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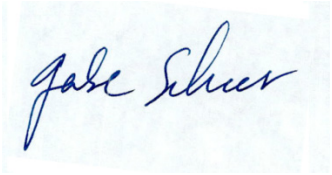
MEMORANDUM

TO: Michele DeHart



FROM: Gabe Scheer

DATE: February 5, 2018

SUBJECT: Upstream survival response to variability in travel times in the Lower Snake River

In response to your request, The Fish Passage Center has evaluated the impacts of travel time and passage in the Lower Snake River on spawning success of hatchery spring Chinook in the Snake River basin. The following are key conclusions:

- Parameters associated with travel time between Lower Monumental Dam and Little Goose Dam were not significant predictors of the probability of reaching hatchery/spawning grounds for any hatchery group in years 2014-2017.
- Parameters associated with travel time between Ice Harbor Dam and Lower Granite Dam were not significant predictors of the probability of reaching hatchery/spawning ground for any hatchery group in years 2005-2017.
- Survival from Little Goose Dam to the hatchery/spawning grounds was not significantly different for transported vs. untransported hatchery spring Chinook detected at both Lower Monumental and Little Goose dams between 2014-2017.
- Survival from Lower Granite Dam to hatchery/spawning grounds was not significantly different for transported vs untransported hatchery spring Chinook detected at both Ice Harbor and Lower Granite dams between 2005-2017.
- Probability of reaching hatchery of origin or other spawning location once past Little Goose Dam varied widely between hatchery groups originating from the Clearwater River and those from the Snake River and associated tributaries.

Methods:

Survival from LGS to Hatchery/Spawning Grounds

We estimated the minimum survival from Little Goose Dam (LGS) to hatchery/spawning grounds for PIT-tagged hatchery spring Chinook adults that were detected both at Lower Monumental Dam (LMN) and LGS during years 2014-2017. Four-digit capture histories were created using: 1) detection at LMN, 2) detection at LGS, 3) detection at Lower Granite Dam (LGR), and 4) detection at either the hatchery of origin, or upriver (in the same watershed) of the hatchery of origin (herein referred to as hatchery/spawning grounds). Using these capture histories, single mark recapture survival estimates were generated using Cormack-Jolly-Seber (CJS) methodology, as described by Burnham et al. (1987) with Program MARK (software available free from Colorado State University)(White and Burnham 1999). We fixed the probability of detection for the final capture occasion to one, therefore, survival estimates from LGR to spawning grounds represent the minimum expected values.

Time between Lower Monumental and Little Goose Dam and Transport

Logistic regression was used to test whether travel time between LMN-LGS, time thresholds at LGS (categorical variable defined as LMN-LGS travel time equal to or in excess of 5, 10, or 15-days), or juvenile transport had an effect on the probability of an adult reaching their hatchery/spawning grounds after passing Little Goose Dam. Travel times were determined for hatchery spring Chinook returning as adults from 2014-2017 that were detected at both LMN and LGS dams between April and June. Individual success was defined as a detection at the hatchery of origin, or at a detection point higher in the basin of origin. Binomial linear models were fit in Program R (R Development Core Team 2008) using the 'logit' link function. Combinations of explanatory variables were included in each regression, and model selection was done using Akaikes Information Criterion. Model sets are summarized in Table 1:

Table 1: Candidate models sets for hatchery spring Chinook adults that were detected at both LMN and LGS, 2014-2017.

Model Sets
Surv~Tr
Surv~TT
Surv~Tr + TT
Surv~Tr*TT
Surv~T5
Surv~T10
Surv~T15
Surv~Y
Surv~Site+Year
Surv~Tr+TT+Y
Surv~Tr+TT+Site
Surv~Tr+TT+Year+Site
Surv~TT+Site+Year
Surv~TT+Site*Y
Surv~T5+Site+Year
Surv~T10+Site+Year
Surv~T15+Site+Year

Tr: Transportation. TT: Travel time between LMN-LGS (days). T5: Travel time of 5 days or more (LMN-LGS). T10: Travel time of 10 days or more (LMN-LGS). T15: travel time of 15 days or more (LMN-LGS). * indicates and interaction term

Time between Ice Harbor and Lower Granite Dam and Transport

To increase our time-series of data, we conducted a similar analysis of travel time and success to the hatchery/spawning grounds for PIT-tagged hatchery spring Chinook that were detected at both Ice Harbor (ICH) and LGR. Specifically, logistic regression was used to test whether travel time between Ice Harbor and LGR dams, travel time thresholds (categorical variable defined as ICH-LGR travel time equal to or in excess of 10, 20, or 30-days), or juvenile transport had an effect on the probability of an adult reaching their hatchery/spawning grounds. Travel times were determined for hatchery spring Chinook returning as adults from 2005-2017 that were detected at both ICH and LGR. We defined individual spawning success as a detection at the hatchery of origin, or at a detection point higher in the basin of origin. Binomial linear models were fit in Program R using the 'logit' link function. Combinations of explanatory variables were included in each regression, and model selection was done using Akaikes Information Criterion. Model sets are summarized in Table 2:

Table 2: Candidate models sets for hatchery spring Chinook adults that were detected at both ICH and LGR, 2005-2017.

