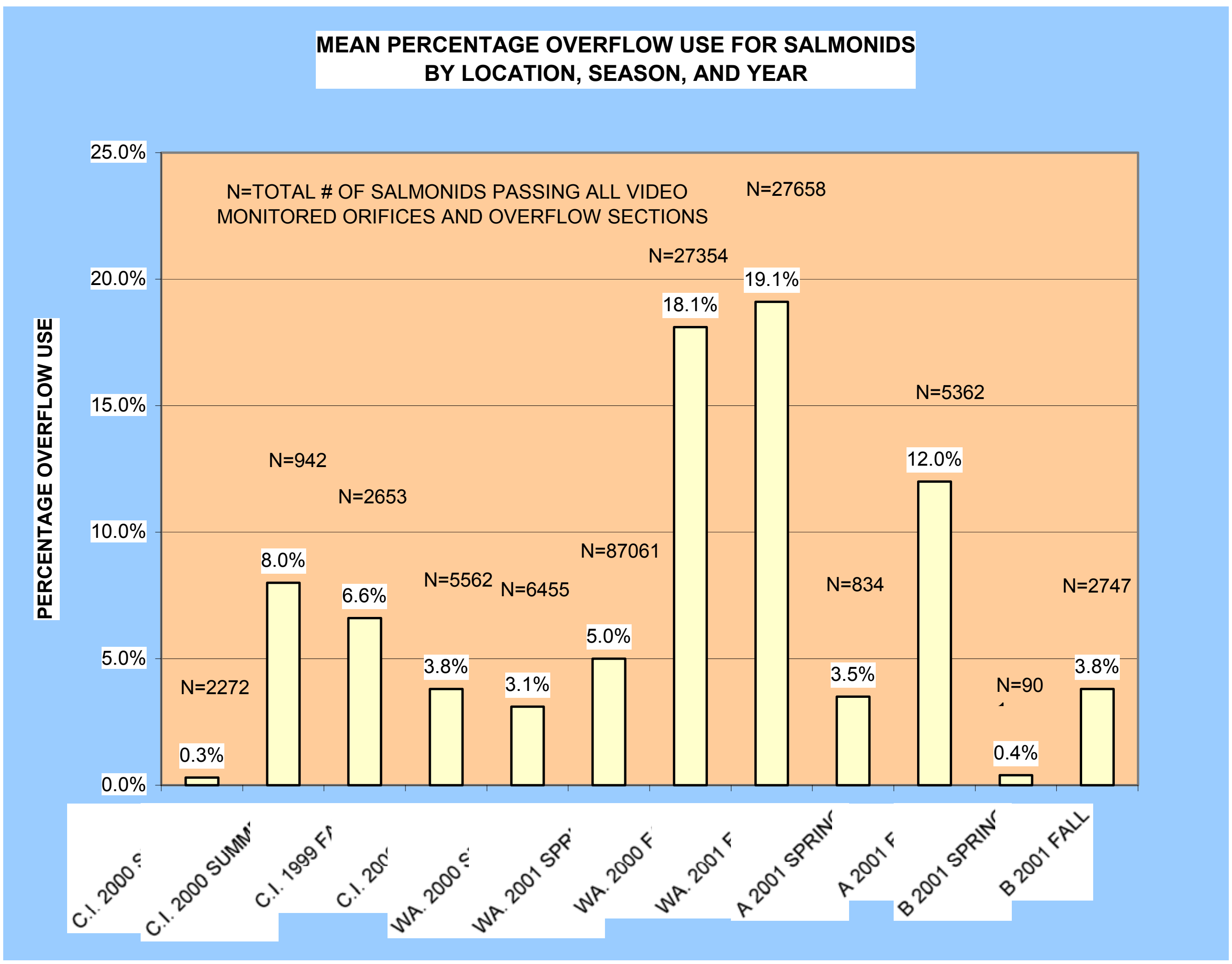

Figure 4. Mean percentage of overflow use for salmonids by location, season, and year.

Overall, fall overflow passage rates were much higher than spring or summer rates. The one exception is Cascades Island summer rates; however, the high overflow rates here are likely due to shad counted as unknown fish. Spring overflow passage rates at Cascades Island and B-branch are the lowest and fall rates at the Washington shore are the highest.

DETECTION EFFICIENCY OF THE PIT-TAG DETECTORS

Detection efficiency is defined as the total number fish with PIT- and streamer tags detected by the orifice detectors (excluding those missed visually) divided by the total number of visually observed fish with PIT- and streamer tags passing through the orifices of the weirs. Detection efficiencies for the adult orifice PIT-tag detectors in the spring and fall for the Washington shore ladder can be seen in Table 4. There were more passage events (1,565) than tagged fish released (646) because multiple weirs were monitored by both video and PIT-tag systems (37, 52, 53, and 56) and multiple passages occurred for some fish. In addition, some fish came within the detection zone of the orifice detectors several times prior to passage. Tagged fish included 303 spring chinook, 36 summer chinook, 158 fall chinook, 29 spring/summer steelhead, 88 fall steelhead, and 32 coho.

Table 4. Spring, summer, and fall adult orifice PIT-tag detector efficiencies at the Washington shore.

	PIT-TAG DETECTIONS	VIDEO DETECTIONS	% PIT-TAG DETECTIONS
SPRING	821	833	98.6%
SUMMER	120	120	100.0%
FALL	611	612	99.8%
TOTAL	1,552	1,565	99.2%

In the spring, there were 833 video observations of tagged fish passing through the four video- and PIT-tag detector weirs and 821 of those were picked up by the PIT-tag detectors. The 12 missed detections (four fish) on all three upper weirs (52, 53, and 56), may indicate a broken PIT-tag, a PIT-tag that worked its way out of the body, or some other problem. These four fish were not detected by any of the eight upper weir detectors. None of the 34 downstream passages included in the above results were missed by the detectors. There were nine additional detections by the PIT-tag orifice detectors that we were unable to see the streamer tag, or in some cases, even see a fish. These data were not included in our analysis of detection efficiency.

There were 88 video passage events in which the we observed a PIT and streamer tagged fish passing the overflow portions of the weirs. In most cases, we were able to determine which individual fish this was based on times of passage on adjacent weirs through orifice detectors. Of the 646 PIT and streamer tagged fish, 52 used the overflow portion of the weir for the three monitored weirs.

Of the 646 PIT and streamer tagged fish released, 29 fish were known to have lost their streamer tags, 10 fish passed after the hours of darkness (no video monitoring), 16 passed downstream (weirs 34-37), 30 fish passed the next day when video was not monitoring, and eight fish passed at other times when we were not monitoring with our cameras. In addition, eight fish were determined to have nosed up to the orifice but did not pass through upstream initially (usually they did pass up several seconds later and were seen) and eight fish nearly fell back but did not pass through. All these cases were excluded from the analysis, as there was typically no chance to view the fish and tag.

Overall, of the 646 tagged fish, the PIT detector system never detected 43 (603/646 or 93.3% detection). Of those 43, the video cameras were able to determine that five were missed passing upstream through the orifices (previously mentioned) and another eight went overflow (at least on the three weirs we video monitored). That leaves 30 fish we were never able to assign a passage route. They likely went overflow and were either missed by the video cameras, or they passed during hours we did not monitor (night, next day, etc.).

PIT-TAG DATA

Using PIT-tag data collected on the eight upstream monitored weirs (52-59) supplied by NMFS, we were able to see how many of the 646 PIT tagged fish for this study used multiple overflow sections by making the assumption that if the tag was not detected, it went by overflow (Appendix Table F1). With a 99% detection rate, this is a reasonable assumption. As can be seen in Figures 5 and 6, the percentage of fish using all eight overflow weirs was highest for summer steelhead (low numbers) and coho (low numbers), lowest for spring chinook, and under 10% for the rest. These figures, plus the 99% detection efficiency, should give managers an idea of what the eight weir orifice PIT-tag detection system would miss of the population of PIT-tagged fish passing the Bonneville Washington shore ladder. It should be noted that these data were collected during a year when record runs passed Bonneville dam, and overflow use by salmonids may be ladder density dependant. We have no data for sockeye.

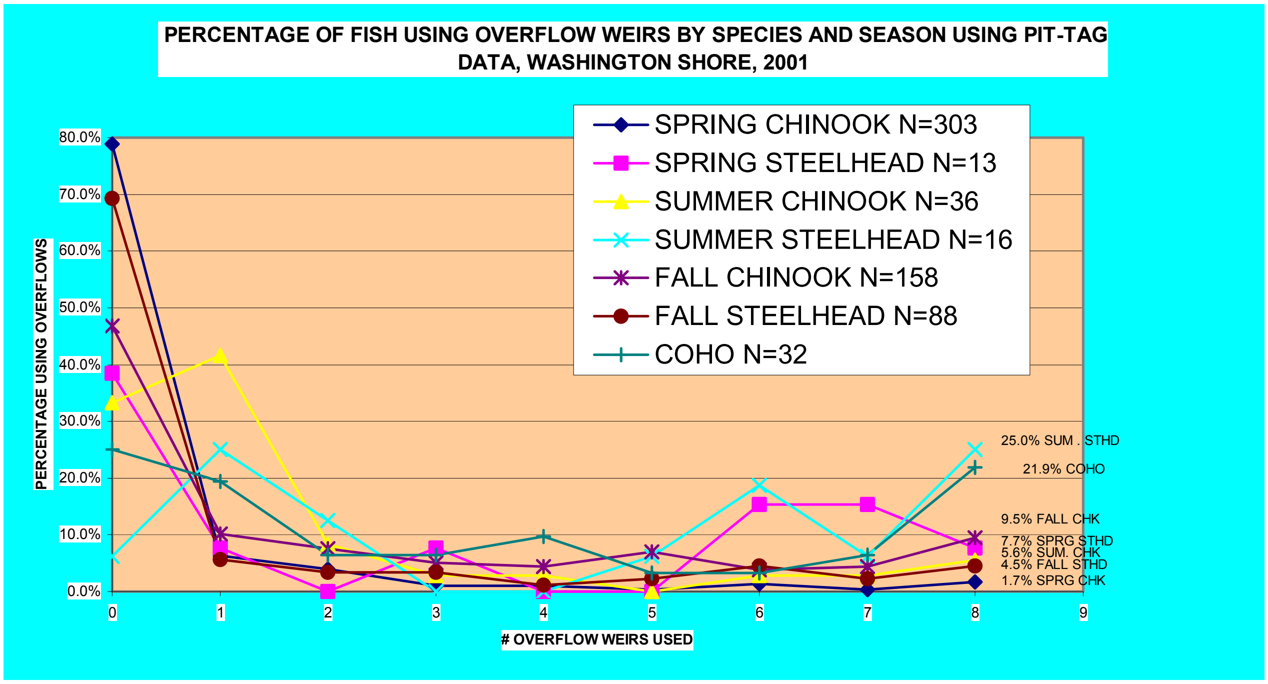

Figure 5. Percentage of fish using overflow weirs by species and season using PIT-tag data, Washington shore, 2001.

