# Section 5C.5.4
# Delta Habitat (Plan Area) Results

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# 5C.5.4 Delta Habitat (Plan Area) Results

## 5C.5.4.1 Yolo Bypass Floodplain Habitat (*CM2 Yolo Bypass Fisheries Enhancement*)

### 5C.5.4.1.1 Sacramento Splittail Habitat Area

The most important spawning habitat for splittail occurs in the seasonally inundated floodplains of the Sutter and Yolo Bypasses of the Sacramento River. The analysis of floodplain habitat availability for splittail is directed primarily at the egg/embryo, larval, and juvenile stages because production of these life stages is especially important in determining year class abundance and because some information is available regarding splittail habitat requirements. As noted in the methods, only depth was considered in the habitat suitability indices because velocity was generally very low over the modeled area (lower velocities are generally suitable for splittail spawning) (Figure 5C.5.4-1).

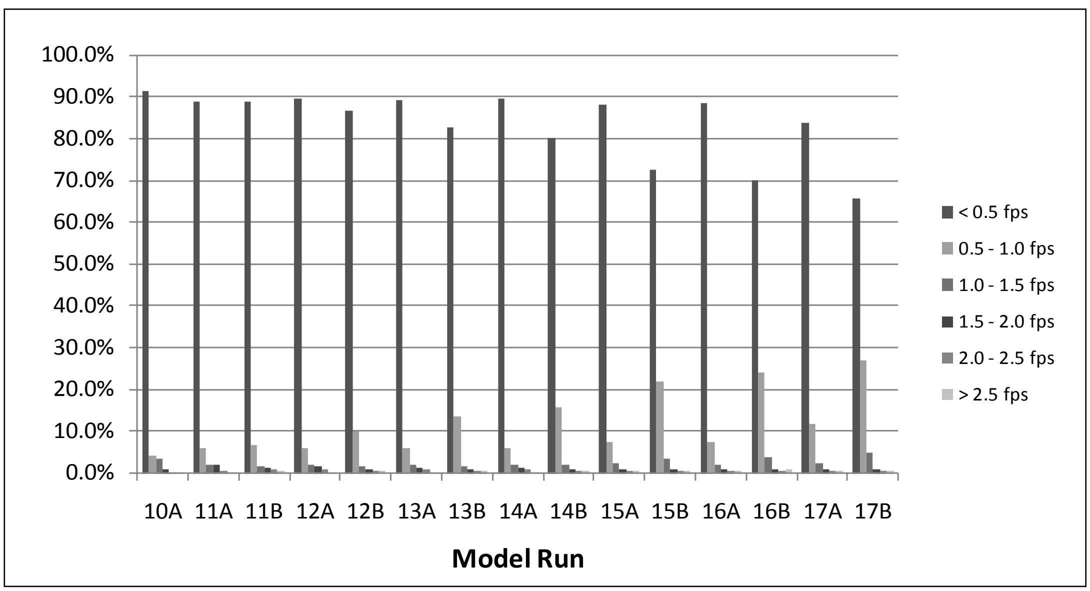
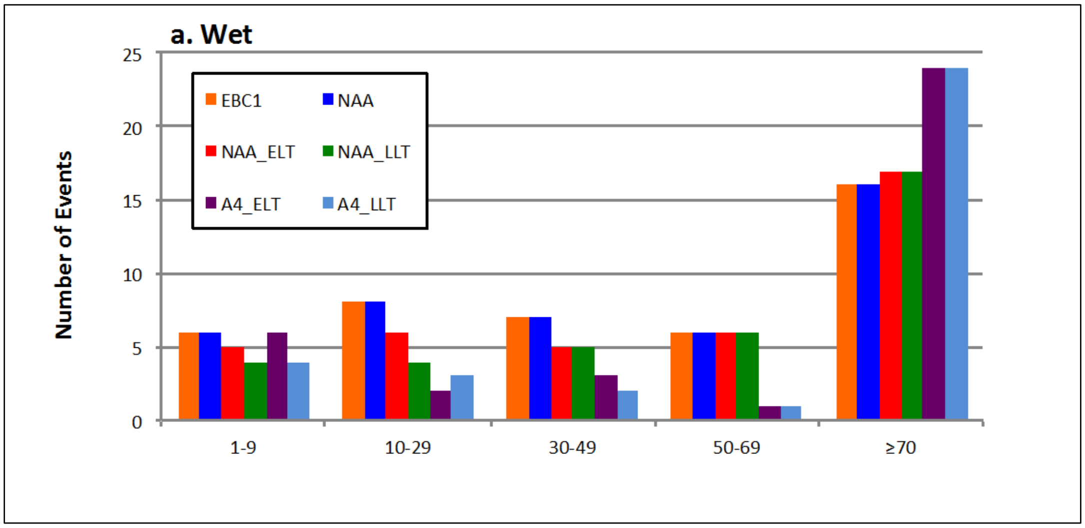
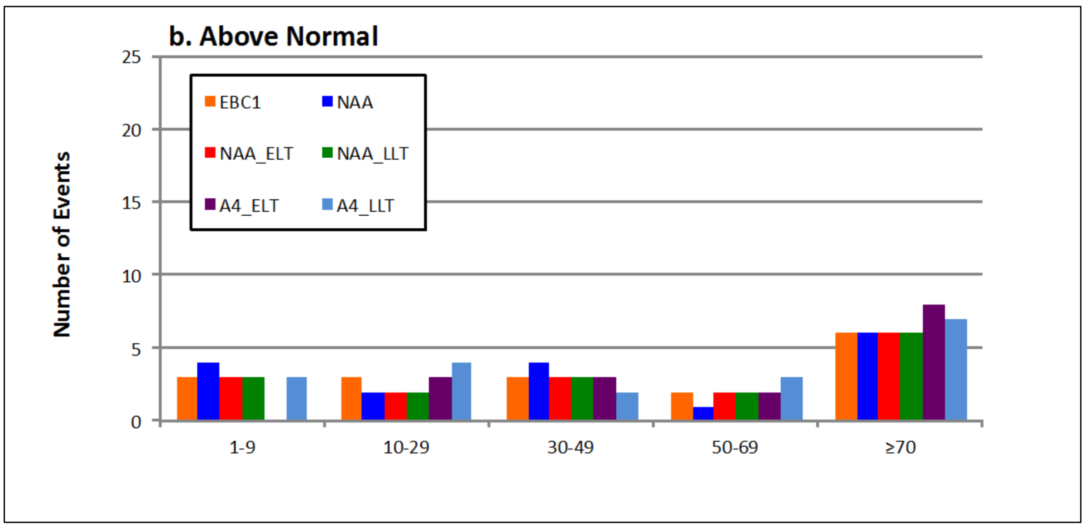



**Figure 5C.5.4-1. Percentages of Total Surface Area with Six Flow Velocity Ranges in the Yolo Bypass from 15 MIKE21 2-D Modeling Runs**

Results of the analyses show that the frequency and duration of inundation events are greater under the evaluated starting operations (ESO) than under either of the existing biological conditions (EBC1 and EBC2), especially for dry and critical water-year types (Figure 5C.5.4-2). Note that only the inundation events lasting more than 30 days are considered biologically beneficial to splittail. For wet water-year types in particular, the ESO results in a reduced frequency of shorter-duration events and an increased frequency of longer-duration events. This change is attributable to the influence of the Fremont Weir notch at lower flows.



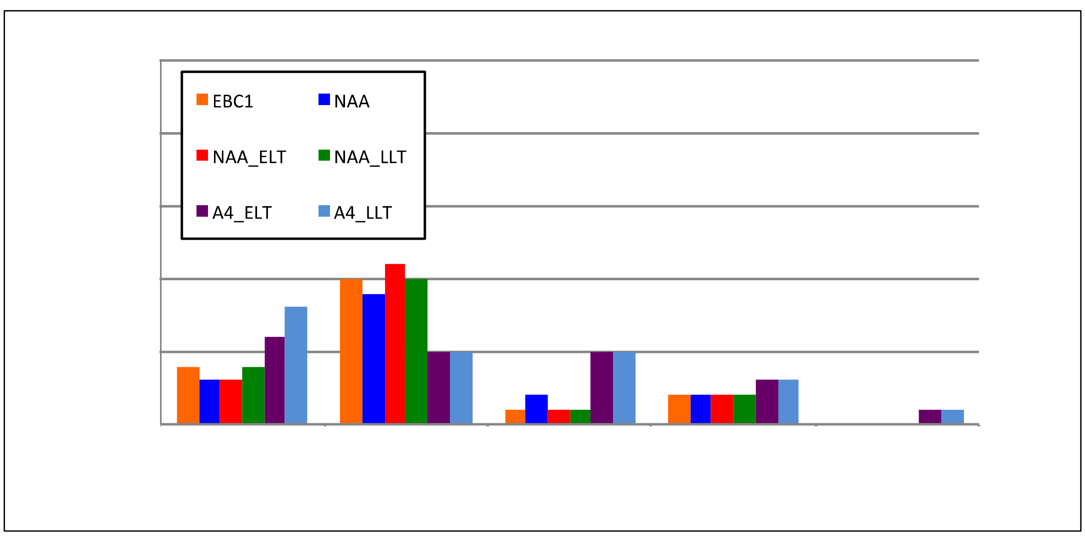
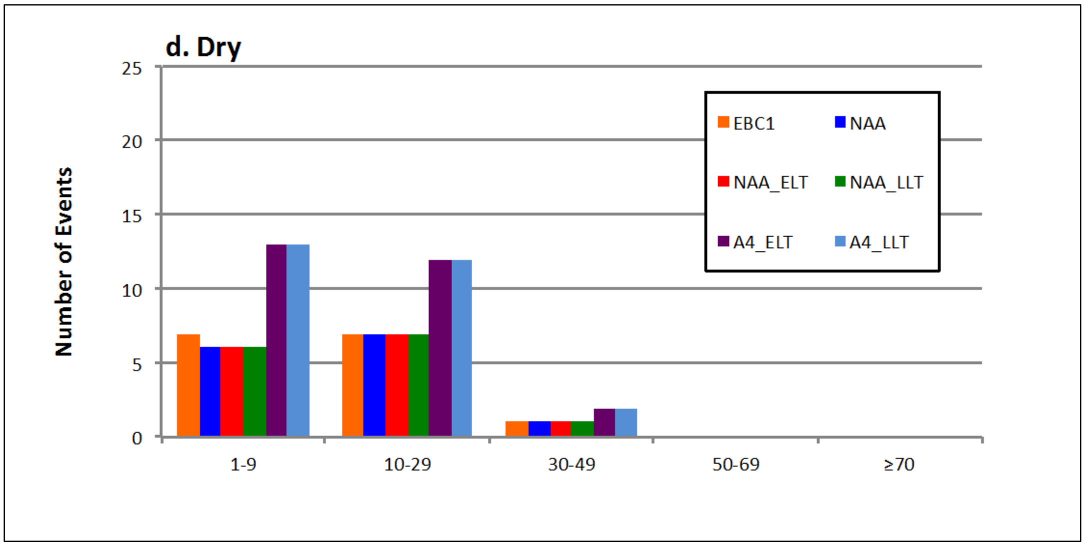




**Figure 5C.5.4-2. Frequencies of Inundation Events (for 82-Year Simulations) of Different Durations on the Yolo Bypass under Different Scenarios and Water-Year Types, February through June, from 15 2-D and Daily CALSIM II Modeling Runs**



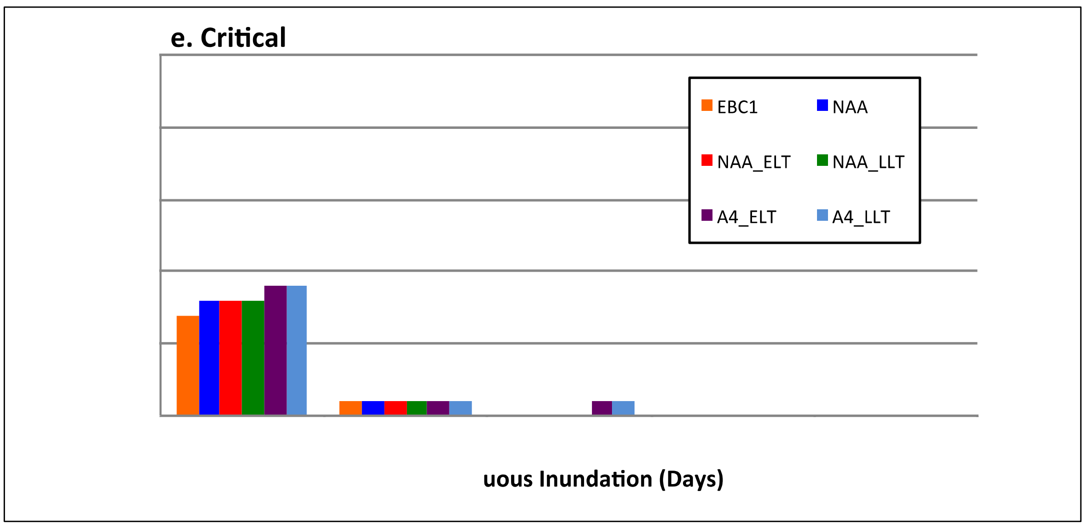




**Figure 5C.5.4-2. Frequencies of Inundation Events (for 82-Year Simulations) of Different Durations on the Yolo Bypass under Different Scenarios and Water-Year Types, February through June, from 15 2-D and Daily CALSIM II Modeling Runs (continued)**

Results of the analyses also indicate that total surface areas of splittail habitat in the Yolo Bypass are substantially higher under the evaluated starting operations than under EBC1 or EBC2 (Table 5C.5.4-1, Figure 5C.5.4-3).

**Table 5C.5.4-1. Percent Increase in Splittail Weighted Habitat Area in Yolo Bypass under ESO Scenarios Compared with EBC Scenarios**

| | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | ESO_ELT | | | ESO_LLT | | |
| **Water-Year Type** | **vs. EBC1** | **vs. EBC2** | **vs. EBC2_ELT** | **vs. EBC1** | **vs. EBC2** | **vs. EBC2_LLT** |
| Wet | 62.5% | 63.4% | 53.4% | 62.8% | 63.7% | 49.4% |
| Above Normal | 58.1% | 63.4% | 58.7% | 56.9% | 62.2% | 55.8% |
| Below Normal | 255.8% | 267.8% | 267.6% | 183.0% | 192.5% | 192.5% |
| Dry[b] | NA | NA | NA | NA | NA | NA |
| Critical[b] | NA | NA | NA | NA | NA | NA |

[a] See Table 5C.0-1 for definitions of scenarios.

[b] Percent differences could not be computed for dry and critical water-year types because no splittail weighted habitat occurred in the bypass in those years for EBC scenarios.

