Appendix 9H

IOS Model Documentation

Information about the methods and assumptions used for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis using the IOS model is provided in this appendix. The appendix comprises two main sections as follows:

- Section 9H.1: IOS Methodology and Assumptions
  - The IOS model analysis is used to quantify winter-run Chinook Salmon escapement and egg survival. The approach and assumptions for the IOS analysis are described in this section.
- Section 9H.2: IOS Model Analysis Results
  - The results of the IOS analysis are presented in this section in a series of figures for each alternative comparison.

9H.1 IOS Model Methodology and Assumptions

9H.1.1 IOS Model Methodology

The IOS model simulates the entire life cycle of winter-run Chinook Salmon through successive generations. This approach allows for the evaluation of individual life-stage effects on the long-term trajectory of the population. A detailed description of the model and sensitivity analysis can be found in Zeug et al. (2012).

The IOS model is composed of six model stages that are arranged sequentially to account for the entire life cycle of the winter run, from eggs to returning spawners. In sequential order, the IOS model stages are: (1) spawning, which models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds; (2) early development, which models the impact of temperature on maturation timing and mortality of eggs at the spawning grounds; (3) fry rearing, which models the relationship between temperature and mortality of salmon fry during the river-rearing period; (4) river migration, which estimates the mortality of migrating salmon smolts in the Sacramento River between the spawning and rearing grounds and the Delta; (5) Delta passage, which models the impact of flow, route selection, and water exports on the survival of salmon smolts migrating through the Delta to San Francisco Bay; and (6) ocean survival, which estimates the impact of natural mortality and ocean harvest to predict survival and spawning returns (escapement) by age. Below is a detailed description of each model stage.

The IOS model uses a system dynamics modeling framework, a technique that is used for framing and understanding the behavior of complex systems over time. System dynamics models are made up of stocks (e.g., number of fish) and flows (e.g., sources of mortality) that are informed by mathematical equations. IOS was implemented in the software GoldSim, which enables the simulation of complex processes through creation of simple object relationships, while incorporating Monte Carlo stochastic methods.

The Delta portion of the model is composed of eight reaches and four junctions (see Figure 9H.1 and Table 9H.1) selected to represent primary salmonid migration corridors where high quality fish and hydrodynamic data were available. For simplification, Sutter Slough and Steamboat Slough are combined as the reach "SS," and the forks of the Mokelumne River and Georgiana Slough are combined as "Geo/DCC." The Geo/DCC reach can be entered by the Mokelumne River fall-run at the head of the South and North forks of the Mokelumne River or by Sacramento runs through the combined junction of Georgiana Slough and Delta Cross Channel (Junction C). The Interior Delta reach can be entered from three different pathways: (1) Geo/DCC, (2) San Joaquin River via Old River Junction (Junction D), or (3) Old River via Junction D. Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the entire Interior Delta region is treated as a single model reach. The four distributary junctions depicted in the Delta portion of the model are: (1) Sacramento River at Freemont Weir (head of Yolo Bypass), (2) Sacramento River at head of Sutter and Steamboat Sloughs, (3) Sacramento River at the combined junction with Georgiana Slough and Delta Cross Channel, and (4) San Joaquin River at the head of Old River (see Figure 9H.1 at the end of this appendix and Table 9H.1). Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the entire Interior Delta region is treated as a single model reach.

The IOS model uses scenario-specific daily DSM2, CalSim II, and Sacramento River Basin Water Temperature Model (HEC-5Q) data as model input. Daily DSM2 data inform fish migration speed, reach-specific survival, and routing at Delta junctions. Daily export data from CalSim II are used to inform export-dependent survival of salmon smolts that enter the Interior Delta from the Geo/DCC reach. Sacramento River Basin Water Temperature Model data at Bend Bridge, California are used to inform temperature-dependent egg and fry survival in the egg development and fry rearing stages of the model.

For Delta reaches where acoustic tagging data supported migration speed responses to flow (Sac1, Sac2, Geo/DCC), daily migration speed is influenced by mean daily flow. Migration speed is modeled as a logarithmic function of reach-specific flow occurring on the first day smolts entered a particular reach.

Table 9H.1 Descriptions of Modeled Delta Reaches and Junctions in the IOS Model

Reach/Junction	Description	Reach Length (kilometers)
Sac1	Sacramento River from Freeport to junction with Sutter Slough	41.04
Sac2	Sacramento River from Sutter Slough junction to junction with DCC	10.78
Sac3	Sacramento River from DCC to Rio Vista	22.37
Sac4	Sacramento River from Rio Vista to Chipps Island	23.98
Yolo	Yolo Bypass from entrance at Fremont Weir to Rio Vista	- [a]
SS	Combined reach of Sutter Slough and Steamboat Slough ending at Rio Vista	26.72
Geo/DCC	Combined reach of Georgiana Slough, DCC, and Sough and North forks of the Mokelumne River ending at confluence with San Joaquin River	25.59
Interior Delta	Begins at end of reach Geo/DCC, San Joaquin River via Junction D, or Old River via Junction D, and ends at Chipps Island	- [b]
A	Junction of Yolo Bypass and Sacramento River	Not applicable
B	Combined junction of Sutter Slough and Steamboat Slough with Sacramento River	Not applicable
C	Combined junction of DCC and Georgiana Slough with Sacramento River	Not applicable
D	Junction of Old River with San Joaquin River	Not applicable

Notes:

a. Reach length for Yolo Bypass is currently undefined because reach length is not currently used to calculate Yolo Bypass speed and ultimate travel time.

b. Reach length for the Interior Delta is undefined due to multiple pathways salmon can take. Timing through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

DCC = Delta Cross Channel

Reach-specific survival through a given Delta reach is calculated and applied the first day smolts enter the reach. For reaches where literature or available tagging data showed support for reach-level responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3, Sac4, SS, Interior Delta via San Joaquin River, and Interior Delta via Old River) or water exports (Interior Delta via Geo/DCC). For these reaches, daily flow (DSM2 data) or exports (CalSim II data) occurring the day of reach-entry is used to predict reach survival through the entire reach. For all other reaches (Geo/DCC and Yolo), reach survival is uninfluenced by Delta conditions and is informed by means and standard deviations of survival from acoustic tagging studies.

At each Delta junction in the model, smolts move in relation to the proportional movement of flow entering each route. Daily DSM2 flow data entering each route are used to inform the proportion of smolts entering each route at a junction. Smolts move in direct proportion to flow at all junctions except Junction C, where a non-proportional relationship is applied as defined by acoustic tagging study data.

Daily simulated water temperature data at Bend Bridge from the Sacramento River Basin Water Temperature Model were applied to inform temperature-dependent egg and fry survival. Daily mortality of eggs and fry is exponentially related to daily water temperature at Bend Bridge

9H.1.2 Model Analysis Scenario Assumptions

A major assumption of the IOS model is that surrogate fish data can be used to inform many model relationships. When local data are limited, model relationships can often be informed by field data from outside the study region, laboratory studies in controlled experimental settings, or artificially raised (hatchery) surrogates. For example, many model relationships rely on data from tagged hatchery surrogates because experimental studies often rely on easily accessible hatchery-origin fish and assume that fish responses are at least similar among individuals of different natal origins. In addition to limited data on wild fish, many of the model relationships are informed by data from a single Chinook Salmon race, thereby making the assumption that all races move, grow, and survive according to the same rules.

9H.2 Model Analysis Results

IOS model results are displayed as comparisons between scenarios. Differences in escapement and egg survival are displayed as time histories across all 81 water years (1922-2002) and box plots of median survival across all years. The following scenario comparisons are presented in Figures 9H.2 through 9H.21 at the end of this appendix.

- No Action Alternative compared to the Second Basis of Comparison
- Alternative 3 compared to the No Action Alternative
- Alternative 3 compared to the Second Basis of Comparison
- Alternative 5 compared to the No Action Alternative
- Alternative 5 compared to the Second Basis of Comparison

9H.3 Reference

Zeug, S.C., P.S. Bergman, B.J. Cavallo and K.S. Jones. 2012. "Application of a life cycle simulation model to evaluate impacts of water management and conservation actions on an endangered population of Chinook Salmon." *Environmental Modeling and Assessment* 17:455-467.

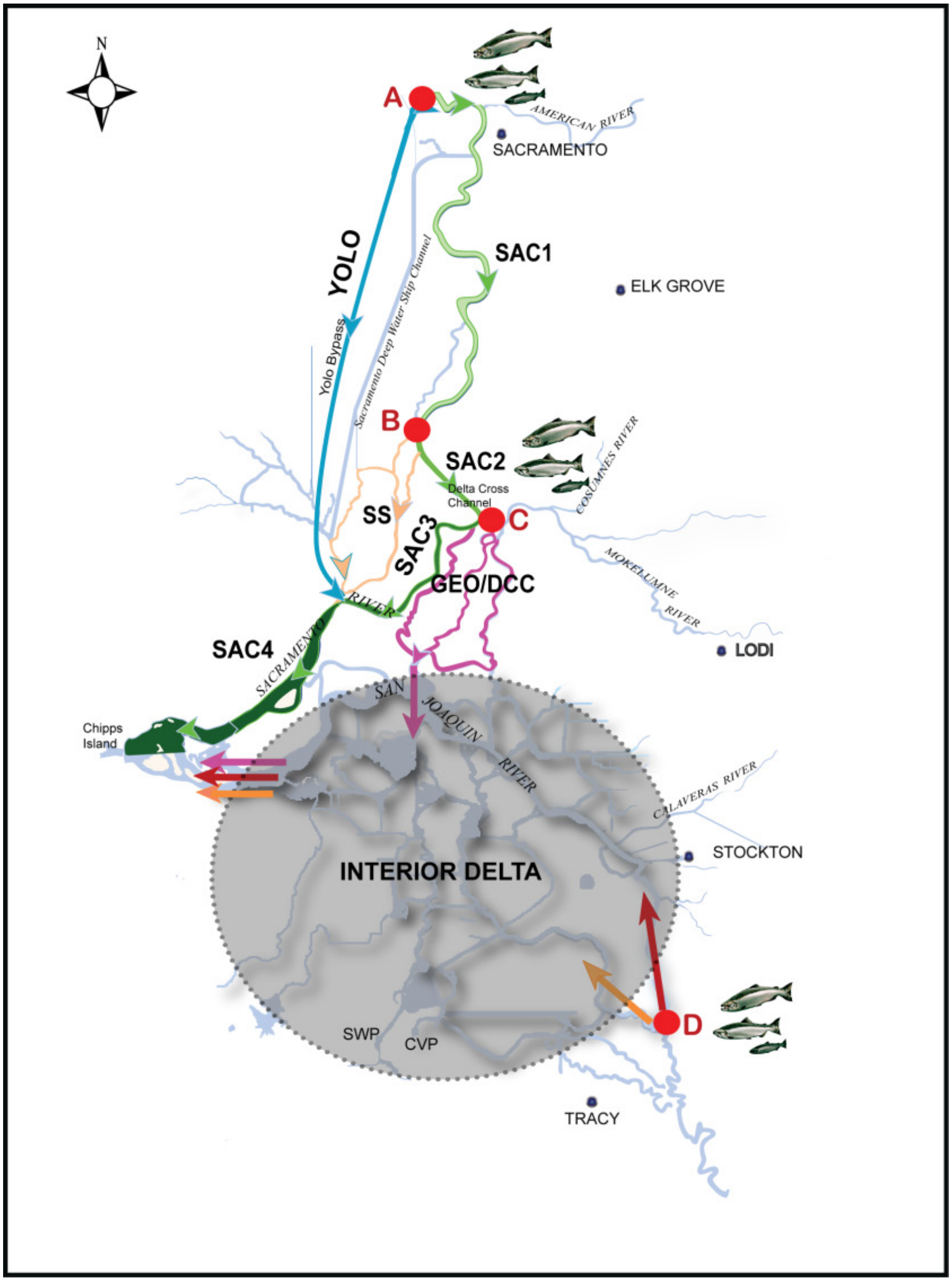

Figure 9H.1 IOS Model Reaches and Junctions in the Delta

Notes: Bold headings label modeled reaches and red circles indicate model junctions. Salmonid icons indicate locations where smolts enter the Delta in the IOS model.

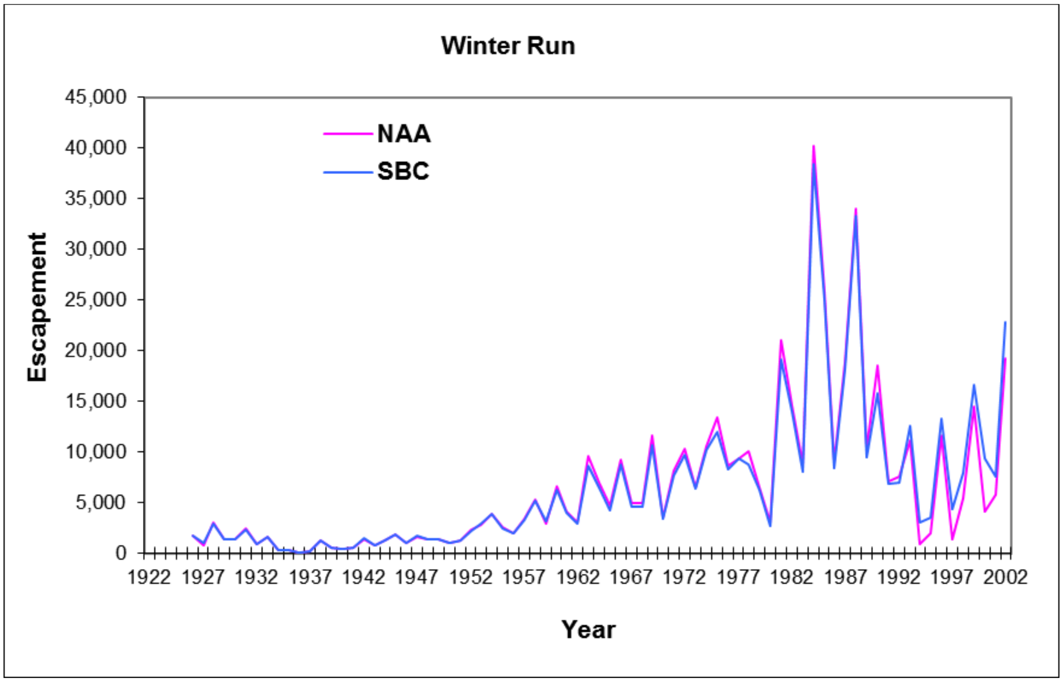

Figure 9H.2 Annual Adult Escapement for Winter-run Chinook Salmon under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) over 81 Water Years Estimated by the IOS Model

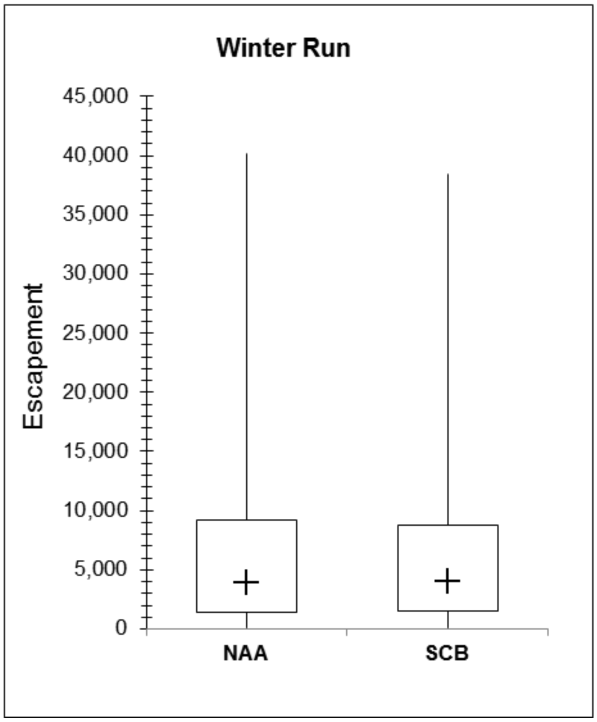

Figure 9H.3 Annual Adult Escapement for Winter-run Chinook Salmon under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

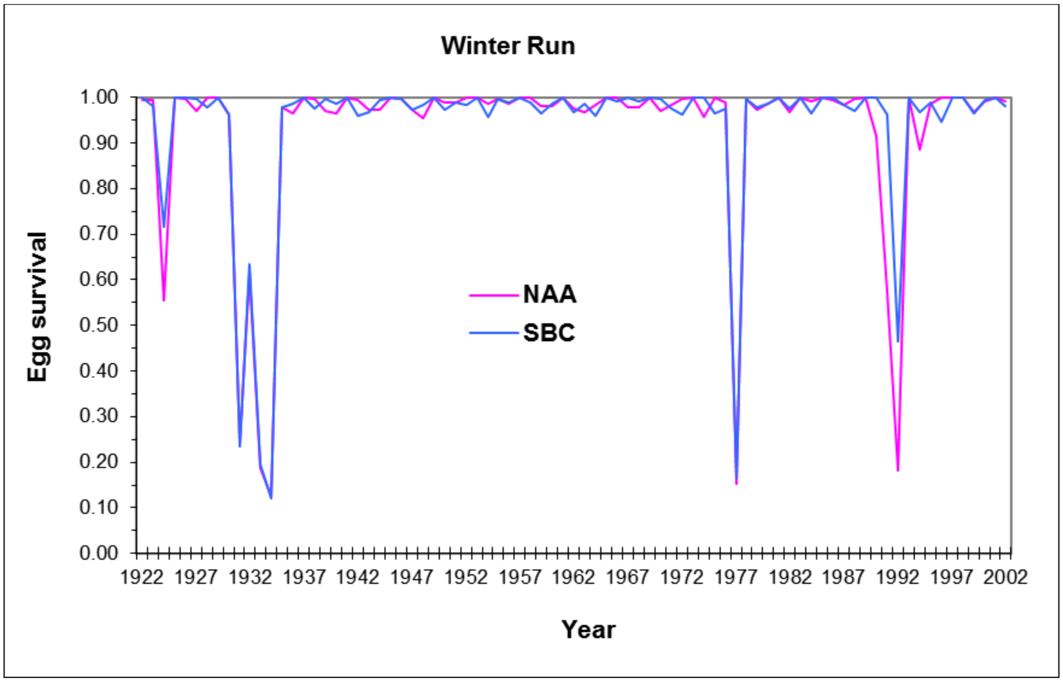

Figure 9H.4 Annual Egg Survival for Winter-run Chinook Salmon under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) over 81 Water Years Estimated by the IOS Model

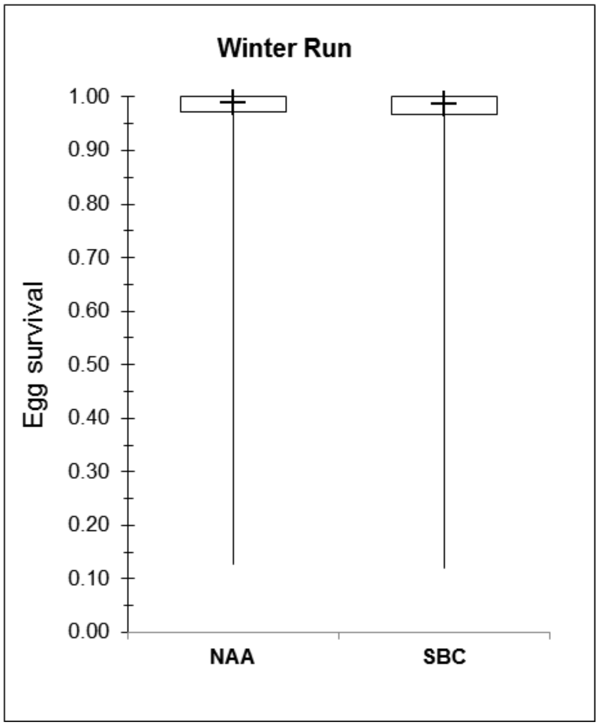

Figure 9H.5 Annual Egg Survival for Winter-run Chinook under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

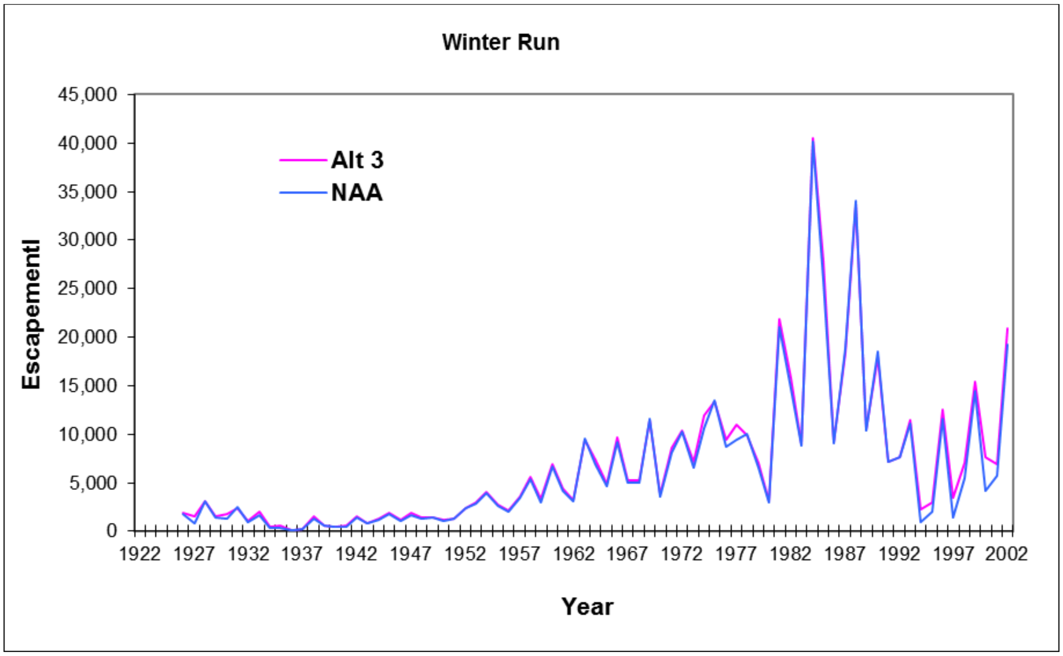

Figure 9H.6 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA) over 81 Water Years Estimated by the IOS Model

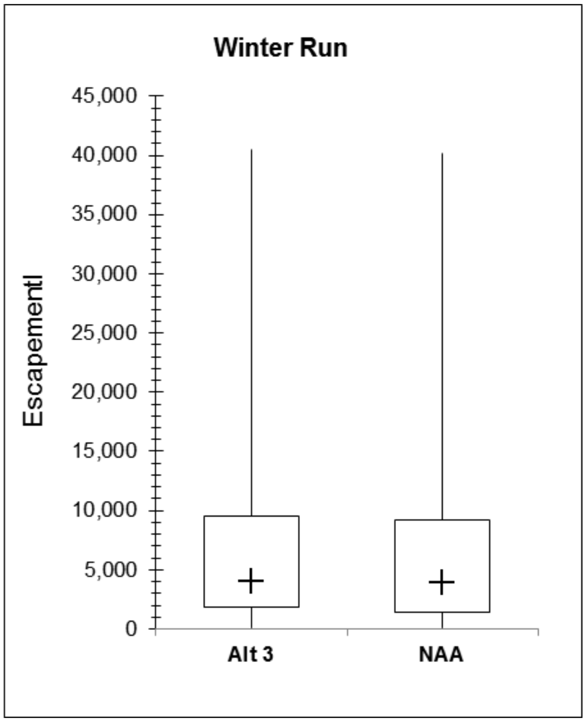

Figure 9H.7 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

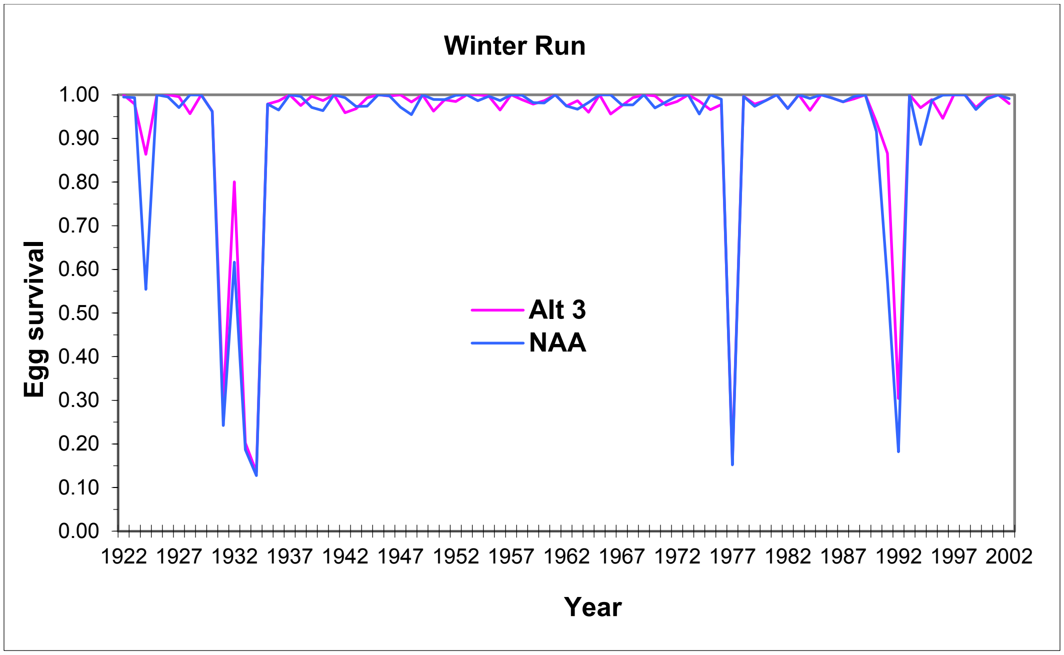

Figure 9H.8 Annual Egg Survival for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA) over 81 Water Years Estimated by the IOS Model

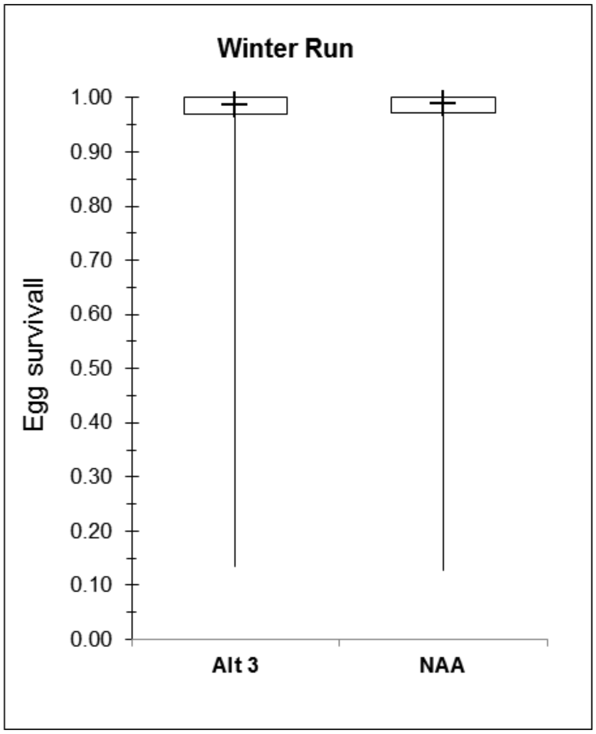

Figure 9H.9 Annual Egg Survival for Winter-run Chinook under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

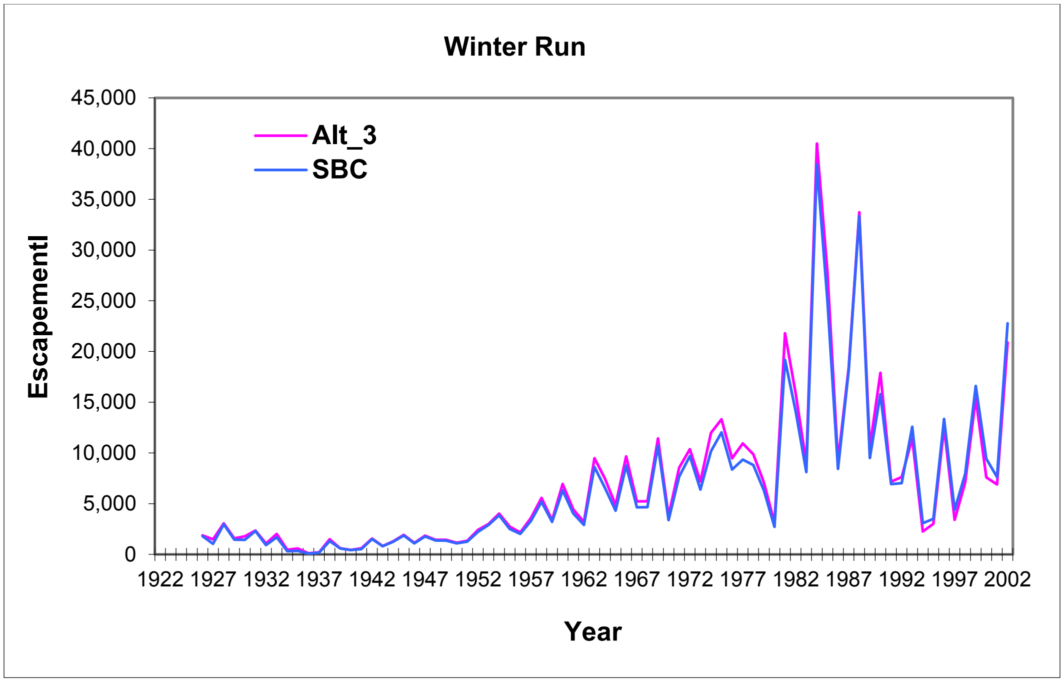

Figure 9H.10 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison over 81 Water Years Estimated by the IOS Model

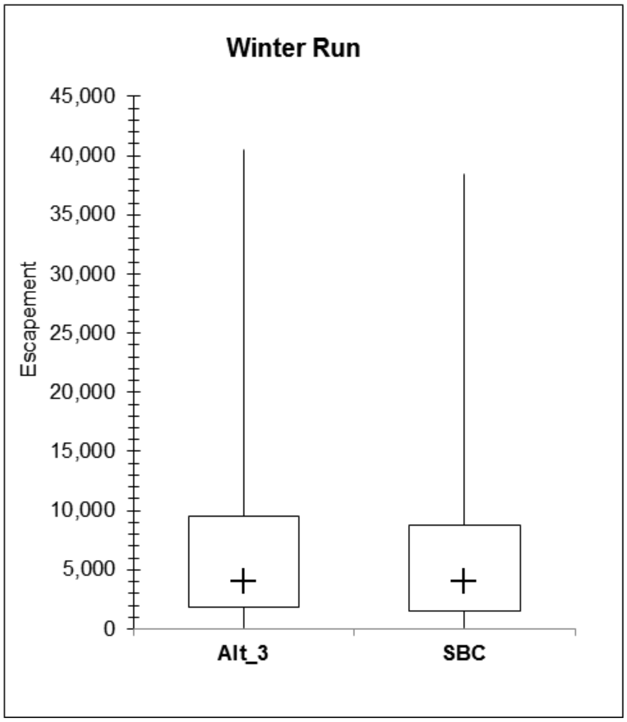

Figure 9H.11 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

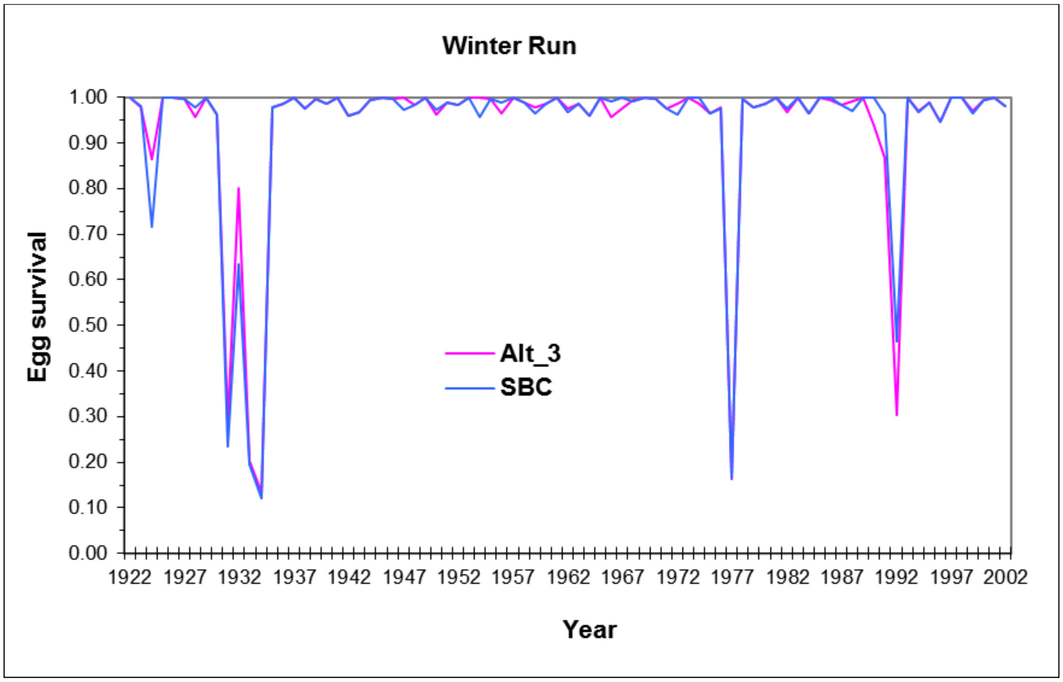

Figure 9H.12 Annual Egg Survival for Winter-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC) over 81 Water Years Estimated by the IOS Model

