Appendix I, Old and Middle River Flow Management

Attachment I.1 Negative Binomial Salvage Model

I.1.1 Model Overview

To evaluate potential changes to the number of length-at-date (LAD) winter-run Chinook salmon, LAD spring-run Chinook salmon, and steelhead salvaged at the Central Valley Project (CVP) and State Water Project (SWP) pumping facilities based on the alternatives, the Bureau of Reclamation (Reclamation) analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation.

I.1.2 Model Development

I.1.2.1 Methods

I.1.2.1.1 Model Development

Winter-run and spring-run LAD Chinook salmon and steelhead salvage and loss records from January 1, 1993, to December 31, 2020, were gathered from the California Department of Fish and Wildlife (CDFW) salvage database posted at the SacPAS website (http://www.cbr.washington.edu/sacramento/data/query_loss_detail.html). Steelhead salvage records from January 1, 1993, to December 31, 2020, were gathered from the CDFW salvage app webpage (https://apps.wildlife.ca.gov/Salvage/). For all models, loss at both salvage facilities was the response variable. To incorporate hydrodynamic effects on salvage count into the models, Delta export (QEXPORT), Sacramento River flow (QSAC), and San Joaquin River (QSJR) were extracted from the California Department of Water Resources Dayflow data (https://data.cnra.ca.gov/dataset/dayflow). Additionally, combined Old and Middle River flow (OMR) data were pulled from the U.S. Geological Survey National Water Information System website (https://nwis.waterdata.usgs.gov/nwis; stations 11313405 and 11312676). Because data gaps exist in the OMR flow data, ordinary least squares regressions were conducted so that each dataset could be used to predict, and therefore complete the dataset (adjusted R^2: 0.97). Lastly, to account for the variable numbers of juvenile Chinook salmon entering the Sacramento–San Joaquin Delta (Delta) by year and month, Sacramento Trawl data were acquired from the Delta Juvenile Fish Monitoring Program through the “deltafish” package available on GitHub (https://github.com/jeanetteclark/deltaFish). Sacramento Trawl catch per unit trawl for each day was calculated for both winter-run-sized and spring-run-sized Chinook salmon. Catch data from Delta fish monitoring for steelhead was sparse and therefore not calculated or used in further analysis.

For each variable, data were averaged by month and year with missing data removed. Because monthly loss values tend to be low or mostly zeroes for most months out of the year, only December to April period was used for winter-run Chinook salmon analysis, only March to June period was used for spring-run Chinook salmon analysis, and only December to June period was used for steelhead analysis. Overdispersion was apparent during initial inspection of the response variable data (mean ≠ variance) supporting the use of negative binomial regression in this analysis.

To avoid collinearity, variance inflation factor (VIF) analyses were conducted for all predictor variables mentioned above. A full negative binomial regression model with all predictor variables was constructed for each Chinook salmon race (winter-run and spring-run), followed by an assessment of VIF values. Per Zuur et al. (2010), the variable with the highest VIF value was removed and models were re-run until all VIF values were below 3. For all models, OMR had the highest VIF value (>25) and had to be removed from further analysis along with Sacramento River flow (VIF value >3). For the final model selection, the covariates included were San Joaquin River flow, Delta export flow value, Sacramento Trawl catch per unit effort for juvenile Chinook salmon (specific to each race), and monthly categorical variable. Each continuous covariate was standardized to z-score prior to the model selection process.

For the two Chinook salmon races and steelhead, the model selection process included all possible additive combination of covariates, as well as addition combination that involves at least one interaction between a continuous variable and the monthly categorical variable. This resulted in 26 possible models (including null) for each Chinook salmon race and 14 possible models for steelhead. The top performing model was determined by Akaike Information Criterion for small sample size (AICc). The top model identified through this model selection process was then further evaluated by using leave-one-out cross validation (LOOCV). This was done to provide a measure for model predictive performance. LOOCV involves removal of a single record from the dataset, refitting the top model to the remaining data, estimating the expected salvage count for the ‘out-of-sample’ data, and comparing the predicted versus observed salvage count. This process is repeated for all records in the dataset. Ordinary least squares linear regression is used to compare the relationship between observed and predicted salvage counts, and the resulting R^2 from this regression is a measure agreement between observed and predicted observations.

I.1.2.1.2 Model Application

The negative binomial salvage model was used to predict daily average salvage of salmonids for each month from 1922 to 2021 by water year type (CalSim 3 WYT) using modeled exports (combined Jones and Banks), San Joaquin River flow at Vernalis, and winter-run Sacramento Trawl CPUE (present only as a variable in the winter-run Chinook salmon model). Monthly historic values from water years 1993 – 2020 were used to generate an average monthly winter-run CPUE chosen as representative of recent patterns. The following scenarios were analyzed: Exploratory 1 (EXP1), Exploratory 3 (EXP3), No Action Alternative (NAA), Alternative 1 (Alt1), Alternative 2 (Alt2) with Temporary Urgency Change Petitions (TUCPs) without Voluntary Agreements (VAs), Alt2 without TUCPs without VAs, Alt2 without TUCPs Delta

VAs, Alt2 without TUCPs All VAs, Alternative 3 (Alt3), and Alternative 4 (Alt4). Modeled average monthly salvage was predicted using individual negative binomial models for spring-run Chinook salmon (months of March through June), winter-run Chinook salmon (months of December through April), and steelhead (months of December through June). Results from all scenarios are presented. For the purposes of the Biological Assessment no comparisons were made, for the purposes of the Environmental Impact Statement comparisons were made for all alternatives with the NAA. Alt2 is the Proposed Action.

I.1.2.2 Assumptions/Uncertainty

Negative binomial salvage model was used to predict average monthly salvage. Results are presented as average monthly salvage averaged by water year type. Historic monthly values for Sacramento Trawl winter-run CPUE were assumed to be representative of recent salmonid temporal distribution patterns and were applied as constant across the full dataset.

I.1.2.3 Code and Data Repository

Salvage inputs: Salvage data available online at http://www.cbr.washington.edu/sacramento/data/query_loss_detail.html

Hydrodynamic inputs (for model development): Available online at CDWR Dayflow data https://data.cnra.ca.gov/dataset/dayflow and the U.S. Geological Survey National Water Information System website https://nwis.waterdata.usgs.gov/nwis; stations 11313405 and 11312676

Fish inputs (for model development): Available online from the DJFMP through “deltafish” package on GitHub https://github.com/jeanetteclark/deltaFish

Exports inputs: CalSim modeled exports available on ICF SharePoint in Negative Binomial Loss or Salvage Model at Reclamation_2021LTO_CS3_VernalisFlow_BA_2022MED_rev01_20230809_EXP1_EXP3_NAA_ALT2-v1-woutTUCP_ALT2-v1-wTUCP_2022MED.xlsx and in Salvage Density Model at Reclamation_2021LTO_CS3_Exports_WYT_BA_2022MED_rev02_20230809_EXP1_EXP3_NAA_ALT2-v1-woutTUCP_ALT2-v1-wTUCP_2022MED.xlsx

Analysis files (for model development and model application): Available online at https://github.com/BDO-Science/salmon_negbinmodel and on ICF SharePoint at Data and Code

I.1.3 Results

I.1.3.1 Model Development

The top supported model for winter-run Chinook salmon salvage included an interaction between the month categorical variable and Sacramento Trawl catch per trawl, as well as export level and San Joaquin River flow (Table I.1-1). The top-ranked winter-run Chinook salmon model was substantially more supported than the null model (ΔAICc = 111.01) and has the majority of the Akaike weight (0.74). For the winter-run Chinook salmon model, the correlation between observed and predicted data (log10 transformed) based on the LOOCV was positive but relatively weak (Adjusted $R^2 = 0.49$). See Table I.1-2 for model coefficients with z-scored covariates.

Table I.1-1. Summary of the Top-Ranked Negative Binomial Regression Models for Winter-Run Chinook Salmon Salvage That Make Up ~0.99 of the Akaike Weight

Model	AICc	ΔAICc	Akaike weight	Cumulative Weight	Log-Likelihood
Month*Sacramento Trawl Catch + Export + San Joaquin River Flow	710.08	0.00	0.74	0.74	-340.60
Month + San Joaquin River Flow + Sacramento Trawl Catch + Export	713.20	3.12	0.15	0.89	-346.91
Month*Sacramento Trawl Catch + Export	714.07	3.98	0.10	0.99	-343.81

AICc = Akaike Information Criterion; ΔAICc = change in Akaike Information Criterion.

Table I.1-2. Summary of model coefficients for Negative Binomial Monthly Winter-Run sized Chinook Salmon Salvage Model.

Model Variable	Estimated Coefficient	Standard Error
Intercept	0.27	0.27
Month – February	1.06	0.33
Month – March	2.25	0.34
Month – April	16.54	6.03
Month – December	-0.48	0.36
Sac Trawl CPUE	0.37	0.19
Export	1.03	0.12
San Joaquin Flow	-0.31	0.11
Month – February: Sac Trawl CPUE	0.18	0.28
Month – March: Sac Trawl CPUE	-0.88	0.34
Month – April: Sac Trawl CPUE	19.7	7.97
Month – December: Sac Trawl CPUE	0.01	0.26

CPUE = catch per unit effort; Sac Trawl = Sacramento Trawl
The month of January was used as the reference categorical variable (i.e., intercept). The dispersion parameter was 1.38.

The top supported model for spring-run Chinook salmon salvage included export level and an interaction between the month categorical variable and San Joaquin River flow (Table I.1-3). The top-ranked spring-run Chinook salmon model was substantially more supported than the null model (ΔAICc = 122.72) and has the majority of the Akaike weight (0.77). For the spring-run

Chinook salmon model, the correlation between observed and predicted data (log10 transformed) based on the LOOCV was higher than that for winter-run Chinook salmon (Adjusted $R^2 = 0.60$). See Table I.1-4 for model coefficients with z-scored covariates.

