Appendix AB-I, Old and Middle River Flow Management

Attachment I.5 Survival, Travel Time, and Routing Simulation Model

I.5.1 Methods

I.5.1.1 Model Overview

The STARS model (Survival, Travel Time, and Routing Simulation) is an individual-based simulation that predicts fish parameters (survival, travel time, entrainment) of juvenile salmonids migrating through the Delta. The fish parameters are related to movement of individual acoustically tagged late-fall and winter-run Chinook salmon connected to daily data (DCC gate status and Sacramento River flow at Freeport). The implementation of the simulation model currently available for use is calibrated to acoustically tagged late-fall fish released from 2007 to 2011. Data inputs to the model can be obtained by assigning monthly CalSim output to constant daily values within each month. Results are for individuals in cohorts, or fish who enter the model's "system" daily at Freeport. The use of the STARS model can inform the migrating behavior of juvenile salmonids (i.e., route selection) and total survival in the Delta. It is constructed to understand the space outside the interior Delta, but interpolation could be used to identify possible behavior of fish once they take a specific route away from the Sacramento River (i.e., Delta Cross Channel or Georgiana Slough). STARS provides overall survival and travel time, route-specific survival and travel time, and proportion of fish on a daily timestep that would use individual migration pathways or routes. An application of the STAR models run in real time: https://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/. The code and supporting document are available from USGS (Russ Perry, USGS, Personal Communication). The model structure and assumptions are documented in peer-reviewed literature (Perry et al. 2018). Model development is not currently open and participatory.

The STARS model can be applied to assess the performance metric of routing probability for winter-run Chinook salmon and possibly also spring-run Chinook salmon. The STARS model was applied to the 2019 NMFS BiOp.

I.5.1.2 Model Application

- **Water Year (WY) Modeling**
    - Water years are modeled from October 1 in a given year to September 30 in the following year (e.g., Water Year 2021 = October 1, 2020 through September 30, 2021)

- CalSim 3 estimates of flow are provided for WYs 1922-2021 to provide 100 model realizations. The number of realizations in the 100-year time series for each WYT are as follows: W=30, AN=13, BN=19, D=22, C=16.

- **DCC gate operations**
  - Modeled DCC gate operations (i.e., days open in a given month) follow specifications in evaluated alternatives. There may be instances that the gates are only open partial months.
  - STARS is built to model daily time-steps, so DCC gate operations are accounted for in the model by indicating for each day whether the DCC gate is expected to be open or closed. If the modeled operations indicate the DCC gate is only open for some of the days in a given month, we assumed the DCC was open for the given number of days at the start of the month.
- **Freeport flows**
  - Freeport flows are monthly values from CalSim 3 runs (variable C_SAC049)
  - STARS is built to model daily time-steps, so survival is modeled under the assumption of constant flow for every day of the month
- **Identifying Water Year Type (WYT)**
  - WYT for each modeled year in CalSim (WY 1922-2021) was identified using the WYT identified by the California Department of Water Resources, based on the historical Sacramento Valley WY Index (WSIHIST (ca.gov))
- **STARS modeling**
  - Reclamation staff ran the STARS model for each day over the full record (100 realizations) of WYs.
  - Joint posterior distribution of parameters: The STARS model was run with Markov Chain Monte Carlo (mcmc) array median parameter values. This lacks ability to calculate uncertainty intervals from posterior predictions but is more time efficient than running the model with 1,000 or 3,000 iterations.
  - Number of fish to simulate for insertion at Freeport on each modeled day: 5,000 fish
  - STARS provides route-specific travel time and survival parameter estimates.
  - STARS results should be interpreted as a parameter (e.g., overall survival by route, route entrainment, etc.) under the assumption of a constant flow for every day of the month.
  - Use of monthly average flows cannot catch peaks of flow, freshets, etc. so predictions will be muted compared to utilization of daily flows.
  - Expected routing proportions and survival for each month are computed as the mean of daily values, each based on daily fish insertions.

I.5.1.3 Code and Data Repository

All model inputs, scripts, and processed model outputs are available from Reclamation upon request.

I.5.2 Results

Section I.5.2.1, *Illustrative STARS Figures*, presents example STARS results for a single WY and alternative (Figure I.5-1 through Figure I.5-3). Section I.5.2.2, *Environmental Impact Statement (EIS) Key Takeaways*, (Table I.5-1 through Table I.5-4, Figure I.5-4 through Figure I.5-11) and Section I.5.2.3, *Biological Assessment (BA) Key Takeaways*, (Table I.5-5 through Table I.5-8, Figure I.5-12 through Figure I.5-19) present summarized results for relevant alternatives and baselines. The EIS results include comparisons among the No Action Alternative (NAA) and all other management alternatives (Alt1 – Alt4), including the Proposed Action (PA, or Alt2). The BA results include results for the NAA, the EXP1 and EXP3 baseline alternatives, and the PA. Results are summarized by month, water year type, and alternative.

I.5.2.1 Illustrative STARS Figures

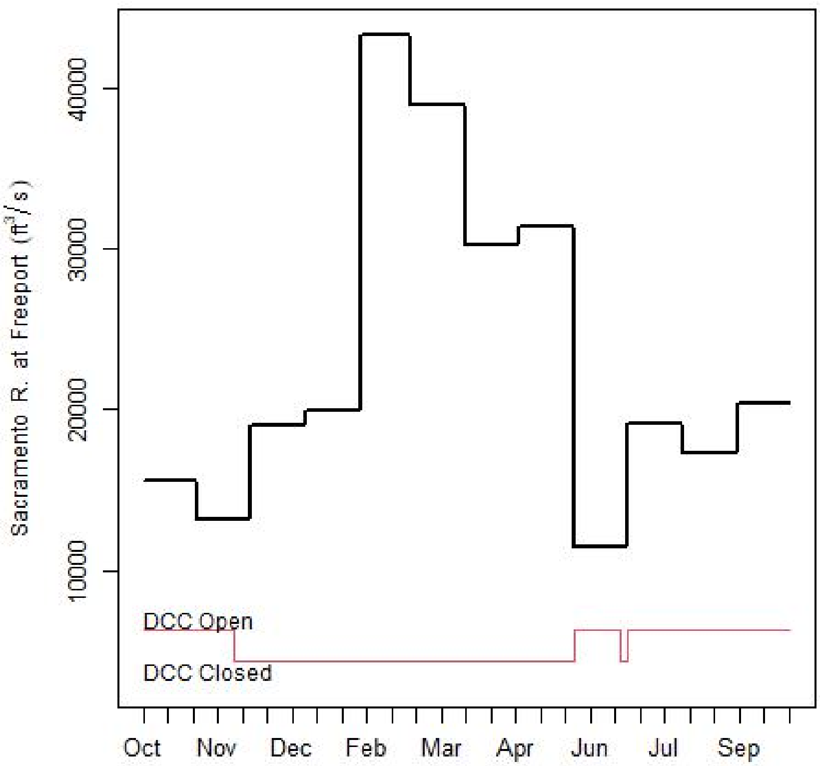

Figure I.5-1. Flow and DCC operation inputs to the STARS model for water year 1922 and the NAA alternative, generated from CalSim 3 model results.

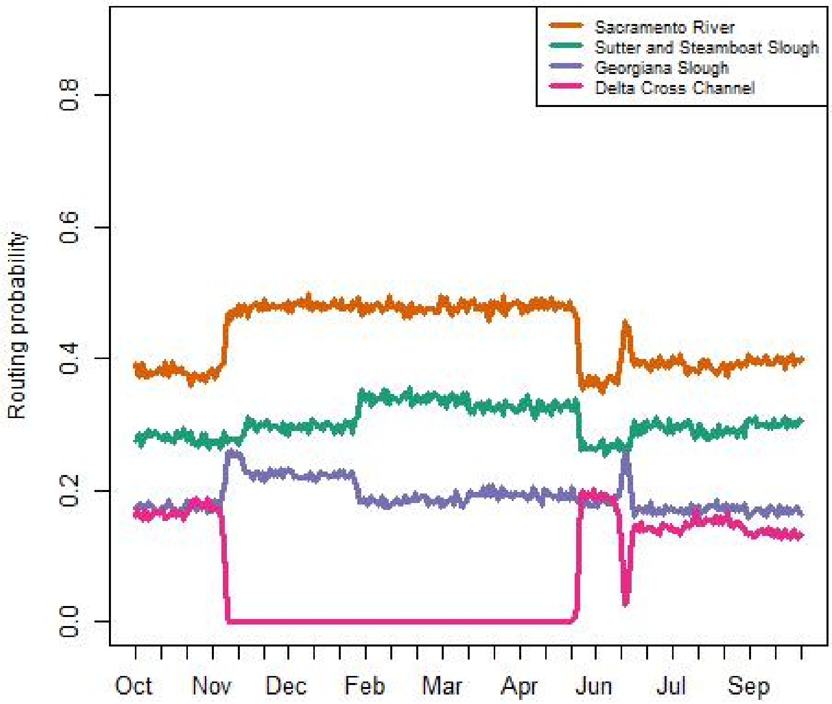

Figure I.5-2. Estimates of routing proportions for each modeled route through the Delta for WY 1922 and the NAA alternative.

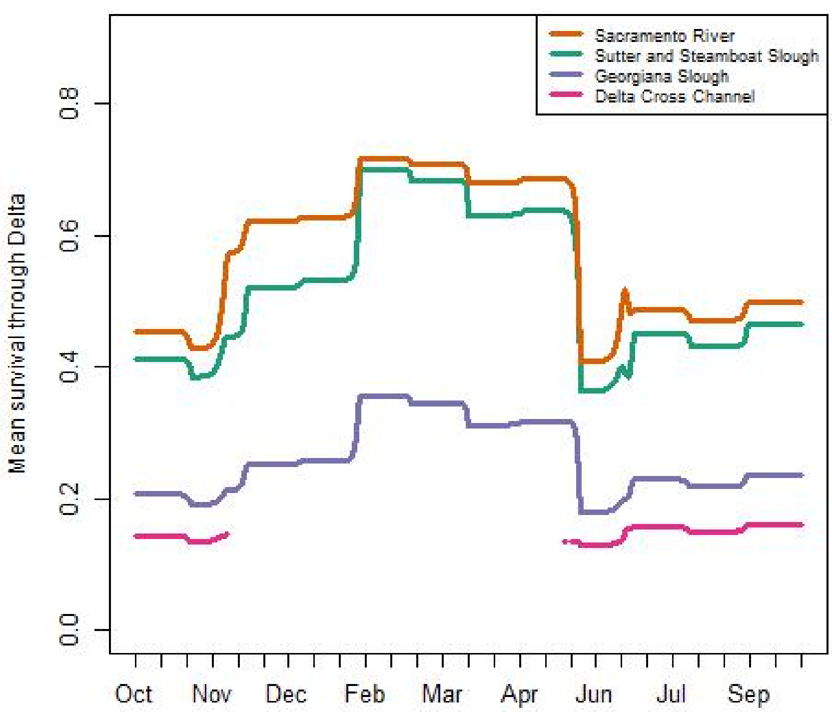

Figure I.5-3. Estimates of mean survival through the Delta for each modeled route for water year 1922 and the NAA alternative.

I.5.2.2 EIS Key Takeaways

The mean proportion of migrating juvenile Chinook salmon routed to the Interior Delta, calculated across different WYTs for each month and alternative, had a narrow range, from a low of 0.206 (Alt3) to a high 0.240 (NAA) (Table I.5-1). The total range of proportions across all simulations was greater, from approximately 0.175 to 0.35 (Figure I.5-4, Figure I.5-5). The range of mean proportions for the four versions of Alt2, calculated across all WYTs for each month and version, was 0.207 to 0.239. The range of proportions for the NAA, calculated across all WYTs for each month, was 0.207 to 0.240. The greatest expected proportions occurred in December or April, depending on WYT, and proportions were lowest and least variable across water years in February. Fewer Chinook salmon can be expected to be routed to the Interior Delta in AN and W WYTs than BN, D, or C WYTs. Lower proportions of fish routed to the Interior Delta in February were accompanied by the highest expected Delta inflows from the Sacramento River, and higher routing proportions in December and April were associated with lower Delta inflows (Appendix AB-B Water Operations and Ecosystem Analyses).

For mean values calculated across all WYTs for each month and alternative, Alt1 resulted in increased proportions of fish routed to the Interior Delta relative to the NAA, particularly in December and January (6.0 and 13.6% increases in routing). Alt3 resulted in slightly decreased proportions of routed fish (between 0.5 and 3.4% decreases in routing). Alt4 resulted in no meaningful changes in fish routing proportions. Alternative Alt2wTUCPwoVA resulted in variable but small differences in fish routing proportions across months (between -0.5 and 0.3% percent differences relative NAA), while Alt2woTUCPDeltaVA and Alt2woTUCPAllVA produced more variable but generally negative differences in fish routing proportions (between -3.7 and 0.2 percent differences relative to NAA). The Alt2woTUCPwoVA resulted in consistently reduced proportions of routed fish relative to NAA (between 0 and 1.7% decreases in routing). The Alt1 was the only alternative with DCC operations meeting D-1641 requirements only; all other alternatives shared a different set of DCC operations based on the 2019 BiOp.