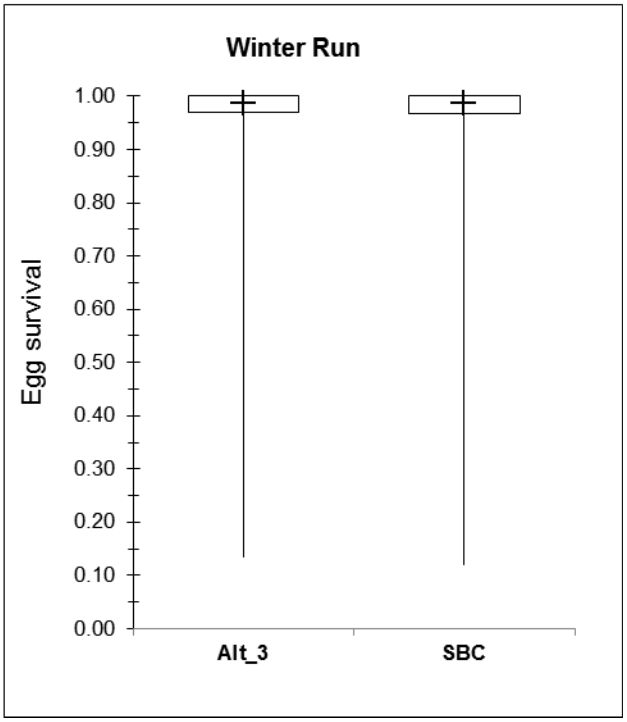

Figure 9H.13 Annual Egg Survival for Winter-run Chinook under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

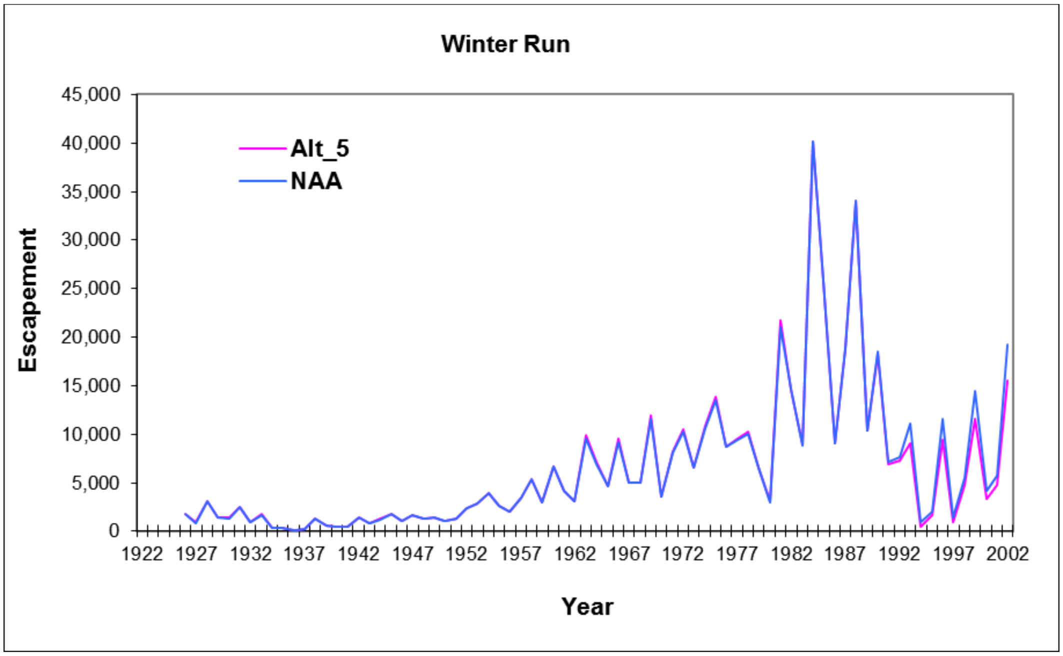

Figure 9H.14 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA) over 81 Water Years Estimated by the IOS Model

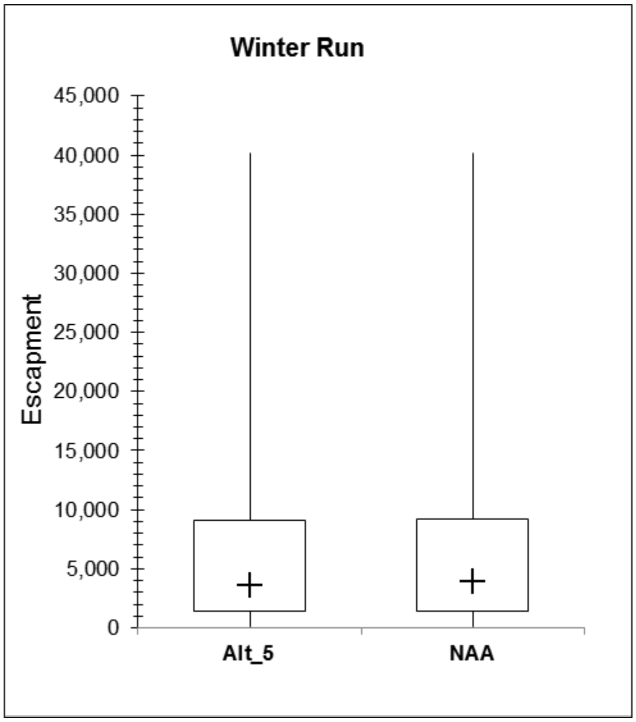

Figure 9H.15 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

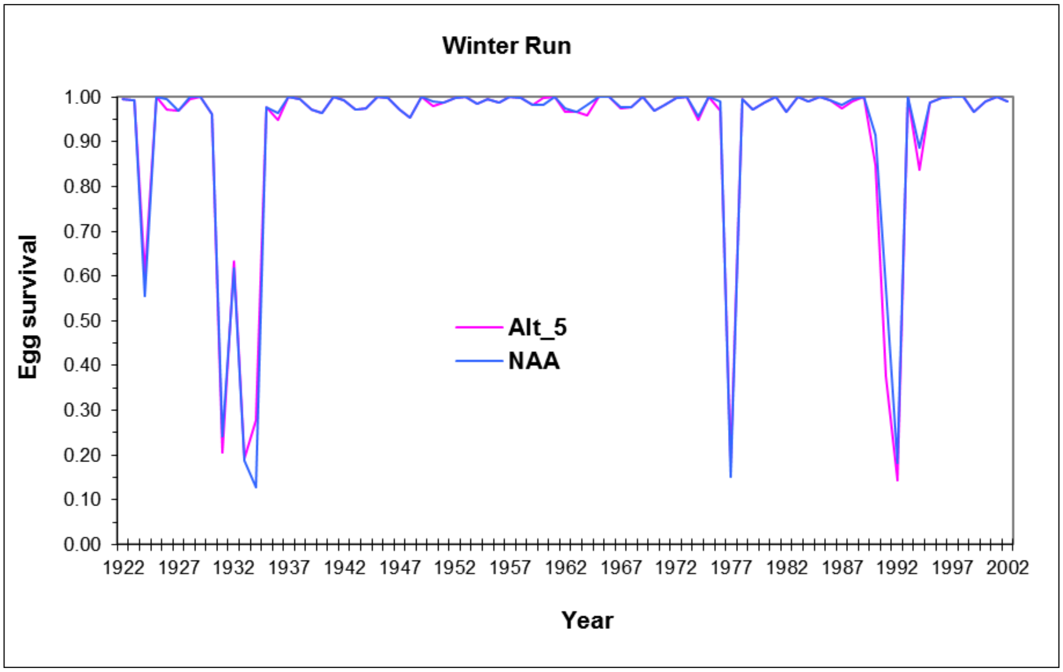

Figure 9H.16 Annual Egg Survival for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA) over 81 Water Years Estimated by the IOS Model

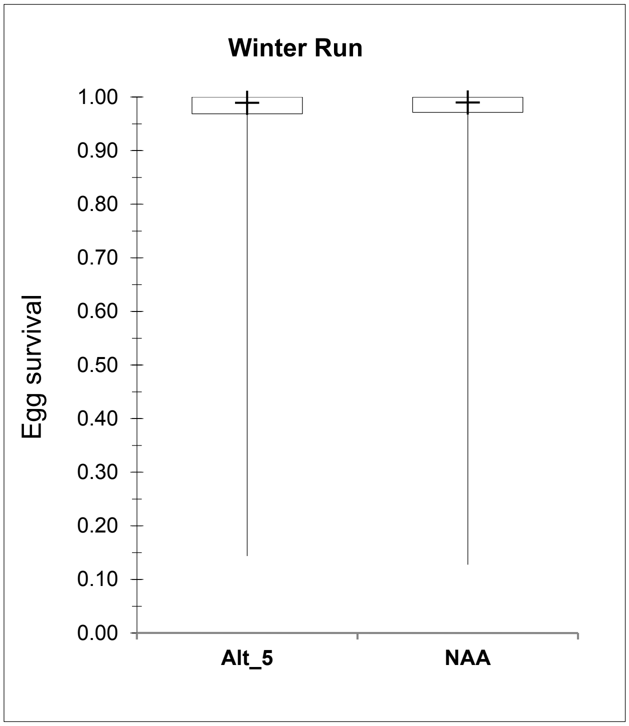

Figure 9H.17 Annual Egg Survival for Winter-run Chinook under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

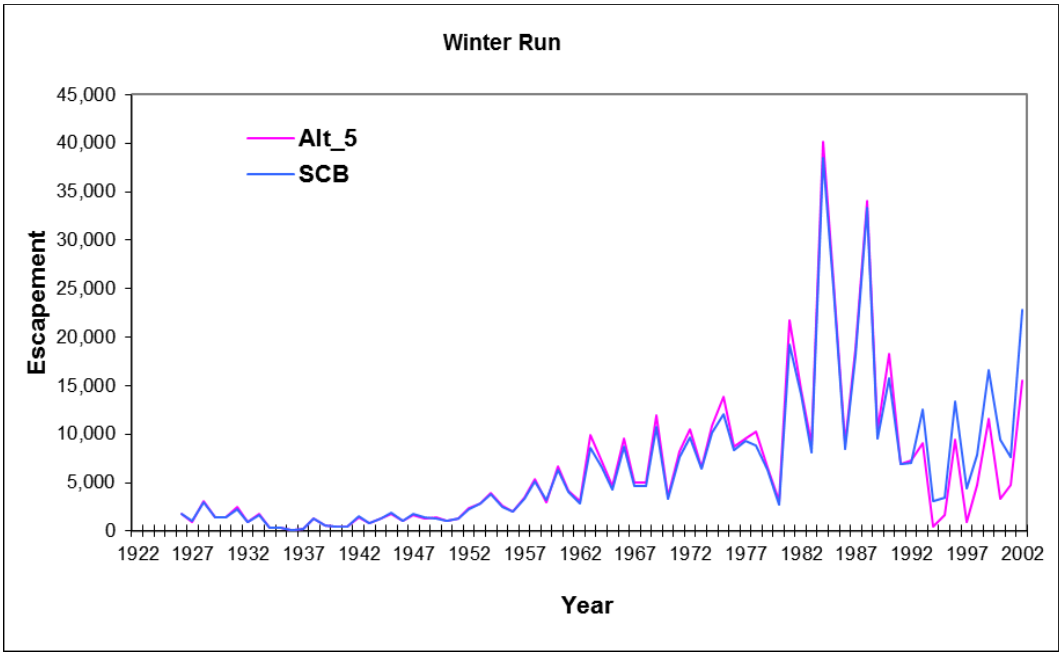

Figure 9H.18 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison over 81 Water Years Estimated by the IOS Model

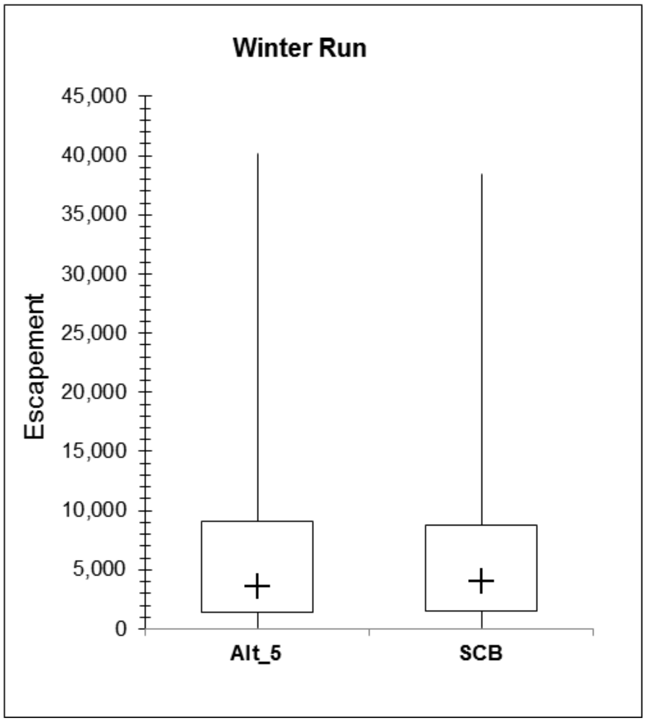

Figure 9H.19 Annual Adult Escapement for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

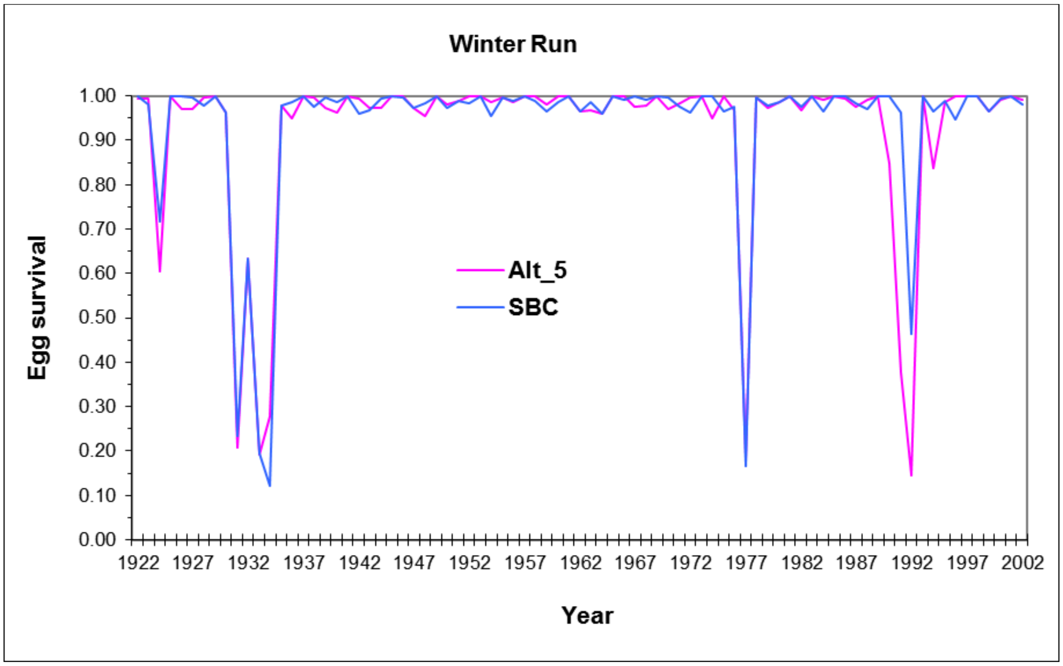

Figure 9H.20 Annual Egg Survival for Winter-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC) over 81 Water Years Estimated by the IOS Model

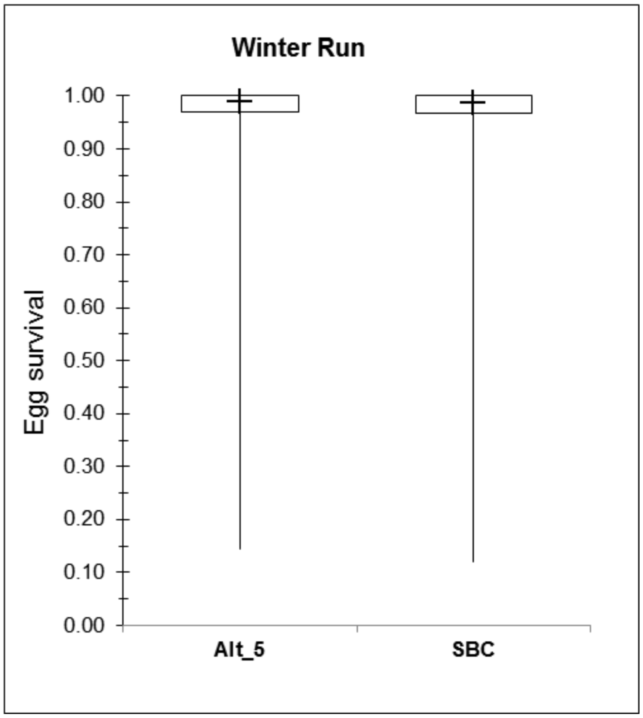

Figure 9H.21 Annual Egg Survival for Winter-run Chinook under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC) estimated by the IOS Model

Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.

Appendix 9I

Oncorhynchus Bayesian Analysis (OBAN) Model Documentation

This appendix provides information about the methods and assumptions used for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis using the Oncorhynhchus Bayesian Analysis (OBAN) model and pertinent results. This appendix is organized into two sections:

- Section 9I.1: Oncorhynchus Bayesian Analysis Model Methodology and Assumptions
  - The winter-run Chinook Salmon analysis uses the OBAN model (Hendrix et al. 2014) to quantify escapement of winter-run Chinook Salmon from the Sacramento River and overall survival, including ocean survival. This section briefly describes the analytical approach and assumptions of the OBAN model.
- Section 9I.2: Oncorhynchus Bayesian Analysis Model Results
  - This section presents the escapement and overall survival of winter-run Chinook Salmon from the Sacramento River. Results are presented in a series of figures for each comparison between alternatives.

9I.1 Oncorhynchus Bayesian Analysis Model Methodology and Assumptions

9I.1.1 Oncorhynchus Bayesian Analysis Model Methodology

Water operations in the Sacramento and San Joaquin Rivers and delta affect the hydrologic environment and therefore have the potential to affect the populations of fish that reside there. These effects may not be observed directly, however, and life-cycle models may be useful to evaluate the potential effects of water operations on fish population dynamics. To understand how anthropogenic factors in the freshwater and marine portions of the life history may affect winter-run Chinook Salmon (*Oncorhynchus tshawytscha*), the winter-run OBAN model was developed. A version of the OBAN model with updated parameter estimates in 2015 was used to evaluate the alternatives.

9I.1.1.1 OBAN Model Structure and Assumptions

- The OBAN model integrates sources of mortality across the life cycle (survival through the early life stages in the Sacramento River, survival through the delta, and survival in the ocean) to calculate escapement.

- For the evaluation of the scenarios, all sources of mortality after the delta (i.e., ocean) are assumed to be exactly the same so that the focus is on the river and delta portions of the life cycle that may be influenced by the alternatives.
- The OBAN model is sensitive to water temperature in the incubation stage (July –September) and minimum flows in the fry rearing stage (August – November).
- The OBAN model is less sensitive to Delta Cross Channel Gates (DCC) position, exports, and Yolo operations.

9I.1.2 Physical Data

Physical data including temperature, flows, and exports were supplied from CalSim II and the temperature model outputs for each of the scenarios in daily and monthly intervals, depending on the physical data. These data were compiled in the format appropriate for the covariates in the OBAN model. The years 1967 to 2002 were used in the analysis because this is the time period for which both escapement estimates and CalSim II output were available for model calibration. For example, daily temperature data from Bend Bridge were summarized into a monthly average from July through September to define alevin survival rates.

In general, the simulated physical parameters that were used in the OBAN model clustered into two groups. One group consisted of the No Action Alternative and Alternative 5 scenarios which had similar temperature (Figure 9I.1), flow (Figure 9I.2), exports (Figure 9I.3), and Delta Cross Channel configuration (Figure 9I.5). The physical parameters for the second group (the Second Basis of Comparison and Alternative 3 scenarios) were similar, but were different from the parameters used in the other group (Figures 9I.1, 9I.2, 9I.3, and 9I.5). In all four scenarios, the Yolo bypass flows were almost equivalent, with some slight differences over simulation years 1995 through 1998 (Figure 9I.4). Indicators of ocean productivity (Upwelling Index and Farallon Temperatures during spring; Figure 9I.6) and Age-3 harvest rates (Figure 9I.7) were constant across scenarios.

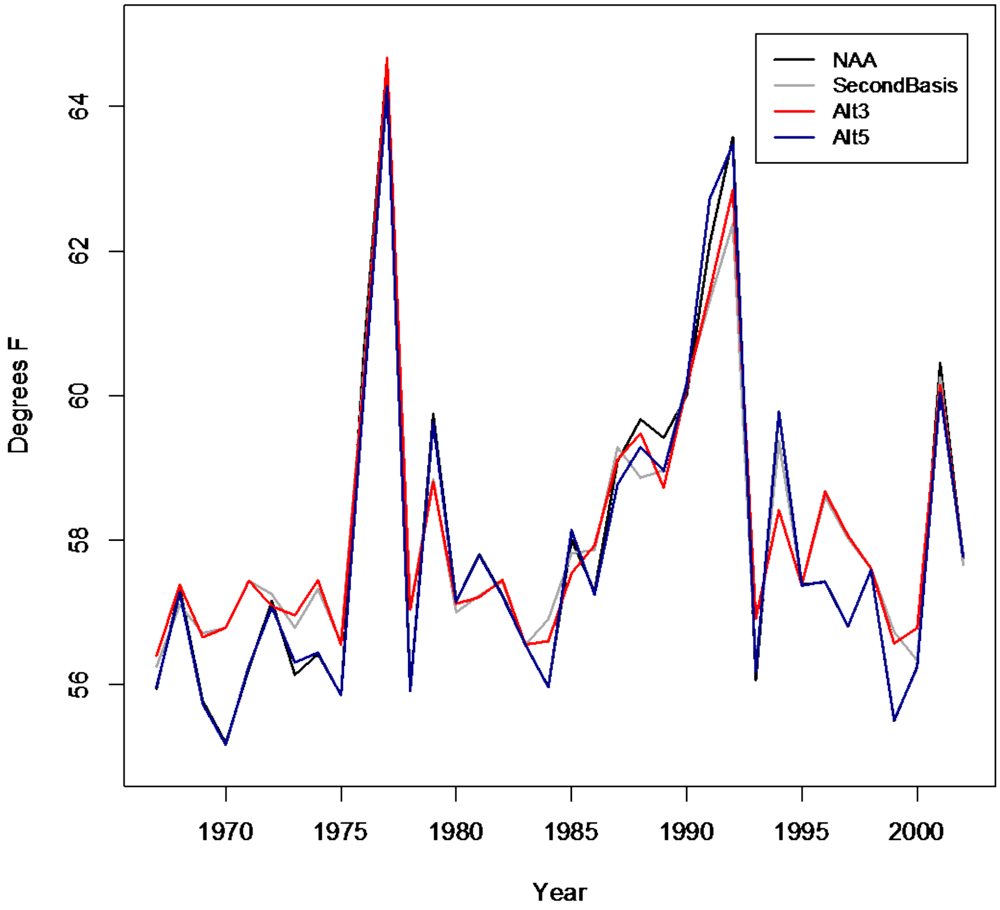

Figure 9I.1 Average Water Temperature from July through September at Bend Bridge for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

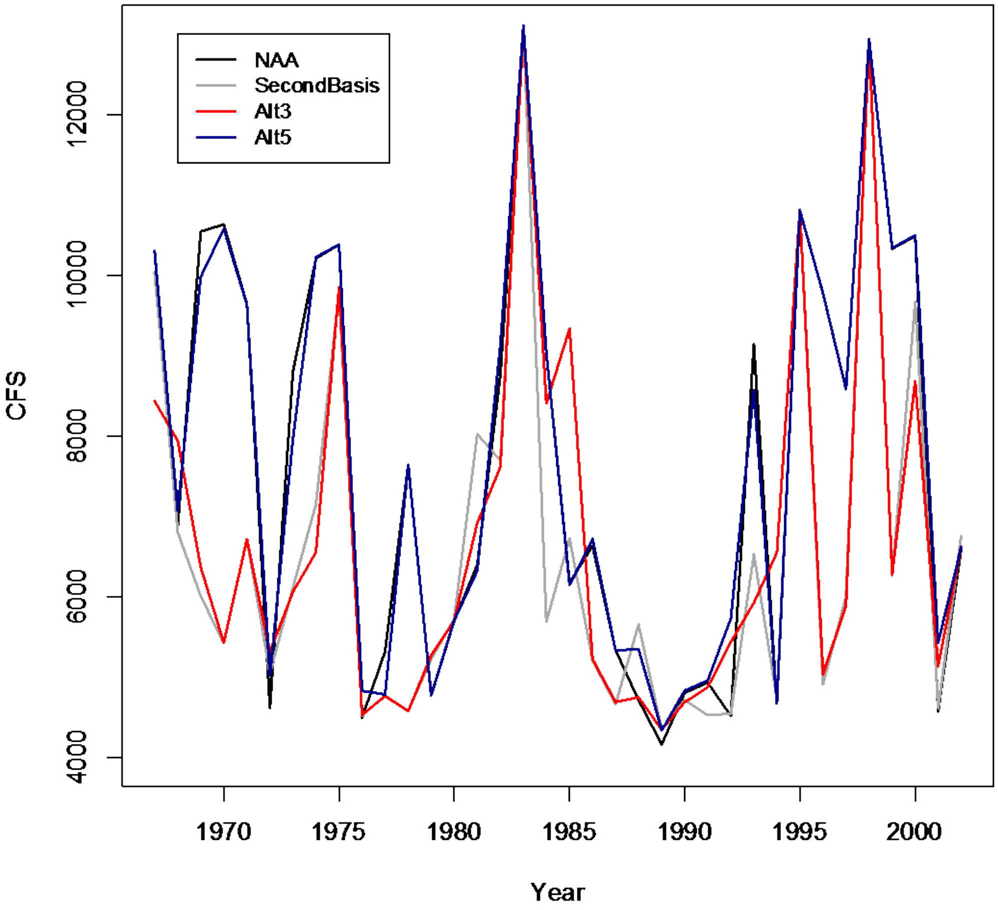

Figure 9I.2 Minimum of Monthly Average Flow from August through November at Bend Bridge for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

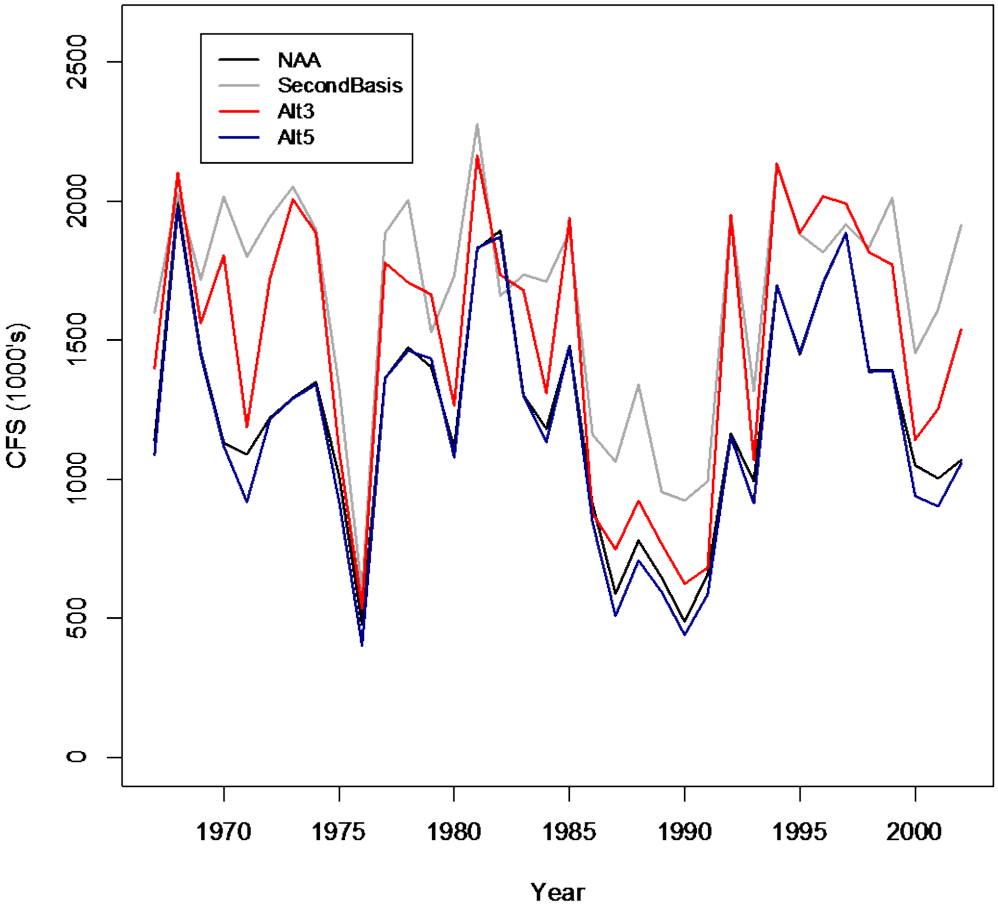

Figure 9I.3 Total Exports from December through June for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

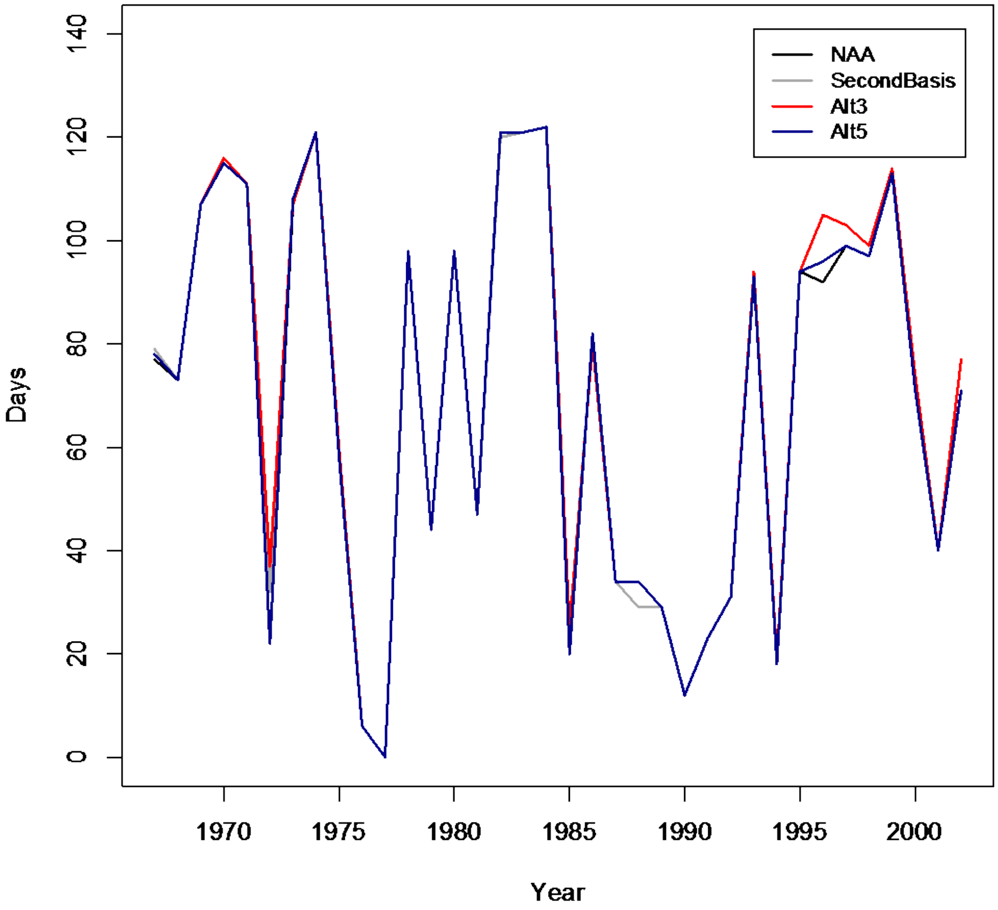

Figure 9I.4 Number of Days when Flow over the Fremont Weir is Greater than 100 Cubic Feet per Second from December through March for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

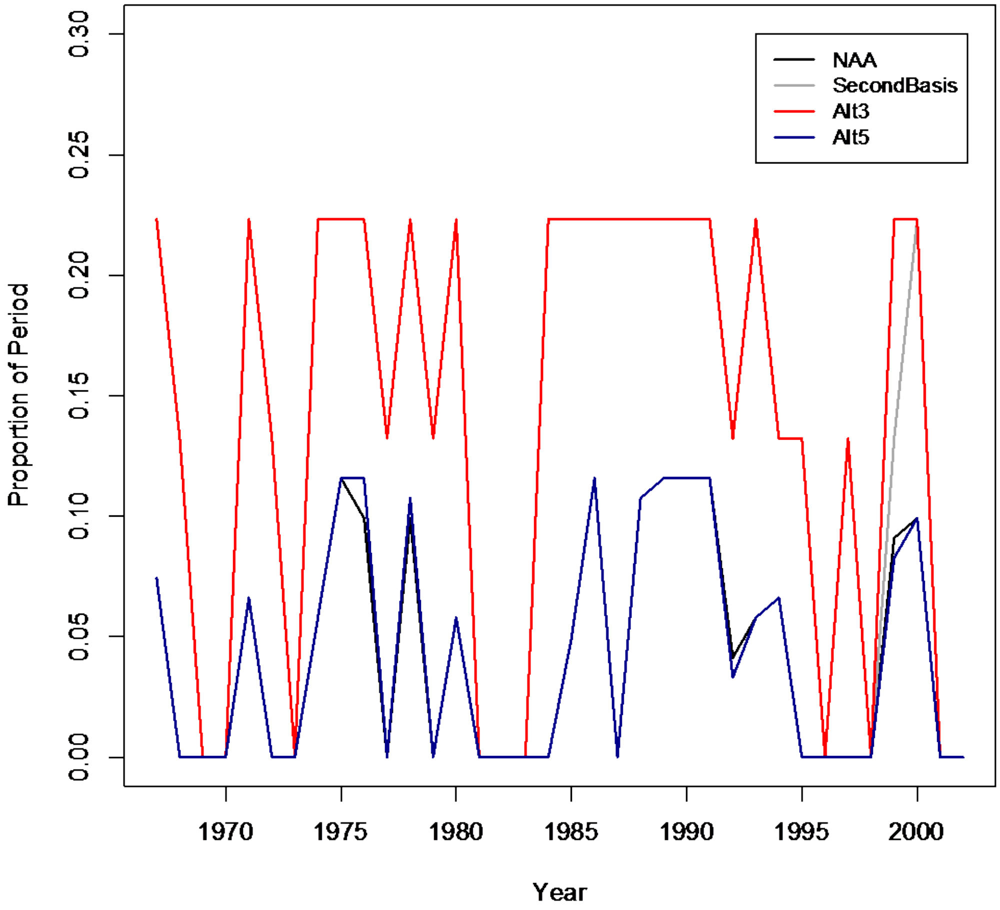

Figure 9I.5 Proportion of Period from December through March when Delta Cross Channel Gates are Open for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

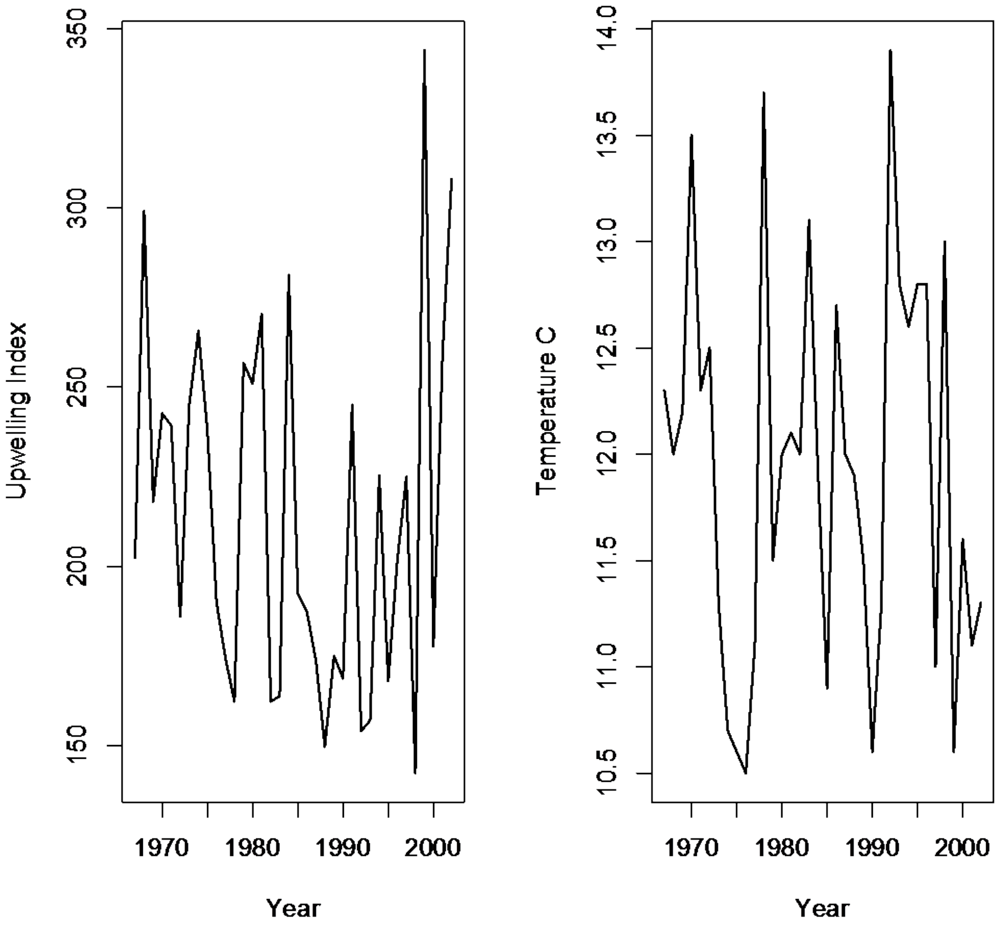

Figure 9I.6 [Indicators of Ocean Productivity including Upwelling Index during Spring (left) and Farallon Temperatures in Spring (right) for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5 (based on historical data).

