An Evaluation of Increased Rearing Density to Improve Adult Returns of Spring Chinook Salmon Adults to Dworshak National Fish Hatchery

Annual Report of Progress
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DISCLAIMER

This report is intended to provide a summary of the data and information compiled to date and is not intended to provide detailed analysis or conclusions. The data is provisional and is subject to future revision and corrections. All questions about the validity or precision of information in this report should be directed to the Idaho Fishery Resource Office, Dworshak Fisheries Complex, U.S. Fish and Wildlife Service, (208) 476-7242.

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INTRODUCTION

The spring Chinook salmon production program at Dworshak National Fish Hatchery (NFH) began in 1982 as part of the Lower Snake River Compensation Plan (LSRCP) to help mitigate for the loss of spring Chinook salmon from the Clearwater River due to the construction of the four lower Snake River hydropower facilities downstream from Lewiston, Idaho (U.S. Army Corp of Engineers 1981). The mitigation goal for the program is to annually return 9,135 adults above Lower Granite Dam annually and provide 36,540 adults for harvest downstream of Lower Granite Dam in the lower Columbia and Snake rivers. In the original planning documents, the agencies estimated that Dworshak NFH would need to release 1.4 million smolts at a size of 20 fish per pound (total production of 70,000 lbs) to reach these goals. A more comprehensive review of the history of the development of the LSRCP and of Dworshak NFH from 1982 to 1990 is provided by Herrig (1990).

In 1998, the LSRCP conducted a program review (U.S. Fish and Wildlife Service 1998) followed by a subsequent review in December 2010 (http://www.fws.gov/lsnakecomplan/Meetings/2010SpringChinookHatcheryReviewSymposium.html). In the 2010 review, Dworshak NFH and the Idaho Fishery Resource Office presented information on smolt production, adult returns, and related metrics from 1996 through 2009. During that period, the program met the adult mitigation goal at Lower Granite Dam in 2001 but has never met the adult mitigation goal for the Columbia and Lower Snake rivers. However, the program has consistently provided sufficient adults to sustain sport and Tribal harvests every year since 1997, except for 1999. With continued concern of the Co-Managers and LSRCP over the inability of the program to meet the established adult mitigation goals, the Dworshak Fisheries Complex Hatchery Evaluation Team (HET) conducted a detailed review of the production program in February of 2011 to attempt to identify particular program components where improvements to fish cultural practices could be made. From 2005 to 2010, adult holding survival averaged 96%, survival of eggs from fertilization to enumerated eye-up averaged 97%, survival of eggs from eye-up to hatching averaged 99%, survival from eyed-egg to the time of marking of juveniles averaged 92%, and survival of fish from marking to release as smolts averaged 98%. The overall on-station performance of the program from 1998 to 2009 averaged 83% survival. Juvenile survival from Dworshak NFH to Lower Granite Dam, estimated using PIT tags, averaged 80% from 1998 to 2010. From 2004 to 2007, the survival was just below 85% and in 2010 was just below 90%. Juvenile survival from Lower Granite Dam to Bonneville Dam from 1998 to 2009 averaged 51.8% (Tuomikoski *et al*. 2012) Performance indicators show that the program is producing a high quality smolt possessing the ability to successfully emigrate and survive to the ocean.

After examining all the various stages of production, the HET concluded that, while it may be possible to make minor incremental improvements in fish cultural practices, there was limited potential to significantly increase adult returns through these types of modifications. Since additional rearing space is currently not available at Dworshak NFH, the only reasonable alternative is to increase the density of smolts in the rearing space on hand. In 2011, the Dworshak Complex HET completed an assessment and submitted a proposal to the Co-Managers to evaluate increased rearing densities (Dworshak Complex Hatchery Evaluation Team 2011). The goal of this evaluation project is to determine the maximum effective carrying capacity of spring Chinook salmon in raceways at Dworshak NFH.

This report presents a summary of data collected during the hatchery rearing and smolt emigration phases for BY 2012. Detailed information on the physical characteristics of the hatchery, the project design, and methods are presented in the Project Study Plan (Dworshak Fisheries Complex Hatchery Evaluation Team 2013).