Sources: 15 2-D and Daily CALSIM II Modeling Runs

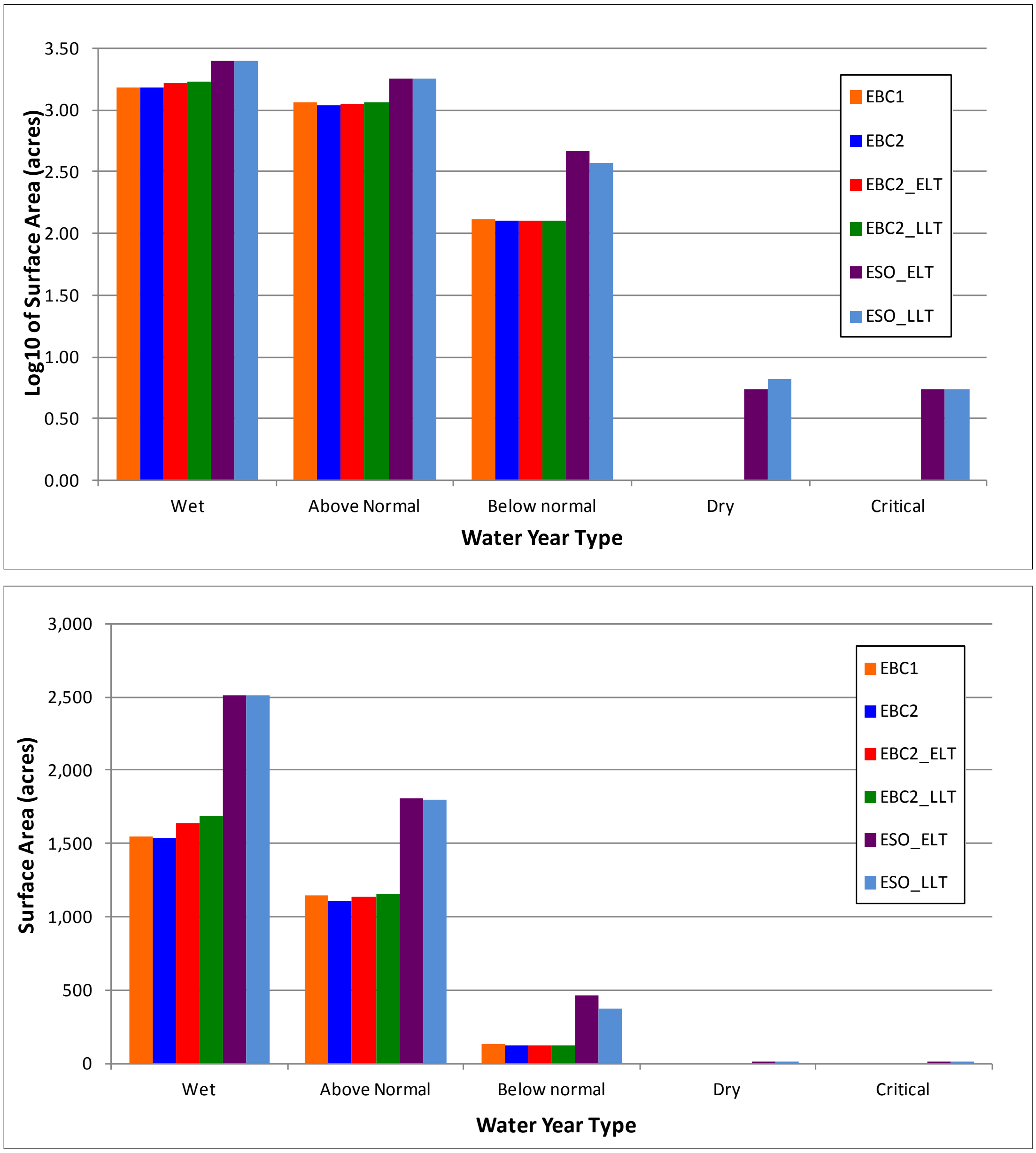



**Figure 5C.5.4-3. Splittail Daily Average Weighted Habitat Area in Yolo Bypass for EBC and ESO Scenarios by Water-Year Type, Shown on a Log (above) and Arithmetic (below) Scale**

Figure 5C.5.4-4 compares the frequencies and cumulative frequencies, respectively, of daily average surface areas of habitat simulated under each model scenario. The figures show that, in comparison with the existing biological conditions, the evaluated starting operations results in reductions in the frequency of days with no habitat area and an increase in the frequency of days with the largest total habitat areas. The reduced frequency of years with no habitat area reflects the influence of the Fremont Weir notch. Inundation events with the largest habitat areas result from flood flows, but the notch extends the duration of such events, resulting in higher average habitat areas for a year.

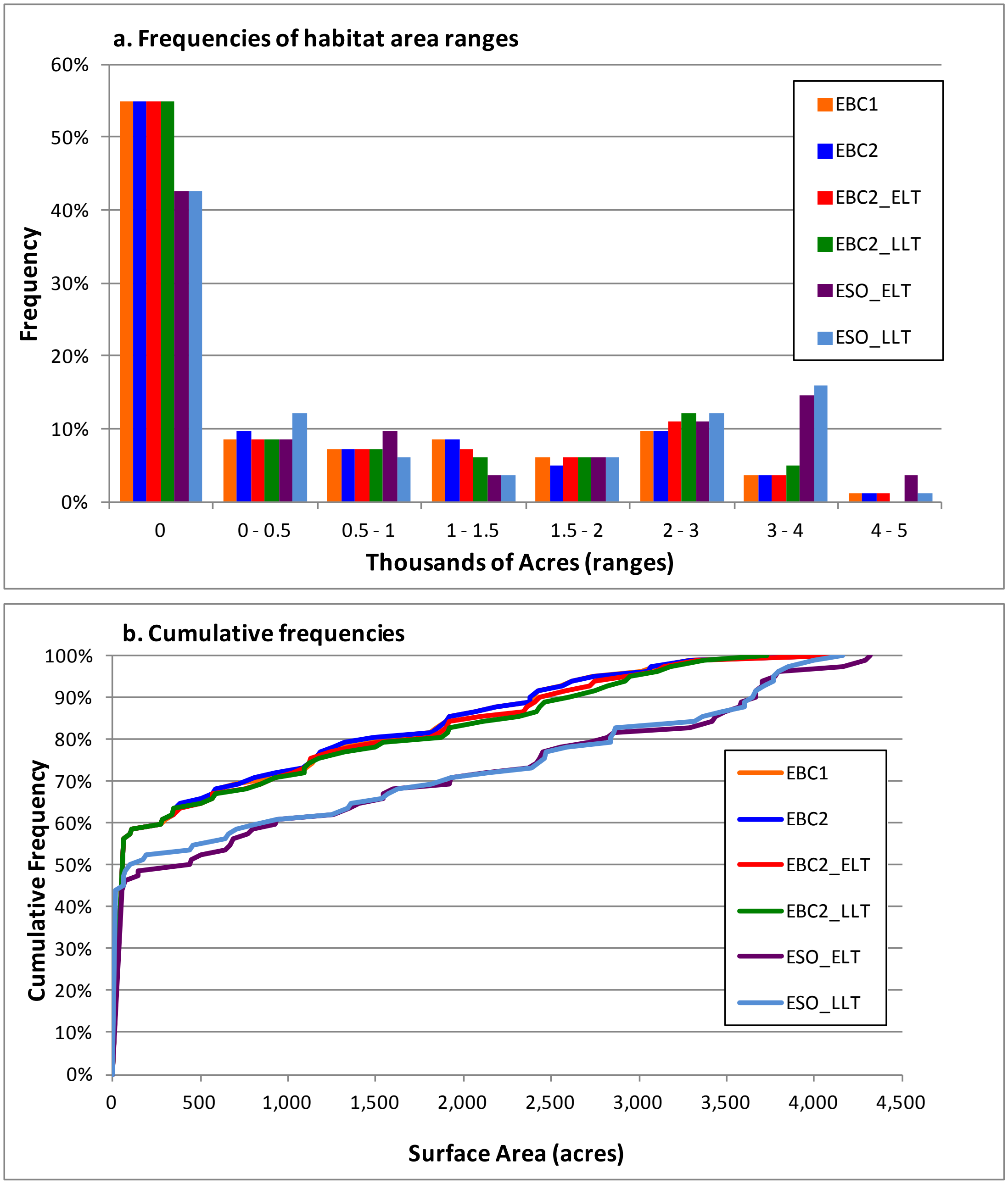



**Figure 5C.5.4-4. Frequencies (a) and Cumulative Frequencies (b) of Splittail Daily Average Weighted Habitat Area in the Yolo Bypass, for EBC and ESO Scenarios**

A potential adverse effect of *CM2 Yolo Bypass Fisheries Enhancement* is reduced inundation of the Sutter Bypass as a result of increased flow diversion at the Fremont Weir. The Fremont Weir notch with gates opened would increase the amount of Sacramento River flow diverted from the river into the bypass when the river's flow is greater than about 14,600 cfs (Munévar pers. comm.). As much as about 6,000 cfs more flow would be diverted from the river with the opened notch than without the notch, resulting in a 6,000 cfs decrease in Sacramento River flow at the weir. A decrease of 6,000 cfs in the river, according to rating curves developed for the river at the Fremont Weir, could result in as much as 3 feet of reduction in river stage (Munévar pers. comm.), although understanding of how notch flows would affect river stage is incomplete (Kirkland pers. comm.). In any case, a lower river stage at the Fremont Weir would be expected to result in a lower level of inundation in the lower Sutter Bypass. This was examined in the Sutter Bypass Inundation Analysis described below.

While the results presented here are preliminary, it appears unlikely that refinements in the analysis methods would affect the conclusion that *CM2 Yolo Bypass Fisheries Enhancement* would substantially increase available habitat for all the floodplain-dependent life stages of splittail on the Yolo Bypass. The results indicate that the increases, on a percentage basis, would be particularly large in drier water-year types, when, historically, availability of this habitat has been especially low.

## 5C.5.4.1.2 Stranding (Steelhead, Chinook Salmon, Sacramento Splittail, White Sturgeon, and Green Sturgeon)

Due to a lack of quantitative tools and historical data to use in the analysis of evaluated starting operations effects on stranding of migratory species, the following discussion provides a narrative summary of potential effects. The Yolo Bypass is exceptionally well-drained because of grading for agriculture, which likely helps limit stranding mortality of covered species such as Sacramento splittail and juvenile Chinook salmon. Moreover, water stage decreases on the bypass are relatively gradual (Sommer et al. 2001). Stranding of Sacramento splittail in perennial ponds on the Yolo Bypass does not appear to be a problem under existing conditions (Feyrer et al. 2004). *CM2 Yolo Bypass Fisheries Enhancement* includes a number of actions designed, in part, to further reduce the risk of stranding. Such actions include grading; removal of existing berms, levees, and water control structures; construction of new berms or levees; and reworking of agricultural delivery channels and the Tule Canal/Toe Drain. These actions would allow water to inundate certain areas of the bypass to maximize biological benefits, while keeping water away from other areas to reduce stranding in isolated ponds. Actions under the evaluated starting operations to increase the frequency of Yolo Bypass inundation would increase the frequency of potential stranding events. For splittail, an increase in inundation frequency would also increase the production of Sacramento splittail in the bypass. While total stranding losses may be greater under evaluated starting operations conditions than under EBC1 or EBC2, the total number of splittail would be expected to be greater under the evaluated starting operations.

In the Yolo Bypass, Sommer et al. (2005) found the potential stranding losses are offset for juvenile Chinook salmon by the improvement in rearing conditions. Henning et al. (2006) also noted the potential for stranding risk as wetlands desiccate and oxygen concentrations decline, but the seasonal timing of use by juvenile salmonids may decrease these risks. Sommer et al. (2005) addressed the question of stranding and concluded the potential improvements in habitat capacity outweighed the potential stranding problems that may exist in some years.

### 5C.5.4.1.2.1 Delta Regional Ecosystem Restoration Implementation Plan Evaluation of Stranding

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) (Essex Partnership 2009) evaluation of Fremont Weir and Yolo Bypass Inundation (previously referred to as Water Operations Conservation Measure 2), Outcome N3 (Increased stranding of covered species) resulted in the following conclusions related to stranding of adults and juveniles of covered fish species (adapted from DRERIP [Essex Partnership 2009]; note that this summary also includes reference to passage issues, which were previously described in Section 5C.5.3).

**Sacramento Splittail (Adult and Juvenile)**

Connectivity problems can strand splittail (Opperman 2008: page 27, citing Sommer et al. 2005). The approach specified for this action includes grading, which may reduce this risk; however, the specifics are not known.

- Magnitude = 1: Densities of splittail are low in isolated ponds in the Yolo Bypass (California Department of Water Resources unpublished data; Feyrer et al. 2004).
- Certainty = 4: Sommer et al. (2005) showed that there is relatively little ponded area following floodplain inundation. Low level of ponding reduces stranding.

**Green/White Sturgeon (Adult/Juvenile)**

Current Fremont and Sacramento Weirs create stranding and passage problems for white sturgeon and green sturgeon (Sommer et al. 2005; Harrell and Sommer 2003). Observations indicate substantial legal/illegal harvest resulting from blocked passage.

- Magnitude = 1: Blocked passage will be minimal behind the modified weir as it will be designed to improve passage, and grading will limit stranding on the floodplain for adults.
- Certainty = 4: The assumption is that the problem of blocked passage will be resolved by the modifications to the weir.

**Steelhead**[1]

Adult passage of white sturgeon, green sturgeon, splittail, steelhead, and salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento Weirs create stranding problems for white sturgeon and green sturgeon (Sommer et al. 2005); hence, efforts to improve passage and redesign weirs will reduce stranding (Harrell and Sommer 2003).

- Magnitude = 1 (adults), 2 (juveniles): Blocked passage will be minimal behind the modified weir as it will be designed to improve passage, and grading will limit stranding on the floodplain for adults. Juveniles are more susceptible to stranding; thus, the effect is greater.
- Certainty = 4: Evidence is good that efficient drainage results in low stranding (Sommer et al. 2005); hence, additional grading should prevent stranding.

**Chinook Salmon**

Most juvenile Chinook salmon can exit the existing floodplain configuration (Sommer et al. 2005). Adult passage of salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento Weirs create stranding problems for salmonids (Sommer et al. 2005); hence, efforts to improve passage and redesign weirs will reduce stranding (Harrell and Sommer 2003). The assumption is that operable gates/ladders would be operable at all times to allow year-round passage.

- Magnitude = 1 (adults), 2 (juveniles): Stranding is minimal on the Yolo Bypass now. This proposal will further reduce stranding behind the weir because the new weir design will improve passage and the floodplain will be graded. There is some possibility of reduced passage if migrating salmon encounter the modified structure when it is closed or there is insufficient flow to allow passage.

[1] Although the majority of this text applies to sturgeon, it also is relevant to steelhead.

- Certainty = 4: Evidence is good that efficient drainage results in low stranding (Sommer et al. 2005); hence, additional grading should prevent stranding.

#### 5C.5.4.1.3 Proportion of Chinook Salmon That Could Benefit from *CM2 Yolo Bypass Fisheries Enhancement*

*CM2 Yolo Bypass Fisheries Enhancements* proposes a number of modifications to the Yolo Bypass and its associated infrastructure (see Chapter 3, *Conservation Strategy*, for more details). Paramount among these modifications is the notching of Fremont Weir that would allow more upstream flow to enter the Yolo Bypass. It is important to place into context the proportion of each Chinook salmon ESU that could potentially benefit from greater access to Yolo Bypass under this action, based on the relative abundance of the constituent populations from different tributaries within each ESU and their geographic position in relation to Fremont Weir. Under the assumption that adult escapement to different tributaries provides a reasonable measure of relative juvenile abundance and emigration from each tributary, it is possible to estimate the proportion of each ESU that is upstream of Fremont Weir and that could access the Yolo Bypass through a Fremont Weir notch when outmigrating as juveniles. The dividing line for upstream/downstream of Fremont Weir is taken to be Butte Creek: In years when flooding of the Sutter Bypass does not occur, Chinook salmon from Butte Creek emigrate down the east and west side channels of the Sutter Bypass and exit into the Sacramento River via Sacramento Slough downstream of the Fremont Weir (ICF Jones & Stokes 2009), thus missing any opportunities to benefit from notching of Fremont Weir. In wetter years when the Sutter Bypass is flooded, spring-run Chinook salmon fry/parr from Butte Creek can enter the Yolo Bypass over Fremont Weir, but this is not a situation that would be enhanced by notching of Fremont Weir because the notch would not be operated when flows exceed the existing weir crest elevation.

Sacramento River winter-run Chinook salmon ESU escapement in the Central Valley only occurs in the upper Sacramento River (Azat 2012) and therefore all winter-run Chinook salmon surviving from upstream to Fremont Weir would have the opportunity to enter the Yolo Bypass via a notch in Fremont Weir when the notch is operational. Note that this does not imply that all juvenile winter-run would enter the Yolo Bypass, merely that they all would be in the river upstream of and approaching the Fremont Weir. Individuals entering the Sutter Bypass via Moulton, Colusa, and Tisdale Weirs would tend to do so in years when Sutter Bypass flow may enter the Yolo Bypass over Fremont Weir, and is not different than the existing situation.

Similar to winter-run Chinook salmon, all or nearly all late fall–run Chinook salmon spawn in the upper Sacramento River (Azat 2011). Late fall–run Chinook salmon are considered part of the Central Valley fall-run/late fall–run Chinook salmon ESU (see below).

Median escapement estimates for the Central Valley spring-run Chinook salmon ESU over the last decade (2002–2011) suggest that around 31% of adults escape to tributaries upstream of Fremont Weir (Table 5C.5.4-2) and therefore their progeny could benefit from *CM2 Yolo Bypass Fisheries Enhancement* during downstream migration. The bulk of escapement is to Butte Creek (65%, or a median of nearly 4,500 adults), suggesting that approximately one-third of Sacramento River basin spring-run Chinook salmon juveniles could benefit from CM2 through enhanced access to Yolo Bypass (although see discussion below regarding potential increased flooding duration). Note that Feather River and Yuba River populations were not included in these estimates due to the hatchery influence on these populations.

For the Central Valley fall-run/late fall–run Chinook salmon ESU, a median of 62% of escapement was from tributaries of downstream of Fremont Weir (Table 5C.5.4-3), which suggests that around 38% of outmigrating juveniles from this ESU would have the potential to benefit from enhanced access to the Yolo Bypass via a notch in Fremont Weir.

Note that this consideration of the potential benefit of *CM2 Yolo Bypass Fisheries Enhancement* is focused solely on entry into Yolo Bypass based on geographic origin of Chinook salmon populations. An important additional benefit is the potential for longer duration of floodplain inundation for fish that would have entered the Yolo Bypass whether it was notched or not. Thus, for example and as noted above, spring-run Chinook salmon fry/parr from Butte Creek would only enter the Yolo Bypass over Fremont Weir during high-flow events during which time the Sutter Bypass floods and provides flow over the Fremont Weir. Notching of Fremont Weir would allow flow to remain passing into Yolo Bypass for a greater duration under the BDCP, which would benefit those spring-run Chinook salmon fry/parr that enter the Bypass during higher flows and would not have continued flow into the Bypass without the notch.