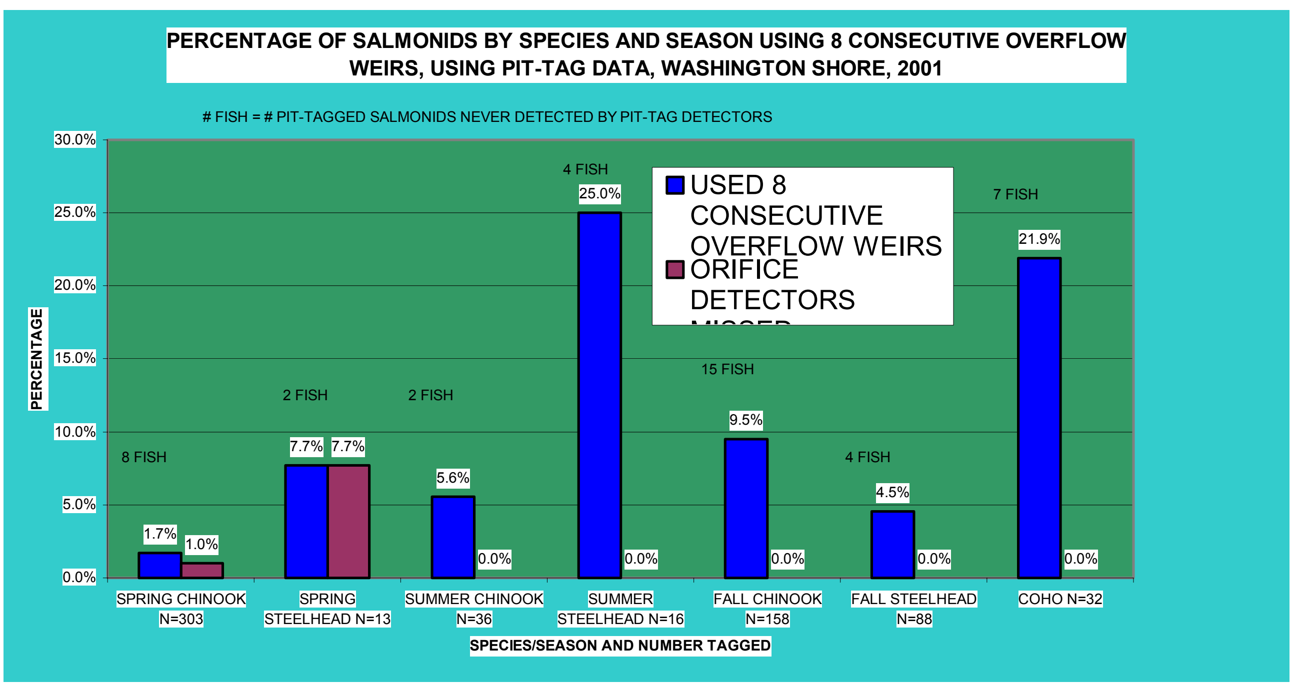

Figure 6. Percentage of salmonids by species and season using eight consecutive overflow weirs, using PIT-tag data, Washington shore, 2001.

DISCUSSION

ORIFICE PIT-TAG IMPACTS

During the 2001 fish passage season at the Washington shore ladder there were no major differences in the proportion of fish passing the overflow of weir 51 (control, no orifice PIT-tag detector inserts) and weirs 52, 53, and 56 (with orifice PIT-tag detector inserts). In the spring, overflow proportions for all PIT-tag weirs were higher than the control weir, yet only by 0.2%, 3.9% and 1.6%. In the fall, only one PIT-tagged weir was higher, by 1.6%, while the other two were actually lower, by 0.3% and 2.1%. Although 2001 data on overflow use of all PIT-tagged weirs were statistically significantly different from the non-PIT-tagged control weir, the magnitude and direction (some were lower) indicates that the detectors did not alter or increase the proportion of fish passing overflow section. Other factors were more likely responsible for the changes in each weir, such as overhead shading, fish passage numbers (density), species composition, etc.

Comparison with 2000 overflow rates shows an increase in overflow use overall for 2001 (Figures 9 and 10). The control weir increased overflow use by 1.0% in the spring and 2.5% in the fall. Overflow use for the PIT-tagged weirs in the spring increased by 1.0%, 1.2%, and 3.4% whereas in the fall one weir increased 9.8% while the other two decreased by 2.0% and 3.2%. It seems apparent that overflow rates are highly variable, both between individual weirs and between years for the same weirs. These data do not indicate that the orifice PIT-tag detectors have any adverse impact on salmonid passage.

OVERFLOW USAGE PROPORTIONS

Our goal is to provide information that will aid managers in making decisions concerning location and placement of adult PIT-tag detectors. One major concern involving the deployment of adult PIT-tag detectors at overflow weirs of fishways has been the question of overflow use by salmonids. How many salmonids use the overflow portion of the weir? Does an individual salmonid pass multiple consecutive overflows? Are submerged orifice PIT-tag detectors alone enough to detect all fish passing? These questions need to be answered before managers can determine whether to proceed with the development of overflow weir PIT-tag detectors. Is the added coverage worth the additional expense?

Video-tape documentation of the overflow sections was poor at times due to a variety of factors. These factors include poor lighting conditions, bubble streams, sunlight reflection/water glare. Areas of both dark shadows and bright sunlight in the view would cause the camera's iris to close making the dark areas too dark to see fish. These factors may have caused us to miss fish passing the overflow and therefore the percentage of fish using the overflow sections of the weirs is a minimum.

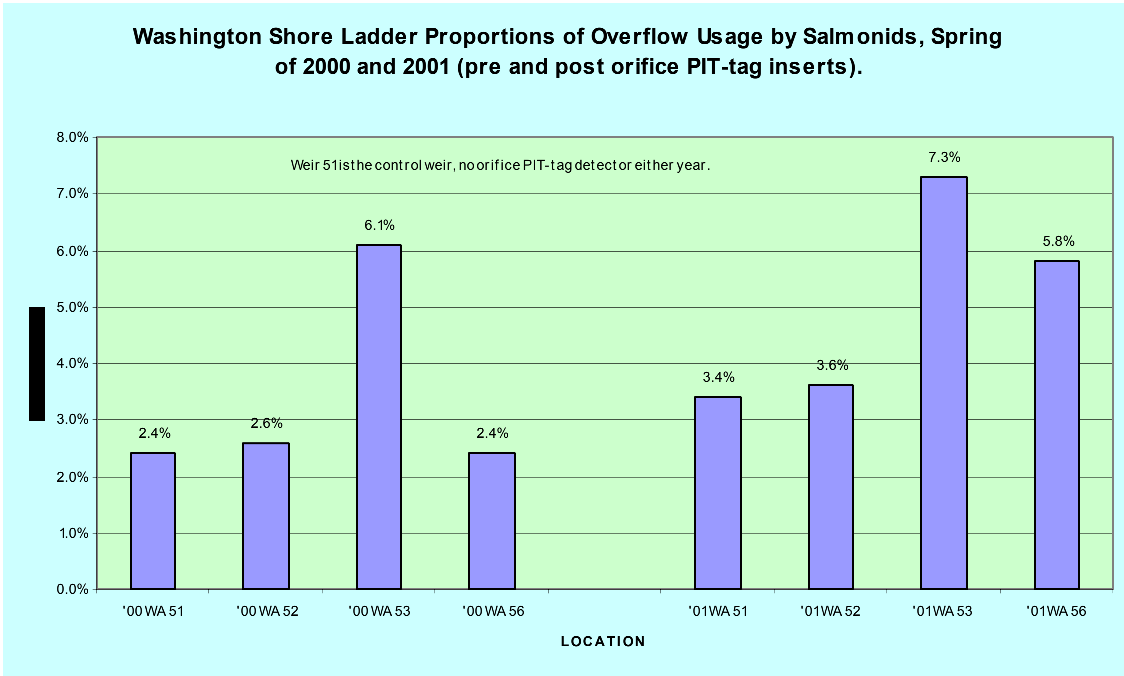

Figure 7. Percentage of fish in the spring using the overflow portion of weirs 51, 52, 53, and 56 at the Washington shore in 2000 (no orifice PIT-tag detectors) and 2001 (weirs 52, 53, and 56 with orifice PIT-tag detectors).

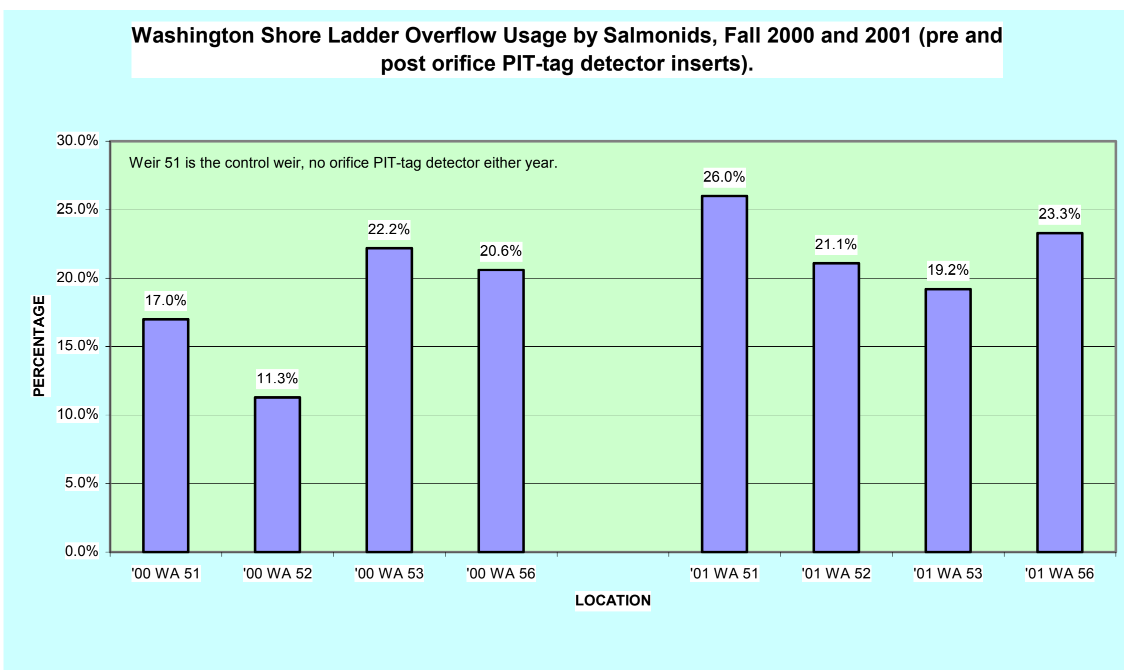

Figure 8. Percentage of fish in the fall using the overflow portion of weirs 51, 52, 53, and 56 at the Washington shore in 2000 (no orifice PIT-tag detectors) and 2001 (weirs 52, 53, and 56 with orifice PIT-tag detectors).

