# Model Documentation

**Subject:** Run Forecasting for Hood River Spring Chinook and Steelhead

**Date:**

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Overview

We developed a series of run forecasting models for Hood River natural-origin (NOR) and hatchery-origin (HOR) spring Chinook, NOR summer steelhead, and NOR and HOR winter steelhead. Previously, Hood River run forecasts were conducted using Excel-based models by Griswold et al. (2009). These models were used as a starting point, then refit with an additional 10+ years of monitoring data, refined through model selection, and transitioned to a more user-friendly workflow using the open-source statistical program R (R Core Team 2023).

During model revision, each model underwent a model selection process to identify the most informative predictors. Predictors were included in final models when they 1) assisted with model fit, 2) had a supported biological explanation for the direction and magnitude of effect, and 3) related to unique life stages. All models included a prior abundance metric as a predictor. Environmental variables that explained variation in return abundance due to conditions during rearing, outmigration, ocean entrance, and return were also examined for inclusion. Data were compiled from Hood River monitoring reports, the “RunForecastingData\_MS.xlsx” spreadsheet used in the prior models, and other publicly available sources (Table 1). Predictors were lagged and weighted based on observed Hood River age-at-return data. For example, NOR winter steelhead were on average 5% 1-salt, 75% 2-salt, and 20% 3-salt. When calculating ocean conditions experienced by return year *t*, ocean conditions from year *t-1* were multiplied by 5%, plus *t-2* times 75%, and finally *t-3* times 20%. Similar calculations were applied for all predictor variables. Overall, the most informative environmental predictors were the North Pacific Gyre Oscillation (NPGO) ocean condition index and minimum daily flow at Tucker bridge one year prior to outmigration. NPGO was included in nearly all models, and minimum flow was included in all NOR models. A host of environmental variables for outmigration and return were also examined but not included in the final models, such as Columbia River flow and temperature, and spill at Bonneville dam.

Models were constructed within a Bayesian framework using the ‘brms’ package for R (Bürkner 2017), and model fit was examined using common statistical metrics including convergence, residual error, and observed versus predicted values. Overall, models were able to account for and accurately predict variation in returns for most years, but provided less accurate predictions in years with exceptionally high or low returns.

Table 1. List of variables and data sources used in the Hood River forecasting models.

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| --- | --- | --- | --- |
| **Variable type** | **Run** | **Variable** | **Source** |
| Abundance | NOR winter steelhead | Adult returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  | NOR steelhead | Smolt outmigrants | CTWS and ODFW (2019) |
|  |  | Unclipped returns to Bonneville minus the Dalles (May 1 – Sept 30) | Columbia Basin Research DART online database |
|  | HOR winter steelhead | HOR winter steelhead returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  |  | Smolt releases | CTWS and ODFW (2019); hatchery FLR slips |
|  | NOR summer steelhead | Adult returns | RunForecastingData\_MS.xlsx |
|  | NOR spring Chinook | Adult returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  |  | Jack returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  | Spring Chinook | Returns to Bonneville minus the Dalles | Columbia Basin Research DART online database |
|  | HOR spring Chinook | Adult returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  |  | Jack returns | CTWS and ODFW (2019); RunForecastingData\_MS.xlsx |
|  |  | Smolt releases | (Confederated Tribes of the Warm Springs (CTWS) and Oregon Department of Fish and Wildlife (ODFW) 2019) |
| Environmental |  | Northern Pacific Gyre Oscillation | Di Lorenzo (2023) |
|  |  | Hood River minimum daily flow | USGS gage at Tucker Bridge (#14120000) |

NOR Winter Steelhead

Data inputs

Return abundance data were collected from (Confederated Tribes of the Warm Springs (CTWS) and Oregon Department of Fish and Wildlife (ODFW) 2019) for the 1992 – 2018 run years, and from the previous forecasting data spreadsheet (“RunForecastingData\_MS.xlsx”) for the 2019 and 2020 run years. These are the estimates of passage above Powerdale Dam (1992 – 2010) and the East Fork Weir (2011 – 2020). Age data used to lag predictors was obtained from scales collected during Powerdale Dam passage (1992 – 2010) and the East Fork Weir (2011 – 2018).