Proportions of migrating juvenile Chinook salmon routed to the Interior Delta also varied across inflow groups (i.e., ranging from low Sacramento River inflow and low San Joaquin River inflow, or lolo, to high Sacramento and San Joaquin River inflow, or hihi; Appendix AB-I., OMR Zone of Influence Analysis Attachment; Table 2; Figure 6). The lowest and least variable routing proportions across water years occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Across all different inflow groups, the Alt1 alternative generally resulted in greater proportions of fish routed to the Interior Delta than NAA (between -1.0 and 14.4% differences relative to NAA). Within inflow groups, there was little difference in routing proportions among OMR bins (Figure I.5-7).

The mean overall survival of migrating juvenile Chinook salmon migrating through the Delta, calculated across all WYTs for each month and alternative, had a wider range, from a low of 0.470 (Alt1) to a high 0.583 (Alt3) (Table I.5-3). The total range of survival estimates across all simulations was greater, from approximately 0.3 to 0.7 (Figure I.5-8, Figure I.5-9). The range of mean survival values for the four versions of Alt2, calculated across all WYTs for each month and version, was 0.500 to 0.580. The range of mean survival values for the NAA, calculated across all WYTs for each month, was 0.499 to 0.579. The greatest expected survival values occurred in January, February, and March, which corresponded to months with greater Delta inflows. Greater survival is expected in AN and W WYTs than BN, D, or C WYTs.

For mean values calculated across all WYTs for each month and alternative, Alt1 resulted in variable but generally decreased fish survival relative to the NAA, particularly in December and January (2.6 and 7.6% decreases in survival). Alt3 resulted in consistently higher survival (between 0.7 and 3.5% increases in survival). Alt4 showed no meaningful changes in survival. The Alt2wTUCPwoVA resulted in generally small, positive differences in fish survival across months (between -0.1 and 0.4% percent differences relative NAA), while the Alt2woTUCPDeltaVA and Alt2woTUCPAllVA produced more variable but generally positive differences in survival (between -0.1 and 3.0 percent differences relative to NAA). The Alt2woTUCPwoVA resulted in consistently increased survival relative to NAA (between 0 and 1.2% increases in survival). Again, the Alt1 was the only alternative with DCC operations meeting D-1641 requirements only; all other alternatives shared a different set of DCC operations based on the 2019 BiOp.

Mean overall survival also varied among inflow groups (Table I.5-4; Figure I.5-10). The highest survival values occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Across all differ inflow groups, the Alt1 alternative generally resulted in more variable and lower survival than NAA (between -9.8 and 1.4% differences relative to NAA). Within inflow groups, there was little difference in mean overall survival among OMR bins (Figure I.5-11).

Table I.5-1. Predicted mean proportion of particles routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), averaged by water year type and month. Parentheses indicate % difference from NAA (negative values indicate a decrease in routing to the Interior Delta, which is considered beneficial).

WYT	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	1	0.218	0.232 (6.0)	0.217 (-0.5)	0.218 (-0.1)	0.219 (0.1)	0.219 (0.2)	0.216 (-1.1)	0.218 (0.0)
All	2	0.207	0.207 (-0.3)	0.208 (0.3)	0.207 (-0.0)	0.208 (0.2)	0.207 (0.1)	0.206 (-0.5)	0.207 (0.0)
All	3	0.215	0.215 (-0.2)	0.216 (0.0)	0.214 (-0.6)	0.214 (-0.6)	0.214 (-0.8)	0.211 (-1.9)	0.216 (0.0)
All	4	0.240	0.236 (-1.5)	0.239 (-0.3)	0.236 (-1.7)	0.236 (-1.4)	0.231 (-3.7)	0.232 (-3.4)	0.239 (-0.3)
All	12	0.235	0.267 (13.6)	0.234 (-0.2)	0.235 (0.0)	0.235 (0.2)	0.235 (0.2)	0.233 (-1.0)	0.235 (0.0)
W	1	0.187	0.188 (0.7)	0.187 (0.1)	0.187 (-0.1)	0.187 (0.0)	0.187 (0.0)	0.186 (-0.4)	0.187 (0.0)
W	2	0.182	0.182 (0.0)	0.182 (0.1)	0.182 (0.0)	0.182 (0.0)	0.182 (0.0)	0.181 (-0.3)	0.181 (-0.1)

WYT	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
W	3	0.187	0.187 (0.0)	0.187 (-0.1)	0.187 (-0.1)	0.187 (-0.2)	0.187 (-0.2)	0.187 (-0.4)	0.187 (-0.1)
W	4	0.199	0.201 (0.7)	0.199 (-0.1)	0.199 (-0.1)	0.199 (-0.1)	0.198 (-0.4)	0.195 (-2.2)	0.199 (-0.1)
W	12	0.196	0.205 (4.6)	0.196 (-0.2)	0.196 (-0.2)	0.196 (0.1)	0.196 (0.0)	0.193 (-1.6)	0.196 (0.0)
AN	1	0.197	0.202 (2.6)	0.196 (-0.4)	0.196 (-0.2)	0.197 (-0.1)	0.197 (0.1)	0.194 (-1.2)	0.197 (-0.1)
AN	2	0.190	0.189 (-0.8)	0.191 (0.2)	0.190 (-0.1)	0.190 (0.1)	0.191 (0.2)	0.187 (-1.8)	0.190 (-0.3)
AN	3	0.187	0.188 (0.2)	0.187 (-0.4)	0.187 (-0.2)	0.187 (-0.4)	0.187 (-0.3)	0.184 (-1.7)	0.186 (-0.6)
AN	4	0.219	0.220 (0.3)	0.219 (0.0)	0.219 (-0.1)	0.220 (0.2)	0.214 (-2.4)	0.207 (-5.5)	0.218 (-0.3)
AN	12	0.233	0.264 (13.3)	0.233 (0.2)	0.233 (0.1)	0.234 (0.4)	0.234 (0.5)	0.230 (-1.2)	0.235 (0.8)
BN	1	0.217	0.228 (5.1)	0.217 (-0.1)	0.216 (-0.2)	0.218 (0.4)	0.218 (0.4)	0.213 (-1.8)	0.217 (-0.1)
BN	2	0.206	0.206 (-0.4)	0.206 (0.0)	0.207 (0.1)	0.207 (0.4)	0.206 (-0.3)	0.206 (-0.2)	0.206 (-0.1)
BN	3	0.211	0.210 (-0.8)	0.211 (-0.2)	0.211 (0.0)	0.211 (0.1)	0.211 (-0.2)	0.205 (-2.8)	0.212 (0.1)
BN	4	0.236	0.237 (0.3)	0.235 (-0.4)	0.235 (-0.4)	0.237 (0.2)	0.227 (-4.1)	0.224 (-5.2)	0.236 (0.1)
BN	12	0.251	0.295 (17.6)	0.252 (0.4)	0.253 (0.8)	0.251 (0.4)	0.252 (0.6)	0.251 (0.1)	0.253 (1.0)
D	1	0.244	0.269 (10.5)	0.244 (0.1)	0.244 (0.1)	0.244 (0.2)	0.244 (0.1)	0.242 (-0.6)	0.245 (0.5)
D	2	0.225	0.223 (-0.9)	0.225 (0.1)	0.225 (0.1)	0.224 (-0.2)	0.225 (0.1)	0.221 (-1.4)	0.224 (-0.4)
D	3	0.234	0.236 (0.8)	0.235 (0.2)	0.233 (-0.6)	0.233 (-0.5)	0.232 (-0.8)	0.225 (-3.8)	0.235 (0.2)
D	4	0.260	0.258 (-0.7)	0.260 (0.0)	0.259 (-0.2)	0.262 (0.7)	0.252 (-3.1)	0.254 (-2.1)	0.260 (0.1)
D	12	0.247	0.291 (18.0)	0.245 (-0.6)	0.246 (-0.4)	0.247 (0.0)	0.247 (-0.1)	0.243 (-1.6)	0.246 (-0.2)
C	1	0.263	0.291 (10.5)	0.257 (-2.4)	0.263 (-0.3)	0.264 (0.1)	0.265 (0.6)	0.258 (-2.2)	0.262 (-0.4)
C	2	0.246	0.247 (0.3)	0.249 (1.1)	0.245 (-0.4)	0.248 (0.7)	0.247 (0.4)	0.248 (0.6)	0.249 (1.0)

WYT	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
C	3	0.270	0.267 (-1.3)	0.272 (0.6)	0.265 (-1.9)	0.265 (-1.9)	0.264 (-2.3)	0.267 (-1.1)	0.271 (0.2)
C	4	0.309	0.285 (-7.5)	0.306 (-0.9)	0.285 (-7.7)	0.285 (-7.6)	0.282 (-8.7)	0.298 (-3.5)	0.305 (-1.1)
C	12	0.274	0.318 (16.1)	0.272 (-0.3)	0.273 (-0.3)	0.275 (0.3)	0.274 (0.3)	0.273 (-0.3)	0.269 (-1.7)

Table I.5-2. Predicted mean proportion of particles routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), averaged by inflow grouping. Parentheses indicate % difference from NAA (negative values indicate a decrease in routing to the Interior Delta, which is considered beneficial). The Inflow Grouping 'All' excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I.5-1.

Inflow Group	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	0.223	0.231 (3.6)	0.223 (-0.1)	0.222 (-0.5)	0.222 (-0.3)	0.221 (-0.8)	0.220 (-1.6)	0.223 (-0.1)
lolo	0.279	0.311 (11.3)	0.279 (-0.3)	0.278 (-0.7)	0.278 (-0.6)	0.279 (-0.2)	0.278 (-0.5)	0.278 (-0.5)
lomed	0.279	0.278 (-0.4)	0.280 (0.4)	0.274 (-1.8)	0.274 (-1.7)	0.272 (-2.7)	0.270 (-3.1)	0.280 (0.3)
lohi	0.276	0.273 (-1.0)	0.274 (-0.6)	0.272 (-1.2)	0.274 (-0.6)	0.277 (0.5)	0.282 (2.4)	0.272 (-1.3)
medlo	0.231	0.264 (14.4)	0.234 (1.3)	0.234 (1.2)	0.233 (1.1)	0.235 (1.8)	0.232 (0.5)	0.232 (0.5)
medmed	0.229	0.236 (3.2)	0.229 (0.1)	0.230 (0.4)	0.229 (0.1)	0.229 (-0.1)	0.228 (-0.5)	0.229 (0.2)
medhi	0.230	0.230 (-0.1)	0.230 (-0.1)	0.230 (-0.1)	0.230 (0.0)	0.229 (-0.5)	0.224 (-2.7)	0.230 (-0.2)
hilo	0.192	0.194 (1.1)	0.193 (0.4)	0.193 (0.6)	0.194 (1.2)	0.193 (0.6)	0.191 (-0.5)	0.193 (0.6)
himed	0.188	0.189 (0.3)	0.189 (0.5)	0.189 (0.5)	0.189 (0.3)	0.189 (0.3)	0.190 (0.7)	0.189 (0.3)
hihi	0.182	0.182 (0.0)	0.182 (0.1)	0.182 (0.0)	0.182 (0.0)	0.182 (0.0)	0.182 (-0.1)	0.182 (0.1)

