Appendix I, Old and Middle River Flow Management

Attachment I.4 Longfin Smelt Salvage-OMR Relationship

I.4.1 Model Overview

The Longfin smelt salvage-OMR relationship is a model of salvage at South Delta facilities as a function of flow based on historical salvage data. The results are a quantitative analysis of loss differences between operating scenarios (including the Proposed Action). The method uses data from 1993-2005, which encompasses all five water year types (Grimaldo et al. 2009 Figure 2), and is reflective of historically high periods of juvenile salvage at the CVP and SWP collection facilities and OMR flows. This period represents conditions prior to the 2009 and 2019 Biological Opinions and 2009/2020 Incidental Take Permits, which imposed greater restrictions on south Delta exports to limit entrainment of state- and federally listed fish.

I.4.2 Model Development

I.4.2.1 Methods

Grimaldo et al. (2009:Figure 7B) found a significant relationship between juvenile Longfin Smelt salvage in April and May as a function of cumulative mean April–May Old and Middle River flows. In order to assess potential differences in salvage between the modeled scenarios, the regression of Grimaldo et al. (2009) was recreated in order to be able to fully account for sources of error in the predictions; this allowed calculation of prediction intervals when using CalSim 3-derived estimates of Old and Middle River flows as input for the modeled scenarios.

Longfin Smelt salvage data for April and May 1993–2005 were obtained from the California Department of Fish and Wildlife salvage monitoring website.[1] Consistent with Grimaldo et al. (2009), a record of 616 Longfin Smelt salvaged on April 7, 1998, was assumed to be in error, and was converted to zero for the analysis. Old and Middle River flow data were provided by Smith (pers. comm. 2012). Following Grimaldo et al. (2009), $\log_{10}$(total juvenile salvage) was regressed against mean April–May Old and Middle River flow (converted to cubic meters/second) (Figure I.4-1-A). The resulting regression equation was very similar to that obtained by Grimaldo et al. (2009; Figure I.4-1-B):

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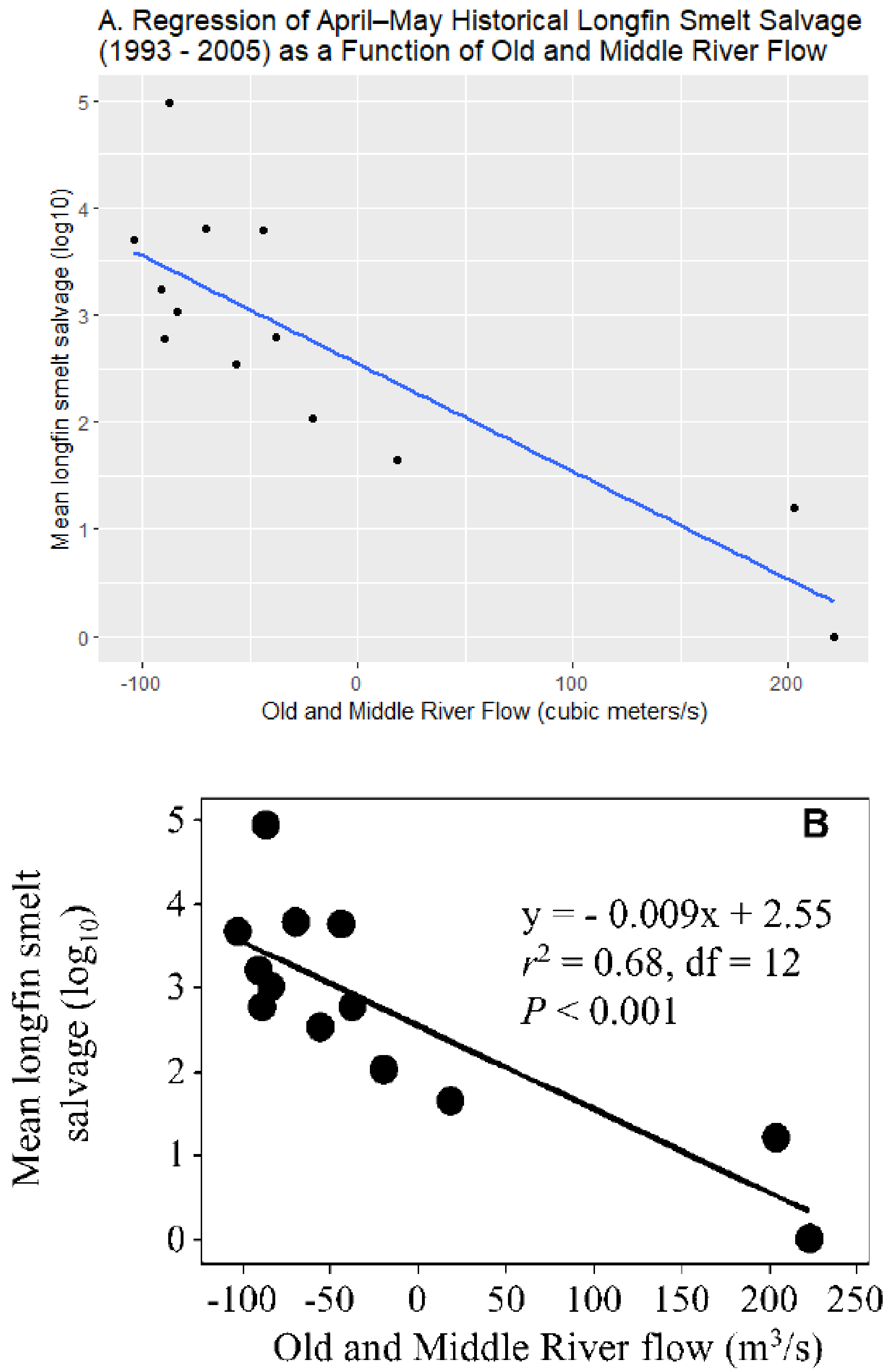
[1] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportChart.aspx?Species=1&SampleDate=1%2f22%2f2016&Facility=1, accessed January 1, 2016, and August 17, 2016 (salvage for Longfin Smelt at both facilities was selected).

