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.

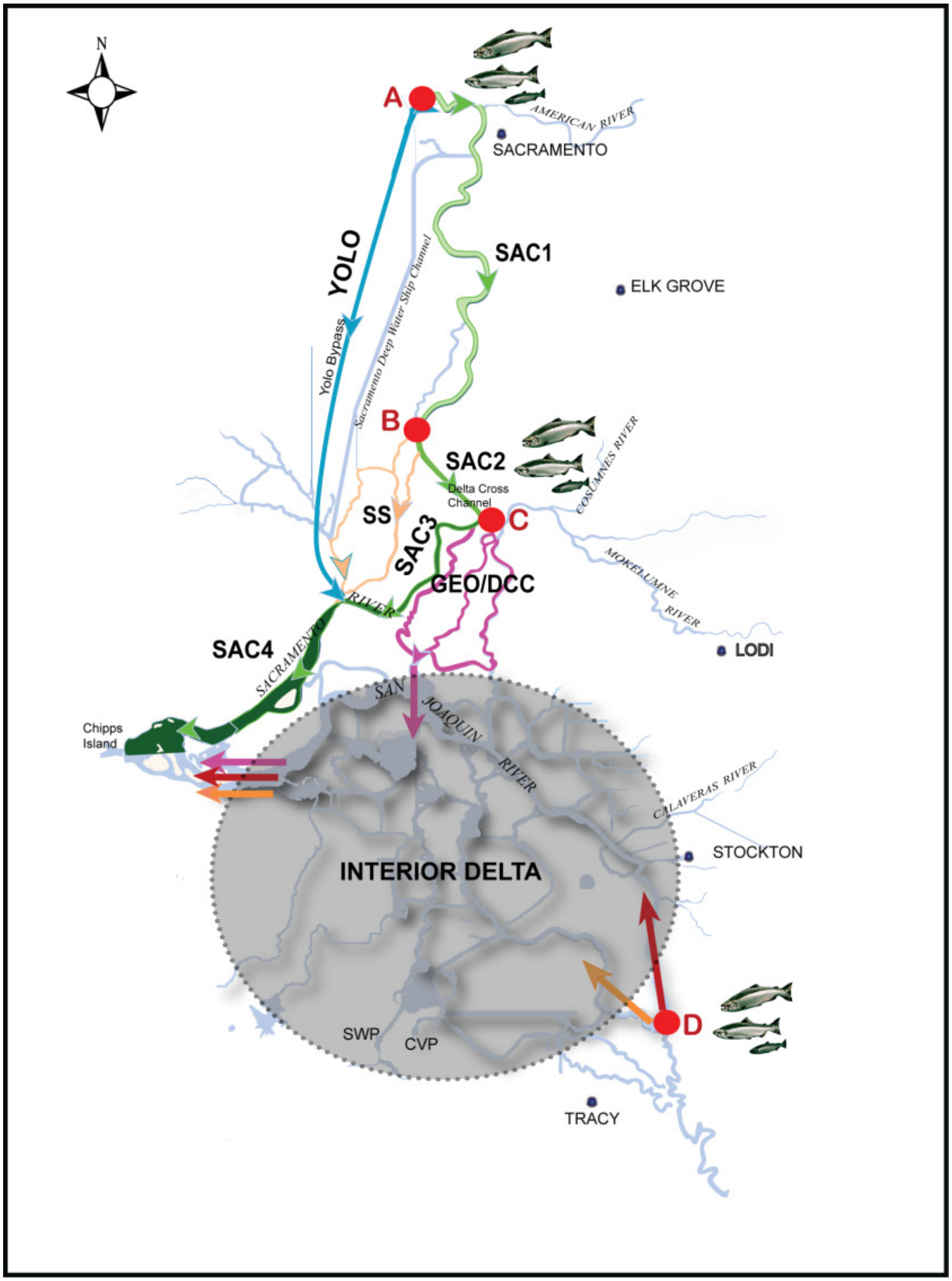

Figure 9J.1 DPM model Reaches and Junctions in the Delta (Notes: Bold headings label modeled reaches and red circles indicate model junctions. Salmonid icons indicate locations where smolts enter the Delta in the DPM model.)

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.

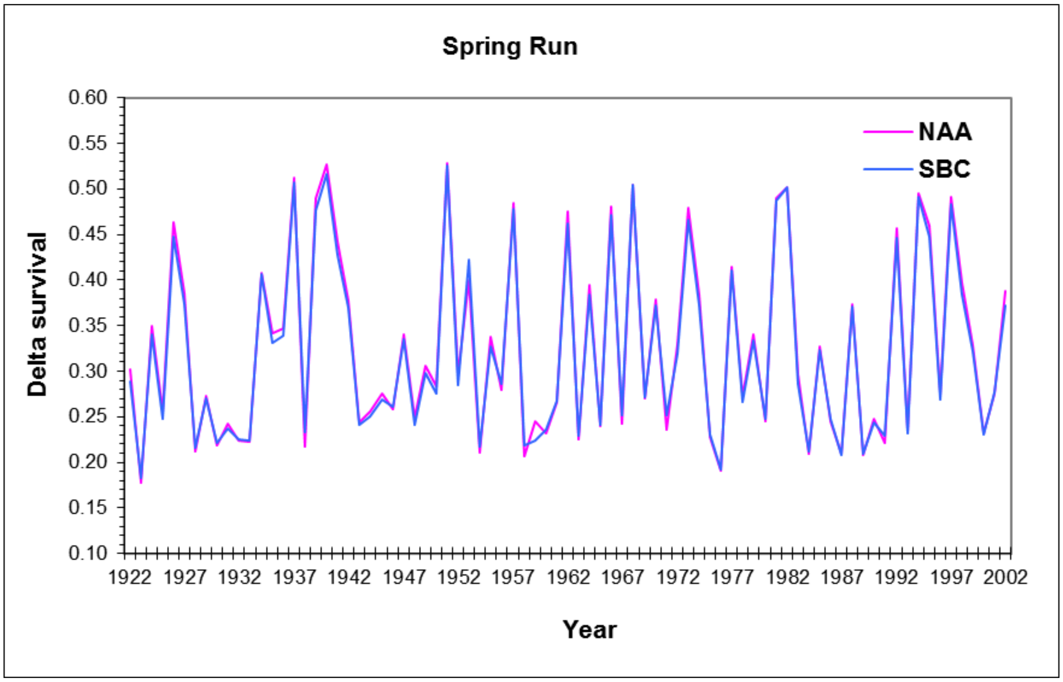

Figure 9J.2 Annual Delta Survival for Spring-run Chinook Salmon under the No Action Alternative (NAA) compared to the Second Basis of Comparison (SBC) over 81 water years estimated by the DPM model

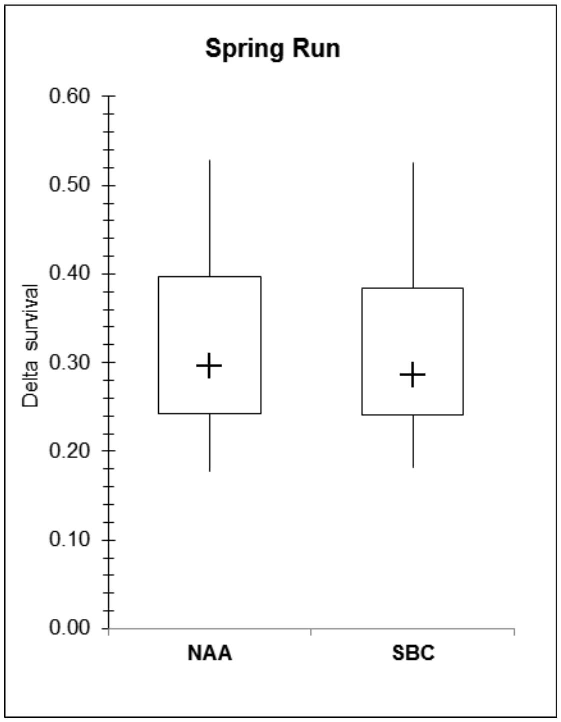

Figure 9J.3 Annual Delta Survival for Spring-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

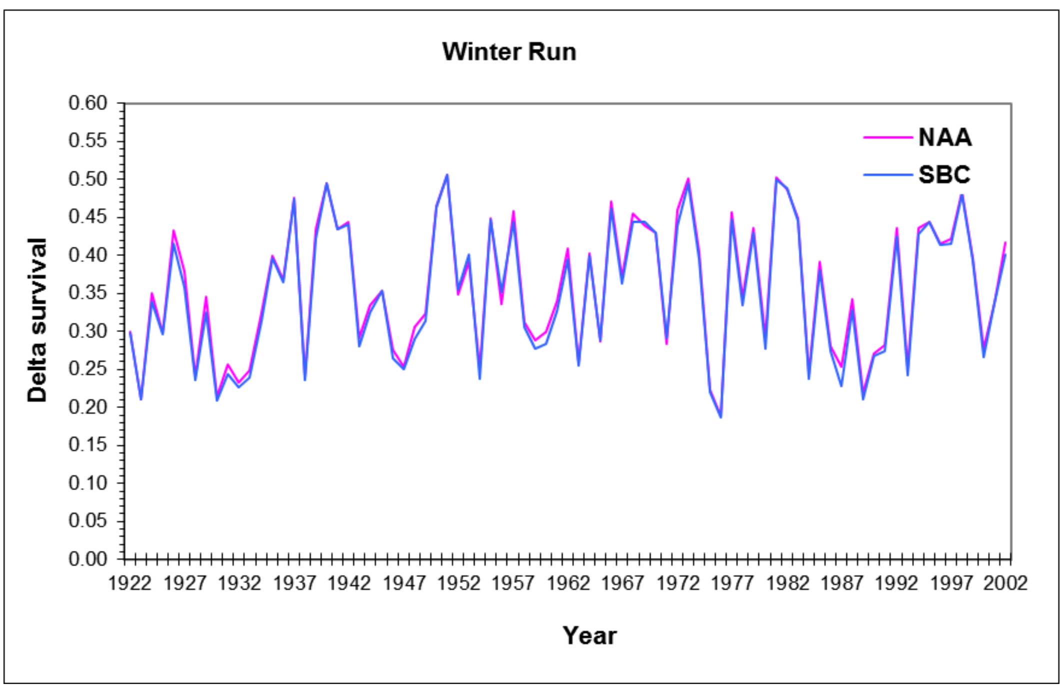

Figure 9J.4 Annual Delta Survival for Winter-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