Model Sets
Surv~Tr
Surv~TT
Surv~Tr+TT
Surv~Tr+TT+Tr*TT
Surv~TT^2
Surv~T10
Surv~T20
Surv~T30
Surv~Y
Surv~Site+Year
Surv~Tr+TT+Y
Surv~Tr+TT+Site
Surv~Tr+TT+Year+Site
Surv~TT+Site+Year
Surv~T10+Site+Year
Surv~T20+Site+Year
Surv~T30+Site+Year
Surv~TT+Site*Y

Tr: Transportation. TT: Travel time between ICH-LGR(days). Y: Year. Site: Hatchery of origin. T10: travel time of 10 days or more (ICH-LGR). T20: travel time of 20 days or more (ICH-LGR). T30: travel time of 30 days or more (ICH-LGR).

Results:

Survival from LGS to Hatchery/Spawning Grounds

For individuals that were detected at both Lower Monumental Dam and Little Goose Dam, survival between LGS and Lower Granite Dam was extremely high. Point estimates of survival ranged from 97%-100% in this reach; with most survival estimates being 100% regardless of hatchery or year (Table 3). Survival estimates above Granite Dam varied

considerably between years and hatchery groups. Survival for the Clearwater and Dworshak hatchery groups were considerably lower in all years for which there were data (Table 4). Clearwater/Dworshak estimates ranged from 11-62%, while Lookingglass and Rapid River hatchery groups had relatively high survival, ranging from 62-100%*.

Additionally, while there were some differences in survival of transported versus untransported fish in some years, there was no evidence that these differences were statistically significant for any hatchery group in any year (Tables 3 and 4)

Table 3: Estimated survival and 95 percent confidence intervals from Little Goose Dam to Lower Granite Dam for Clearwater, Dworshak, Rapid River, and Looking glass hatchery spring Chinook between 2014-2017

		Untransported	Transported
2014	RAPH (N=365)	1.00 (1.00-1.00)	0.97 (0.92-0.99)
	CLWH (N=237)	0.99 (0.96-1.00)	1.00 (1.00-1.00)
	DWOR (N=221)	0.99 (0.96-1.00)	1.00 (1.00-1.00)
	LOOH (N=58)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
2015	RAPH (N=484)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	CLWH (N=267)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	DWOR (N=268)	0.99 (0.97-1.00)	0.97 (0.84-1.00)
	LOOH (N=66)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
2016	RAPH (N=204)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	CLWH (N=161)	0.97 (0.93-0.99)	1.00 (1.00-1.00)
	DWOR (N=136)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	LOOH (N=30)	0.98 (0.05-1.00)	1.00 (1.00-1.00)
2017	RAPH (N=115)	0.99 (0.9-1.00)	1.00 (1.00-1.00)
	CLWH (N=93)	0.99 (0.93-1.00)	1.00 (1.00-1.00)
	DWOR (N=33)	0.97 (0.80-1.00)	1.00 (1.00-1.00)
	LOOH (N=30)	1.00 (1.00-1.00)	1.00 (1.00-1.00)

*Note that final survival estimates to the hatchery of origin or above represent the joint probability of both the probability of being detected at the hatchery or upstream detection point, and the probability of surviving to the hatchery or upstream detection point. With the detection likelihood fixed to one, the survival estimates represent minimum expected survivals, which include any error associated with variable capture probabilities.

