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**MEMORANDUM**

TO: FPAC

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 origiun(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 11:** 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 12:** 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).

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

**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).

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

**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 | Surv~Site+Y | | | Surv~T30+Site+Y | | |
|---|---|---|---|---|---|---|
| Variable | Estimate | Std. Error | p-value | Estimate | Std. Error | Pr(>\|z\|) |
| Intercept | -1.24505 | 0.13798 | < 2e-16 *** | -1.247 | 0.138 | < 2e-16 *** |
| **Travel Time** | | | | | | |
| TT | | | | | | |
| T30 | | | | 0.367 | 0.234 | 0.118 |
| **Year** | | | | | | |
| 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*** |
| **Hatchery** | | | | | | |
| 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 |
| **AIC** | 9008.7 | | | 9008.3 | | |
| **McFadden Pseudo R^2** | 0.1353 | | | 0.135 | | |
| **Cragg/Uhler Pseudo R^2** | 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 | Surv~TT+Site+Y | | | Surv~T20+Site+Y | | |
|---|---|---|---|---|---|---|
| Variable | Estimate | Std. Error | p-value | Estimate | Std. Error | Pr(>\|z\|) |
| Intercept | -3.07488 | 0.344251 | < 2e-16 *** | -1.247 | 0.138 | < 2e-16 *** |
| **Travel Time** | | | | | | |
| TT | -0.02033 | 0.005715 | 0.000374 * | | | |
| T20 | | | | -0.6388 | 0.189 | 0.000725*** |
| **Year** | | | | | | |
| 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 | 3.201172 | 0.389903 | 2.00E-16*** | 3.1523 | 0.18058 | 5.44E-16*** |
| **Hatchery** | | | | | | |
| 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 |
| **AIC** | 4594.2 | | | 4594.7 | | |
| **McFadden Pseudo R^2** | 0.163132 | | | 0.128192 | | |
| **Cragg/Uhler Pseudo R^2** | 0.217523 | | | 0.217075 | | |

**Table 17: :** 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 | Surv~T5+Site+Y | | | Surv~T10+Site+Y | | | Surv~T15+Site+Y | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Estimate | Std. Error | p-value | Estimate | Std. Error | p-value | Estimate | Std. Error | Pr(>\|z\|) |
| Intercept | -3.1195 | 0.3448 | < 2e-16 *** | -3.168 | 0.3429 | < 2e-16 *** | -3.1807 | 0.3427 | < 2e-16 *** |
| **Travel Time** | | | | | | | | | |
| T5 | -0.13662 | 0.07413 | 0.065333 . | | | | | | |
| T10 | | | | -0.139 | 0.1013 | 0.170304 | | | |
| T15 | | | | | | | -0.2416 | 0.1425 | 0.089953 |
| **Year** | | | | | | | | | |
| 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 | 3.18244 | 0.39035 | 3.56e-16 *** | 3.1568 | 0.3896 | 5.36e-16 *** | 3.16 | 0.3896 | 5.02e-16 *** |
| **Hatchery** | | | | | | | | | |
| 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 *** |
| **AIC** | 4604 | | | 4605.5 | | | 4604.5 | | |
| **McFadden Pseudo R^2** | 0.1266088 | | | 0.1263199 | | | 0.1265113 | | |
| **Cragg/Uhler Pseudo R^2** | 0.2146221 | | | 0.2141739 | | | 0.2144708 | | |