Log_{10}(April–May total Longfin Smelt salvage) = 2.5454 (± 0.2072 SE) – 0.0100 (± 0.0020 SE)* (Mean April–May Old and Middle River flow); r^2 = 0.70, 12 degrees of freedom, p-value: 0.0003383.



Source: Grimaldo et al. 2009.

Figure I.4-1. A. Regression of April-May longfin smelt salvage as a function of Old and Middle River flow used in this analysis. B. Regression of April–May longfin smelt salvage as a function of Old and Middle River flow from Grimaldo et al. (2009).

For the comparison of the modeled scenarios, CalSim 3 data outputs were used to calculate mean April–May Old and Middle River flows for each year of the 1922–2021 simulation. The salvage-Old and Middle River flow regression calculated as above was used to estimate salvage for the modeled scenarios. The log-transformed salvage estimates were back-transformed to a linear scale for comparison of the modeled scenarios. Means were calculated by modeled scenarios for each water year type and presented in Tables I.4-1 and I.4-2. Variability in prediction results were illustrated using box plots, see Figures I.4-3 and I.4-4. Statistical analyses were conducted with R statistical software (R Core Team 2023).

I.4.2.2 Assumptions / Uncertainty

This analysis is meant as a tool to compare potential juvenile longfin smelt salvage across different operational scenarios based on OMR flows and is not a predictive tool.

The historical salvage records used to develop this model were from 1993-2005, prior to the USFWS 2008 and 2009 Biological Opinions (BiOp). The USFWS 2008 BiOp included measures implemented specific to entrainment of Delta smelt, and management actions for listed fish protections, such as the "First Flush" action. While this action was meant for Delta smelt, longfin smelt likely benefited as well. The Old and Middle River Flow Management was developed from the 2009 BiOp to reduce vulnerability of listed fish within the lower Sacramento and San Joaquin rivers to entrainment into the Delta fish collection facilities. Analysis of historically more recent (2009 – 2020) Smelt Larval Survey (SLS) data showed proportional entrainment was unlikely to have exceeded 3% of the population likely due to OMR management strategies (USFWS 2022).

This model only has a single covariate and therefore implicitly assumes constant population size across time. More complex models analyzing entrainment in other listed species such as Delta smelt have incorporated water clarity/turbidity (Smith et al. 2021) and behavior (Korman et al. 2021) that are likely to interact with OMR flows to reduce or increase entrainment. The model does not account for the geographical shift in distribution of juvenile longfin smelt during wet years further seaward away from the South Delta, which would decrease risk of entrainment. While OMR flow may be a large factor in the entrainment of longfin smelt, recent studies have also indicated that the proportion of the longfin smelt population entrained into the facilities in a given year are relatively low under the 2009 and 2019 BiOp conditions (Kimmerer and Gross 2022, Gross et al. 2022).

