



# FISH PASSAGE CENTER

847 N.E. 19<sup>th</sup> Avenue, #250, Portland, Oregon 97232

Phone: (503) 833-3900

Fax: (503) 232-1259

[www.fpc.org](http://www.fpc.org)

e-mail us at [fpcstaff@fpc.org](mailto:fpcstaff@fpc.org)

## MEMORANDUM

TO: FPAC

*Michele DeHart*

FROM: Michele DeHart

DATE: 3/6/2018

SUBJECT: Incorporation of FPAC comments and recommendations: Upstream survival of hatchery and wild spring chinook, response to variability in travel times in the Lower Snake River

On February 6, 2018 the Fish Passage Center presented an analysis on the effects of travel time in the lower Snake River on upstream survival success of hatchery origin spring Chinook to FPAC members. The purpose of this analysis was to provide information to managers to illuminate discussions of effects of project operations at Little Goose Dam on juvenile and adult life stages. Specifically to inform discussions of balancing, between operations to protect juvenile migrants and potential for increased adult upstream migration travel time.

FPAC members provided comments on the analyses noting concerns about the accuracy of some of the hatchery survival estimates. In addition FPAC members commented that hatchery mark groups may not be representative of wild spring chinook upstream migrants. FPC addressed the FPAC concerns and comments by repeating the analyses with the same hatchery groups, correcting errors in tag files and incorporating additional tag recoveries through recaptures at weirs and mortalities found during spawning surveys to enhance the accuracy of this analysis. In addition, we have also included wild origin spring Chinook from the Snake River basin in these analyses. The following are results and conclusions from this updated analysis:

- Parameters associated with travel time between Lower Monumental Dam and Little Goose Dam were not significant predictors of the probability of reaching hatchery/basin of origin for any hatchery or wild groups 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/basin of origin for any hatchery group in years 2005-2017.
- Travel times in excess of 20 days between Ice Harbor and Lower Granite Dams reduced the probability that a wild origin spring Chinook would successfully reach their basin of origin. This result was weighted to the Salmon River mark group since the large majority of wild marked fish were from the Salmon River Basin.
- Travel times that were less than 20 days between Ice Harbor and Lower Granite Dams were not significant predictors of the probability of reaching the basin of origin for wild origin spring Chinook.
- Survival from Little Goose Dam to the hatchery/basin of origin was not significantly different for transported vs. untransported hatchery or wild 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 or wild spring Chinook detected at both Ice Harbor and Lower Granite dams between 2005-2017.
- These analyses indicate that additional variables should be examined to further understand the effect of travel time through the Ice Harbor to Lower Granite and Lower Monumental to Little Goose River reaches. Specifically these include, distance to the location of origin, potential seasonality of travel time, effect of water temperature on upstream migration timing, travel time and passage timing at lower river projects

## **Methods:**

### ***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 and wild spring/summer Chinook returning as adults from 2014-2017 that were detected at both LMN and LGS dams between April and June. We defined individual upstream survival success for hatchery origin fish as a detection at the hatchery of origin, or at a detection point within the basin of origin at either an adult weir, antenna array, or as a mortality during a spawning survey. Upstream survival success for wild origin fish was defined similarly, as a detection at an antenna array, recapture at an adult weir, or as a mortality within their basin of origin. For hatchery fish, four populations were used in this analysis: Clearwater (CLWH), Dworshak (DWOR), Rapid River (RAPH), and Looking glass hatchery (LOOH). For wild fish, basin of origin was used to aggregate fish that were trapped and tagged as juveniles within the Salmon (SAL), Imnaha (IMN), Grande Ronde (GDR), and Clearwater River (CLW) basins. 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 Akaike's Information Criterion. Separate analyses were conducted for hatchery and wild Chinook. 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~Site*Y
Surv~TT+Site*Y
Surv~T5+Site+Year
Surv~T10+Site+Year
Surv~T15+Site+Year
Surv~Site
Surv~Site+TT

Explanatory variables include: 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. For hatchery Chinook, site indicates the hatchery of origin (CLWH, DWOR, RAPH, LOOH) while for wild Chinook, site indicates the basin of origin (SAL, IMN, GDR, CLW)