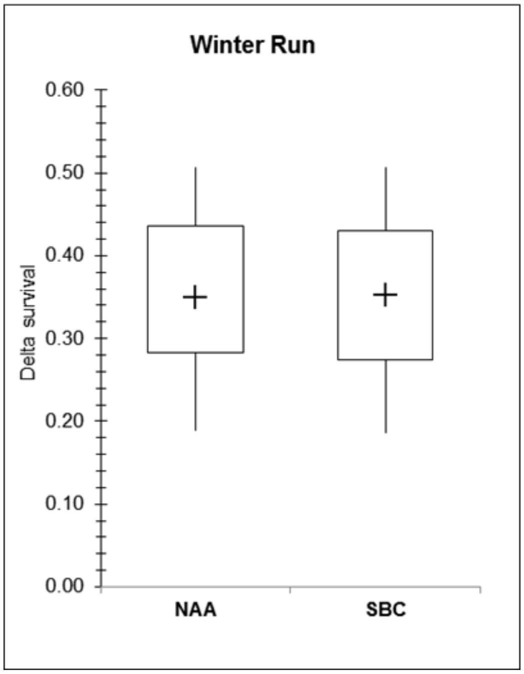

Figure 9J.5 Annual Delta Survival for Winter-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

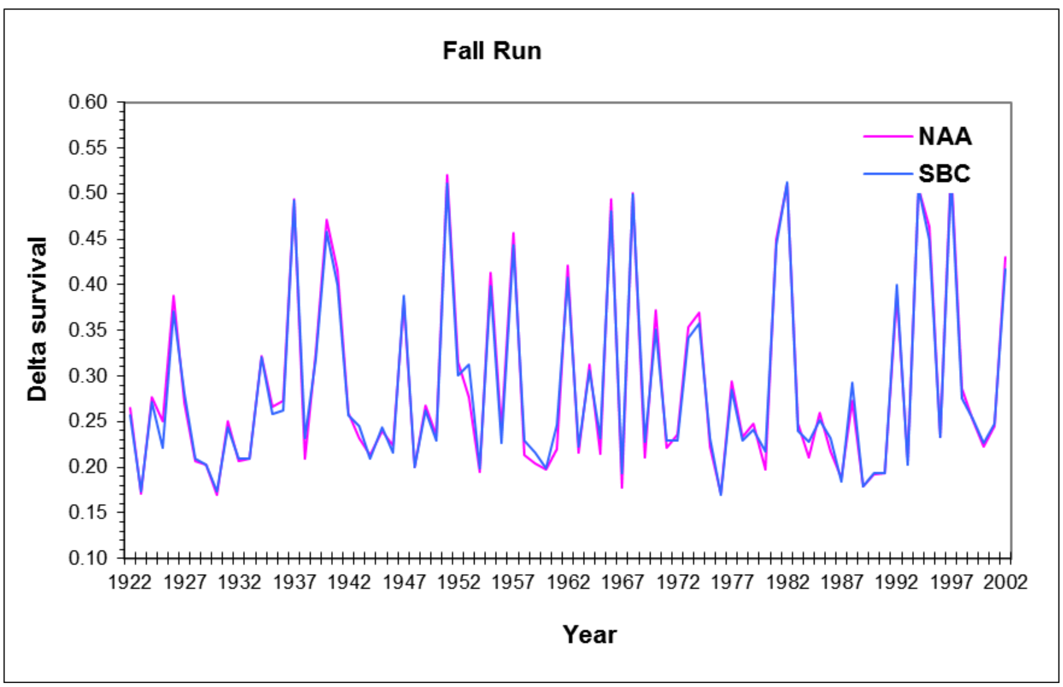

Figure 9J.6 Annual Delta Survival for Fall-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

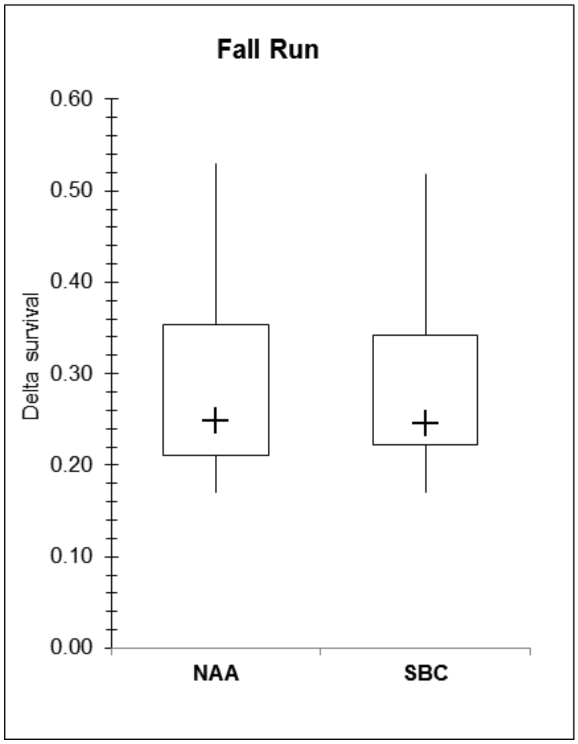

Figure 9J.7 Annual Delta Survival for Fall-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

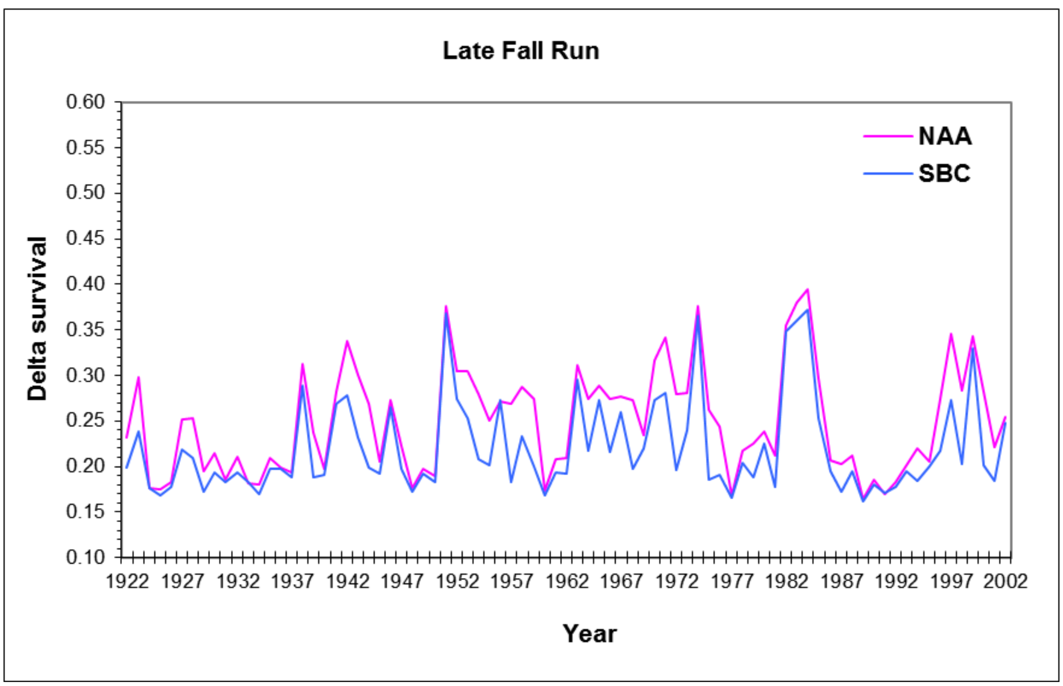

Figure 9J.8 Annual Delta Survival for Late Fall-run Chinook Salmon under the NAA compared to the SBC over 81 water years estimated by the DPM model

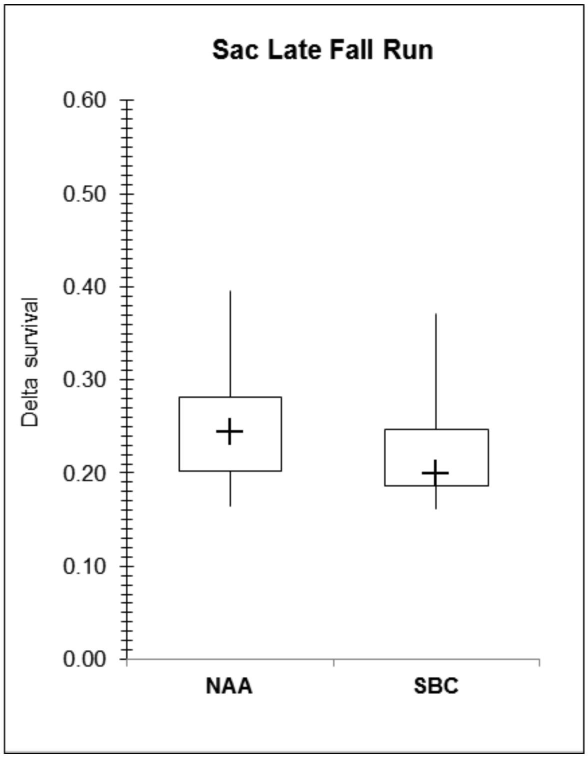

Figure 9J.9 Annual Delta Survival for Late Fall-run Chinook Salmon under the NAA compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