Results for 2001 indicate that overflow use during the spring run is lower than during the fall. For the year, daily overflow usage of fish passing upstream ranged from 0% to 56% at the Washington shore ladder and 0% to 31% for A- and B-branch ladders. Overflow rates for A- and B-branch ladders generally follow those of the Washington shore (i.e. overflow rates being higher in the fall than in the spring) (Appendix Tables C1 and C2). Overflow passage rates between weirs within a ladder were within 3.4% in all cases.

Downstream passage rates indicate that total weir downstream passage rates were higher overall for A- (6.0% spring, 12.2% fall) and B-branch weirs (14.5% spring, 12.0% fall) than for Washington shore weirs (1.2% spring, 0.8% fall). However, fish falling back over the overflow section account for just 0.9% of the passage observed at the Washington shore weirs, 4.5% at A-branch weirs, and 4.2% at B-branch weirs. This compares to fallback observation rates at the orifices of 1.2% at the Washington shore weirs, 13.9% at A-branch weirs, and 14.9% at B-branch weirs.

Some salmonids passed multiple overflow sections at Washington shore weirs 52-59 (PIT-tag data from 646 tagged salmonids, supplied by NMFS). Overall, most of the fish passed all eight weirs through the orifices with less than a third using two or more overflow weirs (Figure 4). However, it was disturbing to note that in the summer and fall (Figures 11, 12 and 13), about 10% of the tagged fish were using the overflow sections of all eight weirs. This reached 22% for coho, although the sample size was small (N=32). These data indicate that some fish are inclined to use the overflow for multiple weirs in succession.

DETECTION EFFICIENCY

Overall, the detection efficiency was over 99%. The detection efficiency of the adult orifice PIT-tag detectors was above 98% for spring (821 of 833), 100% for summer (155 of 155) and 99% for fall (611 of 612). No tagged fish passing downstream through an orifice PIT-tag detector was missed by the system. Tagged fish missed by the orifice PIT-tag detectors could not be determined to species as the video could usually pick out the streamer-tag but the overhead viewing made species identification difficult. The visual streamer-tags used in 2001 worked well even under turbidity levels around 2 m (Secchi disk). However, turbidity, bubble streams, lost tags, distances from the camera lens to the fish greater than 61 cm, and other reasons can cause the underwater cameras to miss fish passage. Additionally, fish nosing up to the orifice but not passing did cause some PIT-tag detections without video verification, but these were excluded from the analysis. Although the underwater cameras can miss visually tagged fish (1,578 video detections out of 1,587 PIT-tag detections or 99% video detection), this does not affect the determination of the detection rate of PIT-tag detectors. The detection efficiency is calculated by using the fish that were seen visually with streamer-tags and determining how many of those fish were also detected with the orifice PIT-tag detectors. Visually detected fish missed by the PIT-tag detectors will reduce the detection efficiency. There may be some instances where both the video cameras and the PIT-tag detectors miss a

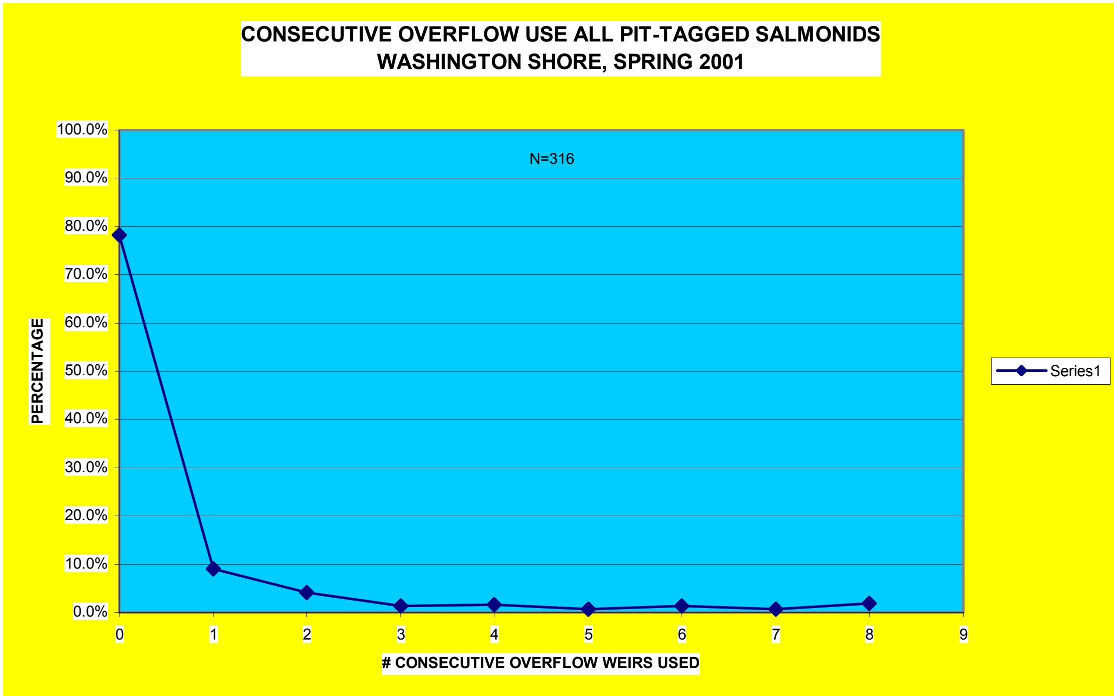

Figure 9. Consecutive overflow weir use by PIT-tagged salmonids through weirs 52-59, Washington shore ladder, spring 2001.

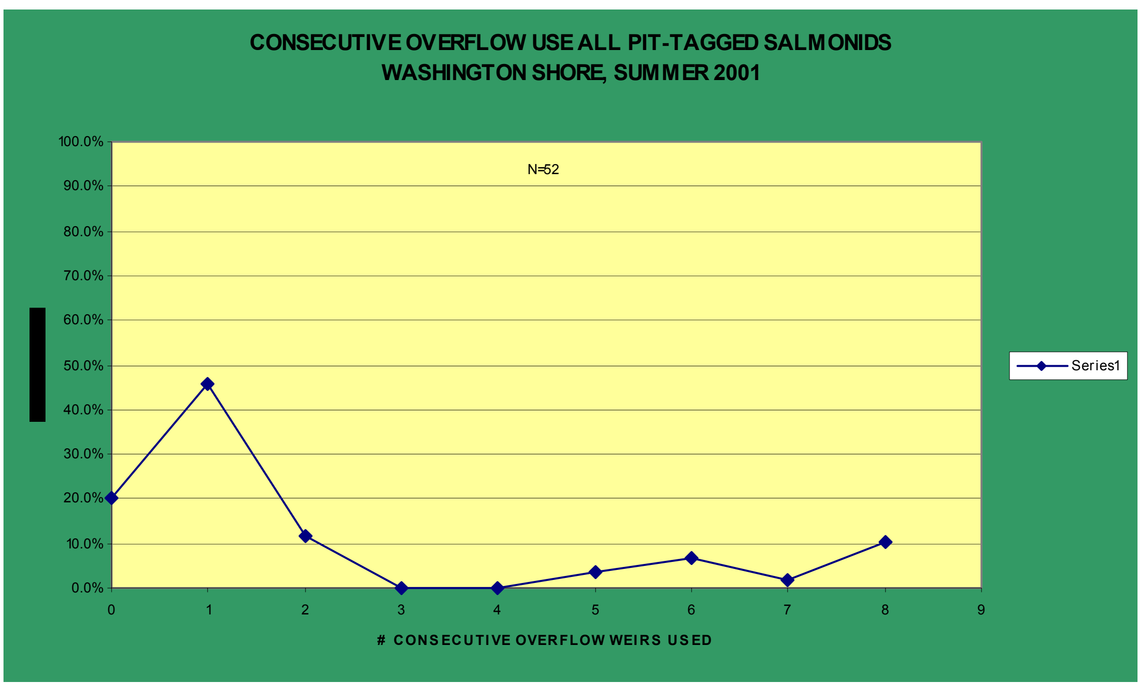

Figure 10. Consecutive overflow weir use by all PIT-tagged salmonids through weirs 52-59, Washington shore ladder, summer 2001.

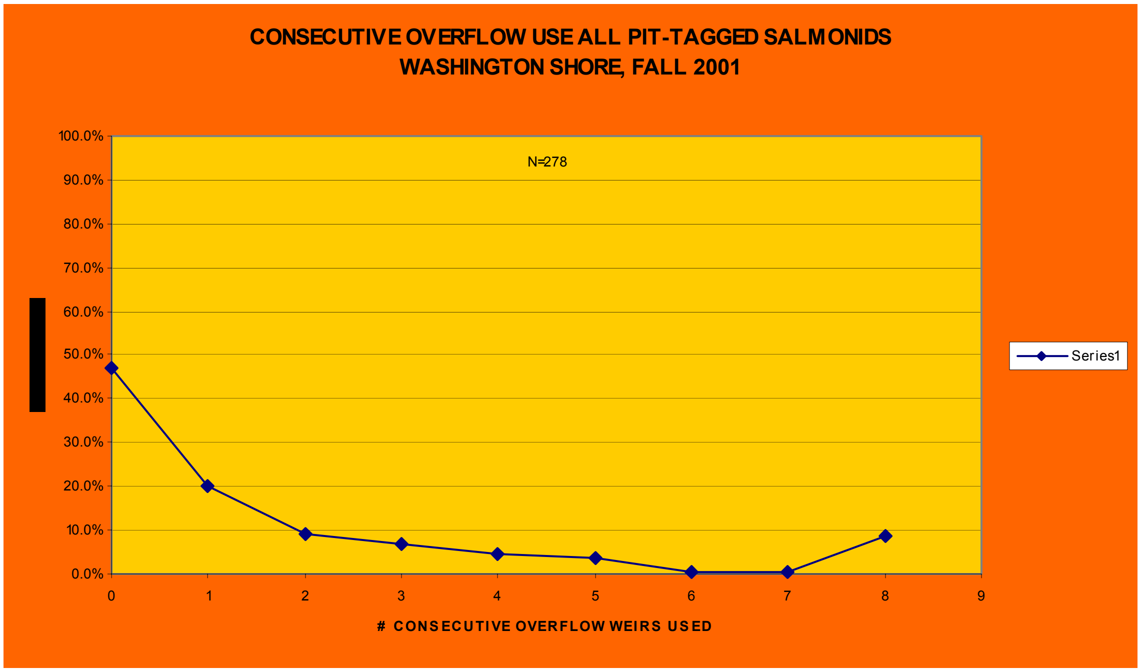

Figure 11. Consecutive overflow weir use by PIT-tagged salmonids through weirs 52-59, Washington shore ladder, fall 2001.

tagged fish passing, but this is highly unlikely judging by the detection rate of both systems.

CONCLUSIONS

1. Salmonids do not avoid orifices with PIT-tag detector inserts that are the same dimensions as orifices without detector inserts.

2. Proportions of salmonids passing overflow sections of weirs varies by location and season and year. At the Washington shore ladder, daily overflow use can vary for any one weir from 0% to 56%. For individual weirs at the Washington shore ladder, overflow use can vary up to 11% (seasonal average). Overflow use at the Washington shore ladder can vary between years by 10%. Cascades Island, A, and B-branch ladders varied and changed slightly less, and had overall less overflow use than Washington shore.