METHODS

The experiment is designed to determine the maximum effective carrying capacity of the raceways for rearing spring Chinook salmon. **Figure 1** shows the schematic layout of the treatment (High Density – 65,000 fish/raceway) and control (Normal Density – 45,000 fish/raceway) groups in the B-Bank raceways. Parental Based Tagging (PBT) is being used to track the adult returns. Secondary variables measured to help interpret results included growth, fish condition, mortality, fish health, and smolt emigration time and survival.

Figure 1. Organization of the density experiment in the spring Chinook salmon raceways at Dworshak National Fish Hatchery. There are three replicate raceways in each treatment, (designated by R).

High Density						Normal Density								
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
R1	R1	R2	R2	R3	R3	R1	R1	R1	R2	R2	R2	R3	R3	R3

The number of adults that return from each replicate will be used to test for a significant difference in mean adult returns between the Treatment and Control using a one-tailed T-Test ($p \leq 0.05$). The first adult returns will be the 1-Ocean returns from BY2012 released in April 2014.

Growth was monitored by measuring fork length, weight, and condition factor monthly from the time of ponding in October 2013 to time of smolt release in April 2014. One raceway per replicate was randomly selected and a random sample of 300 fish was collected. Individual fish were measured for fork length (nearest mm) and weight (nearest 0.1 gram). Condition factors were calculated using the formula for K (Anderson and Guteuter 1983). The data were used to calculate means for each replicate. Significant differences in mean length, mean weight, and mean condition factor between the High and Normal Density groups were determined using a repeated-measures ANOVA ($p \leq 0.05$).

Mortalities in every raceway were collected daily. The data were used to calculate the mean monthly mortality and the mean monthly mortality rate in each replicate. A significant difference in mortality rates between the High and Normal Density groups was determined using a repeated-measures ANOVA ($p \leq 0.05$).

Smolt performance to Lower Granite Dam was evaluated using PIT tags representing both treatment groups. Measures of smolt performance evaluated were emigration time and survival to Lower Granite Dam. Survival probabilities through the Federal Columbia River Power System (FCRPS) were calculated for each replicate in both treatment groups using SURvival under Proportional Hazards 2.1 (SURPH) (Lady *et al*. 2001). Survival probabilities for each replicate

were calculated and a mean survival estimates were estimated for each treatment. A one-tailed two-sample T-test ($p \leq 0.05$) was used to test for a significant difference in juvenile survival between the treatment groups.

Travel times to Lower Granite Dam were calculated for each replicate using SURvival under Proportional Hazards 2.1 (SURPH) (Lady *et al*. 2001) and a mean travel time was estimated for each treatment. A one-tailed two-sample T-test ($p \leq 0.05$) was used to test for a significant difference in travel times between the treatment groups.

RESULTS

Creation of Parental Based Tag Groups

A total of 243 BY2012 adult female Chinook salmon were used to create three replicate groups each for the Normal and High Density treatments. These replicates are being used to compare the performance of the two treatments during on-station production, during smolt emigration, and will be used to compare adult returns to the hatchery from the ocean.

Pre-Release Sampling

Fish were randomly collected from each High Density and Normal Density replicate and were assigned using PBT to Dworshak NFH's BY2012 broodstock to check the accuracy of the loading plan used for the juveniles. PBT assignments are provided for 44 samples (**Table 1**). Two samples failed to genotype and one sample failed to assign to parents. The assignment rate of this collection (99.2%) is not significantly different (binomial test, P = 0.39) from the PBT rate (99.5%) of Dworshak NFH's BY2012 Chinook broodstock. Using the genetic ID of the PBT-determined mother, the intended destination and density treatment of her offspring was compared to the location where the sample was taken (**Table 1**). One sample (OtsDWOR12B_0028) assigned to a mother for which no loading data was available. The intended destination of all other assigned samples could be determined.

Table 1. PBT assignment results of BY2012 spring Chinook salmon fingerlings being raised at High and Normal (Control) Densities at Dworshak NFH.