Table I.1-3. Summary of the Top-Ranked Negative Binomial Regression Models for Spring-Run Chinook Salmon Salvage That Consist of ~0.99 of the Akaike Weight

Model	AICc	ΔAICc	Akaike weight	Cumulative Weight	Log-Likelihood
Month*San Joaquin River Flow + Export	1018.17	0.00	0.77	0.77	-498.00
Month*San Joaquin River Flow + Sacramento Trawl Catch + Export	1020.61	2.44	0.23	1.00	-497.98

AICc = Akaike Information Criterion; ΔAICc = change in Akaike Information Criterion.

Table I.1-4. Summary of model coefficients for Negative Binomial Monthly Spring-Run sized Chinook Salmon Salvage Model.

Model Variable	Estimated Coefficient	Standard Error
Intercept	2.78	0.24
Month – April	2.88	0.34
Month – May	1.99	0.37
Month - June	-2.71	0.39
San Joaquin Flow	1.31	0.21
Export	1.11	0.16
Month – April: San Joaquin Flow	-1.16	0.28
Month – May: San Joaquin Flow	-0.51	0.31
Month – June: San Joaquin Flow	0.66	0.43

The month of March was used as the reference categorical variable (i.e., intercept). The dispersion parameter was 0.84.

The top supported model for steelhead salvage included export level and the month categorical variable (Table I.1-5). The top-ranked steelhead model was substantially more supported than the null model (ΔAICc = 121.47) and has a slight majority in Akaike weight (0.57). For the steelhead top model, the correlation between observed and predicted data (log10 transformed) based on the LOOCV was lower than the Chinook salmon models (Adjusted $R^2 = 0.47$). See Table I.1-6 for model coefficients with z-scored covariates. Collectively these results suggest the top-ranked models for both races of Chinook salmon and steelhead provided reasonable fit to the observed data and have some predictive capability.

Table I.1-5. Summary of the Top-Ranked Negative Binomial Regression Models for Steelhead Salvage That Consist of ~0.99 of the Akaike Weight

Model	AICc	ΔAICc	Akaike weight	Cumulative Weight	Log-Likelihood
Month + Export	2415.45	0.00	0.57	0.57	-1198.22
Export*San Joaquin River Flow + Month	2416.09	0.64	0.41	0.99	-1196.30

AICc = Akaike Information Criterion; ΔAICc = change in Akaike Information Criterion.

Table I.1-6. Summary of model coefficients for Negative Binomial Monthly Steelhead Salvage Model.

Model Variable	Estimated Coefficient	Standard Error
Intercept	4.78	0.26
Month – February	1.02	0.36
Month – March	1.91	0.37
Month – April	2.43	0.39
Month – May	1.98	0.40
Month - June	-0.38	0.37
Month - December	-2.41	0.36
Export	1.44	0.12

The month of January was used as the reference categorical variable (i.e., intercept). The dispersion parameter was 0.57.

I.1.3.1.1 Model Application

Results are provided by species (winter-run Chinook salmon, spring-run Chinook salmon, and steelhead) by month and water year type by alternative in the following tables. Tables of predicted average monthly salvage represent results for the Biological Assessment (odd table numbers) and for the Environmental Impact Statement (even table numbers): LAD winter-run Chinook salmon (Table 7 Biological Assessment, Table 8 EIS), LAD spring-run Chinook salmon (Table 9 Biological Assessment, Table 10 EIS), steelhead (Table 11 Biological Assessment, Table 12 EIS).

Figure I.1-1 through Figure I.1-6 show species-specific predicted average monthly salvage by month and water year type: winter-run Chinook salmon (Figure I.1-1 and Figure I.1-2), spring-run Chinook salmon (Figure I.1-3a, Figure I.1-3b, Figure I.1-4a, and Figure I.1-4b), and steelhead (Figure I.1-5a, Figure I.1-5b, Figure I.1-6a, and Figure I.1-6b).

The mean monthly predicted salvage at the Delta Fish Collection Facilities of LAD winter-run Chinook salmon from the negative binomial regression models calculated across all water year types for the months of December through April and all alternatives has a wide range. The final model included three variables: Sacramento Trawl catch, combined exports at the Banks and Jones facilities, and San Joaquin River flow (VNS). The greatest predicted salvage of LAD winter-run Chinook salmon occurred in March followed by February, in all water year types. The range of mean predicted salvage of winter-run Chinook salmon for the four components of Alt2 for March ranged from 43 (Alt2 with TUCP no VAs and Alt2 without TUCP no VAs) to 39 (Alt2 with Systemwide VAs) in a wet water year type to from 9 (Altwith TUCP no VAs) to 8 (Alt2 with Delta VAs) in a critically dry water year type (Table I.1-7, Figure I.1-1). Alternative 1 had the greatest predicted salvage of LAD winter-run Chinook salmon of all alternatives in all water year types except April of a Wet water year type. The greatest predicted salvage occurred in March followed by February in all water year types. Alternative 1 predicted salvage ranged from 78 to 15 in March of an above normal and critically dry water year type, respectively (Table I.1-7). Alt3 had the least predicted salvage of LAD winter-run Chinook salmon of all alternatives in wet and critical water year types, and the greatest predicted salvage in March followed by February in all water year types. Alt3 predicted salvage ranged from 24 to 6 in March of an Above Normal and Critical water year type, respectively (Table I.1-7). Alt4 has similar predicted salvage of LAD winter-run Chinook salmon to Alt2 without TUCP no VAs and Alt2 with TUCP no VAs. The greatest predicted salvage under Alt4 occurred in March followed by February in all water year types. Alt4 predicted salvage ranged from 48 to 10 in March of a wet and critically dry water year type, respectively (Table I.1-7). NAA had the greatest predicted salvage in March followed by February in all water year types. NAA predicted salvage ranged from 34 to 10 in March of wet and critical water year type, respectively (Table I.1-7). The values from the exploratory modeling scenarios (EXP1 and EXP3) were not included for consideration in the range of mean predicted salvage, exports in EXP1 and EXP3 are zero.

The months of highest predicted winter-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to February through late-fall and winter into spring (Chapter 4, *Seasonal Operations,* Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

The mean monthly predicted salvage at the Delta Fish Collection Facilities of LAD spring-run Chinook salmon from the negative binomial regression model calculated across the months of March through June and all alternatives has a wide range. The final model included two variables: San Joaquin River flow (VNS) and combined exports at the Banks and Jones facilities. The greatest predicted salvage occurred in the months of April followed by May in above normal, dry, and critically dry water year types. In wet water year types, the greatest predicted salvage occurred in May followed by March. In below normal water year types, the greatest predicted salvage occurred in May followed by April. The range of mean predicted salvage of spring-run Chinook salmon for the four components of Alt2 for May ranged from 3,544 (Alt2 with TUCP no VAs) to 3,514 (Alt2 Without TUCP Delta VAs) in a wet water year type to from 32 (Alt2 with TUCP no VAs) to 30 (Alt2 without TUCP no VAs) in a critically dry water year type (Table I.1-9, Figure I.1-3a, and Figure I.1-3b). Alternative 1 often, but not consistently, had the greatest predicted salvage of LAD spring-run Chinook salmon compared with other alternatives. The greatest predicted salvage occurred in May followed by March in a wet water year type. In Above Normal and Dry water year types, the greatest predicted salvage occurred in April followed by March while in Below Normal and Critical water year types, the greatest predicted salvage occurred in April followed by May. Alternative 1 predicted salvage ranged from 3,264 to 33 in May of a wet and critical water year type, respectively (Table I.1-9, Figure I.1-3a, and Figure I.1-3b). Alt3 had the least predicted salvage of LAD spring-run Chinook salmon of all alternatives in all months and water year types. The greatest predicted salvage occurred in March followed by April in Wet and Above Normal water year types. In Below Normal and Critical water year types, the greatest salvage occurred in April followed by May while in a Dry water year the greatest predicted salvage occurred in April followed by March. Alt3 predicted salvage ranged from 89 to 14 in May of a wet and critical water year type, respectively (Table I.1-9, Figure I.1-3a, and Figure I.1-3b). Alt4 has similar predicted salvage of LAD spring-run Chinook salmon among some months to Alt2 without TUCP without VAs and Alt2 with TUCP without VAs. The greatest predicted salvage under Alt4 occurred in April and May in all water year types. Alt4 predicted salvage ranged from 3,431 to 32 in May of a wet and critical water year type, respectively (Table I.1-9, Figure I.1-3a and Figure I.1-3b). NAA had the greatest predicted salvage in April followed by May in above normal, dry, and critical water year types; March followed by May in a wet water year type; and May followed by April in a below normal water year type. NAA predicted salvage ranged from 2,194 to 24 in May of wet and critical water year type, respectively (Table I.1-9, Figure I.1-3a and Figure I.1-3b). Values from the exploratory modeling scenarios (EXP1 and EXP3) were not included for consideration in the range of mean predicted salvage, exports in EXP1 and EXP3 are zero.

The months of highest predicted spring-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile spring-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become slightly more positive or consistent from March through May (Chapter 4, Figure 66). Monthly Sacramento River flows below Keswick Dam, across all water year types, decreases from February through April after increasing since November, and begins to increase in May through the summer months (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

The mean monthly predicted salvage at the Delta Fish Collection Facilities of steelhead from the negative binomial regression model calculated across the months of December through June and all alternatives has a wide range. The final model included a single variable: combined exports at the Banks and Jones facilities. Among the 4 components of Alt2, the greatest predicted salvage occurred in the months of March followed by February in wet, dry, and critical water year types. In above normal water year types, the greatest predicted salvage occurred in February followed by March or May. In below normal water year types, the greatest predicted salvage occurred in February followed by March or May. The range of mean predicted salvage of steelhead for the four components of Alt2 in March ranged from 8,549 (Alt2 with TUCP no VAs) to 7,535 (Alt2 without TUCP with Systemwide VAs) in a wet water year type to from 500 (Alt2 with TUCP no VAs) to 411 (Alt2 without TUCP with Delta VAs) in a critically dry water year type (Table I.1-11, Figure I.1-5a, and Figure I.1-5b). Alternative 1 often, but not across all months and water year types, had the greatest predicted salvage of steelhead compared with other alternatives. The greatest predicted salvage occurred in March followed by February in wet, above normal, and below normal water year types. In dry and critical water year types, the greatest predicted salvage occurred in February followed by March. Alternative 1 predicted salvage ranged from 11,364 to 1,409 in March of an above normal and critical water year type, respectively (Table I.1-11, Figure I.1-5a, and Figure I.1-5b). Alt3 had the least predicted salvage of steelhead of all alternatives in all months and water year types except March of Above Normal, Below Normal, and Critical. The greatest predicted salvage occurred in March followed by February in above normal, below normal, and dry water year types; and in February followed by March in wet and critical water year types. Alt3 predicted salvage ranged from 2,962 to 262 in March of an above normal and critical water year type, respectively (Table I.1-11, Figure I.1-5a, and Figure I.1-5b). NAA had the greatest predicted salvage in March followed by February in dry and critical water year types and in February followed by March in wet, above normal, and below normal water year types. NAA predicted salvage ranged from 6,404 to 579 in March of wet and critical water year type, respectively (Table I.1-11, Figure I.1-5a, and Figure I.1-5b). Values from the exploratory modeling scenarios (EXP1 and EXP3) were not included for consideration in the range of mean predicted salvage, exports in EXP1 and EXP3 are zero.