3. PIT-tag detection efficiency for adult orifice PIT-tag detectors was 99%.

While salmonids do not avoid orifices with PIT-tag detectors and the detector efficiencies are almost 100%, multiple consecutive weir overflow usage suggests that many fish may pass undetected in an eight-weir orifice detector system. Options to consider include more weirs with orifice detectors, spacing out the weirs with orifice detectors, developing overflow detectors, and developing vertical slot detectors. Each dam may vary in the combination of these detector and placement options to achieve specific goals. For example, at Bonneville Dam, some vertical slots at Bradford Island and Washington shore could be out outfitted with PIT-tag detectors (to get near 100% detection) in addition to orifice detectors at Washington shore, Cascades Island, A- and B-branch ladders (to get ladder use information during various powerhouse or spill pattern scenarios).

ACKNOWLEDGMENTS

We would like to thank NMFS, in particular Earl Prentice and Sandra Downing, for their assistance in providing adult orifice PIT-tag detector data on PIT-tagged fish passing through their orifice detectors at the Washington shore weir 52-59, and for developing and tagging the salmonids used for the detection efficiency rate objective. We would also like to thank Washington Department of Fish and Wildlife personnel for assisting us in reviewing the thousands of hours of video-tape. This includes Virginia Phillips, Lucille Worsham, Rebecca Reardon, and Imogene Abrahams. Finally, more thanks go out to our own Biological Technicians that helped review video-tapes and input data: Patricia Madson, Katrina Smolak, Sallie Jones, Mike Jonas, and John Dalen.

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APPENDICES

APPENDIX A

Appendix Table A1. Dates of sampling at the Washington Shore and A- and B-branch ladder weirs in 2001 (X=typically 2hr but a few 3hr, X1=6hr, X2=3hr, X3=1hr).

	WASHINGTON SHORE				A-BRANCH		B-BRANCH	
	WEIR 51	WEIR 52	WEIR 53	WEIR 56	WEIR 50	WEIR 51	WEIR 50	WEIR 51
4/4/2001	X	X	X	X				
4/5/2001	X	X	X	X				
4/11/2001	X	X	X	X				
4/17/2001	X	X	X	X				
4/18/2001	X	X	X	X				
4/19/2001	X	X	X	X				
4/20/2001	X	X	X	X				
4/21/2001	X	X	X	X				
4/27/2001	X	X	X	X				
4/28/2001	X	X	X	X				
4/30/2001	X	X	X	X				
5/3/2001	X	X	X	X				
5/4/2001	X	X	X	X				
5/5/2001	X	X	X	X				
5/10/2001					X1	X1	X1	X1
5/11/2001					X1	X1	X1	X1
5/12/2001							X1	X1
8/21/2001	X	X	X	X	X2	X2		
8/22/2001	X	X	X	X	X2	X2		
8/23/2001	X	X	X	X				
8/27/2001					X2	X2		
8/28/2001					X2	X2		
9/4/2001	X	X	X	X			X2	X2
9/5/2001	X	X	X	X			X2	X2
9/6/2001	X	X	X	X				
9/10/2001							X2	X2
9/11/2001							X2	X2
9/18/2001					X2	X2		
9/19/2001					X3	X3		
9/20/2001					X2	X2		
9/24/2001					X2	X2		
9/25/2001					X2	X2		
10/1/2001							X2	X2
10/2/2001							X2	X2
10/4/2001							X2	X2
10/5/2001							X2	X2
10/9/2001	X	X	X	X				
10/10/2001	X	X	X	X				
10/11/2001	X	X	X	X				
10/15/2001			X		X2	X2		
10/16/2001					X2	X2		
10/17/2001			X					
10/18/2001		X					X2	X2
10/19/2001							X2	X2

APPENDIX B

Appendix Table B1. Upstream and downstream counts by video seen passing orifice and overflow sections of the Washington shore, Cascades Island, A- and B-branch ladders in 1999-2001.

			TOTAL # UP	TOTAL # DOWN	TOTAL % DOWN
WASHINGTON SHORE	SPRING	2001	87061	1019	1.2%
WASHINGTON SHORE	SPRING	2000	6524	144	2.2%
WASHINGTON SHORE	FALL	2001	27658	217	0.8%
WASHINGTON SHORE	FALL	2000	27352	177	0.6%
CASCADES ISLAND	SPRING	2000	2272	203	8.2%
CASCADES ISLAND	SUMMER	2000	942	127	11.9%
CASCADES ISLAND	FALL	2000	4483	528	10.5%
CASCADES ISLAND	FALL	1999	2828	760	21.2%
A-BRANCH	SPRING	2001	834	53	6.0%
A-BRANCH	FALL	2001	5362	747	12.2%
B-BRANCH	SPRING	2001	901	153	14.5%
B-BRANCH	FALL	2001	2747	375	12.0%
	TOTAL	2001	125027	2552	

		ORIFICE UP	ORIFICE DOWN	% ORIFICE DOWN	OVERFLOW UP	OVERFLOW DOWN	% OVERFLOW DOWN
WASHINGTON SHORE	2001	90489	1035	1.3%	24230	201	0.8%
A-BRANCH	2001	5446	759	12.2%	750	34	4.3%
B-BRANCH	2001	3505	522	13.0%	143	6	4.0%

APPENDIX C

Appendix Table C1. Mean, median, range, number of hours and days for upstream passage overflow use of individual weirs at Cascades Island, Washington shore, A- and B-branch ladders for 1999-2001.

YEAR	LADDER	SEASON	WEIR	N - HOURS	N – DAYS	MEAN	MEDIAN	MINIMUM	MAXIMUM
1999	CASC. IS.	FALL	52	102	17	6.0%	6.4%	0.0%	16.3%
1999	CASC. IS.	FALL	53	102	17	7.2%	8.2%	0.0%	17.7%
2000	CASC. IS.	FALL	52	24	4	3.3%	3.3%	2.8%	3.7%
2000	CASC. IS.	FALL	53	24	3	4.5%	4.4%	3.0%	6.1%
2000	CASC. IS.	SPRING	53	24	4	0.3%	0.2%	0.0%	0.7%
2000	CASC. IS.	SPRING	53	24	4	0.3%	0.2%	0.0%	0.8%
2000	CASC. IS.	SUMMER	52	24	3	6.3%	4.0%	1.3%	13.6%
2000	CASC. IS.	SUMMER	53	24	3	9.6%	6.0%	1.4%	21.4%
2000	WASH.	SPRING	51	30	5	2.4%	2.0%	0.8%	4.3%
2000	WASH	SPRING	52	36	6	2.6%	2.9%	0.0%	4.5%
2000	WASH	SPRING	53	24	4	6.1%	6.3%	3.8%	7.9%
2000	WASH	SPRING	56	36	6	2.4%	2.1%	0.9%	4.2%
2000	WASH.	FALL	51	13.5	2	17.0%	17.0%	16.1%	17.9%
2000	WASH	FALL	52	5.5	2	11.3%	11.3%	11.0%	11.5%
2000	WASH	FALL	53	13.5	2	22.2%	22.2%	18.9%	25.4%
2000	WASH	FALL	56	15.5	3	20.6%	19.1%	11.7%	31.1%
2001	WASH.	SPRING	51	33	14	3.4%	1.8%	0.0%	16.0%
2001	WASH	SPRING	52	33	14	3.6%	1.8%	0.0%	20.4%
2001	WASH	SPRING	53	33	14	7.3%	3.7%	0.0%	33.7%
2001	WASH	SPRING	56	33	14	5.8%	1.3%	0.0%	25.4%
2001	WASH.	FALL	51	18	9	26.0%	18.7%	5.6%	54.1%
2001	WASH	FALL	52	20	10	21.1%	12.7%	3.6%	54.8%
2001	WASH	FALL	53	22	11	19.2%	9.8%	2.7%	56.2%
2001	WASH	FALL	56	18	9	23.3%	10.3%	3.3%	55.1%
2001	A	SPRING	50	12	2	5.2%	5.2%	1.6%	8.8%
2001	A	SPRING	51	12	2	1.8%	1.8%	0.6%	2.9%
2001	B	SPRING	50	12	2	0.0%	0.0%	0.0%	0.0%
2001	B	SPRING	51	18	3	0.6%	0.0%	0.0%	1.9%
2001	A	FALL	50	31	11	13.7%	9.9%	5.4%	31.5%
2001	A	FALL	51	31	11	10.3%	8.9%	2.2%	17.3%
2001	B	FALL	50	30	10	2.9%	2.6%	0.0%	9.5%
2001	B	FALL	51	30	10	4.6%	3.7%	0.0%	12.5%

Appendix Table C2. Mean, median, range, number of hours and days for upstream passage overflow use of all individual weirs at Cascades Island, Washington shore, A- and B-branch ladders for 1999-2001.

YEAR	LADDER	SEASON	WEIR	N - HOURS	N - DAYS	MEAN	MEDIAN	MINIMUM	MAXIMUM
1999	CASC. IS.	FALL	ALL	204	17	6.6%	6.8%	0.0%	17.7%
2000	CASC. IS.	FALL	ALL	48	4	3.8%	3.7%	2.8%	6.1%
2000	CASC. IS.	SPRING	ALL	48	6	0.3%	0.2%	0.0%	0.8%
2000	CASC. IS.	SUMMER	ALL	48	3	8.0%	5.0%	1.3%	21.4%
2000	WASH.	SPRING	ALL	126	7	3.1%	3.1%	0.0%	7.9%
2001	WASH	SPRING	ALL	132	14	5.0%	2.0%	0.0%	33.7%
2000	WASH.	FALL	ALL	48	3	18.1%	17.9%	11.0%	31.1%
2001	WASH.	FALL	ALL	78	11	19.1%	9.8%	3.3%	56.2%
2001	A	SPRING	ALL	24	2	3.5%	2.2%	0.6%	8.8%
2001	B	SPRING	ALL	30	3	0.4%	0.0%	0.0%	1.9%
2002	A	SPRING	ALL						
2002	B	SPRING	ALL						
2001	A	FALL	ALL	62	11	12.0%	9.4%	2.2%	31.5%
2001	B	FALL	ALL	60	10	3.8%	2.9%	0.0%	12.5%
2002	A	FALL	ALL						
2002	B	FALL	ALL						

Appendix Table D1. Upstream and downstream overflow use, A-branch ladder.