Eagle Fish Genetics Lab ID	Field ID	Genetic ID of Mother	Treatment
OtsDWOR12B_0046	16A	Genotyped but did not assign	
OtsDWOR12B_0047	16B	OtsDWOR12S_0362	High Density Replicate 1
OtsDWOR12B_0048	16C	OtsDWOR12S_0334	High Density Replicate 1
OtsDWOR12B_0049	17A	OtsDWOR12S_0362	High Density Replicate 1
OtsDWOR12B_0050	17B	OtsDWOR12S_0345	High Density Replicate 1
OtsDWOR12B_0051	17C	OtsDWOR12S_0303	High Density Replicate 1
OtsDWOR12B_0052	18A	OtsDWOR12S_0856	High Density Replicate 2
OtsDWOR12B_0053	18B	OtsDWOR12S_0857	High Density Replicate 2
OtsDWOR12B_0054	18C	OtsDWOR12S_0836	High Density Replicate 2

OtsDWOR12B_0055	19A	OtsDWOR12S_0836	High Density Replicate 2
OtsDWOR12B_0056	19B	OtsDWOR12S_0861	High Density Replicate 2
OtsDWOR12B_0057	19C	OtsDWOR12S_0861	High Density Replicate 2
OtsDWOR12B_0058	20A	OtsDWOR12S_1285	High Density Replicate 3
OtsDWOR12B_0059	20B	OtsDWOR12S_1286	High Density Replicate 3
OtsDWOR12B_0060	20C	OtsDWOR12S_0800	High Density Replicate 3
OtsDWOR12B_0061	21A	OtsDWOR12S_1288	High Density Replicate 3
OtsDWOR12B_0062	21B	OtsDWOR12S_1281	High Density Replicate 3
OtsDWOR12B_0063	21C	Sample Failed to Genotype	
OtsDWOR12B_0064	22A	Sample Failed to Genotype	
OtsDWOR12B_0065	22B	OtsDWOR12S_0342	Normal Density Replicate 1
OtsDWOR12B_0066	22C	OtsDWOR12S_0376	Normal Density Replicate 1
OtsDWOR12B_0067	23A	OtsDWOR12S_0338	Normal Density Replicate 1
OtsDWOR12B_0068	23B	OtsDWOR12S_0366	Normal Density Replicate 1
OtsDWOR12B_0069	23C	OtsDWOR12S_0352	Normal Density Replicate 1
OtsDWOR12B_0070	24A	OtsDWOR12S_0352	Normal Density Replicate 1
OtsDWOR12B_0071	24B	OtsDWOR12S_0365	Normal Density Replicate 1
OtsDWOR12B_0072	24C	OtsDWOR12S_0352	Normal Density Replicate 1
OtsDWOR12B_0073	25A	OtsDWOR12S_0872	Normal Density Replicate 2
OtsDWOR12B_0074	25B	OtsDWOR12S_0887	Normal Density Replicate 2
OtsDWOR12B_0075	25C	OtsDWOR12S_0888	Normal Density Replicate 2
OtsDWOR12B_0076	26A	OtsDWOR12S_0887	Normal Density Replicate 2
OtsDWOR12B_0077	26B	OtsDWOR12S_0891	Normal Density Replicate 2
OtsDWOR12B_0078	26C	OtsDWOR12S_0872	Normal Density Replicate 2
OtsDWOR12B_0079	27A	OtsDWOR12S_0879	Normal Density Replicate 2
OtsDWOR12B_0080	27B	OtsDWOR12S_0879	Normal Density Replicate 2
OtsDWOR12B_0081	27C	OtsDWOR12S_0870	Normal Density Replicate 2
OtsDWOR12B_0082	28A	OtsDWOR12S_1231	Normal Density Replicate 3
OtsDWOR12B_0083	28B	OtsDWOR12S_1222	Normal Density Replicate 3
OtsDWOR12B_0084	28C	OtsDWOR12S_1240	Normal Density Replicate 3
OtsDWOR12B_0085	29A	OtsDWOR12S_1232	Normal Density Replicate 3
OtsDWOR12B_0086	29B	OtsDWOR12S_1236	Normal Density Replicate 3
OtsDWOR12B_0087	29C	OtsDWOR12S_1234	Normal Density Replicate 3
OtsDWOR12B_0088	30A	OtsDWOR12S_1225	Normal Density Replicate 3
OtsDWOR12B_0089	30B	OtsDWOR12S_0804	Normal Density Replicate 3
OtsDWOR12B_0090	30C	OtsDWOR12S_0807	Normal Density Replicate 3

Cost/Benefit Analysis

We estimated that using a 20,000 smolt difference between each High Density and Normal Density raceway, and an average of 3,750 eggs per female, it would require at least seven females to produce the additional 20,000 smolts for the High Density treatment (20,000 smolts / 0.83 survival from eyed-egg to smolt / 3,750 eggs per female). Using 1:1 male to female spawning requires at least 14 adults returning per raceway for replacement. Therefore, if less than equal performance of the High Density treatment occurs, the High Density treatment needs to return more than 14 adults per raceway over the number of adults returned by the Normal Density treatment. That number will be determined from a production management perspective involving a cost/benefit analysis, regardless of whether or not we have statistically useful information.