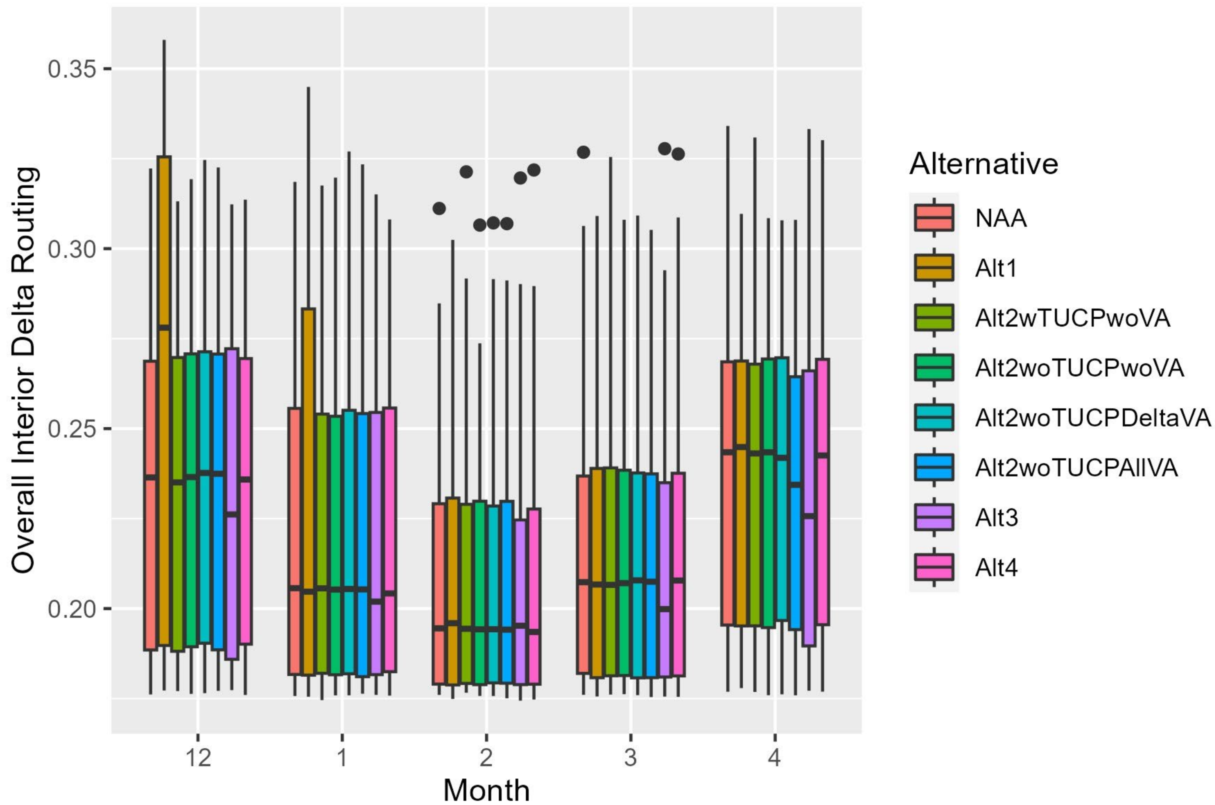

Figure I.5-4. Boxplots of predicted routing proportions to the Interior Delta for relevant migratory months. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

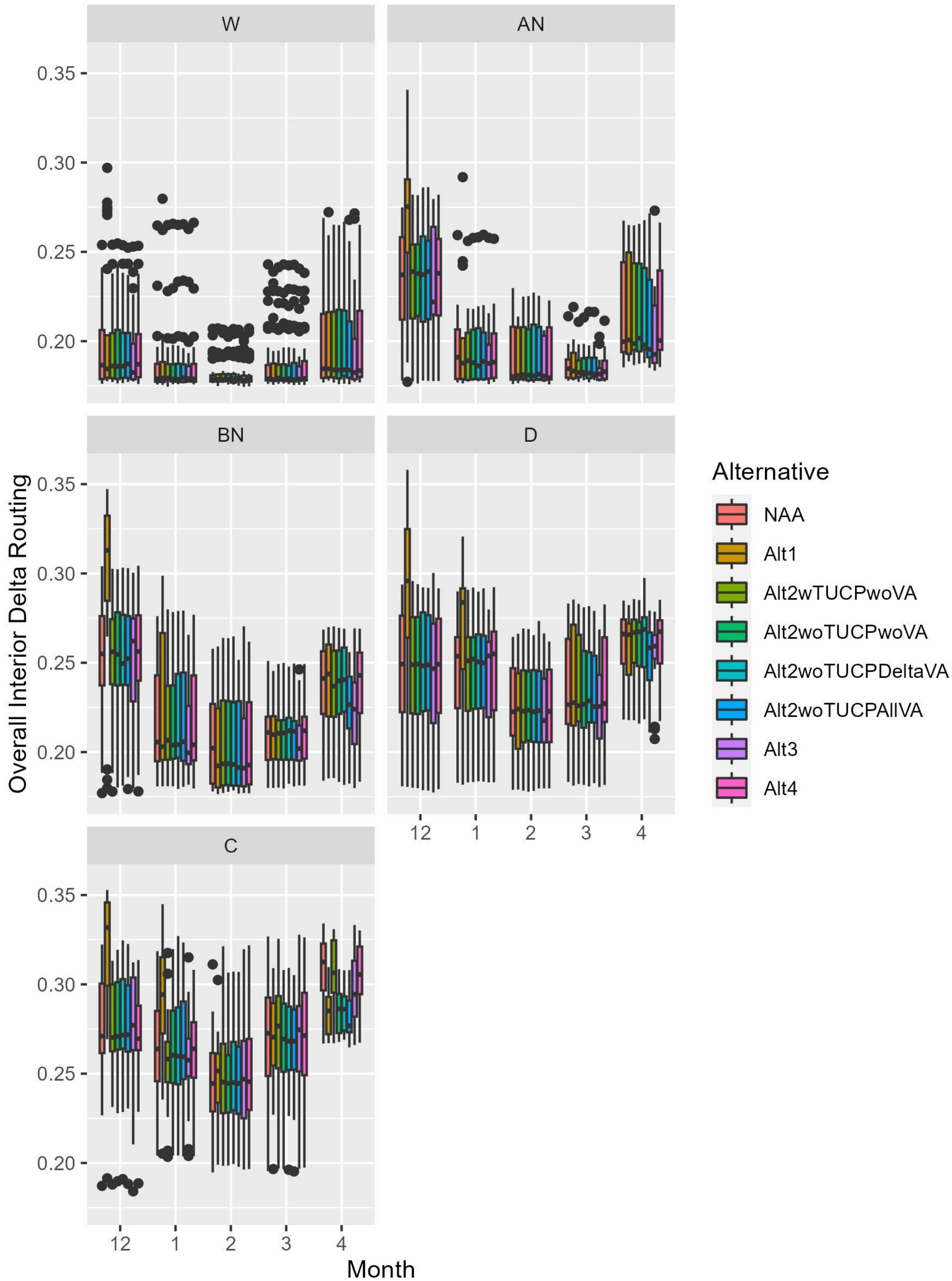

Figure I.5-5. Boxplots of predicted routing proportions to the Interior Delta, separated by water year type. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

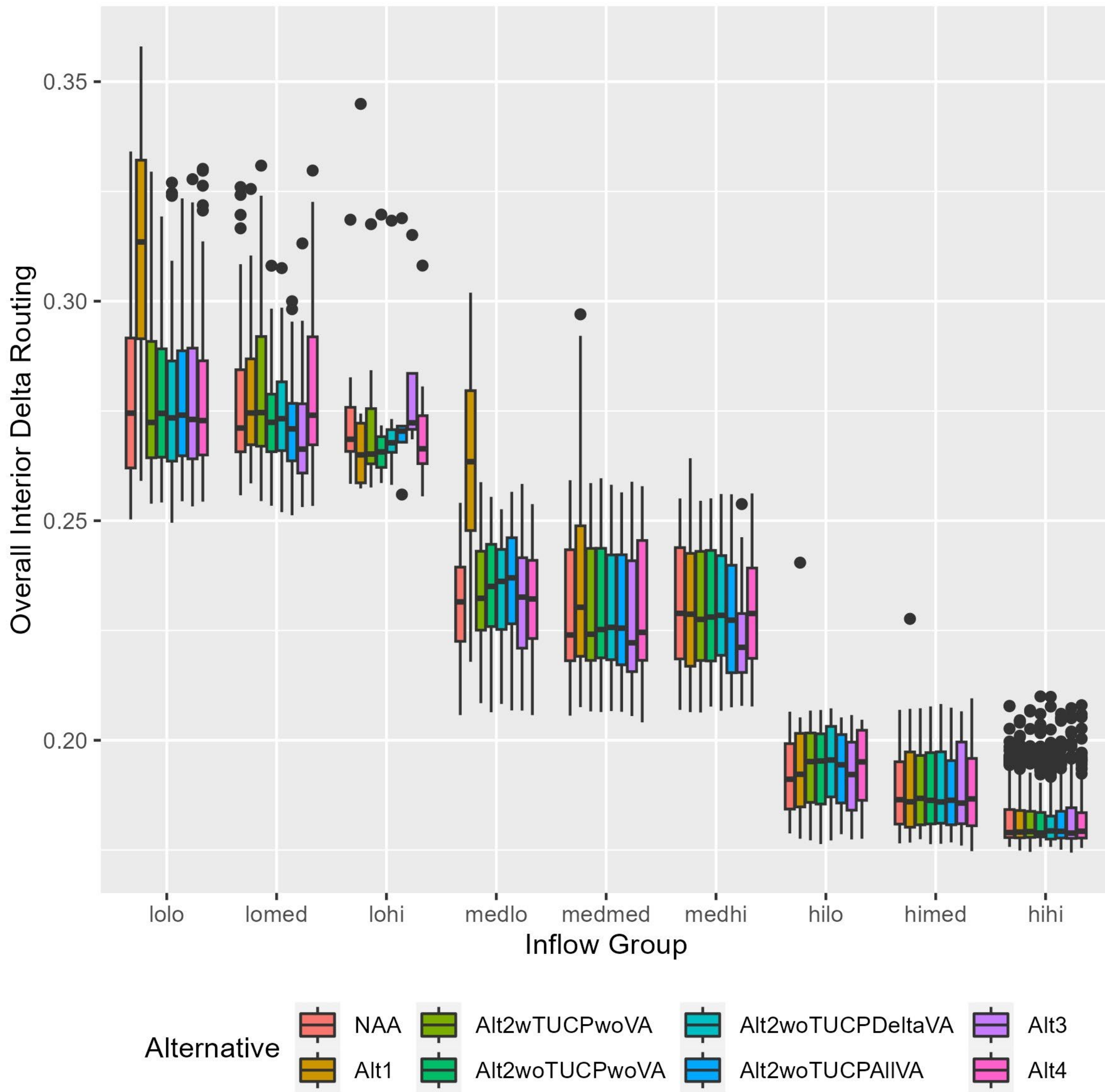

Figure I.5-6. Boxplots of predicted routing proportions to the Interior Delta, separated by inflow grouping. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

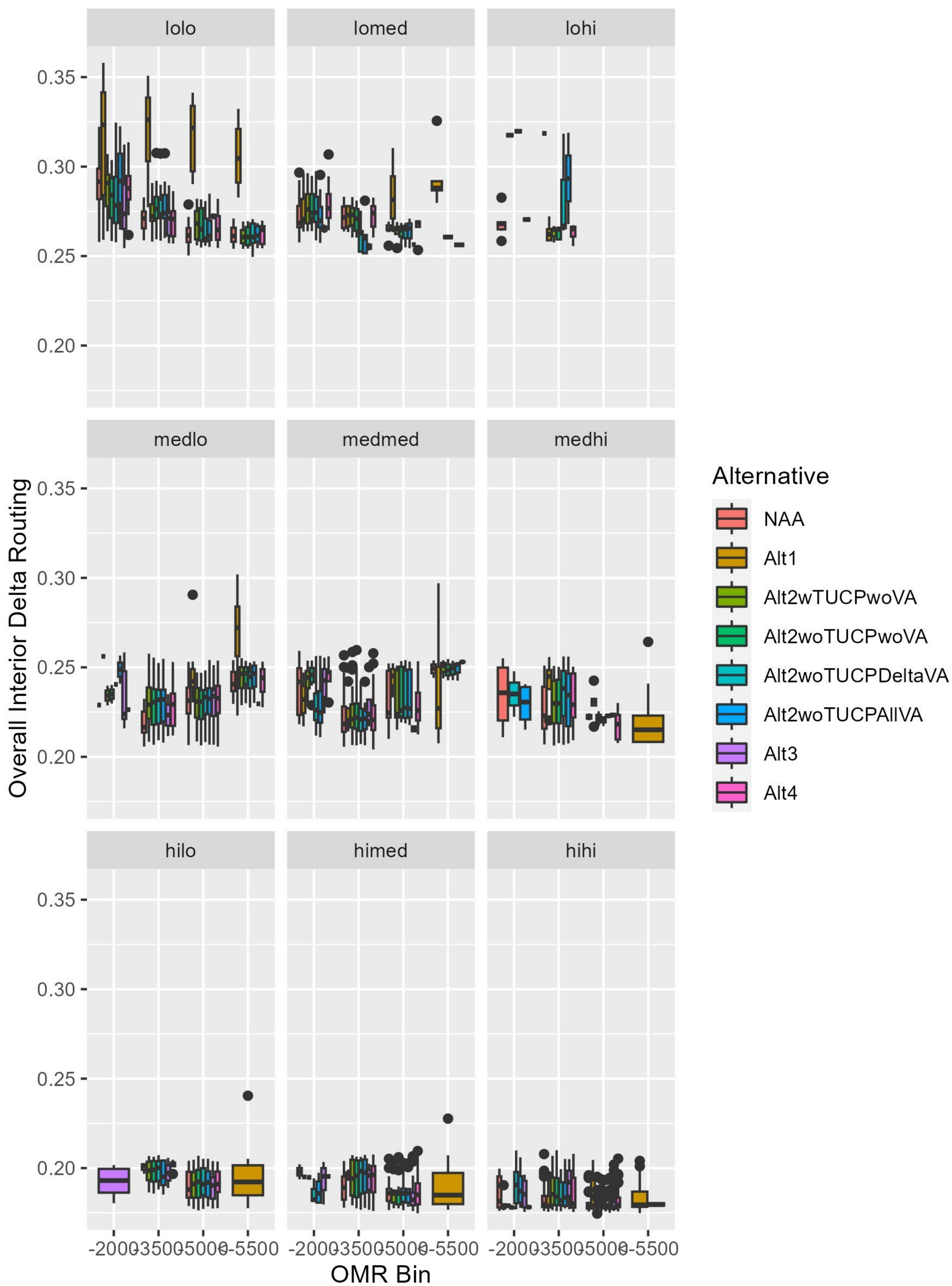

Figure I.5-7. Boxplots of predicted routing proportions to the Interior Delta, separated by inflow grouping (facets) and OMR bins (x-axis). The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Table I.5-3. Predicted through-Delta survival of particles across all routes, averaged by water year type and month. Parentheses indicate % difference from NAA (negative values indicate a decrease in survival).