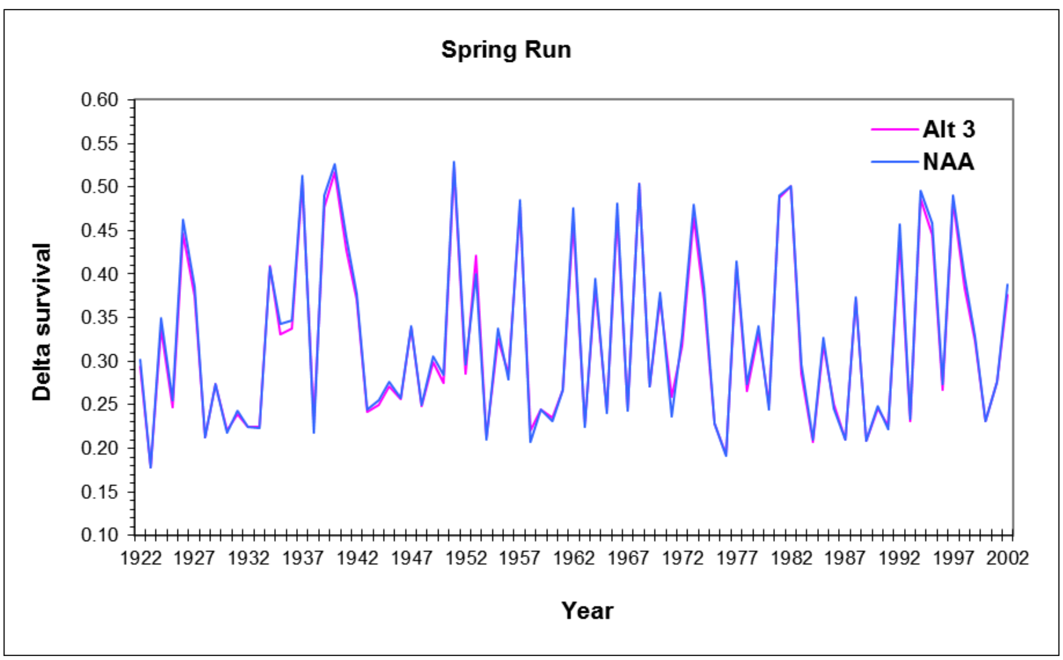

Figure 9J.10 Annual Delta Survival for Spring-run Chinook Salmon under Alternative 3 (Alt 3) as compared to the NAA over 81 water years estimated by the DPM model

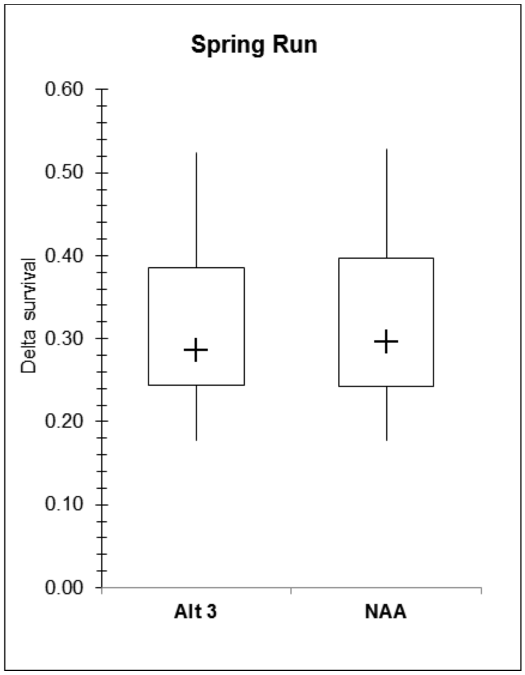

Figure 9J.11 Annual Delta Survival for Spring-run chinook under Alternative 3 (Alt 3) as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

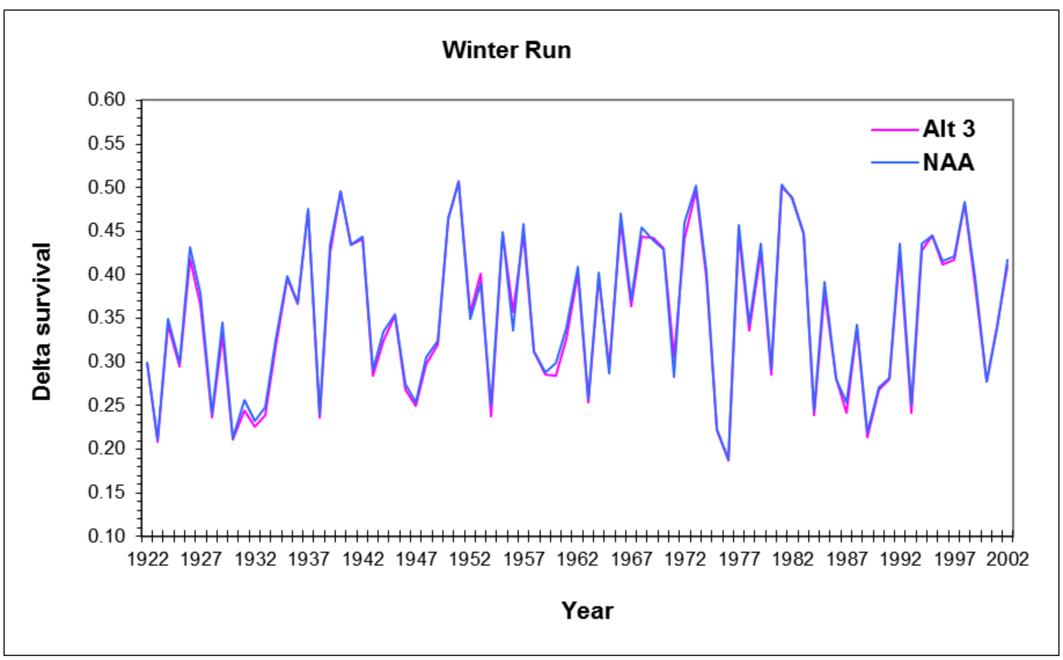

Figure 9J.12 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

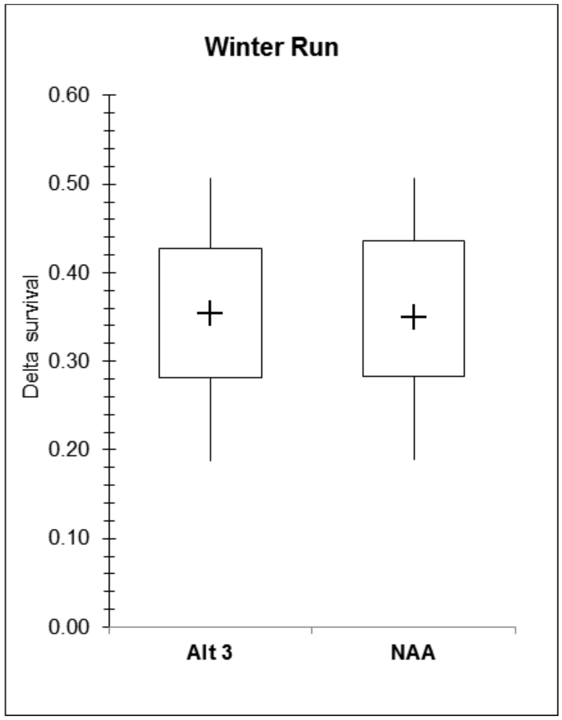

Figure 9J.13 Annual Delta Survival for Winter-run Chinook under Alternative 3 (Alt 3) as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

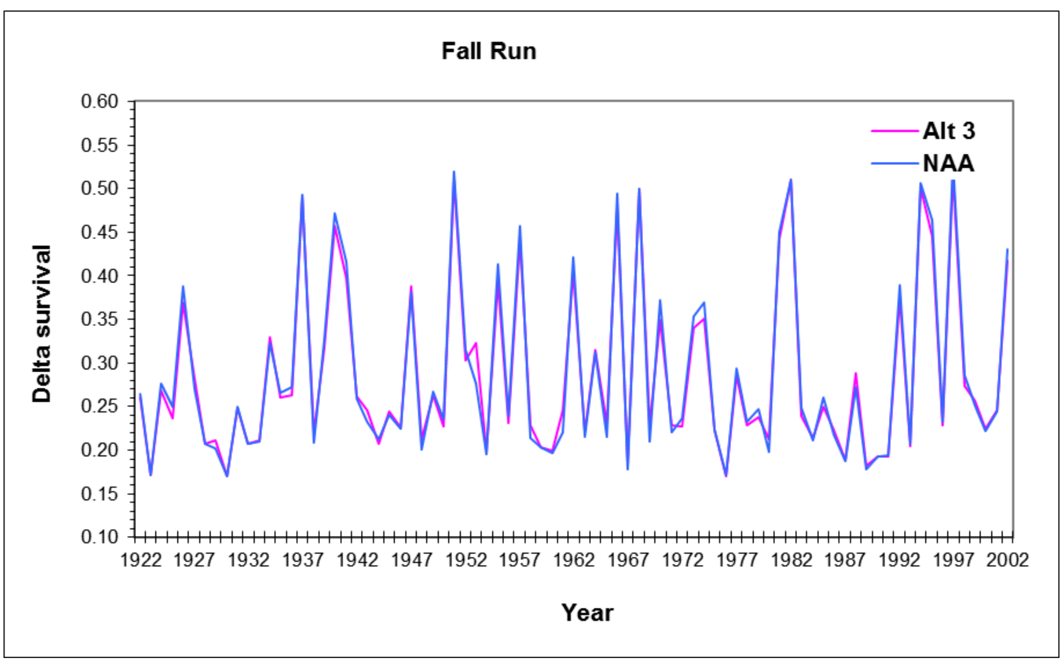

Figure 9J.14 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

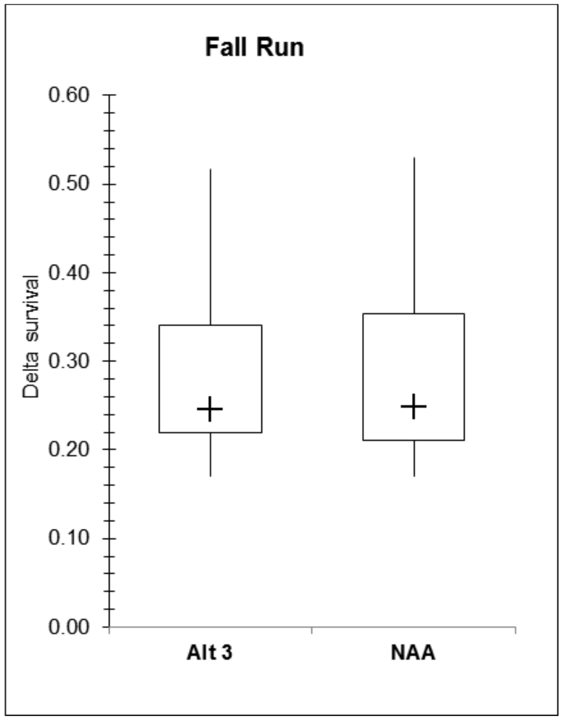

Figure 9J.15 Annual Delta Survival for Fall-run Chinook under Alt 3 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