Listed below, are the various activities identified where costs could reasonably be estimated. Those costs were applied to estimate the extra expense of the additional spawning required and rearing the additional number of fish in the High Density treatment.

Spawning - Increasing density required spawning an extra seven females and seven males to produce about 20,000 fish per raceway. The cost in terms of spawning each adult pair can be estimated by multiplying the average amount of time it requires to bring the fish from the sorting table, to the spawning table, and transferring the fertilized eggs to the incubation room by the total hourly cost of spawning room operations. **Table 2** lists the various spawning room activities that occur and the average hourly cost per position.

The best estimated time required for spawning a male/female pair, from the time of sorting to placing the eggs in incubation trays is about 10 minutes or 0.1667 hours. Cost per pair spawned is estimated to be 0.1667 hours X $330.00 per hour = $55.00 per pair. Total cost to spawn an additional seven pairs to produce 20,000 additional smolts per raceway would be $385.00.

NOTE: For BY2012, we used eggs from a total of 118 different females for the High Density treatment, or an average of 19.6 females per raceway. We used 126 different females for the Normal Density treatment, or an average of 14 females per raceway, a difference of 5.6 females per raceway. The difference is explained by the actual fecundity of about 3,500 eggs per female. However, this may be an artifact of the process of maintaining the genetic integrity of each replicate for the PBT analysis, where eggs from the same female cannot be used in two separate replicates.

Incubation – Activities associated with incubation includes planning and tracking, shocking, enumeration, cleaning and removing dead eggs, and formalin treatments. Initial incubation requires each female to be placed into individual trays until disease testing is completed. At 3,750 eggs per female on average, this required about 32 trays. After enumeration, trays are re-filled with about 5,000 eggs per trays, resulting in about 24 trays of eggs for the High Density treatment. The total cost for the extra 120,000 eggs for the High Density raceways is listed in **Table 3** below and is estimated to be $ 246.00 per raceway ($1476.00 / 6 High Density raceways).

Table 2. Activities required for spring Chinook salmon spawning and the average hourly cost per position.

Position	Activity	Average Hourly Cost
Operations Supervisor	Directs the flow of activity and insures quality control.	$44.80
Crowder/Anesthetics	Delivers fish from holding ponds to sorting table.	$23.20
Sorter	Identifies and delivers sexually mature fish to the spawning tables. Returns sexually immature fish to the holding ponds.	$37.80
Male Spawners (2)	Assigns each fish an identification number and extracts milt.	$75.60
Female Spawner	Assigns each fish an identification number and extracts the eggs.	$37.80
Bucket Runner	Delivers eggs to fertilization room.	$25.20
Fertilization	Fertilizes eggs with milt; Records male and female numbers to track spawning pairs for genetic tracking. Supervises incubation room activities.	$37.80
Rinsing	Rinses fertilized eggs with fresh water to remove blood, tissue, and other foreign materials. Delivers eggs for incubation.	$10.00
Incubation Operator	Prepares incubation trays for receiving fertilized eggs. Insures eggs are properly deposited in incubation trays.	$37.80
Total Cost per Hour		**$330.00**

Table 3. Activities associated with incubation and the estimated related costs. Costs are calculated based on following hourly rates of $38.00 for maintenance worker, $35.00 for animal caretaker, and $46.00 for a biologist.