Table 4: Estimated survival and 95 percent confidence intervals from Lower Granite Dam to hatchery of origin or above for Clearwater, Dworshak, Rapid River, and Looking Glass hatchery spring Chinook between 2014-2017

		Untransported	Transported
2014	RAPH (N=365)	0.97 (0.94-0.99)	0.97 (0.92-0.99)
	CLWH (N=237)	0.11 (0.08-0.16)	0.05 (0.01-0.28)
	DWOR (N=221)	0.36 (0.29-0.43)	0.46 (0.29-0.65)
	LOOH (N=58)	0.93 (0.81-0.98)	1.00 (1.00-1.00)
2015	RAPH (N=484)	0.93 (0.9-0.95)	0.94 (0.89-0.97)
	CLWH (N=267)	0.23 (0.18-0.29)	0.19 (0.09-0.36)
	DWOR (N=268)	0.27 (0.21-0.33)	0.31 (0.18-0.47)
	LOOH (N=66)	1.00 (1.00-1.00)	0.91 (0.75-0.97)
2016	RAPH (N=204)	0.96 (0.9-0.98)	0.99 (0.92-1)
	CLWH (N=161)	0.23 (0.17-0.31)	0.19 (0.08-0.38)
	DWOR (N=136)	0.25 (0.17-0.35)	0.29 (0.18-0.44)
	LOOH (N=30)	0.62 (0.34-0.83)	0.87 (0.59-0.97)
2017	RAPH (N=115)	0.94 (0.86-0.97)	0.97 (0.79-1)
	CLWH (N=93)	0.62 (0.51-0.71)	1.00 (1.00-1.00)
	DWOR (N=33)	0.60 (0.42-0.76)	*
	LOOH (N=30)	0.79 (0.59-0.91)	0.67 (0.27-0.92)

Time between Lower Monumental and Little Goose Dam and Transport

Sample sizes for the logistic regression models are summarized by hatchery and year in Table 5. The best fitting model within the candidate set included Year, Site (Hatchery of origin), and an interaction term between Year and Site. Variables associated with travel time between LMN and LGS and history of transportation showed no significant explanatory power for the probability of successfully reaching spawning grounds in any of the top performing models. Model set AIC rankings are summarized in Table 6, showing the top two models both containing Site*Year interaction terms, and travel time adding little to model fit when included with the Site*Year model. Summary statistics showed Year and Site as significant variables in predicting success to spawning grounds, with individuals originating in Snake river sites (RAPH and LOOH) having substantially higher probabilities of survival to the hatchery/spawning grounds than Clearwater sites (CLWH and DWOR) (Table 7).

Table 5: Sample sizes for the logistic regression analysis of success to the hatchery/spawning ground for fish detected at both LMN and LGS, displayed by hatchery group and year (2014-2017)

	CLWH	DWOR	LOOH	RAPH	N=
2014	237	221	58	365	881
2015	267	268	66	484	1085
2016	161	136	30	204	531
2017	93	33	30	115	271
N=	758	658	184	1168	2768

Table 6: Model sets and corresponding AIC scores for adult spring Chinook detected at both LMN and LGS, 2005-2017. Tr: Transportation. TT: Travel time between LMN-LGS (days). Y: Year. Site: Hatchery of origin. T5: travel time of 5 days or more (LMN-LGS). T10: travel time of 10 days or more (LMN-LGS). T15: travel time of 15 days or more (LMN-LGS). * indicates an interaction term. Blue indicates models with the best fit.

Model	AIC
Surv~Tr	3644.97
Surv~TT	3728.74
Surv~Tr+TT	3646.94
Surv~Tr*TT	3647.49
Surv~T5	3728.71
Surv~T10	3728.23
Surv~T15	3728.42
Surv~Y	3692.13
Surv~Site+Year	2188.35
Surv~Tr+TT+Y	3594.66
Surv~Tr+TT+Site	2238.65
Surv~Tr+TT+Year+Site	2190.42
Surv~TT+Site+Year	2189.54
Surv~Site*Y	2128.75
Surv~TT+Site*Y	2129.12
Surv~T5+Site+Year	2188.38
Surv~T10+Site+Year	2190.27
Surv~T15+Site+Year	2190.34

Table 7: Model summary statistics for the top two models (Site*Y and TT+Site*Y), and the Travel Time model. Blue indicates the best fitting models of the candidate set.

