Appendix AB-I, Old and Middle River Flow Management

# Attachment I.9 Winter-run Chinook Salmon Coded Wire Tag Salvage Model

## I.9.1 Model Overview

The Winter-Run Chinook Salmon Coded Wire Tag (CWT) Proportional Salvage Model was developed to estimate the fraction of juvenile winter-run Chinook salmon in the Delta predicted to be salvaged based on hydrologic conditions and fish size. The model is based on the models of Zeug and Cavallo (2014) who analyzed > 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter-, late fall-run, and fall-run Chinook salmon. These data represent large release groups of tagged smolts where the number of fish representing each release group salvaged at the export facilities has been estimated. Analysis of "raw" salvage (observed salvage without scaling by starting population size) is problematic because the actual stock or basin of origin is often unknown (e.g., poor performance of length-at-date curves). Furthermore, with "raw" salvage, the number of smolts produced and potentially exposed to entrainment and salvage at the Delta fish collection facilities is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

A model specific to winter-run Chinook salmon was constructed by Zeug and Cavallo (2015) to examine the level of evidence for additional hydrologic metrics. This model combined salvage at both the CVP and SWP rather than modeling them separately as was done in Zeug and Cavallo (2014). Model selection included five potential hydrologic predictor variables including Old-Middle River flow (OMR), inflow-export ratio (I-E), total exports (CVP and SWP combined), San Joaquin River flow, Sacramento River flow and one biological variable (mean fork length at release) (Table I.9-1). To select the best approximating model, Akaike's Information Criterion (AIC) was calculated for each model. The model with the lowest AIC value was identified as the best approximating model. A single best model of salvage was selected with no other model having a $\Delta$AIC <2.8. This model had three predictor variables including: mean fork length of fish at release, Sacramento River flow, and total exports.

# I.9.2 Model Development

## I.9.2.1 Methods

### *I.9.2.1.1 Model Development: Salmon Releases*

Hatchery winter-run Chinook salmon are raised at the Livingston Stone National Fish Hatchery located at the base of Shasta Dam. All of the juveniles raised at this hatchery have coded wire tags (CWTs) inserted for identification when recaptured. These tags are short lengths of steel wire with a numeric code that identifies a specific release group. Fish receiving a CWT also have their adipose fin clipped so tagged fish can be visually identified at capture.

Juvenile salmon with an adipose clip collected at the diversions are retained, the CWT is read, and the number of fish salvaged from that release group is estimated. Release data for juvenile salmon were obtained from the Regional Mark Processing Center coded wire tag database maintained by the Pacific States Marine Fisheries Commission (http://www.rmpc.org/). Data from release years 1993–2007 were queried from the database. These years were chosen to represent water management in the Delta which changed in the mid-1990's in response to the Bay-Delta Accord (California State Water Resources Control Board Ruling D-1641). Additionally, releases under 1000 individuals were excluded. The data queried included: release size, date of release, and mean fork length at release. Recovery information was obtained from the United States Fish and Wildlife Service Chipps Island Survival table (http://www.fws.gov/stockton/jfmp/datamanagement.asp). These data included: the expanded number of tagged salmon collected at the CVP and SWP salvage facilities, and the range of dates over which fish from each release group were captured in the trawl.

### *I.9.2.1.2 Model Development: Environmental data*

Juvenile winter-run Chinook salmon are released in the Sacramento River ~ 600 km from CVP and SWP Delta diversions; however, they are not vulnerable to entrainment until they enter the tidal Delta. A study of salmon migration with acoustic telemetry indicated juvenile salmon migrated through the Delta in 6.4 days on average. To capture the conditions experienced during Delta migration, hydrologic variables were averaged over 7 days after salmon entered the Delta. To estimate the date when each release group arrived at the Delta, we calculated the median date between the first and last capture in the Chipps Island trawl at the exit of the Delta. The 7 days prior to the median capture date was the time period over which hydrologic conditions were averaged. Mean daily flow (hereafter ''flow'') for the Sacramento River was obtained from the United States Geological Survey (USGS) gauge 11447650 at Freeport. San Joaquin River flow was obtained from USGS gauge 11303500 at Vernalis. Daily water diversion rates from the CVP and SWP, and OMR were obtained from the DAYFLOW online data archive maintained by the California Department of Water Resources.

#### *I.9.2.1.3 Model Development: Data Analysis*

The response variable in model was the number of fish salvaged. The number of fish released was included as an offset variable to account for differences in release group size.

Independent variables in statistical models were selected based on hypothesized relationships with salvage. These variables could potentially affect the process of salvage or the exposure of fish to salvage. For example, zero salvage could occur because most fish were not exposed to entrainment or died prior to entering the Delta. To account for mortality prior to salvage, fork length at release was included as smaller fish should be more susceptible to gape limited predators and survival was expected to be positively associated with mean fork length. For fish in the Delta it was hypothesized that salvage would increase as flows decreased and as diversion increased. Previous analyses of fish entrainment have utilized a ratio of diversion to flow as a predictor of entrainment risk instead of using these variables as separate independent predictors.

Table I.9-1. Six candidate models of salvage evaluated to determine which hydrologic variables were the best predictors of winter-run Chinook salmon salvage.

| | Length | Sac Flow | SJ Flow | Exports | OMR | I:E Ratio |
|---|---|---|---|---|---|---|
| Model 1 | X | X | - | X | - | |
| Model 2 | X | X | - | - | X | - |
| Model 3 | X | X | X | - | - | - |
| Model 4 | X | X | - | - | - | X |
| Model 5 | X | X | X | - | - | X |
| Model 6 | X | X | - | - | - | - |

The model selection exercise included five potential hydrologic predictor variables including Old-Middle River flow (OMR), inflow-export ratio (I:E), total exports (CVP and SWP combined), San Joaquin River flow, Sacramento River flow, and one biological variable (mean fork length at release). Most of these variables were strongly correlated so models were constructed only with variables that had correlation coefficients <0.70 to avoid multicollinearity. Table I.9-1 contains a list of candidate models examined in this exercise. Screening of the response variable indicated that many releases in both rivers resulted in zero salvage. Thus, a zero-inflated negative binomial model (ZINB) was fit based only on winter run releases (178 release groups, > 1 million individuals) for each candidate model with standardized predictors for both the count and zero-inflation portion of the models and the log number of fish released as an offset variable in the count portion of the model. Model selection proceeded using an information-theoretic approach. Akaike's Information Criterion corrected for sample size (AICc) was calculated for each model. The model with the lowest AICc value was identified as the "best fit" model and any other model within 2 points of the best fit model was considered a competing explanation of the observed data. All modeling was performed with the R statistical program and the packages "pscl" and "MASS".

A single best model was selected that included fish length, Sacramento River flow and exports as predictors (Table I.9-2). All other models had ΔAICc values < 2.0.

Table I.9-2. Parameter estimates from the best approximating model of winter-run Chinook salmon salvage.

| | Count Model | | Zero-Inflated Model | |
|---|---|---|---|---|
| **Model Parameter** | **Coefficient** | **P-Value** | **Coefficient** | **P-Value** |
| Fork Length | 0.709 | < 0.001 | -0.776 | <0.001 |
| Sacramento River Flow | 0.155 | 0.707 | 0.610 | 0.140 |
| Total Exports | 0.350 | 0.006 | -0.957 | <0.001 |

To apply this model to hydrologic scenarios outside of those used to construct the model, we had to use a fixed number of winter-run Chinook salmon entering the Delta each month. The raw output of the model is the number of fish salvaged. However, we used the offset variable to convert this number to a proportion. In this way the model predicts the magnitude of salvage independent of the number of fish that may actually be in the Delta during a given month. The measures of error associated with model parameters are used to quantify uncertainty in model predictions.

### I.9.2.2 Assumptions / Uncertainty

Relationships developed with hatchery-origin winter-run Chinook salmon are applicable to natural-origin winter-run Chinook salmon.

Relationships developed within the time period of the winter-run Chinook salmon CWT releases applies to time periods outside of the CWT releases that winter-run Chinook salmon are still in the Delta.

### I.9.2.3 Code and Data Repository

Analysis files for the WR CWT Proportional Loss input data and WR CWT Proportional Loss analysis are available from Reclamation upon request.

## I.9.3 Results

### I.9.3.1 EIS: Narrative, Figures, and Table Results

Under Alt1 in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 117.2% higher in the month of December to 16.9% higher in the month of November compared to the NAA (Figure I.9-1 and Table I.9-3).

Under Alt2 With TUCP Without VA in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 68.3% higher in the month of May to 3.6% lower in the month of December compared to the NAA.

Under Alt2 Without TUCP Without VA in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 67.8% higher in the month of May to 3.4% lower in the month of December compared to the NAA.

Under Alt2 Without TUCP Delta VA in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 67.5% higher in the month of May to 3.3% lower in the month of December compared to the NAA.

Under Alt2 Without TUCP Systemwide VA in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 67.9% higher in the month of May to 2.4% lower in the month of December compared to the NAA.

Under Alt3 in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 37.5% lower in the month of January to 92% lower in the month of April compared to the NAA.

Under Alt4 in wet water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 64% higher in the month of May to 13.5% lower in the month of December compared to the NAA.