Activity	Personnel and Time Required	Total Cost
Planning and Tracking	Biologist – 6 hours	$276.00
Shocking	Biologist and Animal Caretaker – 1.5 hours	$125.00
Formalin Treatments		$70.00
Cleaning and Dead Egg Removal	Animal Caretaker – 24 hours	$840.00
Enumeration	Biologist – 6 hours	$276.00

Ponding – Moving 24 trays of hatched eggs from the incubation room to the raceways for rearing requires a Biologist and an Animal Caretaker about 1 hour, costing about $120.00

Feeding – From October 2013 to April 2014, The cost of feeding an extra 20,000 fish/raceway for the High Density treatment was estimated at $1,115.27 or $6,691.62 total.

Clipping – The cost for adipose fin clipping is about $20.00 per thousand. High density raceways will require an extra 20,000 fish per raceway for a total estimated cost of $2400.00.

Fish Health – Every spawned female has kidney tissue collected to test for Bacterial Kidney Disease using ELISA. In addition, approximately 50 spawned females have samples of ovarian fluids taken to test for viruses. The cost of fish health sampling was estimated to be about $48.00 per female.

Growth

Table 4 lists the mean length, mean weight, and mean condition factor for each treatment from October 2013 to March 2014.

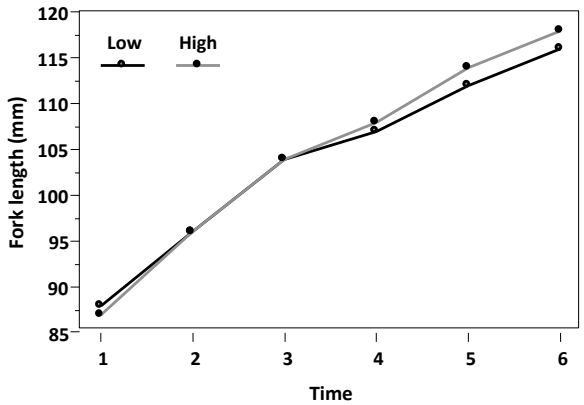
Results of repeated measures ANOVA for Fork Length:

Mean fork length did not vary significantly ($P = 0.6$) between fish from the two density treatments. Mean fork length calculated jointly between fish from the two density treatments increased significantly ($P < 0.0001$) over time. The Trt*Time interaction was not significant ($P = 0.08$) at $\alpha = 0.05$, but it was significant at $\alpha = 0.10$. The interaction plot indicates that growth in FL of fish reared at high densities was higher than growth in fork length of fish reared at low densities from time intervals 3 to 6.

Type 3 Tests of Fixed Effects for fork length.

Effect	Num DF	Den DF	F Value	Pr > F
Trt	1	4	0.3	0.6127
Time	5	20	844.5	<.0001
Trt*Time	5	20	2.3	0.083

Interaction plot for mean fork length.



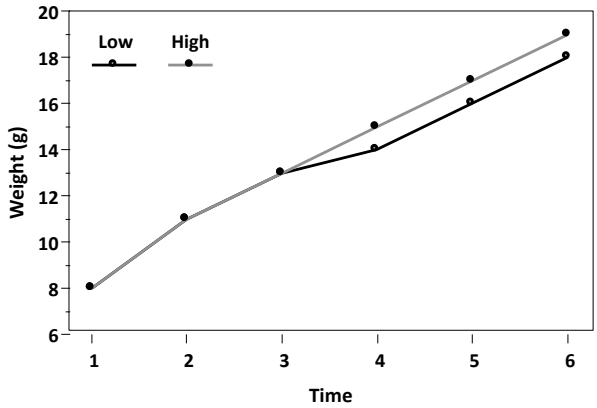
Results of repeated measures ANOVA for Weight:

Mean weight did not vary significantly ($P = 0.3$) between fish from the two density treatments. Mean weight calculated jointly between fish from the two density treatments increased significantly ($P < 0.0001$) over time. The Trt*Time interaction was significant ($P = 0.005$). The interaction plot indicates that growth in weight of fish reared at high densities was higher than growth in weight of fish reared at low densities from time intervals 3 to 6.