Model	***Surv ~ TT***			***Surv ~ Site * Y***			***Surv ~ TT + Site * Y***		
Variable	***Estimate***	***St.Err***	***p-value***	***Estimate***	***St.Err***	***p-value***	***Estimate***	***St.Err***	***p-value***
Intercept	0.415841	0.04983	<2e-16 ***	-2.1377	0.2115	< 2e-16 ***	-2.07874	0.21629	< 2e-16 ***
Travel Time:									
TT	-0.00394	0.014353	0.784				-0.02593	0.02028	0.201037
Hatchery:									
SiteDWOR				1.61	0.2532	2.04e-10 ***	1.61044	0.25325	2.03e-10 ***
SiteLOOH				5.0464	0.6295	1.08e-15 ***	5.07132	0.63024	8.51e-16 ***
SiteRAPH				5.7072	0.3841	< 2e-16 ***	5.70249	0.38413	< 2e-16 ***
Year:									
Y2015				0.8993	0.2573	0.000474 ***	0.88471	0.25758	0.000593 ***
Y2016				0.8568	0.285	0.002645 **	0.85244	0.28507	0.002787 **
Y2017				2.5972	0.3001	< 2e-16 ***	2.65945	0.30456	< 2e-16 ***
Interaction Site*Year:									
SiteDWOR:Y2015				-1.373	0.3234	2.18e-05 ***	-1.37403	0.32347	2.16e-05 ***
SiteLOOH:Y2015				-0.7635	0.8757	0.383282	-0.78921	0.87631	0.367799
SiteRAPH:Y2015				-1.8539	0.4489	3.64e-05 ***	-1.85274	0.44897	3.68e-05 ***
SiteDWOR:Y2016				-1.3507	0.372	0.000283 ***	-1.35647	0.37213	0.000267 ***
SiteLOOH:Y2016				-2.7539	0.7767	0.000391 ***	-2.78652	0.7775	0.000338 ***
SiteRAPH:Y2016				-0.9298	0.5965	0.119024	-0.91823	0.59673	0.123859
SiteDWOR:Y2017				-1.6387	0.4862	0.000750 ***	-1.62676	0.48753	0.000848 ***
SiteLOOH:Y2017				-4.3164	0.7924	5.12e-08 ***	-4.39258	0.79547	3.35e-08 ***
SiteRAPH :Y2017				-3.4306	0.5873	5.19e-09 ***	-3.43199	0.58776	5.25e-09 ***
AIC	3728.7			2128.7			2129.1		
McFadden Pseudo R^2	2.01E-05			0.437084			0.437524		
Cragg/Uhler Pseudo R^2	3.66E-05			0.601186			0.60163		

Time between Ice Harbor and Lower Granite Dam and Transport

Sample sizes for the logistic regression models are summarized by hatchery and year in Table 8. Adequate sample sizes were available for most years, with the exception of 2005 and 2006 for CLWH fish. Overall, Site (Hatchery of origin) and Year appeared to explain most of the variability observed in individual success reaching the hatchery/spawning ground for adult spring Chinook detected at both ICH and LGR. The best fitting models within the candidate set included Year, Site (Hatchery of origin), and an interaction term between Year and Site. However, both models failed to estimate a coefficient for the interaction term RAPH*2017, so these two models were dropped from the candidate set. The next best fitting models also contained predictor variables for Site and Year. Variables associated with travel time between ICH and LGR and history of transportation showed no significant explanatory power for the probability of successfully reaching the hatchery/spawning grounds in any of the top ranked models. Similarly, categorical variables associated with travel time did not show any significant relationship with survival to the hatchery/spawning grounds in any of the models tested. Model set AIC rankings are summarized in Table 9. Summary statistics showed a significant difference between sites, with the probability of success to the hatchery/spawning ground being much higher for Snake River hatchery fish (RAPH and LOOH), than for Clearwater River fish (CLWH and DWOR) (Table 10).

Table 8: Sample sizes for the logistic regression analysis of success to the hatchery/spawning ground for fish detected at both ICH and LGR, displayed by hatchery group and year (2005-2017)

	CLWH	DWOR	LOOH	RAPH	N=
2005	-	77	24	381	482
2006	-	91	20	105	216
2007	17	146	24	157	344
2008	72	280	59	382	793
2009	115	307	91	732	1245
2010	254	198	185	1002	1639
2011	278	252	159	486	1175
2012	240	246	77	218	781
2013	142	130	42	161	475
2014	227	209	55	336	827
2015	262	255	66	464	1047
2016	152	132	28	197	509
2017	86	31	27	108	252
N=	1845	2354	857	4729	9785

Table 9: Model sets and corresponding AIC scores for adult spring Chinook detected at both ICH and LGR, 2005-2017. Tr: Transportation. TT: Travel time between ICH-LGR(days). Y: Year. Site: Hatchery of origin. T10: travel time of 10 days or more (ICH-LGR). T20: travel time of 20 days or more (ICH-LGR). T30: travel time of 30 days or more (ICH-LGR). * indicates an interaction term. Blue indicates models that were removed from candidate set, green indicates best fitting model.