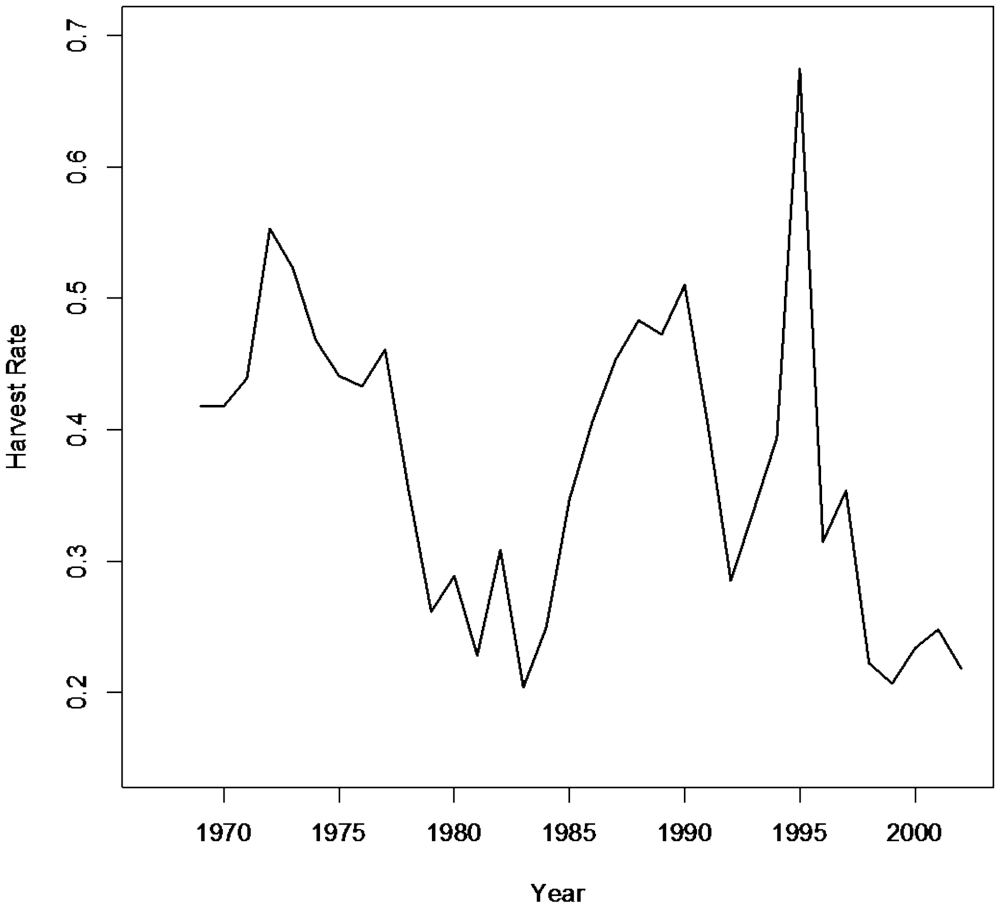

Figure 9I.7 Age 3 Harvest Rate for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5 (based on historical data).

9I.2 Oncorhynchus Bayesian Analysis Model Results

This section describes the OBAN model results for the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

Results are provided separately for each of the following runs:

- No Action Alternative
- Second Basis of Comparison
- Alternative 3
- Alternative 5

The OBAN model, like many other forecasting models, provides inference for future conditions on a relative basis. That is, the forecasts are not accurate in an absolute sense, but do provide important information when evaluating scenarios relative to each other. The pairwise comparisons obtained from OBAN model runs were:

- Alternative 1 compared to No Action Alternative
- Alternative 3 compared to No Action Alternative
- Alternative 5 compared to No Action Alternative
- No Action Alternative compared to Second Basis of Comparison
- Alternative 1 compared to Second Basis of Comparison
- Alternative 3 compared to Second Basis of Comparison
- Alternative 5 compared to Second Basis of Comparison

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternatives 1 and 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

For comparison of alternatives, the relative difference between two alternatives was calculated as:

*(proposal – base)/base * 100 percent*

The alternative listed first was the proposal and the alternative listed second was the base. The OBAN model produces forecasts of escapement and delta survival rates for simulation years 1967 to 2002, and incorporates parameter uncertainty in each of these outputs. As a result, the scenario comparisons also include uncertainty, and both median, 50 percent, and 90 percent probability intervals were calculated.

9I.2.1 OBAN Simulation Results

This section provides information on results from OBAN simulation for all alternatives without a comparison. Comparison of alternatives, which is used in Chapter 9 for impact analysis, is provided in section 9I.2.2.

The OBAN results indicated generally declining escapement levels until 1997, with a small recovery afterward (Figure 9I.1). Similar trends in median escapement between the No Action Alternative and Alternative 5 scenarios were forecast over the simulation period (Figure 9I.8). Similarly, the Alternative 3 and Second Basis model runs had similar escapement levels, with the Second Basis having slightly lower median escapement than the Alternative 3 scenario during some simulation years (for example, 1985 through 1990).

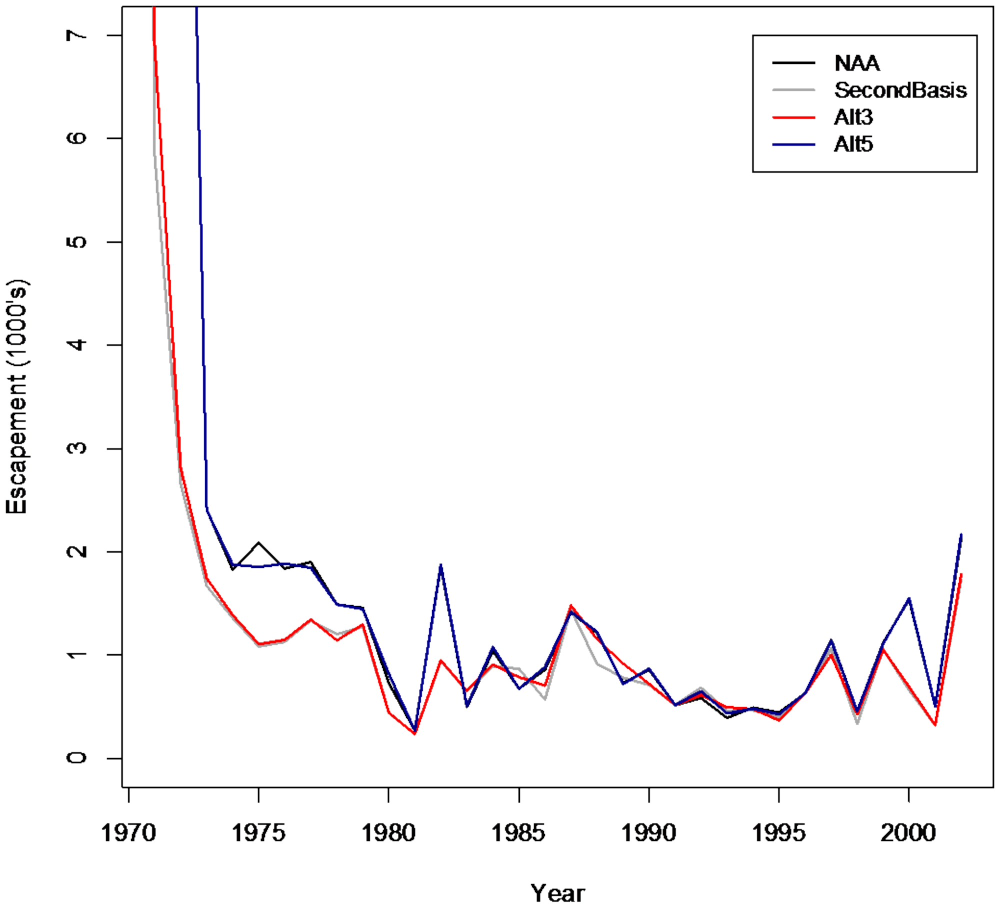

Figure 9I.8 Median Escapement under for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

Median Delta survival was generally higher under the Alternative 5 and the No Action Alternative scenarios and lower under the Alternative 3 and Second Basis of Comparison scenarios (Figure 9I.9).

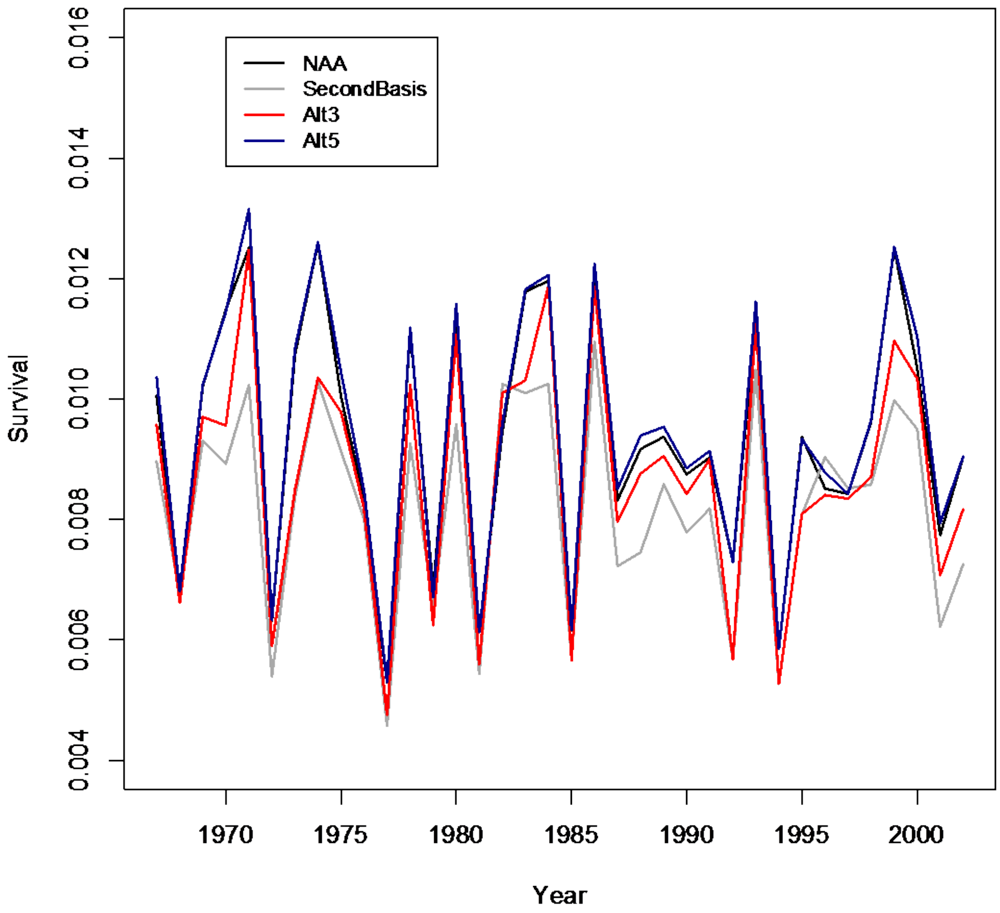

Figure 9I.9 Delta Survival under for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

The probability of exceeding a quasi-extinction threshold of 200 spawners was highest when the median escapement was at low levels (Figure 9I.10). The Alternative 3 and Second Basis scenarios typically had the highest probability of quasi-extinction among the scenarios evaluated.

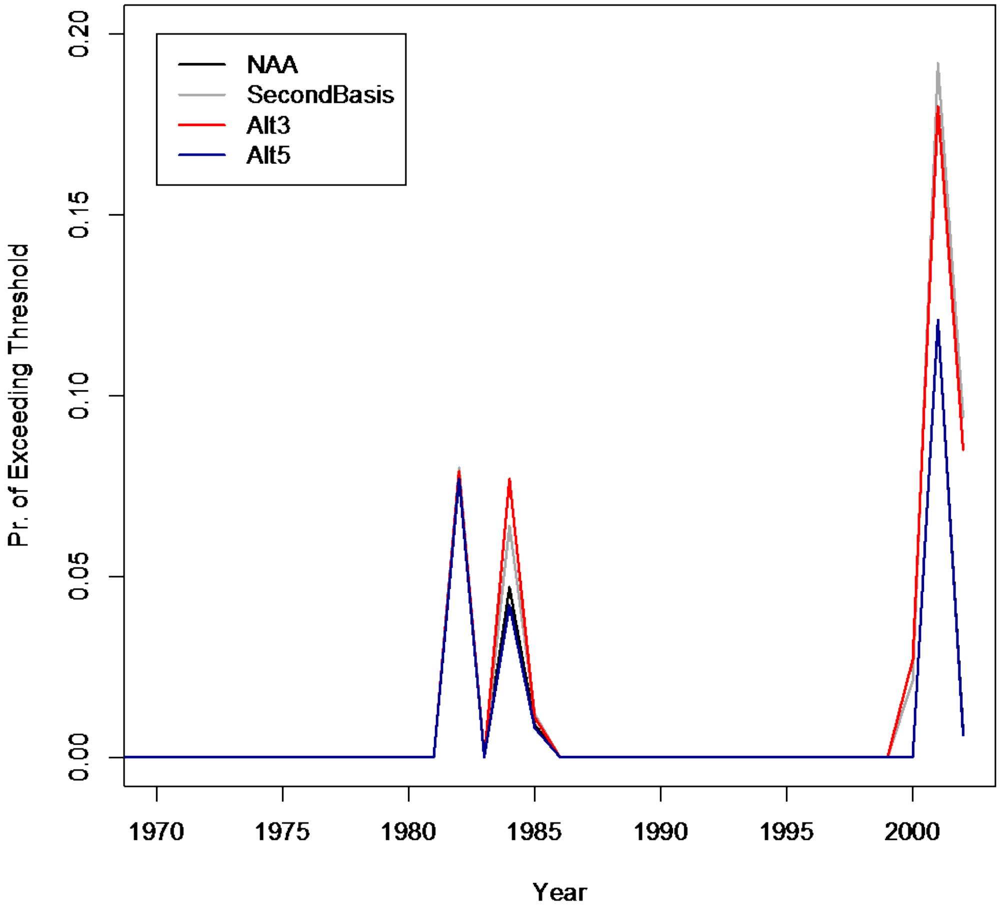

Figure 9I.10 Probability of Exceeding Quasi-Extinction Threshold of 200 Spawners under for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

The escapement estimates incorporating in simulation year 1985[1] indicated slightly higher median escapement of approximately 200 fish for the Second Basis and Alternative 3 scenarios relative to the No Action Alternative and Alternative 5 (Figure 9I.11). There was also a low probability (that is, probability of approximately 0.05) for higher median escapement under the Second Basis and Alternative 3 scenarios relative to the other scenarios in simulation year 1985 (Figure 9I.11)

---

[1] Years 1985 and 2002 were selected as an example to show a year earlier in the time series and a year later in the time series to look at the escapement levels. Because 2002 is the last year of simulation, it integrates the performance of each of the alternatives across the different water year types in the simulation period.

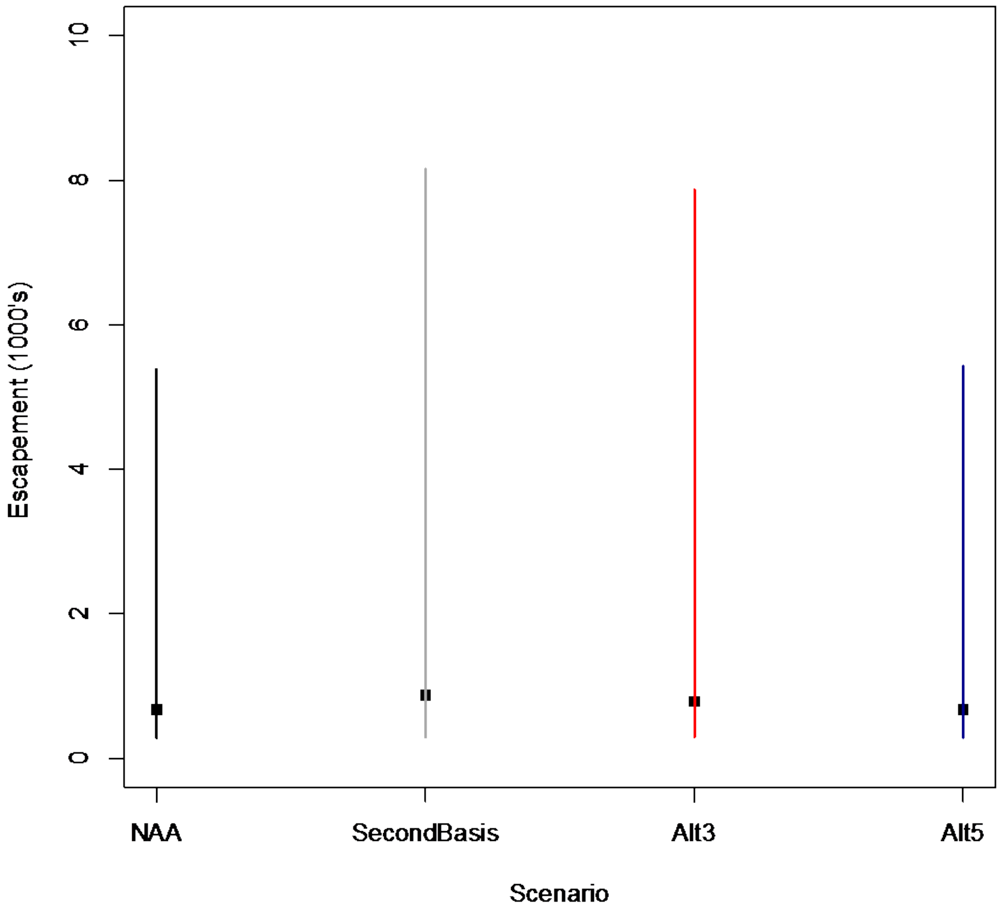

Figure 9I.11 Escapement in Simulation Year 1985 under for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

Note: Squares are median values and lines are 90 percent probability intervals

Comparison of escapement after recovery from the low escapement years of 1992 through 1996 (simulation year 2002) indicated slightly higher median escapement of approximately 300 fish under the No Action Alternative and Alternative 5 scenarios than for the Second Basis and Alternative 3 scenarios (Figure 9I.12).

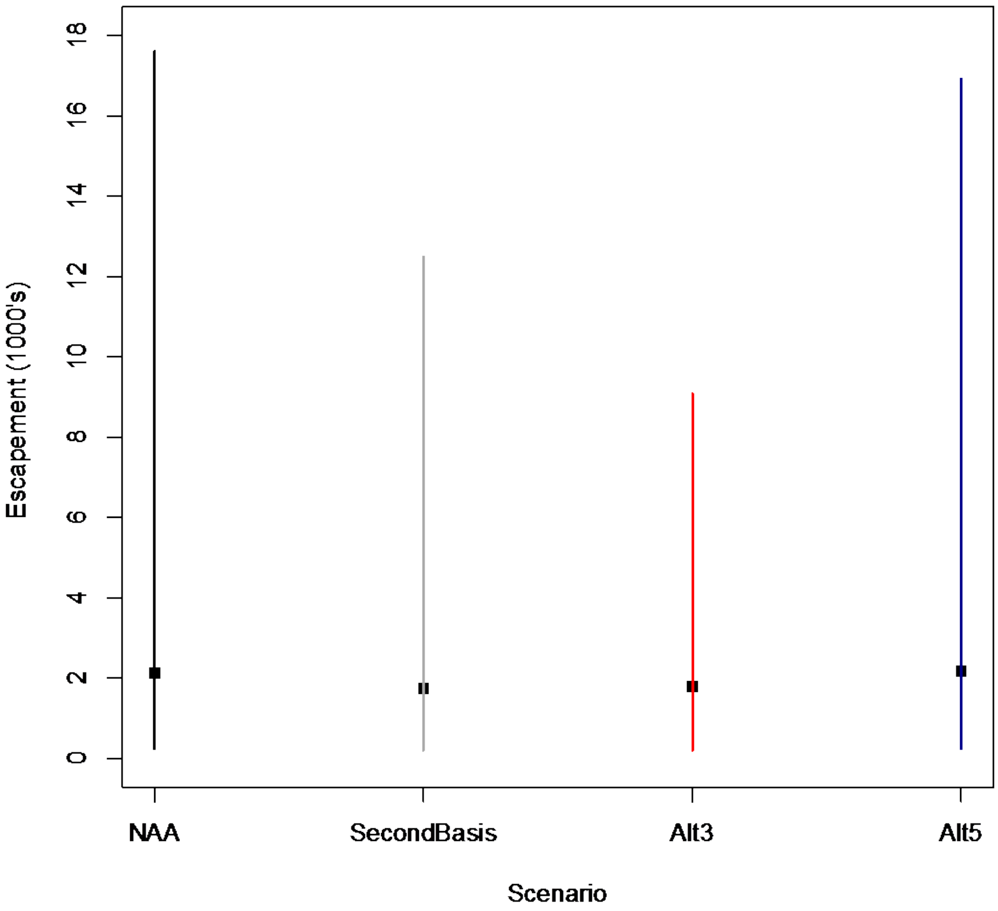

Figure 9I.12 Escapement in Simulation Year 2002 under for No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5

Note: Squares are median values and lines are 90 percent probability intervals

9I.2.2 OBAN Alternative Comparisons

This section provides comparisons of results between alternatives that are used in Chapter 9 for impact analysis. Percent differences provided in this section represent difference in model results between two alternatives (first alternative results minus the second alternative results) divided by the model results of the first alternative multiplied by 100 to present in percentages.

The EIS impact analysis starts with use of the monthly CalSim II model to project CVP and SWP water deliveries. Because this regional model uses monthly time steps to simulate requirements that change weekly or change through observations, it was determined that changes in the model of 5 percent or less were related to the uncertainties in the model processing. Therefore, reductions of 5 percent or less in this comparative analysis are considered to be not substantially different, or “similar.”

9I.2.2.1 No Action Alternative Compared to the Second Basis of Comparison

Escapement was generally higher for the No Action Alternative than for the Second Basis, as indicated by the generally negative percent differences between the Second Basis of Comparison (SBC) and No Action Alternative (NAA) (Figure 9I.13). The median escapement under the Second Basis was higher in 6 of the 32 years of simulation (1971 through 2002), and within the 50 percent probability intervals, the Second Basis of Comparison values exceeded the No Action Alternative estimates in less than 25 percent of simulation years (that is, the dark gray area was below the dashed line in more than 75 percent of years).

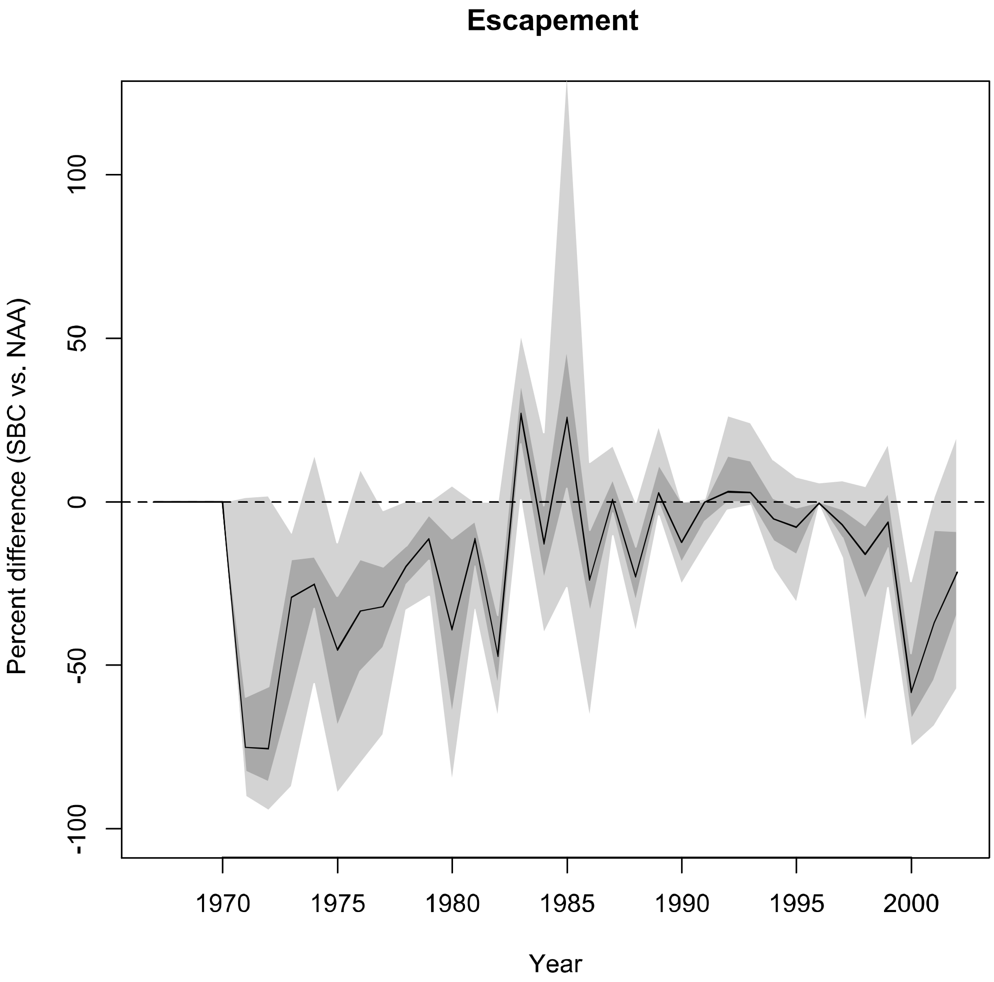

Figure 9I.13 Percent Difference in Escapement between the Second Basis of Comparison and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed

Median delta survival (calculated as the average of the median values across all simulation years) was approximately 12 percent lower under the Second Basis than it was under the No Action Alternative (Figure 9I.14). However, the 50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0 (dashed line in Figure 9I.14), suggesting that no difference between alternatives is highly probable in most years.

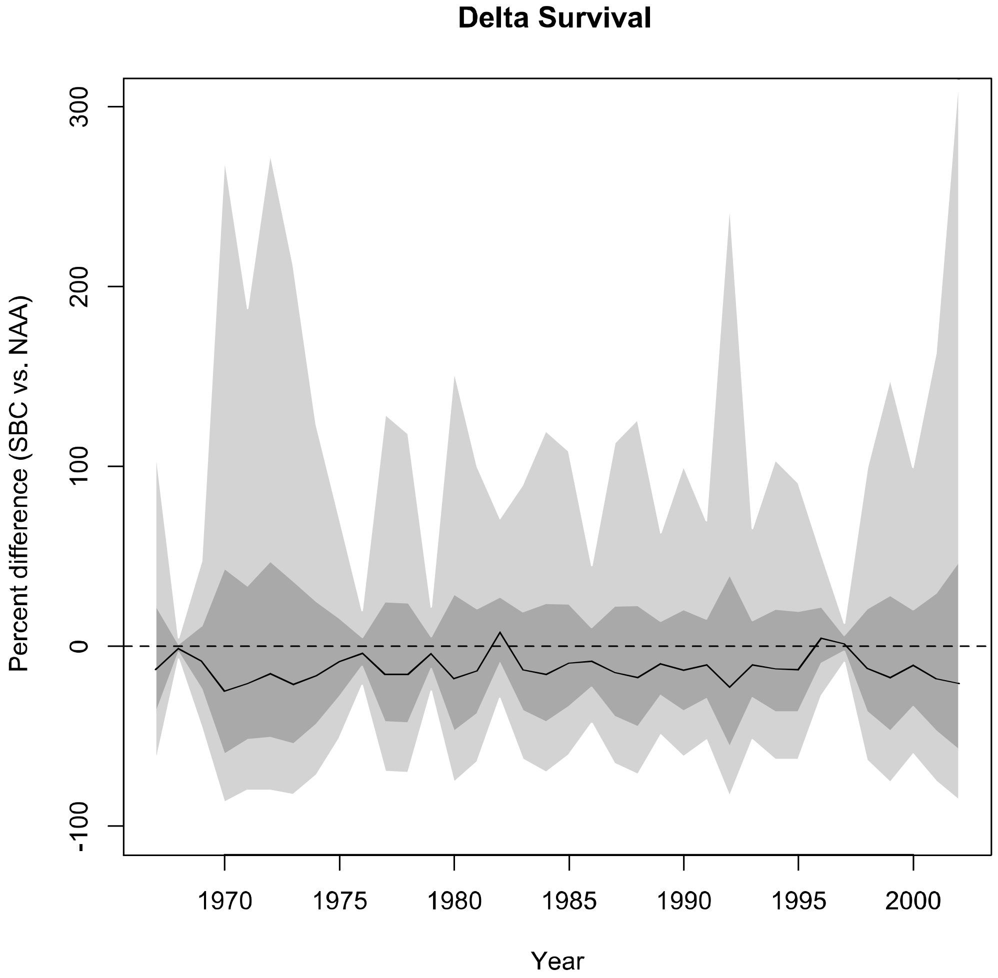

Figure 9I.14 Percent Difference in Delta Survival between the Second Basis of Comparison and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed

9I.2.2.2 Comparison of Alternative 3 versus No Action Alternative

Alternative 3 generally had lower escapement values than the No Action Alternative scenario during the early and late portion of the time series, as indicated by the generally negative percent differences between Alternative 3 and No Action Alternative during those periods (Figure 9I.15). In general, the temporal pattern was similar to the percent differences between the Second Basis of Comparison and the No Action Alternative (Figure 9I.13).