The months of highest predicted steelhead salvage at the facilities temporally coincides with when a large proportion of the juvenile steelhead population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to February through late fall into winter (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). Monthly Stanislaus River flows below Goodwin Dam, across all water year types, increase from November to February before decreasing in March (Chapter 4, Figure 42). This increase of flows in the Sacramento River cues juveniles to outmigrate from the upper Sacramento River through the mainstem. This increase of flows in the Stanislaus River cues juveniles to outmigrate through the San Joaquin River. Fish are present in the South Delta if they become entrained into the Central and Interior Delta at junctions like Georgiana Slough or the Delta Cross Channel, from the Sacramento River route, or at junctions like Head of Old River, from the San Joaquin River route.

Table I.1-7. Predicted average monthly salvage of juvenile Winter-Run Chinook Salmon at the Delta fish collection facilities for Exploratory runs 1 and 3 (EXP1, EXP3), No Action Alternative (NAA), and 4 components of Alternative 2, averaged by water year type and month (December through April), based on the negative binomial salvage method. Absolute values are rounded.

Water Year Type	Month	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2wTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Wet	Dec	0	0	3	2	2	2	2
Wet	Jan	0	0	5	5	5	5	5
Wet	Feb	0	0	16	18	18	18	18
Wet	Mar	1	1	34	43	43	40	39
Wet	Apr	0	0	6	8	8	6	6
AN	Dec	0	0	2	2	2	2	2
AN	Jan	0	0	3	3	3	3	3
AN	Feb	0	0	11	12	13	12	12
AN	Mar	1	1	20	21	21	13	13
AN	Apr	0	0	2	4	4	2	2
BN	Dec	0	0	2	2	2	2	2
BN	Jan	0	0	2	2	2	2	2
BN	Feb	0	0	9	8	8	8	8
BN	Mar	2	2	17	17	17	10	10
BN	Apr	0	0	2	3	3	2	2
Dry	Dec	0	0	1	1	2	1	1
Dry	Jan	0	0	2	2	2	2	2
Dry	Feb	0	0	6	5	5	5	5
Dry	Mar	2	2	15	14	14	10	10
Dry	Apr	1	1	2	2	2	2	2

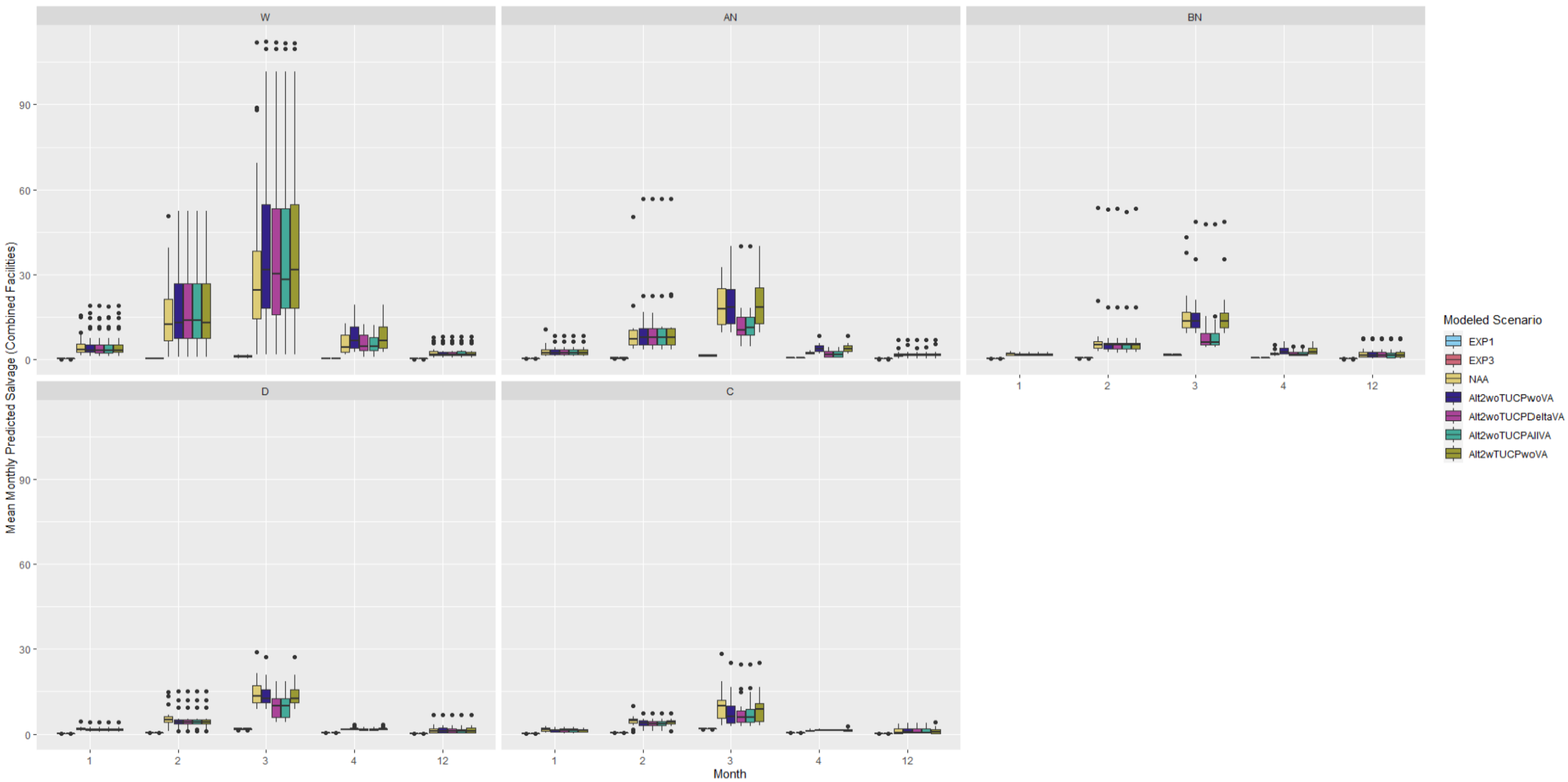
Water Year Type	Month	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2wTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
C	Dec	0	0	1	1	1	1	1
C	Jan	0	0	1	1	1	1	1
C	Feb	1	1	4	4	4	4	4
C	Mar	2	2	10	8	9	8	8
C	Apr	1	1	1	1	1	1	1

Table I.1-8. Predicted average monthly salvage of juvenile Winter-Run Chinook Salmon at the Delta fish collection facilities for the No Action Alternative (NAA), Alternative 1 (Alt1), 4 components of Alternative 2, Alternative 3 (Alt3), and Alternative 4 (Alt4) averaged by water year type and month (December through April), based on the negative binomial salvage method.

Water Year Type	Month	NAA	Alt1	Alt2woTUCP woVA	Alt2wTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
Wet	Dec	3	7 (133%)	2 (-33%)	2 (-33%)	2 (-33%)	2 (-33%)	1 (-67%)	2 (-33%)
Wet	Jan	5	16 (220%)	5 (0%)	5 (0%)	5 (0%)	5 (0%)	4 (-20%)	5 (0%)
Wet	Feb	16	34 (112%)	18 (12%)	18 (12%)	18 (12%)	18 (12%)	8 (-50%)	19 (19%)
Wet	Mar	34	61 (79%)	43 (26%)	43 (26%)	40 (18%)	39 (15%)	16 (-53%)	48 (41%)
Wet	Apr	6	7 (17%)	8 (33%)	8 (33%)	6 (0%)	6 (0%)	1 (-83%)	8 (33%)
AN	Dec	2	6 (200%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	1 (-50%)	2 (0%)
AN	Jan	3	16 (433%)	3 (0%)	3 (0%)	3 (0%)	3 (0%)	2 (-33%)	3 (0%)
AN	Feb	11	35 (218%)	12 (9%)	13 (18%)	12 (9%)	12 (9%)	11 (0%)	15 (36%)
AN	Mar	20	78 (290%)	21 (5%)	21 (5%)	13 (-35%)	13 (-35%)	24 (20%)	23 (15%)
AN	Apr	2	4 (100%)	4 (100%)	4 (100%)	2 (0%)	2 (0%)	1 (-50%)	4 (100%)
BN	Dec	2	4 (100%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	1 (-50%)	1 (-50%)
BN	Jan	2	12 (500%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	1 (-50%)	2 (0%)
BN	Feb	9	25 (178%)	8 (-11%)	8 (-11%)	8 (-11%)	8 (-11%)	7 (-22%)	10 (11%)