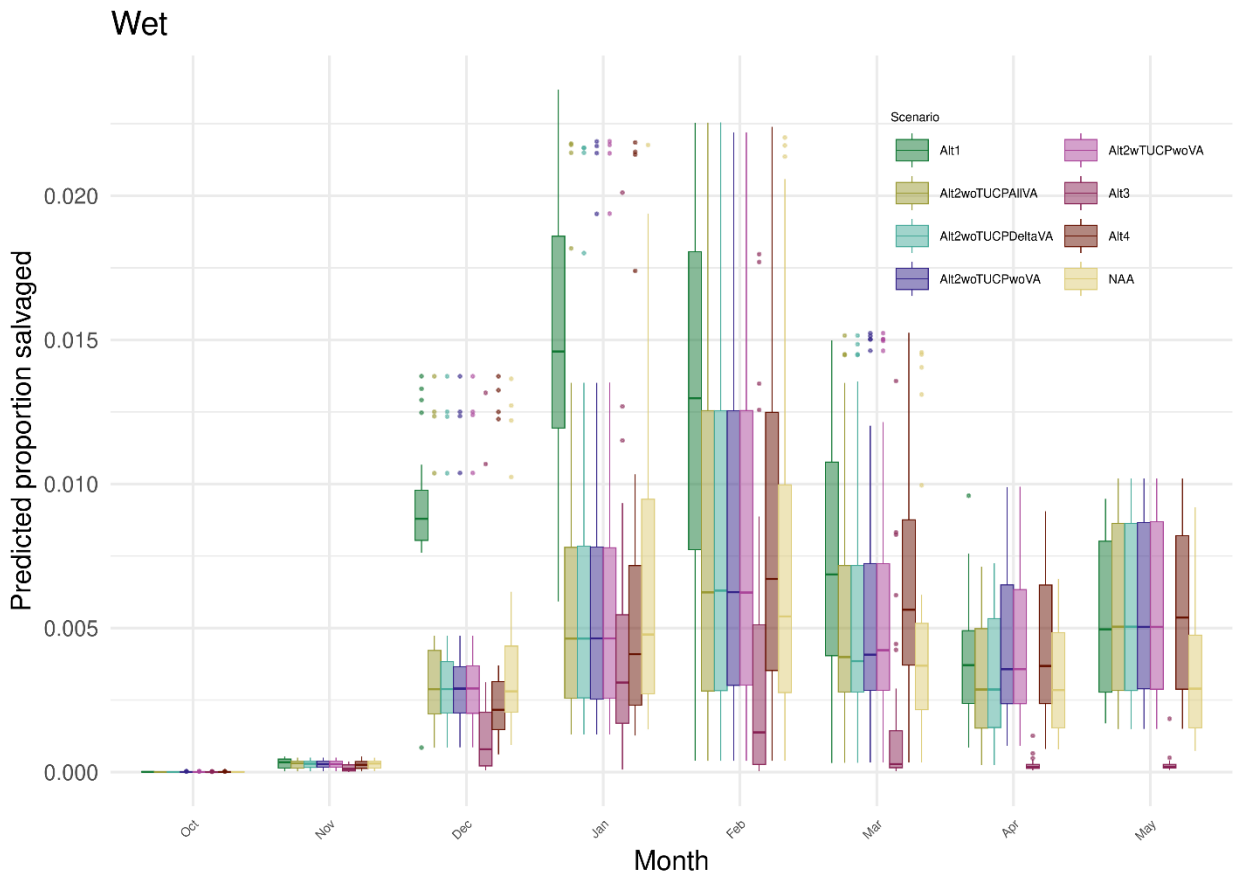


Figure I.9-1. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Wet water year types.

Table I.9-3. Mean predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Wet water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Wet | Oct | 0.0000 | 0.0000 (48.4%) | 0.0000 (-2.8%) | 0.0000 (-3.4%) | 0.0000 (1.0%) | 0.0000 (3.8%) | 0.0000 (-39.9%) | 0.0000 (-1.8%) |
| Wet | Nov | 0.0003 | 0.0003 (16.9%) | 0.0003 (-0.0%) | 0.0003 (0.0%) | 0.0003 (0.9%) | 0.0003 (0.3%) | 0.0001 (-45.9%) | 0.0003 (-4.2%) |
| Wet | Dec | 0.0042 | 0.0091 (117.2%) | 0.0040 (-3.6%) | 0.0040 (-3.4%) | 0.0040 (-3.3%) | 0.0041 (-2.4%) | 0.0019 (-55.5%) | 0.0036 (-13.5%) |
| Wet | Jan | 0.0070 | 0.0151 (116.8%) | 0.0071 (2.4%) | 0.0071 (2.2%) | 0.0071 (1.6%) | 0.0071 (1.7%) | 0.0044 (-37.5%) | 0.0066 (-5.3%) |

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Wet | Feb | 0.0082 | 0.0129 (57.1%) | 0.0090 (10.0%) | 0.0090 (9.4%) | 0.0090 (10.0%) | 0.0090 (9.8%) | 0.0039 (-52.9%) | 0.0094 (15.0%) |
| Wet | Mar | 0.0050 | 0.0077 (54.6%) | 0.0062 (25.5%) | 0.0062 (25.3%) | 0.0058 (16.4%) | 0.0056 (13.4%) | 0.0019 (-61.5%) | 0.0069 (40.0%) |
| Wet | Apr | 0.0032 | 0.0039 (21.5%) | 0.0043 (35.6%) | 0.0044 (37.6%) | 0.0032 (1.2%) | 0.0032 (-0.7%) | 0.0003 (-92.0%) | 0.0044 (36.8%) |
| Wet | May | 0.0033 | 0.0054 (63.6%) | 0.0056 (68.3%) | 0.0056 (67.8%) | 0.0056 (67.5%) | 0.0056 (67.9%) | 0.0003 (-91.7%) | 0.0054 (64.0%) |

Under Alt1 in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 255.8% higher in the month of January to 6.6% higher in the month of November compared to the NAA (Figure I.9-2 and Table I.9-4).

Under Alt2 With TUCP Without VA in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 99.7% higher in the month of April to 4.5% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Without VA in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 99.1% higher in the month of April to 5.3% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Delta VA in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 47.8% higher in the month of May to 38.7% lower in the month of March compared to the NAA.

Under Alt2 Without TUCP Systemwide VA in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 43.7% higher in the month of May to 37.8% lower in the month of March compared to the NAA.

Under Alt3 in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 8.4% higher in the month of March to 81% lower in the month of May compared to the NAA.

Under Alt4 in above normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 100.5% higher in the month of April to 14.5% lower in the month of December compared to the NAA.

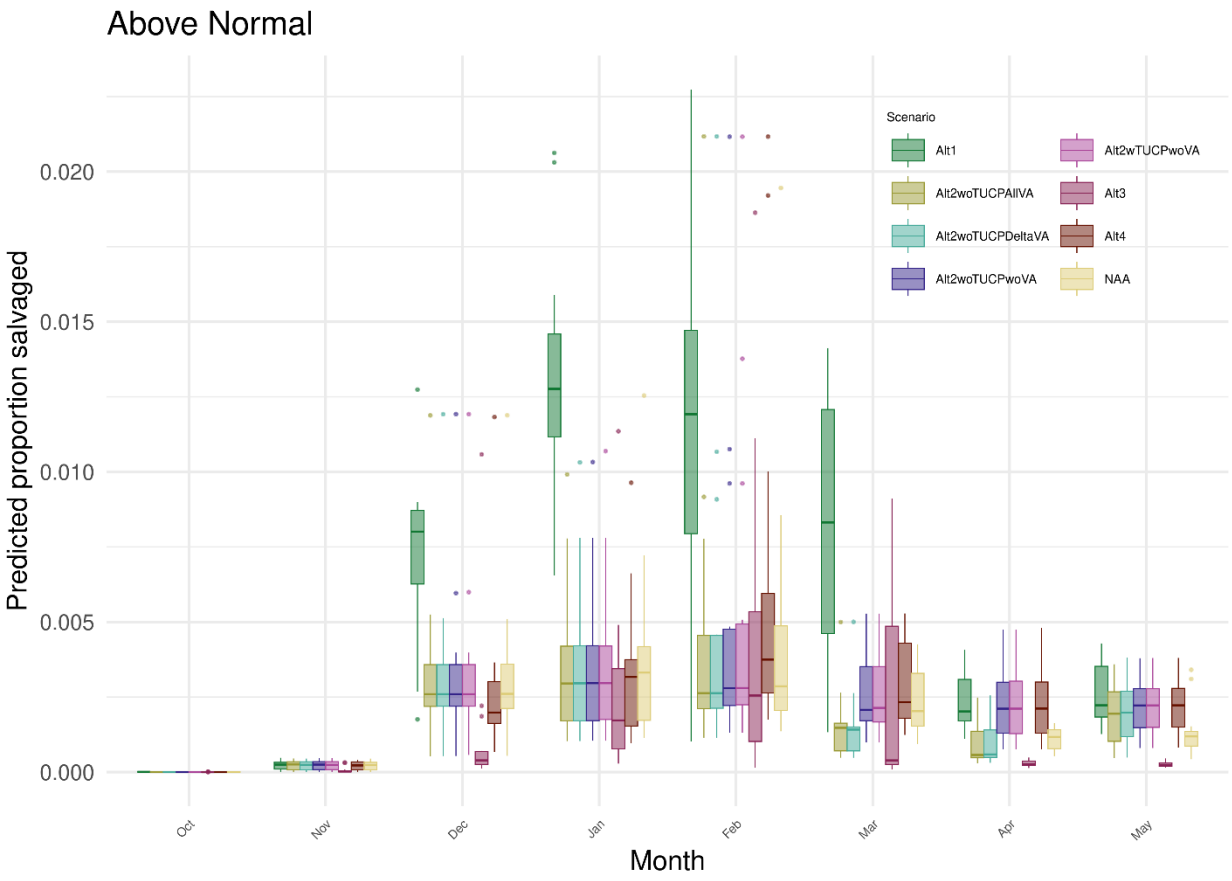


Figure I.9-2. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during above normal water year types.