DATE	A 50 UP OVERFLOW	A 50 UP ORIFICE	A 50 UP % O.F. USE	A 51 UP OVERFLOW	A 51 UP ORIFICE	A 51 UP % O.F. USE	TOTAL UP OVERFLOW	TOTAL UP ORIFICE	OVERALL UP % O.F. USE
SPRING									
5/10/2001	6	370	1.6%	2	330	0.6%	8	700	1.1%
5/11/2001	5	52	8.8%	2	67	2.9%	7	119	5.6%
SPRING TOTAL	**11**	**422**	**2.5%**	**4**	**397**	**1.0%**	**15**	**819**	**1.8%**
SPRING AVERAGE			**5.2%**			**1.8%**			**3.3%**
FALL									
8/21/2001	7	87	7.4%	8	67	10.7%	15	154	8.9%
8/22/2001	23	272	7.8%	15	235	6.0%	38	507	7.0%
8/27/2001	51	441	10.4%	27	333	7.5%	78	774	9.2%
8/28/2001	129	527	19.7%	83	452	15.5%	212	979	17.8%
9/18/2001	68	241	22.0%	50	239	17.3%	118	480	19.7%
9/19/2001	78	234	25.0%	48	253	15.9%	126	487	20.6%
9/20/2001	46	100	31.5%	19	116	14.1%	65	216	23.1%
9/24/2001	16	280	5.4%	24	247	8.9%	40	527	7.1%
9/25/2001	17	154	9.9%	17	184	8.5%	34	338	9.1%
10/15/2001	3	45	6.3%	1	45	2.2%	4	90	4.3%
10/16/2001	2	35	5.4%	3	40	7.0%	5	75	6.3%
FALL TOTAL	**440**	**2416**	**15.4%**	**295**	**2211**	**11.8%**	**735**	**4627**	**13.7%**
FALL AVERAGE			**13.7%**			**10.3%**			**12.1%**

DATE	A 50 DOWN OVERFLOW	A 50 DOWN ORIFICE	A 50 DOWN % O.F. USE	A 51 DOWN OVERFLOW	A 51 DOWN ORIFICE	A 51 DOWN % O.F. USE	TOTAL DOWN OVERFLOW	TOTAL DOWN ORIFICE	OVERALL DOWN % O.F. USE
SPRING									
5/10/2001	18	10	64.3%	8	11	42.1%	26	21	55.3%
5/11/2001	0	0	0.0%	1	5	16.7%	1	5	16.7%
SPRING TOTAL	**18**	**10**	**64.3%**	**9**	**16**	**36.0%**	**27**	**26**	**50.9%**
SPRING AVERAGE			**32.1%**			**29.4%**			**36.0%**
FALL									
8/21/2001	0	15	0.0%	0	16	0.0%	0	31	0.0%
8/22/2001	0	11	0.0%	0	10	0.0%	0	21	0.0%
8/27/2001	0	50	0.0%	0	39	0.0%	0	89	0.0%
8/28/2001	4	62	6.1%	1	73	1.4%	5	135	3.6%
9/18/2001	0	44	0.0%	0	36	0.0%	0	80	0.0%
9/19/2001	0	51	0.0%	1	43	2.3%	1	94	1.1%
9/20/2001	0	9	0.0%	1	8	11.1%	1	17	5.6%
9/24/2001	0	32	0.0%	0	34	0.0%	0	66	0.0%
9/25/2001	0	55	0.0%	0	58	0.0%	0	113	0.0%
10/15/2001	0	29	0.0%	0	22	0.0%	0	51	0.0%
10/16/2001	0	20	0.0%	0	23	0.0%	0	43	0.0%
FALL TOTAL	**4**	**378**	**1.0%**	**3**	**362**	**0.8%**	**7**	**740**	**0.9%**
FALL AVERAGE			**0.6%**			**1.3%**			**0.9%**

Appendix Table D2. Upstream and downstream overflow use, B-branch ladder.

DATE	B 50 UP OVERFLOW	B 50 UP ORIFICE	B 50 UP % O.F. USE	B 51 UP OVERFLOW	B 51 UP ORIFICE	B 51 UP % O.F. USE	TOTAL UP OVERFLOW	TOTAL UP ORIFICE	OVERALL UP % O.F. USE
SPRING									
5/10/2001				3	159	1.9%	3	159	1.9%
5/11/2001	0	133	0.0%	0	118	0.0%	0	251	0.0%
5/12/2001	0	304	0.0%	0	184	0.0%	0	488	0.0%
SPRING TOTAL	**0**	**437**	**0.0%**	**3**	**461**	**0.6%**	**3**	**898**	**0.3%**
SPRING AVERAGE			**0.0%**			**0.6%**			**0.4%**
FALL									
9/4/2001	4	130	3.0%	2	139	1.4%	6	269	2.2%
9/5/2001	17	162	9.5%	14	199	6.6%	31	361	7.9%
9/10/2001	11	443	2.4%	60	420	12.5%	71	863	7.6%
9/11/2001	4	167	2.3%	9	163	5.2%	13	330	3.8%
10/1/2001	2	110	1.8%	1	108	0.9%	3	218	1.4%
10/2/2001	3	103	2.8%	0	67	0.0%	3	170	1.7%
10/4/2001	0	60	0.0%	2	70	2.8%	2	130	1.5%
10/5/2001	2	63	3.1%	2	49	3.9%	4	112	3.4%
10/18/2001	2	43	4.4%	1	27	3.6%	3	70	4.1%
10/19/2001	0	46	0.0%	4	38	9.5%	4	84	4.5%
FALL TOTAL	**45**	**1327**	**3.3%**	**95**	**1280**	**6.9%**	**140**	**2607**	**5.1%**
FALL AVERAGE			**2.9%**			**4.6%**			**3.8%**

DATE	B 50 DOWN OVERFLOW	B 50 DOWN ORIFICE	B 50 DOWN % O.F. USE	B 51 DOWN OVERFLOW	B 51 DOWN ORIFICE	B 51 DOWN % O.F. USE	TOTAL DOWN OVERFLOW	TOTAL DOWN ORIFICE	OVERALL DOWN % O.F. USE
SPRING									
5/10/2001				1	6	14.3%	1	6	14.3%
5/11/2001	0	9	0.0%	3	8	27.3%	3	17	15.0%
5/12/2001	0	113	0.0%	0	13	0.0%	0	126	0.0%
SPRING TOTAL	**0**	**122**	**0.0%**	**4**	**27**	**12.9%**	**4**	**149**	**2.6%**
SPRING AVERAGE			**0.0%**			**13.9%**			**9.8%**
FALL									
9/4/2001	0	19	0.0%	0	13	0.0%	0	32	0.0%
9/5/2001	2	19	9.5%	0	9	0.0%	2	28	6.7%
9/10/2001	0	62	0.0%	0	58	0.0%	0	120	0.0%
9/11/2001	0	63	0.0%	0	55	0.0%	0	118	0.0%
10/1/2001	0	6	0.0%	0	7	0.0%	0	13	0.0%
10/2/2001	0	9	0.0%	0	5	0.0%	0	14	0.0%
10/4/2001	0	9	0.0%	0	7	0.0%	0	16	0.0%
10/5/2001	0	8	0.0%	0	4	0.0%	0	12	0.0%
10/18/2001	0	0	0.0%	0	0	0.0%	0	0	0.0%
10/19/2001	0	13	0.0%	0	7	0.0%	0	20	0.0%
FALL TOTAL	**2**	**208**	**1.0%**	**0**	**165**	**0.0%**	**2**	**373**	**0.5%**
FALL AVERAGE			**1.0%**			**0.0%**			**0.7%**

Appendix Table D3. Upstream overflow use at the Washington shore weirs 51-52.

DATE	WA 51 UP OVERFLOW	WA 51 UP ORIFICE	WA 51 UP % O.F. USE	WA 52 UP OVERFLOW	WA 52 UP ORIFICE	WA 52 UP % O.F. USE
SPRING						
4/4/2001	6	457	1.3%	5	454	1.1%
4/5/2001	6	253	2.3%	8	274	2.8%
4/11/2001	469	3707	11.2%	379	3979	8.7%
4/17/2001	123	1947	5.9%	341	5039	6.3%
4/18/2001	887	4640	16.0%	1723	6739	20.4%
4/19/2001	8	853	0.9%	10	775	1.3%
4/20/2001	8	316	2.5%	10	317	3.1%
4/21/2001	7	220	3.1%	5	213	2.3%
4/27/2001	36	1099	3.2%	37	1068	3.3%
4/28/2001	1	240	0.4%	2	262	0.8%
4/30/2001	0	237	0.0%	1	241	0.4%
5/3/2001	0	271	0.0%	0	264	0.0%
5/4/2001	0	412	0.0%	1	429	0.2%
5/5/2001	0	308	0.0%	0	301	0.0%
SPRING TOTAL	**1551**	**14960**	**9.4%**	**2522**	**20355**	**11.0%**
SPRING AVERAGE			**3.4%**			**3.6%**
FALL						
8/21/2001	25	348	6.7%	37	417	8.1%
8/22/2001	38	426	8.2%	50	390	11.4%
8/23/2001	25	424	5.6%	44	445	9.0%
9/4/2001	801	769	51.0%	822	679	54.8%
9/5/2001	823	698	54.1%	625	761	45.1%
9/6/2001	1338	1337	50.0%	982	1232	44.4%
10/9/2001	27	139	16.3%	5	133	3.6%
10/10/2001	49	160	23.4%	23	131	14.9%
10/11/2001	54	235	18.7%	32	197	14.0%
10/18/2001				6	91	6.2%
FALL TOTAL	**3180**	**4536**	**41.2%**	**2626**	**4476**	**37.0%**
FALL AVERAGE			**26.0%**			**21.1%**

Appendix Table D4. Upstream overflow use at the Washington shore weirs 53 and 56.

DATE	WA 53 UP OVERFLOW	WA 53 UP ORIFICE	WA 53 UP % O.F. USE	WA 56 UP OVERFLOW	WA 56 UP ORIFICE	WA 56 UP % O.F. USE	TOTAL UP OVERFLOW	TOTAL UP ORIFICE	OVERALL UP % O.F. USE
SPRING									
4/4/2001	18	415	4.2%	3	379	0.8%	32	1705	1.8%
4/5/2001	19	268	6.6%	11	197	5.3%	44	992	4.2%
4/11/2001	965	3179	23.3%	730	2965	19.8%	2543	13830	15.5%
4/17/2001	777	4482	14.8%	1063	4262	20.0%	2304	15730	12.8%
4/18/2001	3442	6769	33.7%	2310	6798	25.4%	8362	24946	25.1%
4/19/2001	11	783	1.4%	8	708	1.1%	37	3119	1.2%
4/20/2001	14	298	4.5%	4	286	1.4%	36	1217	2.9%
4/21/2001	7	208	3.3%	4	243	1.6%	23	884	2.5%
4/27/2001	54	1047	4.9%	69	2135	3.1%	196	5349	3.5%
4/28/2001	4	259	1.5%	3	250	1.2%	10	1011	1.0%
4/30/2001	6	221	2.6%	2	229	0.9%	9	928	1.0%
5/3/2001	0	224	0.0%	0	248	0.0%	0	1007	0.0%
5/4/2001	1	385	0.3%	1	368	0.3%	3	1594	0.2%
5/5/2001	2	268	0.7%	0	271	0.0%	2	1148	0.2%
SPRING TOTAL	**5320**	**18806**	**22.1%**	**4208**	**19339**	**17.9%**	**13601**	**73460**	**15.6%**
SPRING AVERAGE			**7.3%**			**5.8%**			**5.1%**
FALL									
8/21/2001	40	350	10.3%	12	354	3.3%	114	1469	7.2%
8/22/2001	63	341	15.6%	42	365	10.3%	193	1522	11.3%
8/23/2001	41	379	9.8%	32	412	7.2%	142	1660	7.9%
9/4/2001	697	608	53.4%	582	543	51.7%	2902	2599	52.8%
9/5/2001	825	643	56.2%	773	631	55.1%	3046	2733	52.7%
9/6/2001	766	1122	40.6%	852	917	48.2%	3938	4608	46.1%
10/9/2001	7	107	6.1%	6	95	5.9%	45	474	8.7%
10/10/2001	6	125	4.6%	25	109	18.7%	103	525	16.4%
10/11/2001	17	176	8.8%	19	193	9.0%	122	801	13.2%
10/15/2001	10	260	3.7%				10	680	1.4%
10/17/2001	8	287	2.7%				8	778	1.0%
10/18/2001							6	91	6.2%
FALL TOTAL	**2480**	**4398**	**36.1%**	**2343**	**3619**	**39.3%**	**10629**	**17029**	**38.4%**
FALL AVERAGE			**19.2%**			**23.3%**			**19.1%**

Appendix Table D5. Downstream overflow use at the Washington shore weirs 51-52.