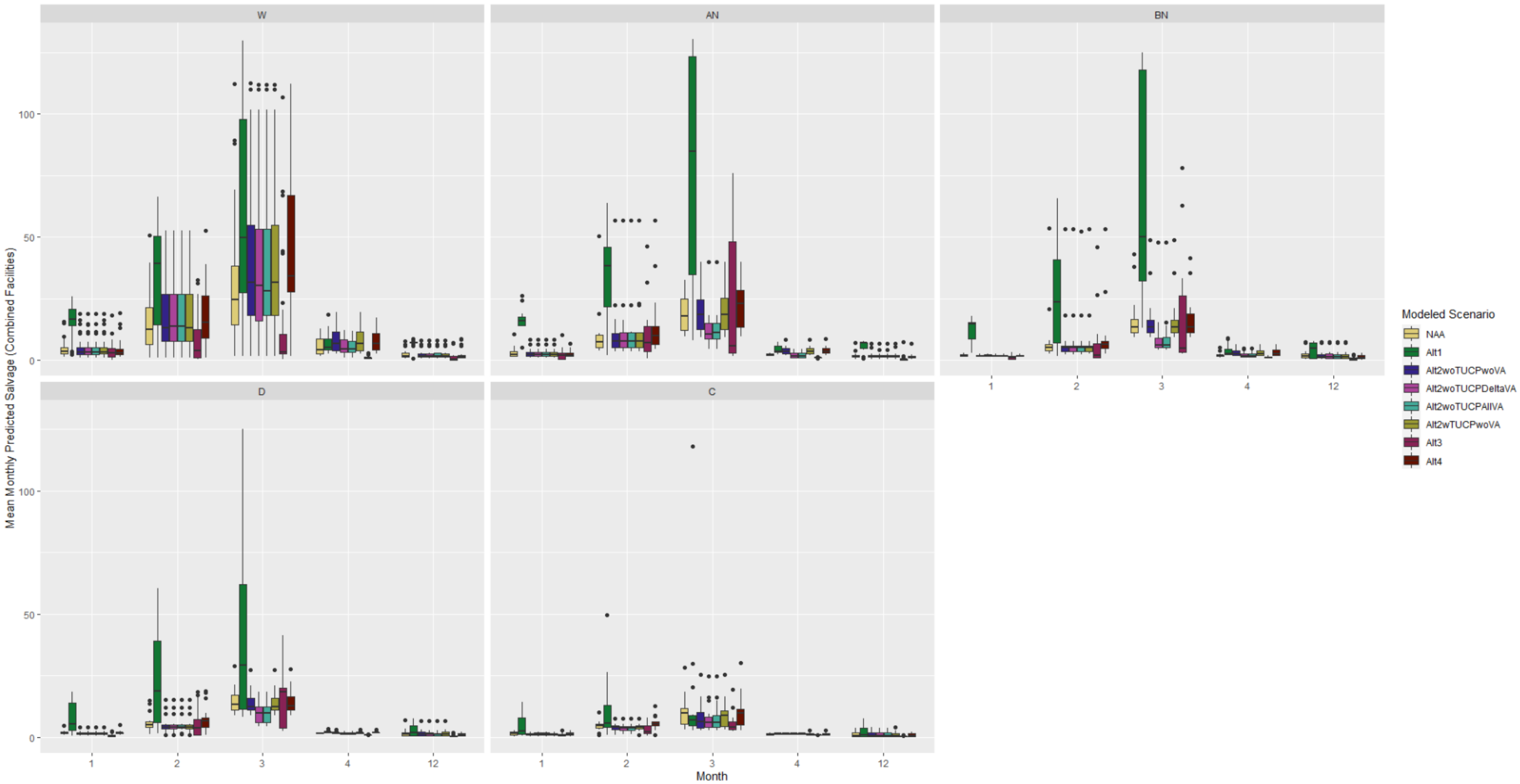
Water Year Type	Month	NAA	Alt1	Alt2woTUCP woVA	Alt2wTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
BN	Mar	17	66 (288%)	17 (0%)	17 (0%)	10 (-41%)	10 (-41%)	19 (12%)	17 (0%)
BN	Apr	2	4 (100%)	3 (50%)	3 (50%)	2 (0%)	2 (0%)	1 (-50%)	3 (50%)
Dry	Dec	1	3 (200%)	1 (0%)	2 (100%)	1 (0%)	1 (0%)	0 (-100%)	1 (0%)
Dry	Jan	2	8 (300%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	1 (-50%)	2 (0%)
Dry	Feb	6	24 (300%)	5 (-17%)	5 (-17%)	5 (-17%)	5 (-17%)	5 (-17%)	7 (17%)
Dry	Mar	15	44 (193%)	14 (-7%)	14 (-7%)	10 (-33%)	10 (-33%)	14 (-7%)	14 (-7%)
Dry	Apr	2	2 (0%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	1 (-50%)	2 (0%)
C	Dec	1	2 (100%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	0 (-100%)	1 (0%)
C	Jan	1	5 (400%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
C	Feb	4	11 (175%)	4 (0%)	4 (0%)	4 (0%)	4 (0%)	3 (-25%)	6 (50%)
C	Mar	10	15 (50%)	8 (-20%)	9 (-10%)	8 (-20%)	8 (-20%)	6 (-40%)	10 (0%)
C	Apr	1	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)

Percentage values in parentheses indicate the difference between NAA and each alternative. Absolute and percentage values are rounded.



The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-7, Table I.1-8.

Figure I.1-1. Predicted average monthly salvage of winter-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-7, Table I.1-8.

Figure I.1-2. Predicted average monthly salvage of winter-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.

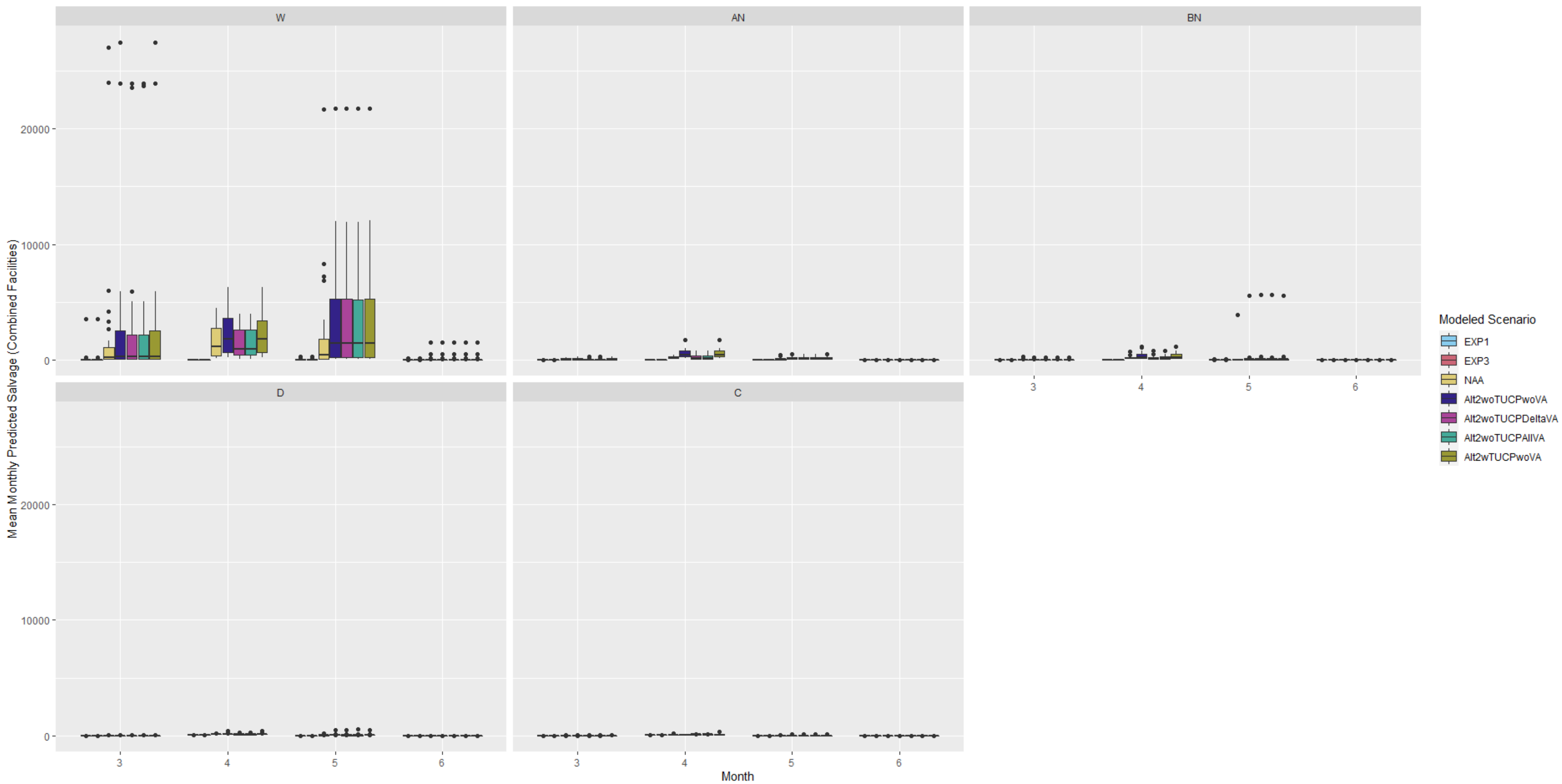
Table I.1-9. Predicted average monthly salvage of juvenile Spring-Run Chinook Salmon at the Delta fish collection facilities for Exploratory runs 1 and 3 (EXP1, EXP3), No Action Alternative (NAA), and 4 components of Alternative 2, averaged by water year type and month (March through June), based on the negative binomial salvage method. Absolute values are rounded.

Water Year Type	Month	EXP1	EXP3	NAA	Alt2 woTUCP woVA	Alt2 wTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	March	151	151	2611	2883	2900	2702	2638
Wet	April	44	44	1563	2250	2197	1526	1489
Wet	May	70	70	2194	3528	3544	3514	3541
Wet	June	9	9	92	92	92	92	93
AN	March	4	4	76	84	84	51	51
AN	April	37	37	264	604	607	250	250
AN	May	16	16	119	202	202	182	178
AN	June	0	0	1	1	1	1	1
BN	March	2	2	45	44	44	25	25
BN	April	36	36	227	391	392	255	262
BN	May	18	18	261	384	390	386	382
BN	June	0	0	1	1	1	1	1
Dry	March	1	1	17	16	16	10	10
Dry	April	34	34	136	171	172	129	130
Dry	May	10	10	41	63	63	59	59
Dry	June	0	0	0	0	0	0	0
C	March	1	1	9	7	8	7	7
C	April	33	33	89	105	103	104	105
C	May	9	9	24	30	32	30	30
C	June	0	0	0	0	0	0	0

Table I.1-10. Predicted average monthly salvage of juvenile Spring-Run Chinook Salmon at the Delta fish collection facilities for the No Action Alternative (NAA), Alternative 1 (Alt1), 4 components of Alternative 2, Alternative 3 (Alt3), and Alternative 4 (Alt4) averaged by water year type and month (March through June), based on the negative binomial salvage method.