Table I.9-4. Mean predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Above Normal water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Above Normal | Oct | 0.000 | 0.0000 (245.8%) | 0.0000 (-0.3%) | 0.0000 (0.5%) | 0.0000 (-0.2%) | 0.0000 (4.7%) | 0.0000 (-28.9%) | 0.0000 (0.4%) |
| Above Normal | Nov | 0.002 | 0.0002 (6.6%) | 0.0002 (3.8%) | 0.0002 (4.9%) | 0.0002 (3.6%) | 0.0002 (4.5%) | 0.0001 (-69.7%) | 0.0002 (-1.5%) |
| Above Normal | Dec | 0.003 | 0.0073 (121.6%) | 0.0034 (3.4%) | 0.0034 (3.2%) | 0.0033 (1.2%) | 0.0033 (1.4%) | 0.0013 (-59.4%) | 0.0028 (-14.5%) |
| Above Normal | Jan | 0.004 | 0.0133 (255.8%) | 0.0036 (-4.5%) | 0.0035 (-5.3%) | 0.0035 (-5.4%) | 0.0035 (-6.4%) | 0.0026 (-29.7%) | 0.0033 (-10.9%) |

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Above Normal | Feb | 0.005 | 0.0117 (159.0%) | 0.0053 (17.9%) | 0.0051 (12.6%) | 0.0049 (8.7%) | 0.0047 (4.2%) | 0.0045 (-1.0%) | 0.0063 (40.1%) |
| Above Normal | Mar | 0.002 | 0.0082 (241.5%) | 0.0027 (10.8%) | 0.0027 (10.9%) | 0.0015 (-38.7%) | 0.0015 (-37.8%) | 0.0026 (8.4%) | 0.0029 (20.5%) |
| Above Normal | Apr | 0.001 | 0.0023 (106.9%) | 0.0022 (99.7%) | 0.0022 (99.1%) | 0.0010 (-13.1%) | 0.0009 (-16.1%) | 0.0003 (-74.1%) | 0.0022 (100.5%) |
| Above Normal | May | 0.001 | 0.0026 (87.3%) | 0.0022 (63.0%) | 0.0022 (62.9%) | 0.0020 (47.8%) | 0.0020 (43.7%) | 0.0003 (-81.0%) | 0.0023 (64.1%) |

Under Alt1 in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 271% higher in the month of January to 2% higher in the month of November compared to the NAA (Figure I.9-3 and Table I.9-5).

Under Alt2 With TUCP Without VA in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 54.8% higher in the month of April to 6.9% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Without VA in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 54.6% higher in the month of April to 6.9% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Delta VA in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 40.1% higher in the month of May to 45.3% lower in the month of March compared to the NAA.

Under Alt2 Without TUCP Systemwide VA in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 36.1% higher in the month of May to 45.2% lower in the month of March compared to the NAA.

Under Alt3 in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 6.8% lower in the month of March to 68.3% lower in the month of November compared to the NAA.

Under Alt4 in below normal water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 56.6% higher in the month of April to 30.9% lower in the month of December compared to the NAA.

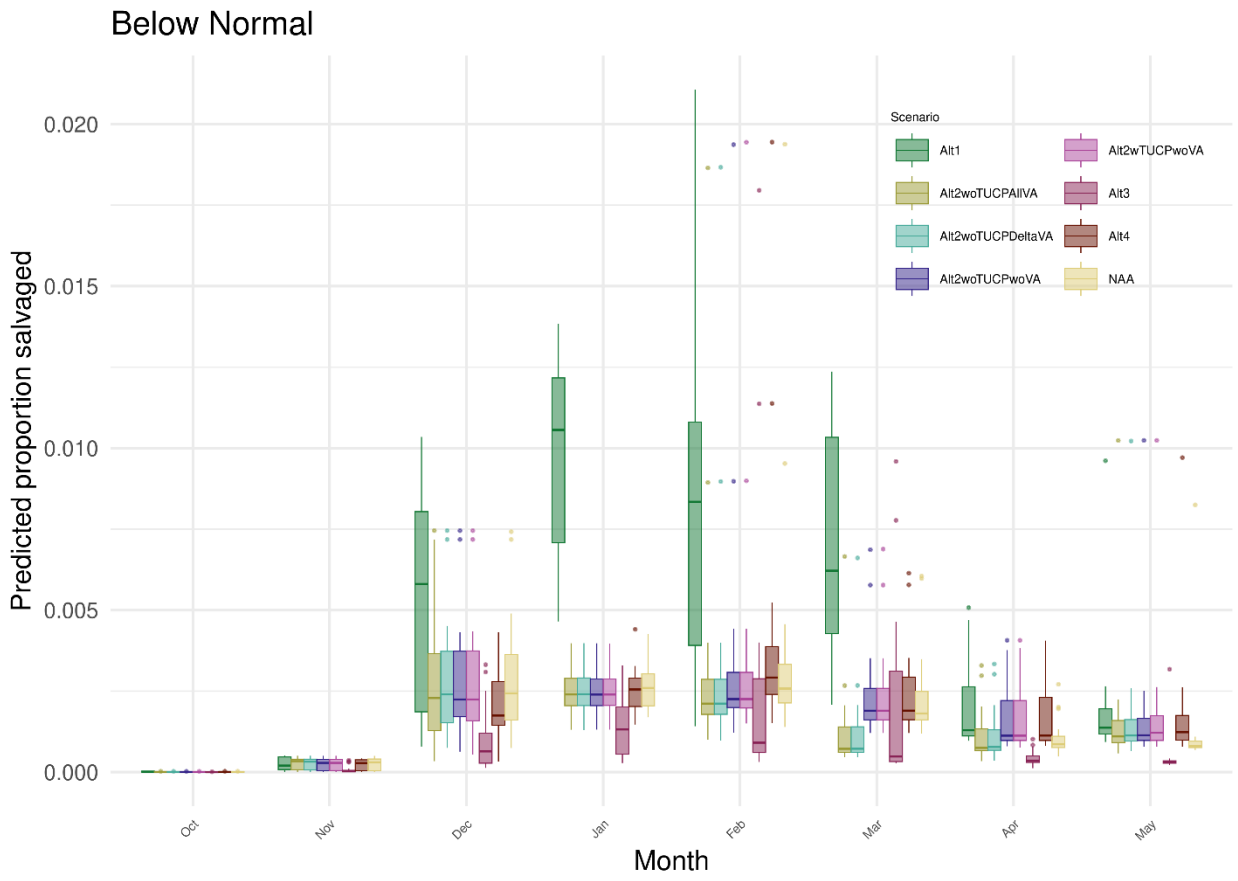


Figure I.9-3. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during below normal water year types.

Table I.9-5. Mean predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Below Normal water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Below Normal | Oct | 0.0000 | 0.0000 (148.3%) | 0.0000 (-3.7%) | 0.0000 (-5.4%) | 0.0000 (-1.0%) | 0.0000 (4.1%) | 0.0000 (-63.0%) | 0.0000 (2.4%) |
| Below Normal | Nov | 0.0002 | 0.0003 (2.0%) | 0.0002 (-2.6%) | 0.0002 (-2.6%) | 0.0003 (2.2%) | 0.0003 (4.0%) | 0.0001 (-68.3%) | 0.0002 (-8.2%) |
| Below Normal | Dec | 0.0030 | 0.0052 (73.2%) | 0.0028 (-6.7%) | 0.0028 (-5.1%) | 0.0029 (-3.7%) | 0.0028 (-8.0%) | 0.0010 (-65.2%) | 0.0021 (-30.9%) |
| Below Normal | Jan | 0.0026 | 0.0098 (271.0%) | 0.0025 (-6.9%) | 0.0025 (-6.9%) | 0.0025 (-6.1%) | 0.0025 (-6.2%) | 0.0015 (-44.4%) | 0.0025 (-4.1%) |

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Below Normal | Feb | 0.0039 | 0.0084 (115.9%) | 0.0037 (-4.6%) | 0.0037 (-5.1%) | 0.0035 (-10.6%) | 0.0035 (-10.7%) | 0.0029 (-26.1%) | 0.0043 (11.6%) |
| Below Normal | Mar | 0.0025 | 0.0069 (182.1%) | 0.0025 (1.4%) | 0.0025 (1.3%) | 0.0013 (-45.3%) | 0.0013 (-45.2%) | 0.0023 (-6.8%) | 0.0025 (1.3%) |
| Below Normal | Apr | 0.0011 | 0.0020 (88.6%) | 0.0017 (54.8%) | 0.0017 (54.6%) | 0.0012 (8.2%) | 0.0012 (7.4%) | 0.0004 (-59.5%) | 0.0017 (56.6%) |
| Below Normal | May | 0.0013 | 0.0020 (58.2%) | 0.0019 (48.2%) | 0.0018 (42.5%) | 0.0018 (40.1%) | 0.0017 (36.1%) | 0.0005 (-62.4%) | 0.0018 (47.5%) |

Under Alt1 in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 182.8% higher in the month of February to 17.9% lower in the month of November compared to the NAA (Figure I.9-4 and Table I.9-6).

Under Alt2 With TUCP Without VA in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 33.7% higher in the month of May to 13.8% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Without VA in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 33.7% higher in the month of May to 13.8% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Delta VA in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 22.2% higher in the month of May to 33.8% lower in the month of March compared to the NAA.