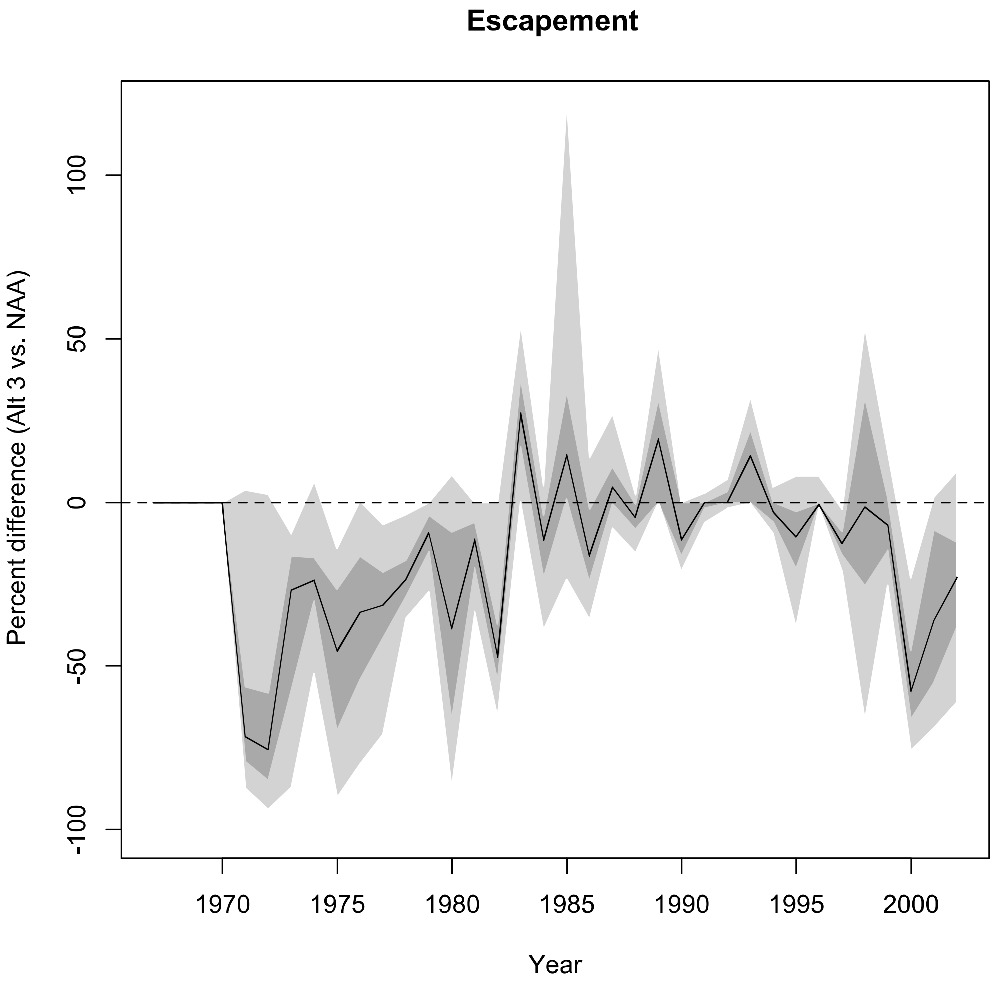

Figure 9I.15 Percent Difference in Escapement between Alternative 3 and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed

With the exception of one year, median delta survival rates were consistently lower (-7 percent) under Alternative 3 than under the No Action Alternative. However, the 50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0 (dashed line in Figure 9I.16), suggesting that no difference between alternatives is highly probable in most years.

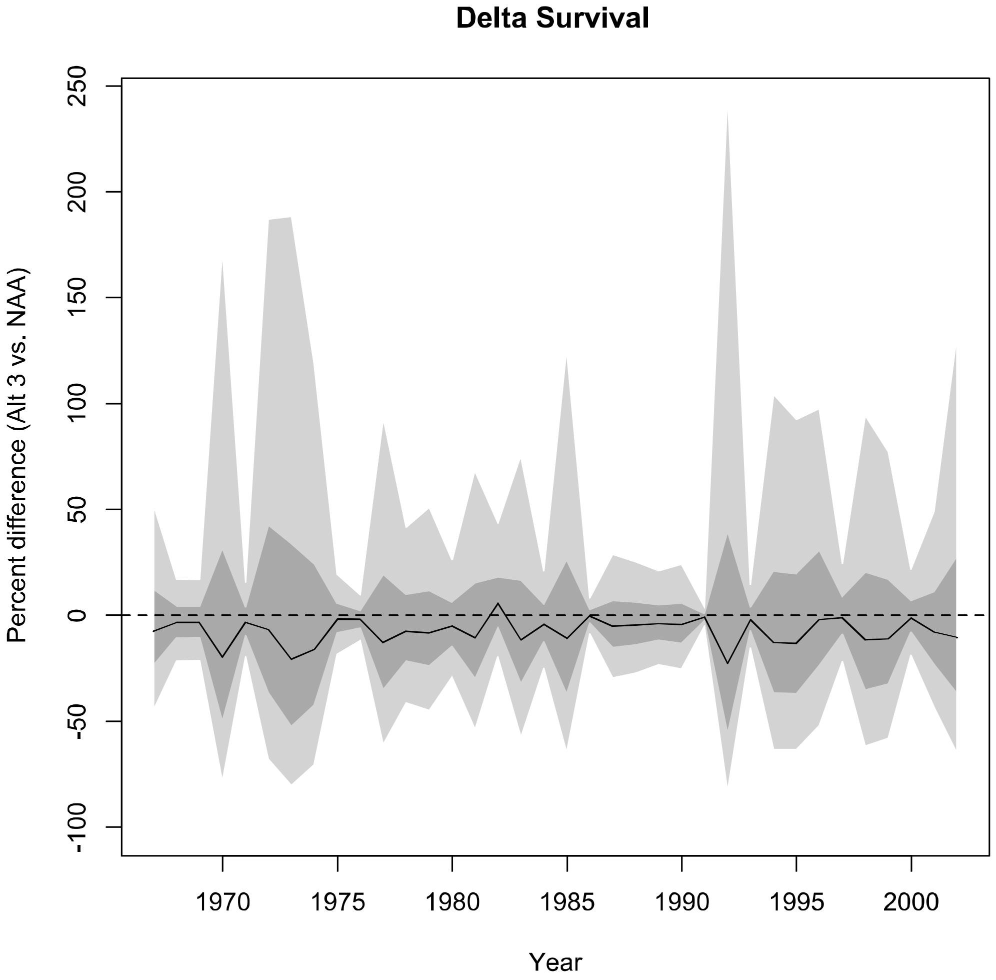

Figure 9I.16 Percent Difference in Delta Survival between Alternative 3 and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line displayed

9I.2.2.3 Comparison of Alternative 3 versus Second Basis of Comparison

Differences in escapement between Alternative 3 and the Second Basis scenarios are presented in Figure 9I.17. Escapement was generally greater for Alternative 3 than for the Second Basis. However, the 50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0 (dashed line in Figure 9I.17), suggesting that no difference between alternatives is highly probable in most years.

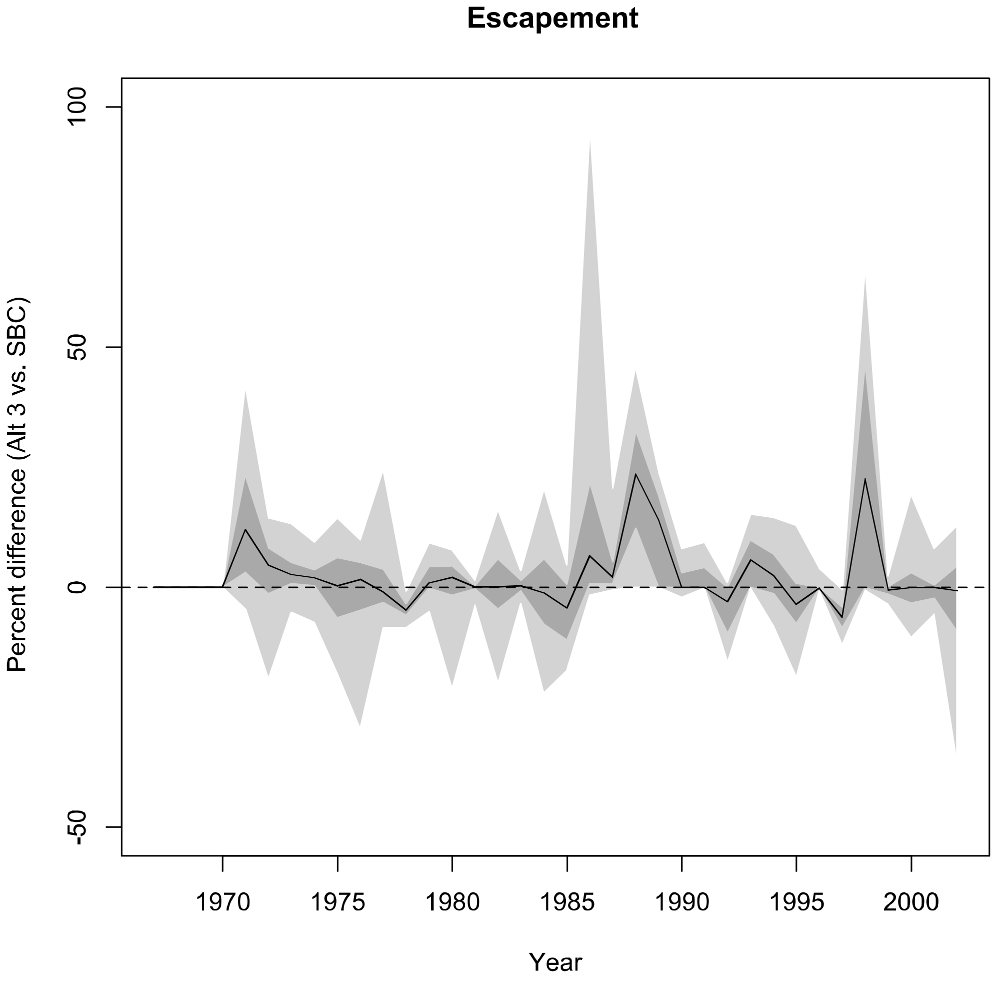

Figure 9I.17 Percent Difference in Escapement between Alternative 3 and the Second Basis of Comparison

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed

The median delta survival was slightly higher for Alternative 3 than it was for the Second Basis scenario (6 percent), although the probability of no difference between alternatives was generally high throughout the simulation time period (50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0) (Figure 9I.18).

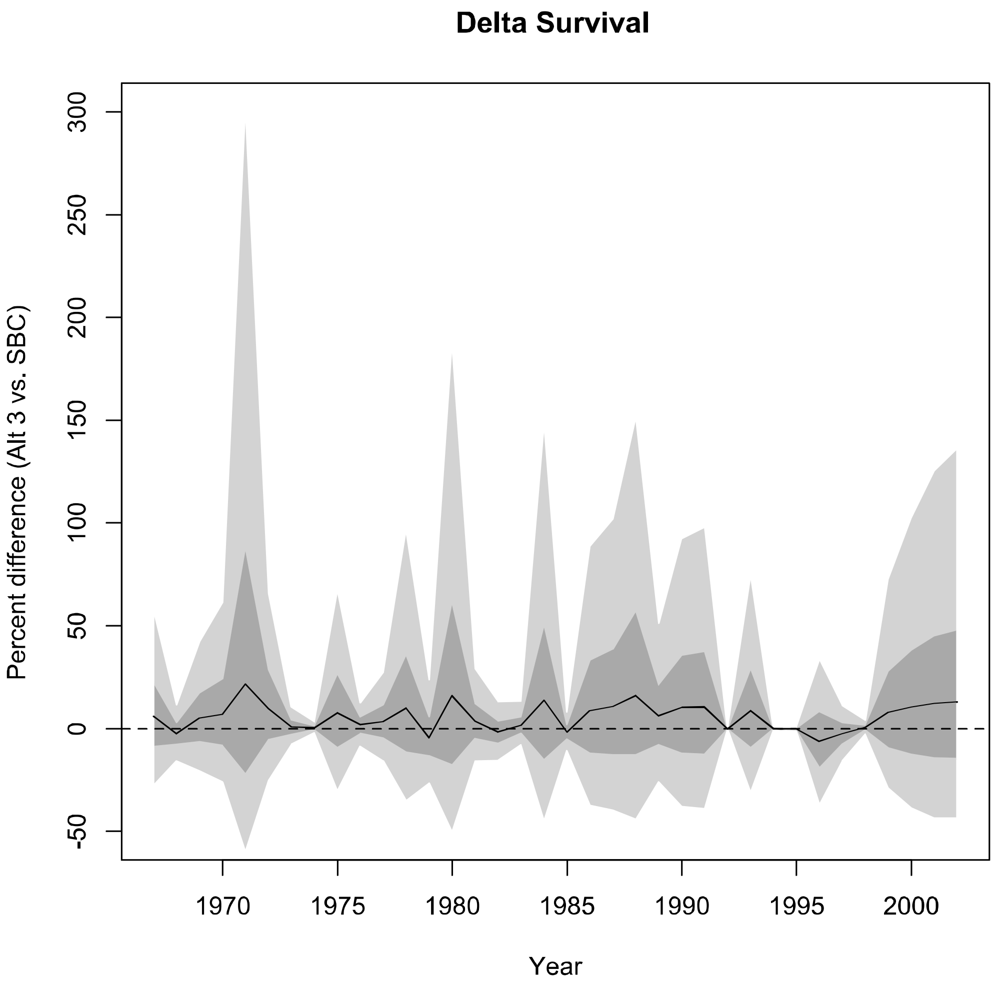

Figure 9I.18 Percent Difference in Delta Survival between Alternative 3 and the Second Basis of Comparison

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed

9I.2.2.4 Comparison of Alternative 5 versus No Action Alternative

Little difference in escapement estimates was evident between the Alternative 5 and No Action Alternative scenarios (Figure 9I.19). The scale of each figure has been altered to incorporate the 90 percent probability intervals, and the intervals in this comparison are smaller than other similar figures (for example, Figures 9I.17 and 9I.13).

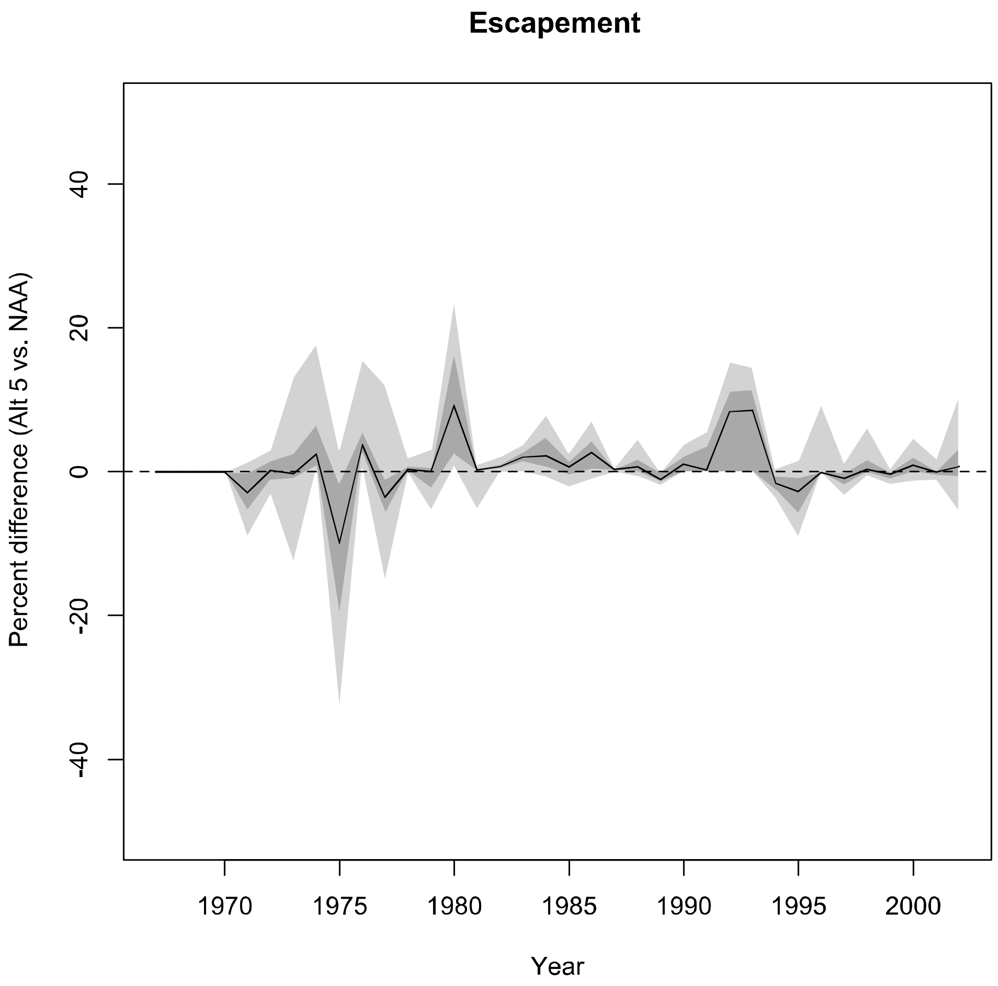

Figure 9I.19 Percent Difference in Escapement between Alternative 5 and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed. Also, the scale of this figure has been altered to incorporate the 90 percent probability intervals, and the intervals in this comparison are smaller than other escapement estimate figures (for example, Figures 9I.13 and 9I.17).

Median Delta survival was similar between the No Action Alternative and Alternative 5 scenarios, with a slight improvement in median values of delta survival (1 percent) under Alternative 5 compared to the No Action Alternative. The 50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0 (dashed line in Figure 9I.20), suggesting that no difference between alternatives is highly probable in most years.

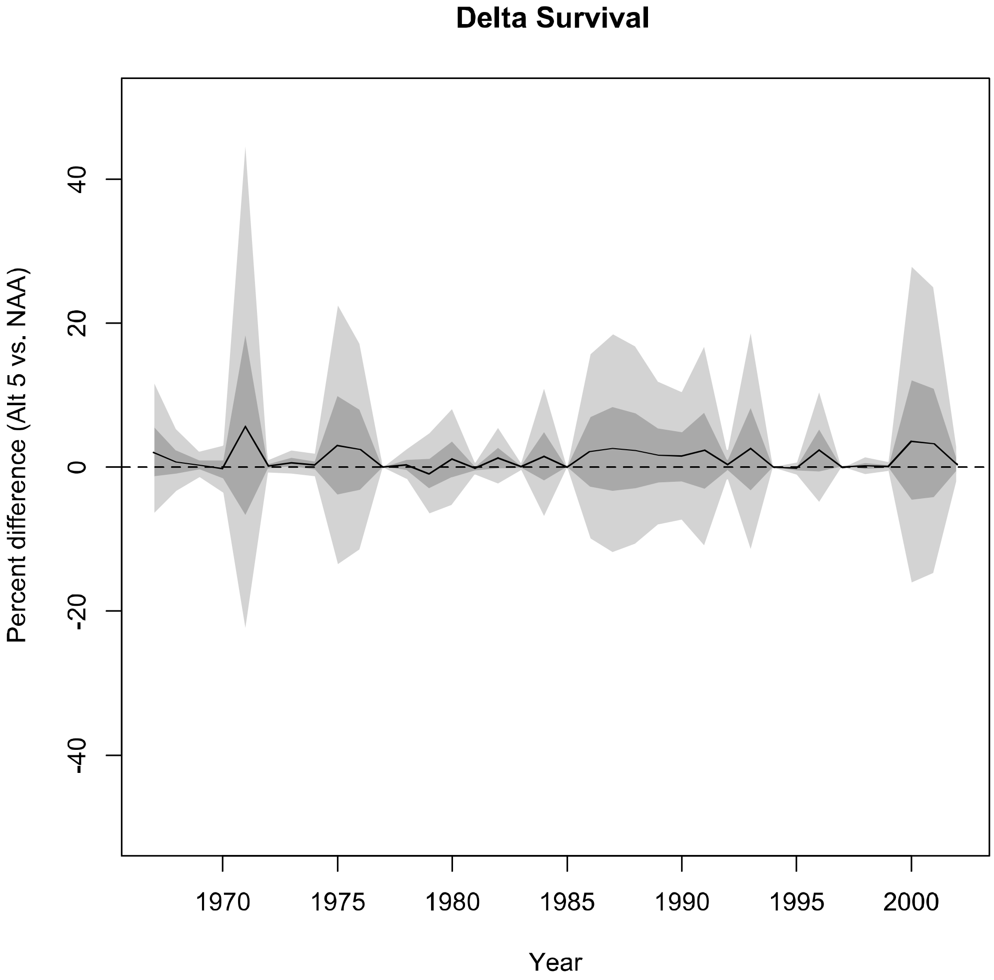

Figure 9I.20 Percent Difference in Delta Survival between Alternative 5 and the No Action Alternative

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed. Also, the scale of this figure has been altered to incorporate the 90 percent probability intervals, and the intervals in this comparison are smaller than other escapement estimate figures (for example, Figures 9I.14 and 9I.18).

9I.2.2.5 Comparison of Alternative 5 versus Second Basis

Differences between Alternative 5 and the Second Basis were moderate (Figure 9I.21). In years prior to 1983 and after 1995, the median escapement values were higher under the Alternative 5 scenario than it was under the Second Basis scenario. In many of the simulation years, the central 50 percent probability interval did not include 0, and in a few years the central 90 percent interval did not include 0, suggesting consistently higher escapement under Alternative 5 than under the Second Basis scenario, despite uncertainty in model parameter values.

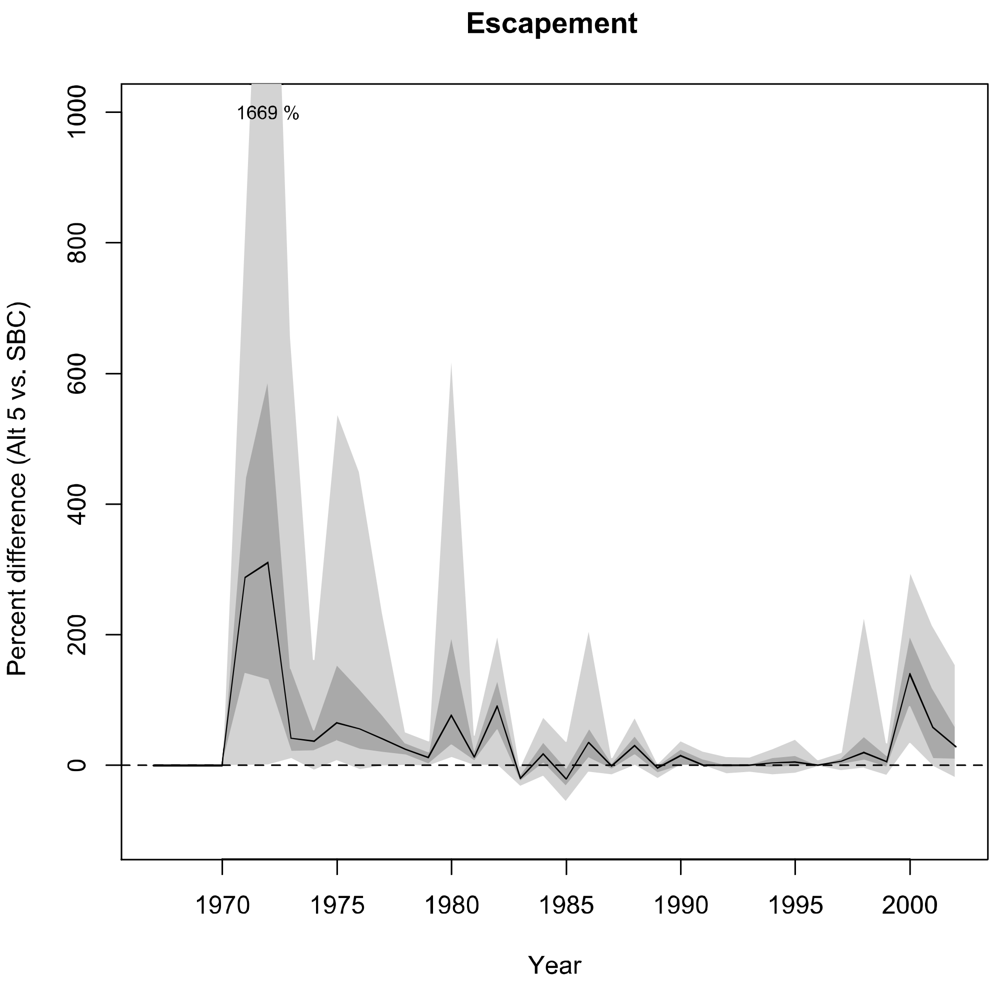

Figure 9I.21 Percent Difference in Escapement between Alternative 5 and the Second Basis of Comparison

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed). Also, the scale of this figure has been altered to incorporate the 90 percent probability intervals, and the intervals in this comparison are larger than other escapement estimate figures (for example, Figures 9I.14 and 9I.18).

Delta survival was generally higher under Alternative 5 (Figure 9I.22) than it was under the Second Basis scenario (15 percent). All years, however, the 50 percent probability intervals and the 90 percent probability intervals are both centered on the value of 0 (dashed line in Figure 9I.22), suggesting that no difference between alternatives is highly probable in most years.

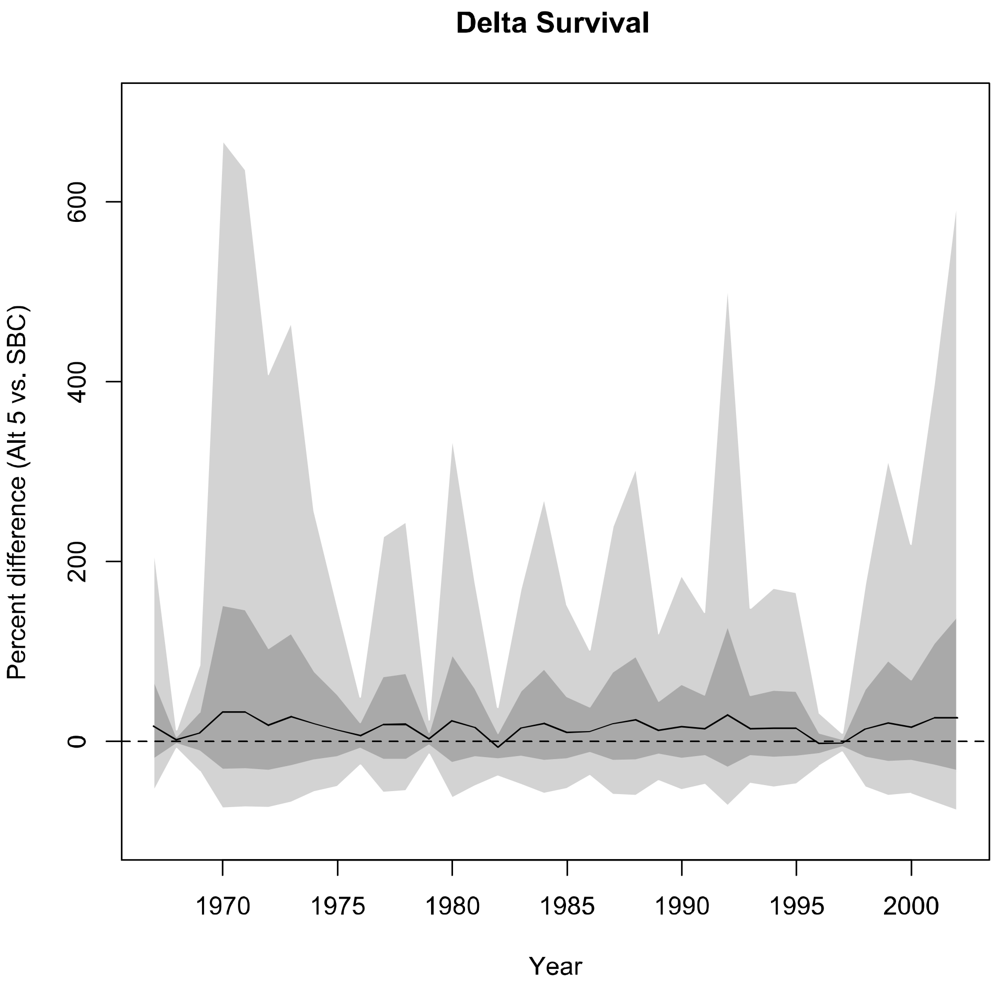

Figure 9I.22 Percent Difference in Delta Survival between Alternative 5 and the Second Basis of Comparison

Note: Median difference (solid line) with 50 percent probability intervals (dark gray) and 90 percent probability intervals (light gray) and reference line of no difference (dashed line) displayed. Also, the scale of this figure has been altered to incorporate the 90 percent probability intervals, and the intervals in this comparison are smaller than other survival estimate figures.

9I.3 References

Hendrix, N., A. Criss, E. Danner, C. M. Greene, H. Imaki, A. Pike, and S. T. Lindley. 2014. Life cycle modeling framework for Sacramento River winter-run Chinook salmon. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC 530.

This page left blank intentionally.

Appendix 9J

Delta Passage Model Documentation

Information about the methods and assumptions used for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis using the Delta Passage Model (DPM) model is provided in this appendix. The appendix comprises two main sections as follows:

- Section 9J.1: DPM Methodology and Assumptions
  - The DPM model analysis is used to quantify survival within the Delta of winter-run, fall-run, and late fall-run Chinook Salmon. The approach and assumptions for the DPM analysis are described in this section.
- Section 9J.2: DPM model Analysis Results
  - The results of the DPM analysis are presented in this section in a series of figures for each alternative comparison.

9J.1 DPM Model Methodology and Assumptions

9J.1.1 DPM Model Methodology

The DPM is based on a detailed accounting of migratory pathways and reach-specific mortality as Chinook Salmon smolts travel through a simplified network of reaches and junctions (Figure 1). The biological functionality of the DPM is based upon the foundation provided by Perry et al. (2010) as well as other acoustic tagging based studies (Michel 2010) and coded wire tag (CWT)-based studies (Newman and Brandes 2010; Newman 2008). Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available.

The major model functions in the DPM are: 1) Delta Entry Timing, that models the temporal distribution of smolts entering the Delta for each race of Chinook Salmon, 2) Fish Behavior at Junctions, that models fish movement as they approach river junctions, 3) Migration Speed, that models reach-specific smolt migration speed and travel time, 4) Reach-specific Survival, that models reach-specific survival, 5) Flow-dependent Survival, that models reach-specific survival response to flow, 6) Export-dependent Survival, that models survival response to water export levels in the Interior Delta reach, and 7) North Delta Intake Predation, that models the mortality associated with predation at a North Delta Intake water diversion (not applicable in this EIS).

The DPM operates on a daily time step using simulated daily average flows and Delta exports as model inputs. The DPM does not attempt to represent sub-daily flows or diel salmon smolt behavior in response to the interaction of tides, flows, and specific channel features. The DPM is intended to represent the net outcome of migration and mortality occurring over days, not three dimensional movements occurring over minutes or hours.

The DPM is composed of eight reaches and four junctions (Figure 9J.1; Table 9J.1) selected to represent primary salmonid migration corridors where high quality fish and hydrodynamic data were available. For simplification, Sutter Slough and Steamboat Slough are combined as the reach "SS," and the forks of the Mokelumne River and Georgiana Slough are combined as "Geo/DCC." The Geo/DCC reach can be entered by Mokelumne River fall-run at the head of the South and North Forks of the Mokelumne River or by Sacramento runs through the combined junction of Georgiana Slough and Delta Cross Channel (DCC) (Junction C). The Interior Delta reach can be entered from three different pathways: 1) Geo/DCC, 2) San Joaquin River via Old River Junction (Junction D), or 3) Old River via Junction D. Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, we treat the entire Interior Delta region as a single model reach. The four distributary junctions depicted in the Delta portion of the model are: A) Sacramento River at Freemont Weir (head of Yolo Bypass), B) Sacramento River at head of Sutter and Steamboat Sloughs, C) Sacramento River at the combined junction with Georgiana Slough and DCC, and D) San Joaquin River at the head of Old River (Figure 9J.1; Table 9J.1). Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, we treat the entire Interior Delta region as a single model reach.

The DPM model uses scenario-specific daily simulation model (DSM2) and CalSim II data as model input. Daily DSM2 data informs fish migration speed, reach-specific survival, and routing at Delta junctions. Daily export data from CalSim II is used to inform export-dependent survival of salmon smolts that enter the Interior Delta from the Geo/DCC reach.

For reaches where acoustic tagging data supported migration speed responses to flow (Sac1, Sac2, and Geo/DCC), daily migration speed is influenced by mean daily flow. Migration speed is modeled as a logarithmic function of reach-specific flow occurring on the first day smolts entered a particular reach.

Reach-specific survival through a given reach is calculated and applied the first day smolts enter the reach. For reaches where literature or available tagging data showed support for reach-level responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3, Sac4, SS, Interior Delta via San Joaquin River, and Interior Delta via Old River) or water exports (Interior Delta via Geo/DCC). For these reaches, daily flow (DSM2 data) or exports (CalSim II data) occurring the day of reach-entry is used to predict reach survival through the entire reach. For all other reaches (Geo/DCC and Yolo), reach survival is uninfluenced by Delta conditions and is informed by means and standard deviations of survival from acoustic tagging studies.