WYT	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	1	0.550	0.536 (-2.6)	0.552 (0.4)	0.551 (0.1)	0.550 (0.0)	0.549 (-0.1)	0.556 (1.2)	0.550 (0.1)
All	2	0.579	0.581 (0.3)	0.579 (-1.1)	0.580 (0.1)	0.579 (-0.1)	0.579 (0.0)	0.583 (0.7)	0.579 (0.0)
All	3	0.558	0.559 (0.0)	0.558 (-0.1)	0.560 (0.3)	0.560 (0.2)	0.561 (0.4)	0.568 (1.7)	0.558 (0.0)
All	4	0.499	0.504 (1.0)	0.500 (0.2)	0.505 (1.2)	0.504 (0.9)	0.514 (3.0)	0.517 (3.5)	0.500 (0.3)
All	12	0.509	0.470 (-7.6)	0.510 (0.2)	0.509 (0.0)	0.508 (-0.1)	0.508 (-0.1)	0.517 (1.5)	0.509 (0.0)
W	1	0.644	0.644 (0.0)	0.645 (0.1)	0.645 (0.1)	0.644 (0.0)	0.644 (0.0)	0.649 (0.7)	0.645 (0.1)
W	2	0.664	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.665 (0.2)	0.664 (0.0)
W	3	0.643	0.642 (-0.1)	0.643 (0.0)	0.643 (0.0)	0.643 (0.0)	0.643 (0.0)	0.645 (0.3)	0.643 (0.0)
W	4	0.600	0.598 (0.5)	0.601 (0.0)	0.601 (0.0)	0.601 (0.0)	0.603 (0.4)	0.613 (2.0)	0.601 (0.0)
W	12	0.606	0.597 (-1.6)	0.607 (0.2)	0.607 (0.2)	0.607 (0.1)	0.607 (0.2)	0.619 (2.0)	0.607 (0.1)
AN	1	0.605	0.601 (-0.8)	0.607 (0.2)	0.606 (0.2)	0.606 (0.1)	0.607 (0.2)	0.612 (1.1)	0.607 (0.2)
AN	2	0.628	0.632 (0.6)	0.629 (0.1)	0.629 (0.1)	0.628 (0.0)	0.628 (0.0)	0.637 (1.5)	0.629 (0.1)
AN	3	0.635	0.632 (-0.4)	0.635 (0.1)	0.634 (-0.1)	0.633 (-0.2)	0.633 (-0.2)	0.643 (1.3)	0.635 (0.1)
AN	4	0.535	0.534 (-0.1)	0.535 (0.0)	0.535 (0.0)	0.534 (-0.2)	0.547 (2.4)	0.565 (5.7)	0.535 (0.1)
AN	12	0.506	0.469 (-7.3)	0.505 (-0.2)	0.505 (-0.2)	0.504 (-0.4)	0.504 (-0.4)	0.515 (1.7)	0.503 (-0.6)
BN	1	0.539	0.528 (-2.0)	0.541 (0.3)	0.540 (0.3)	0.538 (-0.2)	0.538 (-0.1)	0.550 (2.0)	0.540 (0.2)
BN	2	0.574	0.577 (0.5)	0.575 (0.2)	0.574 (0.1)	0.574 (-0.1)	0.576 (0.3)	0.578 (0.8)	0.575 (0.3)

WYT	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
BN	3	0.550	0.554 (0.9)	0.550 (0.1)	0.550 (0.1)	0.550 (0.0)	0.551 (0.2)	0.568 (3.3)	0.550 (0.1)
BN	4	0.491	0.490 (0.0)	0.492 (0.3)	0.492 (0.2)	0.490 (-0.2)	0.510 (4.0)	0.518 (5.6)	0.491 (0.1)
BN	12	0.468	0.415 (-11.4)	0.467 (-0.3)	0.465 (-0.7)	0.466 (-0.4)	0.466 (-0.5)	0.470 (0.4)	0.464 (-0.9)
D	1	0.476	0.447 (-6.2)	0.477 (0.1)	0.477 (0.1)	0.477 (0.1)	0.477 (0.0)	0.480 (0.7)	0.475 (-0.3)
D	2	0.519	0.524 (1.0)	0.519 (0.1)	0.519 (0.1)	0.520 (0.2)	0.519 (0.0)	0.526 (1.5)	0.521 (0.4)
D	3	0.499	0.496 (-0.7)	0.498 (-0.2)	0.501 (0.4)	0.501 (0.3)	0.503 (0.7)	0.517 (3.5)	0.498 (-0.2)
D	4	0.442	0.446 (0.8)	0.442 (0.0)	0.443 (0.2)	0.440 (-0.5)	0.456 (3.2)	0.453 (2.5)	0.443 (0.1)
D	12	0.474	0.417 (-12.1)	0.476 (0.4)	0.475 (0.3)	0.474 (0.0)	0.474 (0.1)	0.484 (2.0)	0.473 (-0.1)
C	1	0.441	0.410 (-7.1)	0.450 (2.0)	0.442 (0.2)	0.441 (-0.1)	0.438 (-0.6)	0.450 (1.9)	0.443 (0.5)
C	2	0.471	0.468 (-0.7)	0.467 (-0.9)	0.472 (0.2)	0.468 (-0.6)	0.468 (-0.6)	0.469 (-0.4)	0.467 (0.8)
C	3	0.430	0.434 (0.8)	0.427 (-0.7)	0.437 (1.7)	0.437 (1.6)	0.439 (2.0)	0.434 (1.0)	0.429 (-0.3)
C	4	0.369	0.401 (8.9)	0.373 (1.3)	0.402 (8.9)	0.401 (8.7)	0.406 (10.1)	0.383 (4.0)	0.374 (1.6)
C	12	0.425	0.372 (-12.5)	0.428 (0.7)	0.426 (0.1)	0.424 (-0.3)	0.424 (-0.4)	0.428 (0.7)	0.431 (1.4)

Table I.5-4. Predicted through-Delta survival across all routes, averaged by inflow grouping. Parentheses indicate % difference from NAA (negative values indicate a decrease in survival). The Inflow Grouping 'All' excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I.5-3.

Inflow Group	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	0.539	0.530 (-1.7)	0.540 (0.1)	0.541 (0.3)	0.540 (0.2)	0.542 (0.6)	0.548 (1.7)	0.539 (0.1)
lolo	0.411	0.374 (-9.0)	0.412 (0.3)	0.413 (0.6)	0.413 (0.6)	0.411 (0.1)	0.413 (0.5)	0.413 (0.5)
lomed	0.410	0.414 (0.8)	0.409 (-0.4)	0.418 (1.8)	0.417 (1.7)	0.422 (2.8)	0.424 (3.2)	0.409 (-0.2)
lohi	0.416	0.422 (1.4)	0.418 (0.4)	0.420 (0.9)	0.419 (0.6)	0.414 (-0.5)	0.407 (-2.1)	0.420 (0.9)
medlo	0.498	0.449 (-9.8)	0.491 (-1.3)	0.491 (-1.2)	0.492 (-1.1)	0.489 (-1.7)	0.495 (-0.5)	0.495 (-0.6)
medmed	0.502	0.492 (-1.9)	0.500 (-0.3)	0.499 (-0.5)	0.501 (-0.2)	0.502 (0.0)	0.504 (0.5)	0.501 (-0.2)
medhi	0.499	0.501 (0.6)	0.499 (0.1)	0.499 (0.1)	0.499 (0.0)	0.501 (0.5)	0.512 (2.7)	0.499 (0.2)
hilo	0.608	0.604 (-0.8)	0.604 (-0.7)	0.604 (-0.8)	0.601 (-1.2)	0.604 (-0.7)	0.611 (0.5)	0.604 (-0.7)
himed	0.625	0.624 (-0.2)	0.621 (-0.6)	0.621 (-0.7)	0.622 (-0.5)	0.623 (-0.3)	0.619 (-0.9)	0.623 (-0.3)
hihi	0.657	0.657 (0.0)	0.657 (0.0)	0.657 (0.0)	0.657 (0.0)	0.656 (-0.1)	0.658 (0.1)	0.656 (-0.1)

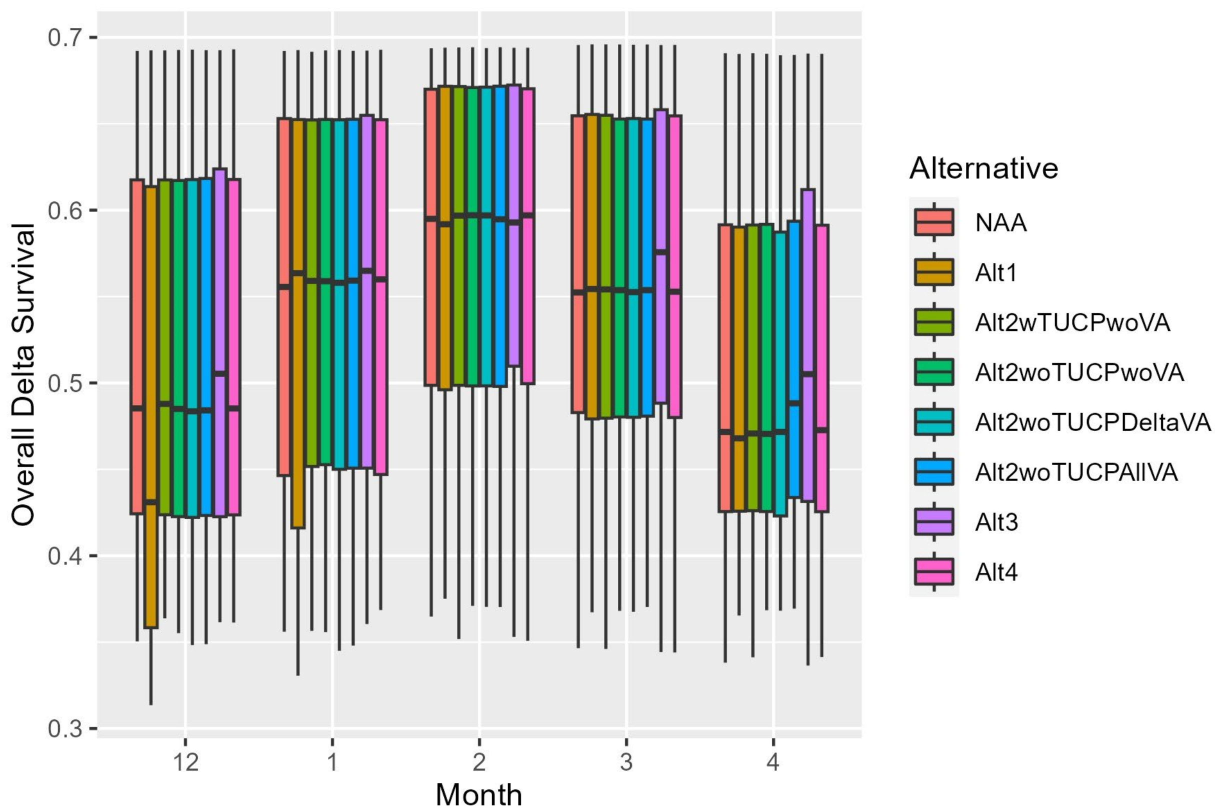

Figure I.5-8. Boxplots of predicted mean survival across all routes for relevant migratory months. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