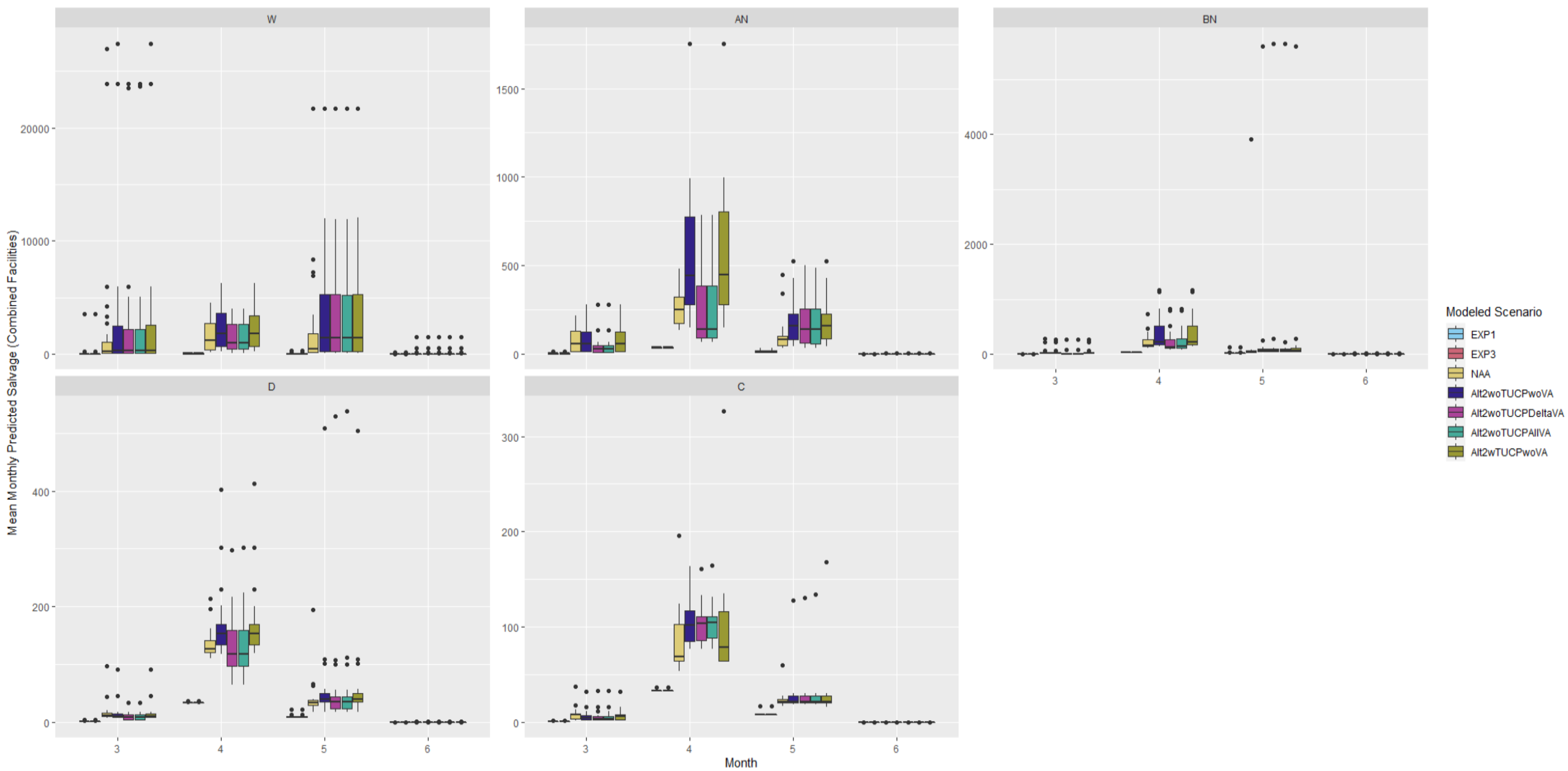
Water Year Type	Month	NAA	Alt1	Alt2woTUCP woVA	Alt2wTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
Wet	March	2611	2390 (-8%)	2883 (10%)	2900 (11%)	2702 (3%)	2638 (1%)	593 (-77%)	3106 (19%)
Wet	April	1563	1862 (19%)	2250 (44%)	2197 (41%)	1526 (-2%)	1489 (-5%)	119 (-92%)	2221 (42%)
Wet	May	2194	3264 (49%)	3528 (61%)	3544 (62%)	3514 (60%)	3541 (61%)	89 (-96%)	3431 (56%)
Wet	June	92	106 (15%)	92 (0%)	92 (0%)	92 (0%)	93 (1%)	35 (-62%)	91 (-1%)
AN	March	76	323 (325%)	84 (11%)	84 (11%)	51 (-33%)	51 (-33%)	121 (59%)	89 (17%)
AN	April	264	605 (129%)	604 (129%)	607 (130%)	250 (-5%)	250 (-5%)	78 (-70%)	611 (131%)
AN	May	119	237 (99%)	202 (70%)	202 (70%)	182 (53%)	178 (50%)	22 (-82%)	204 (71%)
AN	June	1	2 (100%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	0 (-100%)	1 (0%)
BN	March	45	216 (380%)	44 (-2%)	44 (-2%)	25 (-44%)	25 (-44%)	78 (73%)	42 (-7%)
BN	April	227	527 (132%)	391 (72%)	392 (73%)	255 (12%)	262 (15%)	97 (-57%)	398 (75%)
BN	May	261	366 (40%)	384 (47%)	390 (49%)	386 (48%)	382 (46%)	85 (-67%)	363 (39%)
BN	June	1	3 (200%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	0 (-100%)	1 (0%)
Dry	March	17	78 (359%)	16 (-6%)	16 (-6%)	10 (-41%)	10 (-41%)	17 (0%)	16 (-6%)
Dry	April	136	203 (49%)	171 (26%)	172 (26%)	129 (-5%)	130 (-4%)	59 (-57%)	173 (27%)
Dry	May	41	73 (78%)	63 (54%)	63 (54%)	59 (44%)	59 (44%)	17 (-59%)	64 (56%)
Dry	June	0	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)
C	March	9	21 (133%)	7 (-22%)	8 (-11%)	7 (-22%)	7 (-22%)	4 (-56%)	9 (0%)
C	April	89	108 (21%)	105 (18%)	103 (16%)	104 (17%)	105 (18%)	53 (-40%)	105 (18%)
C	May	24	33 (38%)	30 (25%)	32 (33%)	30 (25%)	30 (25%)	14 (-42%)	32 (33%)
C	June	0	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)	0 (NaN%)

Note: Percentage values in parentheses indicate the difference between NAA and each alternative. Absolute and percentage values are rounded.



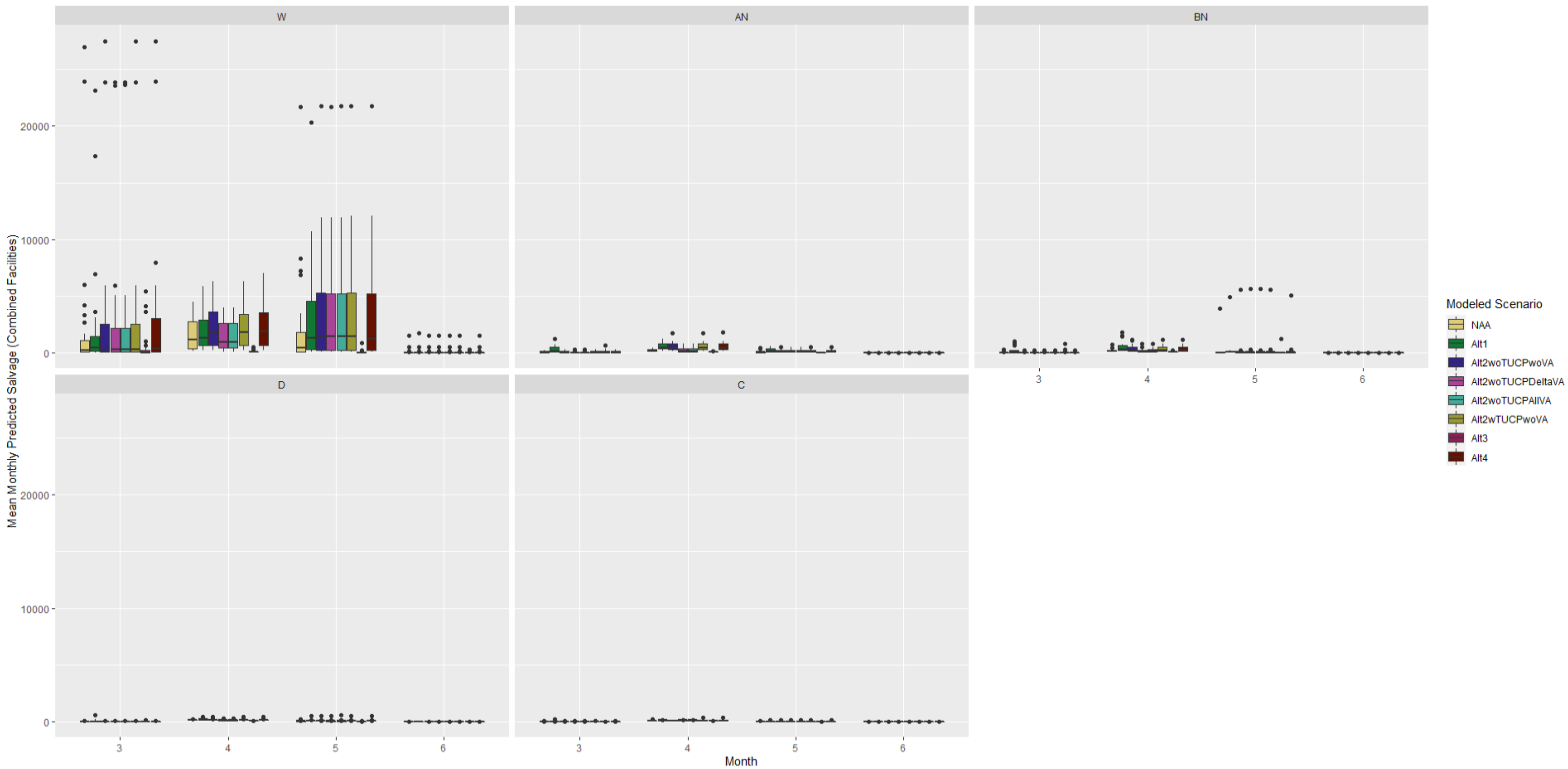
The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-9, Table I.1-10.

