Study Report
Yr 2 Spring Chinook Adult Passage Viability Study
July 5, 2016

Purpose
To conduct a viability study to evaluate the efficacy of employing the Whooshh Fish Transport System (WFTS) to safely transport live spring Chinook.

Introduction
The Cle Elum Supplementation and Research Facility (CESRF) in the Washington Yakima River basin has an integrated spring Chinook Salmon hatchery program designed to increase natural production. The program has been in place since the late 1990's and has proven to be successful at increasing salmon returns to the basin and reducing the risks of repopulation genetic effects that have confounded conventional salmon hatcheries. The program involves a long-term comprehensive monitoring program tied together with the hatchery propagation program which are controlled and designed to accommodate additional arms of research investigation (Fast, 2015). The second consecutive year of evaluating the WFTS in terms of transport-associated adult survival, production spawning and egg viability is complete. The study has been conducted in partnership with the Yakama Nation engaging their operations and expertise at RAMF (Roza Adult Monitoring Facility) and CESRF.

It has been reported that dams impact anadromous fish species in a number of ways from inundating shoreline and spawning areas to changing the flow patterns of rivers, creating reservoirs and still water which can result in a rise in water temperatures with a domino of ecosystem impacts (Harrison, 2008). The most obvious impediment however is that dams block anadromous fish passage between spawning, juvenile habitats and the ocean. The spawning migrations of Pacific salmon are fueled by energy stores acquired during ocean residency prior to entering freshwater rivers and streams (Nadeau, 2010). Because salmon populations have genetic adaptations optimized for migration efficiency for specific river conditions, it is expected that the stresses encountered in travel through man-made passage facilities could have negative implications regarding spawning success. Man-made passage impediments often require additional travel time and energy expenditures for the fish. Traditional ladder passage may cause fish to tap into energy reserves as they are forced to swim through a series of high gradient cascades to pass the barrier. This output of energy may deplete a portion of the population inhibiting them from reaching the spawning grounds or having adequate energy remaining for spawning. In addition, there is growing evidence that dam-associated increases in water temperature, which often feed the upper section of ladders by gravity, is contributing to downstream fallback and represents a significant migration obstacle concern (Crozier, 2013 and Caudill, 2013).

With the WFTS, it is possible to implement rapid, safe fish passage with minimal fish energy expenditure. WFTS is an innovative fish passage system developed by Whooshh Innovations,

LLC (Whooshh) that utilizes a novel differential pressure system to facilitate movement of individual fish through a soft tube structure in a matter of seconds. The tube is made of a flexible material which is highly adaptable to location needs and challenges, and provides the ability to direct entry and exit at desired locations (Whooshh, 2016). A number of successful studies and applications have been conducted employing 40 and 250 ft tubes to transfer fish from holding tanks and traps in rivers to haul trucks and raceways. In a comparative study conducted by PNNL, evaluating fish well-being of net capture and haul, to a 40 or 250 ft WFTS tube transfer yielded favorable results with the WFTS transported fish, (both 40 ft and 250 ft transport) demonstrating equal to or better outcomes in health, survival and reproduction measures (PNNL, 2014). With the ability to alter the pressure, the system is designed such that deceleration at exit can be achieved to NMFS standards. The current study results compare two consecutive years of adult survival, production spawning and egg viability data of standard hand carriage verses WFTS transported spring Chinook taken at the RAMF and monitored as part of the CESRF.

Methods

Typically, a total of ~400-600 adult spring Chinook salmon are transported from the RAMF to the CESRF via established protocols and trained Yakama Nation (YN) personnel (Fast, 2015). In the past two years, after measurements and tagging, a percentage of fish have been hand carried to a haul truck and the remaining WFTS transported directly into the truck. The WFTS represents ~40 ft of tube through which the fish is transported from the RAMF into the haul truck. The fish are randomly selected for hand carriage verse WFTS 40 transport and together compose the necessary population required for the CESRF program.