**Table 5C.5.4-2. Escapement of Spring-Run Chinook Salmon To Tributaries Based on Potential Enhanced Access of Outmigrating Juveniles to Yolo Bypass through a Notch in Fremont Weir**

| Year | Sacramento River Upstream of Red Bluff Diversion Dam | Sacramento River Downstream of Red Bluff Diversion Dam | Battle Creek | Clear Creek | Cottonwood Creek | Antelope Creek | Mill Creek | Deer Creek | Big Chico Creek | Total Upstream | Butte Creek[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 195 | 0 | 222 | 66 | 125 | 46 | 1,594 | 2,195 | 0 | 4,443 | 8,785 |
| 2003 | 0 | 0 | 221 | 25 | 73 | 46 | 1,426 | 2,759 | 81 | 4,631 | 4,398 |
| 2004 | 370 | 0 | 90 | 98 | 17 | 3 | 998 | 804 | 0 | 2,380 | 7,390 |
| 2005 | 0 | 30 | 73 | 69 | 47 | 82 | 1,150 | 2,239 | 37 | 3,727 | 10,625 |
| 2006 | 0 | 0 | 221 | 77 | 55 | 102 | 1,002 | 2,432 | 299 | 4,188 | 4,579 |
| 2007 | 248 | 0 | 291 | 194 | 34 | 26 | 920 | 644 | 0 | 2,357 | 4,943 |
| 2008 | 0 | 52 | 105 | 200 | 0 | 2 | 362 | 140 | 0 | 861 | 3,935 |
| 2009 | 0 | 0 | 194 | 120 | 0 | 0 | 220 | 213 | 6 | 753 | 2,059 |
| 2010 | 0 | 0 | 172 | 21 | 15 | 17 | 482 | 262 | 2 | 971 | 1,160 |
| 2011 | 0 | 0 | 157 | 8 | 2 | 6 | 366 | 271 | 124 | 934 | 2,130 |
| Average (percent of total count) | 81 | 8 | 175 | 88 | 37 | 33 | 852 | 1,196 | 55 | 2,525 (34%) | 5,000 (66%) |
| Median (percent of total count) | 0 | 0 | 183 | 73 | 26 | 22 | 959 | 724 | 4 | 2,369 (35%) | 4,489 (65%) |

[a] Outmigrating juveniles from Butte Creek typically enter the Sacramento River downstream of Fremont Weir via the Sutter Bypass.
Source: Azat 2012.

**Table 5C.5.4-3. Escapement of Fall-Run and Late Fall–Run Chinook Salmon To Tributaries Based on Enhanced Access of Outmigrating Juveniles to the Yolo Bypass through a Notch in Fremont Weir**

| Year | Sacramento River Upstream of RBDD | Battle Creek | Clear Creek | Sacramento River Downstream RBDD | Mill Creek | Deer Creek | Total Upstream | Butte Creek | Feather River | Yuba River | American River | Cosumnes River | Mokelumne River | Stanislaus River | Tuolumne River | Merced River | Total Downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 63,903 | 397,247 | 16,071 | 21,063 | 2,611 | | 500,895 | 3,665 | 105,163 | 24,051 | 124,252 | 1,350 | 2,840 | 7,787 | 7,173 | 8,866 | 285,147 |
| 2003 | 102,489 | 64,980 | 9,475 | 22,744 | 2,426 | | 202,114 | 3,492 | 89,946 | 28,316 | 163,742 | 122 | 2,122 | 5,902 | 2,163 | 2,530 | 298,335 |
| 2004 | 39,396 | 23,918 | 6,365 | 9,702 | 1,192 | 300 | 80,873 | 2,516 | 54,171 | 15,269 | 99,230 | 1,208 | 1,588 | 4,015 | 1,984 | 3,270 | 183,251 |
| 2005 | 53,774 | 20,560 | 14,824 | 12,062 | 2,426 | 963 | 104,609 | 4,255 | 49,160 | 17,630 | 62,679 | 370 | 10,406 | 1,427 | 668 | 1,942 | 148,537 |
| 2006 | 56,061 | 19,516 | 8,422 | 9,931 | 1,403 | 1,905 | 97,238 | 1,920 | 76,414 | 8,121 | 24,540 | 530 | 1,732 | 1,923 | 562 | 1,429 | 117,171 |
| 2007 | 21,775 | 9,954 | 4,157 | 5,449 | 851 | 563 | 42,749 | 1,225 | 21,909 | 2,604 | 10,120 | 77 | 470 | 443 | 224 | 485 | 37,557 |
| 2008 | 36,932 | 4,358 | 7,677 | 3,086 | 166 | 194 | 52,413 | 275 | 5,939 | 3,508 | 2,514 | 15 | 173 | 1,392 | 372 | 389 | 14,577 |
| 2009 | 8,984 | 3,066 | 3,228 | 807 | 102 | 58 | 16,245 | 306 | 4,847 | 4,635 | 5,297 | 0 | 680 | 595 | 124 | 358 | 16,842 |
| 2010 | 17,248 | 6,663 | 7,192 | 2,613 | 144 | 166 | 34,026 | 370 | 44,914 | 14,375 | 14,688 | 740 | 1,920 | 1,086 | 540 | 651 | 79,284 |
| 2011 | 14,466 | 12,540 | 4,841 | 1,773 | 1,231 | 662 | 35,513 | 416 | 47,289 | 8,928 | 25,626 | 53 | 2,674 | 1,309 | 893 | 1,571 | 88,759 |
| Average (percent of total count) | 41,503 | 56,280 | 8,225 | 8,923 | 1,255 | 601 | 116,668 (48%) | 1,844 | 49,975 | 12,744 | 53,269 | 447 | 2,461 | 2,588 | 1,470 | 2,149 | 126,946 (52%) |
| Median | 39,263 | 22,184 | 7,441 | 7,709 | 1,120 | 601 | 78,245 (41%) | 1,662 | 44,456 | 11,613 | 46,170 | 356 | 2,423 | 2,068 | 900 | 1,477 | 111,126 (59%) |

### 5C.5.4.1.4 Chinook Salmon Fry Yolo Bypass Growth Analysis

#### 5C.5.4.1.4.1 Yolo Bypass Fry Rearing Model Results

The following describes the results of the YBFR model based on application of the model to the ESO_ELT and ESO_LLT scenarios and proposed Fremont Weir modifications. The potential benefits of these scenarios are evaluated by comparing the model results with those of the EBC scenarios (EBC1, EBC2, EBC2_ELT, and EBC2_LLT). The results of the application of the model to fall-run are examined in detail below followed by a comparison of the results based on application of the model to winter-run. This is followed by 1) a summary of the results of a sensitivity analysis to evaluate the effects of changes in fry survival in the lower Sacramento River on overall benefits associated with increased floodplain rearing in the Yolo Bypass, and 2) an evaluation of the benefits of the HOS scenarios relative to the ESO scenarios. The LOS winter and spring operations are identical to the ESO operations and therefore LOS results are assumed to be the same as those presented for ESO.

**Fall-Run Chinook Salmon**

***Percentage of Juveniles Entering Yolo Bypass***

Figure 5C.5.4-5, Figure 5C.5.4-6, Figure 5C.5.4-7, Figure 5C.5.4-8, Figure 5C.5.4-9, and Figure 5C.5.4-10 summarize the differences in annual percentages of fall-run Chinook salmon juveniles entering the Yolo Bypass as fry (<70 mm in length) among the modeled scenarios for the entire 82-year simulation period and by water-year type. These results reflect differences in the timing and magnitude of upstream flows (i.e., number of flow events triggering peak fry movements) in the Sacramento River and differences in spill characteristics of the Fremont Weir under existing and proposed weir modifications.

Under the ESO scenarios and associated weir modifications, fall-run Chinook salmon fry would enter the Yolo Bypass in 74 (90%) of the years compared to 44–46 (54–56%) of the years under the EBC scenarios. The median percentage of fish entering the Yolo Bypass over the 82-year simulation period was 8% (range: 0–32%) under the ESO scenarios and ≤1% (range: 0–24%) under the EBC scenarios.

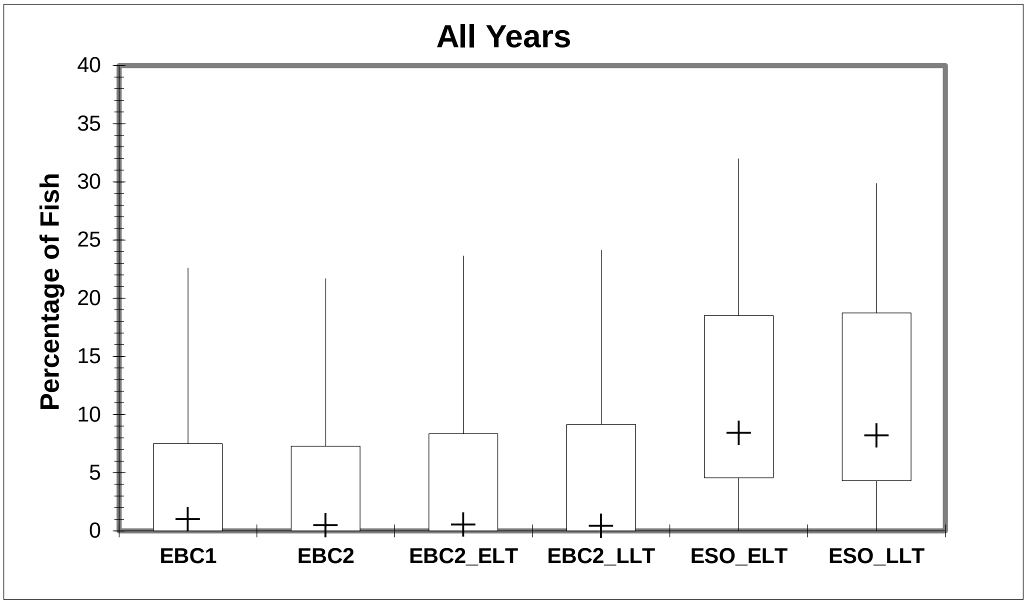
In critical water years, Fremont Weir spills associated with floodplain inundation (≥3,000 cfs) occurred only under the ESO scenarios; spills of this magnitude occurred in 7 of the 12 critical years. The median percentage of fish entering the Yolo Bypass in critical water years was <1% (range: 0–7%) of the total numbers of juveniles passing the Fremont Weir.

In dry years, spills occurred in 16 of the 18 years under the ESO scenarios and only 4 years under the EBC scenarios. The median percentage of fish entering the Yolo Bypass over the 82-year simulation period was 4–5% (range: 0–8%) under the ESO scenarios and 0% (range: 0–6%) under the EBC scenarios.

In below normal water years, spills occurred in all or nearly all years (13–14 years) under the ESO scenarios and only 4–5 years under the EBC scenarios. The median percentage of fish entering the Yolo Bypass in below normal years was 7% (range: 0–19%) under the ESO scenarios and 0% (range: 0–6%) under the EBC scenarios.

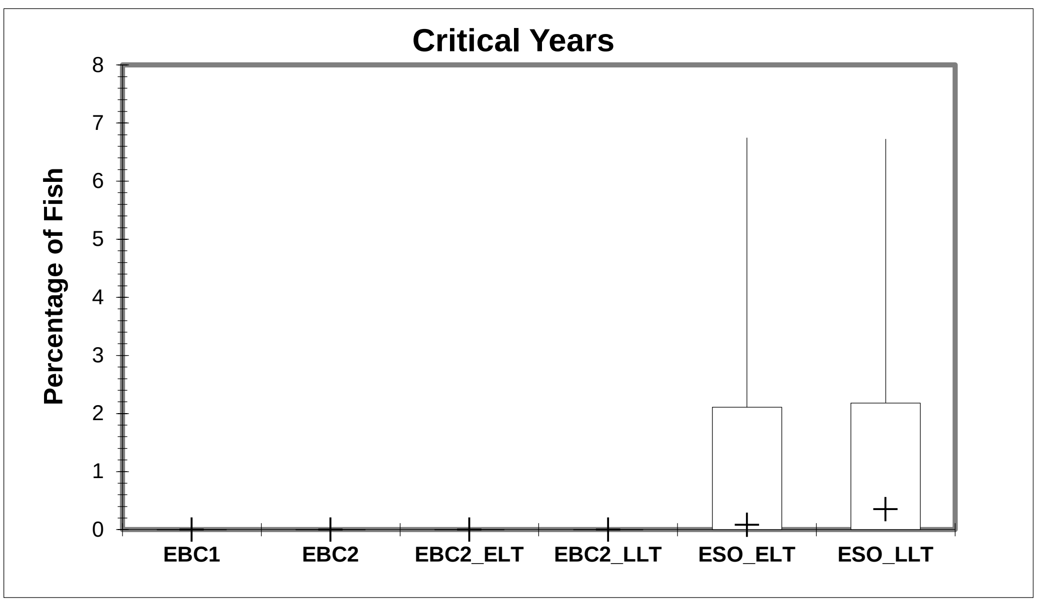
In above normal years, spills occurred in all years (12 years) under the ESO scenarios and 10 of the 12 years under the EBC scenarios. The median percentage of juveniles entering the Yolo Bypass as fry was 16–17% (range: 6–32%) under the ESO scenarios and 4–5% (range: 0–14%) under the EBC scenarios.

Spills occurred in all wet years (26 years) under the ESO and EBC scenarios. The frequency and magnitude of spills was highest in wet years, resulting in median values of 21–22% (range: 10–30%) of the fish entering the Yolo Bypass as fry under the ESO scenarios and 11–12% (range: <1–24%) of the fish entering the Bypass as fry under the EBC scenarios.



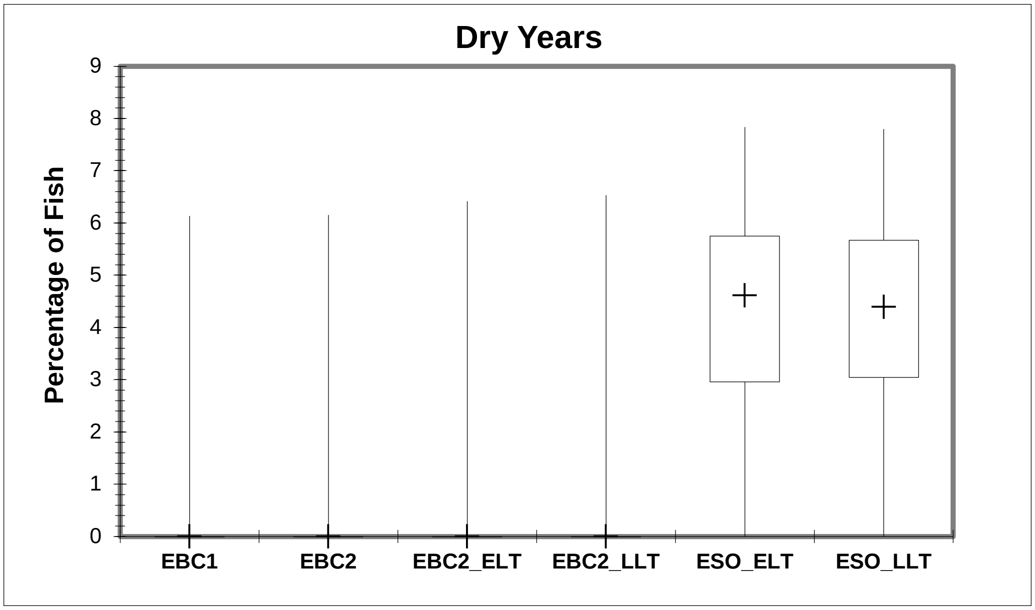

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-5. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (All Modeled Years)**