Under Alt2 Without TUCP Systemwide VA in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 18.2% higher in the month of May to 34.1% lower in the month of March compared to the NAA.

Under Alt3 in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 12.2% lower in the month of March to 75.2% lower in the month of November compared to the NAA.

Under Alt4 in dry water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 34.2% higher in the month of May to 18.2% lower in the month of December compared to the NAA.

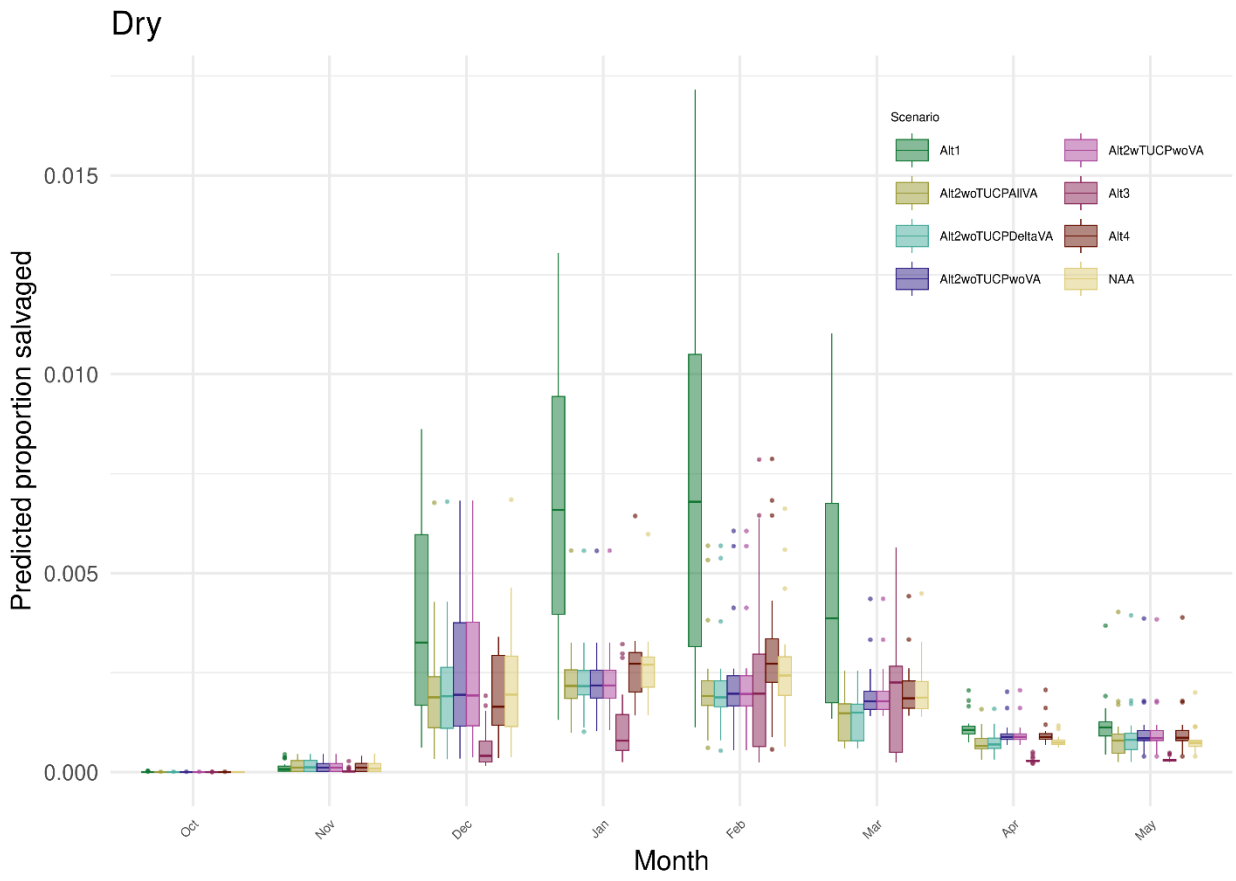


Figure I.9-4. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during dry water year types.

Table I.9-6. Mean predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Dry water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Dry | Oct | 0.0000 | 0.0000 (130.2%) | 0.0000 (-1.7%) | 0.0000 (-2.1%) | 0.0000 (6.6%) | 0.0000 (11.9%) | 0.0000 (-63.4%) | 0.0000 (-1.3%) |
| Dry | Nov | 0.0004 | 0.0001 (-17.9%) | 0.0001 (1.9%) | 0.0001 (1.5%) | 0.0002 (13.1%) | 0.0002 (12.3%) | 0.0000 (-75.2%) | 0.0001 (-3.2%) |
| Dry | Dec | 0.0022 | 0.0039 (78.3%) | 0.0023 (3.3%) | 0.0022 (1.6%) | 0.0021 (-3.3%) | 0.0021 (-6.2%) | 0.0006 (-71.4%) | 0.0018 (-18.2%) |
| Dry | Jan | 0.0026 | 0.0068 (156.3%) | 0.0023 (-13.8%) | 0.0023 (-13.8%) | 0.0023 (-13.0%) | 0.0023 (-12.8%) | 0.0011 (-57.0%) | 0.0027 (0.4%) |

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Dry | Feb | 0.0026 | 0.0074 (182.8%) | 0.0023 (-13.0%) | 0.0023 (-13.0%) | 0.0022 (-17.2%) | 0.0022 (-15.3%) | 0.0023 (-12.8%) | 0.0031 (18.4%) |
| Dry | Mar | 0.0020 | 0.0047 (129.0%) | 0.0020 (-4.0%) | 0.0020 (-4.0%) | 0.0014 (-33.8%) | 0.0013 (-34.1%) | 0.0018 (-12.2%) | 0.0020 (-0.5%) |
| Dry | Apr | 0.0008 | 0.0011 (45.3%) | 0.0010 (24.1%) | 0.0010 (23.8%) | 0.0007 (-5.7%) | 0.0007 (-7.9%) | 0.0003 (-61.4%) | 0.0010 (25.3%) |
| Dry | May | 0.0008 | 0.0012 (56.3%) | 0.0010 (33.7%) | 0.0010 (33.7%) | 0.0009 (22.2%) | 0.0009 (18.2%) | 0.0003 (-59.2%) | 0.0010 (34.2%) |

Under Alt1 in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 124% higher in the month of January to 5.1% lower in the month of November compared to the NAA (Figure I.9-5 and Table I.9-7).

Under Alt2 With TUCP Without VA in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 21.8% higher in the month of May to 15% lower in the month of January compared to the NAA.

Under Alt2 Without TUCP Without VA in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 17.6% higher in the month of May to 22.7% lower in the month of March compared to the NAA.

Under Alt2 Without TUCP Delta VA in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 18.1% higher in the month of May to 25.6% lower in the month of March compared to the NAA.

Under Alt2 Without TUCP Systemwide VA in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 17.7% higher in the month of May to 25.2% lower in the month of March compared to the NAA.

Under Alt3 in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is lower than NAA, ranging from 32.6% lower in the month of February to 86.6% lower in the month of November compared to the NAA.

Under Alt4 in critical water years, mean predicted salvage proportion of winter-run Chinook salmon is higher than NAA, ranging from 23.2% higher in the month of February to 10.6% lower in the month of December compared to the NAA.

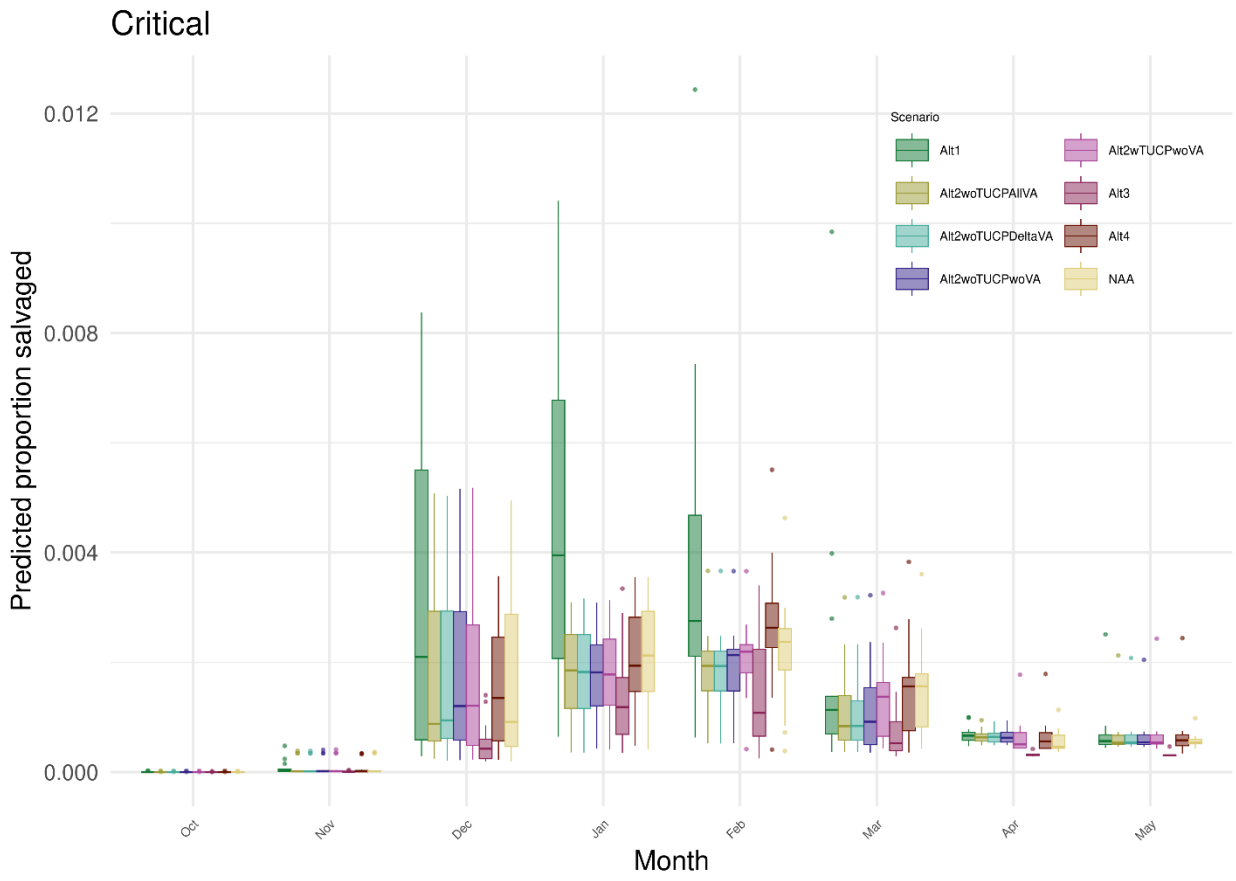


Figure I.9-5. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during critically dry water year types.