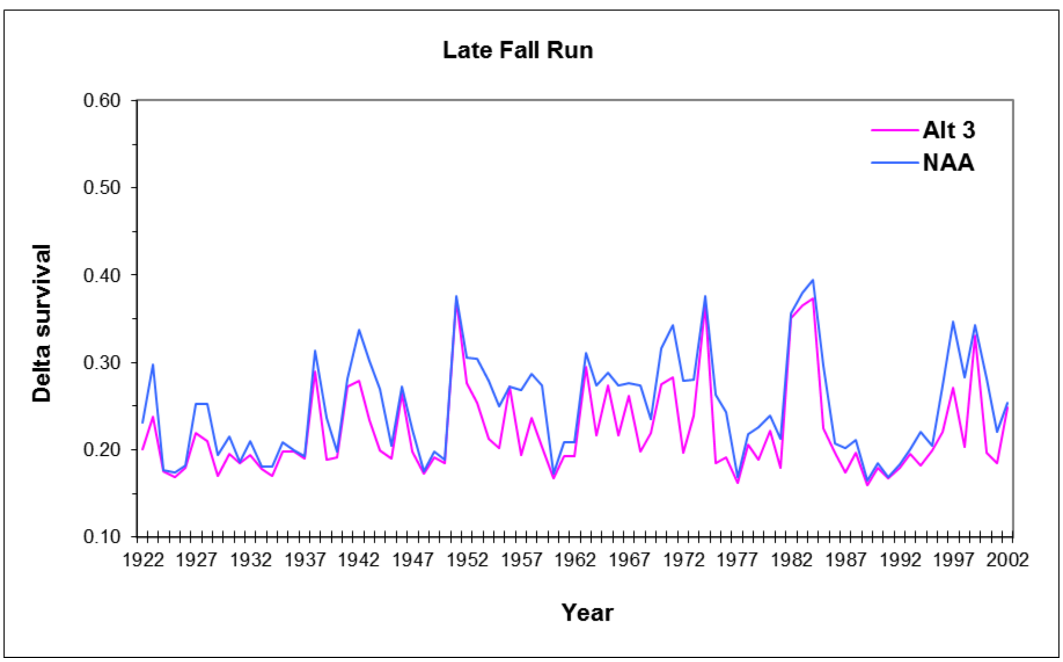

Figure 9J.16 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the NAA over 81 water years estimated by the DPM model

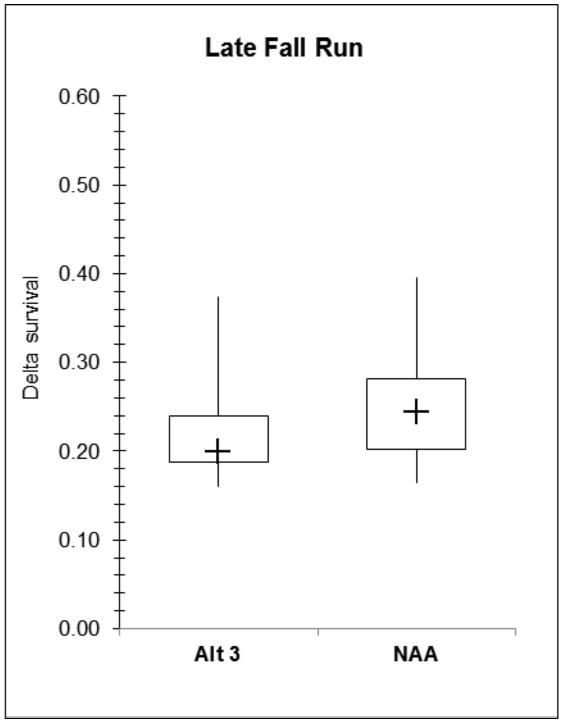

Figure 9J.17 Annual Delta Survival for Late Fall-run Chinook under Alt 3 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

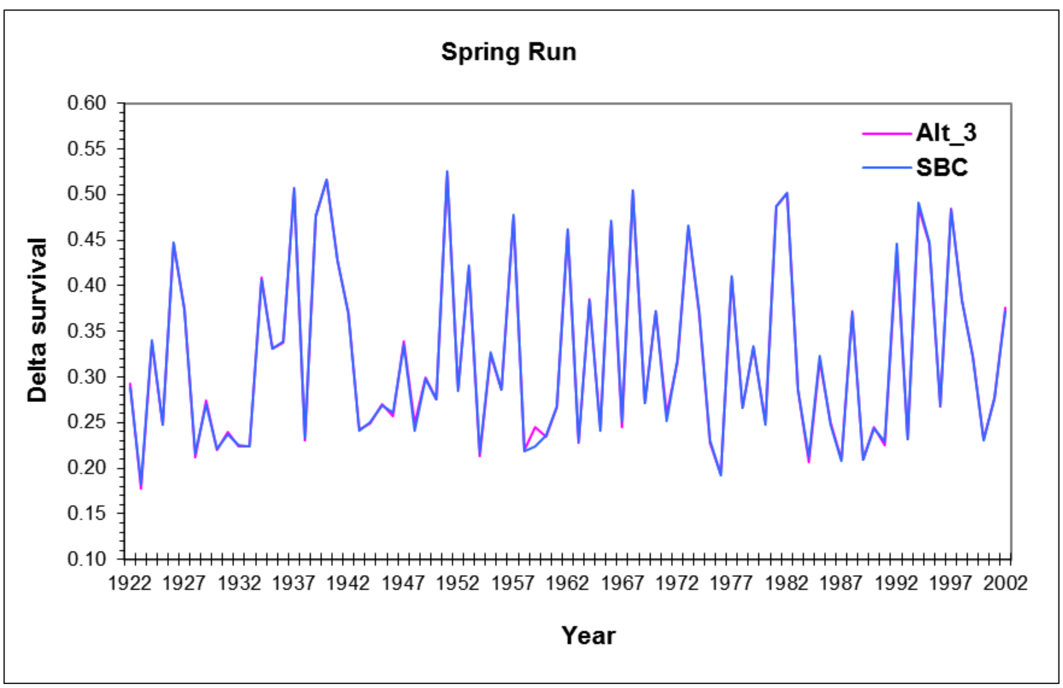

Figure 9J.18 Annual Delta Survival for Spring-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

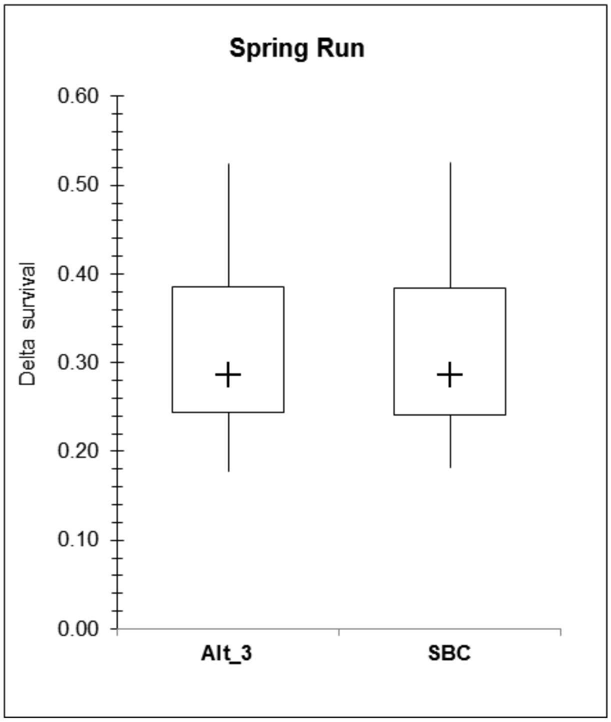

Figure 9J.19 Annual Delta Survival for Spring-run Chinook Salmon under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