Type 3 Tests of Fixed Effects for weight

Effect	Num DF	Den DF	F Value	Pr > F
Trt	1	4	1.38	0.3047
Time	5	20	890.17	<.0001
Trt*Time	5	20	4.82	0.0047

Interaction plot for mean weight



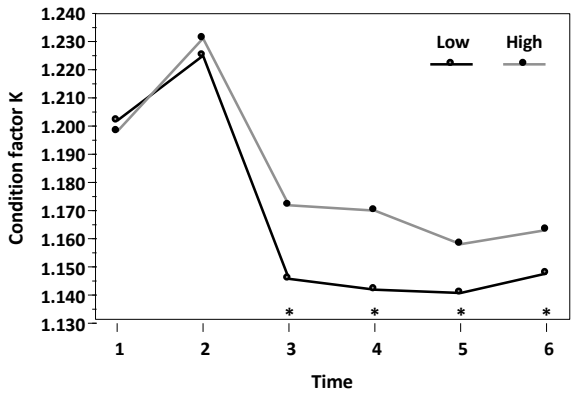
Results of repeated measures ANOVA for Condition Factor K:

Mean K varied significantly ($P = 0.05$) between fish from the two density treatments. Mean K calculated jointly between fish from the two density treatments increased significantly ($P < 0.0001$) over time. The Trt*Time interaction was not significant ($P = 0.7$), but the interaction plot is useful for identifying significant pairwise comparisons (results given in [*] and below plot [*P* values]).

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	1	4	7.52	0.0518
Time	5	20	14.87	<.0001
Trt*Time	5	20	0.56	0.7319

Interaction plot for mean K



t test results:

Time 1 $P = 0.7$
Time 2 $P = 0.9$
Time 3 $P = 0.04$
Time 4 $P = 0.02$
Time 5 $P = 0.03$
Time 6 $P = 0.008$

Table 4. Mean lengths, weights, and condition factors for the Normal and High Density treatments at Dworshak NFH.

Month	Normal Density						High Density					
	Fork Length (mm)		Weight (g)		Condition Factor (k)		Length (mm)		Weight (g)		Condition Factor (k)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
10/29/2013	88	0.57	8.2	0.11	1.20	0.01	87	1.30	8	0.37	1.19	0.01
11/29/2013	96	0.97	10.9	0.26	1.22	0.03	95	0.91	10.8	0.23	1.23	0.01
12/29/2013	104	1.32	13	0.56	1.14	0.01	103	0.73	13.1	0.24	1.17	0.01
1/29/2014	107	1.00	14.1	0.31	1.14	0.01	108	0.89	14.9	0.36	1.17	0.01
2/28/2014	112	0.70	16.2	0.32	1.14	0.01	114	0.52	17.4	0.26	1.16	0.01
3/21/2014	116	1.08	18.2	0.44	1.15	0.01	118	0.63	19.1	0.28	1.16	0.01

Mortality

Mean monthly mortality ranged from 8 to 48 fish per raceway (0.01 to 0.07% per raceway) for the High Density treatment and from 11 to 62 fish per raceway (0.02 to 0.14% per raceway) for the Normal Density treatment. The highest rate of mortality for both treatments occurred in October 2013. Conversely, the mean monthly survival rate for both treatments during all sampling periods was greater than 99%.

Results of repeated measures ANOVA:

Mean mortality rates did not vary significantly ($P = 0.06$) between fish from the two density treatments. Mean mortality rate calculated jointly between fish from the two density treatments varied significantly ($P < 0.0001$) among time intervals. The Trt*Time interaction was not significant ($P = 0.08$).

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	1	4	6.87	0.0587
Time	5	20	16.78	<.0001
Trt*Time	5	20	2.34	0.0797

Table 5. Mean monthly mortality for the High Density and Normal Density at Dworshak NFH.

Month	Treatment	N	Mean Monthly Mortality Rate	SE
10/13	High Density	3	0.074	0.005
	Normal Density	3	0.141	0.034
11/13	High Density	3	0.028	0.011
	Normal Density	3	0.034	0.007
12/13	High Density	3	0.013	0.001
	Normal Density	3	0.030	0.004
1/14	High Density	3	0.022	0.005
	Normal Density	3	0.026	0.004
2/14	High Density	3	0.022	0.005
	Normal Density	3	0.026	0.008
3/14	High Density	3	0.025	0.004
	Normal Density	3	0.028	0.005

Fish Health

Table 6 lists the results of fish health monitoring for the two treatments during juvenile rearing and includes the pre-release. No pathogens of concern were detected during the rearing period. In January 2014, the Normal Density treatment had minor epithelocystis, a gram negative intracellular bacterium that affects gill and skin epithelium. In addition to the epithelocystis there were also low numbers of external protozoa parasites observe. No issues were noted with the standard observations except for minor gill hyperplasia in both treatments in February 2014. Hematocrit levels were normal in both treatments.