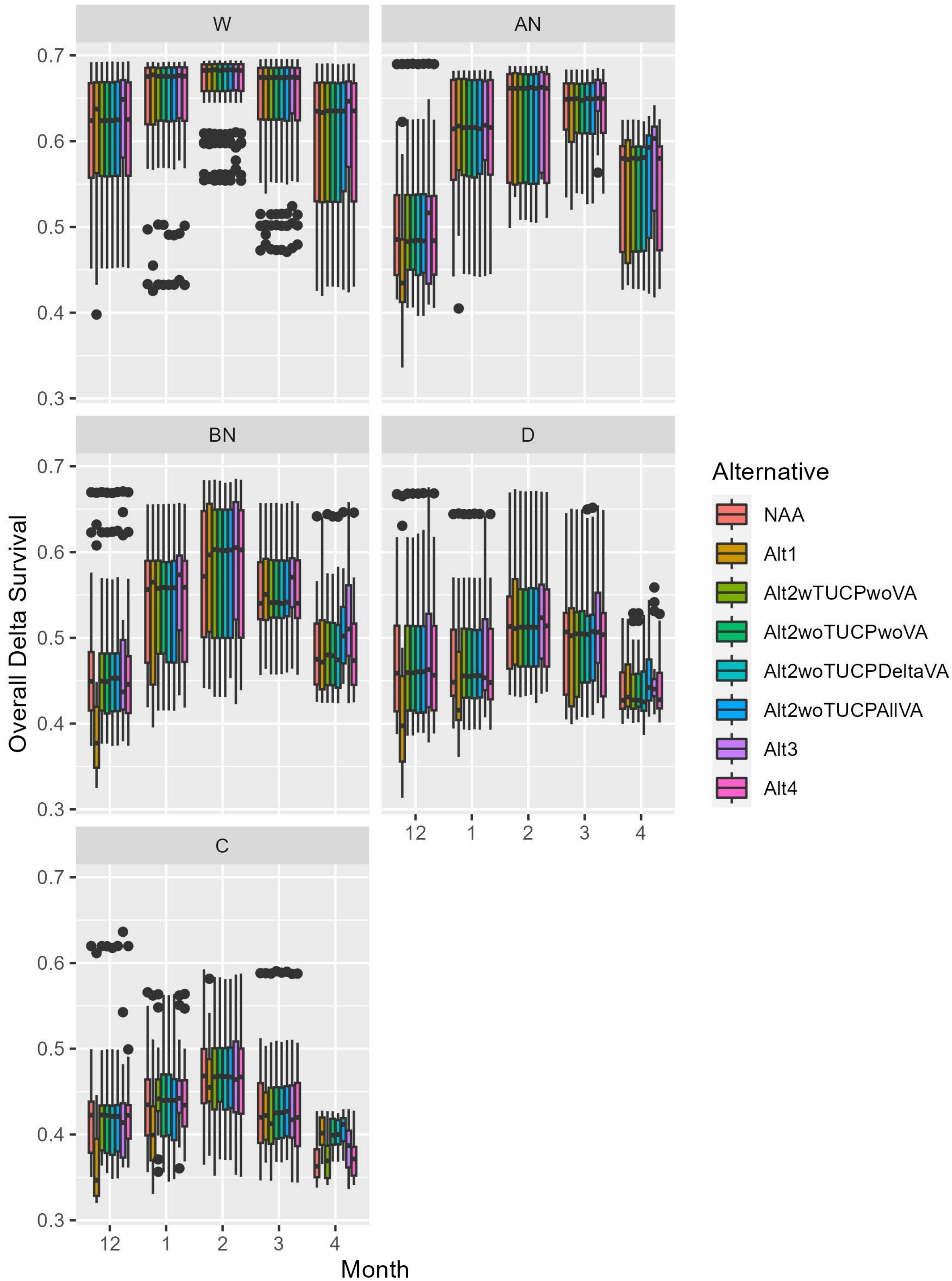

Figure I.5-9. Boxplots of predicted mean survival across all routes, separated by water year type. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

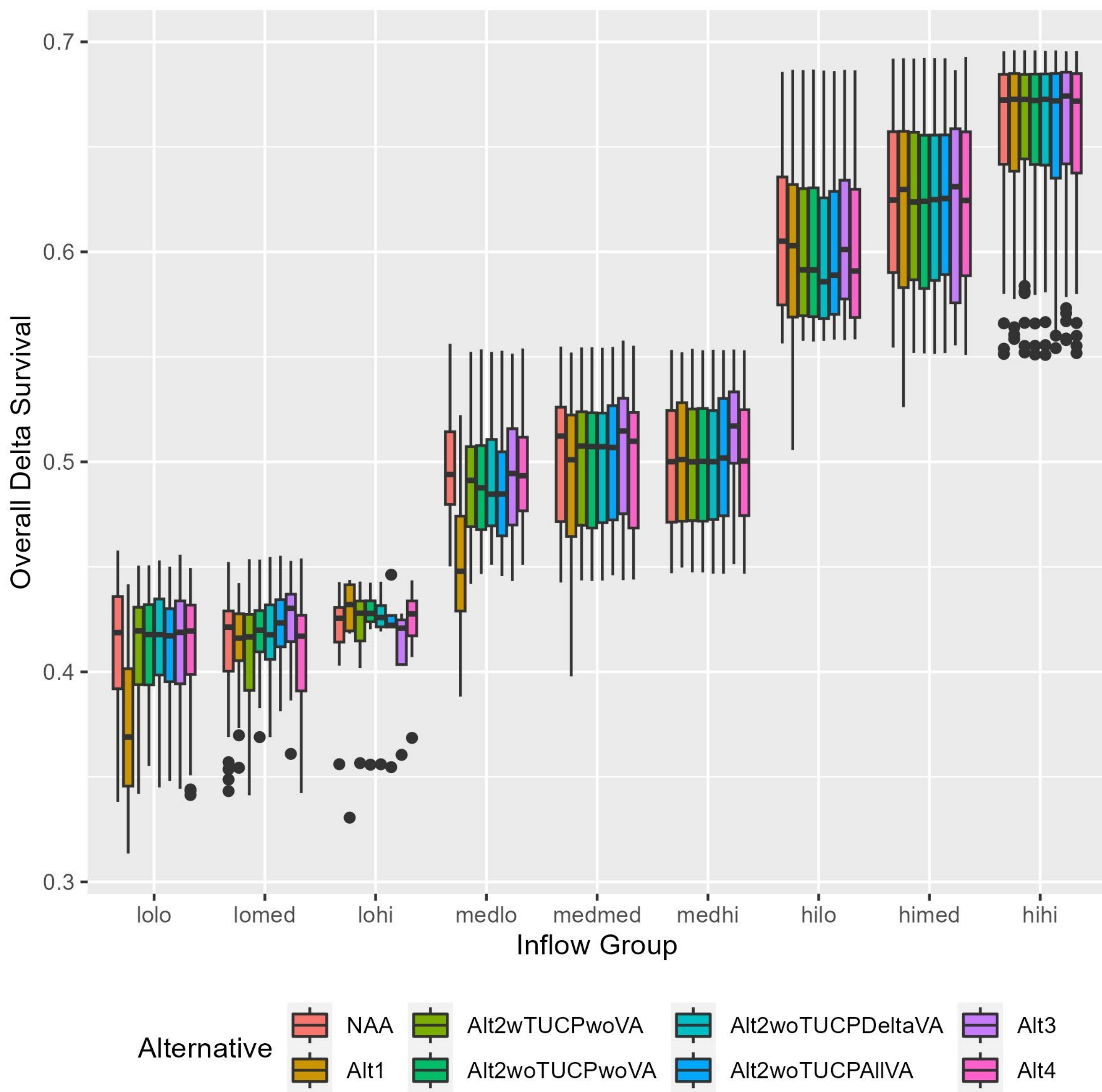

Figure I.5-10. Boxplots of predicted mean survival across all routes, separated by inflow grouping. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

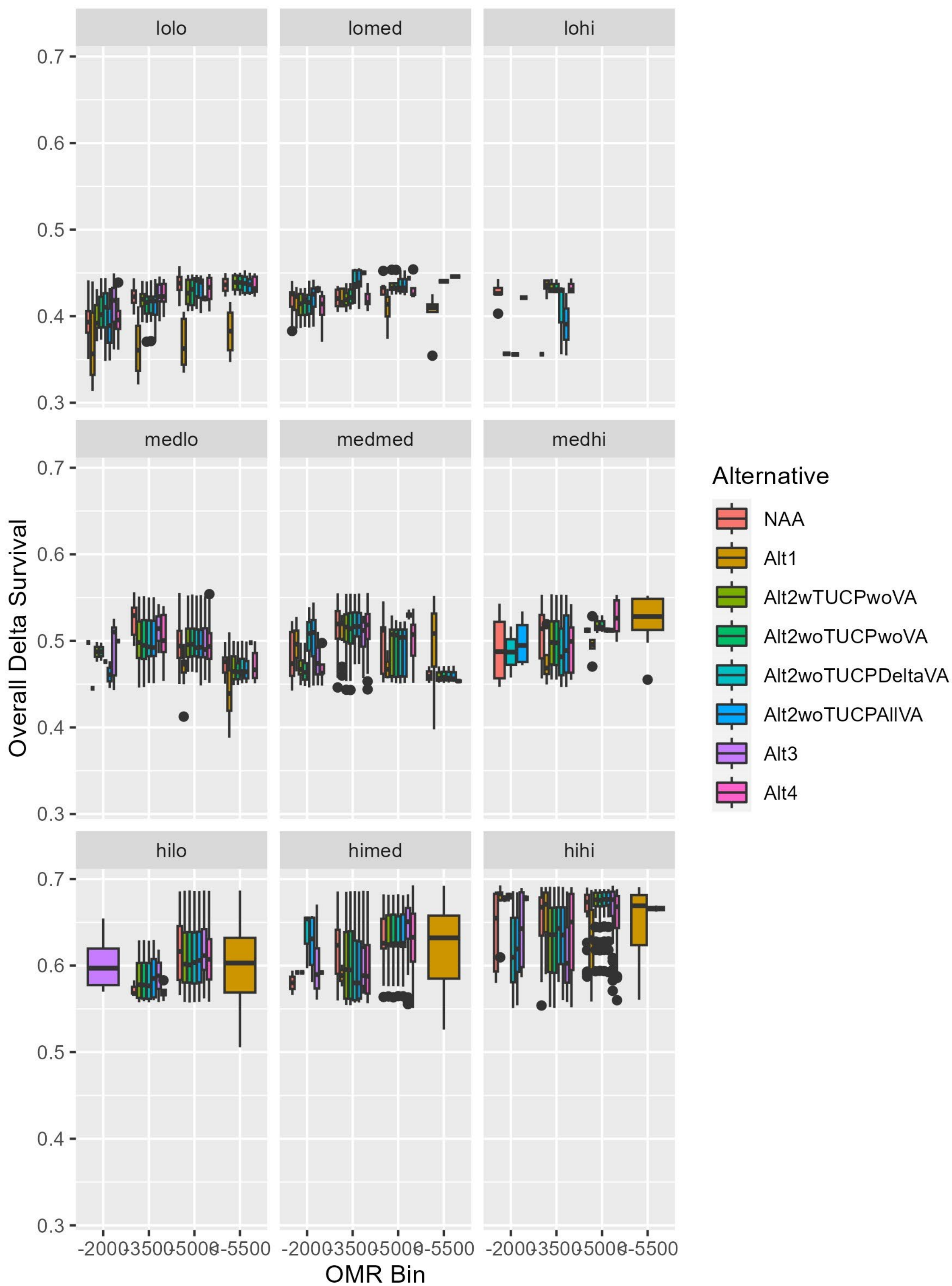

Figure I.5-11. Boxplots of predicted mean survival across all routes, separated by inflow grouping (facets) and OMR bins (x-axis). The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

I.5.2.3 BA Key Takeaways

The mean proportion of migrating juvenile Chinook salmon routed to the Interior Delta, calculated across all WYTs for each month and alternative, had a narrow range, from a low of 0.207 (NAA, Alt2woTUCPwoVA, Alt2woTUCPAllVA) to a high of 0.240 (NAA) (Table I.5-5). The total range of proportions across all simulations was greater, from approximately 0.175 to 0.4 (Figure I.5-12, Figure I.5-13). The range of mean proportions for the four versions of Alt2, calculated across all WYTs for each month and version, was 0.207 to 0.239. The range of proportions for the NAA, calculated across all WYTs for each month, was 0.207 to 0.240. The greatest expected proportions occurred in December or April, depending on WYT, which corresponded to lower expected Delta inflows from the Sacramento River in those months. Fewer Chinook salmon can be expected to be routed to the Interior Delta in AN and W WYTs than BN, D, or C WYTs.

The mean proportion of migrating juvenile Chinook salmon routed to the Interior Delta also varied among inflow groups (i.e., ranging from low Sacramento River inflow and low San Joaquin River inflow, or lolo, to high Sacramento and San Joaquin River infow, or hihi; Table I.5-6; Figure I.5-14). The lowest and least variable routing proportions across water years occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Within inflow groups, there was little difference in routing proportions among OMR bins (Figure I.5-15).