Predictors for the model were prior NOR steelhead smolt outmigration abundance, minimum daily flow at Tucker bridge (USGS gage # 14120000) in the year prior to outmigration, and May North Pacific Gyre Oscillation (NPGO) in the year of ocean entry. Spawning escapement was also examined as a predictor, however smolt abundance provided a significantly better fit.

**S**molt outmigration abundance estimates were not available for outmigration years 2021 and 2022, so they were imputed using the same regression model framework as the forecasting models. For the smolt outmigration model, predictors were prior spawning escapement of NOR and HOR winter steelhead and minimum daily flow at Tucker bridge one year prior to outmigration. Smolt model details are located at the end of this document (see NOR Winter Steelhead Smolt Estimation).

Model Results

The model performed particularly well, owing to the 29-year returns dataset. Outmigration abundance, minimum flow, and NPGO were all informative predictors, accounting for a substantial amount of variation across winter steelhead life history. Predicted values followed trends in observed data in most cases (Figure 1).



Figure . Observed and predicted values for the NOR winter steelhead forecasting model. The error bars represent 95% credible intervals.

HOR Winter Steelhead

Data Inputs

Return abundance data were collected from CTWS and ODFW (2019) for the 1997 – 2018 run years, and from the previous forecasting data spreadsheet (“RunForecastingData\_MS.xlsx”) for the 2019 – 2021 run years. Abundance data were estimates of passage above Powerdale Dam (1997 – 2010) and the East Fork Weir (2011 – 2021). Predictors were lagged using age-at-return data collected from scales during passage through Powerdale Dam (2008 – 2010) and the East Fork Weir (2011 – 2015).

Returns were predicted using prior HOR winter steelhead smolt releases and May NPGO in the year of ocean entry.

Model Results

The length of the 25-year returns dataset assisted with model predictive capacity and predicted values followed general trends in return abundance. However, residual error was relatively high (σ2 = 504), and this is unexplained variation is evident in years with particularly high or low returns (Figure 2).



Figure . Observed and predicted values for the HOR winter steelhead model. Error bars represent 95% credible intervals.

NOR Summer Steelhead

Data inputs

Return abundance data were obtained from the prior forecasting model data inputs spreadsheet (“RunForecastingData\_MS.xlsx”). Abundance data was available for the 1994 – 2010 and 2015 – 2017 return years. Age data was obtained from scales collected from 2010 – 2018.

Due to data gaps in the summer steelhead return abundance data and uncertainty if annual return estimates will be available in the in the future, the abundance predictor was chosen to be unclipped steelhead dam counts between May 1 and September 30 from Bonneville Dam, minus counts at the Dalles for the same time period. The May 1 through September 30 window was selected based on return timing of Hood River summer steelhead to collection sites, minus the average 30-day travel time from Bonneville (Simpson 2020).

Environmental predictors were minimum flow at Tucker bridge one year prior to outmigration and May NPGO in the year of ocean entry.

Model Results

Model parameters converged appropriately (Rhat < 1.05), and predictors for rearing and ocean conditions were informative. This resulted in a model that accounted for the majority of variance in the 21-year returns dataset (Figure 3).



Figure . Observed and predicted values for the NOR summer steelhead model. Error bars represent 95% credible intervals.

NOR Spring Chinook

NOR spring Chinook forecasts consist of separate jack and adult models.

Data Inputs

Return abundance of adults and jacks were primarily obtained from (Confederated Tribes of the Warm Springs (CTWS) and Oregon Department of Fish and Wildlife (ODFW) 2019). Adult abundance was available for return years 1997 – 2010 and 2016. Additional adult abundance data for run years 2011, 2012, and 2022 were obtained from the prior forecasting model data inputs spreadsheet (“RunForecastingData\_MS.xlsx”). Jack data was available for run years 1997 – 2010. Age data for NOR spring Chinook was not available, so HOR spring Chinook age data was used to lag predictors.