Table I.9-7. Mean predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during Critical water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Critical | Oct | 0.0000 | 0.0000 (46.5%) | 0.0000 (0.6%) | 0.0000 (-1.9%) | 0.0000 (-0.6%) | 0.0000 (-0.1%) | 0.0000 (-47.8%) | 0.0000 (1.2%) |
| Critical | Nov | 0.0004 | 0.0001 (-5.1%) | 0.0001 (4.0%) | 0.0001 (2.3%) | 0.0001 (-0.9%) | 0.0001 (-0.1%) | 0.0000 (-86.6%) | 0.0001 (-3.1%) |
| Critical | Dec | 0.0018 | 0.0032 (78.4%) | 0.0018 (1.3%) | 0.0019 (6.9%) | 0.0019 (5.0%) | 0.0019 (5.2%) | 0.0005 (-69.9%) | 0.0016 (-10.6%) |
| Critical | Jan | 0.0021 | 0.0046 (124.0%) | 0.0017 (-15.0%) | 0.0017 (-16.3%) | 0.0018 (-12.7%) | 0.0018 (-12.5%) | 0.0014 (-33.2%) | 0.0020 (-3.3%) |

| Water Year Type | Month | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|---|
| Critical | Feb | 0.0022 | 0.0039 (75.4%) | 0.0021 (-4.5%) | 0.0019 (-12.8%) | 0.0019 (-15.4%) | 0.0019 (-15.6%) | 0.0015 (-32.6%) | 0.0027 (23.2%) |
| Critical | Mar | 0.0015 | 0.0018 (17.9%) | 0.0014 (-9.4%) | 0.0012 (-22.7%) | 0.0011 (-25.6%) | 0.0011 (-25.2%) | 0.0008 (-49.7%) | 0.0015 (0.5%) |
| Critical | Apr | 0.0006 | 0.0007 (18.3%) | 0.0006 (13.9%) | 0.0007 (14.8%) | 0.0006 (13.7%) | 0.0006 (13.8%) | 0.0003 (-43.9%) | 0.0007 (15.0%) |
| Critical | May | 0.0006 | 0.0007 (24.7%) | 0.0007 (21.8%) | 0.0007 (17.6%) | 0.0007 (18.1%) | 0.0007 (17.7%) | 0.0003 (-44.2%) | 0.0007 (20.4%) |

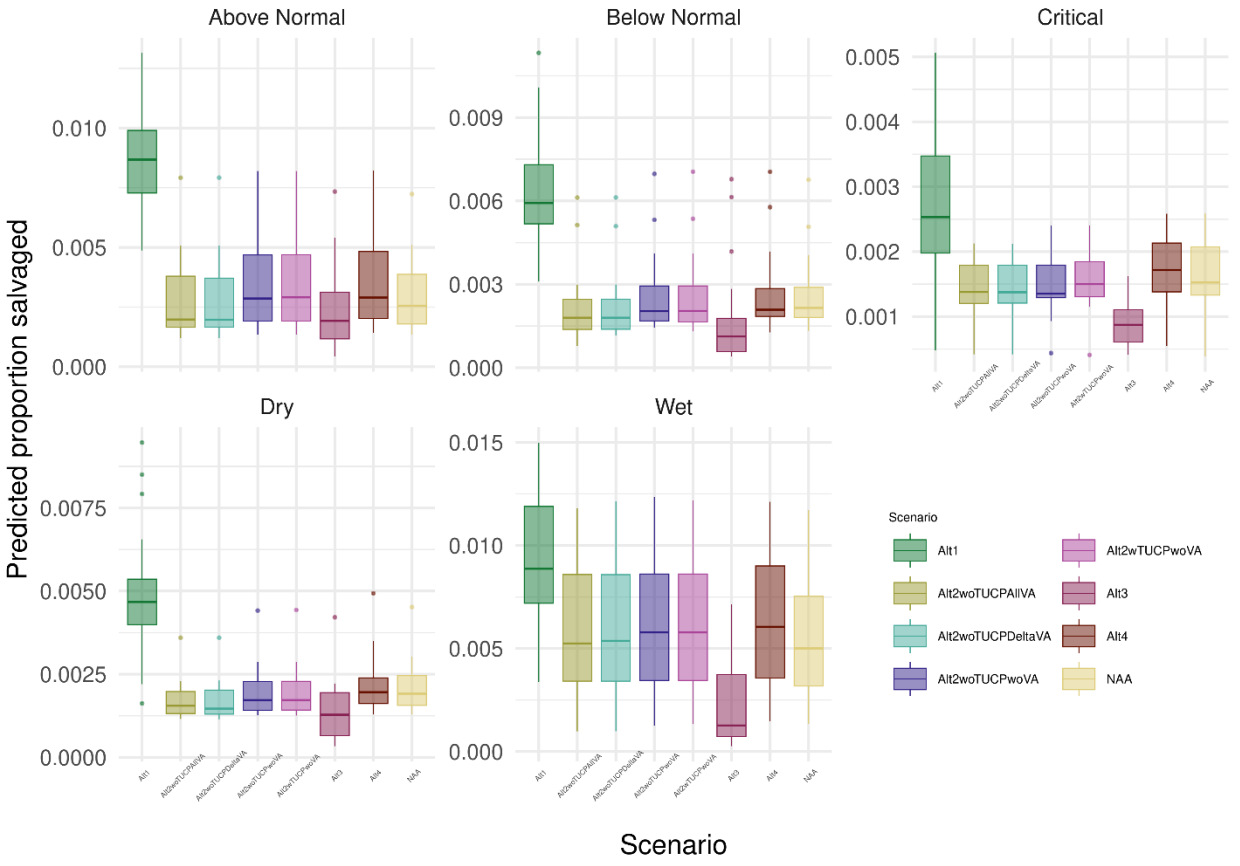


Figure I.9-6. Boxplot of predicted annual proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during different water year types.

Table I.9-8. Mean predicted annual proportion of winter-run Chinook salmon salvaged at CVP and SWP for alternatives during different water year types. Percent difference from NAA indicated in parenthesis.

| Water Year Type | NAA | Alt1 | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|
| Above Normal | 0.003 | 0.0086 (182.4%) | 0.0034 (12.7%) | 0.0034 (10.5%) | 0.0028 (-6.6%) | 0.0028 (-8.3%) | 0.0025 (-17.0%) | 0.0036 (19.2%) |
| Below Normal | 0.003 | 0.0065 (141.3%) | 0.0027 (-1.6%) | 0.0027 (-1.5%) | 0.0022 (-17.4%) | 0.0022 (-18.3%) | 0.0018 (-32.1%) | 0.0027 (-0.1%) |
| Critical | 0.002 | 0.0027 (65.6%) | 0.0015 (-5.8%) | 0.0015 (-11.4%) | 0.0014 (-12.9%) | 0.0014 (-12.8%) | 0.0009 (-45.2%) | 0.0017 (6.0%) |
| Dry | 0.002 | 0.0049 (137.7%) | 0.0020 (-6.1%) | 0.0019 (-6.4%) | 0.0017 (-18.3%) | 0.0017 (-18.4%) | 0.0014 (-32.4%) | 0.0021 (3.2%) |
| Wet | 0.006 | 0.0094 (71.9%) | 0.0062 (12.6%) | 0.0062 (12.4%) | 0.0059 (8.3%) | 0.0059 (7.5%) | 0.0024 (-55.3%) | 0.0064 (16.0%) |

### I.9.3.2 BA: Narrative, Figures, and Table Results

Highest predicted salvage proportion of winter-run Chinook salmon occurred under Alt2 Without TUCP Delta VA in February of wet water years (0.009), followed by February of wet water years under Alt2 Without TUCP Systemwide VA (0.009). The lowest predicted salvage proportion of winter-run Chinook salmon occurred under Alt2 Without TUCP Without VA in October in dry water years (0) followed by October of dry water years under NAA (0). (Figure I.9-7 through Figure I.9-12, Table I.9-9 through Table I.9-14).