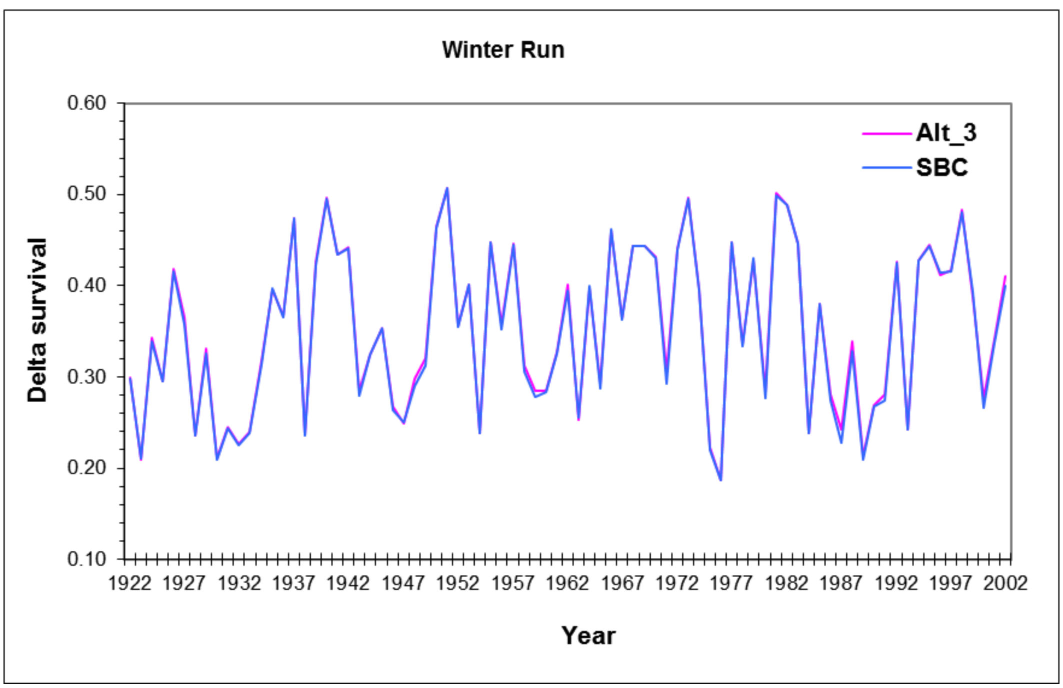

Figure 9J.20 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

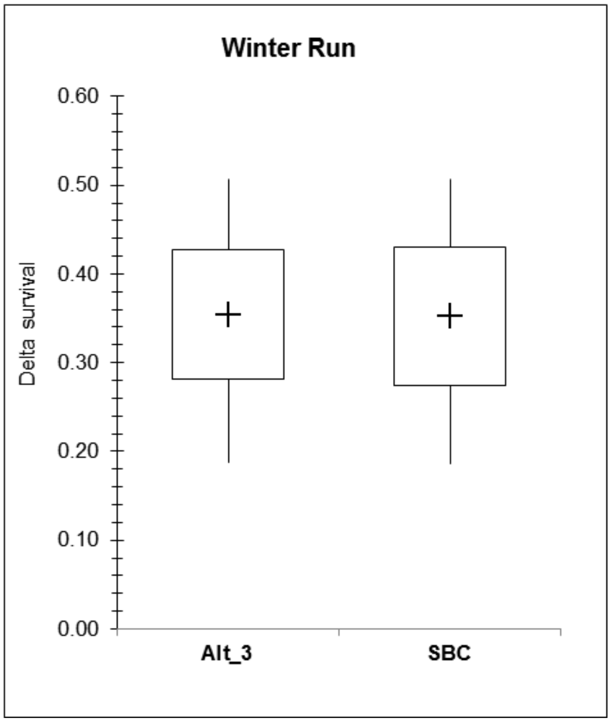

Figure 9J.21 Annual Delta Survival for Winter-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

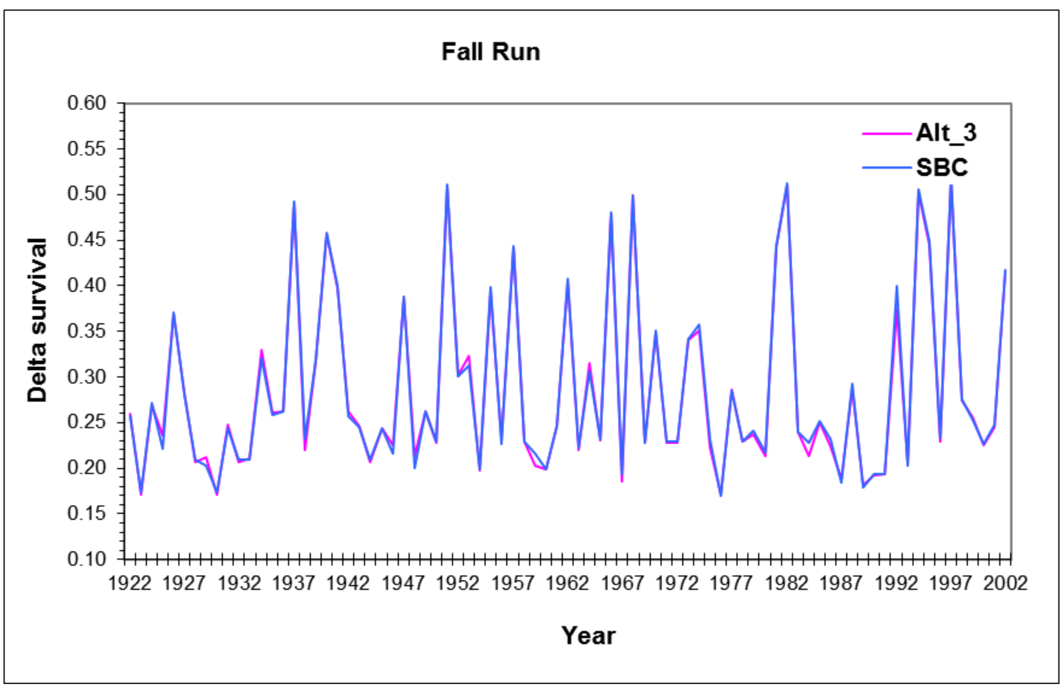

Figure 9J.22 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

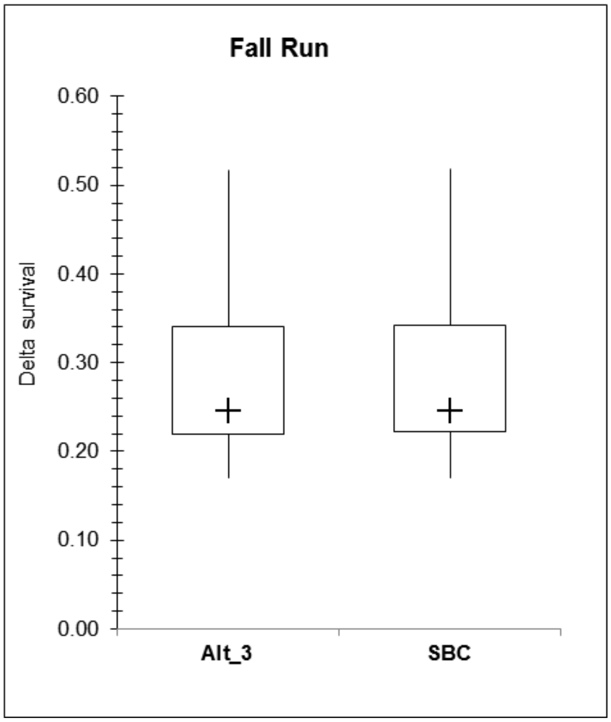

Figure 9J.23 Annual Delta Survival for Fall-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

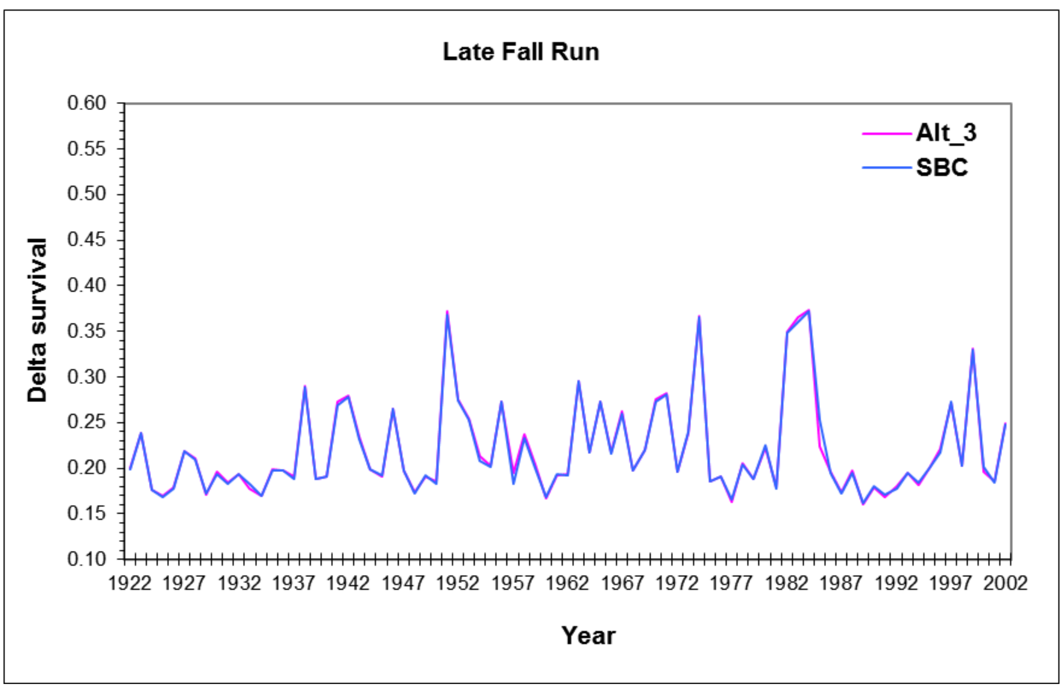

Figure 9J.24 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

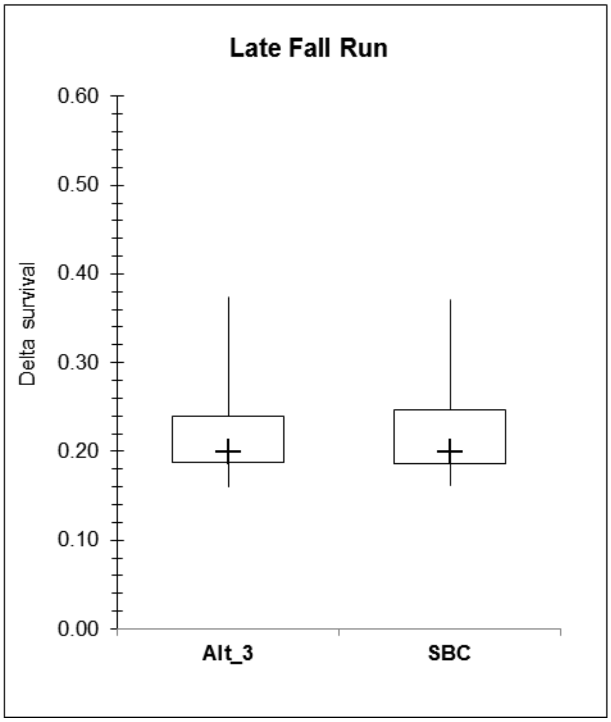

Figure 9J.25 Annual Delta Survival for Late Fall-run Chinook under Alt 3 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