Adult returns were predicted with Bonneville Dam spring Chinook counts minus counts from the Dalles, and minimum flow at Tucker bridge one year prior to outmigration. This metric was used due to data availability concerns, as Hood River escapement or smolt outmigration abundance data will not always be readily available.

Jack returns were predicted using the same abundance metric, lagged by only 3 years. Minimum flow during rearing was not an informative predictor, however September NPGO in the year of ocean entry was associated with returns and included.

Model Results

**Jacks**

Model parameters converged appropriately (Rhat < 1.05) and predictions followed the general trends of observed values (Figure 4). However, given the sparsity of returning NOR spring Chinook jacks, model forecasts may not be verifiable. If the Hood River spring Chinook population experiences significant uplift, it is unlikely that the model will forecast accordingly and will require revision.



Figure . Observed and predicted values for the NOR spring Chinook jack model. Error bars represent 95% credible intervals.

**Adults**

Similar to the jacks model, reliance on Bonneville and the Dalles dam passage data resulted in less precise estimates. Model parameters converged appropriately (Rhat < 1.05), however residual error remained relatively high (σ2 = 87).



Figure . Observed and predicted values for the NOR spring Chinook adult model. Error bars represent 95% credible intervals.

HOR Spring Chinook

HOR spring Chinook forecasts consists of two separate models that predict adult and jack returns.

Data Inputs

Return abundance of adults and jacks from 1997 – 2017 was obtained from (Confederated Tribes of the Warm Springs (CTWS) and Oregon Department of Fish and Wildlife (ODFW) 2019). Jack abundance for 2018 – 2021 and adult abundance for 2018 – 2022 was obtained from the prior forecasting model data inputs spreadsheet (“RunForecastingData\_MS.xlsx”). Age data was obtained from scales collected from 2009 – 2022.

Both models predict returns using hatchery smolt release abundances and May NPGO, with predictors lagged differently according to age-at-return data.

Model Results

**Jacks**

The jack model parameters converged appropriately (Rhat < 1.05), however there appears to be substantial variation in returns that is not explained by the predictors (Figure 6). This may be due to fluctuations in the proportion of a run that consisted of jacks, potentially due to environmental factors or hatchery rearing practices.



Figure . Observed and predicted values for the HOR spring Chinook jack model. Error bars represent 95% credible intervals.

**Adults**

Model parameters converged appropriately (Rhat < 1.05) and accounted for some of the variation in return abundance. This resulted in accurate predictions for years with near-average escapement (Figure 7). However, the model was fairly inaccurate at predicting returns at particularly low or high abundances. Similar to the jack model, this may be due to the substantial unexplained variation in the proportion of a return that consisted of jacks.



Figure . Observed and predicted values for the HOR spring Chinook adult model. Error bars represent 95% credible intervals.

NOR Winter Steelhead Smolt Estimation

This model was developed to estimate NOR steelhead smolt outmigration abundance for 2021 and 2022. Direct estimates were not available, as the rotary screw traps in the main stem Hood River were not operated consistently during smolt outmigration. Therefore, we developed a regression model similar to those presented in the main body of the document to estimate outmigration abundance. The model predicts NOR steelhead smolt abundance as a function of previous adult steelhead spawning escapement and minimum daily flow at Tucker bridge one year prior to outmigration. Model predictors converged appropriately (Rhat > 1.05) and predictions followed trends in observed abundance, though residual error remained relatively high (σ2 = 6,756). Predictions for 2021 and 2022 were 15,316 and 15,021 smolts, respectively.



Figure . Observed and predicted values for the NOR winter steelhead smolt model. Error bars represent 95% credible intervals.

References

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