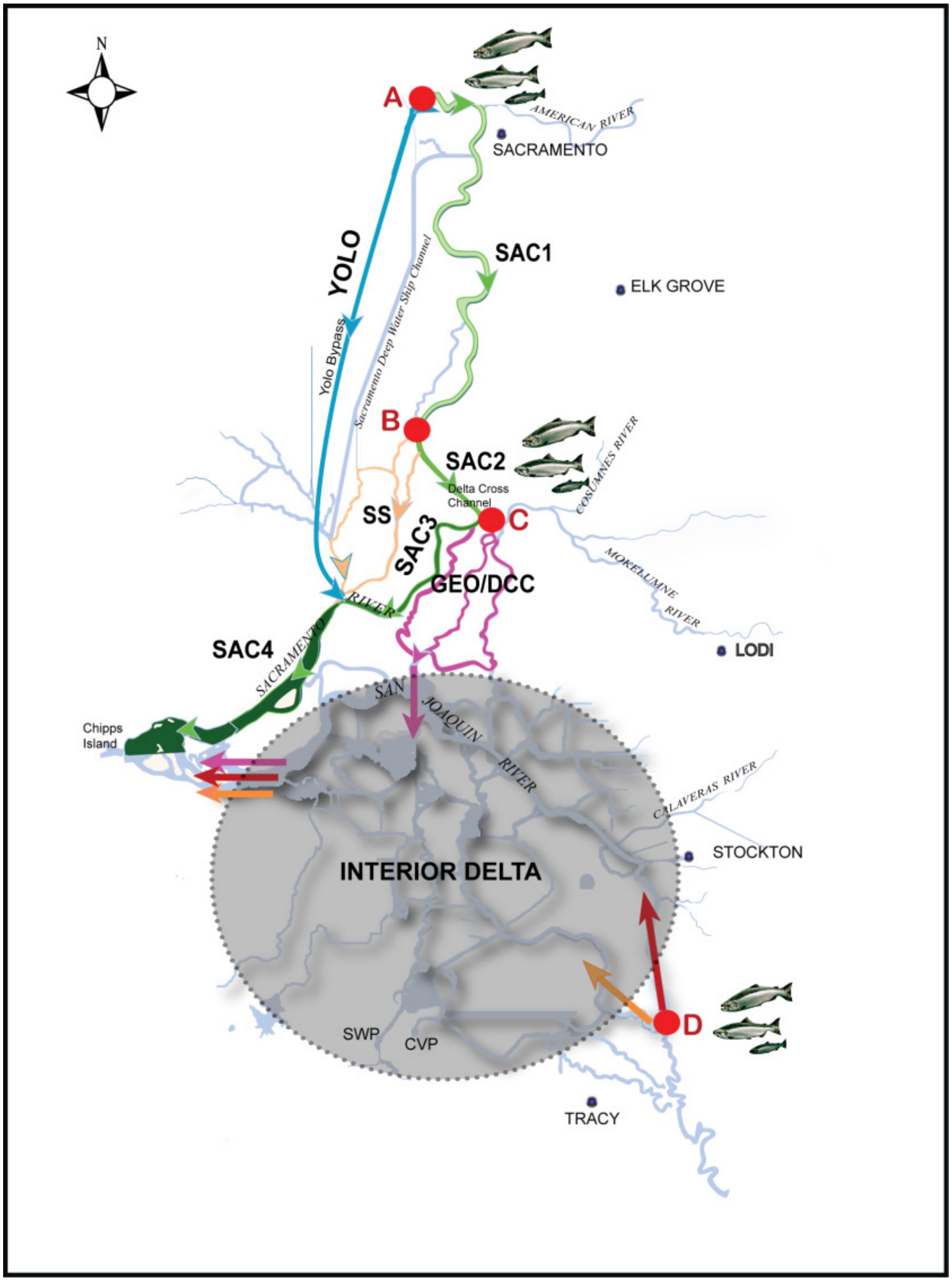

Figure 9J.1 DPM model Reaches and Junctions in the Delta (Notes: Bold headings label modeled reaches and red circles indicate model junctions. Salmonid icons indicate locations where smolts enter the Delta in the DPM model.)

Table 9J.1 Description of Modeled Delta Reaches and Junctions in the DPM Model

Reach/Junction	Description	Reach Length (kilometers)
Sac1	Sacramento River from Freeport to junction with Sutter Slough	41.04
Sac2	Sacramento River from Sutter Slough junction to junction with DCC)	10.78
Sac3	Sacramento River from DCC to Rio Vista	22.37
Sac4	Sacramento River from Rio Vista to Chipps Island	23.98
Yolo	Yolo Bypass from entrance at Fremont Weir to Rio Vista	– [a]
SS	Combined reach of Sutter Slough and Steamboat Slough ending at Rio Vista	26.72
Geo/DCC	Combined reach of Georgiana Slough, DCC, and Sough and North forks of the Mokelumne River ending at confluence with San Joaquin River	25.59
Interior Delta	Begins at end of reach Geo/DCC, San Joaquin River via Junction D, or Old River via Junction D, and ends at Chipps Island	– [b]
A	Junction of Yolo Bypass and Sacramento River	Not applicable
B	Combined junction of Sutter Slough and Steamboat Slough with Sacramento River	Not applicable
C	Combined junction of DCC and Georgiana Slough with Sacramento River	Not applicable
D	Junction of Old River with San Joaquin River	Not applicable

Notes:

a. Reach length for Yolo Bypass is currently undefined because reach length is not currently used to calculate Yolo Bypass speed and ultimate travel time.

b. Reach length for the Interior Delta is undefined due to the multiple pathways salmon can take. Timing through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

At each junction in the model, smolts move in relation to the proportional movement of flow entering each route. Daily DSM2 flow data entering each route is used to inform the proportion of smolts entering each route at a junction. Smolts move in direct proportion to flow at all junctions except Junction C, where a non-proportional relationship is applied as defined by acoustic tagging study data.

9J.1.2 Model Analysis Scenario Assumptions

A major assumption of the DPM model is that surrogate fish data can be used to inform many model relationships. Simulation model relationships can often be informed by field data from outside the study region, laboratory studies in controlled experimental settings, or artificially raised (hatchery) surrogates. For example, many of our model relationships rely on data from tagged hatchery surrogates because experimental studies often rely on easily accessible hatchery-origin fish and assume that fish responses are at least similar among individuals of different natal origins. In addition to limited data on wild fish, many of the model relationships are informed by data from a single Chinook Salmon race, thereby making the assumption that all races move, grow, and survive according to the same rules.

9J.2 Model Analysis Results

DPM model results are organized by each Chinook Salmon run (spring-run, winter-run, fall-run, and late-fall-run). Differences in Delta survival of juvenile Chinook Salmon between scenarios are displayed as time histories across all 81 water years (1922-2002), and box plots of median survival across all years. The following scenario comparisons are presented in Figures 9J.2 through 9J.41.

- No Action Alternative compared to the Second Basis of Comparison
- Alternative 3 compared to the No Action Alternative
- Alternative 3 compared to the Second Basis of Comparison
- Alternative 5 compared to the No Action Alternative
- Alternative 5 compared to the Second Basis of Comparison

9J.3 References

Michel, C. 2010. “River and estuarine survival and migration of yearling Sacramento River Chinook salmon (Oncorhynchus tshawytscha) smolts and the influence of environment.” Masters Thesis, University of California Santa Cruz, Santa Cruz, CA.

Newman, K. B. 2008. *An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies*. Project number SCI-06-G06-299. U.S. Fish and Wildlife Service. November.

Newman, K.B. 2010. “Analyses of Salmon CWT releases into the San Joaquin system.” Handout to the VAMP review panel. March 2nd 2010.

Newman, K.B. & Brandes, P.L. 2010. “Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports.” *North American Journal of Fisheries Management* 30:157-169.

Perry, R.W., Skalski, J.R., Brandes, P.L., Sandstrom, P.T., Klimley, A.P., Ammann, A. and MacFarlane. 2010. “Estimating survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta.” *North American Journal of Fisheries Management*. 30:142-156.

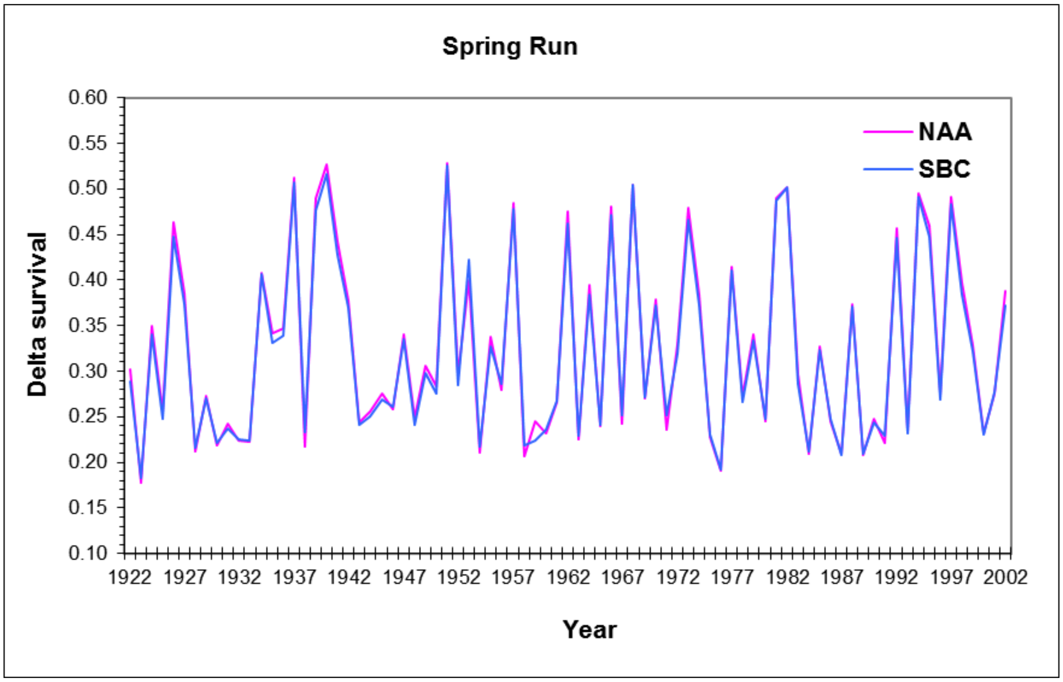

Figure 9J.2 Annual Delta Survival for Spring-run Chinook Salmon under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) over 81 water years estimated by the DPM model

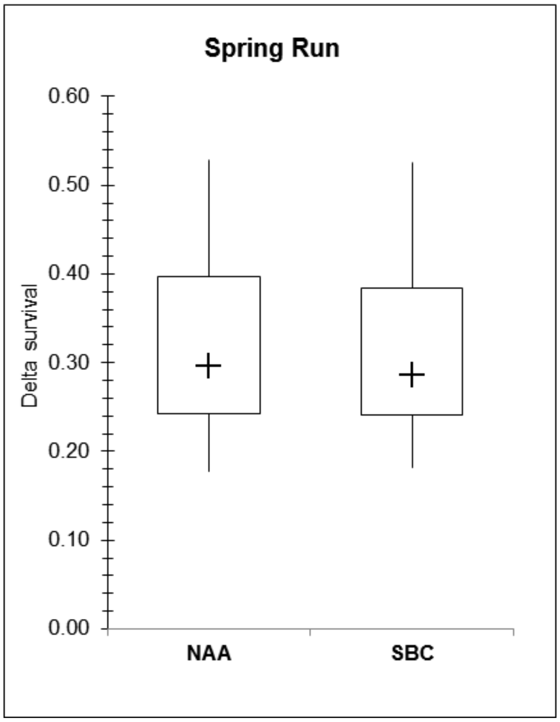

Figure 9J.3 Annual Delta Survival for Spring-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

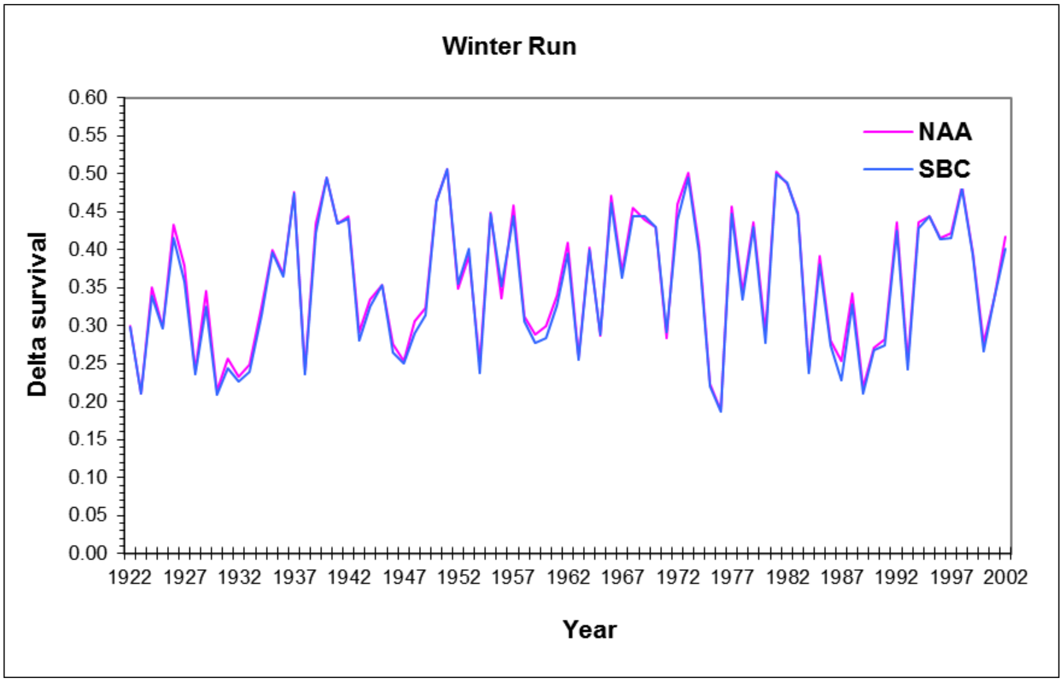

Figure 9J.4 Annual Delta Survival for Winter-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

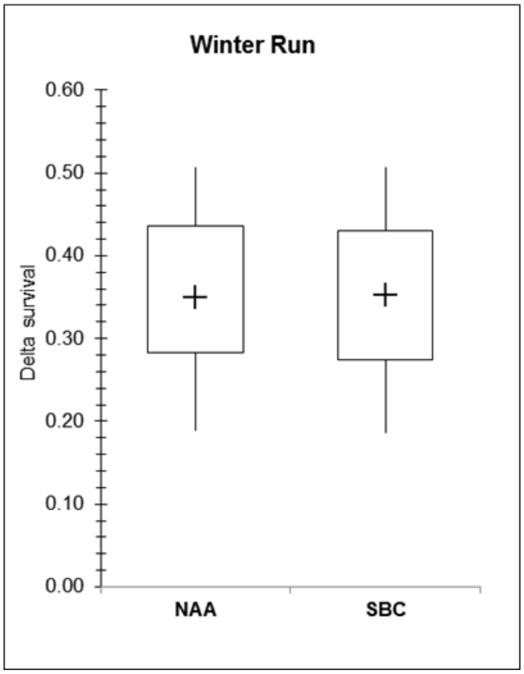

Figure 9J.5 Annual Delta Survival for Winter-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

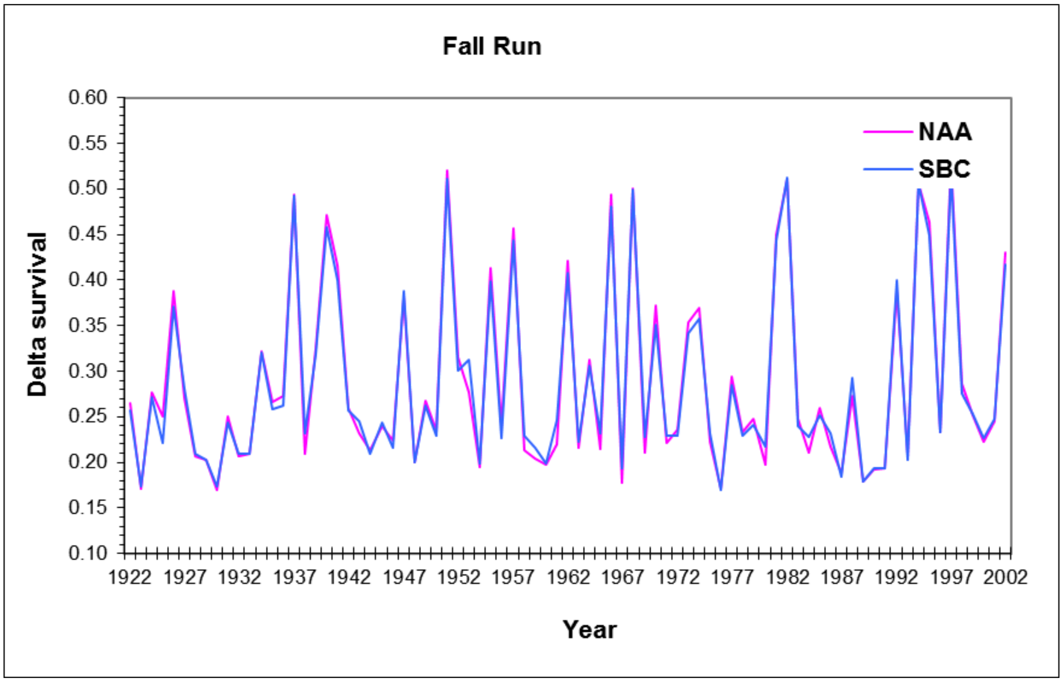

Figure 9J.6 Annual Delta Survival for Fall-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

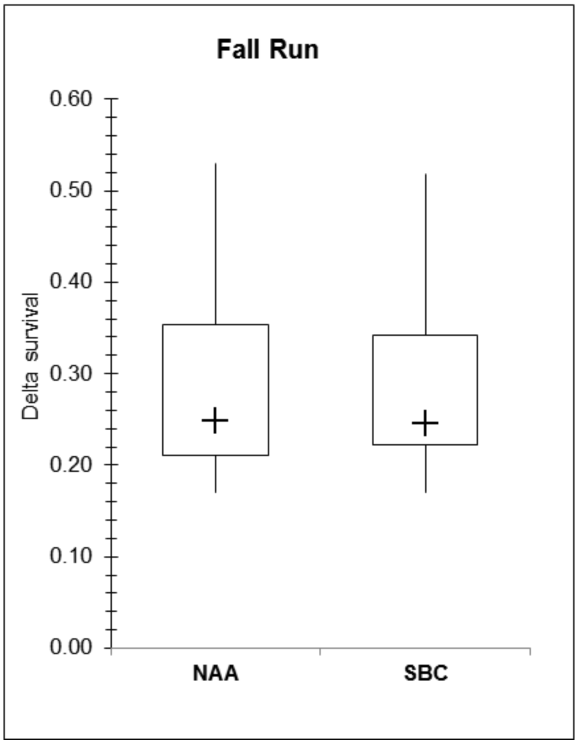

Figure 9J.7 Annual Delta Survival for Fall-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

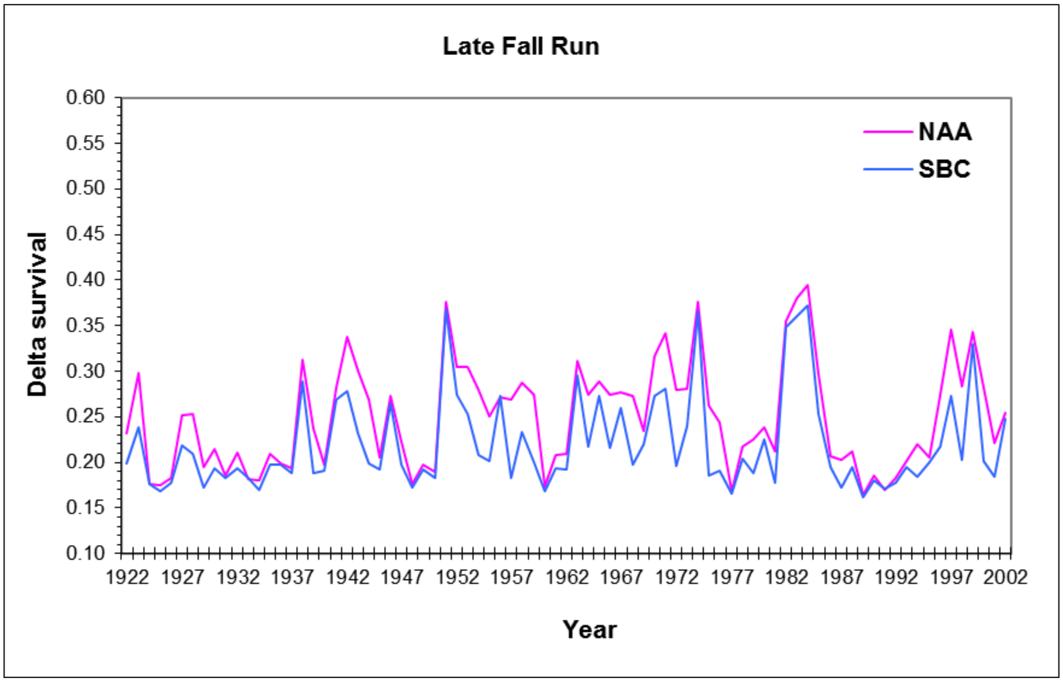

Figure 9J.8 Annual Delta Survival for Late Fall-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

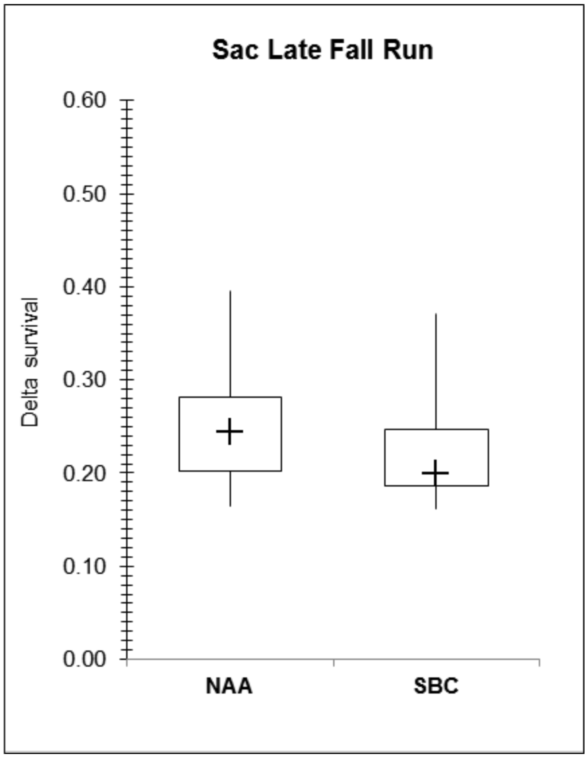

Figure 9J.9 Annual Delta Survival for Late Fall-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

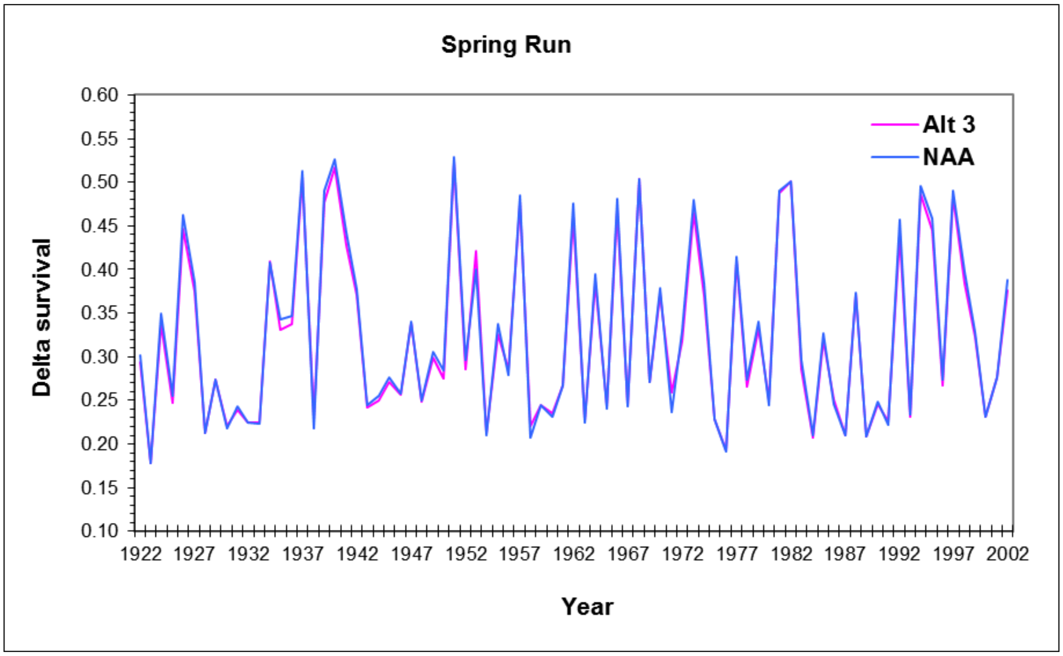

Figure 9J.10 Annual Delta Survival for Spring-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the NAA over 81 water years estimated by the DPM model

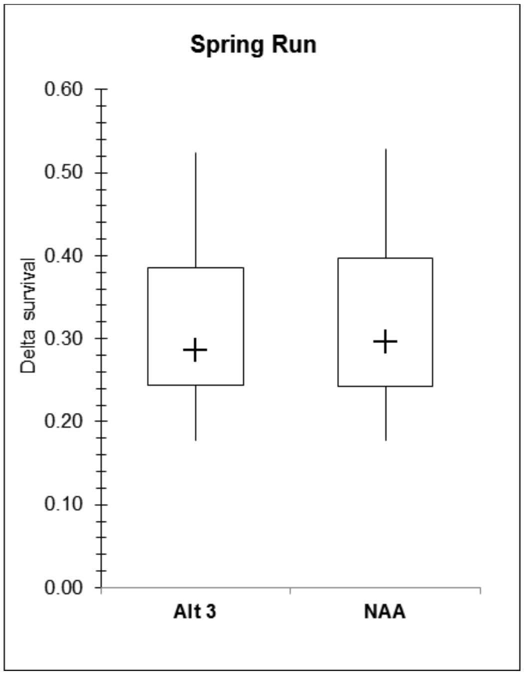

Figure 9J.11 Annual Delta Survival for Spring-run chinook under Alternative 3 (Alt 3) as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

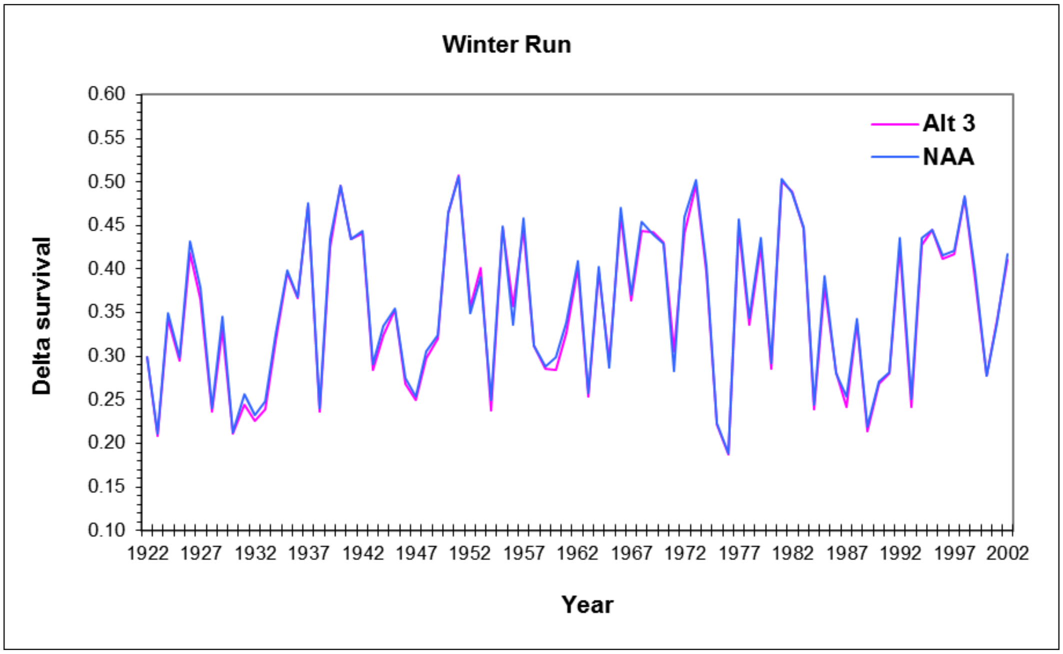

Figure 9J.12 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

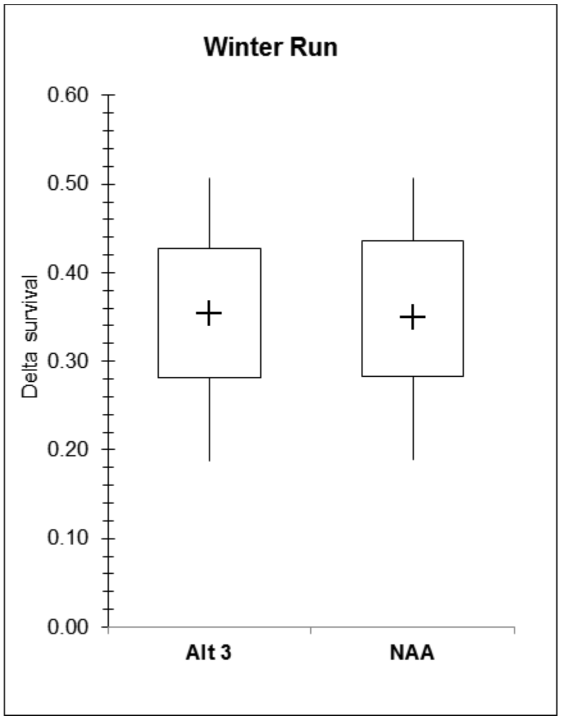

Figure 9J.13 Annual Delta Survival for Winter-run Chinook under Alternative 3 (Alt 3) as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

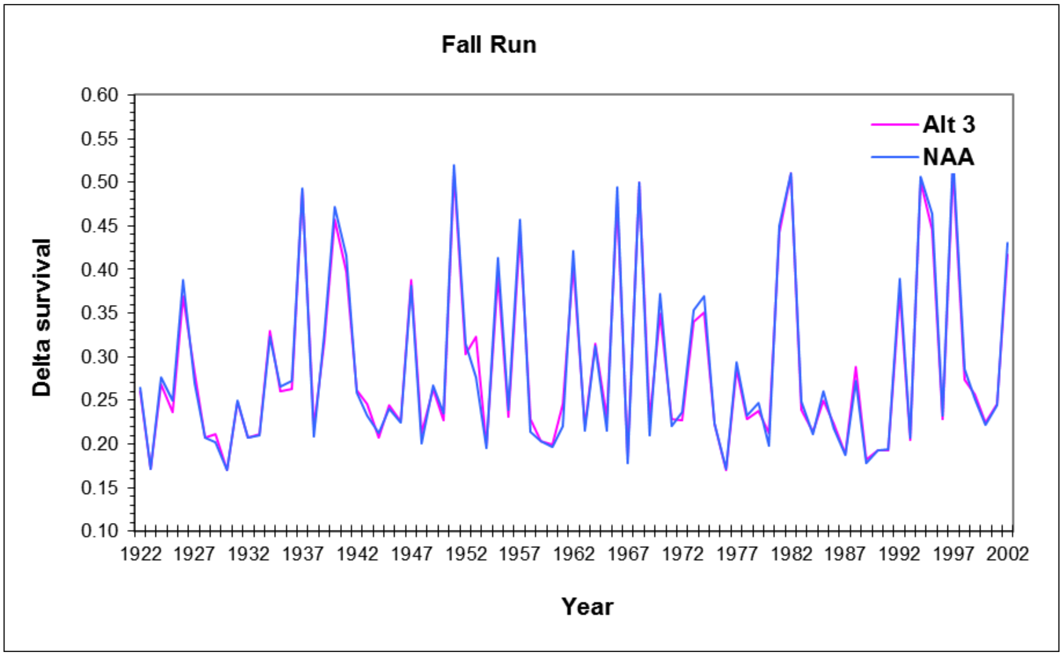

Figure 9J.14 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

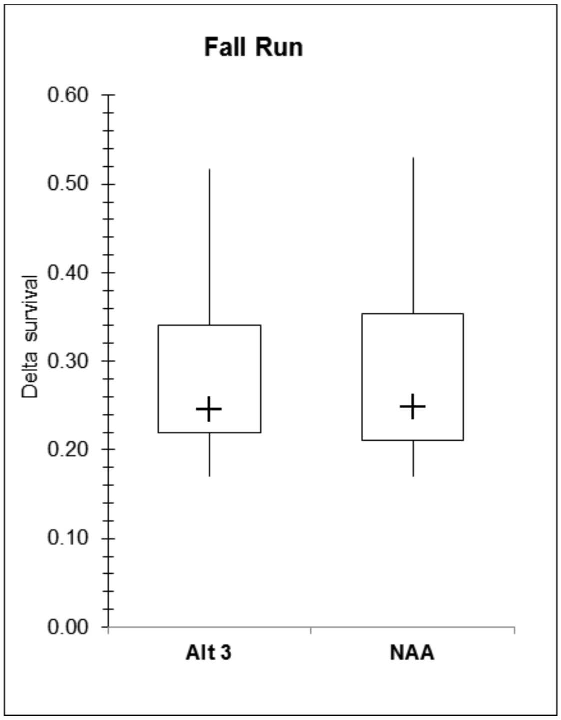

Figure 9J.15 Annual Delta Survival for Fall-run Chinook under Alt 3 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