DATE	WA 51 DOWN OVERFLOW	WA 51 DOWN ORIFICE	WA 51 DOWN % O.F. USE	WA 52 DOWN OVERFLOW	WA 52 DOWN ORIFICE	WA 52 DOWN % O.F. USE
SPRING						
4/4/2001	1	2	33.3%	0	0	0.0%
4/5/2001	1	5	16.7%	0	3	0.0%
4/11/2001	20	47	29.9%	8	49	14.0%
4/17/2001	5	23	17.9%	8	30	21.1%
4/18/2001	18	35	34.0%	18	43	29.5%
4/19/2001	5	24	17.2%	2	20	9.1%
4/20/2001	3	20	13.0%	0	20	0.0%
4/21/2001	2	5	28.6%	4	4	50.0%
4/27/2001	0	48	0.0%	0	19	0.0%
4/28/2001	2	21	8.7%	0	12	0.0%
4/30/2001	0	13	0.0%	0	10	0.0%
5/3/2001	0	8	0.0%	0	1	0.0%
5/4/2001	0	9	0.0%	0	1	0.0%
5/5/2001	1	9	10.0%	2	0	100.0%
SPRING TOTAL	**58**	**269**	**17.7%**	**42**	**212**	**16.5%**
SPRING AVERAGE			**14.9%**			**16.0%**
FALL						
8/21/2001	0	2	0.0%	0	3	0.0%
8/22/2001	0	1	0.0%	0	4	0.0%
8/23/2001	0	8	0.0%	0	4	0.0%
9/4/2001	0	7	0.0%	0	16	0.0%
9/5/2001	2	8	20.0%	4	7	36.4%
9/6/2001	4	9	30.8%	0	9	0.0%
10/9/2001	0	8	0.0%	0	4	0.0%
10/10/2001	1	4	20.0%	0	2	0.0%
10/11/2001	1	8	11.1%	0	10	0.0%
10/18/2001				0	4	0.0%
FALL TOTAL	**8**	**55**	**12.7%**	**4**	**63**	**6.0%**
FALL AVERAGE			**9.1%**			**3.6%**

Appendix Table D6. Downstream overflow use at the Washington shore weirs 53 and 56.

DATE	WA 53 DOWN OVERFLOW	WA 53 DOWN ORIFICE	WA 53 DOWN % O.F. USE	WA 56 DOWN OVERFLOW	WA 56 DOWN ORIFICE	WA 56 DOWN % O.F. USE	TOTAL DOWN OVERFLOW	TOTAL DOWN ORIFICE	OVERALL DOWN % O.F. USE
SPRING									
4/4/2001	1	2	33.3%	0	2	0.0%	2	6	25.0%
4/5/2001	1	6	14.3%	1	2	33.3%	3	16	15.8%
4/11/2001	12	44	21.4%	11	49	18.3%	51	189	21.3%
4/17/2001	4	13	23.5%	3	18	14.3%	20	84	19.2%
4/18/2001	23	34	40.4%	11	37	22.9%	70	149	32.0%
4/19/2001	4	24	14.3%	3	18	14.3%	14	86	14.0%
4/20/2001	3	14	17.6%	0	15	0.0%	6	69	8.0%
4/21/2001	0	4	0.0%	0	3	0.0%	6	16	27.3%
4/27/2001	0	22	0.0%	0	17	0.0%	0	106	0.0%
4/28/2001	0	16	0.0%	0	4	0.0%	2	53	3.6%
4/30/2001	0	7	0.0%	0	6	0.0%	0	36	0.0%
5/3/2001	0	0	0.0%	0	0	0.0%	0	9	0.0%
5/4/2001	0	0	0.0%	0	0	0.0%	0	10	0.0%
5/5/2001	0	1	0.0%	0	3	0.0%	3	13	18.8%
SPRING TOTAL	**48**	**187**	**20.4%**	**29**	**174**	**14.3%**	**177**	**842**	**17.4%**
SPRING AVERAGE			**11.8%**			**7.4%**			**13.2%**
FALL									
8/21/2001	0	2	0.0%	0	1	0.0%	0	8	0.0%
8/22/2001	0	3	0.0%	0	0	0.0%	0	8	0.0%
8/23/2001	0	4	0.0%	2	5	28.6%	2	21	8.7%
9/4/2001	2	8	20.0%	0	3	0.0%	2	34	5.6%
9/5/2001	1	5	16.7%	0	7	0.0%	7	27	20.6%
9/6/2001	4	5	44.4%	1	4	20.0%	9	27	25.0%
10/9/2001	0	3	0.0%	0	3	0.0%	0	18	0.0%
10/10/2001	0	2	0.0%	0	4	0.0%	1	12	7.7%
10/11/2001	0	6	0.0%	1	4	20.0%	2	28	6.7%
10/17/2001	1	2	33.3%				1	4	20.0%
10/18/2001							0	4	0.0%
FALL TOTAL	**8**	**44**	**15.4%**	**4**	**31**	**11.4%**	**24**	**193**	**11.1%**
FALL AVERAGE			**10.4%**			**7.6%**			**9.0%**

APPENDIX E

Appendix Table E1. Summary of observation and passage data for PIT and streamer-tagged fish passing he Washington shore weirs with PIT-tag detectors and cameras (37, 52, 53, and 56) in spring 2001.

	SPRING TOTALS	4/25/2001	4/24/2001	4/18/2001	4/17/2001	4/16/2001	4/11/2001
# SALMONIDS TAGGED	316	76	30	75	30	59	46
# CHINOOK TAGGED	303						
# STEELHEAD TAGGED	13						
# COHO TAGGED	0						
# PASS AT NIGHT	7	1	1	0	1	3	1
# PASS NEXT DAYS	17	3	1	1	4	6	2
# PASS BUT NOT MONITORING	5	0	0	0	5	0	0
# PIT SYSTEM NEVER DETECTED	10	2	0	1	0	5	2
# CHINOOK NEVER DETECTED	9						
# STEELHEAD NEVER DETECTED	2						
# COHO NEVER DETECTED							
# DOWNSTREAM WEIR 37	11	2	0	3	1	4	1
# VISUAL TAGS LOST	24	3	1	3	0	0	17
# PASS ORIFICE-NO PIT DET. FISH	4	0	0	0	0	2	2
# PASS ORIFICE-NO PIT DET. WEIRS	12	0	0	0	0	6	6
# PASS ORIFICE-NO VIDEO DET. WEIRS	3	0	0	3	0	0	0
# POTENTIAL OVERFLOW PASSES	50	13	0	10	5	10	12
# OVERFLOWS SEEN TO DATE	20	0	0	7	4	1	8
# MISSING FISH ACCOUNTED FOR	4	0	0	0	0	2	2
# TOTAL UP VIDEO	863	205	88	233	76	130	131
# TOTAL DOWN VIDEO	20	2	0	5	1	4	8
# UP OVERFLOW	48	13	0	9	5	10	11
# DOWN OVERFLOW	2	0	0	1	0	0	1
# UP ORIFICE	815	192	88	224	71	120	120
# DOWN ORIFICE	18	2	0	4	1	4	7
# VIDEO PASSAGE EVENTS	883	207	88	238	77	134	139
# NOSE UP BEHAVIOR	6	0	0	3	1	0	2
# NOSE DOWN BEHAVIOR	4	0	1	1	0	1	1
# OF PREVIOUS DAY FISH PASS	12	1	1	4	6	0	0
# IND. FISH USING O.F. 3 VIDEO WEIRS, 1+	27	6	0	7	2	4	8
# TOTAL O.F. USED BY PIT FISH	190	29	1	52	26	37	45

Appendix Table E2. Summary of observation and passage data for PIT and streamer-tagged fish passing the Washington shore weirs with PIT-tag detectors and cameras (37, 52, 53, and 56) in summer 2001.

	SUMMER TOTALS 6/13/2001
# SALMONIDS TAGGED	52
# CHINOOK TAGGED	36
# STEELHEAD TAGGED	16
# COHO TAGGED	
# PASS AT NIGHT	2
# PASS NEXT DAYS	0
# PASS BUT NOT MONITORING	0
# PIT SYSTEM NEVER DETECTED	6
# CHINOOK NEVER DETECTED	2
# STEELHEAD NEVER DETECTED	4
# COHO NEVER DETECTED	
# DOWNSTREAM WEIR 37	0
# VISUAL TAGS LOST	0
# PASS ORIFICE-NO PIT DET. FISH	0
# PASS ORIFICE-NO PIT DET. WEIRS	0
# PASS ORIFICE-NO VIDEO DET. WEIRS	2
# POTENTIAL OVERFLOW PASSES	35
# OVERFLOWS SEEN TO DATE	27
# MISSING FISH ACCOUNTED FOR	5
# TOTAL UP VIDEO	155
# TOTAL DOWN VIDEO	0
# UP OVERFLOW	35
# DOWN OVERFLOW	0
# UP ORIFICE	120
# DOWN ORIFICE	0
# VIDEO PASSAGE EVENTS	155
# NOSE UP BEHAVIOR	1
# NOSE DOWN BEHAVIOR	0
# OF PREVIOUS DAY FISH PASS	0
# IND. FISH USING O.F. 3 VIDEO WEIRS, 1+	16
# TOTAL O.F. USED BY PIT FISH	130

Appendix Table E3. Summary of observation and passage data for PIT and streamer-tagged fish passing he Washington shore weirs with PIT-tag detectors and cameras (37, 52, 53, and 56) in fall 2001.