I.4.2.3 Code and Data Repository

OMR Data: Old Middle River flow data are available online at: https://data.cnra.ca.gov/dataset/dayflow

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

Model predictions are available upon request.

I.4.3 Results

Mean longfin smelt salvage by water year type for each alternative is present in Table I.4-1 and Table I.4-2.

Tables include results from Explanatory 1 (EXP1), Explanatory 3 (EXP3), No Action Alternative (NAA), Alternative 2 with TUCPs (Alt2wTUCPwoVA), Alternative 2 without TUCPs (Alt2woTUCPwoVA), Alternative 2 with Delta VA (Alt2woTUCPDeltaVA), and Alternative 2 with systemwide VAs (Alt2woTUCPAllVA).

Another set of tables includes results from No Action Alternative (NAA), Alternative 1 (Alt1), Alternative 2 with TUCPs (Alt2wTUCPwoVA), Alternative 2 without TUCPs (Alt2woTUCPwoVA), Alternative 2 with Delta VA (Alt2woTUCPDeltaVA), and Alternative 2 with systemwide VAs (Alt2woTUCPAllVA), Alternative 3 (Alt3), Alternative 4 (Alt4).

During the **wet year type**, mean salvage was highest for Alternative 1 (4032) which was a 197% increase compared to the NAA, followed by Alt2woTUCPwoVA (3712, 173% increase), Alt2wTUCPwoVA (3706, 173% increase), Alt4 (3508, 158% increase), Alt2woTUCPDeltaVA (2764, 103% increase) and Alt2woTUCPAllVA (2697, 98% increase). Mean salvage was lowest for Alternative 3 (109) which was a 92% decrease compared to the NAA.

During the **above normal year type**, mean salvage was highest for Alternative 1 (5280) which was a 295% increase compared to the NAA, followed by Alt4 (3813, 185% increase), Alt2wTUCPwoVA (3757, 181% increase), Alt2woTUCPwoVA (3754, 181% increase), Alt2woTUCPDeltaVA (1829, 37% increase) and Alt2woTUCPAllVA (1779, 33% increase). Mean salvage was lowest for Alternative 3 (265) which was a 80% decrease compared to the NAA.

During the **below normal year type**, mean salvage was highest for Alternative 1 (3388) which was a 134% increase compared to the NAA, followed by Alt4 (2700, 86% increase), Alt2wTUCPwoVA (2647, 82% increase), Alt2woTUCPwoVA (2537, 75% increase), Alt2woTUCPDeltaVA (1901, 31% increase) and Alt2woTUCPAllVA (1763, 22% increase). Mean salvage was lowest for Alternative 3 (395) which was a 73% decrease compared to the NAA.

During the **dry year type**, mean salvage was highest for Alternative 1 (2390) which was a 63% increase compared to the NAA, followed by Alt4 (2124, 45% increase), Alt2wTUCPwoVA (2091, 43% increase), Alt2woTUCPwoVA (2090, 43% increase), Alt2woTUCPDeltaVA (1578, 8% increase) and Alt2woTUCPAllVA (1403, 4% decrease). Mean salvage was lowest for Alternative 3 (449) which was a 69% decrease compared to the NAA.

During the **critical year type**, mean salvage was highest for Alternative 1 (1226) which was a 35% increase compared to the NAA, followed by Alt4 (1114, 23% increase), Alt2woTUCPDeltaVA (1170, 29% increase), Alt2woTUCPwoVA (1168, 29% increase), Alt2woTUCPAllVA (1126, 24% increase) and Alt2wTUCPwoVA (1110, 23% decrease). Mean salvage was lowest for Alternative 3 (477) which was a 47% decrease compared to the NAA.

For Alt 1, Alt2wTUCPwoVA, Alt2woTUCPwoVA, Alt2woTUCPDeltaVA, Alt2woTUCPAllVA, Alt 4, mean OMR values across April – May were most negative for Above Normal, followed by Below Normal, then Wet, Dry, Critical (Table I.4-3). For Alt 3 mean OMR values decreased as the water year type became drier.