Figure I.1-3a. Predicted average monthly salvage of spring-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



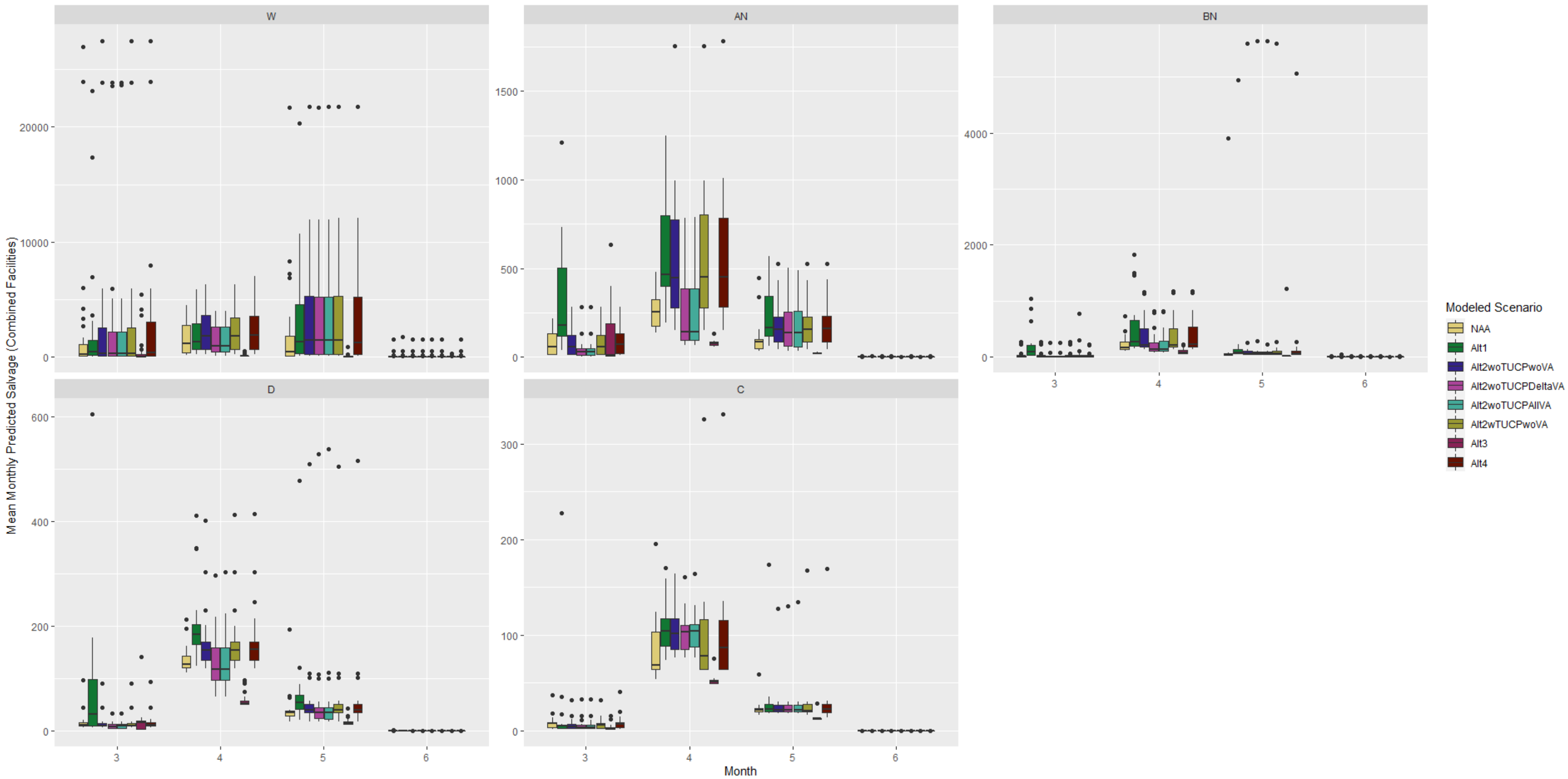
The y-axis scale is free. Figure displays data given in the preceding two data tables: Table I.1-9, Table I.1-10.

Figure I.1-3b. Predicted average monthly salvage of spring-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-9, Table I.1-10.

Figure I.1-4a. Predicted average monthly salvage of spring-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



The y-axis scale is free. Figure displays data given in the preceding two data tables: Table I.1-9, Table I.1-10.

Figure I.1-4b. Predicted average monthly salvage of spring-run Chinook salmon at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.

Table I.1-11. Predicted average monthly salvage of juvenile Steelhead at the Delta fish collection facilities for Exploratory runs 1 and 3 (EXP1, EXP3), No Action Alternative (NAA), and 4 components of Alternative 2, averaged by water year type and month (December through June), based on the negative binomial salvage method.

Water Year Type	Month	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2wTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Wet	Dec	1	1	84	80	80	80	81
Wet	Jan	7	7	1649	1782	1783	1739	1750
Wet	Feb	20	20	7077	7625	7722	7824	7824
Wet	Mar	48	48	6404	8522	8549	7976	7535
Wet	Apr	81	81	4176	6281	6126	4075	3969
Wet	May	51	51	2313	5404	5439	5418	5438
Wet	Jun	5	5	316	308	309	310	310
AN	Dec	1	1	56	59	59	57	57
AN	Jan	7	7	503	423	424	423	423
AN	Feb	20	20	2770	3481	3808	3482	3266
AN	Mar	48	48	1800	1996	2008	1067	1080
AN	Apr	81	81	696	1728	1737	664	665
AN	May	51	51	534	976	977	866	846
AN	Jun	5	5	89	73	73	72	72
BN	Dec	1	1	46	43	43	44	43
BN	Jan	7	7	174	157	157	159	159
BN	Feb	20	20	2024	1947	1953	1952	1948
BN	Mar	48	48	1363	1372	1373	726	727
BN	Apr	81	81	622	1114	1116	699	719
BN	May	51	51	713	1119	1153	1105	1092
BN	Jun	5	5	87	72	70	71	71

Water Year Type	Month	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2wTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Dry	Dec	1	1	25	26	27	24	23
Dry	Jan	7	7	168	138	138	139	140
Dry	Feb	20	20	622	521	521	520	530
Dry	Mar	48	48	900	839	839	540	542
Dry	Apr	81	81	370	477	479	352	353
Dry	May	51	51	232	352	352	322	318
Dry	Jun	5	5	56	42	42	40	40
C	Dec	1	1	19	21	19	20	20
C	Jan	7	7	119	89	91	100	99
C	Feb	20	20	408	333	360	316	315
C	Mar	48	48	579	433	500	411	416
C	Apr	81	81	236	285	280	281	284
C	May	51	51	149	186	201	188	190
C	Jun	5	5	15	13	13	13	13

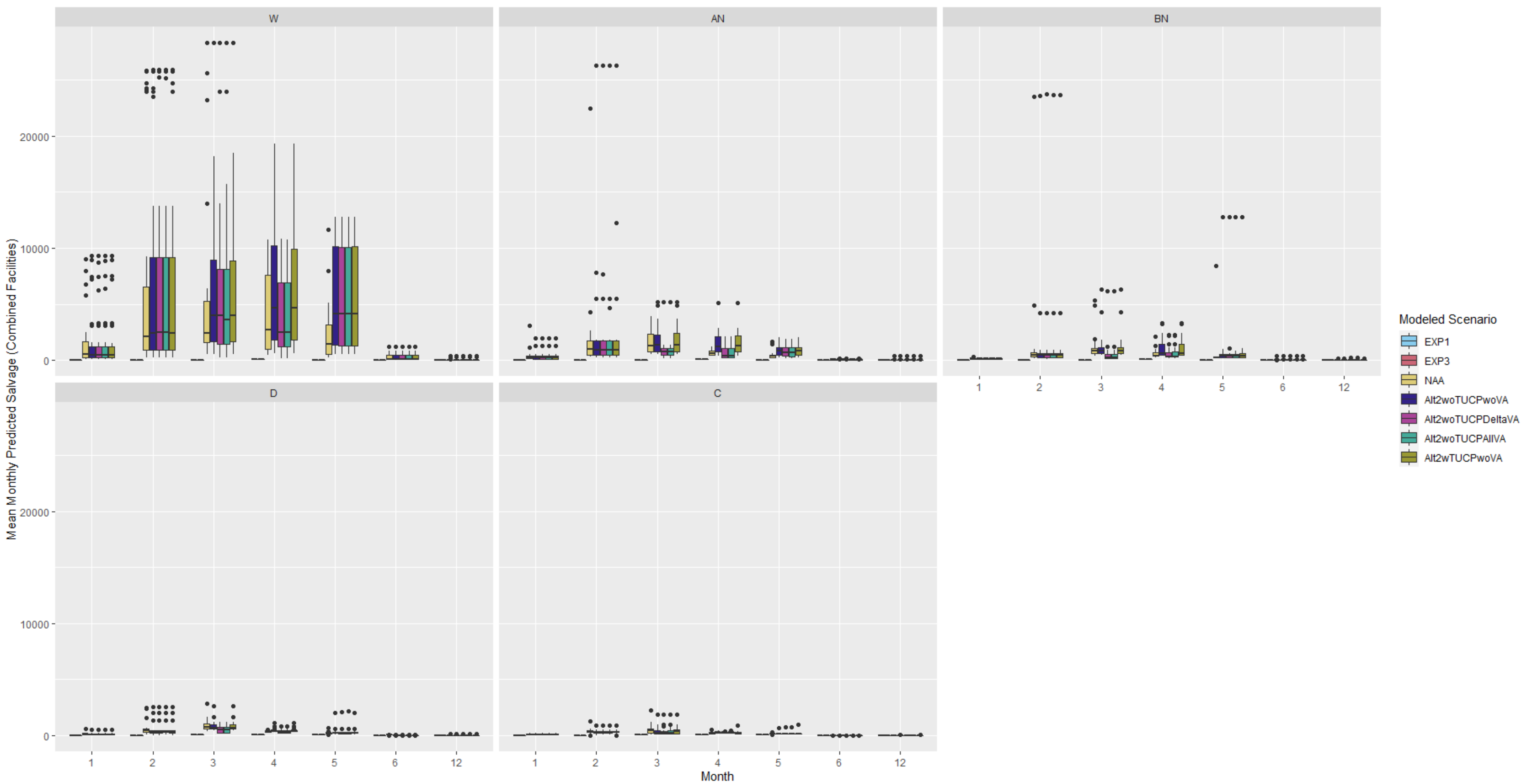
Absolute values are rounded.