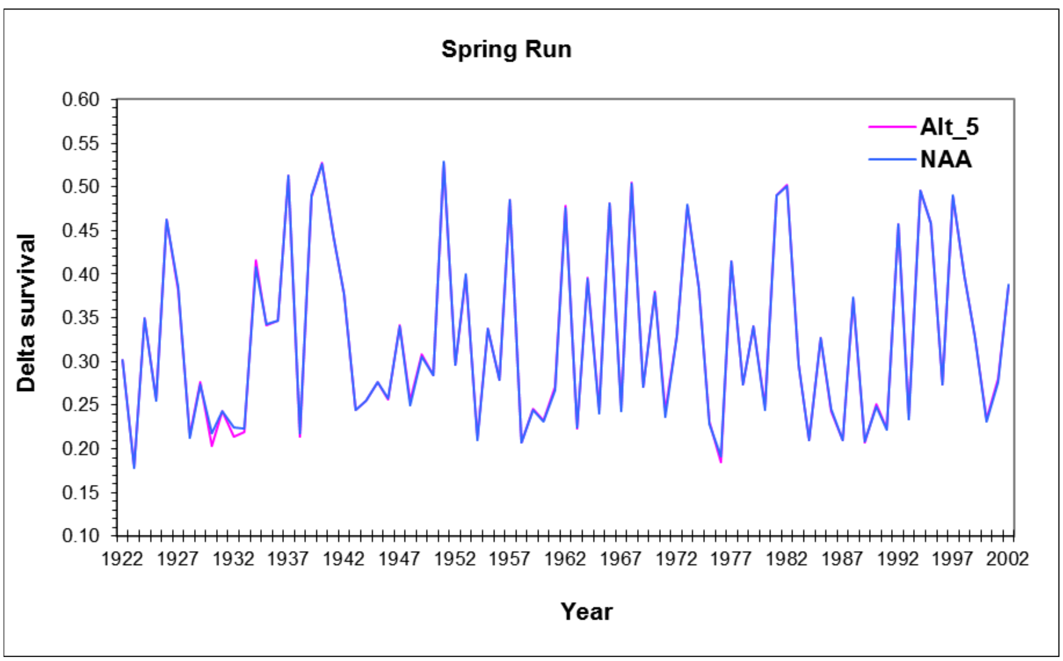

Figure 9J.26 Annual Delta Survival for Spring-run Chinook Salmon under Alternative 5 (Alt 5) as compared to the NAA over 81 water years estimated by the DPM model

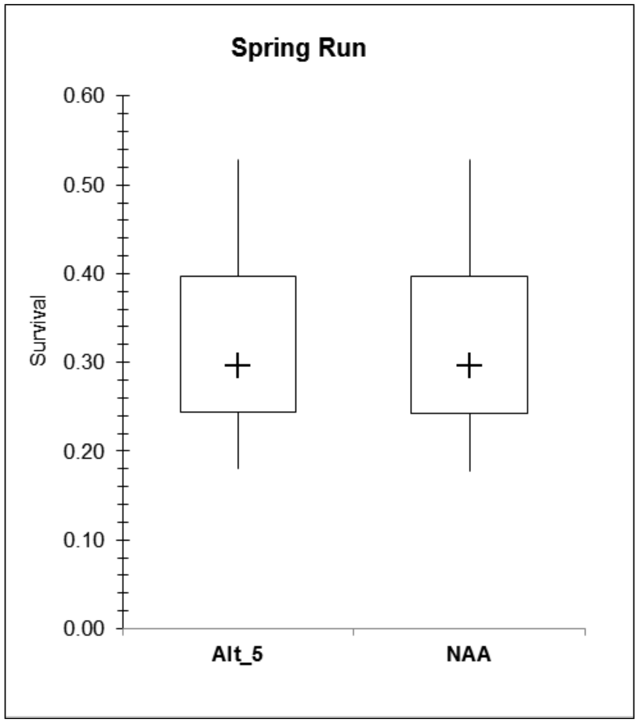

Figure 9J.27 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

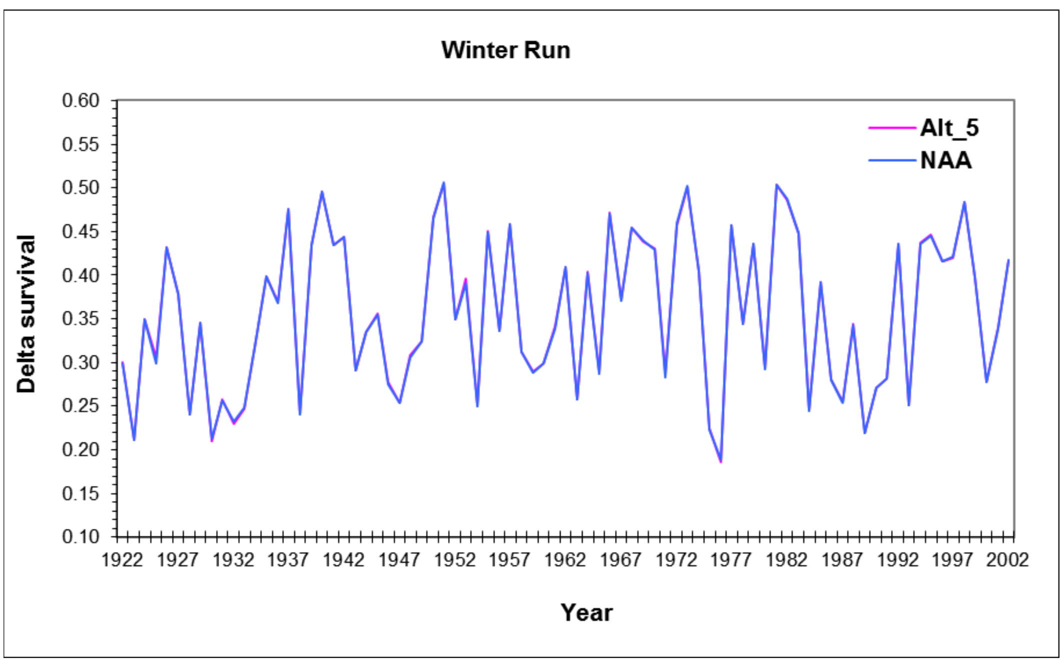

Figure 9J.28 Annual Delta Survival for Winter-run Chinook Salmon under Alt 5 as compared to the NAA over 81 water years estimated by the DPM model

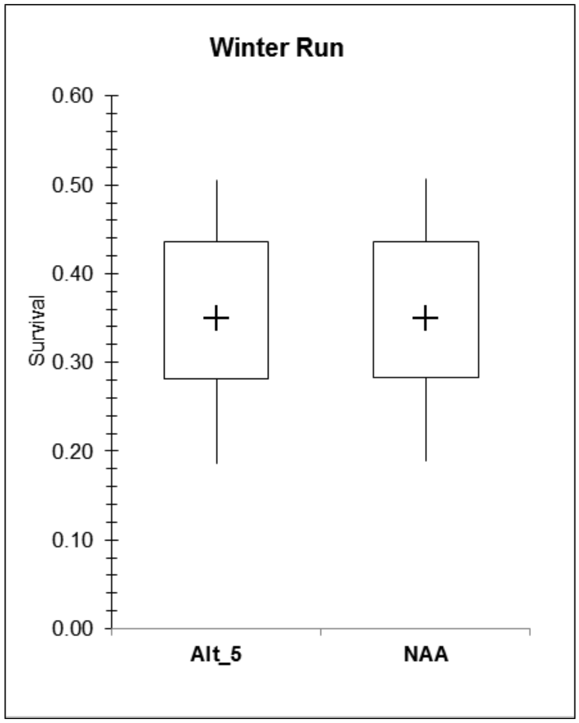

Figure 9J.29 Annual Delta Survival for Winter-run Chinook under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

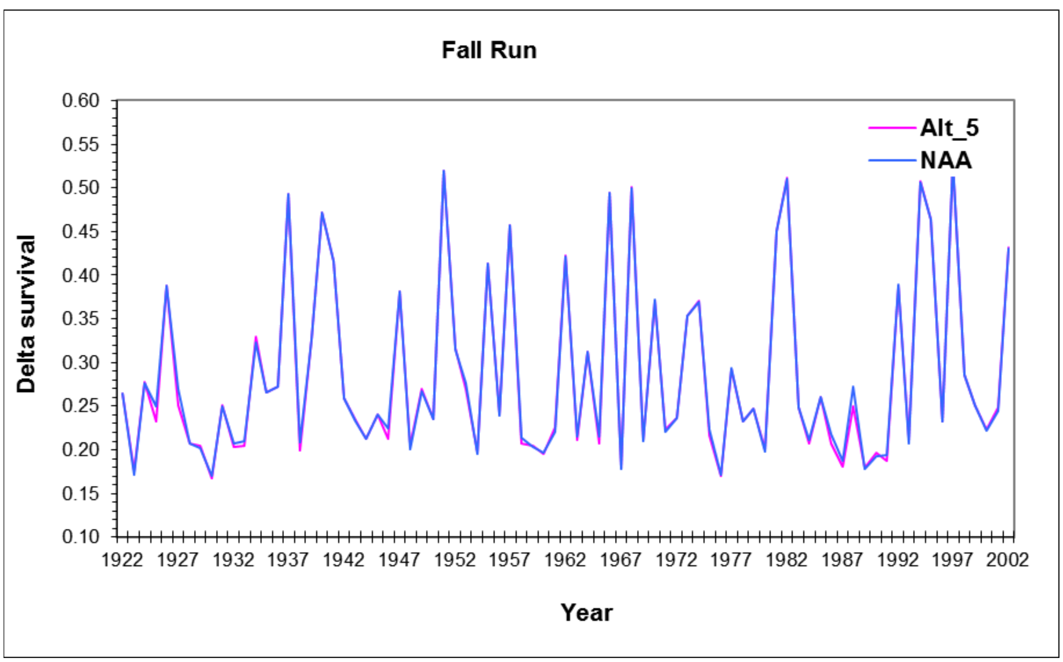

Figure 9J.30 Annual Delta Survival for Fall-run Chinook Salmon under (Alt 5) as compared to the NAA over 81 water years estimated by the DPM model