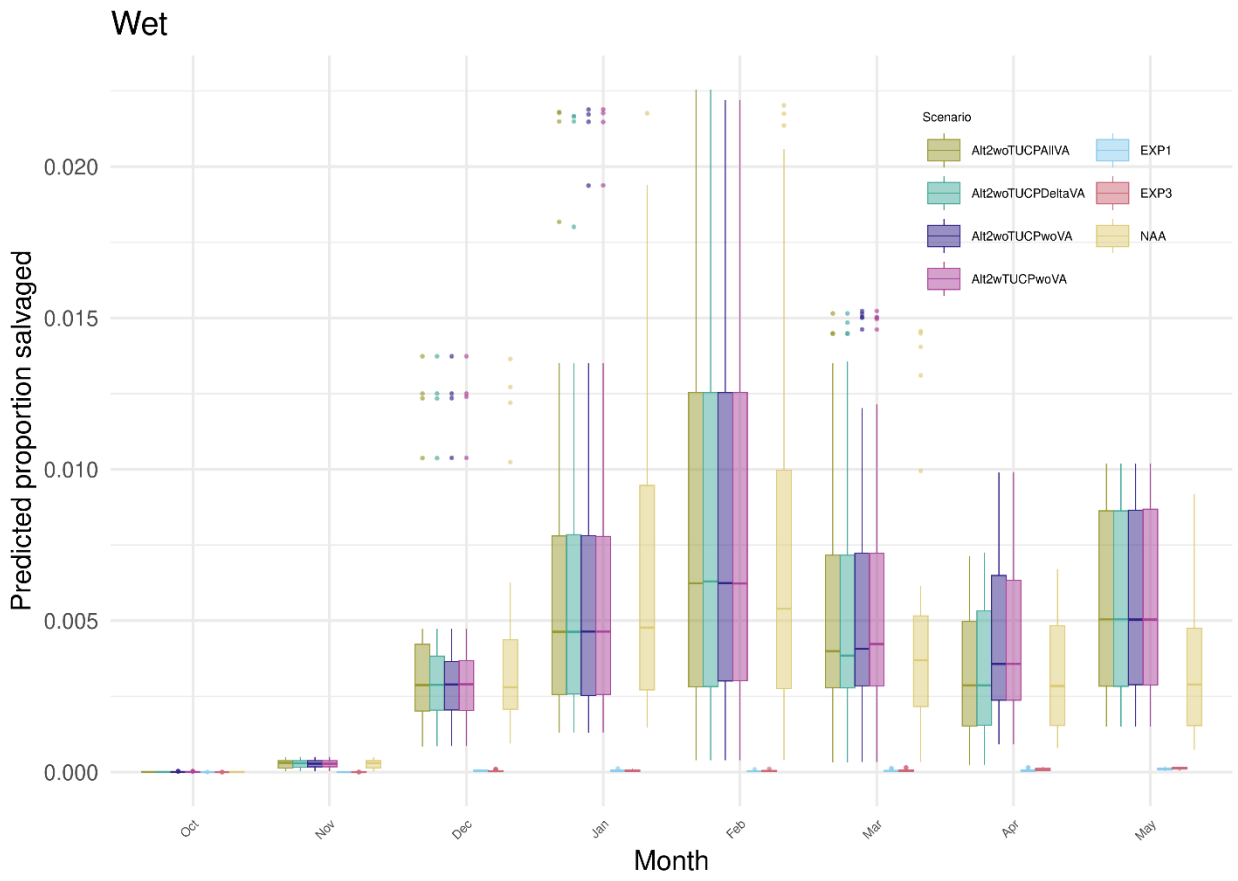


Figure I.9-7. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during wet water year types.

Table I.9-9. Predicted mean of monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during wet water year types.

| Water Year Type | Month | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|---|
| Wet | Oct | 0.0000 | 0.0000 | 0 | 0 | 0 | 0 | 0 |
| Wet | Nov | 0.0000 | 0.0000 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| Wet | Dec | 0.0000 | 0.0000 | 0.0042 | 0.004 | 0.004 | 0.004 | 0.0041 |
| Wet | Jan | 0.0000 | 0.0000 | 0.007 | 0.0071 | 0.0071 | 0.0071 | 0.0071 |
| Wet | Feb | 0.0000 | 0.0000 | 0.0082 | 0.009 | 0.009 | 0.009 | 0.009 |
| Wet | Mar | 0.0000 | 0.0001 | 0.005 | 0.0062 | 0.0062 | 0.0058 | 0.0056 |
| Wet | Apr | 0.0001 | 0.0001 | 0.0032 | 0.0043 | 0.0044 | 0.0032 | 0.0032 |
| Wet | May | 0.0001 | 0.0001 | 0.0033 | 0.0056 | 0.0056 | 0.0056 | 0.0056 |

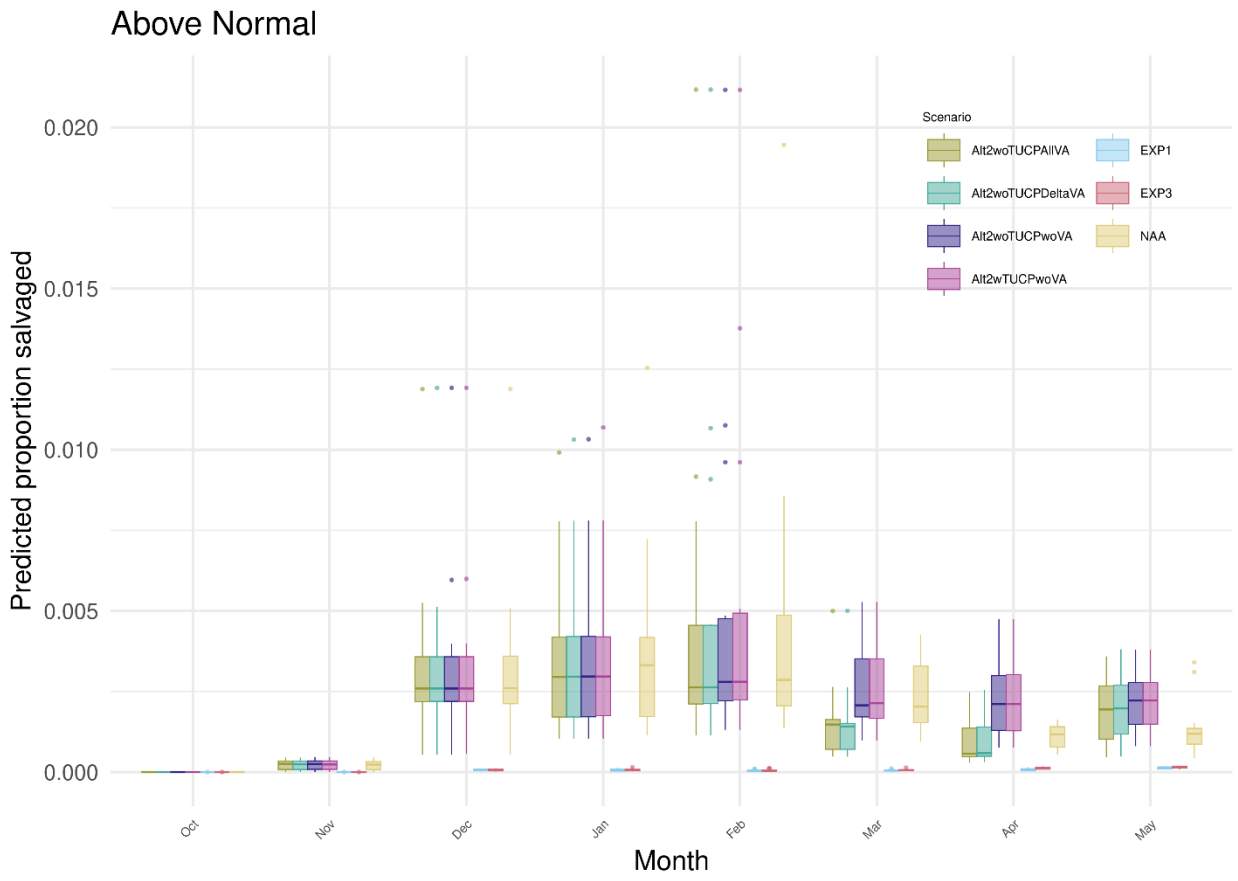


Figure I.9-8. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during above normal water year types.

Table I.9-10. Predicted mean of monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during above normal water year types.

| Water Year Type | Month | EXP1 | EXP3 | NAA | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA |
|---|---|---|---|---|---|---|---|---|
| Above Normal | Oct | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Above Normal | Nov | 0.0000 | 0.0000 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| Above Normal | Dec | 0.0001 | 0.0001 | 0.0030 | 0.0034 | 0.0034 | 0.0033 | 0.0033 |
| Above Normal | Jan | 0.0001 | 0.0001 | 0.0040 | 0.0036 | 0.0035 | 0.0035 | 0.0035 |
| Above Normal | Feb | 0.0000 | 0.0001 | 0.0050 | 0.0053 | 0.0051 | 0.0049 | 0.0047 |
| Above Normal | Mar | 0.0001 | 0.0001 | 0.0020 | 0.0027 | 0.0027 | 0.0015 | 0.0015 |
| Above Normal | Apr | 0.0001 | 0.0001 | 0.0010 | 0.0022 | 0.0022 | 0.0010 | 0.0009 |
| Above Normal | May | 0.0001 | 0.0002 | 0.0010 | 0.0022 | 0.0022 | 0.0020 | 0.0020 |