The pre-release inspection was conducted on March 7, 2014. Thirty juvenile spring Chinook salmon were collected from each treatment. ELISA screening for *Renibacterium salmoninarum*, bacterial kidney disease, detected a low antigen level in one, two fish pool from the Normal Density treatment. No viral or parasite pathogens were detected from either treatment. Hematocrit levels were normal for both treatments. Standard observations of condition of gills and organs were normal.

Smolt Performance

Survival – **Table 7** lists the survival rate of each replicate in both treatment groups from release to Lower Granite and Bonneville dams. The Normal Density treatment had slightly lower survival to Lower Granite Dam than the High Density treatment but higher survival overall to Bonneville Dam. The average survival rates for both treatments to Lower Granite and Bonneville dams are higher than the previous 5-year averages. The previous 5-year (2009 to

2013) average survival rates to Lower Granite and Bonneville dams are 76.9% and 52.6%, respectively.

Table 6. Result of fish health monitoring for brood year 2012 spring Chinook salmon in the High Density and Normal Density treatments.

Treatment	Date	Sample Size	*Renibacterium salmoninarum*	Virology	Bacteria	External Parasites	Mean Hematocrits
Normal	10/30/2013	10	0/5-2fp +	NA	NA	0/5 +	44.1
High	10/30/2013	10	0/5-2fp +	NA	NA	1/5 +	43.9
Normal	11/25/2013	10	0/5-2fp +	NA	NA	0/5 +	42.1
High	11/25/2013	10	0/5-2fp +	NA	NA	0/5 +	37.6
Normal	12/27/2013	10	0/5-2fp +	NA	NA	0/5 +	44.9
High	12/27/2013	10	0/5-2fp +	NA	NA	0/5 +	40.0
Normal	01/30/2014	10	0/5-2fp +	NA	NA	3/5 +	40.3
High	01/30/2014	10	0/5-2fp +	NA	NA	0/5 +	45.1
Normal	02/26/2014	10	0/5-2fp +	NA	NA	0/5 +	40.1
High	02/12/2014	10	0/5-2fp +	NA	NA	0/5 +	42.0
Normal	03/06/2014	30	1/15-2fp +	0/6-5fp +	0/6-5fp +	0/5 +	43.5
High	03/06/2014	30	0/15-2fp +	0/6-5fp +	0/6-5fp +	0/5 +	45.4

Table 7. Estimated proportional survival to Lower Granite and Bonneville dams for PIT-tagged spring Chinook salmon smolts in the Normal and High Density treatments.

Treatment	Replicate	Lower Granite Dam	Bonneville Dam
Normal Density	1	0.8015	0.6955
	2	0.7930	0.8860
High Density	1	0.8451	0.5573
	2	0.8759	0.7140

Travel Time – **Table 8** lists the travel time in days of each replicate in both treatment groups to Lower Granite and Bonneville dams. There was little difference in travel time between the two treatments to either Lower Granite Dam or to Bonneville Dam. The average travel times for both treatments to Lower Granite and Bonneville dams are lower than the previous 5-year averages. The previous 5-year (2009 to 2013) average travel time to Lower Granite and Bonneville dams were 30.8 and 42.8 days, respectively.

Table 8. Estimated travel time to Lower Granite and Bonneville dams for PIT-tagged spring Chinook salmon smolts in the Normal and High Density treatments.

Treatment	Replicate	Lower Granite Dam	Bonneville Dam
Normal Density	1	22	38
	2	22	38
High Density	1	20	37
	2	22	39

SUMMARY

Pre-release testing of PBT assignments to the various replicate raceways in each treatment indicated high accuracy in making those assignments, providing a high level of confidence in being able to assign returning adults to their respective replicate rearing units in each treatment.

The preliminary cost estimate of rearing an additional 20,000 smolts per rearing unit, for the purposes of conducting a cost/benefit analysis of adult returns, was estimated at $2,160.00.

The preliminary growth, mortality, fish health, and smolt performance information for BY2013 spring Chinook salmon indicates no meaningful differences between the Normal and High Density treatments.

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