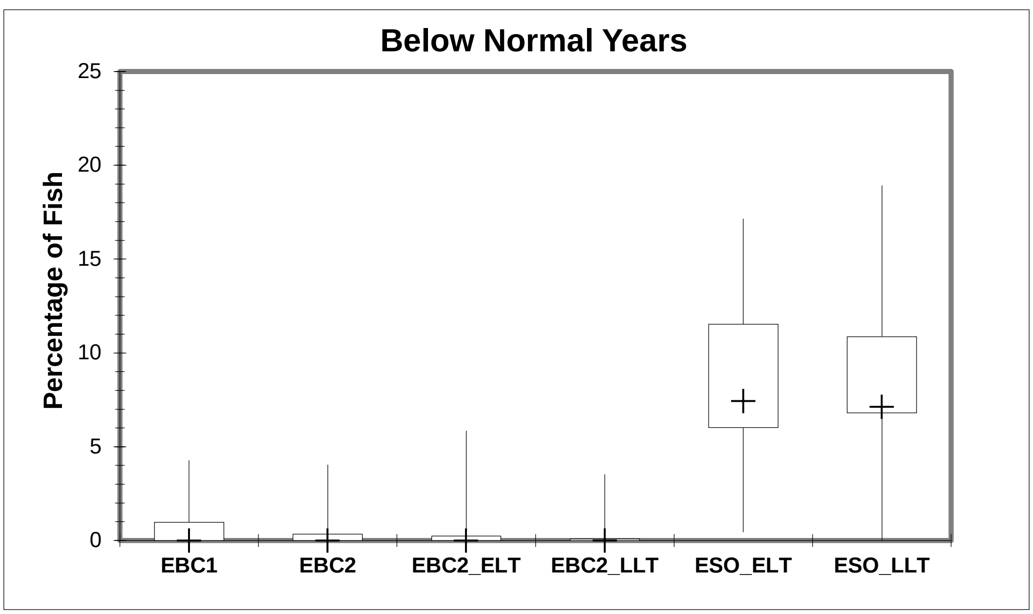

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-6. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (Critical Water Years)**



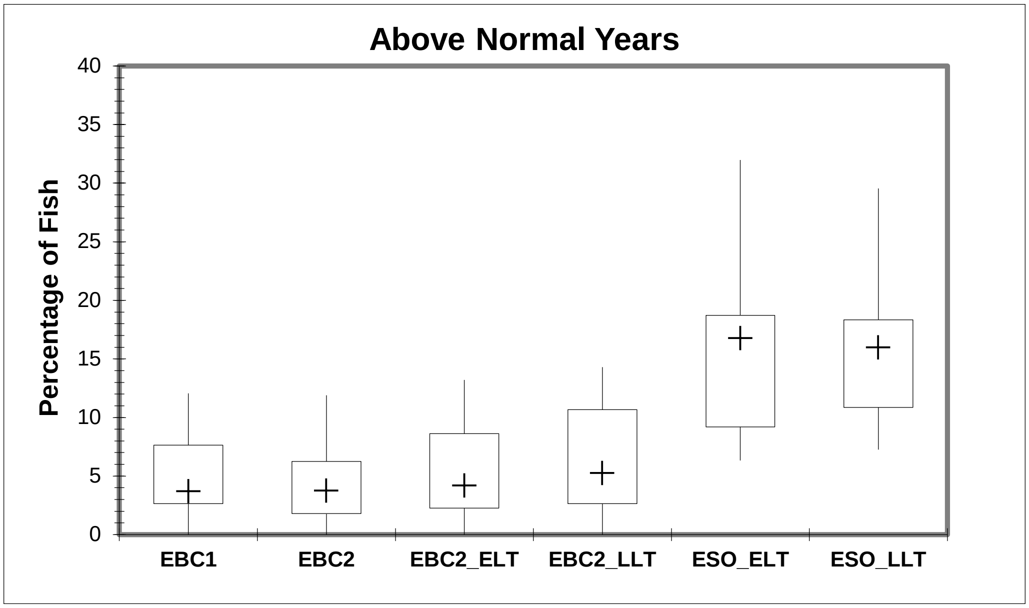

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-7. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (Dry Water Years)**



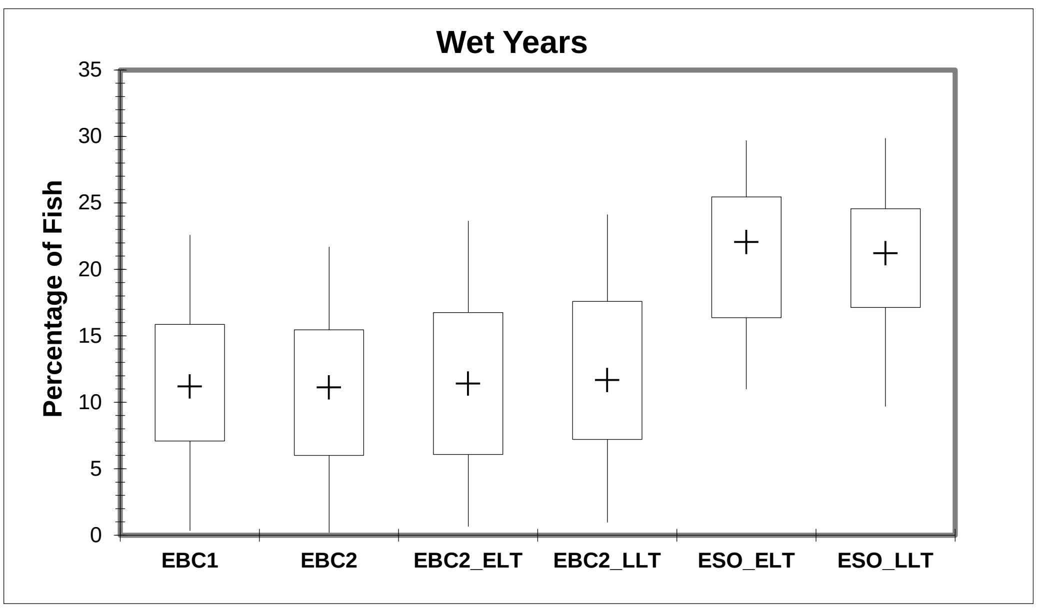

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-8. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (Below Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-9. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (Above Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual percentages by modeled scenario.

**Figure 5C.5.4-10. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry (Wet Water Years)**

***Duration of Floodplain Rearing***

Figure 5C.5.4-11, Figure 5C.5.4-12, Figure 5C.5.4-13, Figure 5C.5.4-14, Figure 5C.5.4-15, and Figure 5C.5.4-16 summarize the differences in duration of floodplain rearing of fall-run Chinook salmon (assuming maximum residence time) among the modeled scenarios for the entire 82-year simulation period and by water-year type. These results reflect differences in the timing and duration of spills ≥3,000 cfs under existing and proposed Fremont Weir modifications.

The median duration of floodplain rearing over the 82-year simulation period was 53–56 days per year under the ESO scenarios and 13–16 days per year under the EBC scenarios. Floodplain inundation periods of 30 days or more (representing one or more events during the annual flood season) would occur in 58 years under the ESO scenarios (71% of the years) and 32–34 years under the EBC scenarios (39–41% of the years).

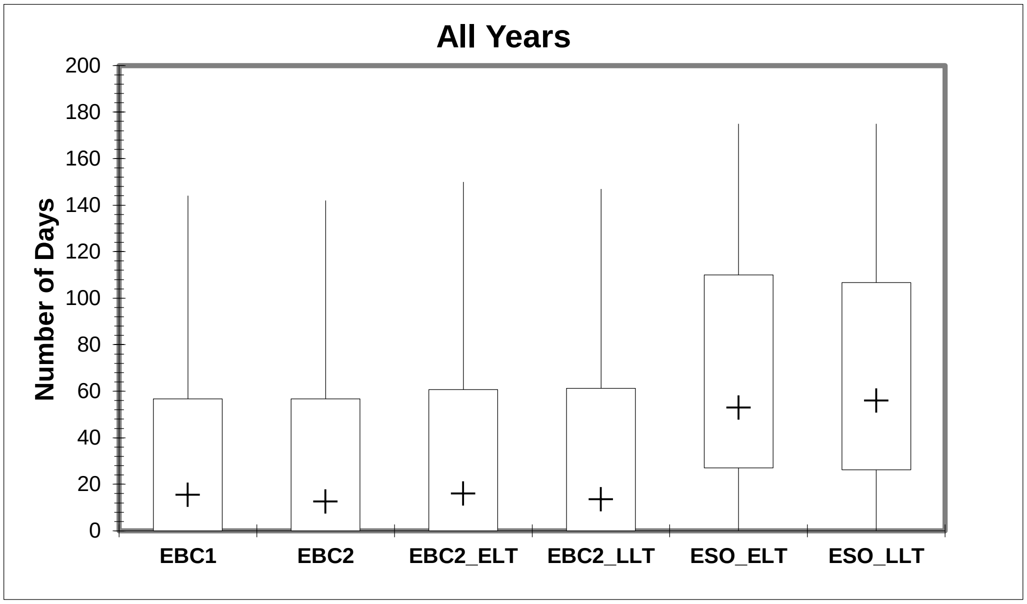
In critical water years, no floodplain rearing opportunities would occur under the EBC scenarios and existing weir configuration. Operation of the proposed notch under the ESO scenarios would result in a median value of 4 days of floodplain rearing (range: 0–34 days). Floodplain inundation periods of 30 days or more would occur in 3 of the 12 critical years.

In dry years, the median duration of floodplain rearing under the ESO scenarios would increase to 27 days (range: 0–56 days) compared to 0 days under the EBC scenarios (range: 0–23 days). Operation of the proposed notch under the ESO scenarios would result in 30 days or more of floodplain inundation in 6–7 of the 18 dry years.

In below normal years, the median duration of floodplain rearing under the ESO scenarios would increase to 45 days (range: 0–100 days) compared to 0 days under the EBC scenarios (range: 0–23 days). Operation of the proposed notch under the ESO scenarios would result in 30 days or more of floodplain inundation in 10–11 of the 14 dry water years.

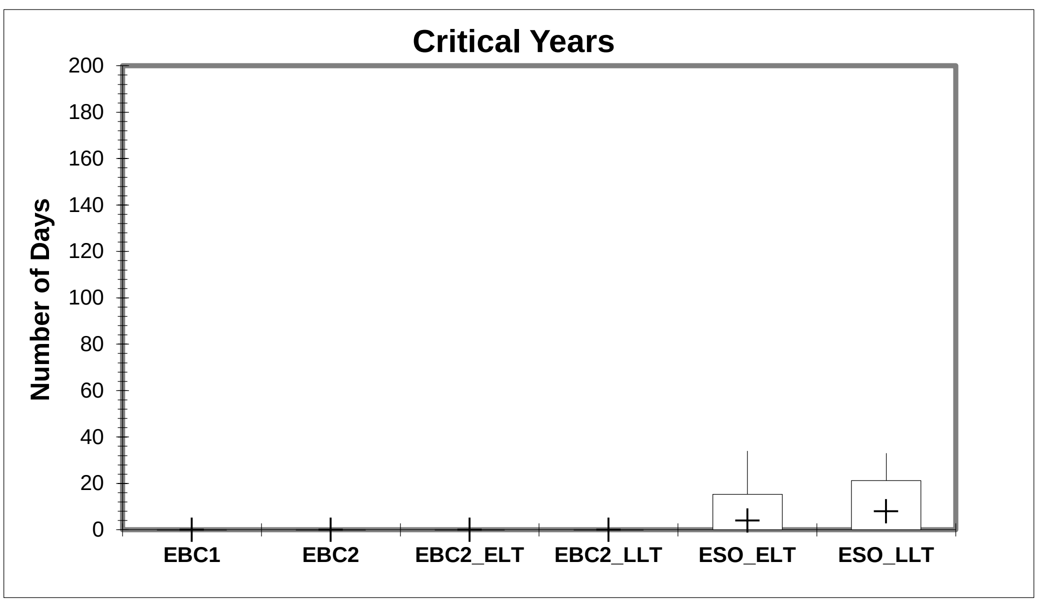
In above normal years, the median duration of floodplain rearing under the ESO scenarios would increase to 99–104 days (range: 32–133 days) compared to 38–52 days under the EBC scenarios (range: 0–72 days). Floodplain inundation periods of 30 days or more would occur in all above normal years (12 years) under the ESO scenarios and 7–9 of the 12 years under the EBC scenarios.

In wet years, the median duration of floodplain rearing under the ESO scenarios would increase to 123–126 days (range: 67–175 days) compared to 68–70 days under the EBC scenarios (range: 11–150 days). Floodplain inundation periods of 30 days or more would occur in all above normal years (26 years) under the ESO scenarios and 25 of the 26 years under the EBC scenarios.