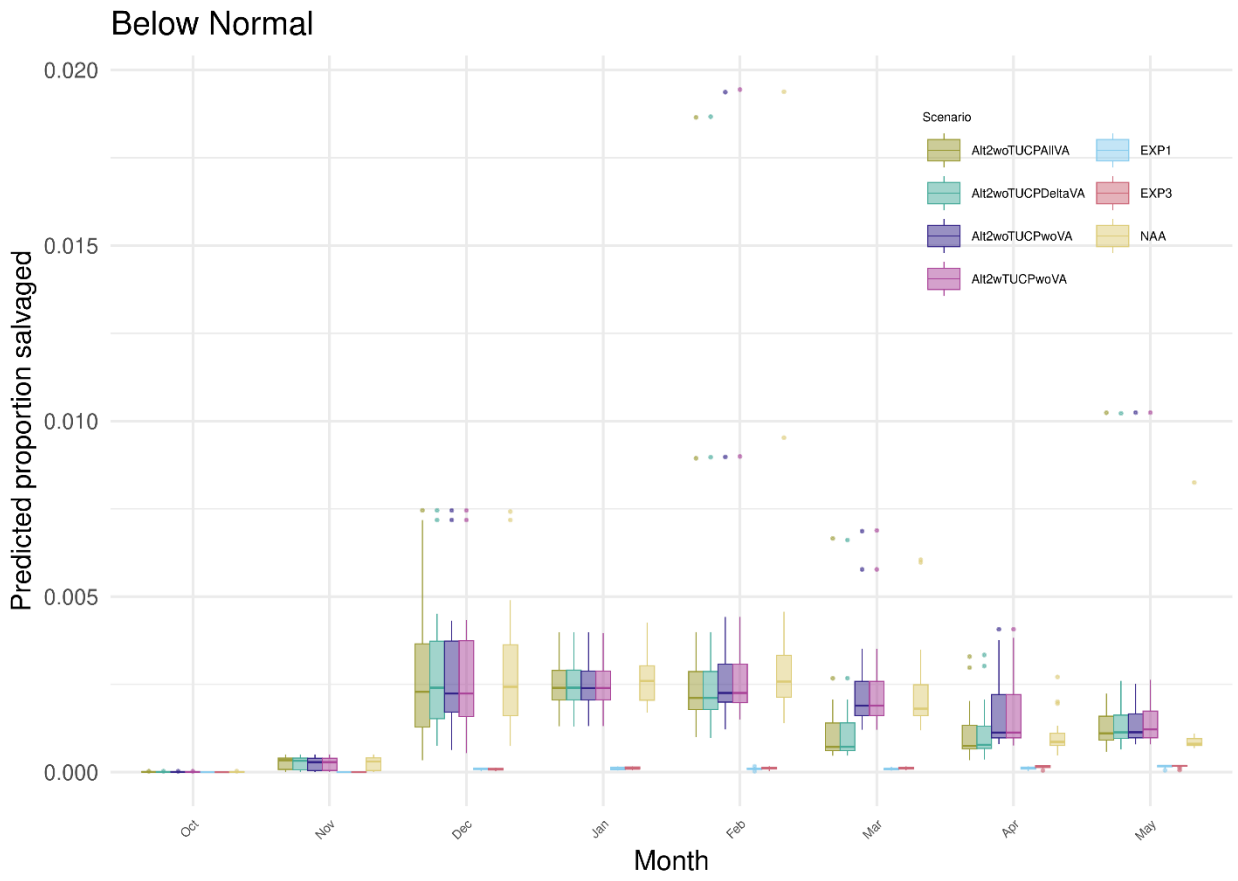


Figure I.9-9. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during below normal water year types.

Table I.9-11. Predicted mean of monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during below normal water year types.

| Water Year Type | Month | EXP1 | EXP3 | NAA | Alt2 wTUCP woVA | Alt2 woTUCP woVA | Alt2 woTUCP DeltaVA | Alt2 woTUCP AllVA |
|---|---|---|---|---|---|---|---|---|
| Below Normal | Oct | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Below Normal | Nov | 0.0000 | 0.0000 | 0.0002 | 0.0002 | 0.0002 | 0.0003 | 0.0003 |
| Below Normal | Dec | 0.0001 | 0.0001 | 0.0030 | 0.0028 | 0.0028 | 0.0029 | 0.0028 |
| Below Normal | Jan | 0.0001 | 0.0001 | 0.0026 | 0.0025 | 0.0025 | 0.0025 | 0.0025 |
| Below Normal | Feb | 0.0001 | 0.0001 | 0.0039 | 0.0037 | 0.0037 | 0.0035 | 0.0035 |
| Below Normal | Mar | 0.0001 | 0.0001 | 0.0025 | 0.0025 | 0.0025 | 0.0013 | 0.0013 |
| Below Normal | Apr | 0.0001 | 0.0002 | 0.0011 | 0.0017 | 0.0017 | 0.0012 | 0.0012 |
| Below Normal | May | 0.0002 | 0.0002 | 0.0013 | 0.0019 | 0.0018 | 0.0018 | 0.0017 |

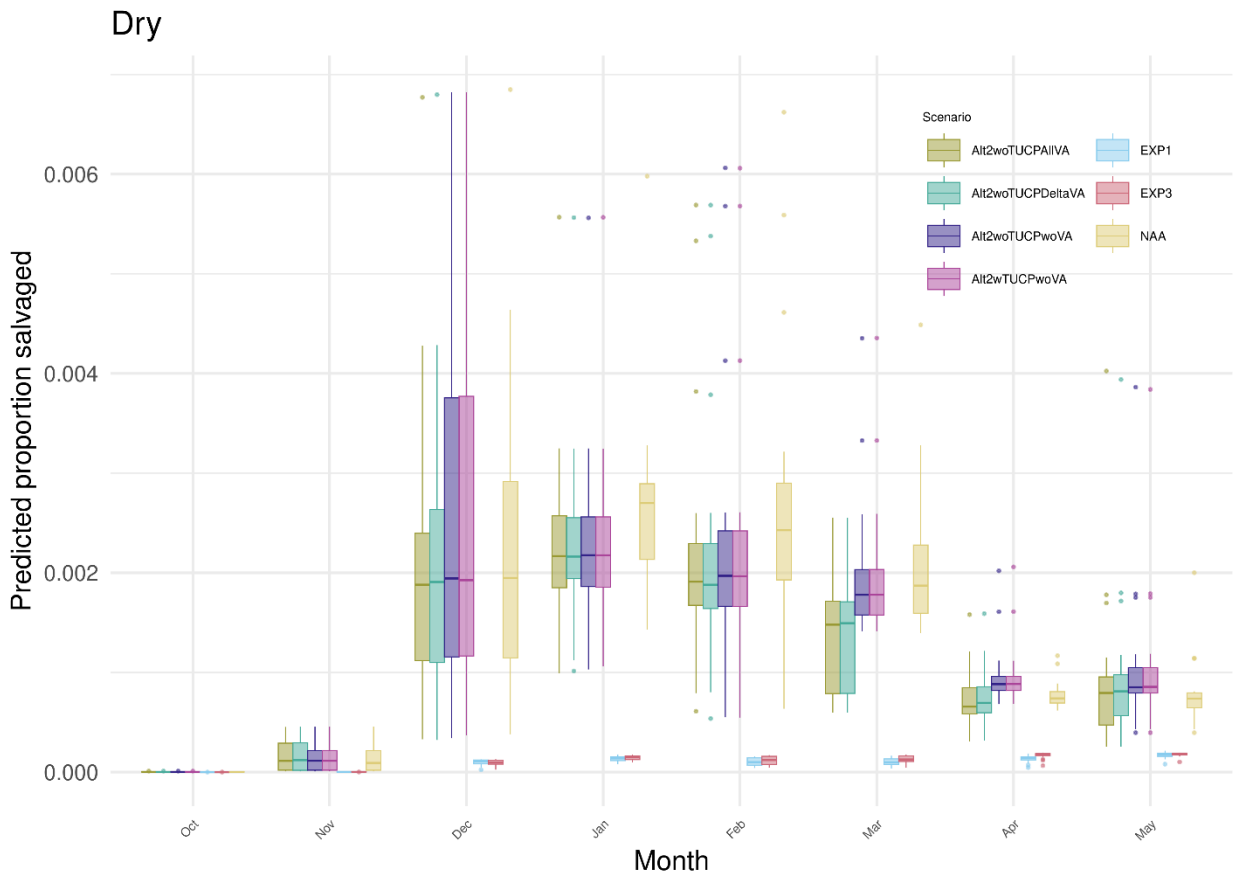


Figure I.9-10. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during dry water year types.