Trained YN personnel manage the fish trafficking, monitoring, measuring, tagging and transport methods. Measuring and tagging were conducted after the fish were mildly anesthetized in a MS-222 solution. Hand carriage fish are carried while in this state as the calm state helps to prevent dropping or damaging the fish. WFTS selected fish will be allowed to partially recover from anesthetic treatment prior to loading into the system. The safety of the fish at exit of WFTS is greatly benefitted by non-anesthetized freedom to move its tail, to turn and swim. The behavior of the fish after they enter the haul truck tanks was visually observed. Standard behavior of swimming in a righted position, collecting near the bottom of the tank, and typical fish to fish interactions were considered.

Once in the hauling truck, all fish, regardless of study group, were treated in an identical manner. They were hauled to the Cle Elum hatchery in trucks within chilled, oxygenated tanks at which point the fish were moved into holding raceways until spawning. Standard hatchery practices were employed with regard to feeding, water flow etc. At spawning 3x3 crosses were performed to allow for viability assessment without single pairing incompatibility confounders. The fertilized eggs were handled per CESRF protocol, physically shocked, sorted and counted.

Results

In 2014, 466 spring Chinook were transported from RAMF to CESRF whereas in 2015, 562 spring Chinook were transported. In both years 13.9% of the fish were transported via 40 ft WFTS. There were some gender differences in terms of counts within the groups and across the years. This is most readily viewed by comparing the female to male ratios. The ratios between the study groups were closer in 2015 at 1.64 to 1 for the hand and haul group verses 1.89 to 1 for the Whooshh group (Table 1). In all cases, across study group and year, the take was predominantly female.

Table 1. Comparison of the hand and haul (H&H) and Whooshh transported groups of fish. Gender and female/male ratio data are captured as the composition of the group may influence outcome interpretation. 2014 data are in shades of green and 2015 data in shades of blue. (* = Acct'd w/known/true sex, ** Hand & Haul = Non-Whooshh)

Chinook Sampled*		
	H&H**	WHOOSHH
2014 Total = 466		
Females	218	43
Males	183	22
Ratio Female/Male	1.19/1	1.95/1
2015 Total = 562		
Females	301	51
Males	103	27
Ratio Female/Male	1.64/1	1.89/1

The overall composition of the fish in the study groups and across the two years, 2014 and 2015, were very similar. It was observed that there was a slight decline in 2015 in body weight compared to 2014 (Table 2).

2015 has been called a drought year with excessive temperatures reached over a considerable length of time during the spring, summer and fall seasons. This temperature excess impacted water temperatures and resulted in an increase in adult mortality numbers across the board. In 2014 the adult mortality of Whooshh transported fish appeared to be slightly less than the hand carriage group, however, the significance of the observation may be artificially accentuated due to unequal study group sizes and differences noted in the female/male ratios within the test groups (Table 3). Adult female survival was notably better than male survival in 2014. This gender mortality difference was not observed in 2015. In 2015 the female/male ratios were similar in the study groups, however, the disparity in study group sizes remained resulting in the potential of a larger percentage shift due to a single mortality event in the Whooshh test group as the number of samples in that group was considerably smaller. Overall the adult mortality was similar between the study groups, a consistent finding across two consecutive years.

Table 2. Recorded measurements of the 2014 and 2015 Whooshh transported fish. 2014 data are in shades of green and 2015 data in shades of blue.

	2014 Whooshh Transported Chinook				2015 Whooshh Transported Chinook			
Female	**Forklength**	**Pohlength**	**Weight**	**Age**	**Forklength**	**Pohlength**	**Weight**	**Age**
Ave	70.23	60.19	4.73	~4	70.76	60.69	4.17	~4
Max	80	70	6.8		78	67	5.3	
Min	64	54	3.4		62	52	3	
Count	43	43	43		51	51	51	
Male								
Ave	71.18	59.91	4.78	~4	71.44	69.33	4.13	~4
Max	78	66	5.9		77	66	5.4	
Min	63	52	3		62	52	3	
Count	22	22	22		27	27	27	
Total								
Ave	70.55	60.09	4.74	~4	71	60.56	4.16	~4
Max	80	70	6.8		78	67	5.4	
Min	63	52	3		62	52	3	
Count	65	65	65		78	78	78	

Table 3. Adult Mortality percentages for Hand carriage verses Whooshh transported in 2014 and 2015. 2014 data are in shades of green and 2015 data in shades of blue. (Includes pre-spawn and sort mortality)