***Time between Ice Harbor and Lower Granite Dam and Transport***

To increase our time-series, we conducted a similar analysis of travel time and success to the hatchery/spawning grounds for PIT-tagged hatchery spring and wild spring/summer Chinook that were detected at both Ice Harbor (ICH) and LGR. Specifically, logistic regression was used to test whether travel time between ICH and LGR dams, travel time thresholds (categorical variable defined as ICH-LGR travel time equal to or in excess of 5, 10, 15, 20, 25, 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 and wild spring/summer Chinook returning as adults from 2005-2017 that were detected at both ICH and LGR. We defined individual upstream survival success for hatchery origin fish as a detection at the hatchery of origin, or at a detection point within the basin of origin at either an adult weir, antenna array, or as a mortality during a spawning survey. Upstream survival success for wild origin fish was defined similarly as a detection at an antenna array, recapture at an adult weir, or as a mortality within their basin of origin. For hatchery fish, four populations were used in this analysis: Clearwater (CLWH), Dworshak (DWOR), Rapid River (RAPH), and Looking Glass hatchery (LOOH). For wild fish, basin of origin was used to aggregate fish that were trapped and tagged as juveniles within the Salmon (SAL), Imnaha (IMN), Grande Ronde (GDR), and Clearwater

River (CLW) basins. 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 Akaike’s Information Criterion (AIC), choosing the most parsimonious model within four AIC units of the lowest AIC score. Model sets are summarized in Table 2.

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

Model Sets	
Surv~Tr	Surv~T10+Year
Surv~TT	Surv~T15+Year
Surv~Tr+TT	Surv~T20+Year
Surv~Tr+TT+Tr*TT	Surv~T25+Year
Surv~T5	Surv~T30+Year
Surv~T10	Surv~T5+Year+Site
Surv~T15	Surv~T10+Year+Site
Surv~T20	Surv~T15+Year+Site
Surv~T25	Surv~T20+Year+Site
Surv~T30	Surv~T25+Year+Site
Surv~Y	Surv~T30+Year+Site
Surv~Site	Surv~TT+Site+Year
Surv~Site+Year	Surv~TT+Year
Surv~T5+Year	

Explanatory variables include: 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. For hatchery Chinook, site indicates the hatchery of origin (CLWH, DWOR, RAPH, LOOH) while for wild Chinook, site indicates the basin of origin (SAL, IMN, GDR, CLW)

***Survival from LGR to Hatchery/Spawning Grounds***

Survival estimates were calculated as the number of adults detected within their basin of origin (as previously defined), divided by the number of fish detected at both ICH and LGR for wild and hatchery origin spring Chinook (2005-2017). We estimated 90% confidence intervals using the Clopper Pearson binomial confidence interval methodology (Clopper and Pearson 1934).

**Results:**

***Time between Lower Monumental and Little Goose Dam and Transport Hatchery spring Chinook***

Sample sizes for hatchery origin fish are summarized by hatchery and year in Table 3. Model set AIC rankings are summarized in Table 4, 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 (Table 5). Summary statistics for each of the top two models indicate that Year and Site are significant variables in predicting success to spawning grounds while travel time (TT) in the top model was not a significant predictor of the probability of upstream survival success (p-value=0.38) (Appendix A: Table 13).

**Table 3:** Sample sizes for the logistic regression analysis of success to the hatchery/spawning ground for hatchery spring chinook detected at both LMN and LGS, displayed by hatchery group and year (2014-2017)

	CLWH	DWOR	LOOH	RAPH	N=
2014	302	220	185	364	1071
2015	345	268	191	484	1288
2016	175	134	103	203	615
2017	125	33	59	113	330
N=	947	655	538	1164	3304

**Table 4:** Model sets and corresponding AIC scores for adult hatchery spring Chinook detected at both LMN and LGS, 2014-2017. 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	3939.91
Surv~TT	3944.998
Surv~Tr+TT	3938.76
Surv~Tr*TT	3940.76
Surv~T5	3947.787
Surv~T10	3946.148
Surv~T15	3946.941
Surv~Year	3897.404
Surv~Site+Year	3555.812
Surv~Tr+TT+Year	3895.355
Surv~Tr+TT+Site	3604.848
Surv~Tr+TT+Year+Site	3559.402
Surv~TT+Site+Year	3557.501
Surv~Site*Year	3534.191
Surv~TT+Site*Year	3532.948
Surv~T5+Site+Year	3555.76
Surv~T10+Site+Year	3557.811
Surv~T15+Site+Year	3557.683
Surv~Site	3603.448
Surv~Site+TT	3603.486