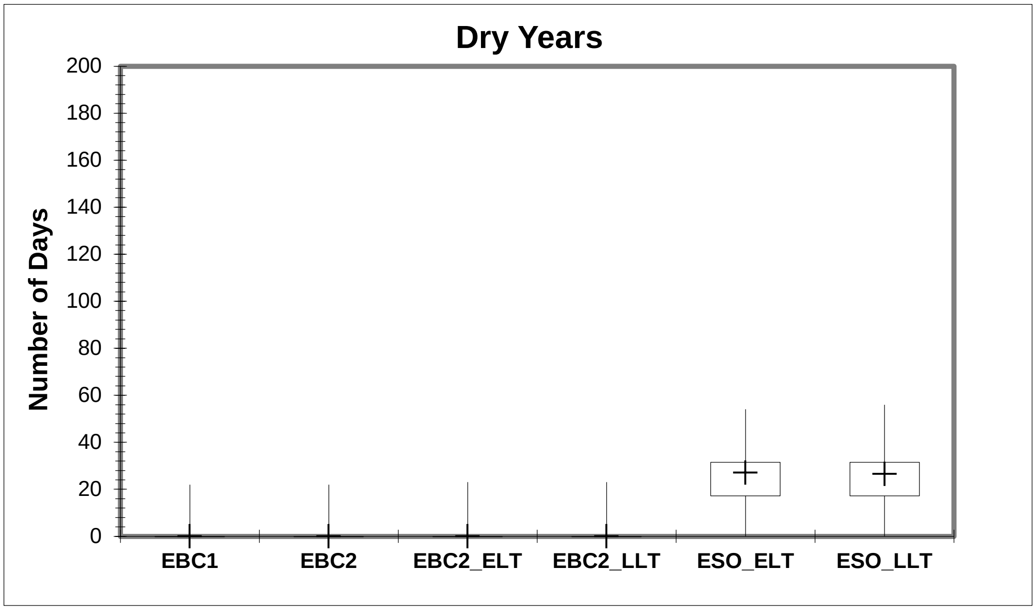

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

**Figure 5C.5.4-11. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (All Modeled Years)**



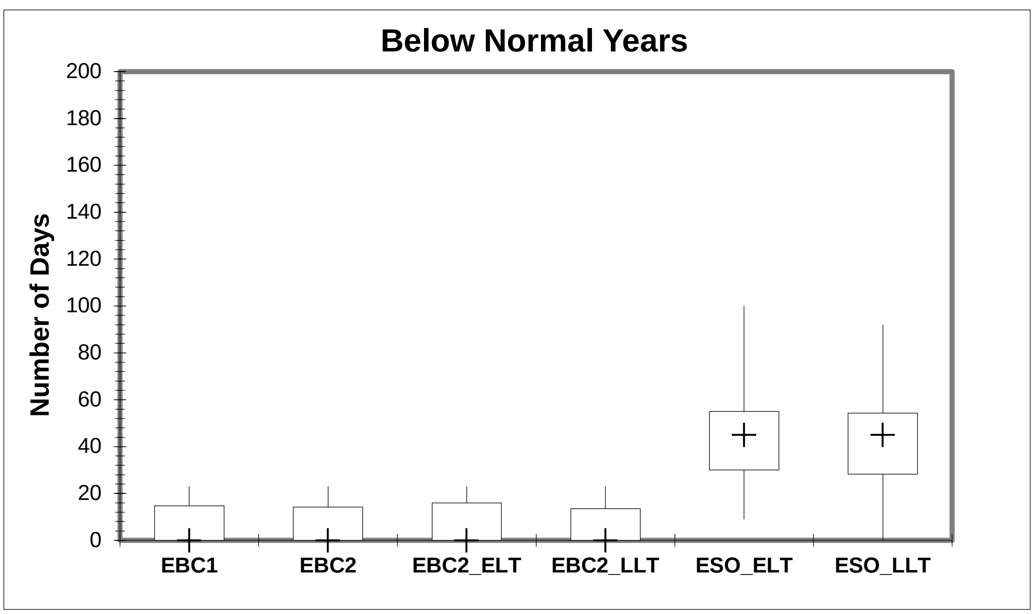

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

**Figure 5C.5.4-12. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (Critical Water Years)**



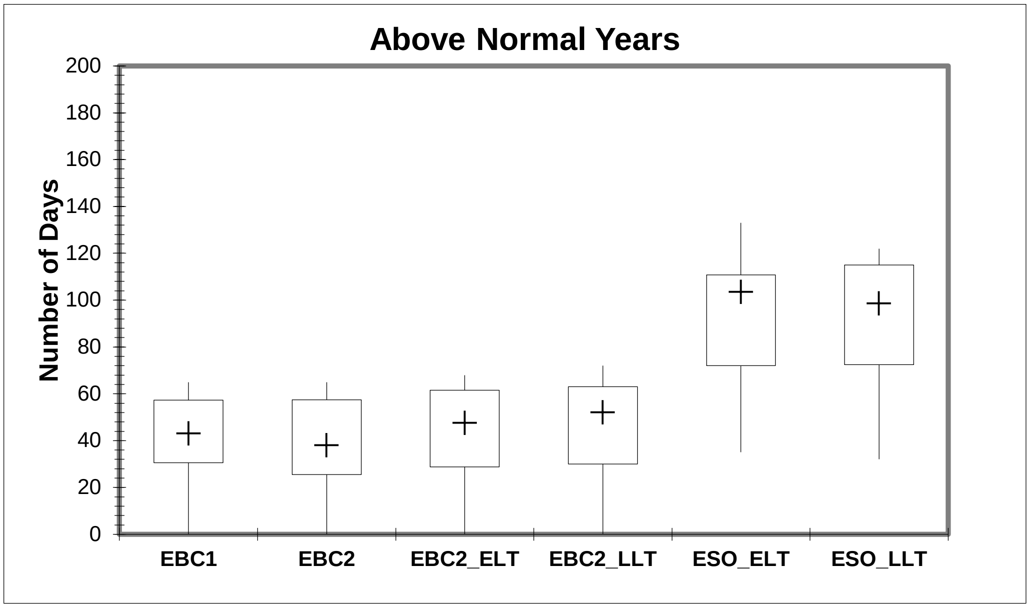

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

**Figure 5C.5.4-13. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (Dry Water Years)**



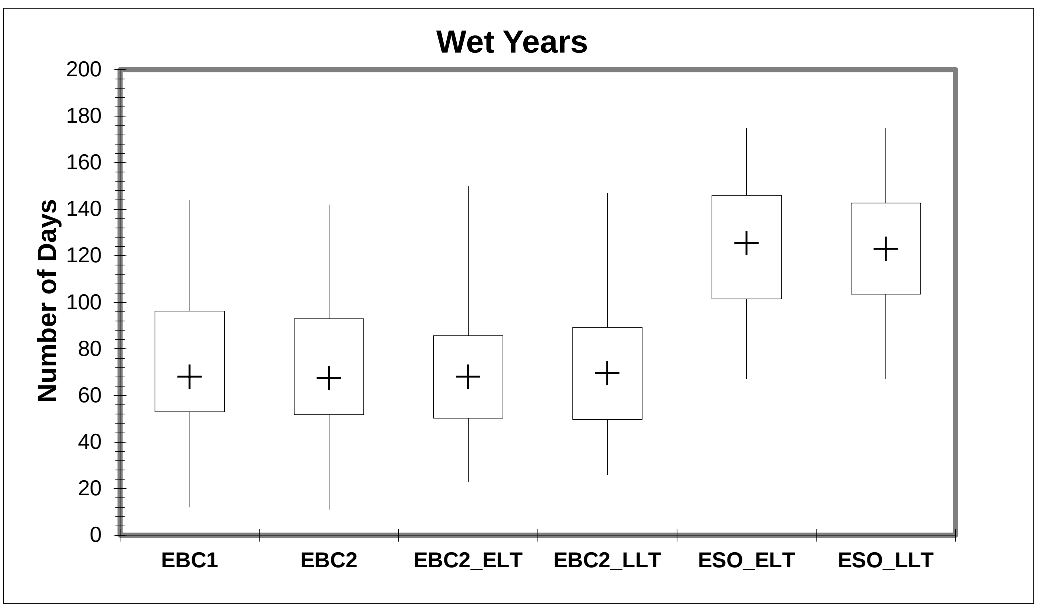

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

**Figure 5C.5.4-14. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (Below Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

**Figure 5C.5.4-15. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (Above Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of annual duration of floodplain rearing by modeled scenario.

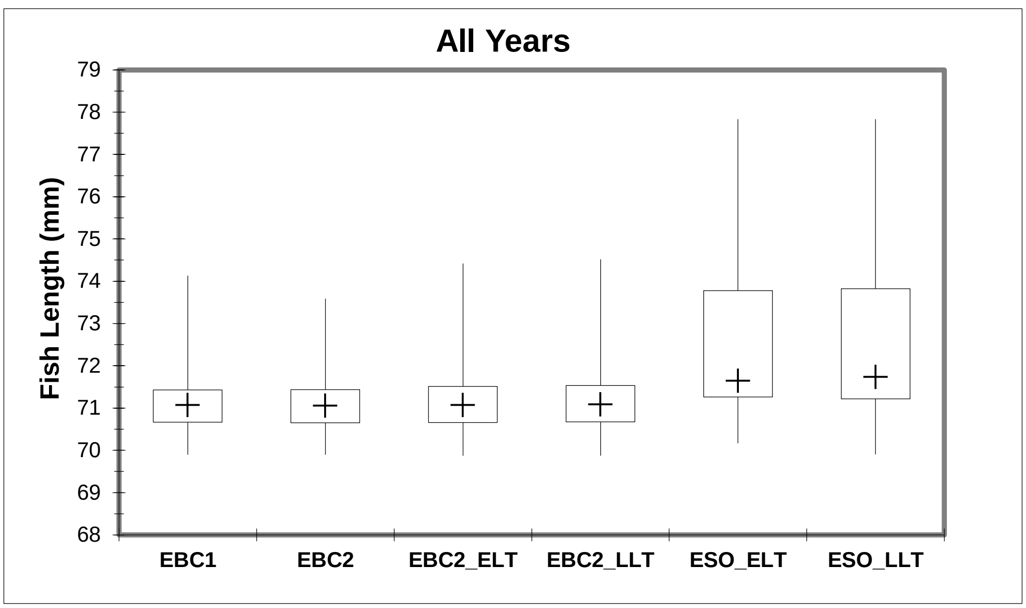
**Figure 5C.5.4-16. Number of Days of Floodplain Rearing of Juvenile Fall-Run Chinook Salmon in the Yolo Bypass (Wet Water Years)**

***Length of Fish Entering Estuary***

Figure 5C.5.4-17, Figure 5C.5.4-18, Figure 5C.5.4-19, Figure 5C.5.4-20, Figure 5C.5.4-21, and Figure 5C.5.4-22 summarize the differences in average length of juvenile fall-run Chinook salmon entering the estuary among the modeled scenarios for the 82-year simulation period and by water-year type. The results represent the differences in Chinook salmon fry (≤70 mm) that entered the Yolo Bypass or the lower Sacramento River, and survived to Chipps Island. The results reflect the combined effect of upstream flows and Fremont Weir spills on the timing and percentage of fry entering the Yolo Bypass, the duration of floodplain inundation in the Yolo Bypass, and differences in growth and survival of juveniles in the Yolo Bypass and Sacramento Rivers.

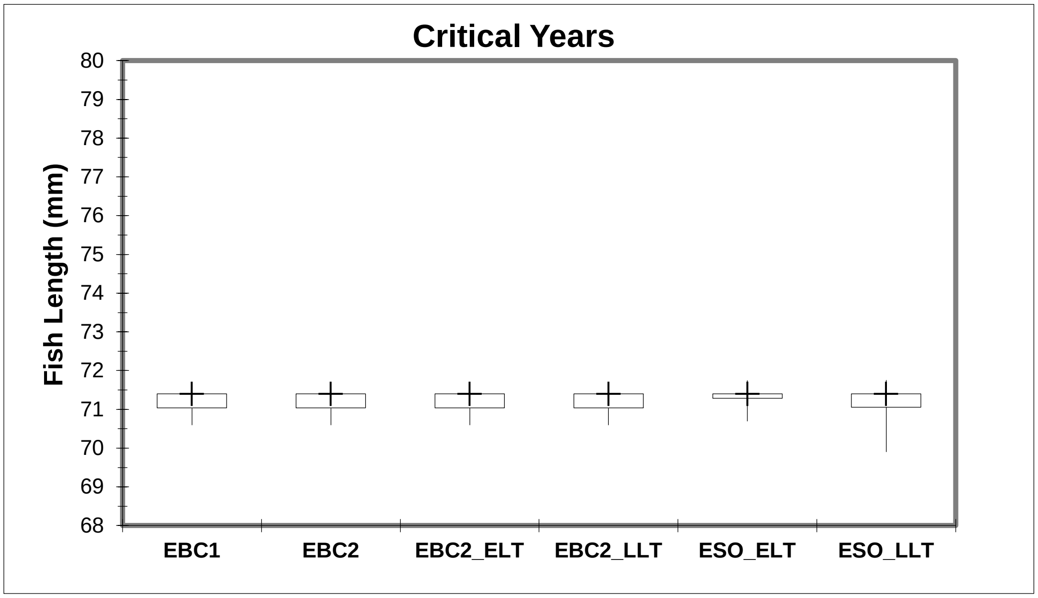
Median lengths were only slightly higher under the ESO scenarios relative to the EBC scenarios. However, under the ESO scenarios, there were 17 years (mostly wet years) in which average lengths were 3–6 mm higher than the average lengths achieved under the EBC scenarios.

There were only slight differences in average lengths among scenarios in critical and dry water years because of the low frequency and magnitude of spills in these years. The overall differences in lengths between the ESO and EBC scenarios generally increased in the wetter years, with the largest differences occurring in above normal and wet years.



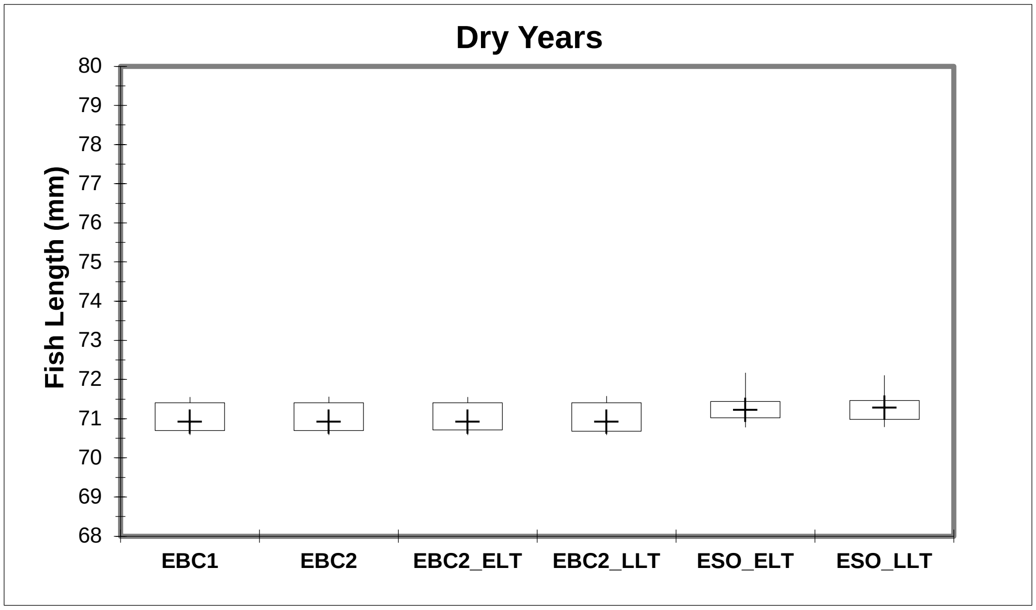

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

**Figure 5C.5.4-17. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (All Modeled Years)**



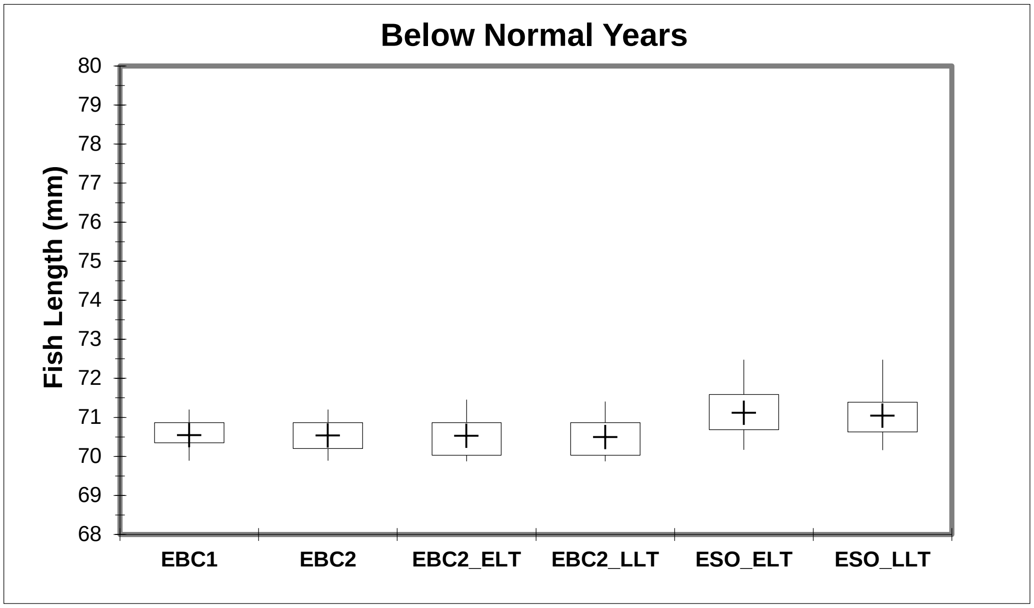

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

**Figure 5C.5.4-18. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (Critical Water Years)**



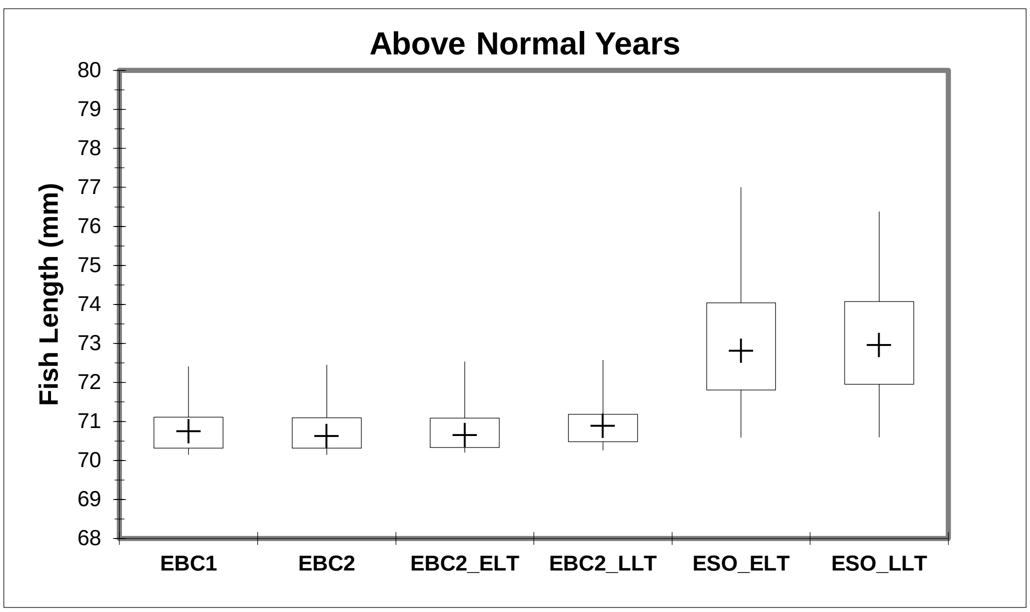

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

**Figure 5C.5.4-19. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (Dry Water Years)**



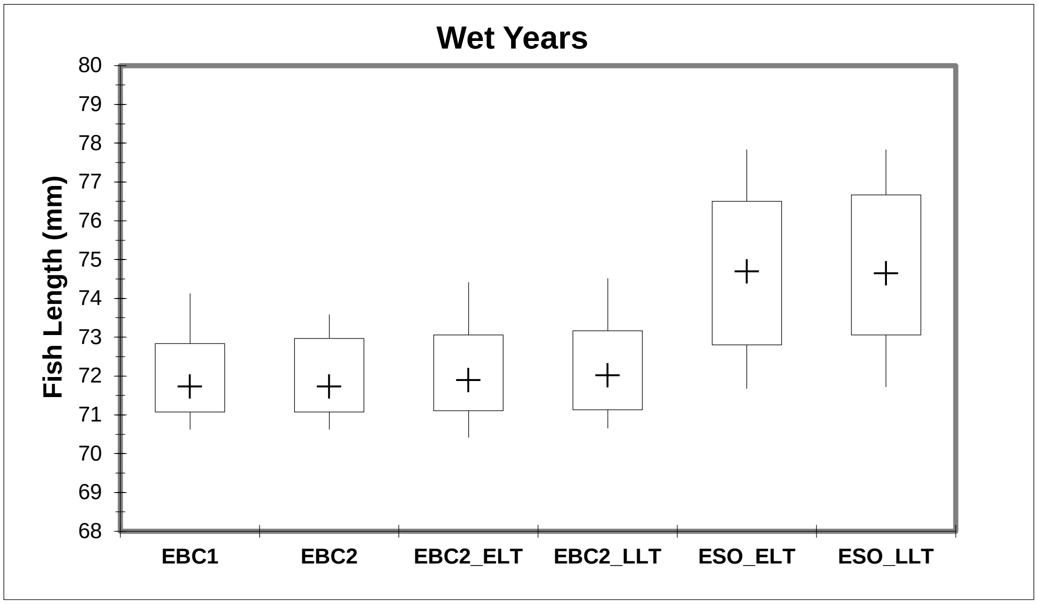

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

**Figure 5C.5.4-20. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (Below Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

**Figure 5C.5.4-21. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (Above Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of average length by modeled scenario.