	FALL TOTALS	9/26/2001	9/25/2001	9/19/2001	9/18/2001
# SALMONIDS TAGGED	278	85	72	90	31
# CHINOOK TAGGED	158				
# STEELHEAD TAGGED	88				
# COHO TAGGED	32				
# PASS AT NIGHT	1	0	0	0	1
# PASS NEXT DAYS	13	5	4	4	0
# PASS BUT NOT MONITORING	3	2	0	1	0
# PIT SYSTEM NEVER DETECTED	26	8	7	7	4
# CHINOOK NEVER DETECTED	15				
# STEELHEAD NEVER DETECTED	4				
# COHO NEVER DETECTED	7				
# DOWNSTREAM WEIR 37	5	1	1	1	2
# VISUAL TAGS LOST	5	1	2	0	2
# PASS ORIFICE-NO PIT DET. FISH	1	0	0	1	0
# PASS ORIFICE-NO PIT DET. WEIRS	1	0	0	1	0
# PASS ORIFICE-NO VIDEO DET. WEIRS	4	0	1	3	0
# POTENTIAL OVERFLOW PASSES	197	59	41	68	29
# OVERFLOWS SEEN TO DATE	41	8	2	23	8
# MISSING FISH ACCOUNTED FOR	4	0	0	3	1
# TOTAL UP VIDEO	793	240	205	262	86
# TOTAL DOWN VIDEO	16	6	1	6	3
# UP OVERFLOW	197	59	41	68	29
# DOWN OVERFLOW	0	0	0	0	0
# UP ORIFICE	596	181	164	194	57
# DOWN ORIFICE	16	6	1	6	3
# VIDEO PASSAGE EVENTS	809	246	206	268	89
# NOSE UP BEHAVIOR	1	0	1	0	0
# NOSE DOWN BEHAVIOR	4	0	4	0	0
# OF PREVIOUS DAY FISH PASS	4	2	0	2	0
# IND. FISH USING O.F. 3 VIDEO WEIRS, 1+	9	3	2	4	0
# TOTAL O.F. USED BY PIT FISH	530	166	104	179	81

APPENDIX F

Appendix Table F1. Overflow use by PIT-tagged fish at the Washington shore, 2001.

# OVERFLOW WEIRS USED	# SPRING CHINOOK	% SPRING CHINOOK	# SPRING STEELHEAD	% SPRING STEELHEAD
0	239	78.9%	5	38.5%
1	19	6.3%	1	7.7%
2	12	4.0%	0	0.0%
3	3	1.0%	1	7.7%
4	3	1.0%	0	0.0%
5	1	0.3%	0	0.0%
6	4	1.3%	2	15.4%
7	1	0.3%	2	15.4%
8	5	1.7%	1	7.7%
ORIFICE DETECTORS MISSED	3	1.0%	1	7.7%
DOWNSTREAM	13	4.3%	0	0.0%
TOTAL	303	100%	13	100%

Appendix Table F2. Overflow use by PIT-tagged fish at the Washington shore, 2001.

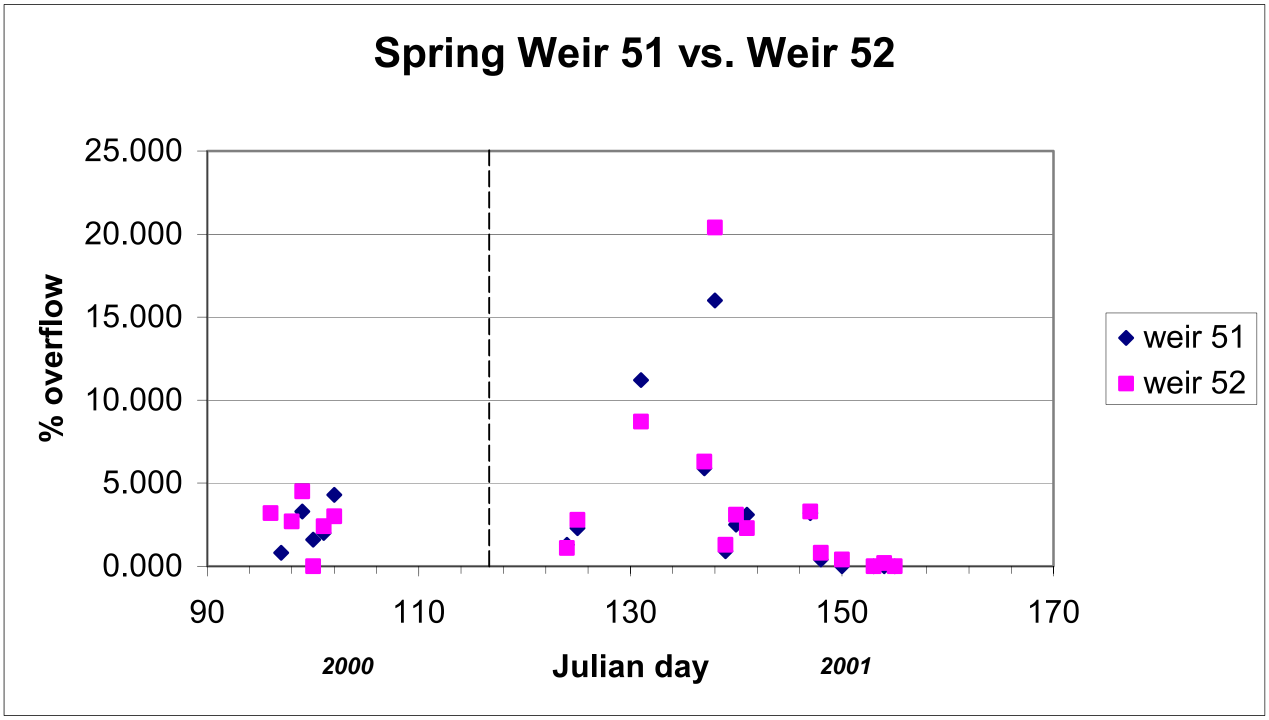
# OVERFLOW WEIRS USED	# SUMMER CHINOOK	% SUMMER CHINOOK	# SUMMER STEELHEAD	% SUMMER STEELHEAD
0	12	33.3%	1	6.3%
1	15	41.7%	4	25.0%
2	3	8.3%	2	12.5%
3	1	2.8%	0	0.0%
4	1	2.8%	0	0.0%
5	0	0.0%	1	6.3%
6	1	2.8%	3	18.8%
7	1	2.8%	1	6.3%
8	2	5.6%	4	25.0%
ORIFICE DETECTORS MISSED	0	0.0%	0	0.0%
DOWNSTREAM	0	0.0%	0	0.0%
TOTAL	36	100%	16	100%

Appendix Table F3. Overflow use by PIT-tagged fish at the Washington shore, 2001.

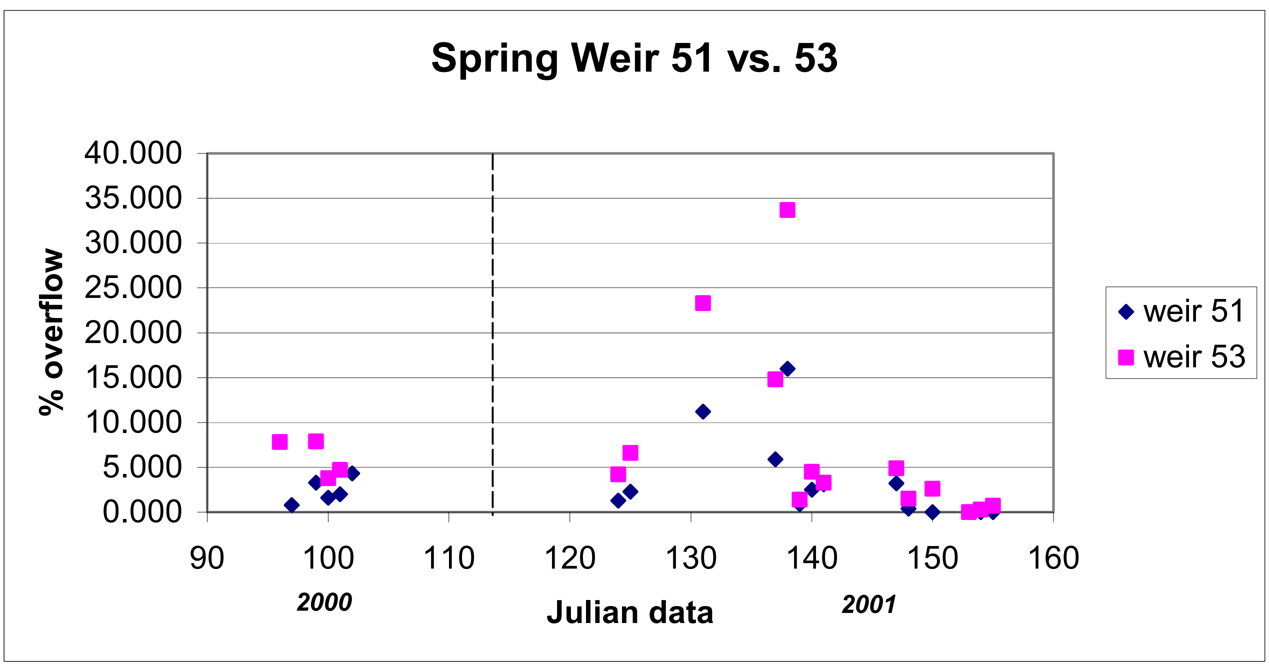
# OVERFLOW WEIRS USED	# FALL CHINOOK	% FALL CHINOOK	# FALL STEELHEAD	% FALL STEELHEAD	# FALL COHO	% FALL COHO
0	74	46.8%	61	69.3%	8	25.0%
1	16	10.1%	5	5.7%	6	18.8%
2	12	7.6%	3	3.4%	2	6.3%
3	8	5.1%	3	3.4%	2	6.3%
4	7	4.4%	1	1.1%	3	9.4%
5	11	7.0%	2	2.3%	1	3.1%
6	6	3.8%	4	4.5%	1	3.1%
7	7	4.4%	2	2.3%	2	6.3%
8	15	9.5%	4	4.5%	7	21.9%