Wild spring/summer Chinook

Sample sizes for wild origin spring Chinook are summarized by basin of origin and year in Table 5. The top two performing models included Site and travel time, however, travel time was not a significant explanatory variable for the probability of upstream survival success in any of the models tested (p-value=0.34). Model set AIC rankings are summarized in Table 6, showing the top two models both containing Site (basin of origin), with travel time decreasing the overall support when added to the “Site” model. Summary statistics for the top two models are compiled in Appendix A (Table 14)

**Table 5:** Sample sizes for the logistic regression analysis of upstream survival success for wild spring Chinook detected at both LMN and LGS, displayed by basin of origin and year (2014-2017)

	CLW	GDR	IMN	SAL	N=
2014	28	81	46	273	428
2015	22	96	38	213	369
2016	10	76	41	131	258
2017	4	27	33	46	110
N=	64	280	158	663	1165

**Table 6:** Model sets and corresponding AIC scores for adult wild spring Chinook detected at both LMN and LGS, 2014-2017. Tr: Transportation. TT: Travel time between LMN-LGS (days). Y: Year. Site: basin 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	1404.887
Surv~TT	1407.117
Surv~Tr+TT	1406.706
Surv~Tr*TT	1408.705
Surv~T5	1407.281
Surv~T10	1407.281
Surv~T15	1407.252
Surv~Year	1408.196
Surv~Site+Year	1348.006
Surv~Tr+TT+Year	1409.086
Surv~Tr+TT+Site	1344.639
Surv~Tr+TT+Year+Site	1349.179
Surv~TT+Site+Year	1348.529
Surv~Site*Year	1346.397
Surv~TT+Site*Year	1345.438
Surv~T5+Site+Year	1349.817
Surv~T10+Site+Year	1349.247
Surv~T15+Site+Year	1349.549
Surv~Site	1343.158
Surv~Site+TT	1344.265

***Time between Ice Harbor and Lower Granite Dam and Transport***

***Hatchery spring Chinook***

Sample sizes for the hatchery spring Chinook logistic regression models are summarized by hatchery and year in Table 7. Adequate sample sizes were available to estimate upstream survival for most years, with the exception of 2005 and 2006 for CLWH fish (Table 8). Model set AIC rankings are summarized in Table 9. Overall, most of the variability in individual success reaching the hatchery/basin of origin for adult spring Chinook is accounted for by Site (Hatchery of origin) and Year. The best fitting model within the candidate set included Year, Site, and a categorical variable for T30 (TT>30days). And while the best fitting model included a variable associated with travel time, it did not have a significant relationship with the probability of successfully reaching the hatchery/basin of origin (p-value=0.12). Similarly, no other variables associated with travel time between ICH and LGR or a history of transportation showed significant explanatory power in any of the top ranked models. Model set AIC rankings are summarized in Table 8. Summary statistics showed a significant difference between sites, with the probability of success to the hatchery/basin of origin varying considerably between years and sites (Table 9 and Appendix A: Table 15).

**Table 7:** Sample sizes for the logistic regression analysis of success to the hatchery/basin of origin for hatchery 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 8:** Upstream survival success for hatchery origin spring Chinook detected at both ICH and LGR dams between 2005-2017

	CLWH	DWOR	LOOH	RAPH
2005		0 (0-0.04)	0.58 (0.4-0.75)	0.22 (0.18-0.26)
2006		0 (0-0.03)	0.9 (0.72-0.98)	0.4 (0.32-0.48)
2007	0.06 (0-0.25)	0.53 (0.46-0.6)	0.5 (0.32-0.68)	0.43 (0.37-0.5)
2008	0 (0-0.04)	0 (0-0.01)	0.73 (0.62-0.82)	0.17 (0.14-0.2)
2009	0.22 (0.16-0.29)	0.01 (0-0.03)	0.36 (0.28-0.45)	0.17 (0.15-0.2)
2010	0.21 (0.17-0.26)	0.16 (0.12-0.21)	0.92 (0.88-0.95)	0.09 (0.07-0.1)
2011	0.09 (0.07-0.13)	0.15 (0.11-0.19)	0.2 (0.15-0.26)	0.21 (0.18-0.24)
2012	0.23 (0.19-0.28)	0.18 (0.14-0.22)	0.97 (0.92-1)	0.06 (0.04-0.1)
2013	0.42 (0.35-0.49)	0.39 (0.32-0.47)	0.95 (0.86-0.99)	0.19 (0.14-0.25)
2014	0.18 (0.14-0.22)	0.36 (0.31-0.42)	0.89 (0.8-0.95)	0.1 (0.07-0.13)
2015	0.21 (0.17-0.26)	0.29 (0.24-0.34)	0.88 (0.79-0.94)	0.07 (0.05-0.09)
2016	0.22 (0.17-0.29)	0.27 (0.21-0.34)	0.89 (0.75-0.97)	0.17 (0.13-0.22)
2017	0.64 (0.55-0.73)	0.61 (0.45-0.76)	0.85 (0.69-0.95)	0.19 (0.13-0.26)