Generally, salvage was higher for the alternatives with more negative mean April-May OMR values. Across all water year types, Alt 3 had the lowest salvage and either positive (during Wet and Above Normal WYT) or the least negative mean April-May OMR values (during Below Normal, Dry and Critical WYT) which resulted in the fewest fish being salvaged. Alt 1 had the most negative mean OMR values across all WYT and the highest predicted salvage. For the phases of Alt 2, Alt2woTUCPDeltaVA and Alt2woTUCPAllVA, had less predicted salvage than Alt2wTUCP and Alt2woTUCPwoVA because of the less negative mean April-May OMR values across all WYT except for the Critical WYT (Figure I.4-2). For phases Alt2woTUCPDeltaVA and Alt2woTUCPAllVA, mean predicted salvage was highest during Wet years even though mean April-May OMR was most negative for the Above Normal WYT (Table I.4-2 and Table I.4-3). However, OMR flow was more variable and the median and range of OMR flow was more negative in Wet years (Figure I.4-2) which explains why salvage was higher during the Wet WYT. In general, OMR and thus salvage was variable, particularly during the Wet and Above Normal water year types (Figure I.4-2).

I.4.4 Tables

Table I.4-1. April – May mean predicted Longfin Smelt salvage by water year type (WYT) for modeled scenarios. Values are rounded to the nearest integer.

WYT	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	28	37	1359	3706	3712	2764	2697
Above Normal	89	117	1335	3757	3754	1829	1779
Below Normal	152	172	1451	2647	2537	1901	1763
Dry	218	247	1464	2091	2090	1578	1403
Critical	304	286	905	1110	1168	1170	1126

Table I.4-2. April – May mean predicted Longfin Smelt salvage by water year type (WYT) for modeled scenarios. Values are rounded to the nearest integer.

WYT	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	1359	4,032 (197%)	3,706 (173%)	3,712 (173%)	2,764 (103%)	2,697 (98%)	109 (-92%)	3,508 (158%)

WYT	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Above Normal	1335	5,280 (295%)	3,757 (181%)	3,754 (181%)	1,829 (37%)	1,779 (33%)	265 (-80%)	3,813 (185%)
Below Normal	1451	3,388 (134%)	2,647 (82%)	2,537 (75%)	1,901 (31%)	1,763 (22%)	395 (-73%)	2,700 (86%)
Dry	1464	2,390 (63%)	2,091 (43%)	2,090 (43%)	1,578 (8%)	1,403 (-4%)	449 (-69%)	2,124 (45%)
Critical	905	1,226 (35%)	1,110 (23%)	1,168 (29%)	1,170 (29%)	1,126 (24%)	477 (-47%)	1,114 (23%)

Table I.4-3. Mean April-May OMR flows.

WYT	NAA	A1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	A3	A4
Wet	-1472	-2804	-2789	-2797	-2349	-2312	3581	-2740
Above Normal	-2005	-4006	-3542	-3541	-2348	-2296	678	-3561
Below Normal	-2087	-3329	-3033	-2979	-2505	-2389	-135	-3057
Dry	-2151	-2850	-2625	-2624	-2163	-1987	-347	-2646
Critical	-1419	-1824	-1637	-1772	-1774	-1735	-461	-1623