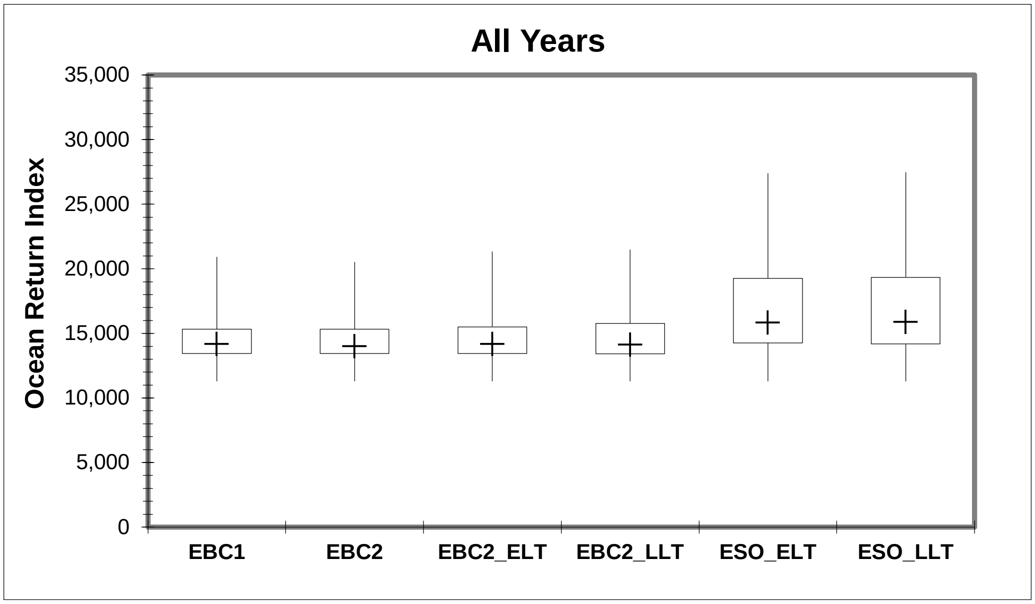
**Figure 5C.5.4-22. Average Length of Juvenile Fall-Run Chinook Salmon Entering Estuary (Wet Water Years)**

***Ocean Fishery Returns***

Figure 5C.5.4-23, Figure 5C.5.4-24, Figure 5C.5.4-25, Figure 5C.5.4-26, Figure 5C.5.4-27, and Figure 5C.5.4-28 summarize the differences in annual return indices of fall-run Chinook salmon fry to the ocean fishery among the modeled scenarios for the entire 82-year simulation period and by water-year type. The results reflect the combined effects of upstream flows and Fremont Weir spills on the number of juveniles entering the Yolo Bypass as fry, differences in growth and survival of fry in the Yolo Bypass and Sacramento River, and the number and sizes of juveniles (smolts) reaching the estuary.

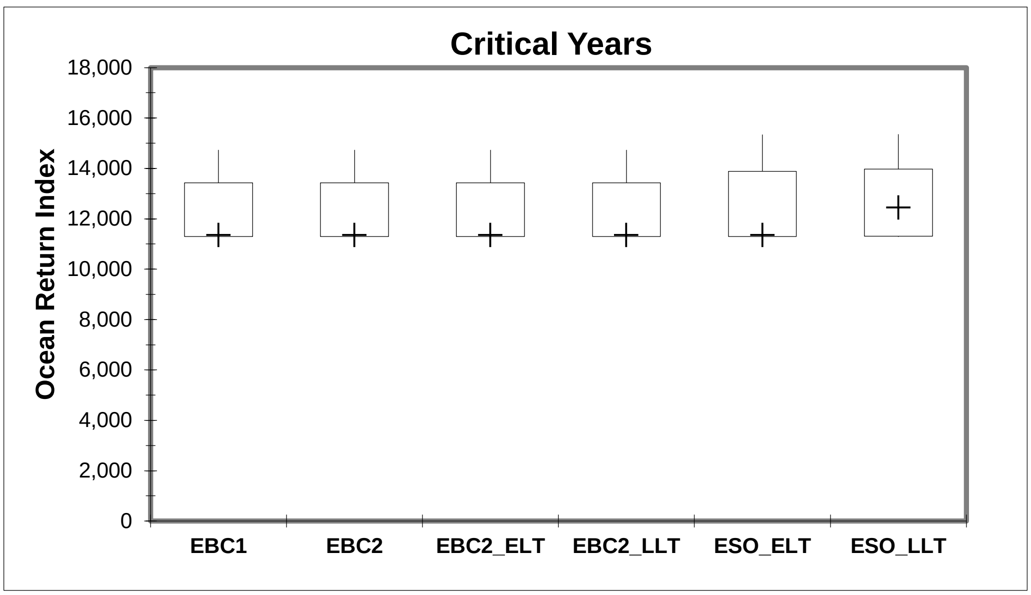
Median annual returns were approximately 15,800 fish under the ESO scenarios (range: 11,300–27,500) and 14,100 fish under the EBC scenarios (range: 11,300–21,500), representing approximately 14% greater annual fishery returns attributable to fry (<70 mm) under the ESO scenarios (Figure 5C.5.4-23)[2]. An examination of the results by water-year type shows that the potential benefits of operating the proposed notch under the ESO scenarios are minimal in critical and dry water years and increase in wetter years (Figure 5C.5.4-24, Figure 5C.5.4-25, Figure 5C.5.4-26, Figure 5C.5.4-27, and Figure 5C.5.4-28). The average differences in returns between the ESO and EBC scenarios ranged from 2% more fish in critical years to 28% more fish in wet years under the ESO scenarios.

[2] This percent difference reflects increases in fishery return indices attributable to fry only; larger juveniles (>70 mm) were excluded from the analysis (see Section 5C.4.4.2.3).



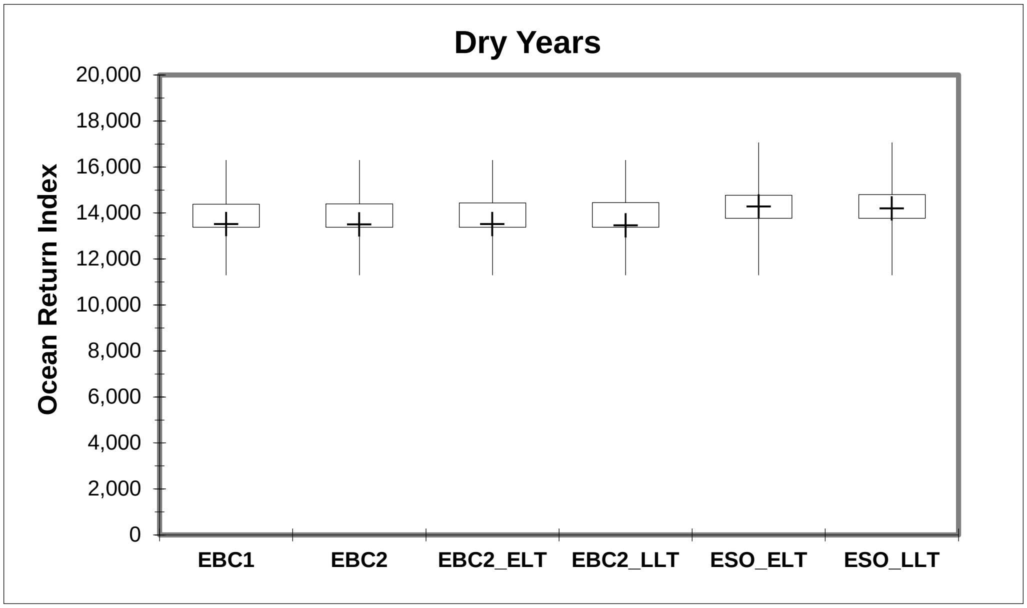

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-23. Fall-Run Chinook Salmon Ocean Return Indices (All Modeled Years)**



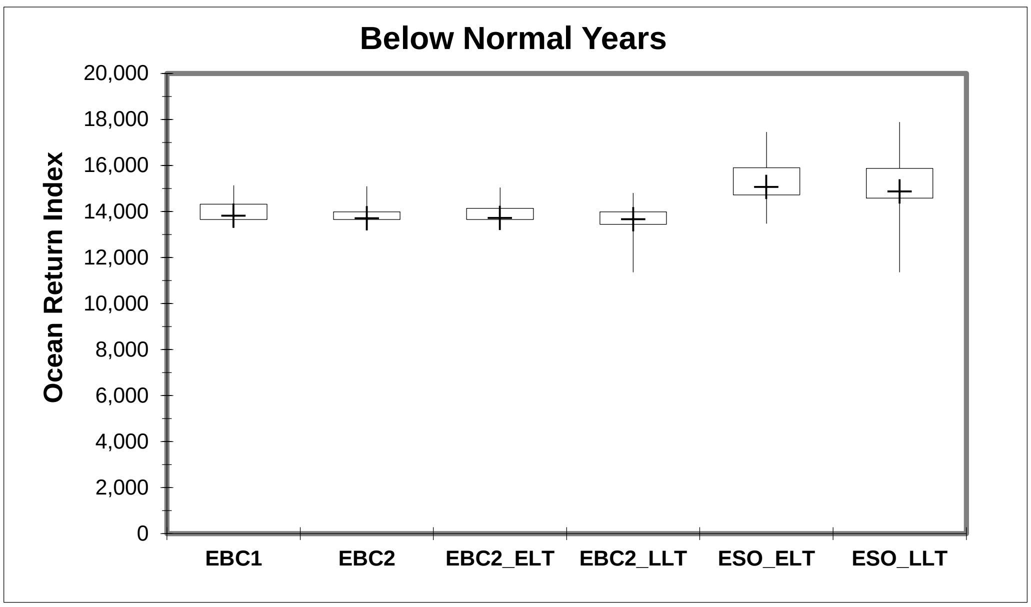

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-24. Fall-Run Chinook Salmon Ocean Return Indices (Critical Water Years)**



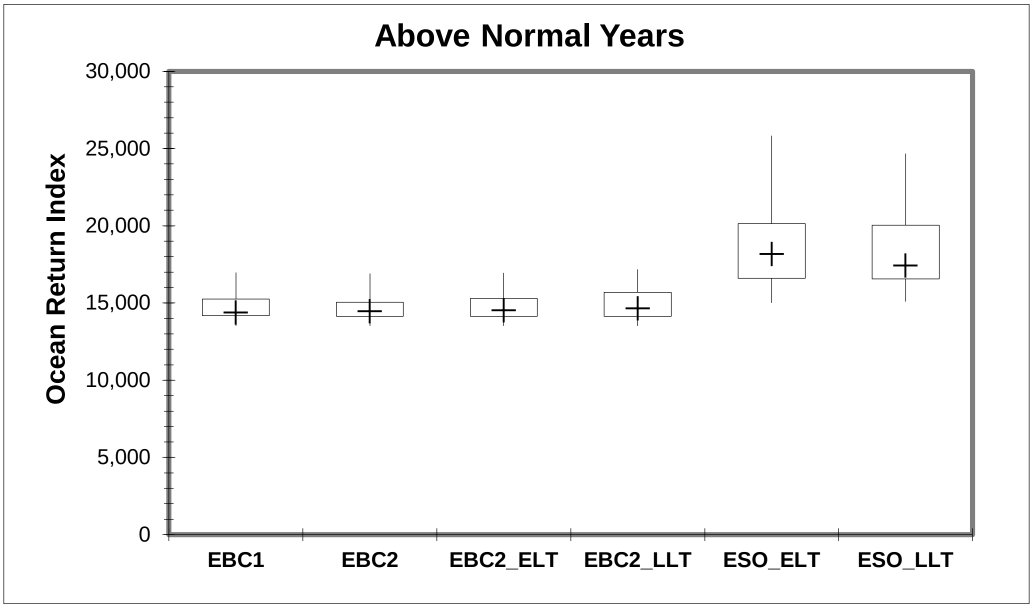

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-25. Fall-Run Chinook Salmon Ocean Return Indices (Dry Water Years)**



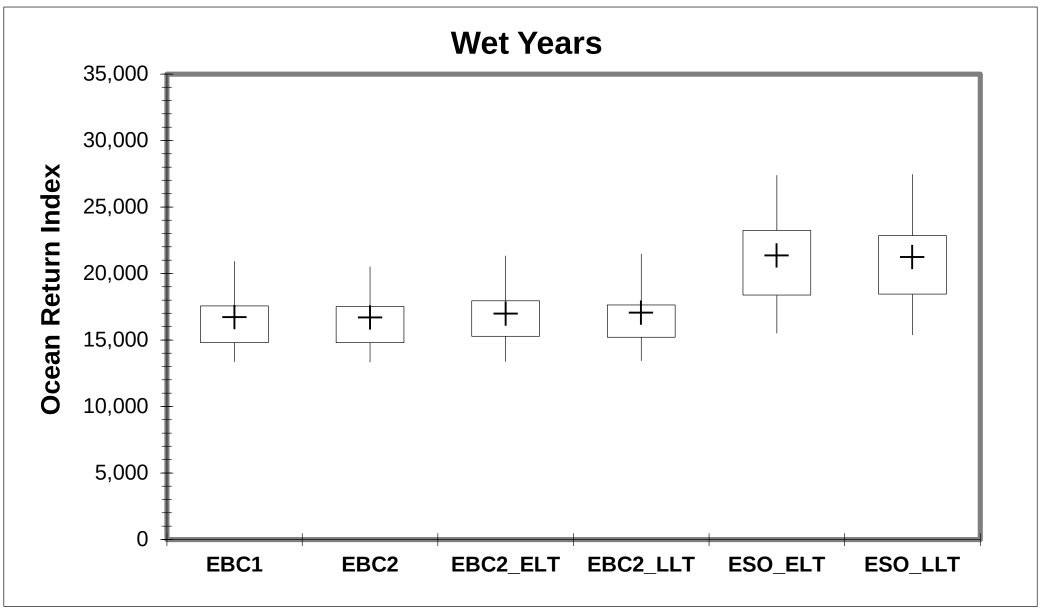

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-26. Fall-Run Chinook Salmon Ocean Return Indices (Below Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-27. Fall-Run Chinook Salmon Ocean Return Indices (Above Normal Water Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-28. Fall-Run Chinook Salmon Ocean Return Indices (Wet Water Years)**

***Water Years 1998–2002***

Water years 1998–2002 were selected to further illustrate the model results for the ESO and EBC scenarios over a range of hydrological conditions. The following examines the results for the late long-term (LLT) ES0 and EBC scenarios.

In 1998, a wet year in which the Yolo Bypass was flooded continuously between mid-January and early April, the model results indicate that 27% of the juvenile fall-run Chinook salmon approaching the Fremont Weir entered the Yolo Bypass as fry under the ESO_LLT, compared to 18% under the EBC2_LLT (Figure 5C.5.4-29). Under the ESO_LLT, spills associated with floodplain inundation in the Yolo Bypass (≥3,000 cfs) occurred from January 4 through April 30 and encompassed most of the fry emigration period (Figure 5C.5.4-30). This includes a large spill event and migration pulse that resulted in large numbers of fry entering the bypass in January (Figure 5C.5.4-31). In contrast, under the EBC2_LLT, spills associated with floodplain inundation occurred 9 days later and were shorter in duration (Figure 5C.5.4-30), missing a portion of the fry migration pulse and resulting in fewer overall opportunities for fry to access the Yolo Bypass relative to the ESO_LLT (Figure 5C.5.4-32). Overall, proposed operation of the notch extended the duration of spills from 78 days under the EBC2_LLT to 117 days under the ESO_LLT, and the duration of floodplain inundation from 85 to 124 days, respectively.

In water year 1999, a wet year, the magnitude and duration of spills was lower than in 1998 (Figure 5C.5.4-33), resulting in smaller percentages of juveniles entering the Yolo Bypass. The model results indicate that 16% of the juvenile fall-run Chinook salmon approaching the Fremont Weir entered the Yolo Bypass as fry under the ESO_LLT, compared to 10% under the EBC2_LLT (Figure 5C.5.4-29). The differences in daily numbers of fry entering the Yolo Bypass under the ESO_LLT and EBC2_LLT are illustrated in Figure 5C.5.4-34 and Figure 5C.5.4-35. Overall, proposed operation of the notch extended the duration of spills from 49 days under the EBC2_LLT to 89 days under the ESO_LLT, and the duration of floodplain inundation from 62 to 105 days, respectively.