**Table 9:** Model sets and corresponding AIC scores for hatchery adult spring Chinook detected at both ICH and LGR, 2005-2017. Blue indicates the models with the most support of the candidate set

Model	AIC
Surv~Tr	10381.67
Surv~TT	10381.48
Surv~Tr+TT	10382.83
Surv~Tr+TT+Tr*TT	10378.93
Surv~T5	10378.51
Surv~T10	10382.25
Surv~T15	10382.26
Surv~T20	10382.19
Surv~T25	10382.19
Surv~T30	10381.99
Surv~Y	10058.26
Surv~Site	9383.854
Surv~Site+Year	9008.658
Surv~T5+Year	10058.21
Surv~T10+Year	10060.13
Surv~T15+Year	10060.06
Surv~T20+Year	10060.25
Surv~T25+Year	10060.19
Surv~T30+Year	10058.81
Surv~T5+Year+Site	9009.165
Surv~T10+Year+Site	9009.754
Surv~T15+Year+Site	9009.726
Surv~T20+Year+Site	9010.156
Surv~T25+Year+Site	9010.319
Surv~T30+Year+Site	9008.33
Surv~TT+Site+Year	9010.538
Surv~TT+Year	10060.19

\* Tr: Transportation. TT: Travel time between ICH-LGR(days). Y: Year. Site: Hatchery of origin. M: Month of Ice Harbor detection (approximate upstream migration timing). T5: Travel time of 5 days or more (ICH-LGR). T10: travel time of 10 days or more (ICH-LGR). T15: Travel time of 15 days or more (ICH-LGR). T20: travel time of 20 days or more (ICH-LGR). T25: Travel time of 25 days or more (ICH-LGR). T30: travel time of 30 days or more (ICH-LGR)

Wild spring/summer Chinook

Sample sizes for the wild spring Chinook logistic regression models are summarized by basin of origin and year in Table 10. Sample sizes were adequate to estimate upstream survival for all; years and basins of origin (Table 11). Model set AIC rankings are summarized in Table 12. The top models included variables for Site, Year and Travel Time, indicating support for some effect of travel time on upstream survival success. The second ranked model, which carried nearly the same level of support, included the categorical variable of T20 (TT>20days), showing a significant effect on the probability of upstream survival success for individuals taking longer than 20 days to travel from ICH to LGR (Tables 12 and Appendix A: Table 16). However, travel times between ICH and LGR below the 20 day threshold did not show significant relationships with the probability of upstream survival success in any of the other models (Appendix A: Table 17). This indicates travel times below 20 days (ICH-LGR) are not likely to affect the probability of an individual's upstream survival success.

**Table 10:** Sample sizes for the logistic regression analysis of success to the spawning ground for wild spring/summer Chinook detected at both ICH and LGR, displayed by basin group and year (2005-2017).

	CLW	GDR	IMN	SAL	N=
2005	8	23	24	42	97
2006	11	19	33	42	105
2007	10	21	15	43	89
2008	36	40	17	113	206
2009	27	70	55	201	353
2010	29	101	115	384	629
2011	24	105	85	255	469
2012	71	55	66	222	414
2013	45	36	23	209	313
2014	25	70	42	246	383
2015	20	90	39	212	361
2016	9	69	41	130	249
2017	3	25	32	47	107
N=	318	724	587	2146	3775

**Table 51:** Upstream survival success of wild spring/summer Chinook detected at both ICH and LGR dams between 2005-2017.