Model	AIC
Surv~Tr	12955.51
Surv~TT	13298.80
Surv~Tr+TT	12928.61
Surv~Tr*TT	12930.49
Surv~D10	13310.21
Surv~D20	13310.21
Surv~D30	13315.92
Surv~Y	13018.67
Surv~Site+Year	6450.91
Surv~TT+Site+Year	6452.99
Surv~Tr+TT+Y	12684.04
Surv~Tr+TT+Site	6896.27
Surv~Tr+TT+Year+Site	6454.90
Surv~TT+Site+Year	6452.90
Surv~Site*Y	----------
Surv~TT+Site*Y	----------
Surv~D10+Site+Year	6452.42
Surv~D20+Site+Year	6452.16
Surv~D30+Site+Year	6452.51

* Two models: Site*Y(AIC=6064.8) and TT+Site*Y(AIC=6066.8) were removed from the candidate set due to failure to estimate one of the interaction parameters.

Table 10: Model summary statistics for the top two models (Site+Y and TT+Site+Y), and the Travel Time model. Green indicates the best fitting model of the candidate set.

Model	Surv~TT			Surv~Site+Y				Surv~TT+Site+Y			
Variable	Estimate	Std. Error	p-value	Estimate	Std. Error	p-value		Estimate	Std. Error	Pr(>|z|)	
Intercept	0.421287	0.030905	< 2e-16	-2.41188	0.19522	< 2e-16	***	-2.40887	0.197986	< 2e-16	***
Travel Time											
TT	-0.01472	0.003442	1.91E-05***				*	-0.00051	0.005548	0.927205	
Year											
Y2006				-0.56832	0.28198	0.043854		-0.5673	0.282196	0.044398	*
Y2007				-0.35133	0.25271	0.164464		-0.35071	0.252803	0.165351	
Y2008				-0.63421	0.20935	0.00245	**	-0.63337	0.209547	0.002506	**
Y2009				-0.45776	0.19688	0.02007	*	-0.45797	0.1969	0.020025	*
Y2010				-0.4009	0.1909	0.035724	*	-0.39993	0.191191	0.036456	*
Y2011				0.03693	0.19986	0.853384		0.039677	0.202108	0.844363	
Y2012				0.13581	0.21182	0.521434		0.135752	0.211823	0.521605	
Y2013				1.43735	0.22103	7.88E-11	***	1.436897	0.221088	8.07E-11	***
Y2014				1.06524	0.20869	3.32E-07	***	1.065156	0.208695	3.33E-07	***
Y2015				0.99646	0.20407	1.04E-06	***	0.996181	0.204091	1.06E-06	***
Y2016				1.04446	0.22384	3.07E-06	***	1.044538	0.223843	3.07E-06	***
Y2017				2.4256	0.25999	< 2e-16	***	2.427549	0.260874	< 2e-16	***
Hatchery											
SiteDWOR				0.35368	0.09237	0.000129	***	0.353687	0.092375	0.000129	***
SiteLOOH				3.22487	0.11402	< 2e-16	***	3.224489	0.114097	< 2e-16	***
SiteRAPH				5.18767	0.10832	< 2e-16	***	5.187371	0.108372	< 2e-16	***
AIC	13301			6451				6453			
McFadden Pseudo R^2	1.41E-03			0.517921				0.517921			
Cragg/Uhler Pseudo R^2	2.57E-03			0.680219				0.680219			

Discussion:

This analysis showed a difference in survival above Lower Granite Dam between spring Chinook originating in the Clearwater River and those originating elsewhere in the Snake River basin, with Clearwater fish showing lower success in reaching their hatchery/spawning ground in all years. Within these two groups, survival estimates between Clearwater (DWOR/CLWH) and Snake River (RAPH/LOOH) hatcheries showed similar point estimates and overlapping confidence intervals in all years from 2014-2017. However, no differences in timing or environmental condition exist between these two populations.

Whether using fish detected at LMN and LGS or ICH and LGR, the probability that an individual will reach their hatchery/spawning grounds once they passed Little Goose Dam or Lower Granite Dam showed no significant relationship with any variable associated with a history of juvenile transport, travel time, or time spent between projects. While this does not account for varying environmental conditions experienced by individuals during passage, it does

provide some evidence that in this data sets time spent in the lower Snake River does not appear to affect the subsequent probability of reaching the hatchery/spawning ground for adult hatchery spring Chinook. When viewed within the context of Snake River spring Chinook spawn timing (~August/September), time spent when river temperatures are cool does not appear to affect the success of individuals that will not spawn for a number of months. When considering alternative management actions, this result may be relevant when weighing operational adjustments that are detrimental for other life stages.