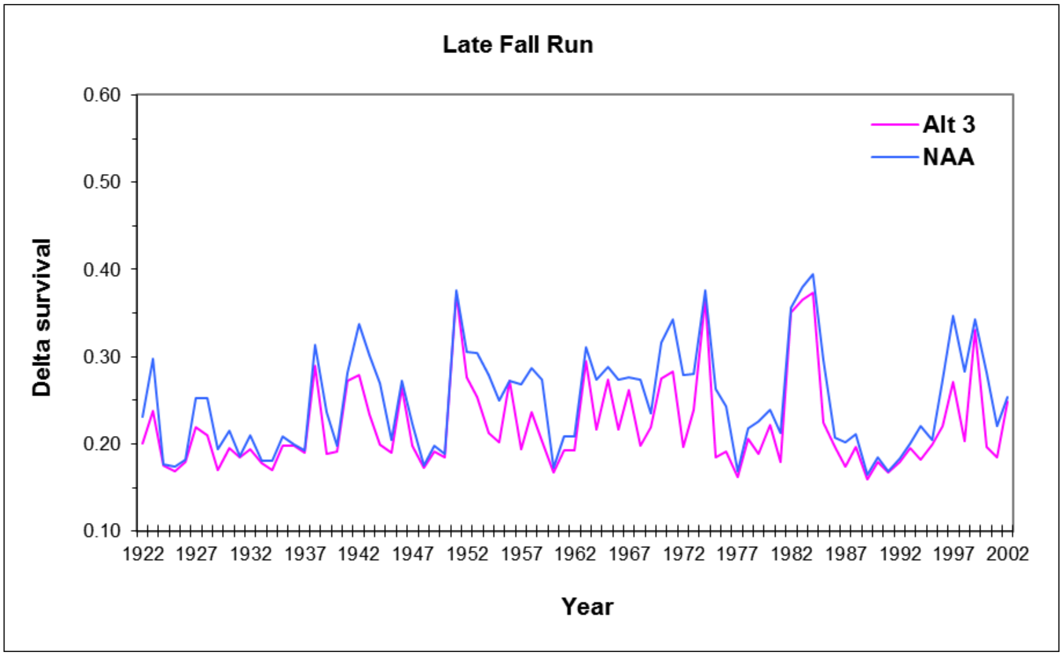

Figure 9J.16 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

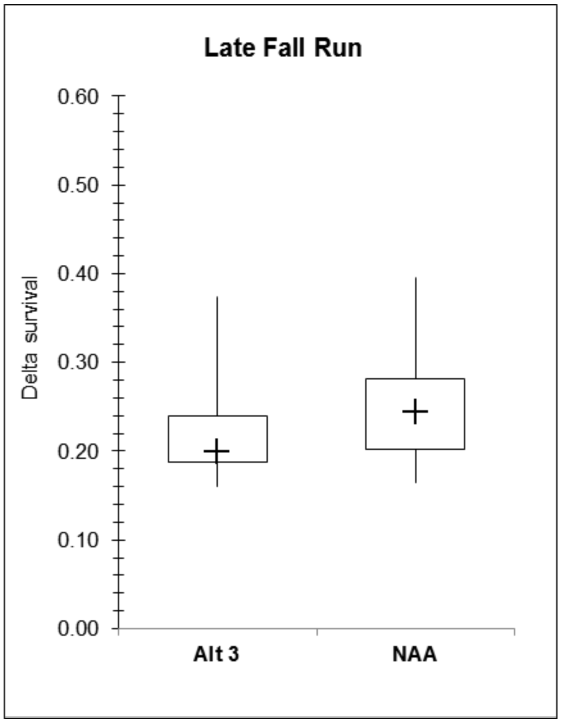

Figure 9J.17 Annual Delta Survival for Late Fall-run Chinook under Alt 3 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

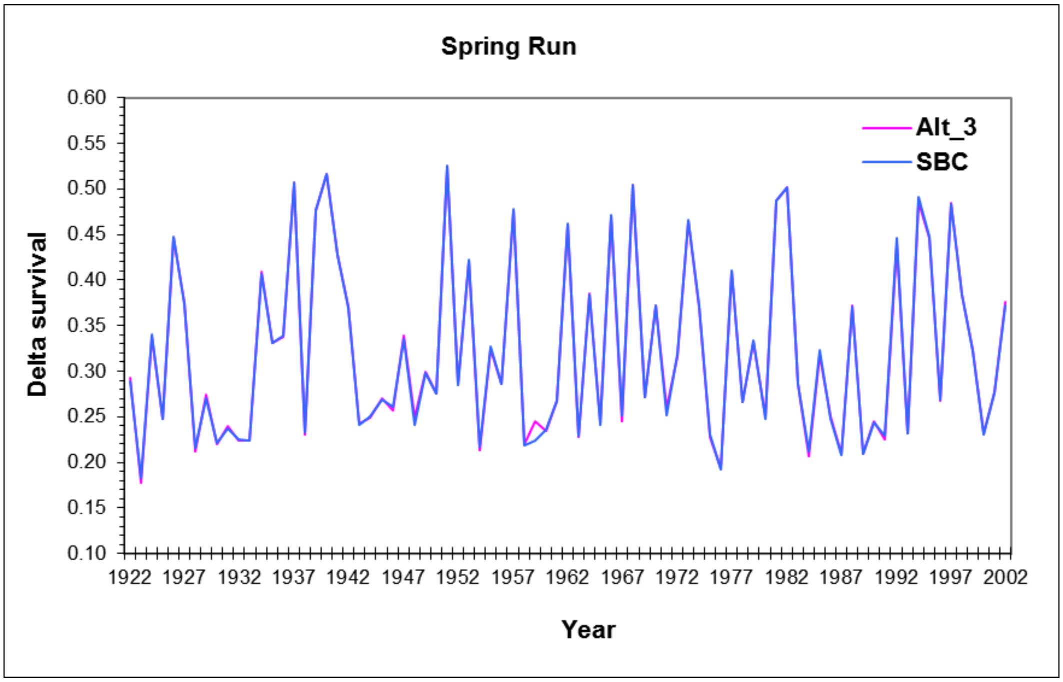

Figure 9J.18 Annual Delta Survival for Spring-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

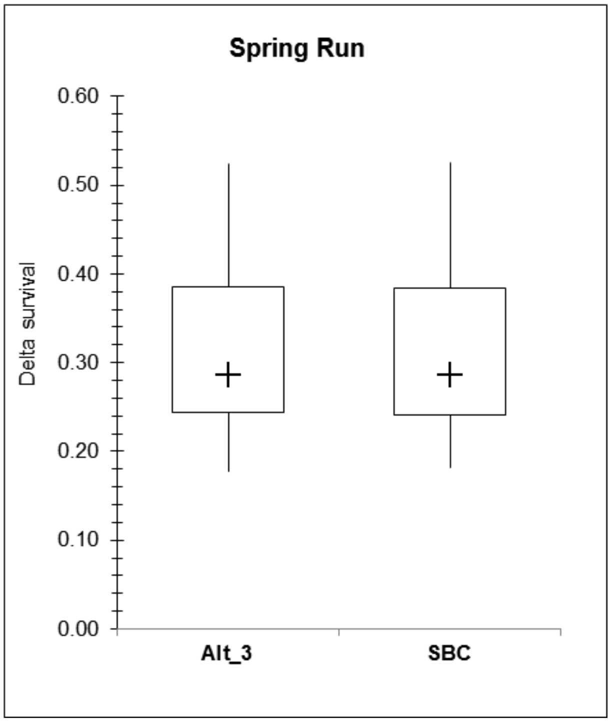

Figure 9J.19 Annual Delta Survival for Spring-run Chinook Salmon under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

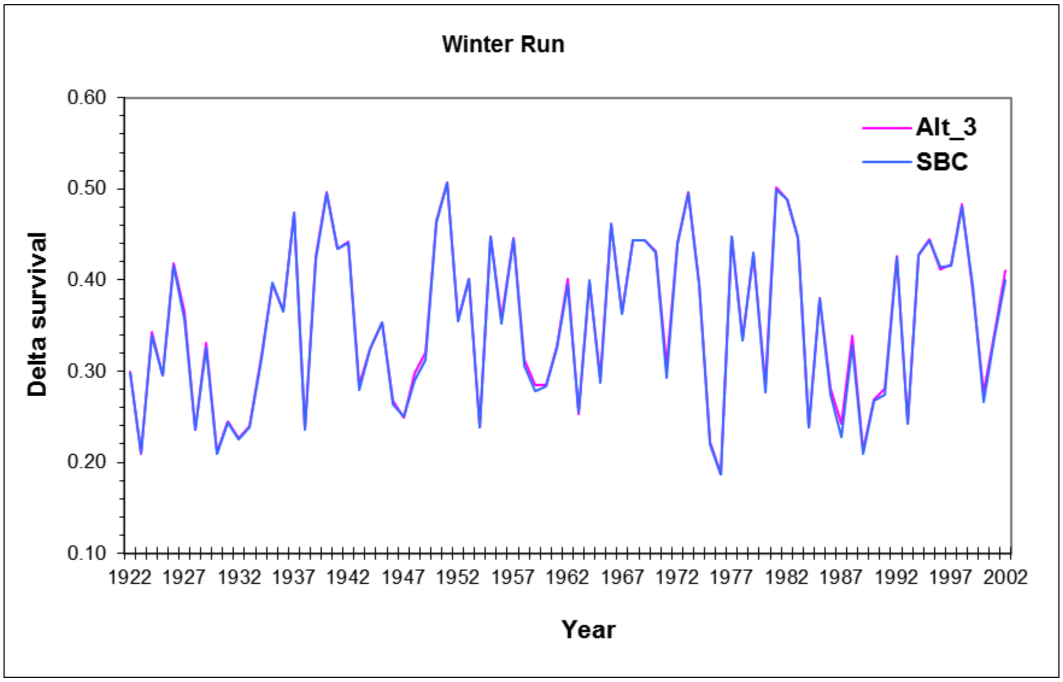

Figure 9J.20 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

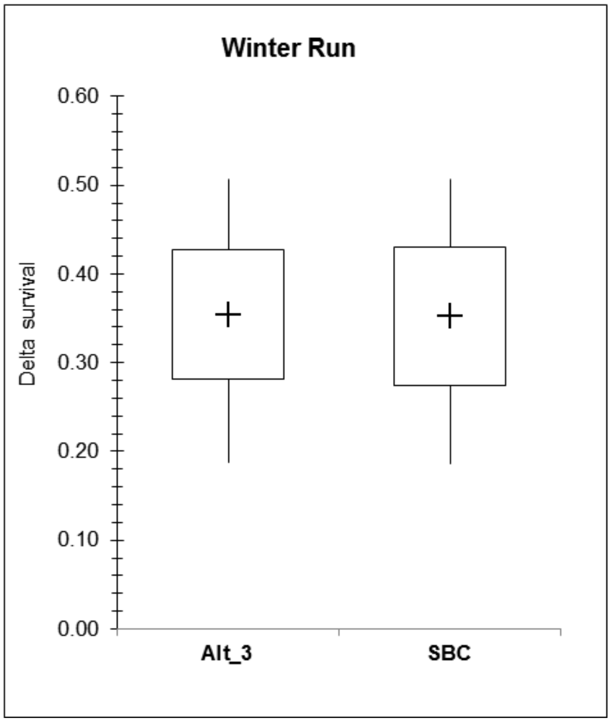

Figure 9J.21 Annual Delta Survival for Winter-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

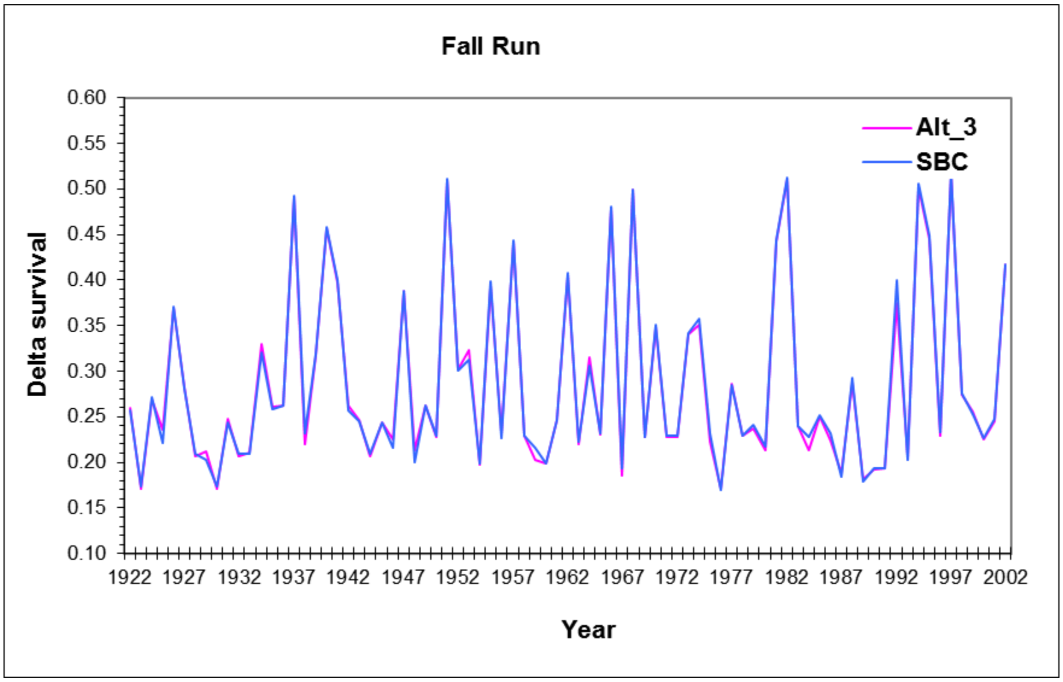

Figure 9J.22 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

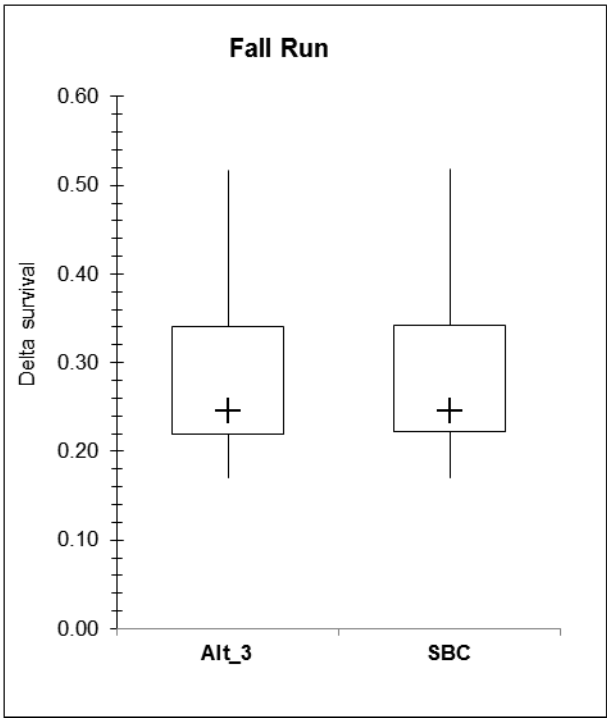

Figure 9J.23 Annual Delta Survival for Fall-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

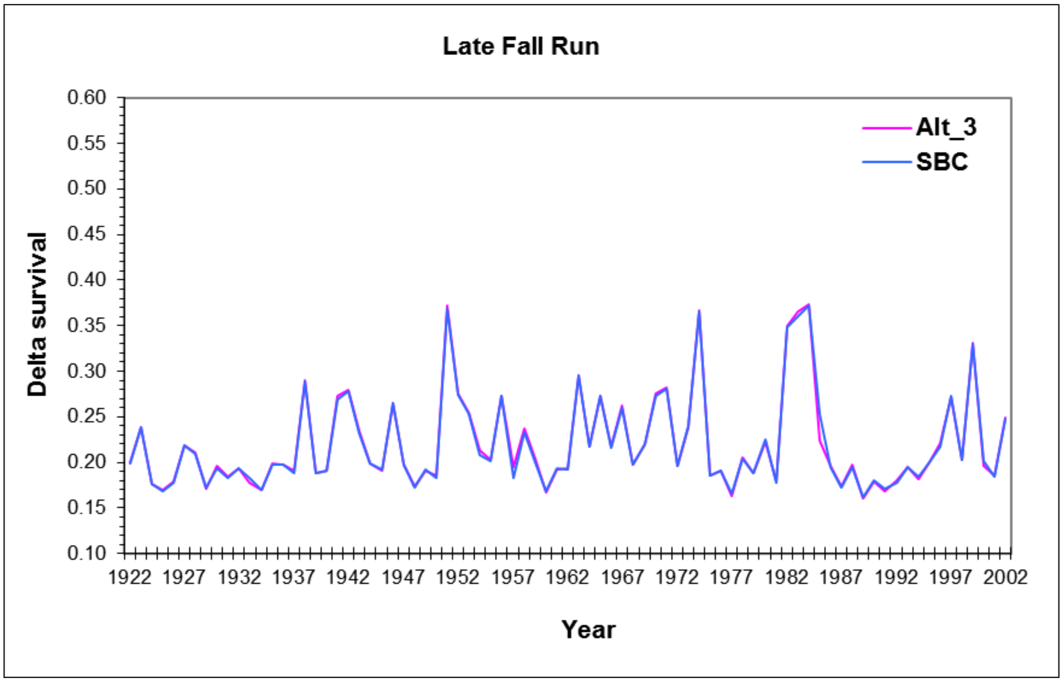

Figure 9J.24 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

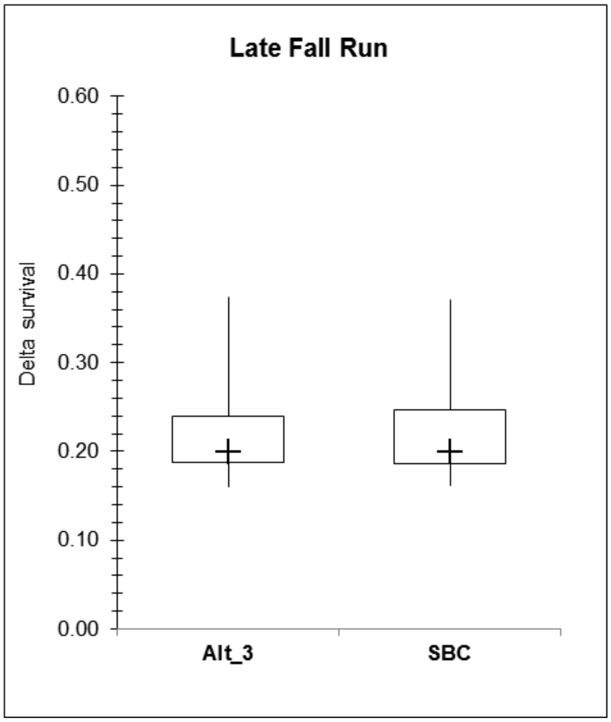

Figure 9J.25 Annual Delta Survival for Late Fall-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

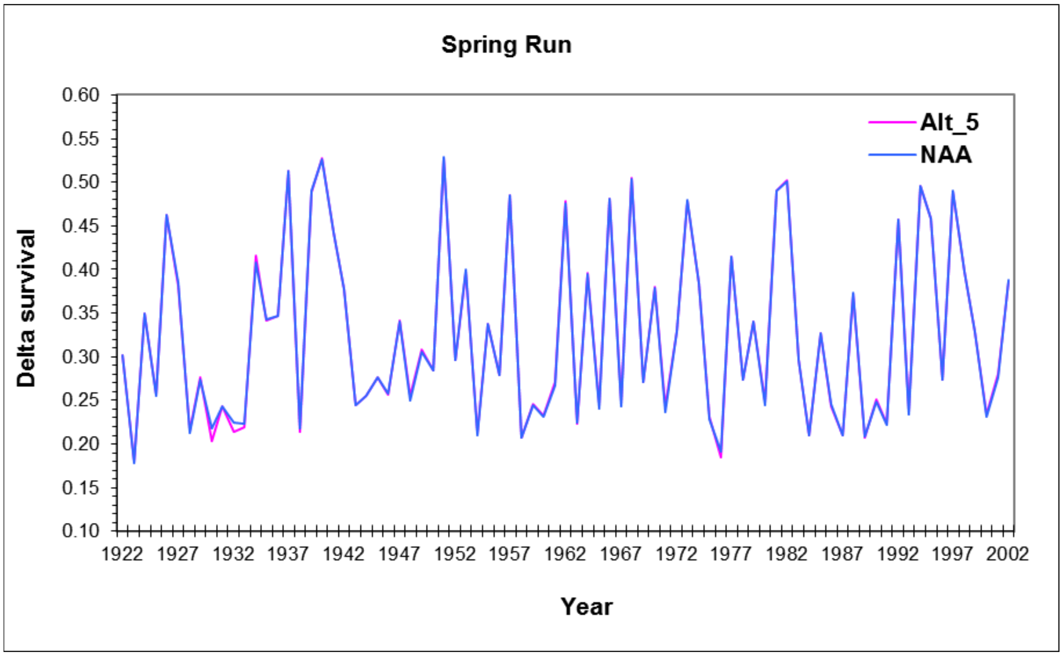

Figure 9J.26 Annual Delta Survival for Spring-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the NAA over 81 water years estimated by the DPM model

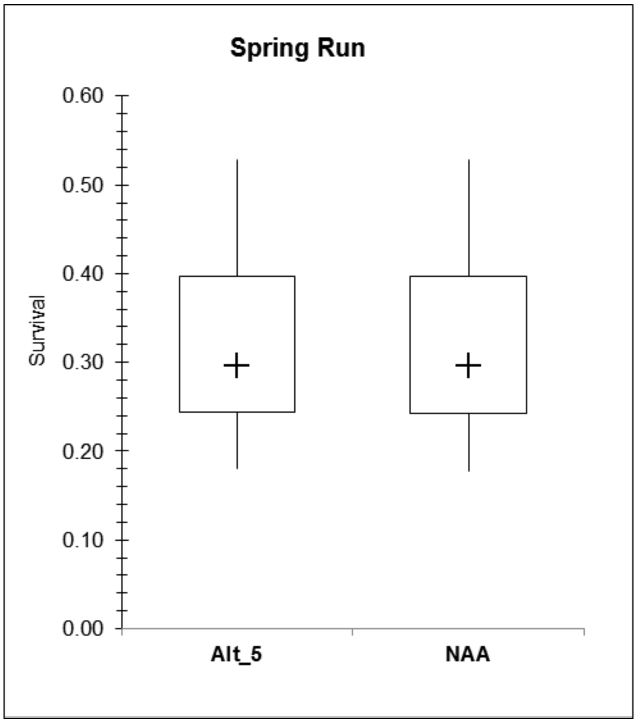

Figure 9J.27 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

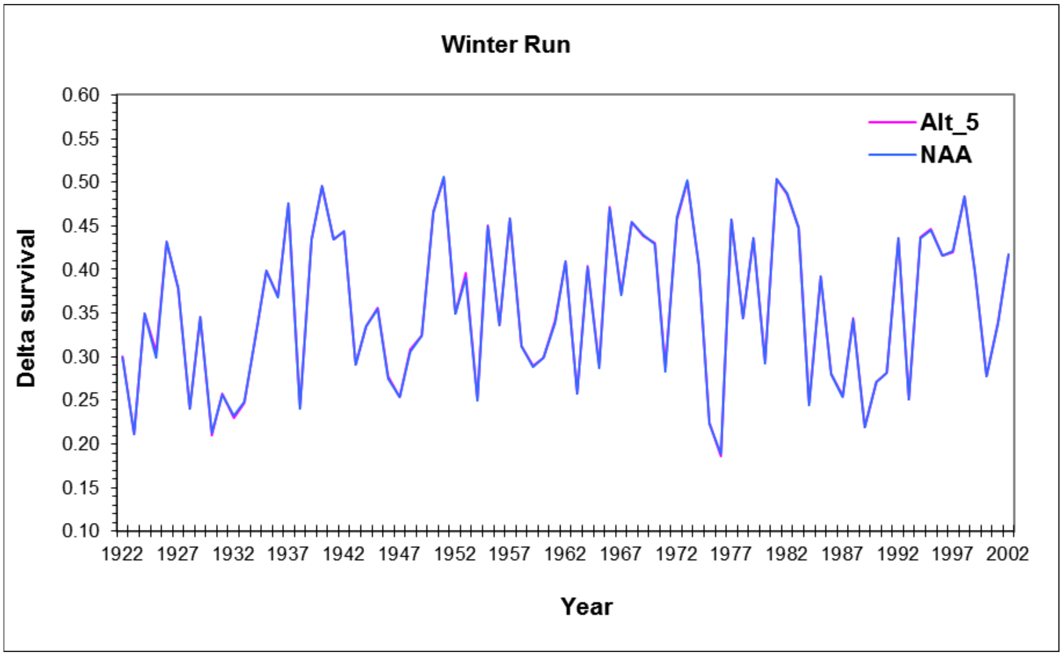

Figure 9J.28 Annual Delta Survival for Winter-run Chinook Salmon under Alt 5 as compared to the NAA over 81 water years estimated by the DPM model

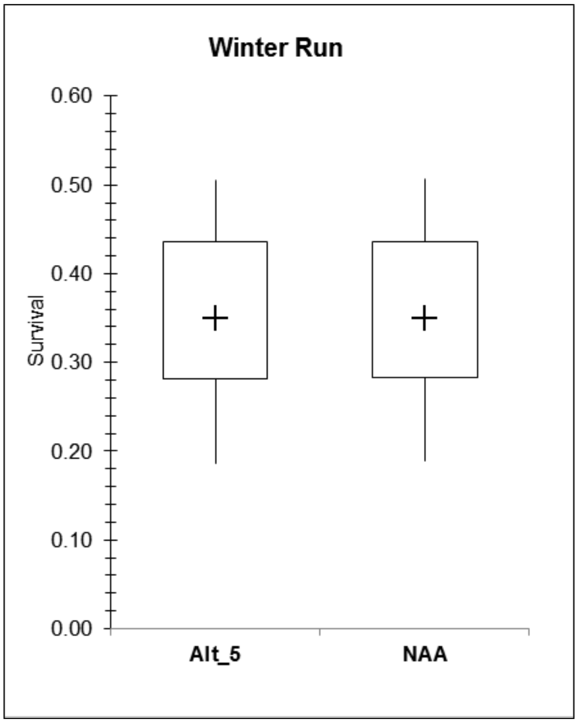

Figure 9J.29 Annual Delta Survival for Winter-run Chinook under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

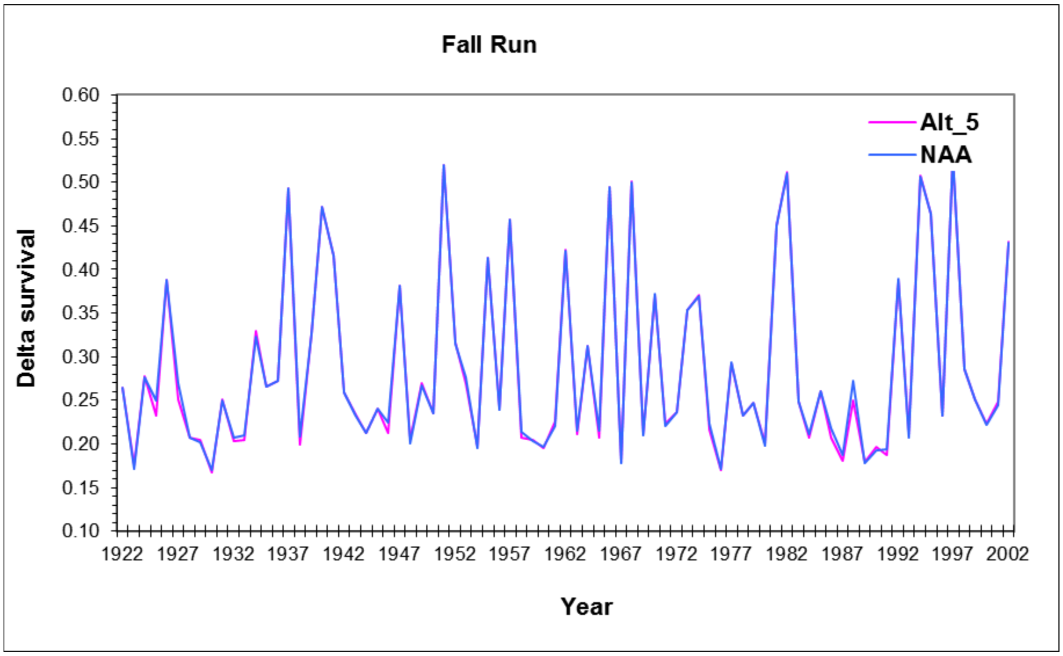

Figure 9J.30 Annual Delta Survival for Fall-run Chinook Salmon under (Alt 5) as compared to the NAA over 81 water years estimated by the DPM model

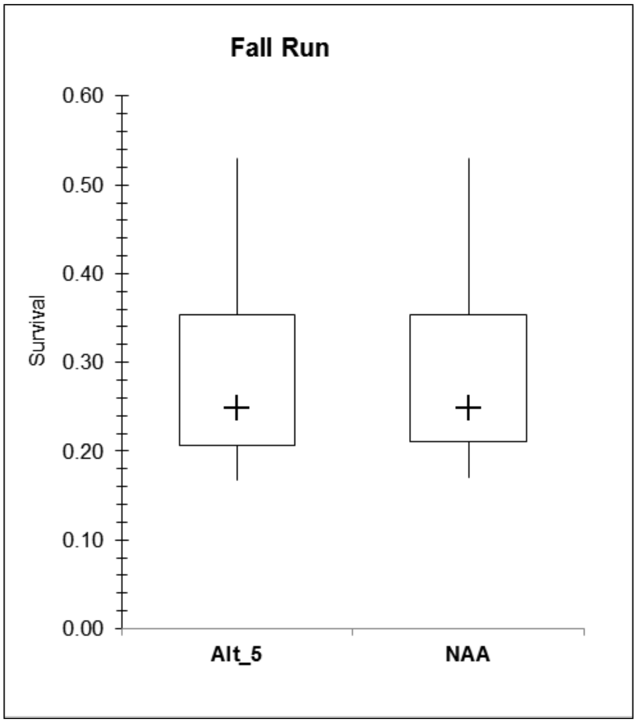

Figure 9J.31 Annual Delta Survival for Fall-run Chinook under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

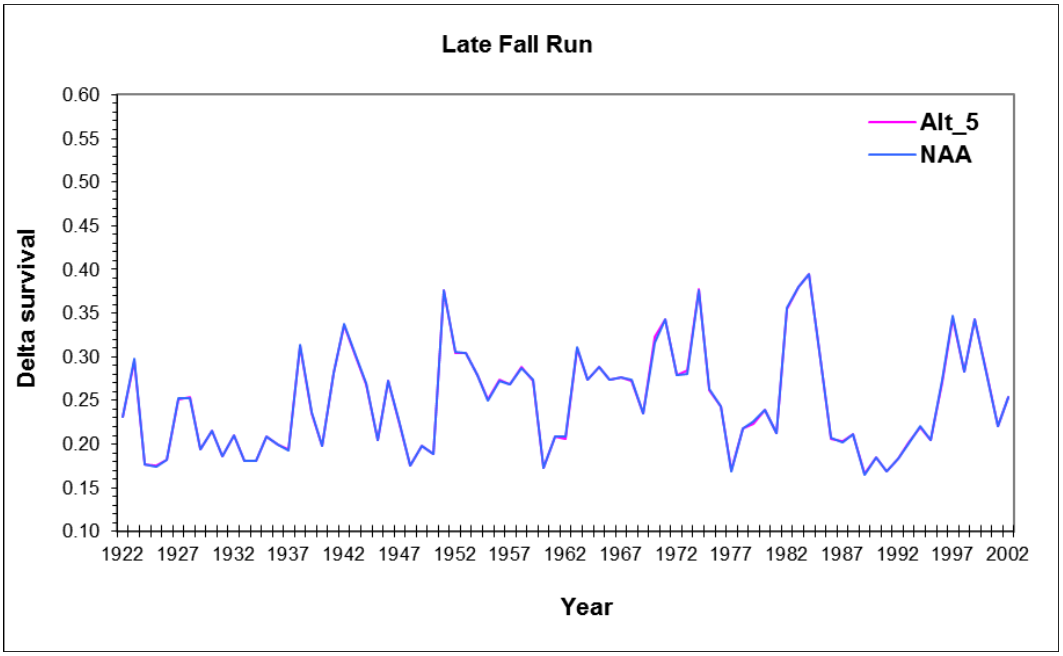

Figure 9J.32 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 5 as compared to the NAA over 81 water years estimated by the DPM model