The mean overall survival of juvenile Chinook salmon migrating through the Delta, calculated across all WYTs for each month and alternative, had a wider range, from a low of 0.499 (NAA) to a high 0.580 (Alt2woTUCPwoVA) (Table I.5-7). The total range of survival estimates across all simulations was greater, from approximately 0.3 to 0.7 (Figure I.5-16, Figure I.5-17). The range of mean survival values for the four versions of Alt2, calculated across all WYTs for each month and version, was 0.500 to 0.580. The range of mean survival values for the NAA, calculated across all WYTs for each month, was 0.499 to 0.579. The greatest expected survival values occurred in January, February, and March, corresponding to months with greater Delta inflows. Greater survival is expected in AN and W WYTs than BN, D, or C WYTs.

Mean overall survival also varied among inflow groups (Table I.5-8; Figure I.5-18). The highest survival values occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Within inflow groups, there was little difference in survival among OMR bins (Figure I.5-19).

Table I.5-5. Predicted proportion of particles routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), averaged by water year type and month.

WYT	Month	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
All	1	0.212	0.216	0.218	0.217	0.218	0.219	0.219
All	2	0.199	0.207	0.207	0.208	0.207	0.208	0.207
All	3	0.199	0.213	0.215	0.216	0.214	0.214	0.214
All	4	0.220	0.247	0.240	0.239	0.236	0.236	0.231
All	12	0.230	0.220	0.235	0.234	0.235	0.235	0.235
W	1	0.184	0.185	0.187	0.187	0.187	0.187	0.187
W	2	0.180	0.181	0.182	0.182	0.182	0.182	0.182
W	3	0.182	0.188	0.187	0.187	0.187	0.187	0.187
W	4	0.187	0.201	0.199	0.199	0.199	0.199	0.198
W	12	0.189	0.187	0.196	0.196	0.196	0.196	0.196
AN	1	0.190	0.192	0.197	0.196	0.196	0.197	0.197
AN	2	0.183	0.185	0.190	0.191	0.190	0.190	0.191
AN	3	0.180	0.184	0.187	0.187	0.187	0.187	0.187
AN	4	0.193	0.219	0.219	0.219	0.219	0.220	0.214
AN	12	0.223	0.211	0.233	0.233	0.233	0.234	0.234
BN	1	0.204	0.210	0.217	0.217	0.216	0.218	0.218
BN	2	0.199	0.206	0.206	0.206	0.207	0.207	0.206
BN	3	0.191	0.205	0.211	0.211	0.211	0.211	0.211
BN	4	0.205	0.242	0.236	0.235	0.235	0.237	0.227
BN	12	0.251	0.230	0.251	0.252	0.253	0.251	0.252
D	1	0.234	0.241	0.244	0.244	0.244	0.244	0.244
D	2	0.209	0.222	0.225	0.225	0.225	0.224	0.225
D	3	0.207	0.228	0.234	0.235	0.233	0.233	0.232
D	4	0.239	0.283	0.260	0.260	0.259	0.262	0.252
D	12	0.238	0.228	0.247	0.245	0.246	0.247	0.247
C	1	0.265	0.265	0.263	0.257	0.263	0.264	0.265
C	2	0.234	0.252	0.246	0.249	0.245	0.248	0.247
C	3	0.246	0.273	0.270	0.272	0.265	0.265	0.264
C	4	0.295	0.314	0.309	0.306	0.285	0.285	0.282
C	12	0.279	0.268	0.274	0.272	0.273	0.275	0.274

Table I.5-6. Predicted mean proportion of particles routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), averaged by inflow grouping. The Inflow Grouping 'All' excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I.5-5.

Inflow Group	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
All	0.212	0.221	0.223	0.223	0.222	0.222	0.221
lolo	0.283	0.284	0.279	0.279	0.278	0.278	0.279
lomed	0.292	0.281	0.279	0.280	0.274	0.274	0.272
lohi	NA	0.272	0.276	0.274	0.272	0.274	0.277
medlo	0.234	0.232	0.231	0.234	0.234	0.233	0.235
medmed	0.234	0.224	0.229	0.229	0.230	0.229	0.229
medhi	0.220	0.226	0.230	0.230	0.230	0.230	0.229
hilo	0.193	0.193	0.192	0.193	0.193	0.194	0.193
himed	0.189	0.189	0.188	0.189	0.189	0.189	0.189
hihi	0.181	0.182	0.182	0.182	0.182	0.182	0.182

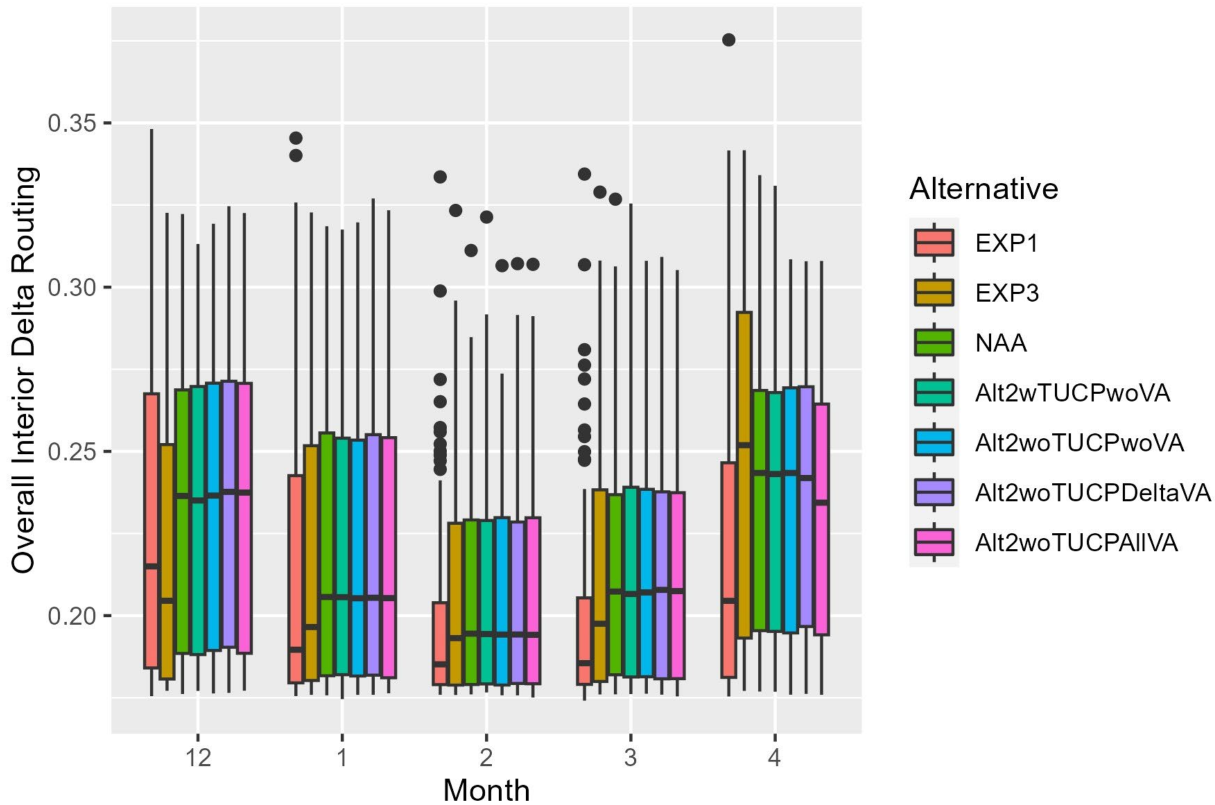

Figure I.5-12. Boxplots of predicted routing proportions to the Interior Delta for relevant migratory months. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

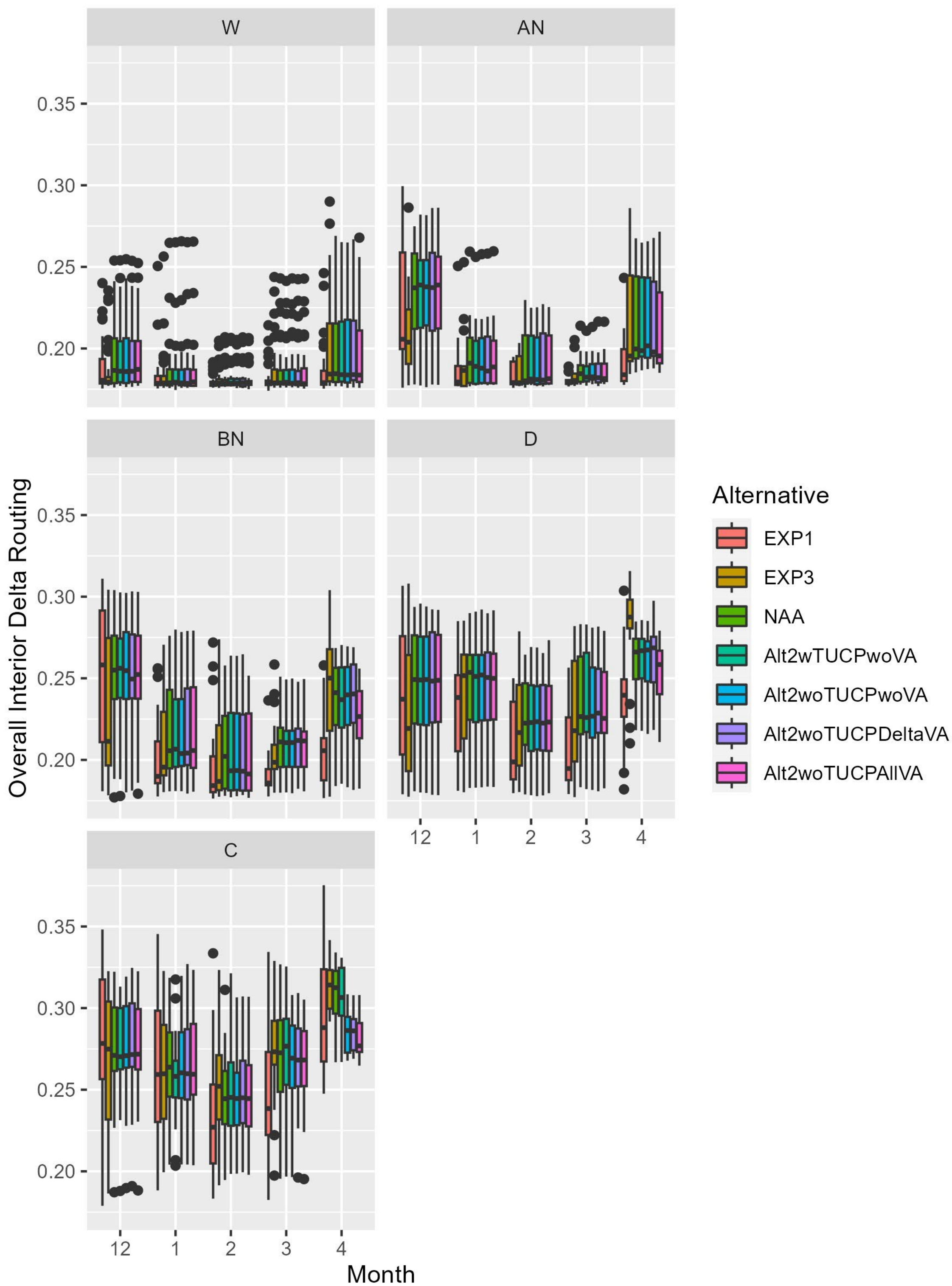

Figure I.5-13. Boxplots of predicted routing proportions to the Interior Delta, separated by WYT. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