I.4.5 Figures

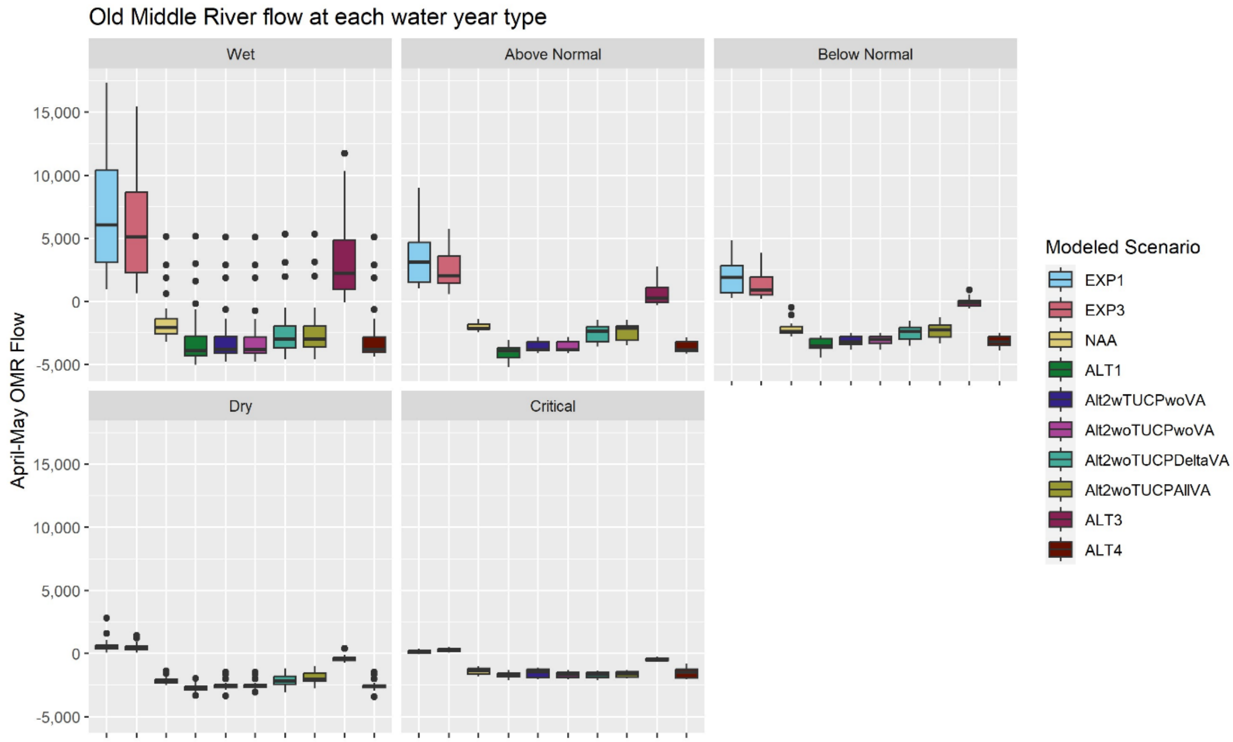


Figure I.4-2. April - May median, quartile and interquartile ranges of Old and Middle River flows by water year type for all scenarios, 1922-2021. Note the y-axis scale is fixed.