Table I.1-12. Predicted average monthly salvage of juvenile Steelhead at the Delta fish collection facilities for the No Action Alternative (NAA), Alternative 1 (Alt1), 4 components of Alternative 2, Alternative 3 (Alt3), and Alternative 4 (Alt4) averaged by water year type and month (December through June), based on the negative binomial salvage method.

Water Year Type	Month	NAA	Alt1	Alt2woTUCP woVA	Alt2wTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
Wet	Dec	84	229 (173%)	80 (-5%)	80 (-5%)	80 (-5%)	81 (-4%)	39 (-54%)	79 (-6%)
Wet	Jan	1649	4675 (184%)	1782 (8%)	1783 (8%)	1739 (5%)	1750 (6%)	898 (-46%)	1602 (-3%)
Wet	Feb	7077	11661 (65%)	7625 (8%)	7722 (9%)	7824 (11%)	7824 (11%)	2950 (-58%)	7848 (11%)
Wet	Mar	6404	10783 (68%)	8522 (33%)	8549 (33%)	7976 (25%)	7535 (18%)	2665 (-58%)	9545 (49%)
Wet	Apr	4176	5100 (22%)	6281 (50%)	6126 (47%)	4075 (-2%)	3969 (-5%)	269 (-94%)	6167 (48%)
Wet	May	2313	5130 (122%)	5404 (134%)	5439 (135%)	5418 (134%)	5438 (135%)	139 (-94%)	5097 (120%)
Wet	Jun	316	419 (33%)	308 (-3%)	309 (-2%)	310 (-2%)	310 (-2%)	207 (-34%)	284 (-10%)
AN	Dec	56	165 (195%)	59 (5%)	59 (5%)	57 (2%)	57 (2%)	32 (-43%)	48 (-14%)
AN	Jan	503	3767 (649%)	423 (-16%)	424 (-16%)	423 (-16%)	423 (-16%)	381 (-24%)	344 (-32%)
AN	Feb	2770	8926 (222%)	3481 (26%)	3808 (37%)	3482 (26%)	3266 (18%)	2943 (6%)	4951 (79%)
AN	Mar	1800	11364 (531%)	1996 (11%)	2008 (12%)	1067 (-41%)	1080 (-40%)	2962 (65%)	2193 (22%)
AN	Apr	696	1744 (151%)	1728 (148%)	1737 (150%)	664 (-5%)	665 (-4%)	193 (-72%)	1748 (151%)
AN	May	534	1187 (122%)	976 (83%)	977 (83%)	866 (62%)	846 (58%)	96 (-82%)	987 (85%)
AN	Jun	89	207 (133%)	73 (-18%)	73 (-18%)	72 (-19%)	72 (-19%)	28 (-69%)	73 (-18%)
BN	Dec	46	109 (137%)	43 (-7%)	43 (-7%)	44 (-4%)	43 (-7%)	9 (-80%)	20 (-57%)
BN	Jan	174	2278 (1209%)	157 (-10%)	157 (-10%)	159 (-9%)	159 (-9%)	97 (-44%)	158 (-9%)
BN	Feb	2024	6048 (199%)	1947 (-4%)	1953 (-4%)	1952 (-4%)	1948 (-4%)	1717 (-15%)	2298 (14%)
BN	Mar	1363	8712 (539%)	1372 (1%)	1373 (1%)	726 (-47%)	727 (-47%)	2042 (50%)	1330 (-2%)
BN	Apr	622	1542 (148%)	1114 (79%)	1116 (79%)	699 (12%)	719 (16%)	248 (-60%)	1135 (82%)
BN	May	713	1126 (58%)	1119 (57%)	1153 (62%)	1105 (55%)	1092 (53%)	207 (-71%)	1088 (53%)

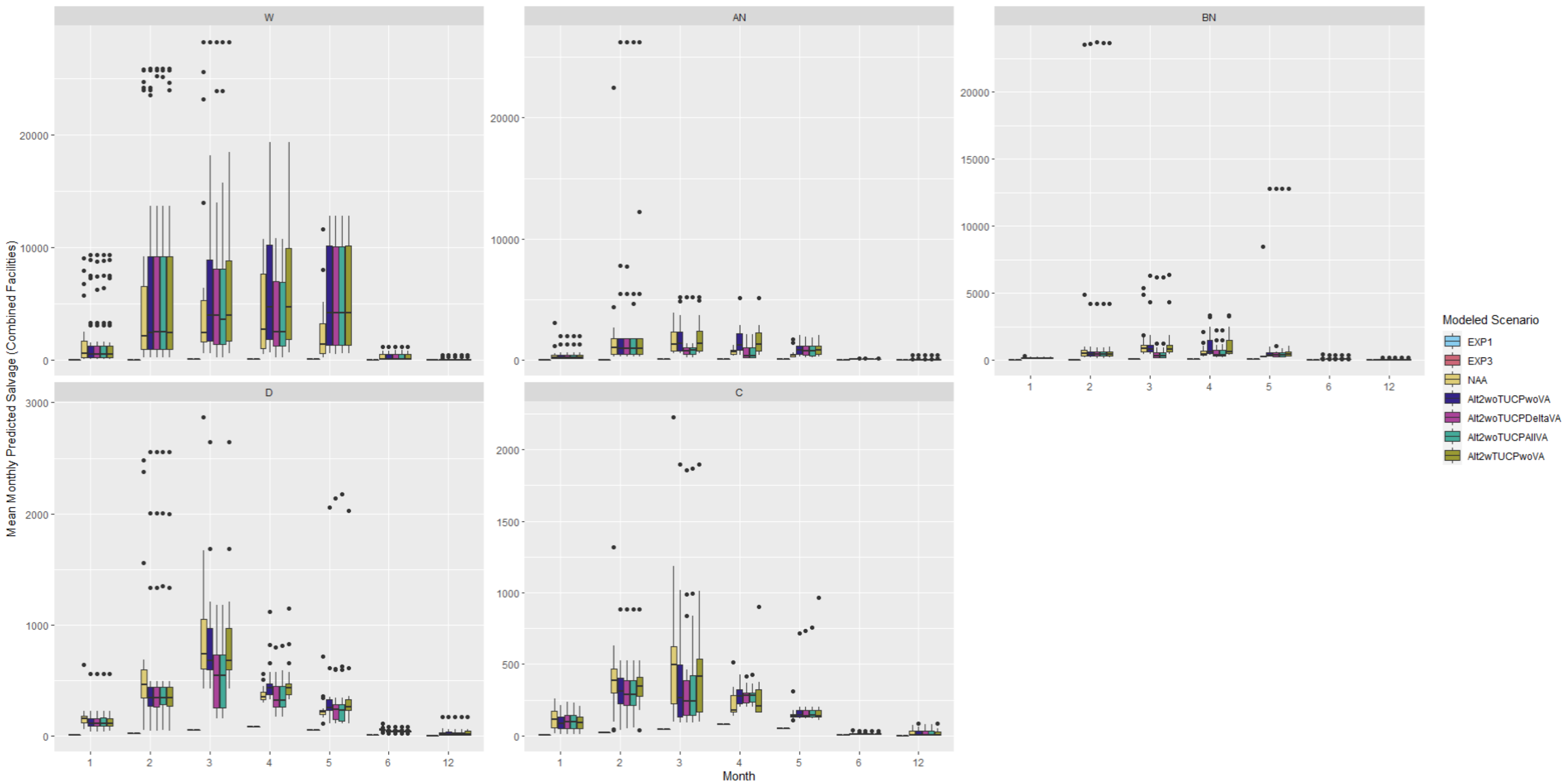
Water Year Type	Month	NAA	Alt1	Alt2woTUCP woVA	Alt2wTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
BN	Jun	87	185 (113%)	72 (-17%)	70 (-20%)	71 (-18%)	71 (-18%)	19 (-78%)	67 (-23%)
Dry	Dec	25	67 (168%)	26 (4%)	27 (8%)	24 (-4%)	23 (-8%)	5 (-80%)	15 (-40%)
Dry	Jan	168	1308 (679%)	138 (-18%)	138 (-18%)	139 (-17%)	140 (-17%)	58 (-65%)	166 (-1%)
Dry	Feb	622	4957 (697%)	521 (-16%)	521 (-16%)	520 (-16%)	530 (-15%)	681 (9%)	863 (39%)
Dry	Mar	900	4752 (428%)	839 (-7%)	839 (-7%)	540 (-40%)	542 (-40%)	953 (6%)	885 (-2%)
Dry	Apr	370	570 (54%)	477 (29%)	479 (29%)	352 (-5%)	353 (-5%)	149 (-60%)	484 (31%)
Dry	May	232	407 (75%)	352 (52%)	352 (52%)	322 (39%)	318 (37%)	92 (-60%)	354 (53%)
Dry	Jun	56	65 (16%)	42 (-25%)	42 (-25%)	40 (-29%)	40 (-29%)	10 (-82%)	42 (-25%)
C	Dec	19	54 (184%)	21 (11%)	19 (0%)	20 (5%)	20 (5%)	3 (-84%)	14 (-26%)
C	Jan	119	730 (513%)	89 (-25%)	91 (-24%)	100 (-16%)	99 (-17%)	76 (-36%)	108 (-9%)
C	Feb	408	1716 (321%)	333 (-18%)	360 (-12%)	316 (-23%)	315 (-23%)	270 (-34%)	564 (38%)
C	Mar	579	1409 (143%)	433 (-25%)	500 (-14%)	411 (-29%)	416 (-28%)	262 (-55%)	590 (2%)
C	Apr	236	294 (25%)	285 (21%)	280 (19%)	281 (19%)	284 (20%)	134 (-43%)	284 (20%)
C	May	149	206 (38%)	186 (25%)	201 (35%)	188 (26%)	190 (28%)	83 (-44%)	199 (34%)
C	Jun	15	18 (20%)	13 (-13%)	13 (-13%)	13 (-13%)	13 (-13%)	9 (-40%)	12 (-20%)