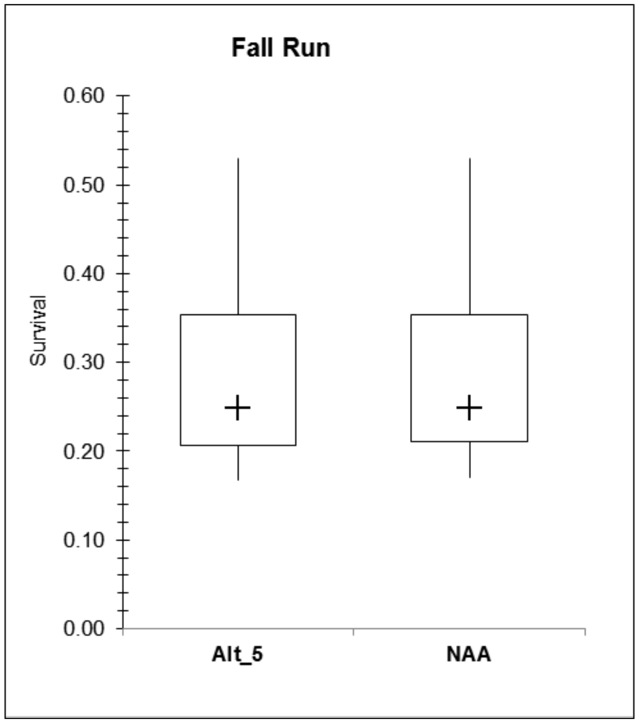

Figure 9J.31 Annual Delta Survival for Fall-run Chinook under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

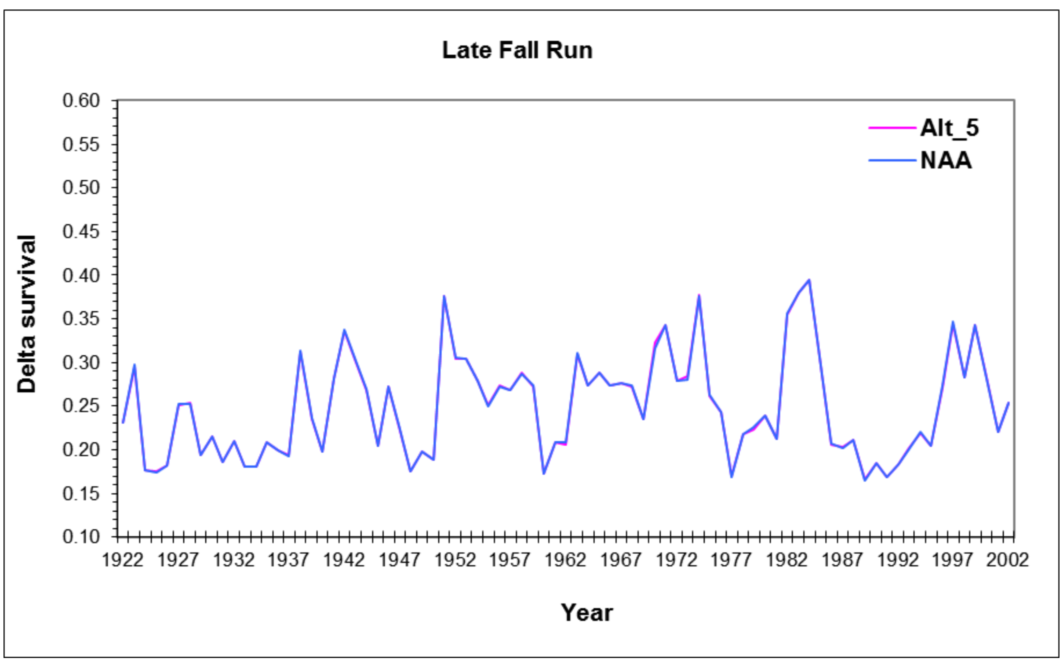

Figure 9J.32 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 5 as compared to the NAA over 81 water years estimated by the DPM model

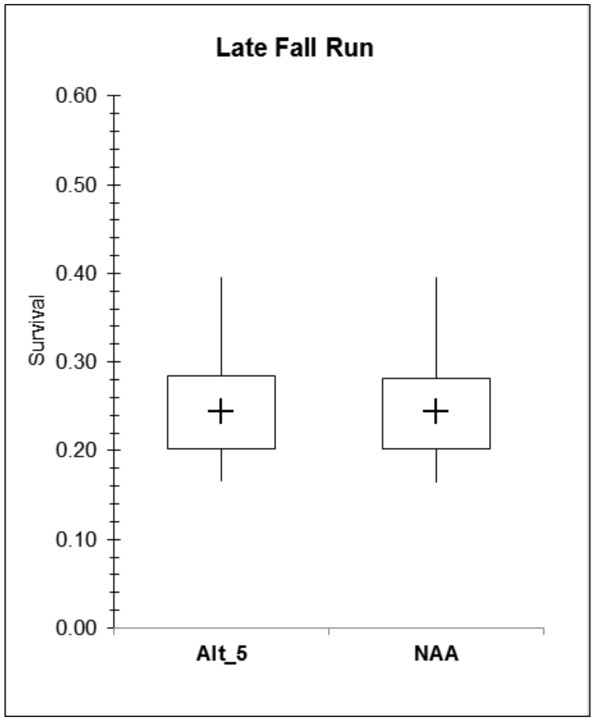

Figure 9J.33 Annual Delta Survival for Late Fall-run Chinook Salmond under Alt 5 as compared to the NAA estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

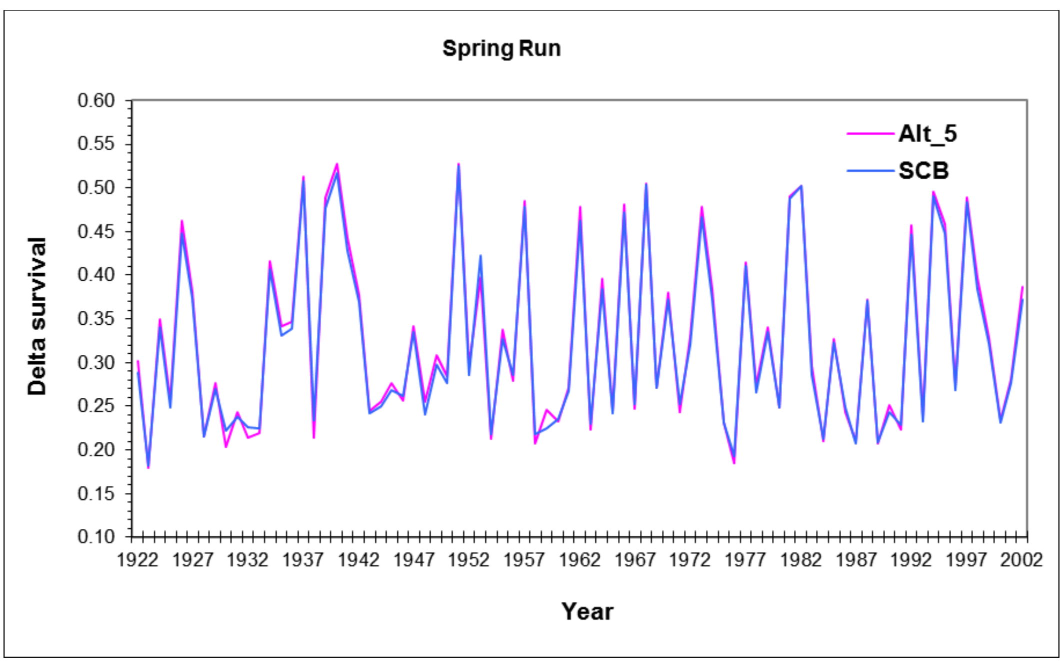

Figure 9J.34 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the SBC over 81 water years estimated by the DPM model

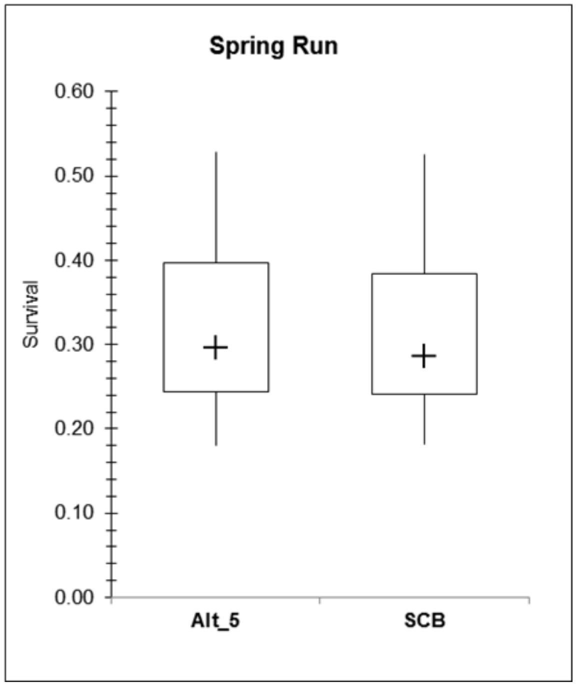

Figure 9J.35 Annual Delta Survival for Spring-run Chinook Salmon under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

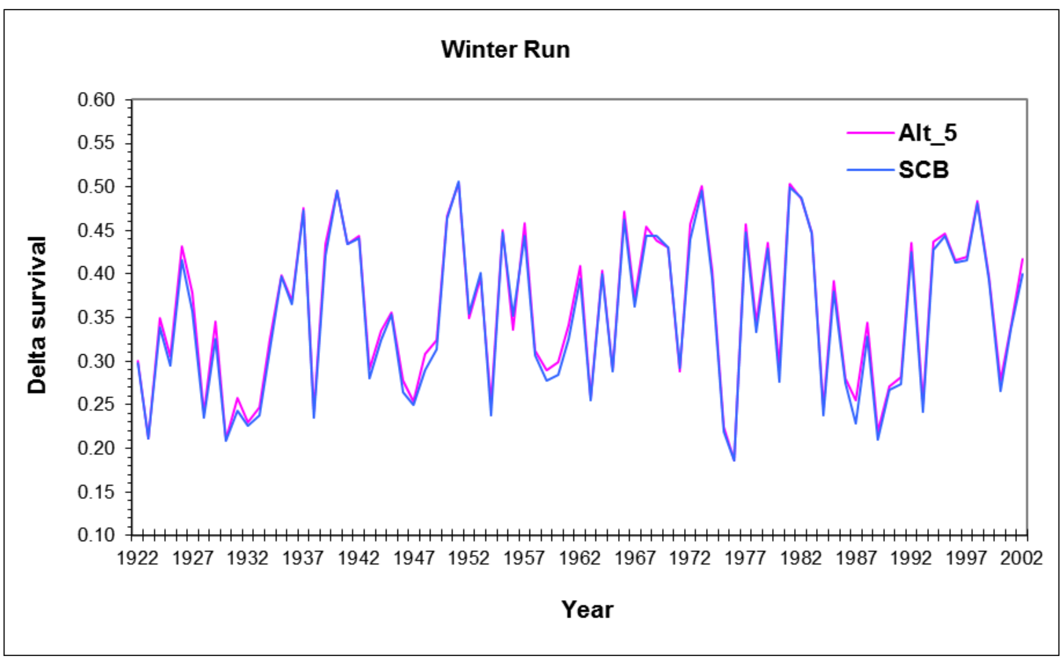

Figure 9J.36 Annual Delta Survival for Winter-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