In water year 2000, an above normal year, somewhat higher percentages of fry entered the Yolo Bypass than in 1999 because of the larger magnitude of spills and the occurrence of two fry migration pulses instead of one during the primary fry emigration period (Figure 5C.5.4-36, Figure 5C.5.4-37, and Figure 5C.5.4-38). The model results indicate that 18% of the juvenile fall-run Chinook salmon that approached the Fremont Weir entered the Yolo Bypass as fry under the ESO_LLT, compared to 12% under the EBC2_LLT (Figure 5C.5.4-29). Earlier initiation of spilling under the ESO_LLT contributed to these differences by increasing the number of fry that entered the bypass during the initial fry migration pulse (Figure 5C.5.4-37).

In 2001 and 2002, both of which were dry years, spill over the Fremont Weir under the EBC_LLT was limited to a single 6-day event in early January 2002; no spills occurred in water year 2001 (Figure 5C.5.4-39, Figure 5C.5.4-40, Figure 5C.5.4-41, and Figure 5C.5.4-42). Under the ESO_LLT, proposed operation of the notch at the Fremont Weir resulted in two or more spills of sufficient magnitude to inundate floodplain habitat in the Yolo Bypass for 25 days in 2001 and 48 days in 2002 (Figure 5C.5.4-39 and Figure 5C.5.4-42). The majority of these spills coincided with the occurrence of peak fry movements, resulting in passage of 5% of the population into the bypass in 2001 (compared to 0% under the EBC_LLT) and 6% of the population into the bypass in 2002 (compared to 1% under the EBC_LLT) (Figure 5C.5.4-29, Figure 5C.5.4-40 and Figure 5C.5.4-41, Figure 5C.5.4-43 and Figure 5C.5.4-44).

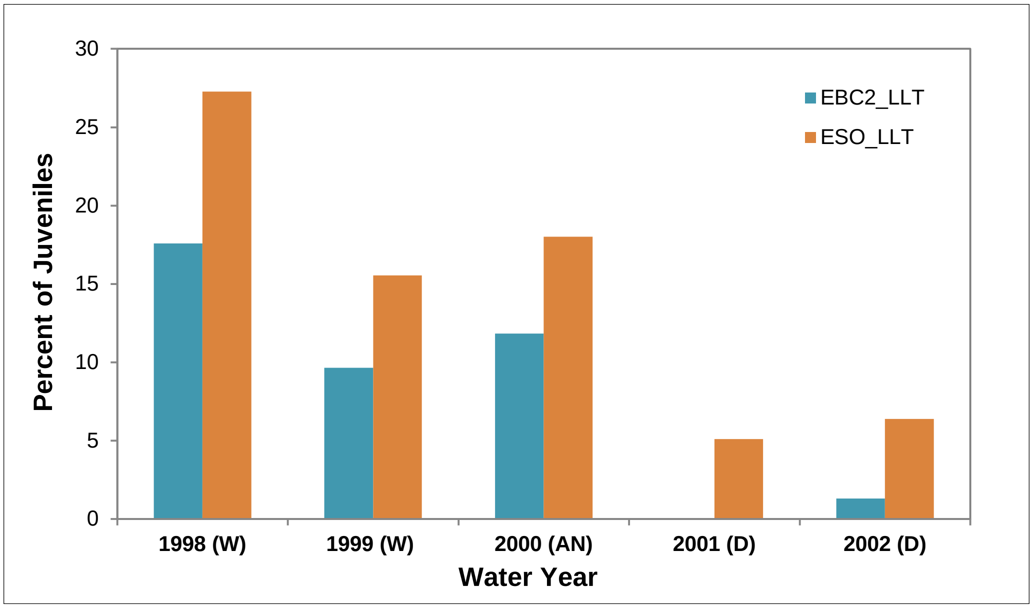



**Figure 5C.5.4-29. Percentage of Juvenile Fall-Run Chinook Salmon Entering Yolo Bypass as Fry under EBC2_LLT and ESO_LLT Scenarios (Water Year 1998–2002)**

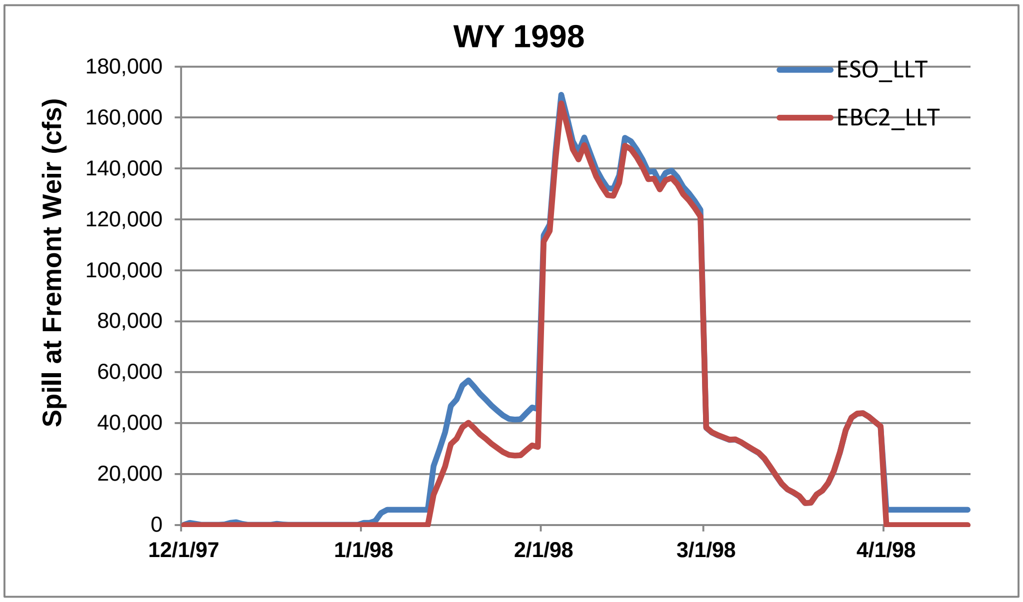



**Figure 5C.5.4-30. Modeled Daily Spills at the Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (January 1–April 15, 1998)**

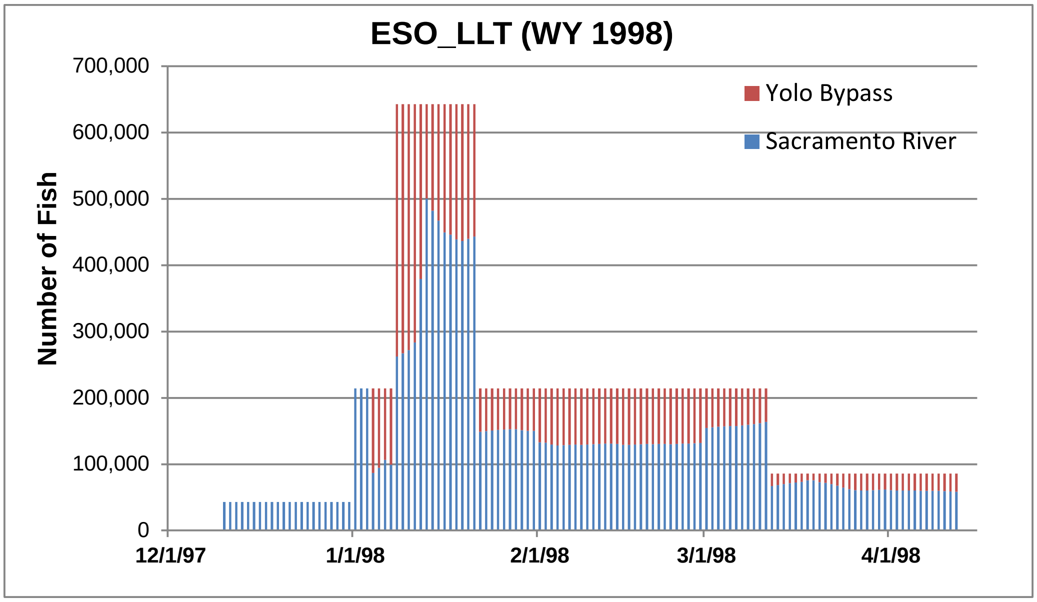



**Figure 5C.5.4-31. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the ESO_LLT Scenario (Water Year 1998)**

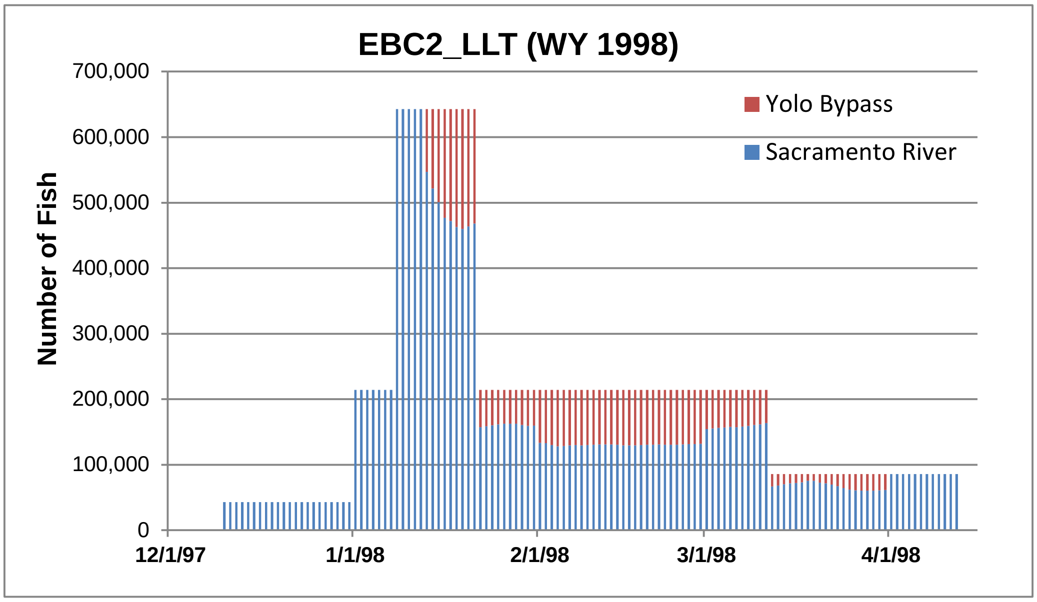



**Figure 5C.5.4-32. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the EBC2_LLT Scenario (Water Year 1998)**

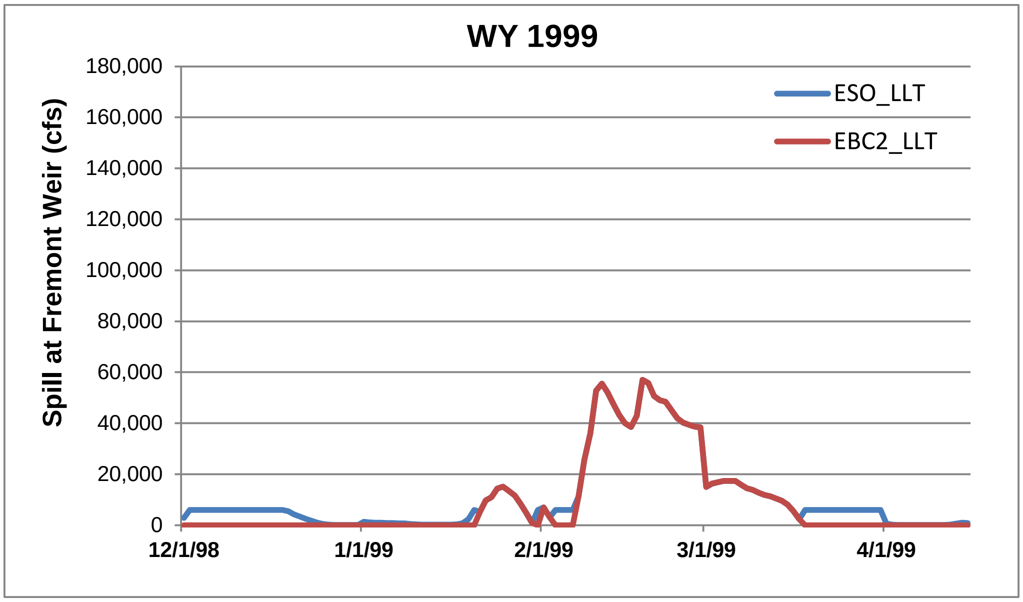



**Figure 5C.5.4-33. Modeled Daily Spills at the Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (January 1–April 15, 1999)**

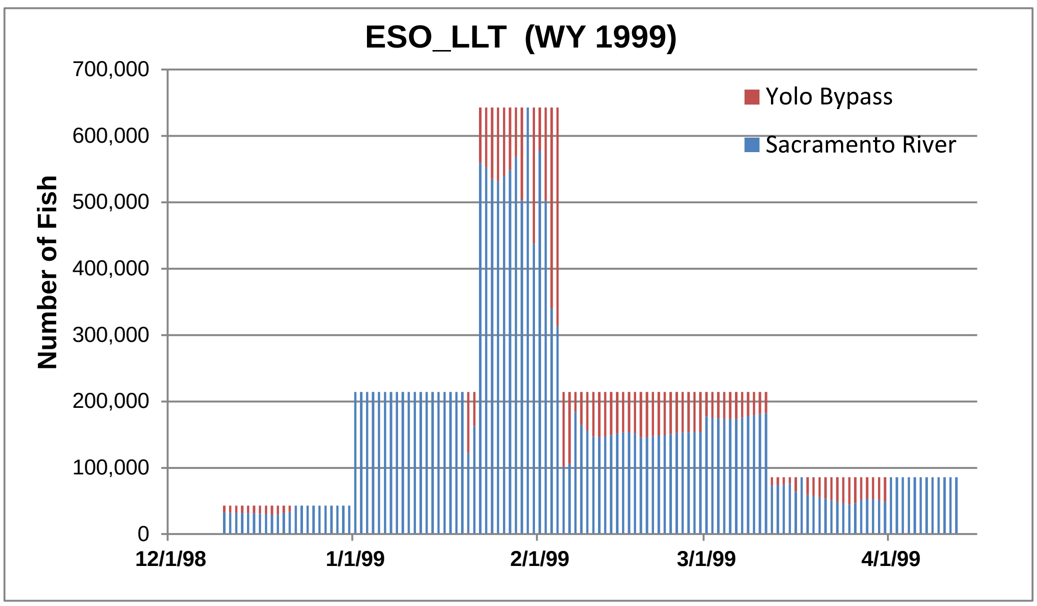



**Figure 5C.5.4-34. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the ESO_LLT Scenario (Water Year 1999)**

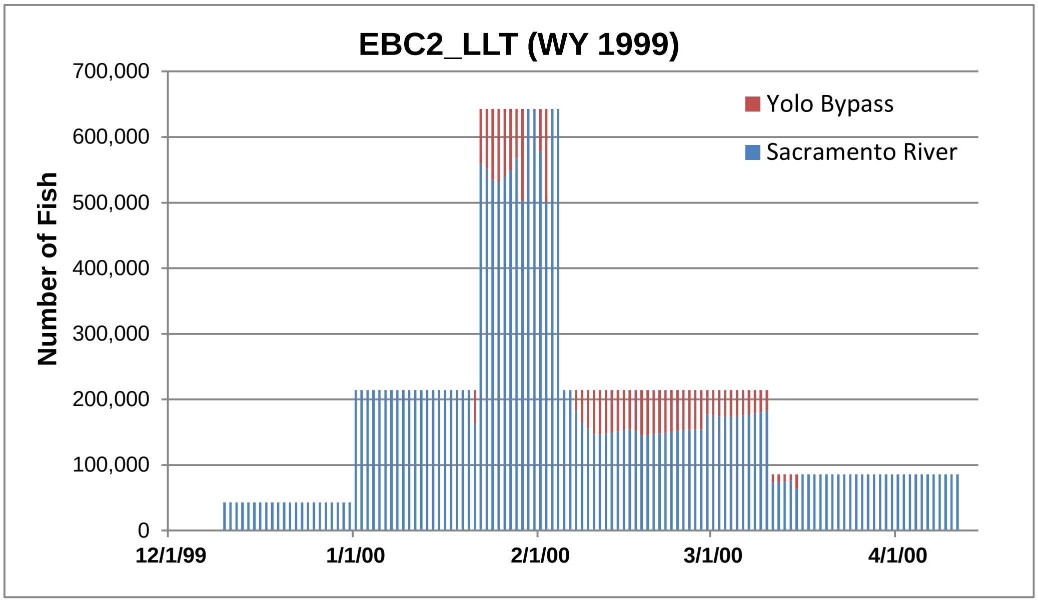



**Figure 5C.5.4-35. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the EBC2_LLT Scenario (Water Year 1999)**

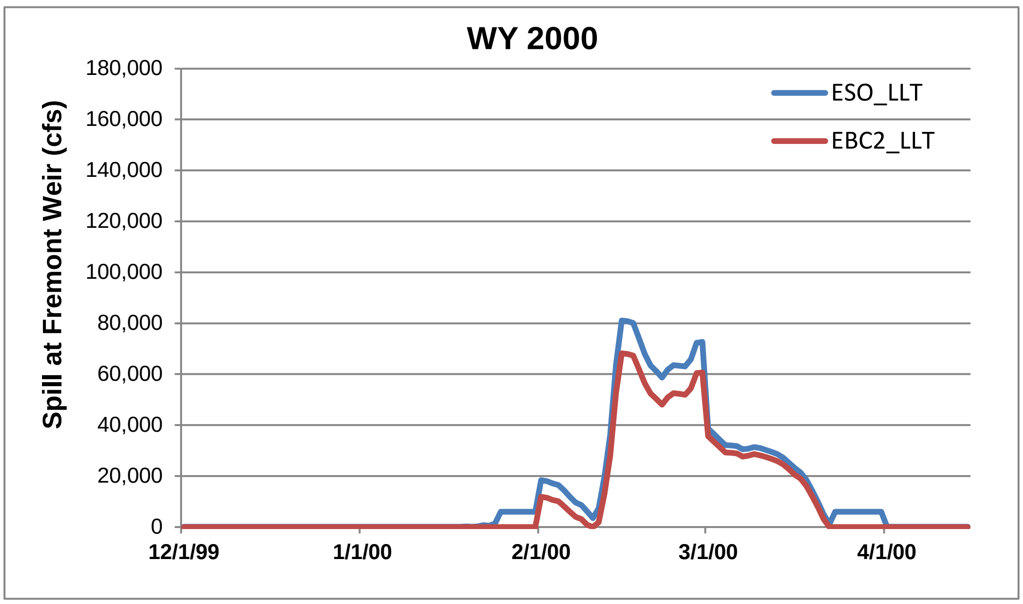



**Figure 5C.5.4-36. Modeled Daily Spills at the Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (January 1–April 15, 2000)**