Percentage values in parentheses indicate the difference between NAA and each alternative. Absolute and percentage values are rounded.



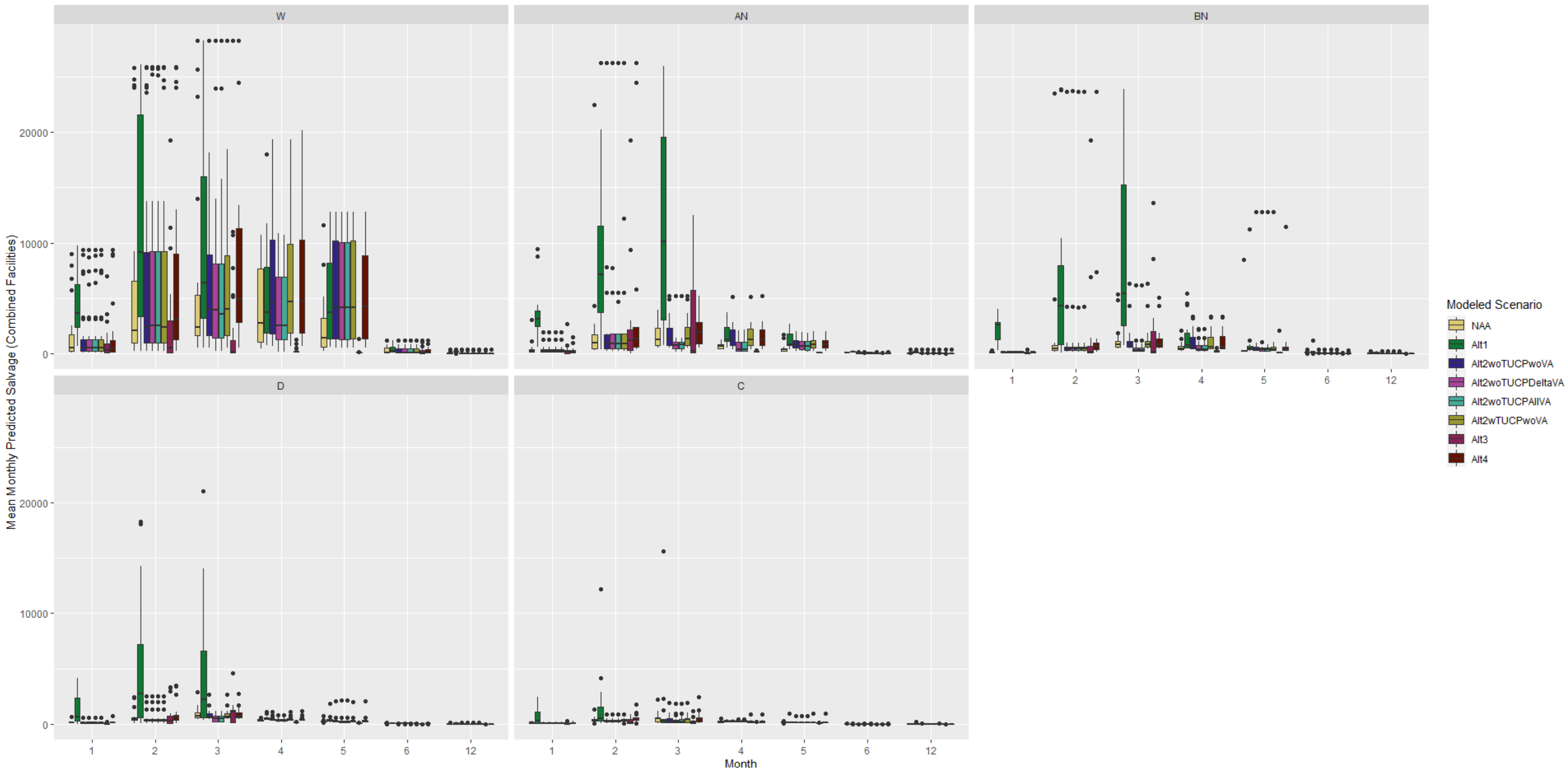
The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-11, Table I.1-12.

Figure I.1-5a. Predicted average monthly salvage of steelhead at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



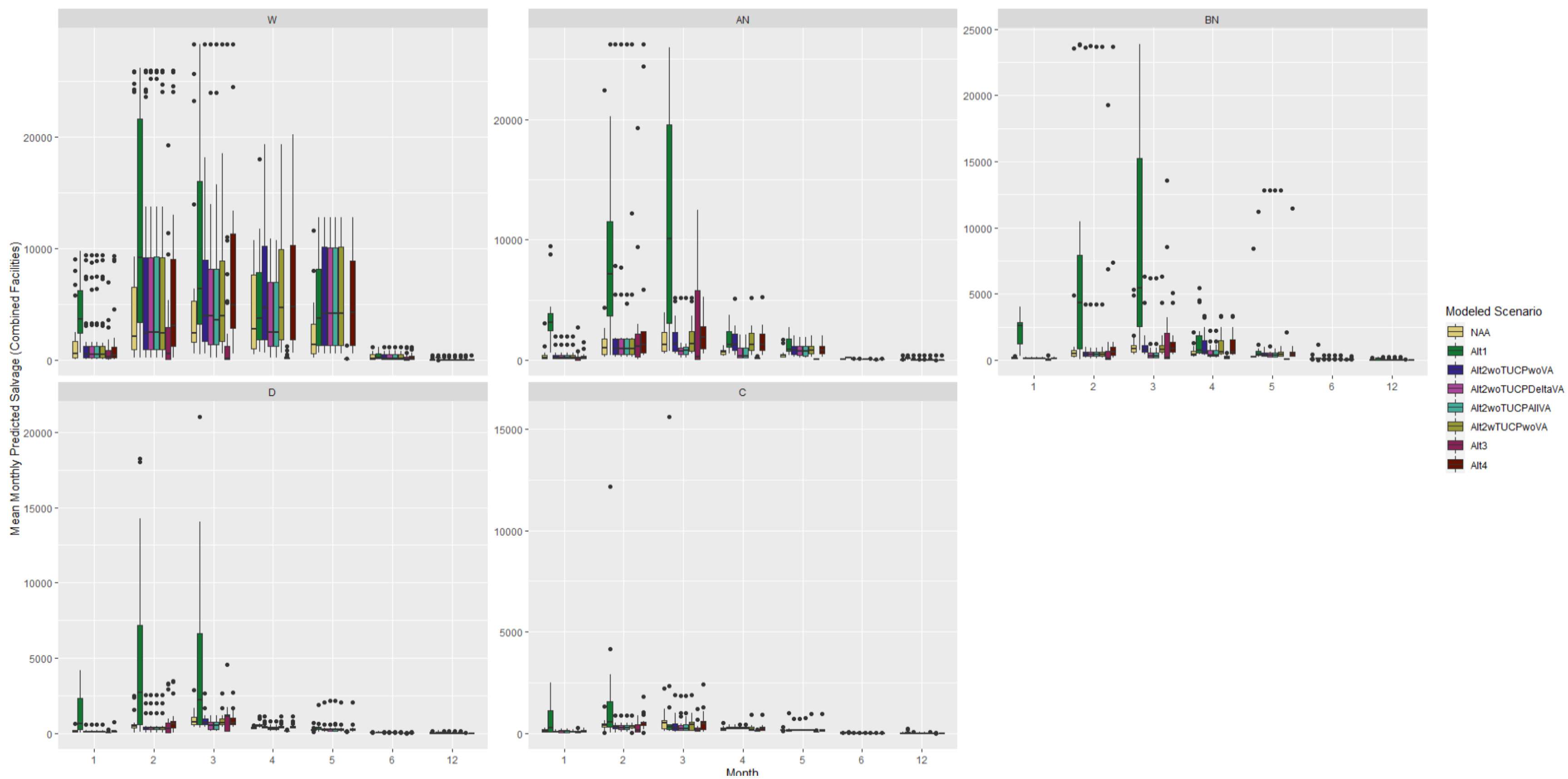
The y-axis scale is free. Figure displays data given in the preceding two data tables: Table I.1-11, Table I.1-12.

Figure I.1-5b. Predicted average monthly salvage of steelhead at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



The y-axis scale is fixed. Figure displays data given in the preceding two data tables: Table I.1-11, Table I.1-12.

Figure I.1-6a. Predicted average monthly salvage of steelhead at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.



The y-axis scale is free. Figure displays data given in the preceding two data tables: Table I.1-11, Table I.1-12.

Figure I.1-6b. Predicted average monthly salvage of steelhead at the Delta fish collection facilities by water year type and month, based on the negative binomial salvage method.

I.1.4 References

Zuur et al. 2010