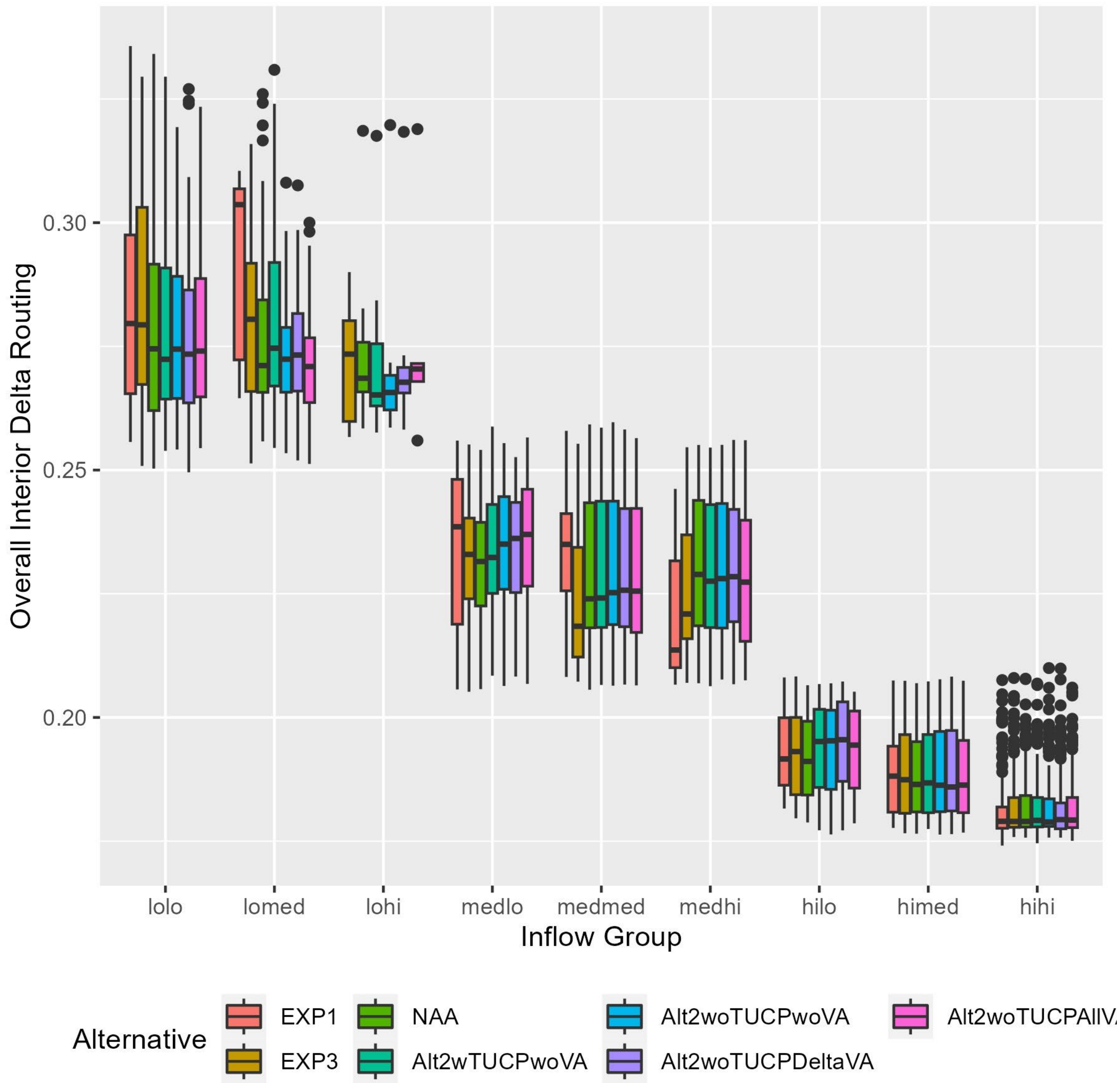

Figure I.5-14. Boxplots of predicted routing proportions to the Interior Delta, separated by inflow grouping. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

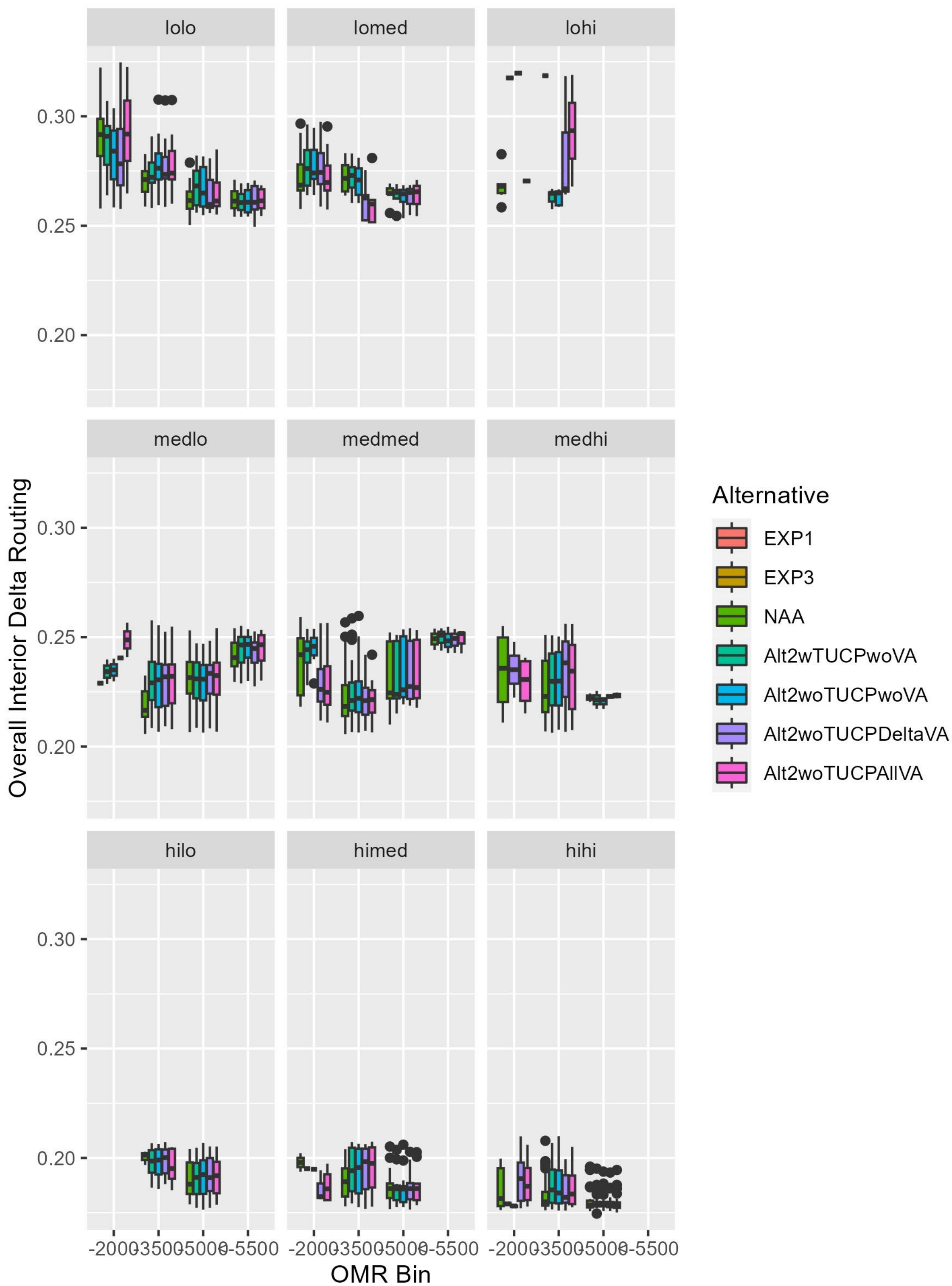

Figure I.5-15. Boxplots of predicted routing proportions to the Interior Delta, separated by inflow grouping (facets) and OMR bin (x-axis). The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Table I.5-7. Predicted survival of particles across all routes, averaged by water year type and month.

WYT	Month	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
All	1	0.571	0.560	0.550	0.552	0.551	0.550	0.549
All	2	0.605	0.584	0.579	0.579	0.580	0.579	0.579
All	3	0.603	0.567	0.558	0.558	0.560	0.560	0.561
All	4	0.551	0.489	0.499	0.500	0.505	0.504	0.514
All	12	0.527	0.549	0.509	0.510	0.509	0.508	0.508
W	1	0.657	0.652	0.644	0.645	0.645	0.644	0.644
W	2	0.672	0.665	0.664	0.664	0.664	0.664	0.664
W	3	0.661	0.642	0.643	0.643	0.643	0.643	0.643
W	4	0.643	0.598	0.600	0.601	0.601	0.601	0.603
W	12	0.630	0.642	0.606	0.607	0.607	0.607	0.607
AN	1	0.630	0.620	0.605	0.607	0.606	0.606	0.607
AN	2	0.654	0.644	0.628	0.629	0.629	0.628	0.628
AN	3	0.664	0.646	0.635	0.635	0.634	0.633	0.633
AN	4	0.611	0.538	0.535	0.535	0.535	0.534	0.547
AN	12	0.533	0.559	0.506	0.505	0.505	0.504	0.504
BN	1	0.579	0.559	0.539	0.541	0.540	0.538	0.538
BN	2	0.600	0.583	0.574	0.575	0.574	0.574	0.576
BN	3	0.614	0.569	0.550	0.550	0.550	0.550	0.551
BN	4	0.573	0.486	0.491	0.492	0.492	0.490	0.510
BN	12	0.475	0.519	0.468	0.467	0.465	0.466	0.466
D	1	0.500	0.485	0.476	0.477	0.477	0.477	0.477
D	2	0.563	0.528	0.519	0.519	0.519	0.520	0.519
D	3	0.568	0.518	0.499	0.498	0.501	0.501	0.503
D	4	0.488	0.408	0.442	0.442	0.443	0.440	0.456
D	12	0.499	0.520	0.474	0.476	0.475	0.474	0.474
C	1	0.448	0.441	0.441	0.450	0.442	0.441	0.438
C	2	0.502	0.463	0.471	0.467	0.472	0.468	0.468
C	3	0.478	0.425	0.430	0.427	0.437	0.437	0.439
C	4	0.391	0.362	0.369	0.373	0.402	0.401	0.406
C	12	0.426	0.439	0.425	0.428	0.426	0.424	0.424

Table I.5-8. Predicted through-Delta survival across all routes, averaged by inflow grouping. The Inflow Grouping ‘All’ excludes water year and month combinations that did not map into the listed inflow groupings and values may differ from those reported in Table I.5-3.

Inflow Group	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	0.571	0.550	0.539	0.540	0.541	0.540	0.542
lolo	0.407	0.404	0.411	0.412	0.413	0.413	0.411
lomed	0.394	0.408	0.410	0.409	0.418	0.417	0.422
lohi	NA	0.421	0.416	0.418	0.420	0.419	0.414
medlo	0.493	0.495	0.498	0.491	0.491	0.492	0.489
medmed	0.491	0.512	0.502	0.500	0.499	0.501	0.502
medhi	0.521	0.509	0.499	0.499	0.499	0.499	0.501
hilo	0.600	0.605	0.608	0.604	0.604	0.601	0.604
himed	0.622	0.622	0.625	0.621	0.621	0.622	0.623
hihi	0.662	0.659	0.657	0.657	0.657	0.657	0.656

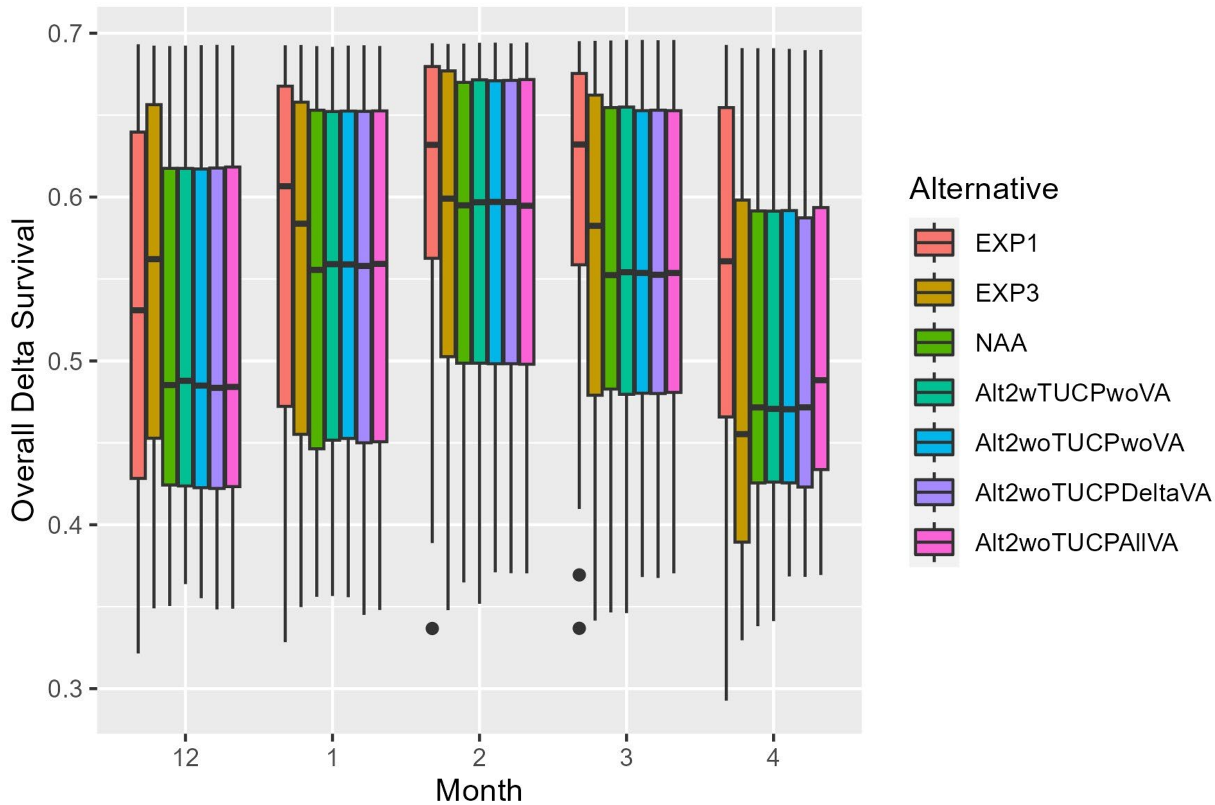

Figure I.5-16. Boxplots of predicted mean survival across all routes for relevant migratory months. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