	CLW	GDR	IMN	SAL
2005	0 (0-0.31)	0.17 (0.06-0.35)	0.21 (0.09-0.39)	0.07 (0.02-0.17)
2006	0 (0-0.24)	0.53 (0.32-0.73)	0.3 (0.17-0.46)	0.17 (0.08-0.29)
2007	0 (0-0.26)	0.33 (0.17-0.54)	0.47 (0.24-0.7)	0.26 (0.15-0.39)
2008	0 (0-0.08)	0.2 (0.1-0.33)	0.35 (0.17-0.58)	0.35 (0.27-0.43)
2009	0 (0-0.11)	0.3 (0.21-0.4)	0.35 (0.24-0.46)	0.46 (0.4-0.52)
2010	0 (0-0.1)	0.24 (0.17-0.32)	0.25 (0.19-0.33)	0.45 (0.41-0.49)
2011	0 (0-0.12)	0.15 (0.1-0.22)	0.93 (0.87-0.97)	0.45 (0.4-0.5)
2012	0.45 (0.35-0.56)	0.4 (0.29-0.52)	0.98 (0.93-1)	0.65 (0.59-0.7)
2013	0.62 (0.49-0.74)	0.69 (0.55-0.82)	0.96 (0.81-1)	0.65 (0.59-0.71)
2014	0.64 (0.46-0.8)	0.66 (0.55-0.75)	0.95 (0.86-0.99)	0.66 (0.61-0.71)
2015	0.65 (0.44-0.82)	0.53 (0.44-0.62)	0.95 (0.85-0.99)	0.66 (0.6-0.71)
2016	0.33 (0.1-0.66)	0.71 (0.61-0.8)	0.98 (0.89-1)	0.62 (0.55-0.69)
2017	1 (0.37-1)	0.68 (0.5-0.83)	1 (0.91-1)	0.6 (0.47-0.72)

**Table 62:** Model sets and corresponding AIC scores for wild adult spring Chinook detected at both ICH and LGR, 2005-2017. Blue indicates the models with the most support of the candidate set

Model	AIC
Surv~Tr	5205.81
Surv~TT	5215.765
Surv~Tr+TT	5187.933
Surv~Tr+TT+Tr*TT	5189.233
Surv~T5	5222.057
Surv~T10	5226.405
Surv~T15	5231.718
Surv~T20	5225.988
Surv~T25	5230.947
Surv~T30	5232.06
Surv~Y	4792.868
Surv~Site	5092.48
Surv~Site+Year	4605.429
Surv~T5+Year	4791.501
Surv~T10+Year	4793.39
Surv~T15+Year	4792.308
Surv~T20+Year	4784.917
Surv~T25+Year	4787.899
Surv~T30+Year	4790.194
Surv~T5+Year+Site	4604.034
Surv~T10+Year+Site	4605.546
Surv~T15+Year+Site	4604.545
Surv~T20+Year+Site	4595.749
Surv~T25+Year+Site	4598.716
Surv~T30+Year+Site	4602.286
Surv~TT+Site+Year	4594.232
Surv~TT+Year	4782.564

\* Tr: Transportation. TT: Travel time between ICH-LGR(days). Y: Year. Site: Hatchery of origin. M: Month of Ice Harbor detection (approximate upstream migration timing). T5: Travel time of 5 days or more (ICH-LGR). T10: travel time of 10 days or more (ICH-LGR). T15: Travel time of 15 days or more (ICH-LGR). T20: travel time of 20 days or more (ICH-LGR). T25: Travel time of 25 days or more (ICH-LGR). T30: travel time of 30 days or more (ICH-LGR).

**Discussion:**

For hatchery origin spring Chinook, whether using fish detected at LMN and LGS or ICH and LGR, the probability that an individual will reach their hatchery/basin of origin once they passed Little Goose or Lower Granite Dam showed no significant relationship with any variable associated with a history of juvenile transport, 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, time spent in the lower Snake River does not appear to affect the subsequent probability of reaching the hatchery/basin of origin for adult hatchery spring Chinook.

For wild origin spring/summer Chinook, there was evidence that prolonged travel times between ICH and LGR does have some negative effect on the probability of upstream survival success. While travel time seems to be a significant variable in explaining some variability in upstream success, it was not significant in increments below the twenty day threshold tested in the candidate model set. This finding was not mirrored in the analysis of wild Chinook detected at LMN and LGS, and this may be due to the limited number of years for which data were available (2014-2017). Additionally, this analysis did not incorporate seasonality (early, middle, late) of run timing, or the distance to the sub-basin that each wild fish was returning. These may be important variables in refining our understanding of how, when, and the degree to which time spent in the lower Snake River effects upstream survival success of wild spring Chinook.