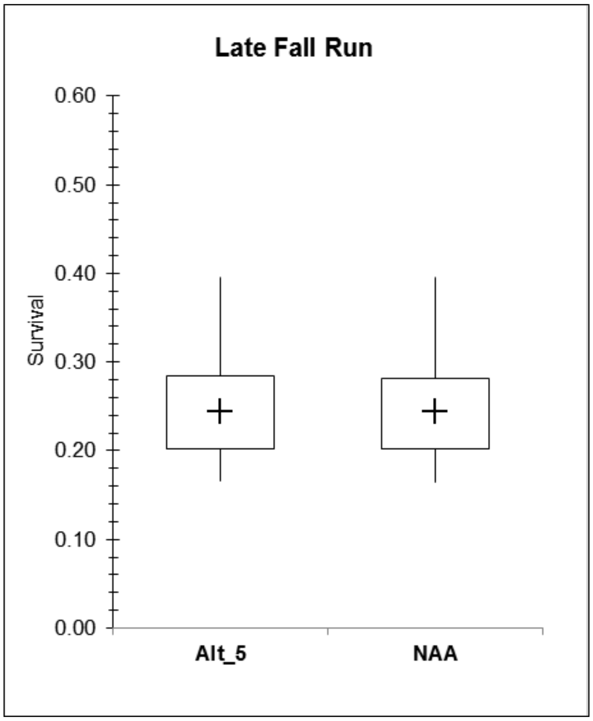

Figure 9J.33 Annual Delta Survival for Late Fall-run Chinook Salmond under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

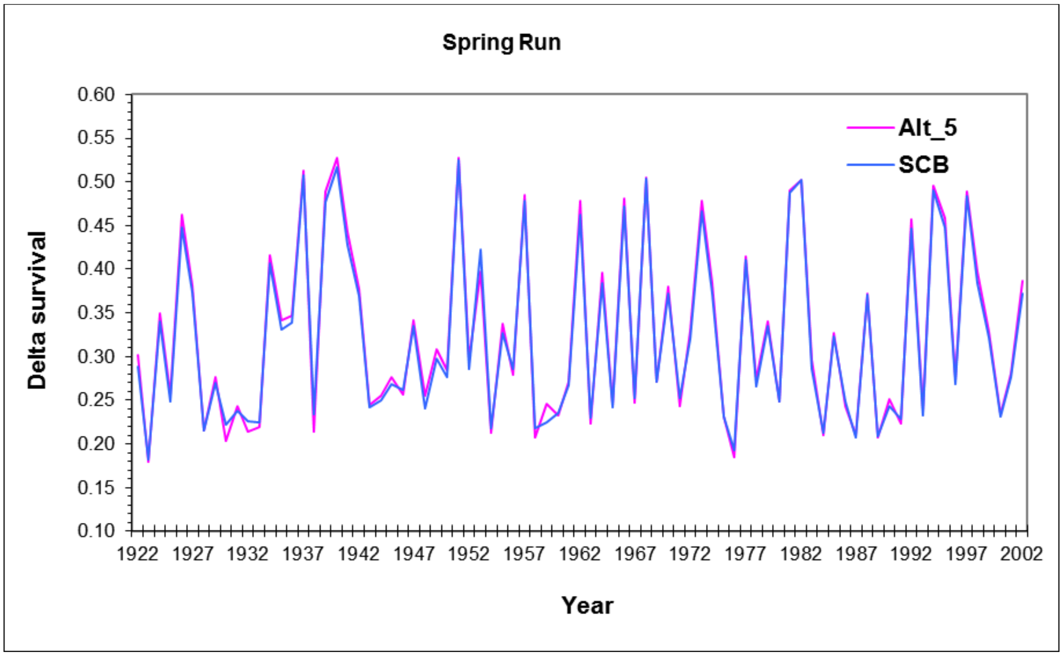

Figure 9J.34 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the SBC over 81 water years estimated by the DPM model

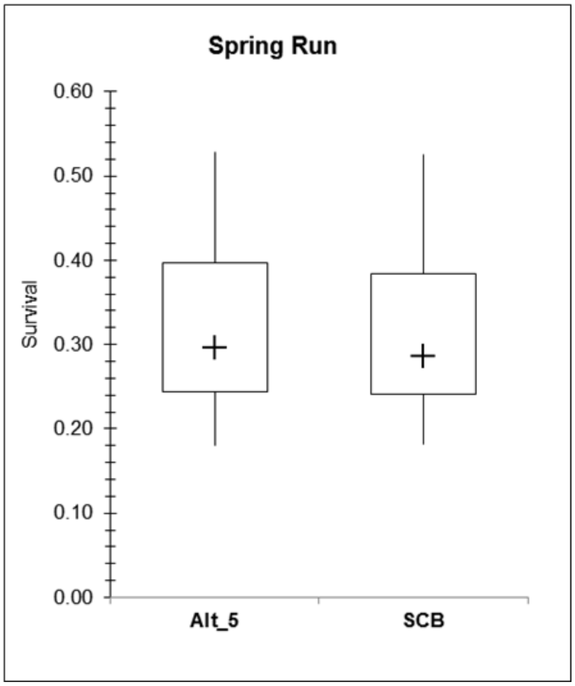

Figure 9J.35 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

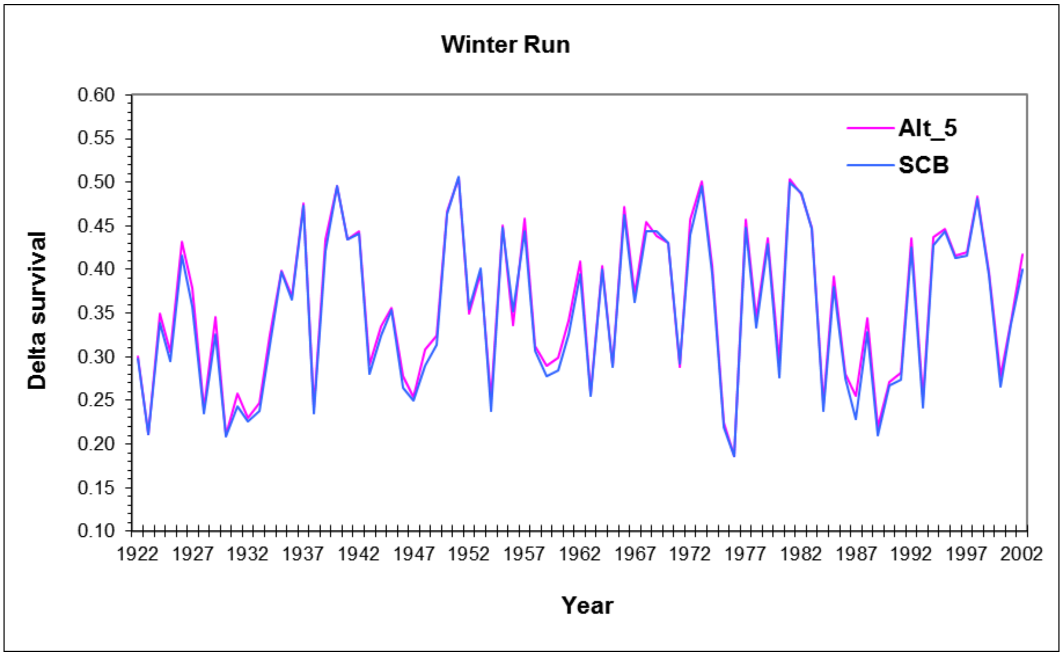

Figure 9J.36 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

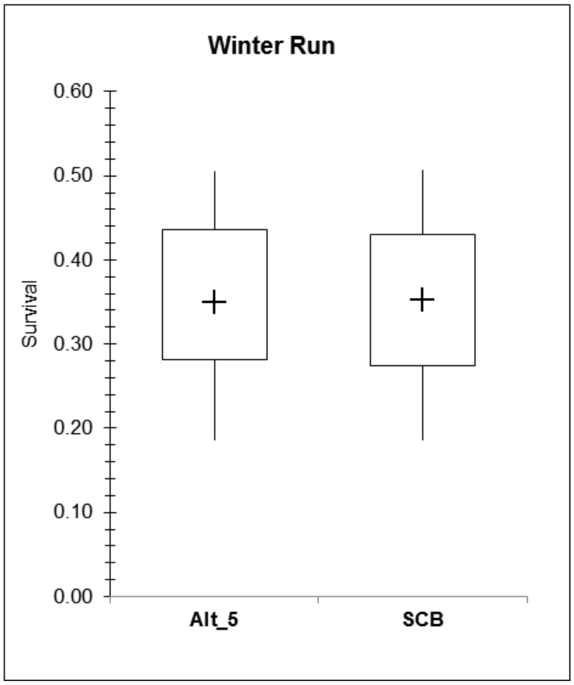

Figure 9J.37 Annual Delta Survival for Winter-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

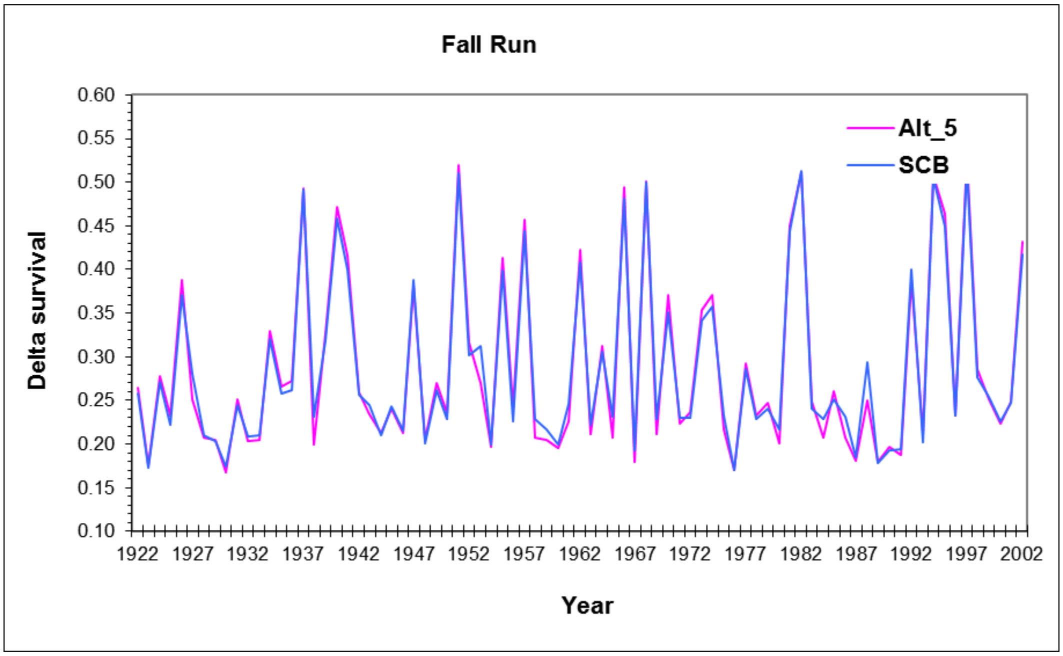

Figure 9J.38 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

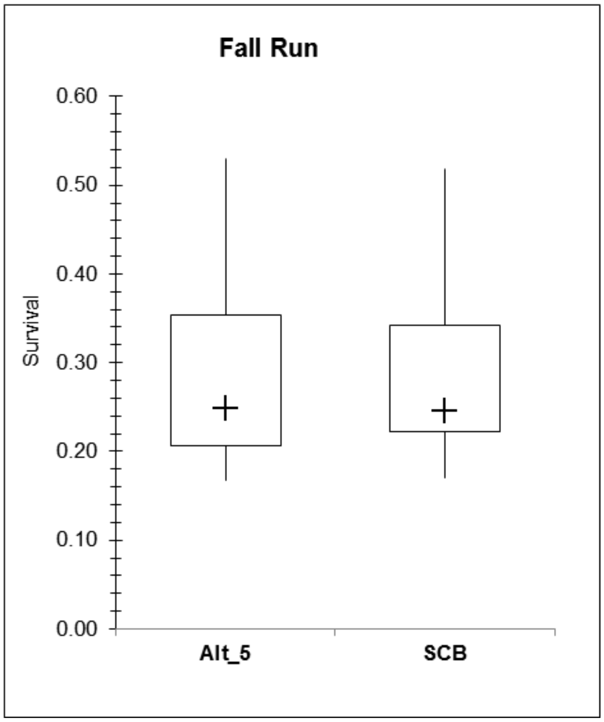

Figure 9J.39 Annual Delta Survival for Fall-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

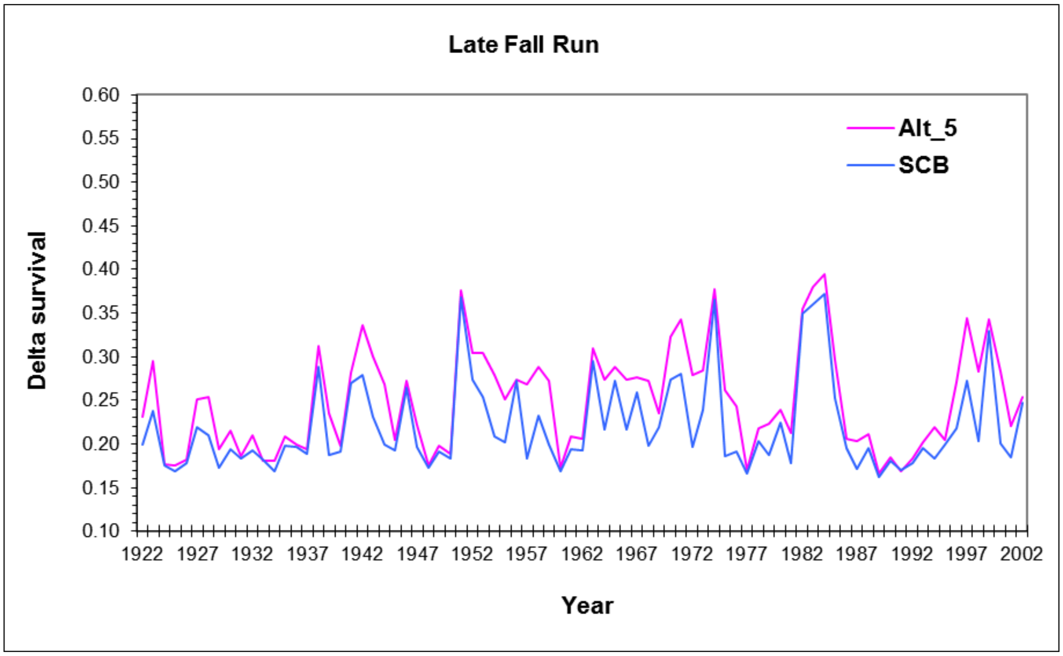

Figure 9J.40 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

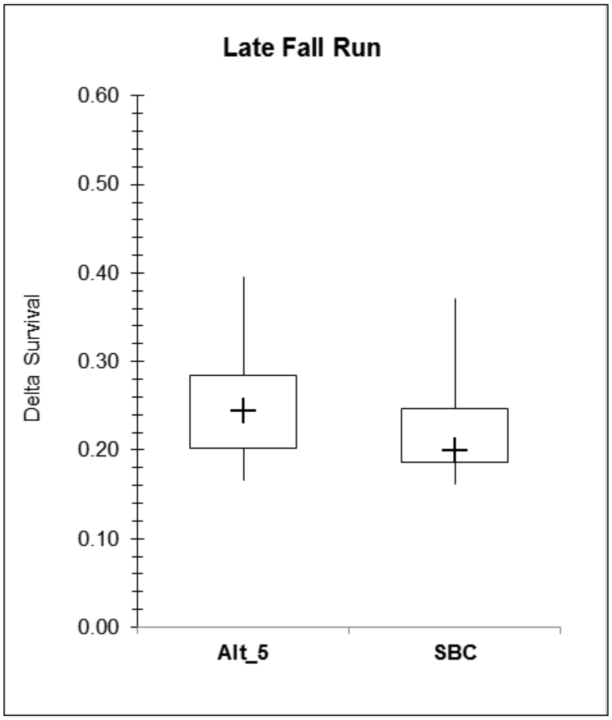

Figure 9J.41 Annual Delta Survival for Late Fall-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

Appendix 9K

Delta Hydrodynamic Analysis Documentation

This appendix provides information about the methods and assumptions used for the Coordinated Long Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis using the Delta Hydrodynamic analysis. This appendix is organized into the following sections:

- Section 9K.1: Delta Hydrodynamic Analysis Methodology and Assumptions
  - The Delta Hydrodynamic analysis summarizes 15-minute velocity output from DSM2 over the 82-year simulation period (1922 to 2003). This section briefly describes the approach and assumptions for the Delta Hydrodynamic analysis.
- Section 9K.2: Delta Hydrodynamic Analysis Results
  - This section presents the results of the Delta Hydrodynamic analysis. Results are presented in a series of figures showing the proportion positive velocity for each alternative comparison for five DSM2 Hydro channels.

9K.1 Delta Hydrodynamic Analysis Methodology and Assumptions

9K.1.1 Delta Hydrodynamic Analysis Methodology

For this analysis, 15-minute DSM2 Hydro output (velocity) was summarized over the 82-year simulation period (1922 to 2003) at the midpoint of five DSM2 channels, as follows:

- San Joaquin River mainstem downstream of the Head of Old River (DSM2 channel 21)
- Old River downstream of the facilities (DSM2 channel 212)
- Old River upstream of the facilities (DSM2 channel 94)
- Sacramento River near Georgiana Slough (DSM2 channel 421)
- San Joaquin River mainstem near the confluence with the Mokelumne River (DSM2 channel 45)

DSM2 output is summarized as the proportion of 15-minute observations with a value greater than 0 feet/second (proportion positive velocity). The proportion positive velocity is selected as the hydrodynamic metric because there is evidence that juvenile anadromous fish selectively migrate with the tides (Forward and Tankersly 2001). Thus, in a tidally-influenced system, a metric that measures the frequency and directionality of the velocity (proportion positive velocity) is arguably more relevant for anadromous fish migration than a metric that measures the magnitude of the velocity (e.g., mean velocity).

The 15-minute observations were summarized for every combination of scenario (No Action Alternative, Second Basis of Comparison, Alternative 3, and Alternative 5) for 81 water years (1922 to 2003); DSM2 channels (21, 45, 94, 212, 421); and January through June to provide a total of 9,840 observations (4 * 82 * 5 * 6).

9K.1.2 Delta Hydrodynamic Analysis Scenario Assumptions

The key assumption in the Delta Hydrodynamic analysis is that the proportion positive velocity of a channel, measured at a monthly time step, is an indicator of the likelihood that juvenile anadromous fish will successfully migrate through that channel towards the ocean.

9K.2 Delta Hydrodynamic Analysis Results

The results are provided as box-whiskers plots[1] summarizing the proportion of positive velocities in each month at various locations over the 82-year CalSim II simulation period for following runs:

- No Action Alternative
- Second Basis of Comparison (same as Alternative 1)
- Alternative 3
- Alternative 5

The following scenario comparisons are presented in Figures 9K.1 through 9K.25:

- No Action Alternative compared to the Second Basis of Comparison
- Alternative 3 compared to the No Action Alternative
- Alternative 3 compared to the Second Basis of Comparison
- Alternative 5 compared to the No Action Alternative
- Alternative 5 compared to the Second Basis of Comparison

9K.3 Reference

Forward, Jr. R.B. & R.A. Tankersley. 2001. "Selective Tidal-stream Transport of Marine Animals." *Oceanogr. Mar. Biol. Ann. Rev.* 39: 305-353.

---

[1] The box represents 25th and 75th percentiles, the line represents the median, and whiskers extend to the data point to 1.5 times the length of the box away from the box. Outliers are represented in points.

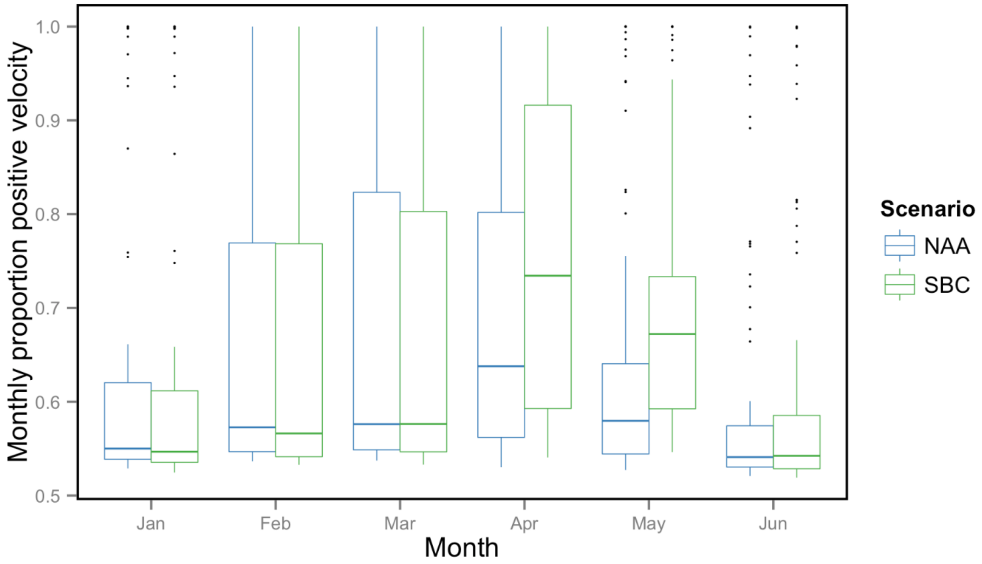

Figure 9K.1 Proportion of Monthly Positive Velocities in the San Joaquin River Downstream of the Head of Old River under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC)

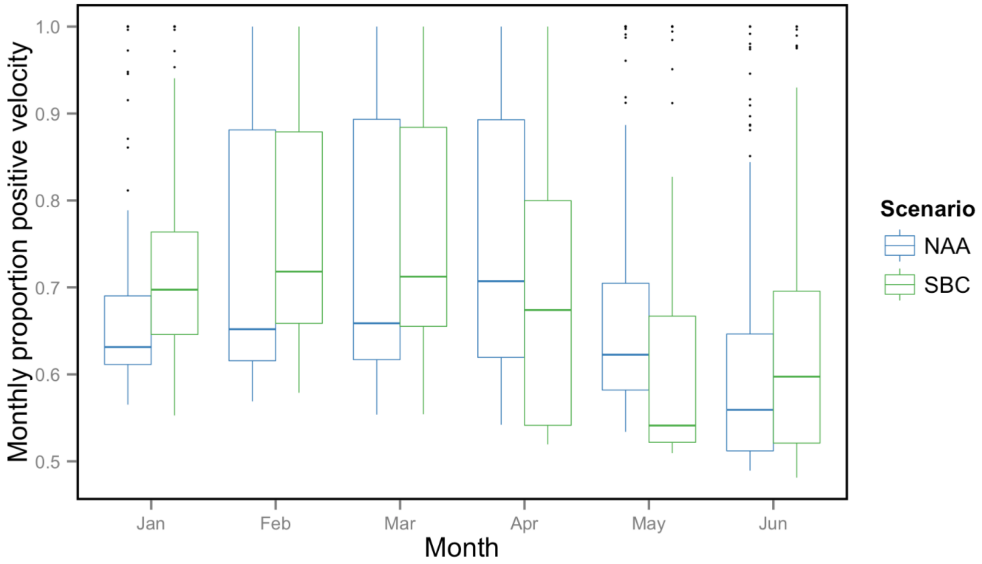

Figure 9K.2 Proportion of Monthly Positive Velocities in Old River Upstream of the Facilities under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC)

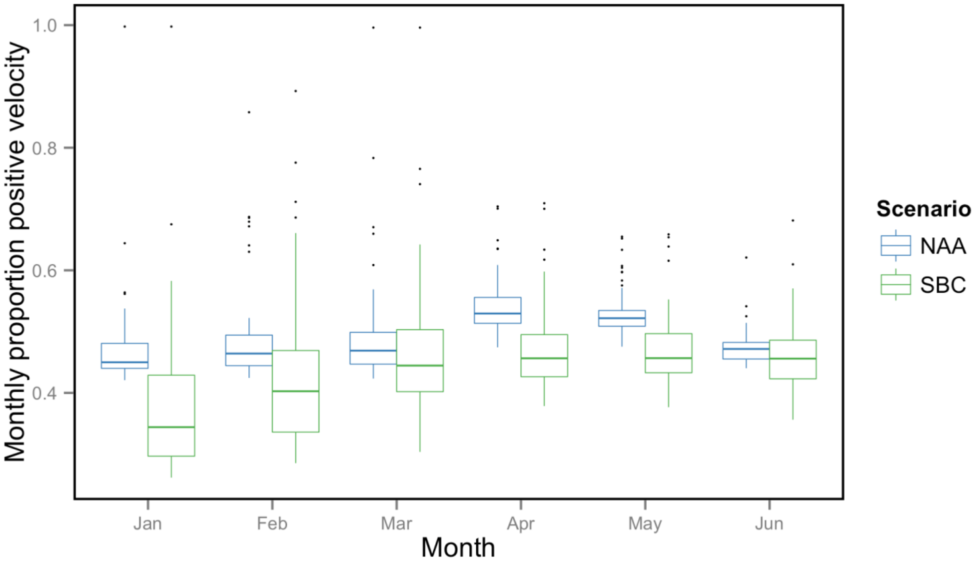

Figure 9K.3 Proportion of Monthly Positive Velocities in Old River Downstream of the Facilities under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC)

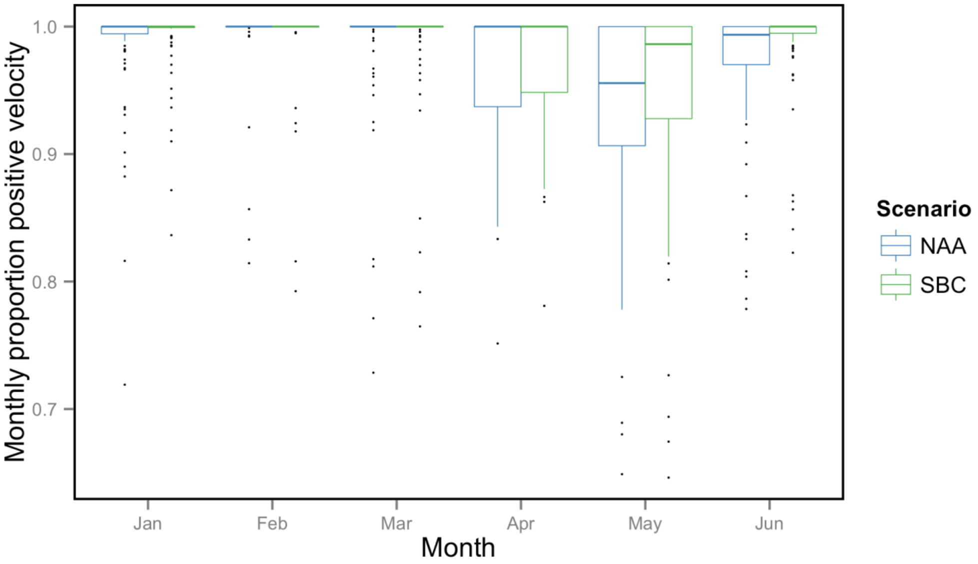

Figure 9K.4 Proportion of Monthly Positive Velocities in Sacramento River near Georgiana Slough under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC)

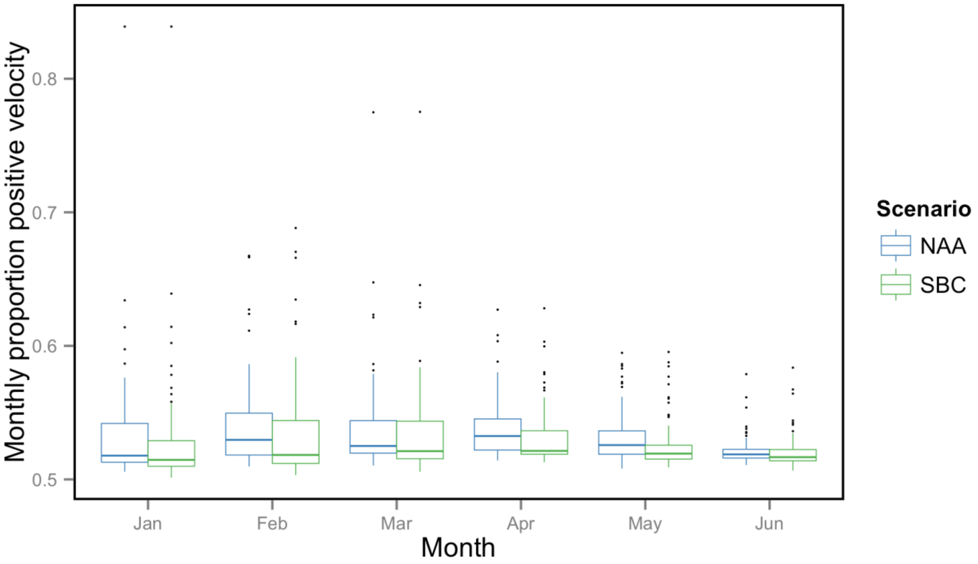

Figure 9K.5 Proportion of Monthly Positive Velocities in the San Joaquin River near Confluence with Mokelumne River under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC)

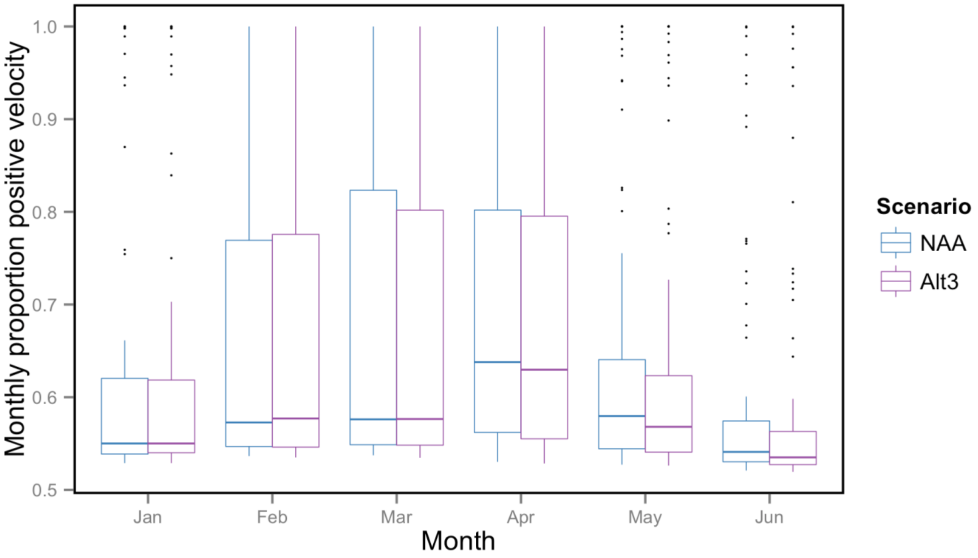

Figure 9K.6 Proportion of Monthly Positive Velocities in the San Joaquin River Downstream of the Head of Old River under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA)

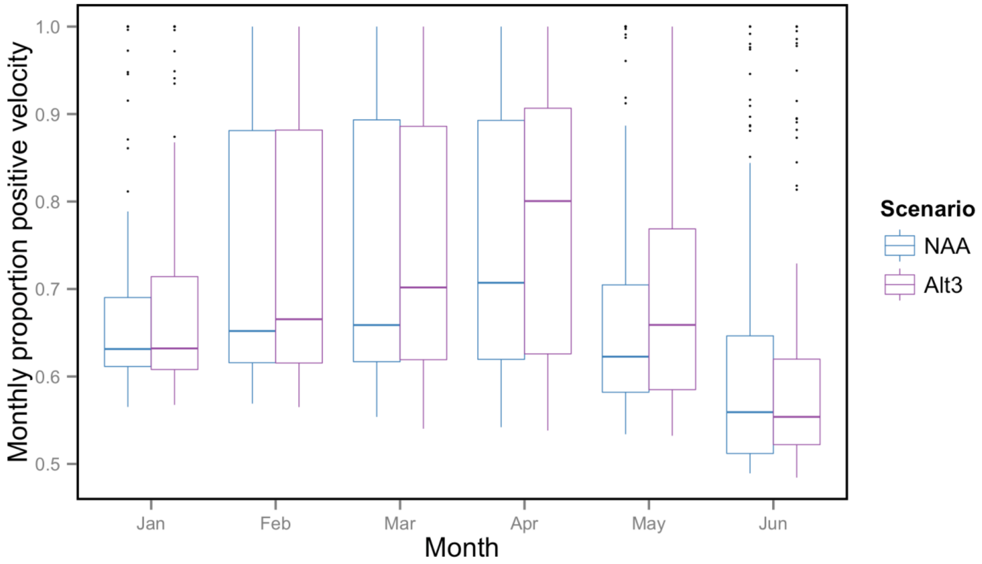

Figure 9K.7 Proportion of Monthly Positive Velocities in Old River Upstream of the Facilities under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA)

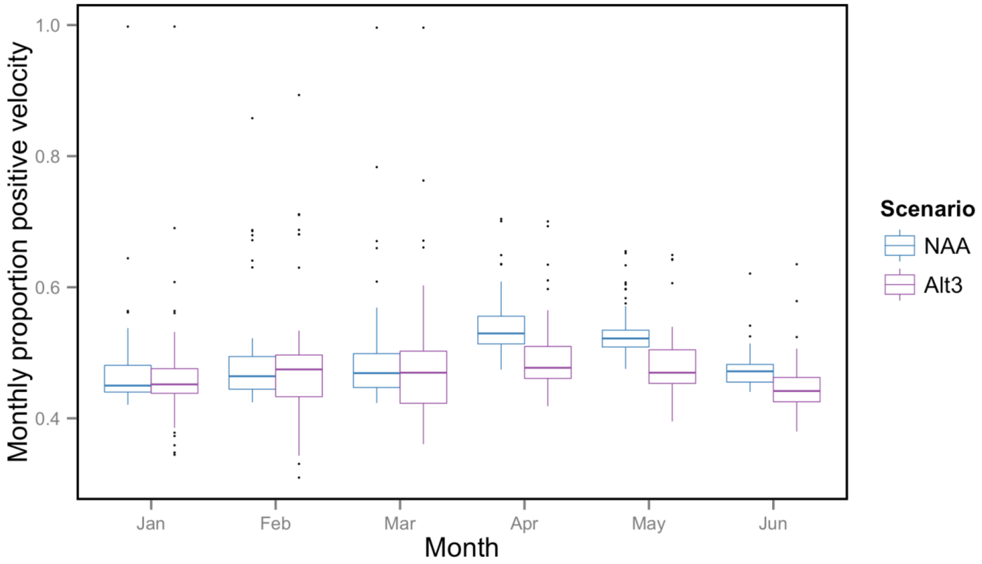

Figure 9K.8 Proportion of Monthly Positive Velocities in Old River Downstream of the Facilities under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA)