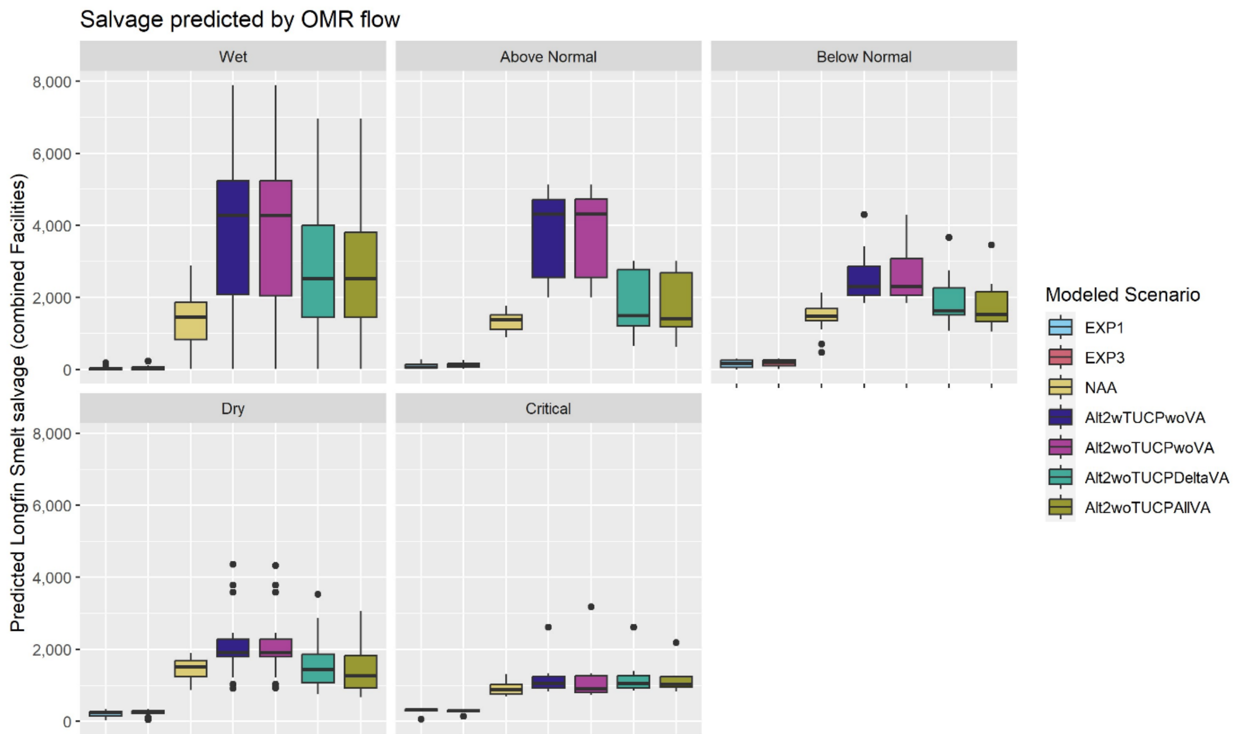


Figure I.4-3. Predicted median, quartile and interquartile ranges of longfin smelt salvage from April-May at USBR and CDWR facilities from 1922-2021 by alternative and water year type, predicted from CalSim3 Old and Middle River simulated flows.

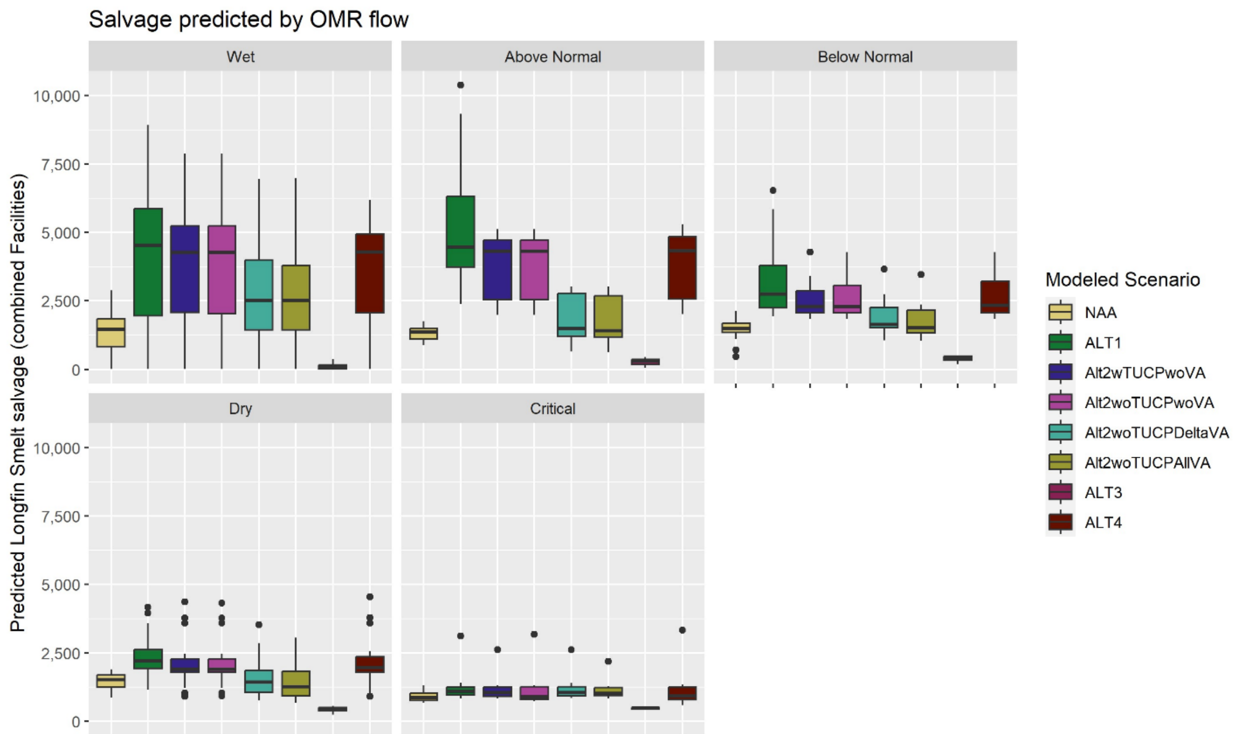


Figure I.4-4. Predicted median, quartile and interquartile ranges of longfin smelt salvage from April-May at USBR and CDWR facilities from 1922-2021 by alternative and water year type, predicted from CalSim3 Old and Middle River simulated flows.

I.4.6 References

Grimaldo, L., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. Moyle, P. Smith, and B. Herbold. 2009. Factors Affecting Fish Entrainment into Massive Water Diversions in a Freshwater Tidal Estuary: Can Fish Losses Be Managed? *North American Journal of Fisheries Management* 29:1253–1270.

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