ORIFICE DETECTORS MISSED	0	0.0%	0	0.0%	0	0.0%
DOWNSTREAM	2	1.3%	3	3.4%	0	0.0%
TOTAL	158	100%	88	100%	32	100%

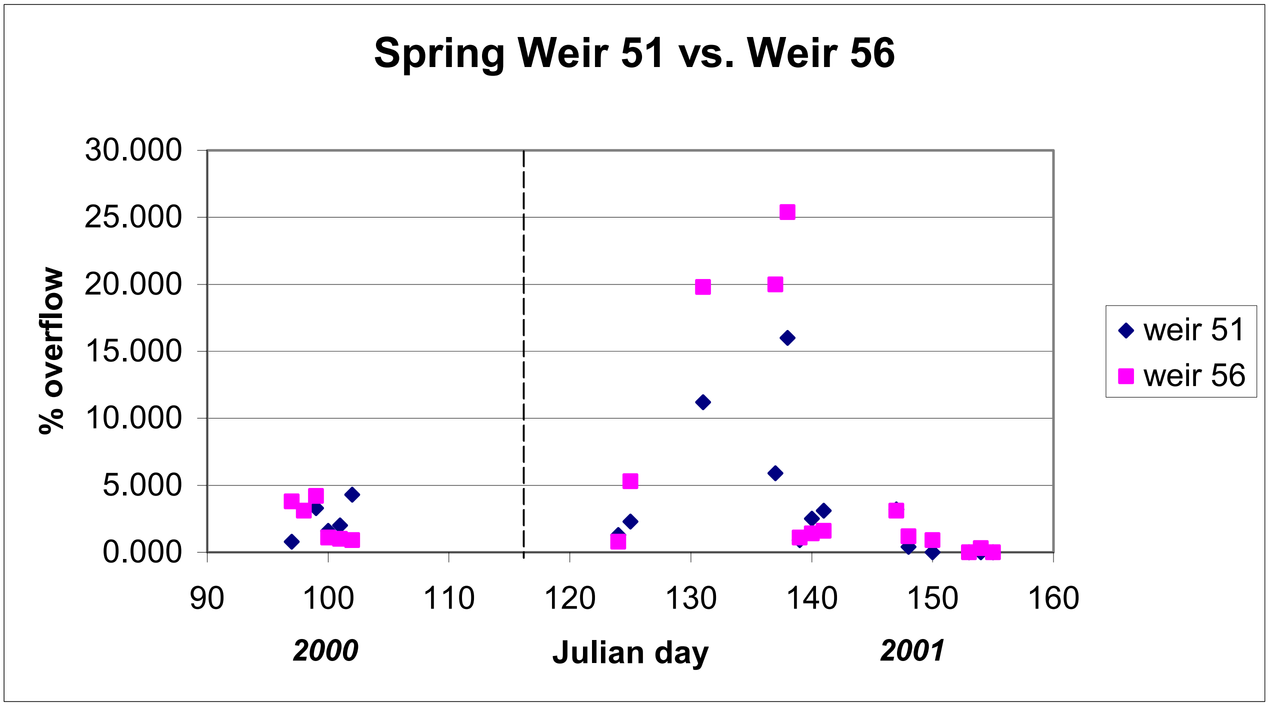
APPENDIX G



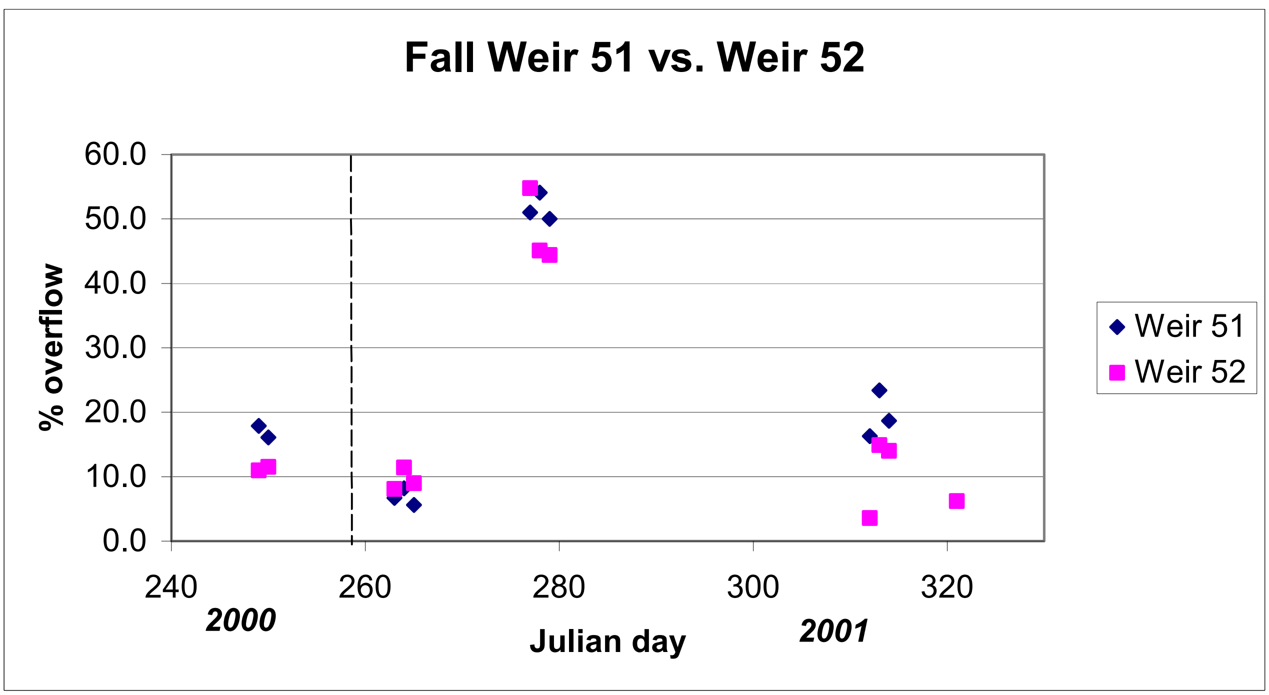
Appendix Figure G1. Spring overflow rates weir 51 and 52, 2000 and 2001.



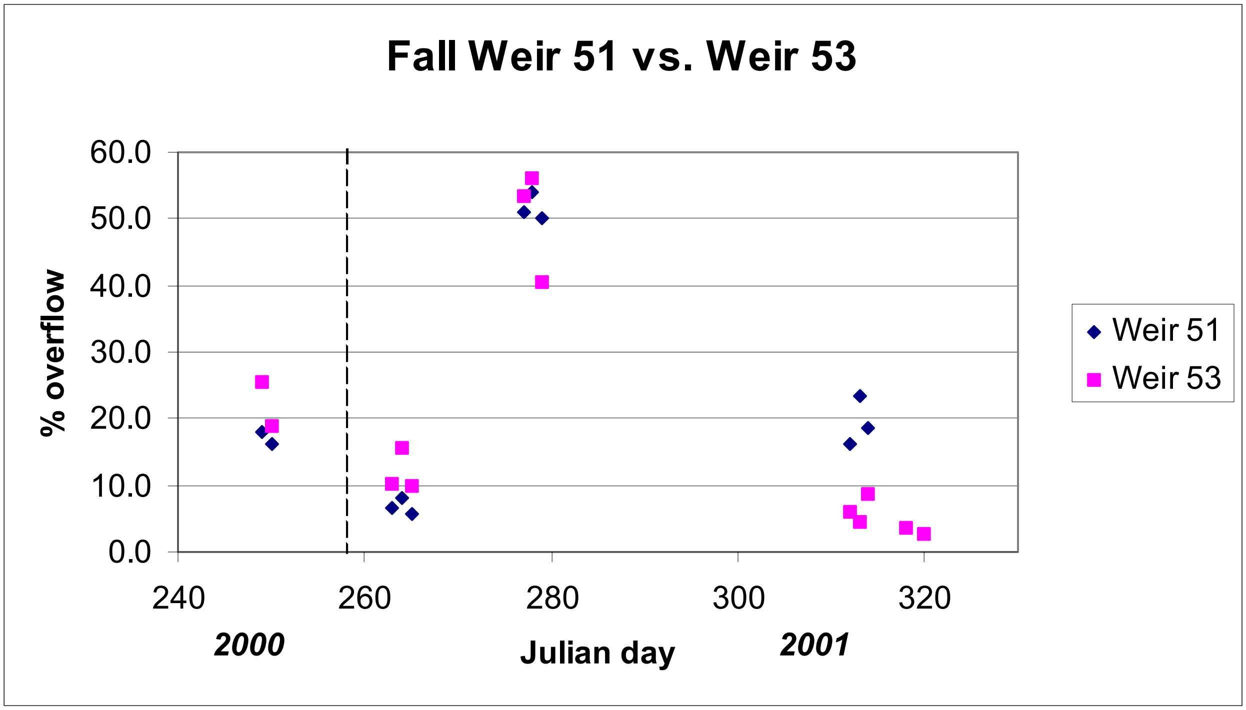
Appendix Figure G2. Spring overflow rates weir 51 and 53, 2000 and 2001.



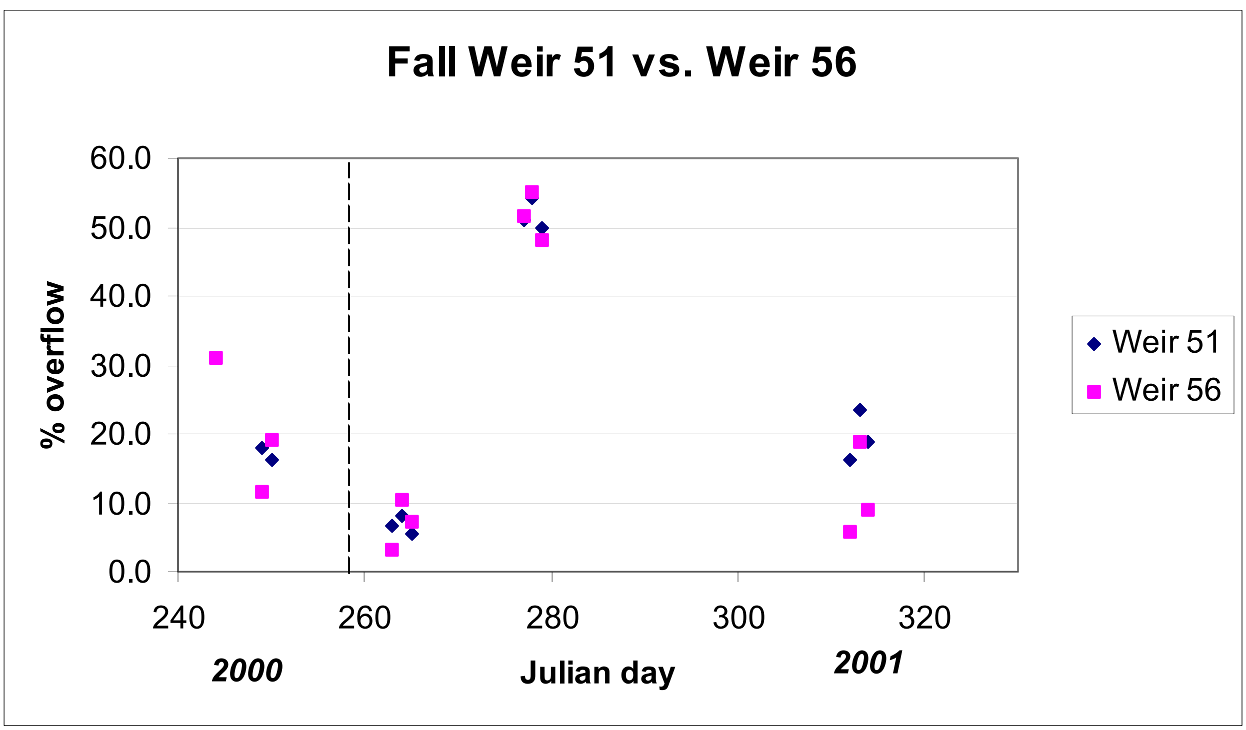
Appendix Figure G3. Spring overflow rates weir 51 and 56, 2000 and 2001.



Appendix Figure G4. Fall overflow rates weir 51 and 52, 2000 and 2001.



Appendix Figure G5. Fall overflow rates weir 51 and 53, 2000 and 2001.



Appendix Figure G6. Fall overflow rates weir 51 and 56, 2000 and 2001.