When viewed within the context of Snake River spring Chinook spawn timing (~August/September), moderate travel times spent when temperatures are cool in the lower Snake River are not likely to affect adult spring Chinook 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.

## Appendix A:

**Table 13:** Model summary statistics for hatchery spring Chinook detected as adults at both Lower Monumental and Little Goose Dams (2014-2017). Parameter estimates and summary statistics presented for the top two models (Site\*Y and TT+Site\*Y).

<i>Model Variable</i>	<i>Surv ~ Site * Y</i>			<i>Surv ~ TT + Site * Y</i>		
	<i>Estimate</i>	<i>St.Err</i>	<i>p-value</i>	<i>Estimate</i>	<i>St.Err</i>	<i>p-value</i>
<i>Intercept</i>	-0.87266	0.12622	4.71e-12 ***	-0.84159	0.13122	1.42e-10 ***
<b>Travel Time:</b>						
<i>TT</i>				-0.01386	0.01607	0.388299
<b>Hatchery:</b>						
<i>SiteDWOR</i>	0.35212	0.18808	0.0611.	0.35293	0.1881	0.060613 .
<i>SiteLOOH</i>	1.03517	0.19415	9.73e-08 ***	1.03959	0.19426	8.72e-08 ***
<i>SiteRAPH</i>	-1.33684	0.21623	6.32e-10 ***	-1.33989	0.21628	5.82e-10 ***
<b>Year:</b>						
<i>Y2015</i>	0.01172	0.20807	0.9550	0.27424	0.16927	0.105199
<i>Y2016</i>	1.41346	0.22434	2.97e-10 ***	0.01003	0.2081	0.961541
<i>Y2017</i>	-0.76308	0.25884	0.0031 **	1.44285	0.22711	2.11e-10 ***
<b>Interaction Site*Year:</b>						
<i>SiteDWOR:Y2015</i>	-0.76308	0.25884	0.0031 **	-0.76355	0.25886	0.003181 **
<i>SiteLOOH:Y2015</i>	-0.55999	0.2671	0.0360 *	0.26719	0.034536 *	0.367799
<i>SiteRAPH:Y2015</i>	-0.68763	0.30317	0.0233 *	-0.68622	0.30318	0.023611 *
<i>SiteDWOR:Y2016</i>	-0.53095	0.31844	0.0954 .	-0.53443	0.3185	0.093349 .
<i>SiteLOOH:Y2016</i>	-0.5878	0.32492	0.0704 .	-0.594	0.32505	0.067638 .
<i>SiteRAPH:Y2016</i>	0.62916	0.32961	0.0562	0.32965	0.055346 .	0.123859
<i>SiteDWOR:Y2017</i>	-0.46214	0.4435	0.2973	-0.45216	0.44402	0.308523
<i>SiteLOOH:Y2017</i>	-1.40608	0.37467	0.0001 ***	-1.42767	0.37566	0.000144 ***
<i>SiteRAPH :Y2017</i>	-0.74083	0.37671	0.0492 *	-0.74261	0.37685	0.048772 *
<b>AIC</b>	3534.2			3532.9		
<b>McFadden</b>	0.112373			0.112565		
<b>Pseudo R^2</b>						
<b>Cragg/Uhler</b>	0.180132			0.18042		
<b>Pseudo R^2</b>						

**Table 14:** Model summary statistics for wild spring Chinook detected as adults at both Lower Monumental and Little Goose Dams (2014-2017). Parameter estimates and summary statistics presented for the top two models (Site+TT and Site).

<i>Model Variable</i>	<i>Surv ~ Site+TT</i>			<i>Surv ~ Site</i>		
	<i>Estimate</i>	<i>St.Err</i>	<i>p-value</i>	<i>Estimate</i>	<i>St.Err</i>	<i>p-value</i>
<i>Intercept</i>	0.60674	0.26225	0.0207 *	0.578078	0.260516	0.0265 *
<b>Travel Time:</b>						
<i>TT</i>	-0.01551	0.0162	0.3382			
<b>Hatchery:</b>						
<i>SiteGDR</i>	0.01876	0.28902	0.9483	0.009709	0.288832	0.9732
<i>SiteIMN</i>	2.37922	0.44783	1.08e-07 ***	2.353116	0.44668	1.38e-07 ***
<i>SiteSAL</i>	0.22742	0.27422	0.4069	0.211696	0.273665	0.4392
<b>AIC</b>	1344.3			1343.2		
<b>McFadden</b>	0.048546			0.049183		
<b>Pseudo R^2</b>						
<b>Cragg/Uhler</b>	0.081121			0.082154		
<b>Pseudo R^2</b>						

**Table 15:** Model summary statistics hatchery spring Chinook detected at both Ice Harbor and Lower Granite Dams (2005-2017). Parameter estimates and summary statistics presented for the top two models (“Site+Y” and “T30+Site+Y”).