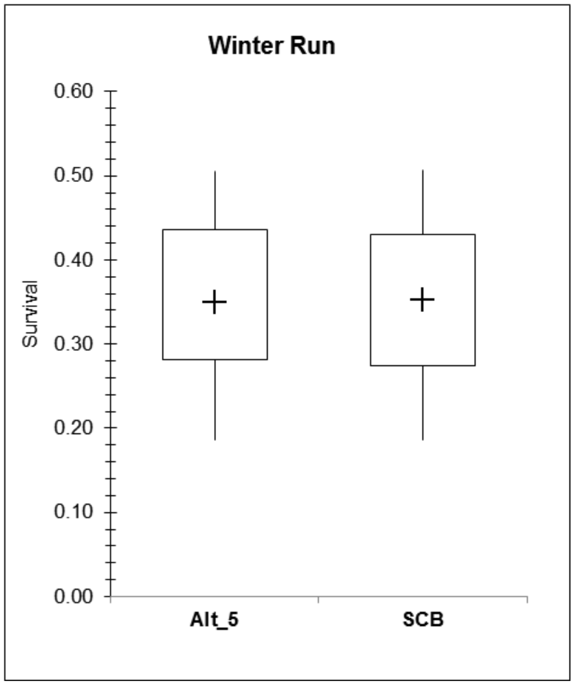

Figure 9J.37 Annual Delta Survival for Winter-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

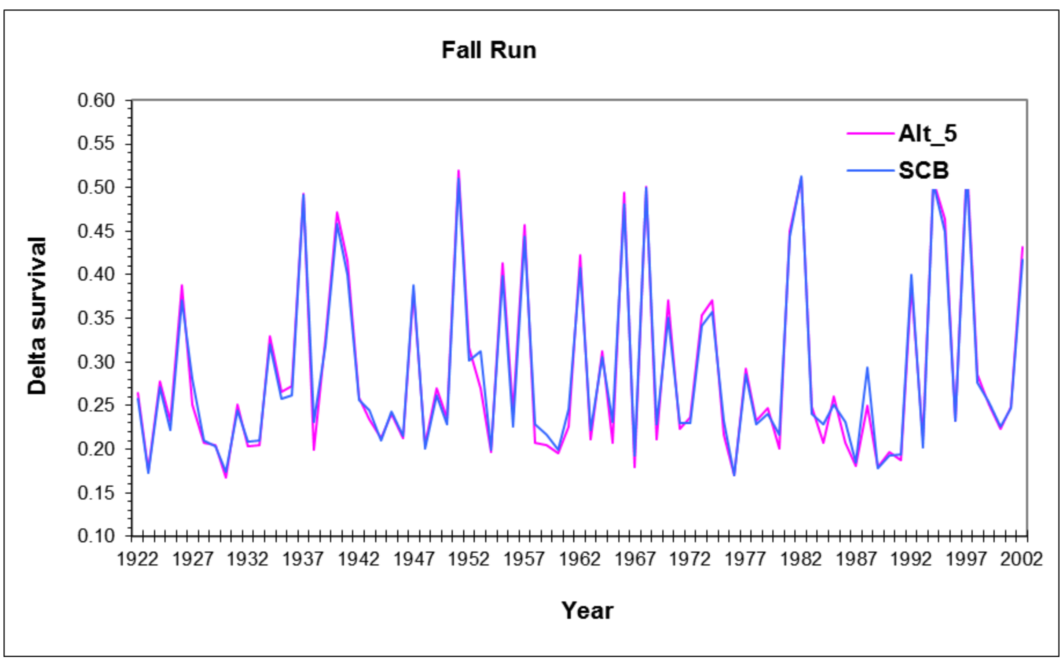

Figure 9J.38 Annual Delta Survival for Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

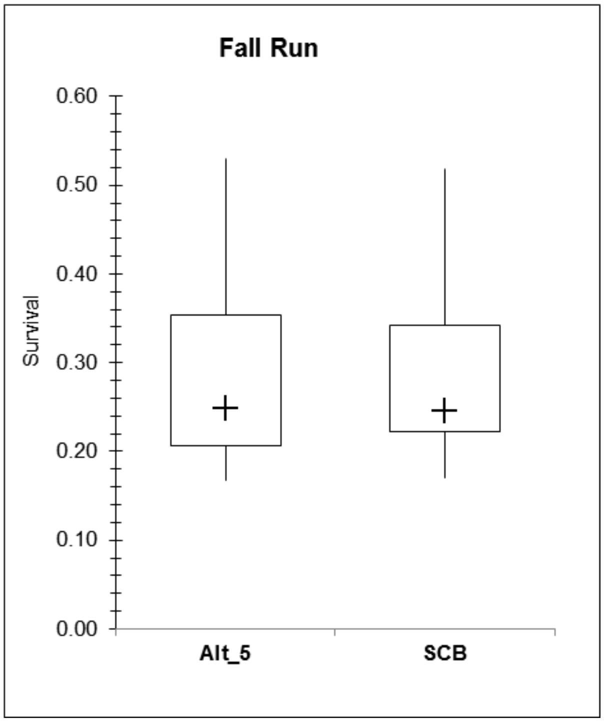

Figure 9J.39 Annual Delta Survival for Fall-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)

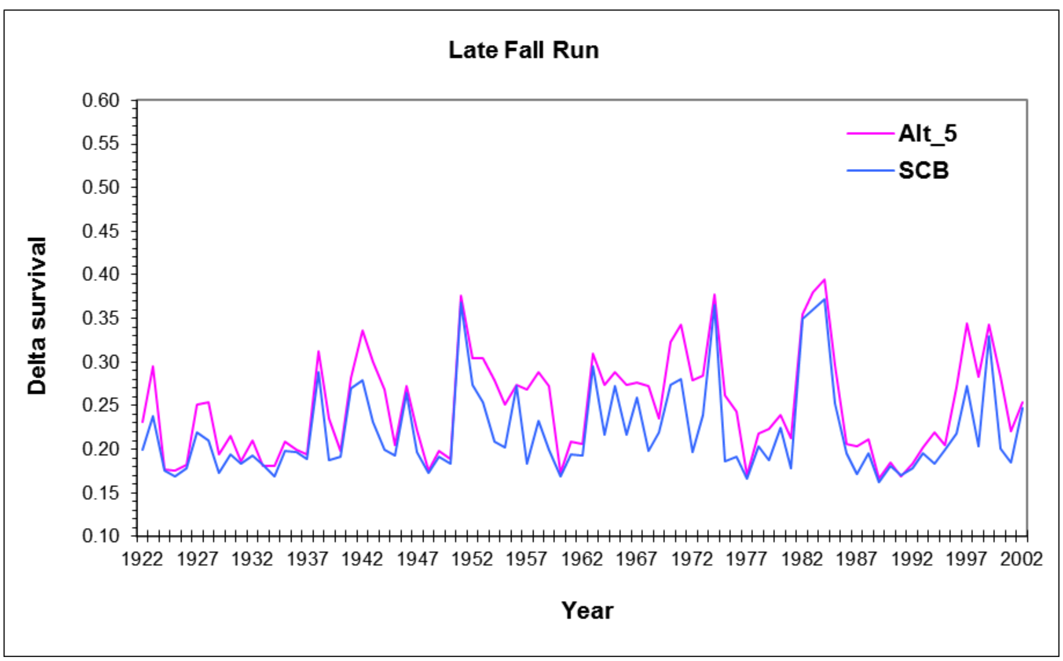

Figure 9J.40 Annual Delta Survival for Late Fall-run Chinook Salmon under Alt 3 as compared to the SBC over 81 water years estimated by the DPM model

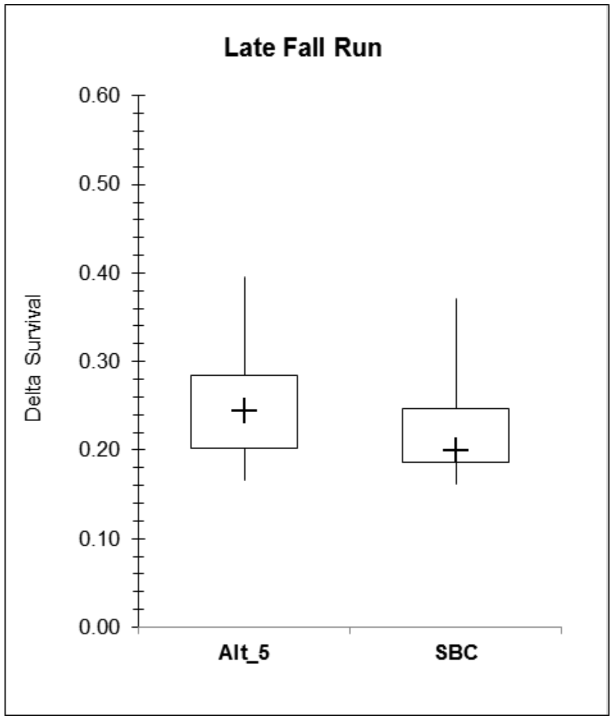

Figure 9J.41 Annual Delta Survival for Late Fall-run Chinook under Alt 5 as compared to the SBC estimated by the DPM model (Note: The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values.)