2014 CHINOOK	H&H	WHOOSHH
Female Mortality	4.6%	2.3%
Male Mortality	15.3%	9.1%
Total Mortality	9.5%	4.6%
2015 CHINOOK	H&H	WHOOSHH
Female Mortality	26.8%	29.4%
Male Mortality	27.9%	11.1%
Total Mortality	27.5%	23.1%

Of the fish transported to CESRF, the vast majority fall into the wild/natural subpopulation category. The size of this subpopulation in both study groups was of sufficient size to make comparisons with regard to female production spawning. Whooshh transported fish made up 14.8% of the wild/natural subpopulation take in both 2014 and 2015 (Table 4). Because there

was significant adult mortality across the study groups in 2015, the impact of the elevated temperatures, and a few cases noted in the data in which fish were not tested or released back into the river, the percentage of production spawners shifted slightly from the take percentages, although the shift was not significant. The data indicated no significant differences in spawning between the study groups across two years of testing.

Table 4. Data from the female wild/natural subpopulation within the study. Total count numbers of wild/natural females and the percentage of the wild/natural females taken are present on the left (these numbers do not account for adult mortality). Those females that survived and actively spawned are indicated in count and percentage on the right. 2014 data are in shades of green and 2015 data in shades of blue.

2014 Wild Females	Counts	Percentage	**2014 Wild Spawners**	Counts	Percentage
TOTAL	196		TOTAL	188	
WHOOSHH	29	14.8%	WHOOSHH	29	15.4%
Non-WHOOSHH	167	85.2%	Non-WHOOSHH	159	84.6%
2015 Wild Females			**2015 Wild Spawners**		
TOTAL	257		TOTAL	181	
WHOOSHH	38	14.8%	WHOOSHH	25	13.8%
Non-WHOOSHH	219	85.2%	Non-WHOOSHH	156	86.2%

The eggs and milt were collected and 3x3 crosses conducted. After physical shock, sorting and counting, it was observed that, (as is consistently observed at CESRF) a very high egg survival rate was achieved in both 2014 and 2015 and within both of the study groups (Table 5). The differences in study group percentages are not statistically significant. Nearly identical egg survival rates were achieved across the two years of study.

Table 5. Egg viability data post shock. Percentage of live fertilized eggs after shock and sorting that were live are presented for the wild/natural take subpopulation for 2014 and 2015 described in Table 4. 2014 data are in shades of green and 2015 data in shades of blue.

Egg Viability	H&H	WHOOSHH
2014 Chinook: Wild/Natural	94.6%	92.1%
2015 Chinook: Wild/Natural	94.2%	92.8%

Conclusions

Two consecutive years of viability data have been collected on spring Chinook of the Yakima River transported after treatment at RAMF. The fish are collected and transported to the

hatchery associated with CESRF. Typically, the fish are hand hauled after measurements and tagging into a transport truck. For this study approximately 14% of the take have been transported through a 40 ft WFTS into the haul truck. The effects of transport, hand and haul verses WFTS, on adult survival, productive spawning and egg viability, were measured. The 2014 and 2015 data presented here demonstrate a definite trend in data reproducibility across years. There were no measureable differences in the survival assessments between WFTS transported and hand and haul transported fish (non-inferiority of WFTS survival measures relative to standard hand and haul was established), as evaluated by comparing adult mortality, production spawning and egg viability in the study groups. The data support the conclusion that the means of transport had no measurable impact on adult viability and reproduction potential.

In 2015, the excessive temperatures impacted all study groups at the level of adult survival. Mortality rates were elevated in all categories. Of those adults that survived to spawn, the temperature had no notable impact on their ability to spawn nor on the viability of the fertilized eggs.

The outcomes support the conclusion that the WFTS is a viable alternative to standard hand and haul methods from the fish safety perspective and provides a reduced risk benefit to the fish of damage due to accidental dropping. From the fish handler perspective, the WFTS is easy to use, fast, may reduce potential fish injury, and adds a measure of safety for the fish handler. All the evidence supports the use of the WFTS for safe transport of live fish.

References

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