Model Variable	Surv~Site+Y			Surv~T30+Site+Y		
	Estimate	Std. Error	p-value	Estimate	Std. Error	Pr(> z )
Intercept	-1.24505	0.13798	< 2e-16 ***	-1.247	0.138	< 2e-16 ***
<b><u>Travel Time</u></b>						
TT						
T30				0.367	0.234	0.118
<b><u>Year</u></b>						
Y2006	0.26911	0.2031	0.185158	0.2645	0.20312	0.192864
Y2007	1.2083	0.16472	2.21e-13 ***	1.20711	0.16473	2.34E-13***
Y2008	-0.72007	0.16499	1.28e-05 ***	-0.72186	0.16499	1.21E-05***
Y2009	-0.55935	0.14772	0.000153 ***	-0.56041	0.14773	0.000149**
Y2010	-0.25473	0.13807	0.065058	-0.25513	0.13809	0.064658
Y2011	-0.72577	0.15075	1.48e-06 ***	-0.75103	0.15182	7.54E-07***
Y2012	-0.0518	0.15289	0.734787	-0.05509	0.15291	0.718656
Y2013	0.73743	0.15784	2.98e-06 ***	0.73788	0.15786	2.95E-06***
Y2014	0.06881	0.14944	0.645184	0.06811	0.14946	0.64858
Y2015	-0.10337	0.14589	0.478595	-0.10304	0.1459	0.480035
Y2016	0.18218	0.16234	0.261749	0.17959	0.16235	0.268657
Y2017	1.08235	0.1805	2.02e-09 ***	1.07573	0.18058	2.57E-09***
<b><u>Hatchery</u></b>						
SiteDWOR	-0.16999	0.08111	0.036087 *	-0.16907	0.08112	0.037127
SiteLOOH	2.29019	0.09779	< 2e-16 ***	2.29321	0.09784	2.00E-16
SiteRAPH	-0.35131	0.07366	1.85e-06 ***	-0.34998	0.07368	2.03E-06
<b><u>AIC</u></b>	9008.7			9008.3		
<b><u>McFadden</u></b>						
<b><u>Pseudo R^2</u></b>	0.1353			0.135		
<b><u>Cragg/Uhler</u></b>						
<b><u>Pseudo R^2</u></b>	0.204			0.204		

**Table 16:** Model summary statistics for wild spring Chinook detected at both Ice Harbor and Lower Granite Dams (2005-2017). Parameter estimates and summary statistics presented for the top two models (TT+Site+Y and T20+Site+Y).

Model Variable	Surv~TT+Site+Y			Surv~T20+Site+Y		
	Estimate	Std. Error	p-value	Estimate	Std. Error	Pr(> z )
Intercept <b>Travel Time</b>	-3.07488	0.344251	< 2e-16 ***	-1.247	0.138	< 2e-16 ***
TT T20 <b>Year</b>	-0.02033	0.005715	0.000374 *	-0.6388	0.189	0.000725***
Y2006	0.92317	0.390233	0.017996*	0.92317	0.390233	0.017996***
Y2007	1.215116	0.398067	0.002269**	1.215116	0.398067	0.002269***
Y2008	1.188905	0.355726	0.000831***	1.188905	0.355726	0.000831***
Y2009	1.586879	0.334987	2.17E-06***	1.586879	0.334987	2.17E-06***
Y2010	1.460112	0.326469	7.73E-06***	1.460112	0.326469	7.73E-06***
Y2011	1.997653	0.331237	1.63E-09***	1.997653	0.331237	1.63E-09***
Y2012	2.807217	0.333761	2.00E-16***	2.807217	0.333761	2.00E-16***
Y2013	2.99557	0.340453	2.00E-16***	2.99557	0.340453	2.00E-16***
Y2014	3.02184	0.336027	2.00E-16***	3.02184	0.336027	2.00E-16***
Y2015	2.870018	0.336133	2.00E-16***	2.870018	0.336133	2.00E-16***
Y2016	2.97716	0.345984	2.00E-16***	2.97716	0.345984	2.00E-16***
Y2017 <b>Hatchery</b>	3.201172	0.389903	2.00E-16***	3.1523	0.18058	5.44E-16***
SiteGDR	0.596875	0.156371	0.000135	0.5958	0.1563	0.000138
SiteIMN	1.951606	0.165564	2.00E-16	1.9547	0.1655	2.00E-16
SiteSAL	1.113187	0.140456	2.27E-15	1.1134	0.1404	2.20E-15
<b>AIC</b>	4594.2			4594.7		
<b>McFadden Pseudo R<sup>2</sup></b>	0.163132			0.128192		
<b>Cragg/Uhler Pseudo R<sup>2</sup></b>	0.217523			0.217075		