Table I.9-12. Predicted mean monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during dry water year types.

| Water Year Type | Month | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|---|
| Dry | Oct | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Dry | Nov | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0002 |
| Dry | Dec | 0.0001 | 0.0001 | 0.0022 | 0.0023 | 0.0022 | 0.0021 | 0.0021 |
| Dry | Jan | 0.0001 | 0.0001 | 0.0026 | 0.0023 | 0.0023 | 0.0023 | 0.0023 |
| Dry | Feb | 0.0001 | 0.0001 | 0.0026 | 0.0023 | 0.0023 | 0.0022 | 0.0022 |
| Dry | Mar | 0.0001 | 0.0001 | 0.0020 | 0.0020 | 0.0020 | 0.0014 | 0.0013 |
| Dry | Apr | 0.0001 | 0.0002 | 0.0008 | 0.0010 | 0.0010 | 0.0007 | 0.0007 |
| Dry | May | 0.0002 | 0.0002 | 0.0008 | 0.0010 | 0.0010 | 0.0009 | 0.0009 |

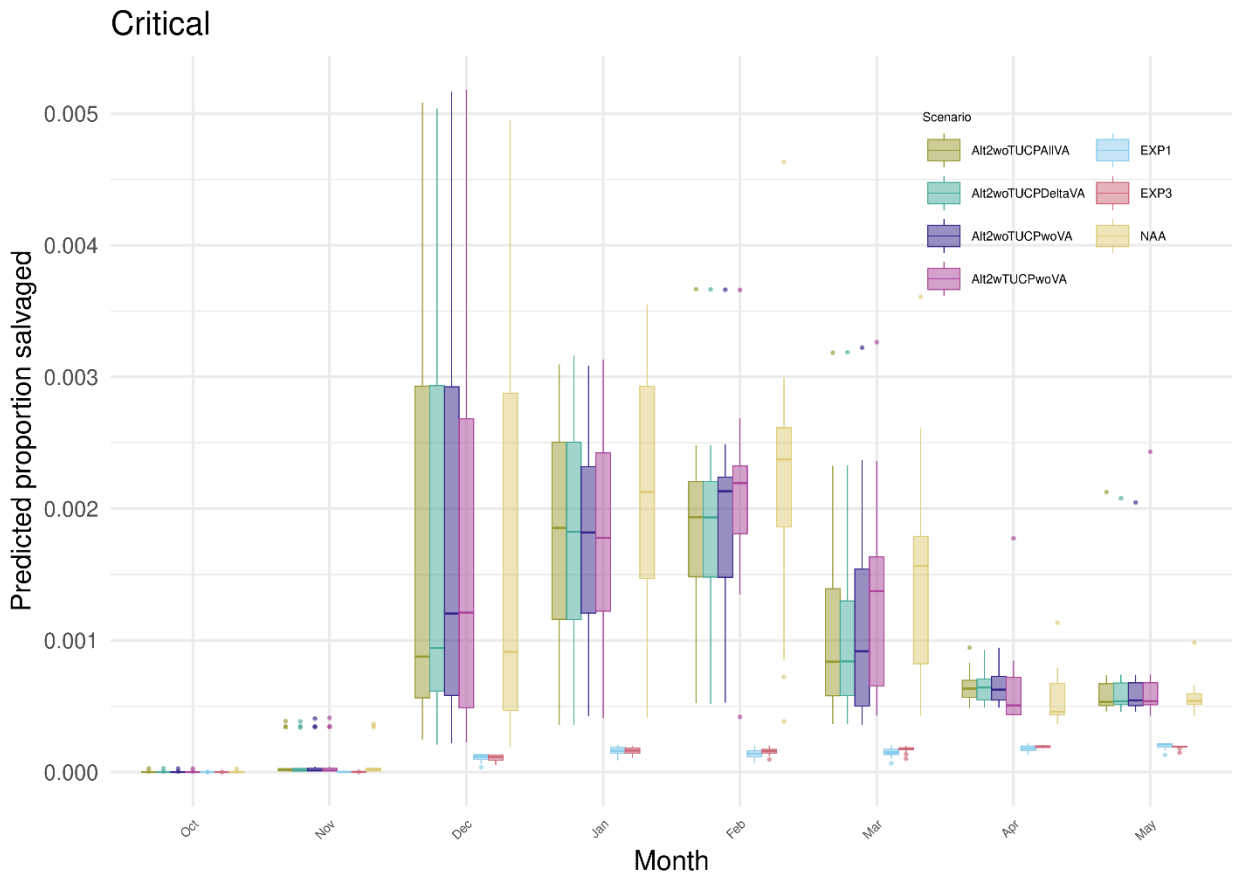


Figure I.9-11. Boxplot of predicted monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during critically dry water year types.

Table I.9-13. Predicted mean of monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during critical water year types.

| Water Year Type | Month | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|---|
| Critical | Oct | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Critical | Nov | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Critical | Dec | 0.0001 | 0.0001 | 0.0018 | 0.0018 | 0.0019 | 0.0019 | 0.0019 |
| Critical | Jan | 0.0002 | 0.0002 | 0.0021 | 0.0017 | 0.0017 | 0.0018 | 0.0018 |
| Critical | Feb | 0.0001 | 0.0002 | 0.0022 | 0.0021 | 0.0019 | 0.0019 | 0.0019 |
| Critical | Mar | 0.0001 | 0.0002 | 0.0015 | 0.0014 | 0.0012 | 0.0011 | 0.0011 |
| Critical | Apr | 0.0002 | 0.0002 | 0.0006 | 0.0006 | 0.0007 | 0.0006 | 0.0006 |
| Critical | May | 0.0002 | 0.0002 | 0.0006 | 0.0007 | 0.0007 | 0.0007 | 0.0007 |

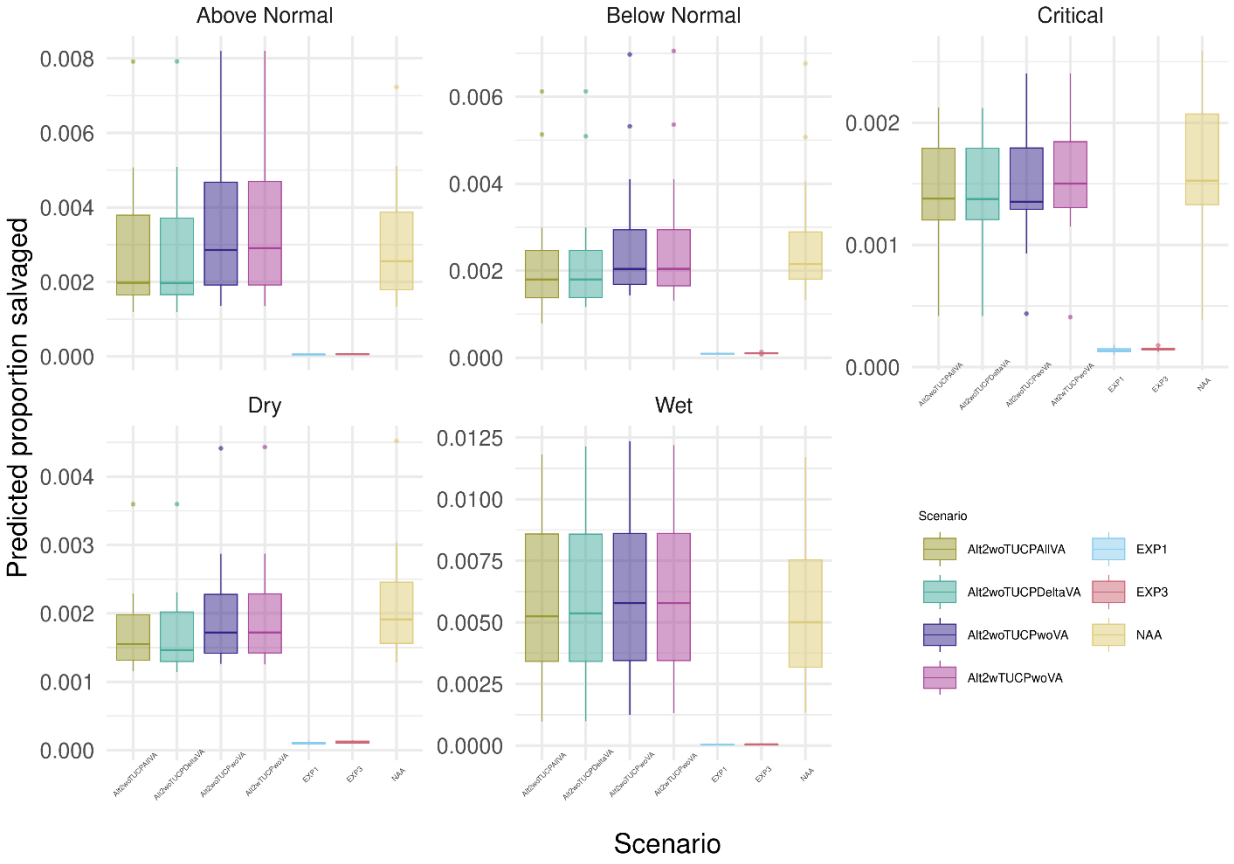


Figure I.9-12. Boxplot of predicted annual proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during different water year types.

Table I.9-14. Predicted mean of annual proportion of winter-run Chinook salmon salvaged at CVP and SWP for EXP1, EXP3, NAA, and Alt2 phases during different water year types.

| Water Year Type | EXP1 | EXP3 | NAA | Alt2wTUCP woVA | Alt2woTUCP woVA | Alt2woTUCP DeltaVA | Alt2woTUCP AllVA |
|---|---|---|---|---|---|---|---|
| Above Normal | 0.0001 | 0.0001 | 0.003 | 0.0034 | 0.0034 | 0.0028 | 0.0028 |
| Below Normal | 0.0001 | 0.0001 | 0.0027 | 0.0027 | 0.0027 | 0.0022 | 0.0022 |
| Critical | 0.0001 | 0.0001 | 0.0016 | 0.0015 | 0.0015 | 0.0014 | 0.0014 |
| Dry | 0.0001 | 0.0001 | 0.0021 | 0.002 | 0.0019 | 0.0017 | 0.0017 |
| Wet | 0.0000 | 0.0000 | 0.0055 | 0.0062 | 0.0062 | 0.0059 | 0.0059 |

## I.9.4 References

Zeug S. and B. Cavallo (2014) Controls on the Entrainment of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) into Large Water Diversions and Estimates of Population-Level Loss. *PLoS ONE* 9(7): e101479. doi:10.1371/journal.pone.0101479.

Zeug, S., and B. Cavallo. 2015. *Sacramento River Winter-run entrainment risk evaluation.* Research Gate. Prepared for Delta Operations for Salmonids and Sturgeon (DOSS).

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