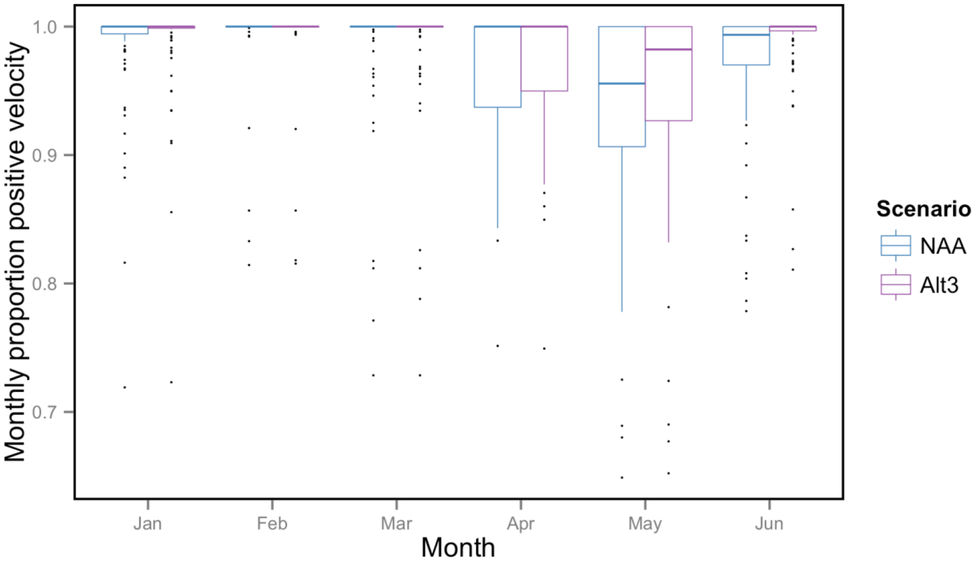

Figure 9K.9 Proportion of Monthly Positive Velocities in Sacramento River near Georgiana Slough under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA)

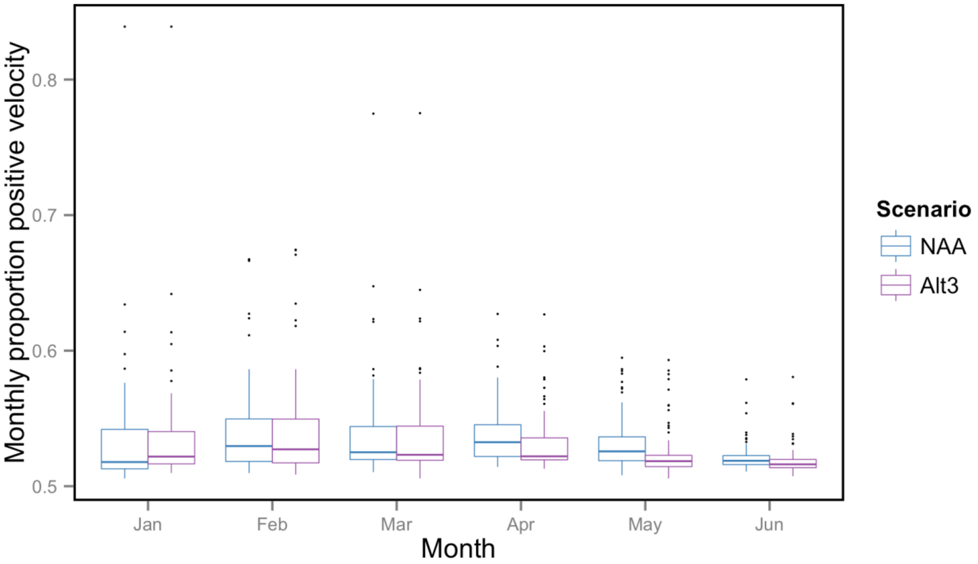

Figure 9K.10 Proportion of Monthly Positive Velocities in the San Joaquin River near Confluence with Mokelumne River under Alternative 3 (Alt 3) as compared to the No Action Alternative (NAA)

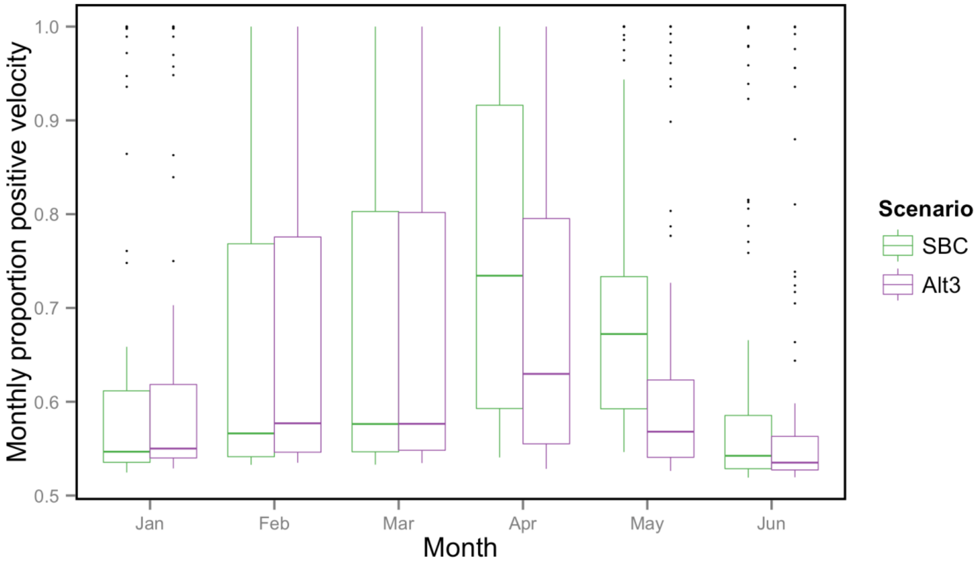

Figure 9K.11 Proportion of Monthly Positive Velocities in the San Joaquin River Downstream of the Head of Old River under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC)

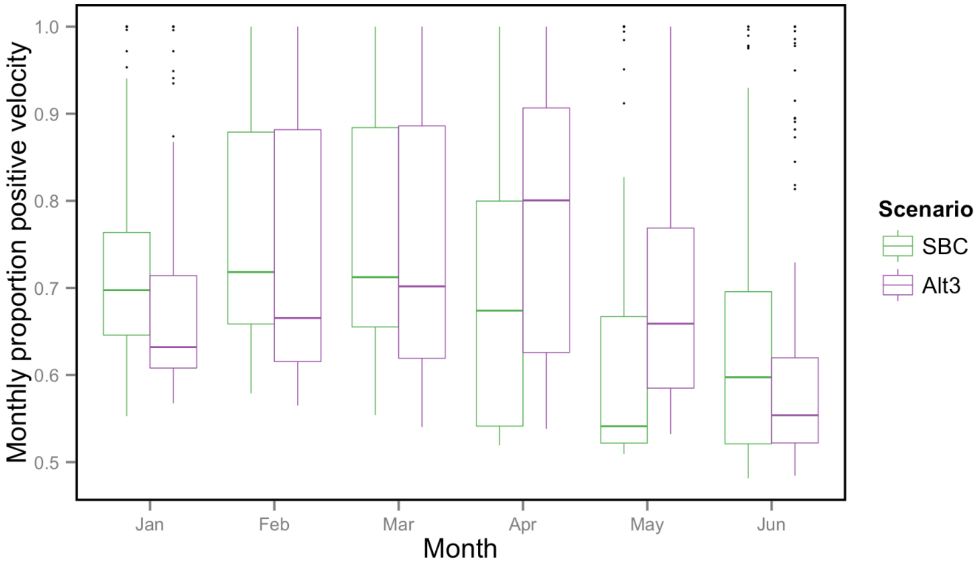

Figure 9K.12 Proportion of Monthly Positive Velocities in Old River Upstream of the Facilities under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC)

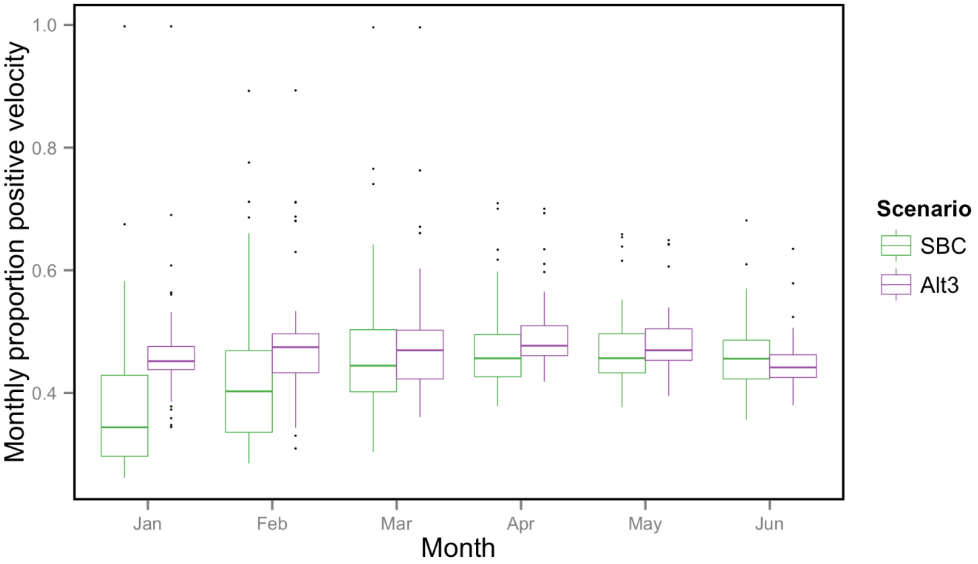

Figure 9K.13 Proportion of Monthly Positive Velocities in Old River Downstream of the Facilities under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC)

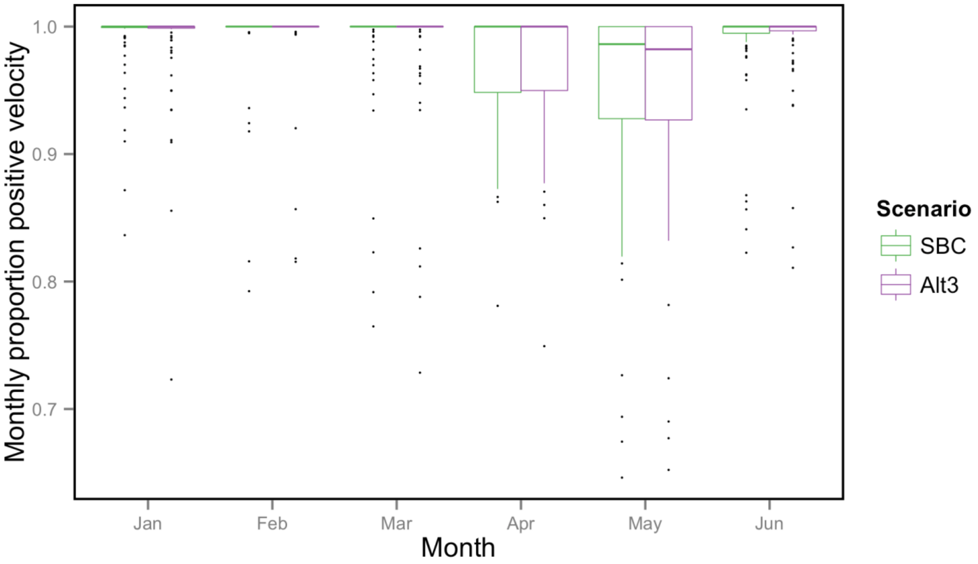

Figure 9K.14 Proportion of Monthly Positive Velocities in Sacramento River near Georgiana Slough under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison (SBC)

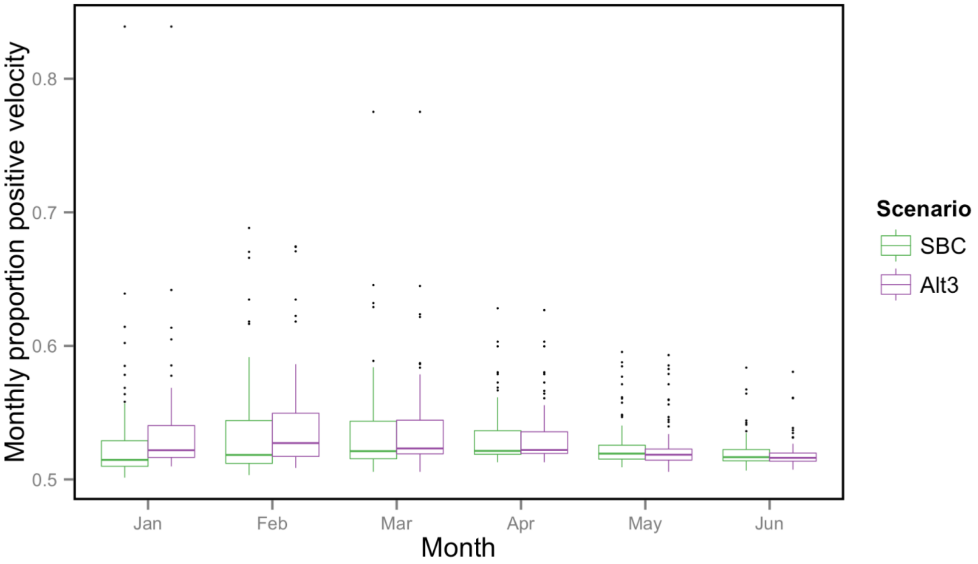

Figure 9K.15 Proportion of Monthly Positive Velocities in the San Joaquin River near Confluence with Mokelumne River under Alternative 3 (Alt 3) as compared to the Second Basis of Comparison

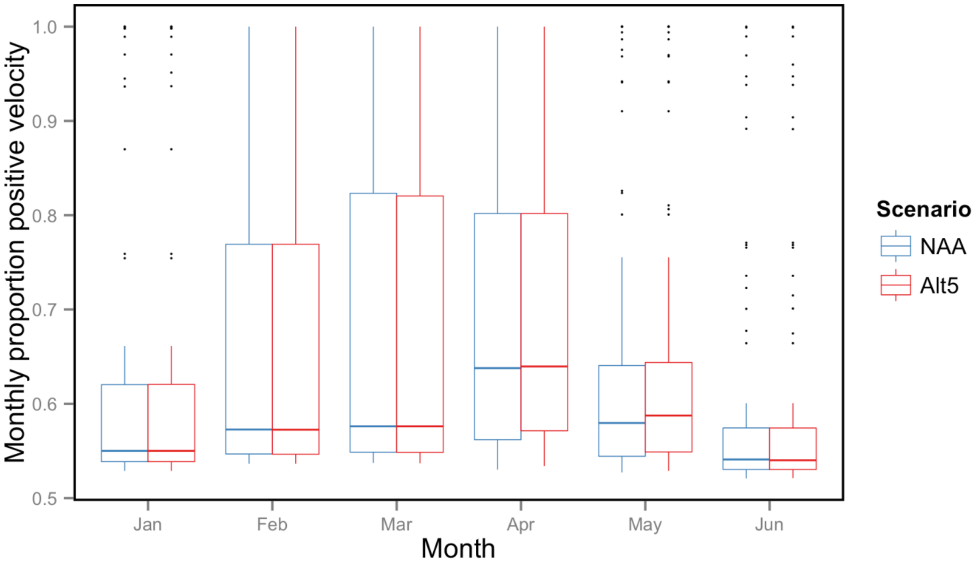

Figure 9K.16 Proportion of Monthly Positive Velocities in the San Joaquin River Downstream of the Head of Old River under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA)

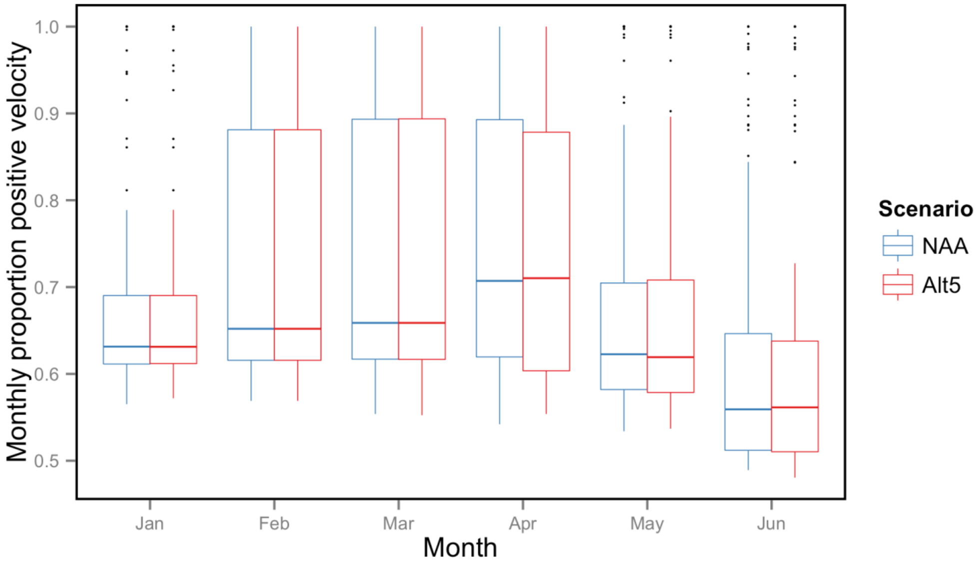

Figure 9K.17 Proportion of Monthly Positive Velocities in Old River Upstream of the Facilities under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA)

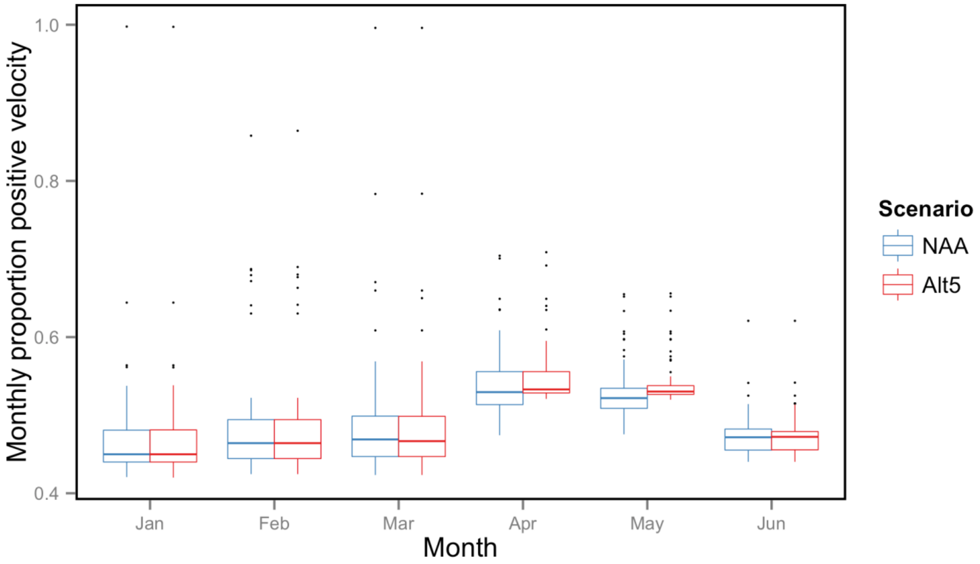

Figure 9K.18 Proportion of Monthly Positive Velocities in Old River Downstream of the Facilities under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA)

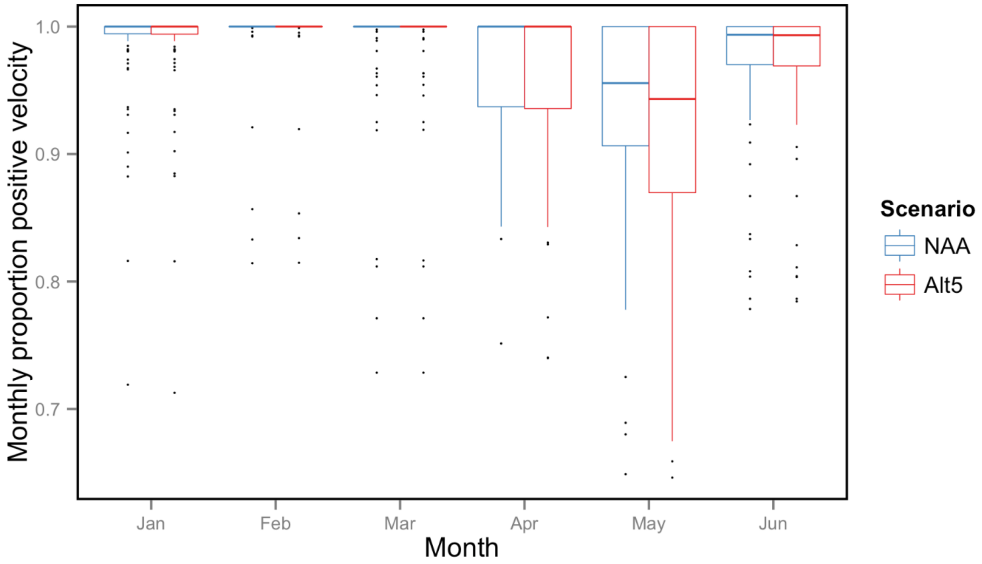

Figure 9K.19 Proportion of Monthly Positive Velocities in Sacramento River near Georgiana Slough under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA)

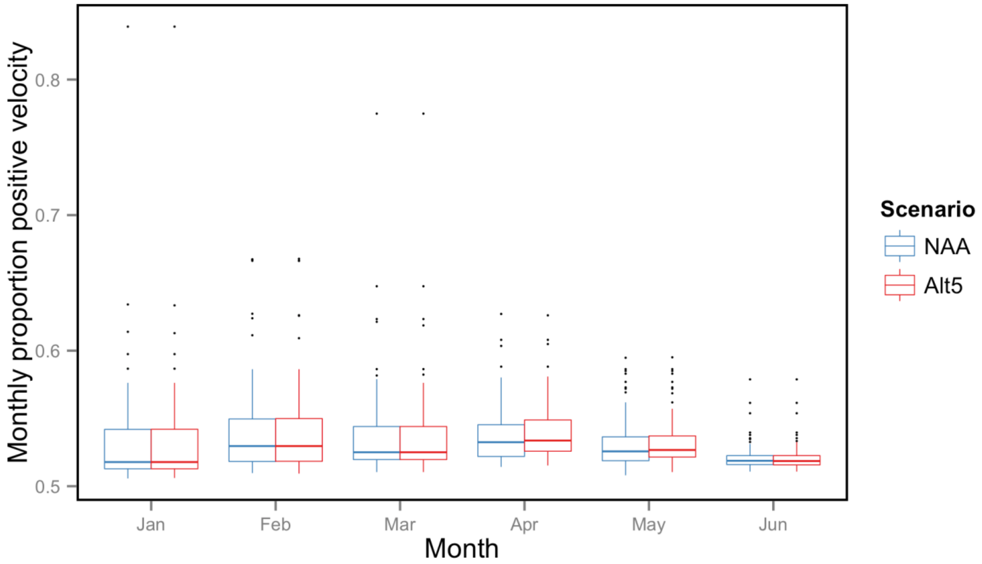

Figure 9K.20 Proportion of Monthly Positive Velocities in the San Joaquin River near Confluence with Mokelumne River under Alternative 5 (Alt 5) as compared to the No Action Alternative (NAA)

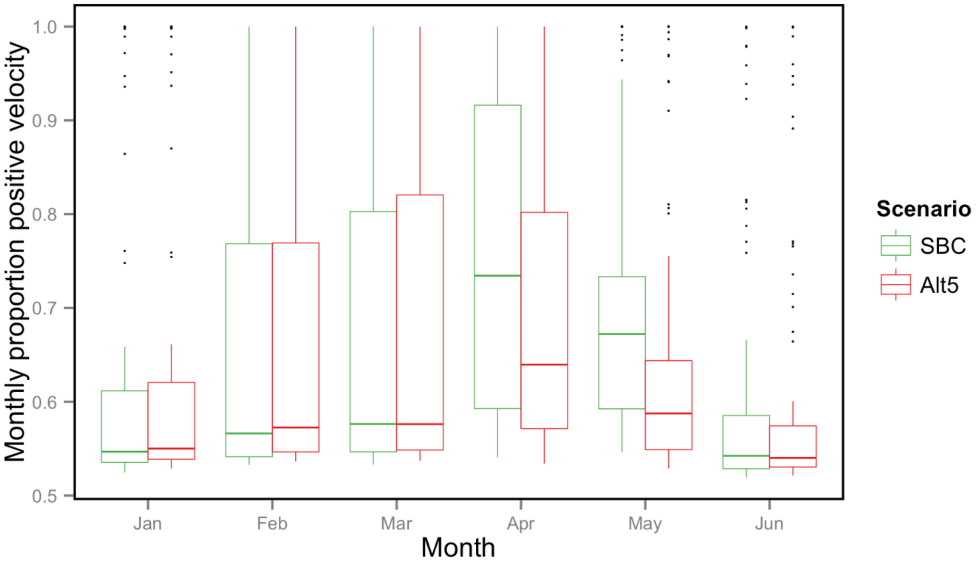

Figure 9K.21 Proportion of Monthly Positive Velocities in the San Joaquin River Downstream of the Head of Old River under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC)

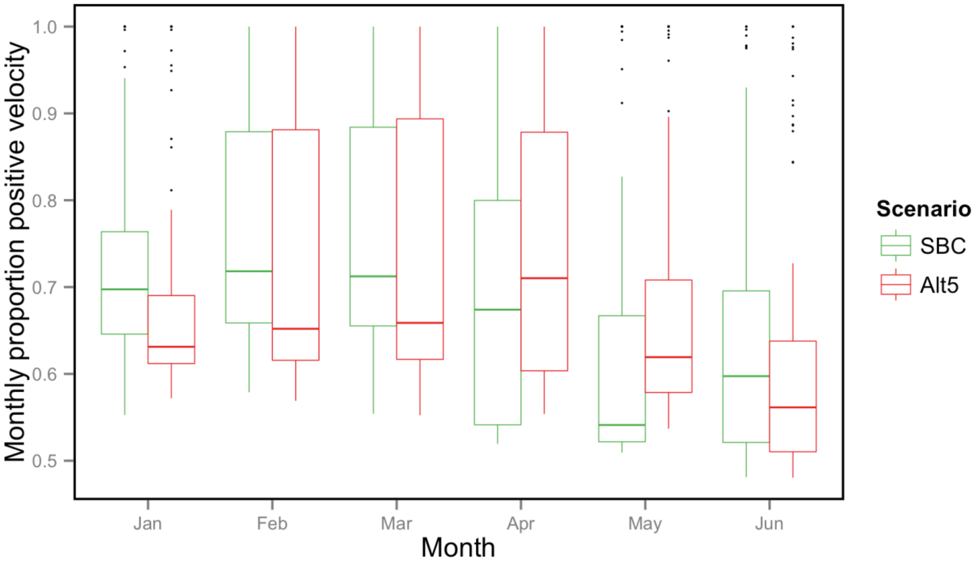

Figure 9K.22 Proportion of Monthly Positive Velocities in Old River Upstream of the Facilities under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC)

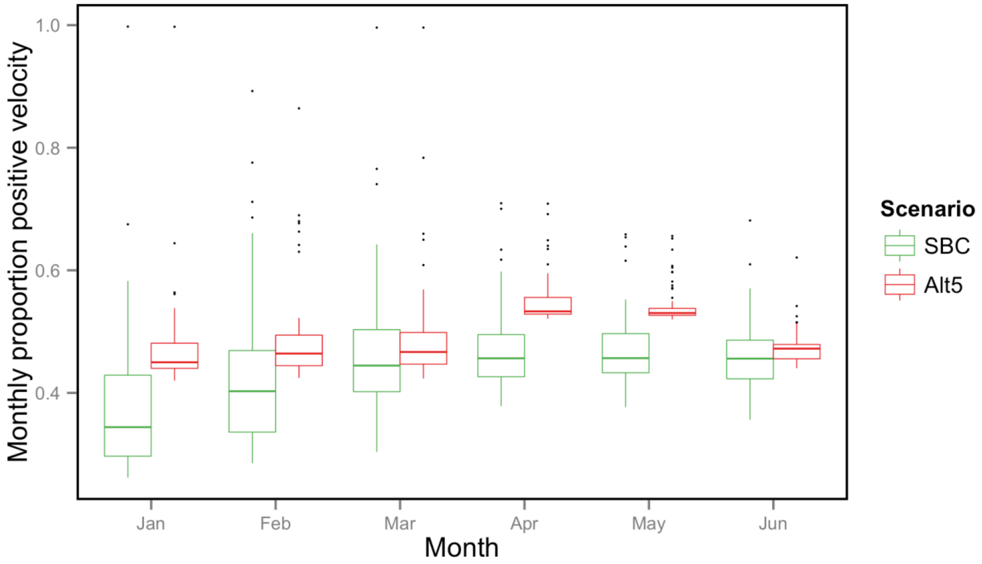

Figure 9K.23 Proportion of Monthly Positive Velocities in Old River Downstream of the Facilities under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC)

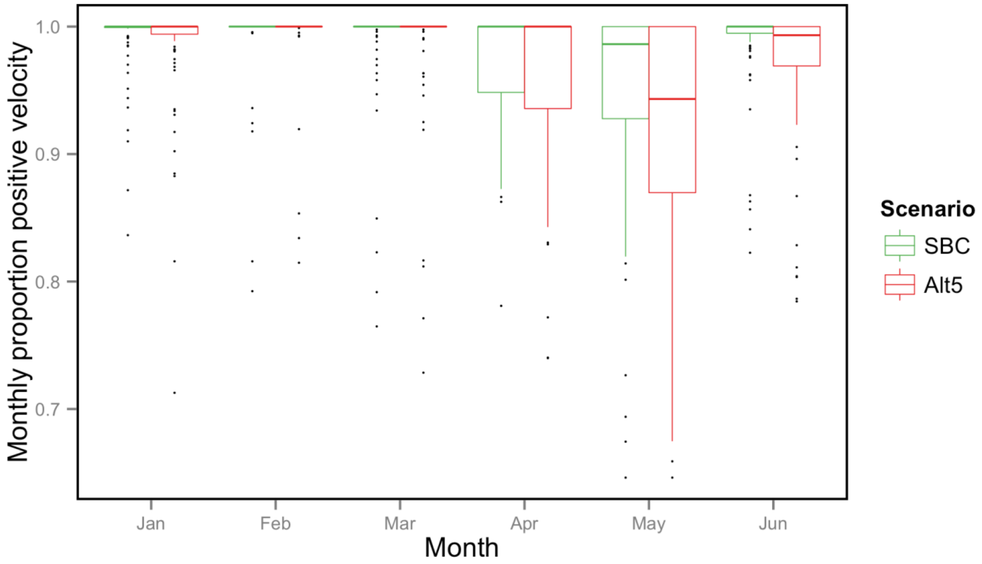

Figure 9K.24 Proportion of Monthly Positive Velocities in Sacramento River near Georgiana Slough under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC)

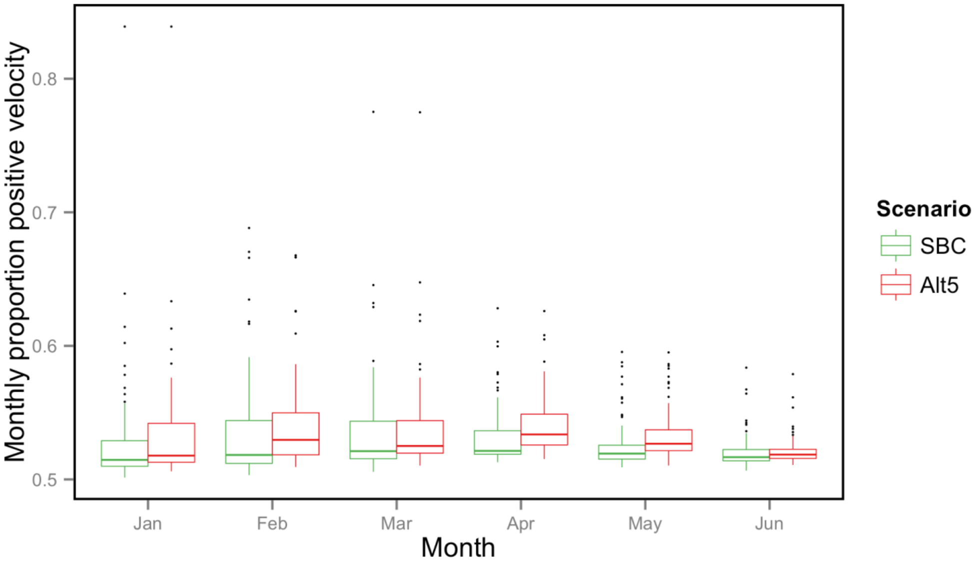

Figure 9K.25 Proportion of Monthly Positive Velocities in the San Joaquin River near Confluence with Mokelumne River under Alternative 5 (Alt 5) as compared to the Second Basis of Comparison (SBC)

This page left blank intentionally.