**Table 77: :** Model summary statistics for wild spring Chinook detected at both Ice Harbor and Lower Granite Dams (2005-2017). Parameter estimates and summary statistics presented for the best fitting models with travel time variables under 20 days.

Model Variable	Surv~T5+Site+Y			Surv~T10+Site+Y			Surv~T15+Site+Y		
	Estimate	Std. Error	p-value	Estimate	Std. Error	p-value	Estimate	Std. Error	Pr(> z )
Intercept <b>Travel Time</b>	-3.1195	0.3448	< 2e-16 ***	-3.168	0.3429	< 2e-16 ***	-3.1807	0.3427	< 2e-16 ***
T5 T10 T15 <b>Year</b>	-0.13662	0.07413	0.065333 .	-0.139	0.1013	0.170304	-0.2416	0.1425	0.089953
Y2006	0.89724	0.39045	0.021562 *	0.8867	0.39	0.022995 *	0.9016	0.3902	0.020850 *
Y2007	1.20266	0.39811	0.002520 **	1.1855	0.3977	0.002877 **	1.1972	0.3978	0.002617 **
Y2008	1.19579	0.35597	0.000782 ***	1.176	0.3555	0.000939 ***	1.1769	0.3554	0.000928 ***
Y2009	1.59226	0.33515	2.02e-06 ***	1.5787	0.3348	2.42e-06 ***	1.5886	0.3347	2.07e-06 ***
Y2010	1.46192	0.3268	7.70e-06 ***	1.4491	0.3263	8.95e-06 ***	1.4453	0.3262	9.37e-06 ***
Y2011	1.919	0.33049	6.38e-09 ***	1.9073	0.3301	7.56e-09 ***	1.9248	0.3305	5.73e-09 ***
Y2012	2.80286	0.33394	< 2e-16 ***	2.792	0.3336	< 2e-16 ***	2.8027	0.3335	< 2e-16 ***
Y2013	2.99661	0.34057	< 2e-16 ***	2.9868	0.3403	< 2e-16 ***	2.9967	0.3401	< 2e-16 ***
Y2014	3.0089	0.33622	< 2e-16 ***	2.9968	0.3357	< 2e-16 ***	3.0066	0.3357	< 2e-16 ***
Y2015	2.86044	0.33628	< 2e-16 ***	2.8539	0.336	< 2e-16 ***	2.8688	0.3358	< 2e-16 ***
Y2016	2.98205	0.34613	< 2e-16 ***	2.9779	0.3459	< 2e-16 ***	2.987	0.3457	< 2e-16 ***
Y2017 <b>Hatchery</b>	3.18244	0.39035	3.56e-16 ***	3.1568	0.3896	5.36e-16 ***	3.16	0.3896	5.02e-16 ***
SiteGDR	0.59855	0.1562	0.000127 ***	0.5991	0.1561	0.000124 ***	0.5989	0.1561	0.000125 ***
SiteIMN	1.94943	0.16547	< 2e-16 ***	1.949	0.1654	< 2e-16 ***	1.9491	0.1654	< 2e-16 ***
SiteSAL	1.10413	0.14031	3.57e-15 ***	1.1109	0.1402	2.30e-15 ***	1.1101	0.1402	2.45e-15 ***
<b>AIC</b>	4604			4605.5			4604.5		
<b>McFadden Pseudo R^2</b>	0.1266088			0.1263199			0.1265113		
<b>Cragg/Uhler Pseudo R^2</b>	0.2146221			0.2141739			0.2144708		