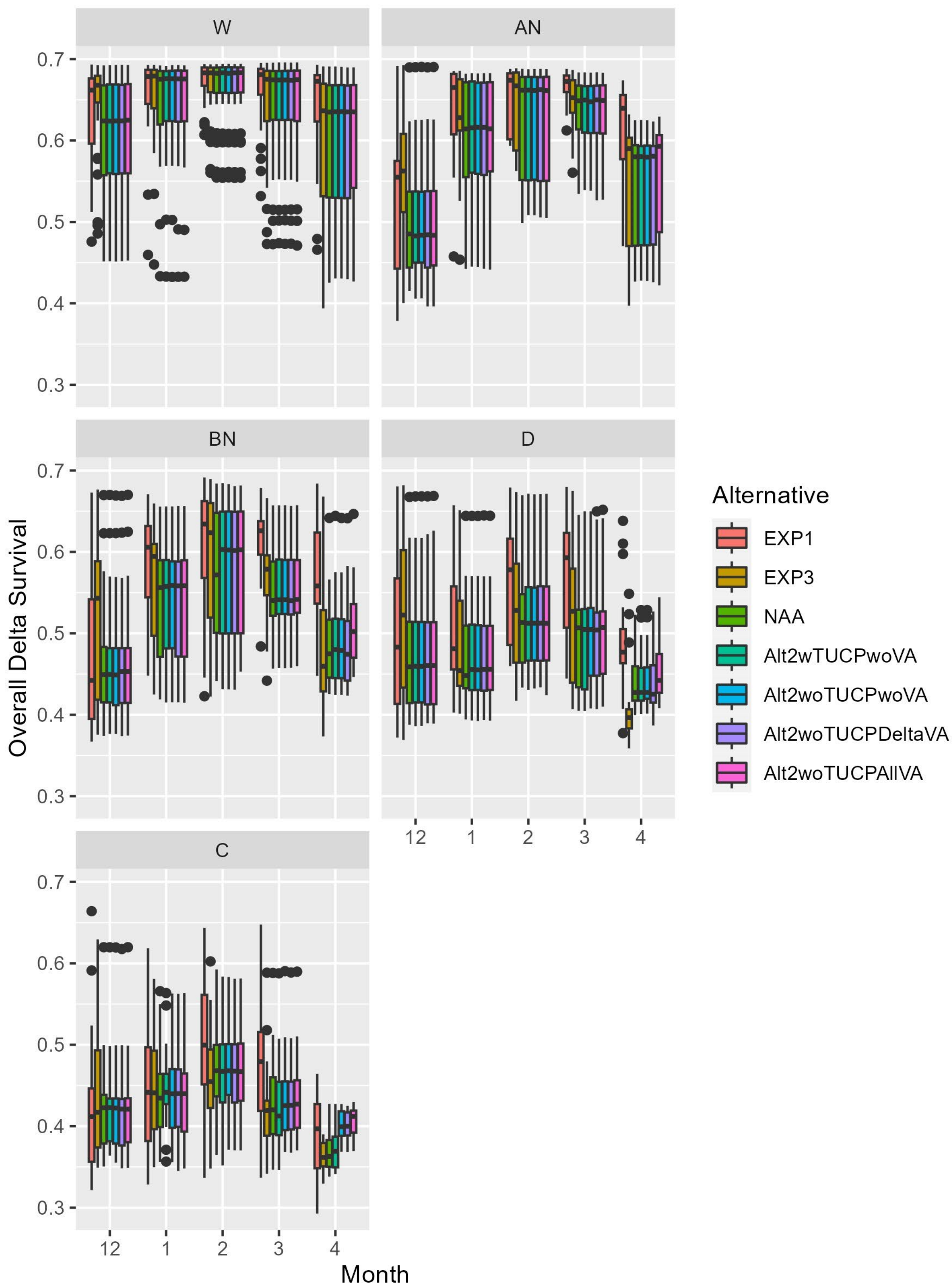

Figure I.5-17. Boxplots of predicted mean survival across all routes, separated by WYT. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

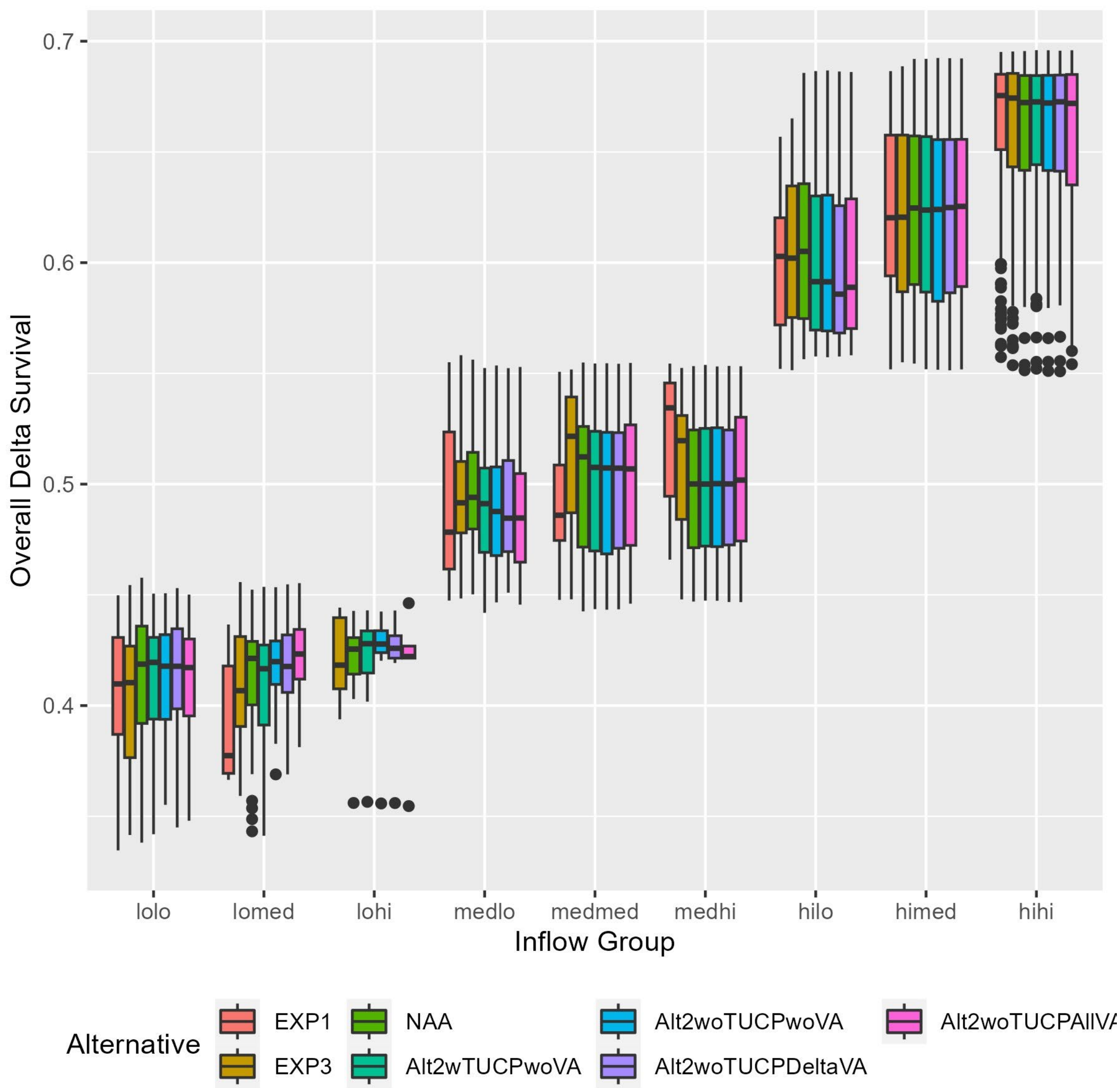

Figure I.5-18. Boxplots of predicted mean survival across all routes, separated by inflow grouping. The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

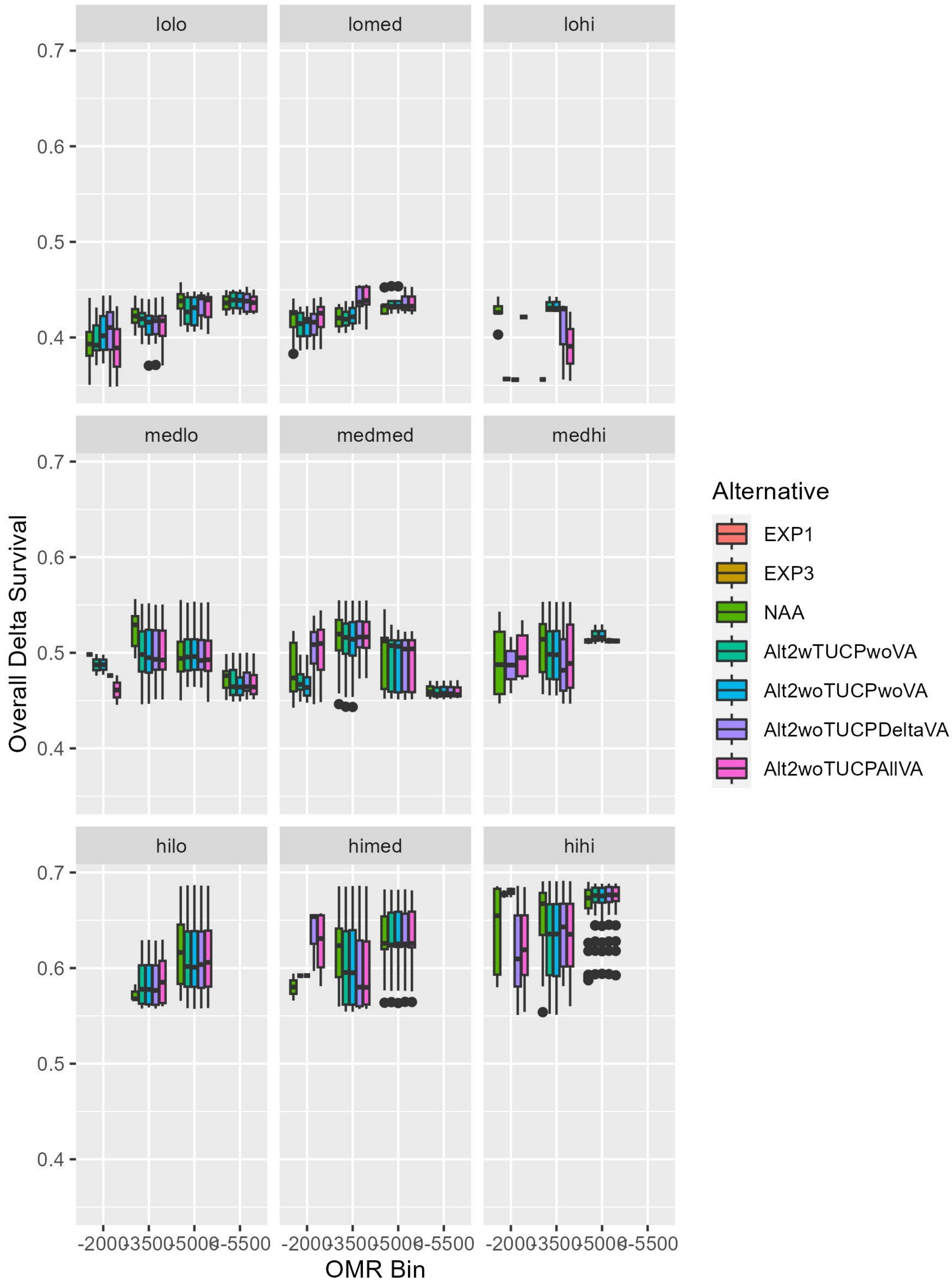

Figure I.5-19. Boxplots of predicted mean survival across all routes, separated by inflow grouping (facets) and OMR bin (x-axis). The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

I.5.3 References

Perry, R.W., Pope, A.C., Romine, J.G., Brandes, P.L., Burau, J.R., Blake, A.R., et al. 2018. Flow-mediated effects on travel time, routing, and survival of juvenile Chinook salmon in a spatially complex, tidally forced river delta. *Can. J. Fish. Aquat. Sci.* 75(11): 1886–1901. doi:10.1139/cjfas-2017-0310.