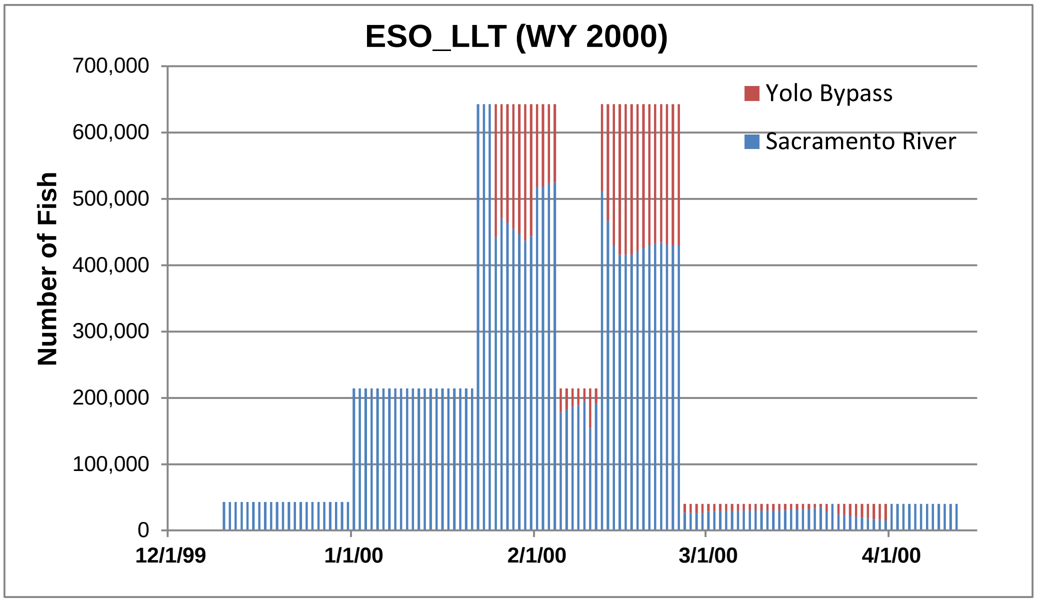



**Figure 5C.5.4-37. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the ESO_LLT Scenario (Water Year 2000)**

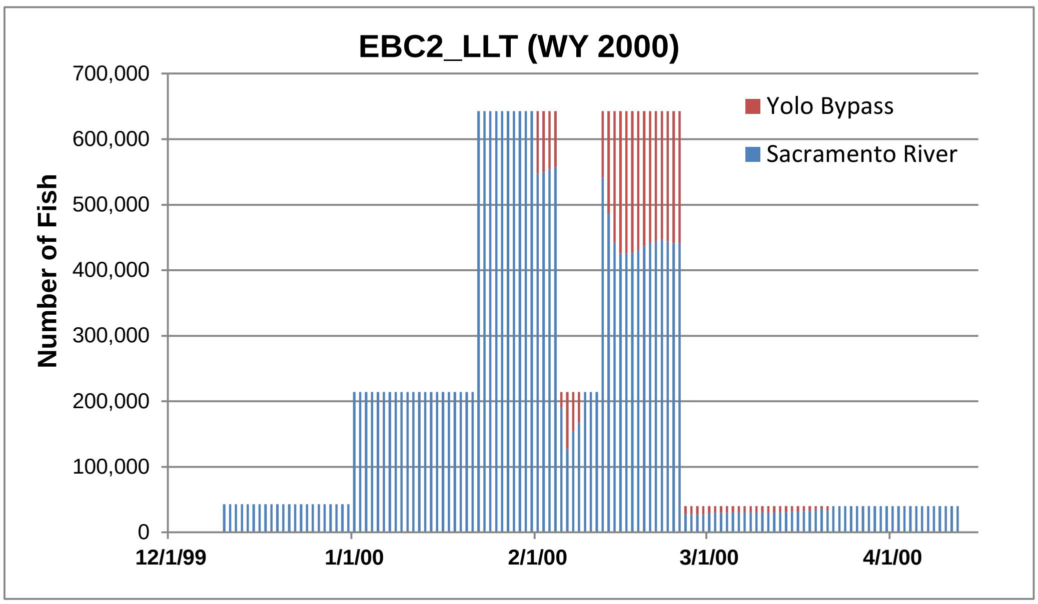



**Figure 5C.5.4-38. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the EBC2_LLT Scenario (Water Year 2000)**

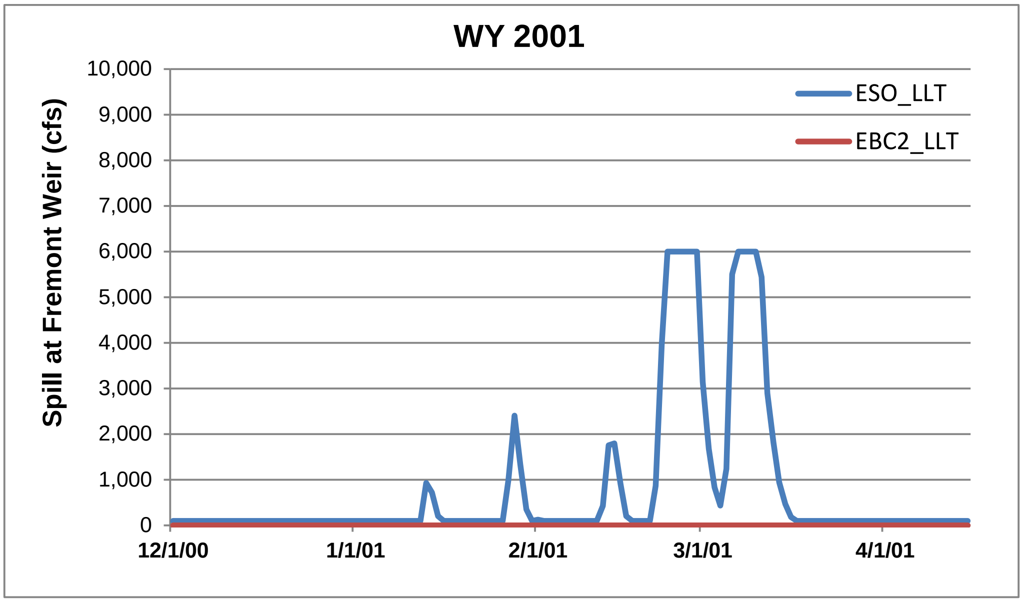



**Figure 5C.5.4-39. Modeled Daily Spills at the Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (January 1–April 15, 2001)**

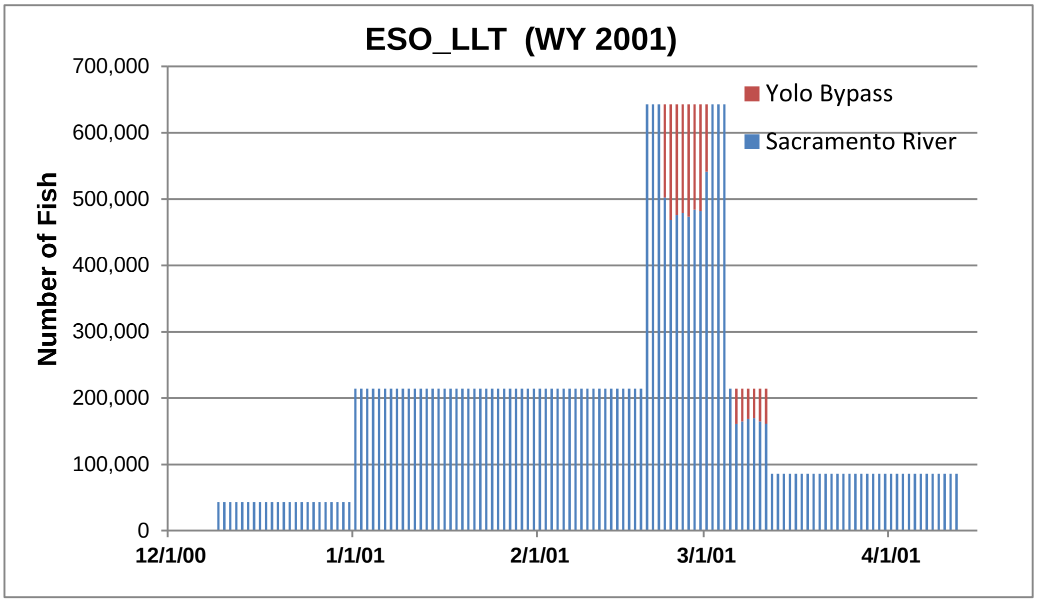



**Figure 5C.5.4-40. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the ESO_LLT Scenario (Water Year 2001)**

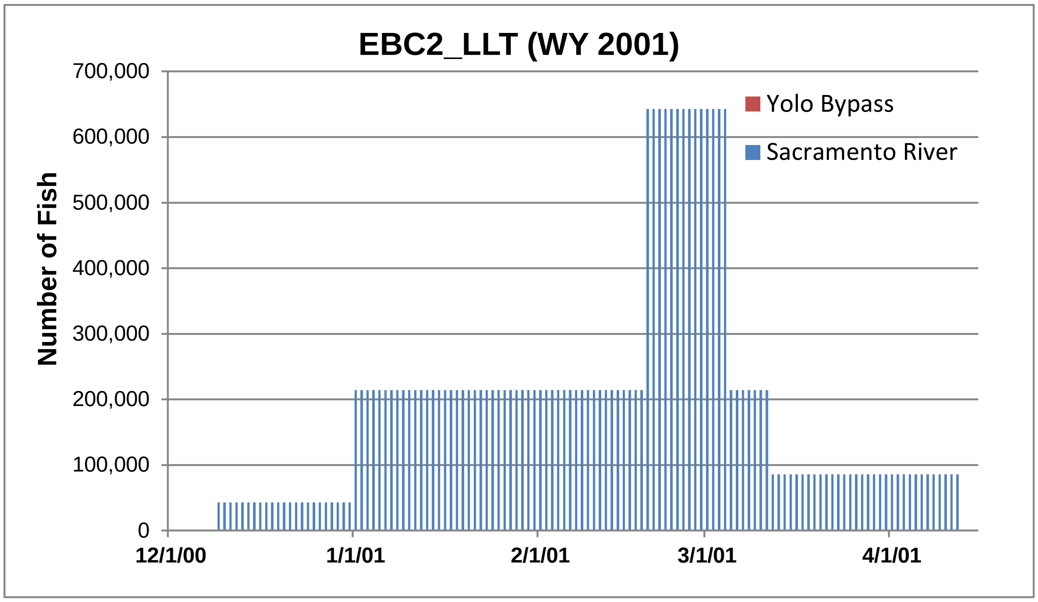



**Figure 5C.5.4-41. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the EBC2_LLT Scenario (Water Year 2001)**

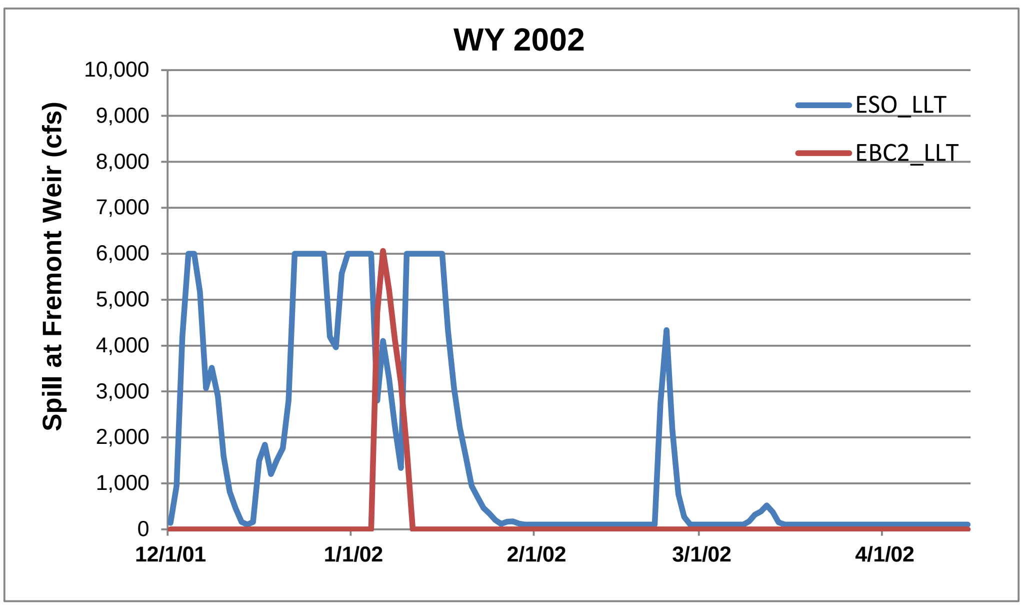



**Figure 5C.5.4-42. Modeled Daily Spills at the Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (January 1–April 15, 2002)**

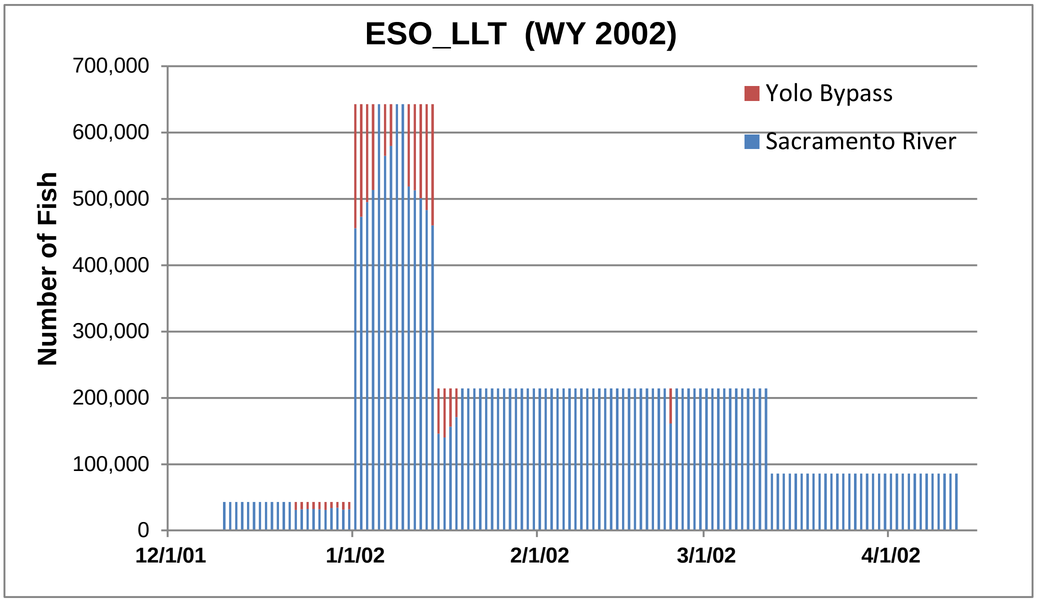



**Figure 5C.5.4-43. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the ESO_LLT Scenario (Water Year 2002)**

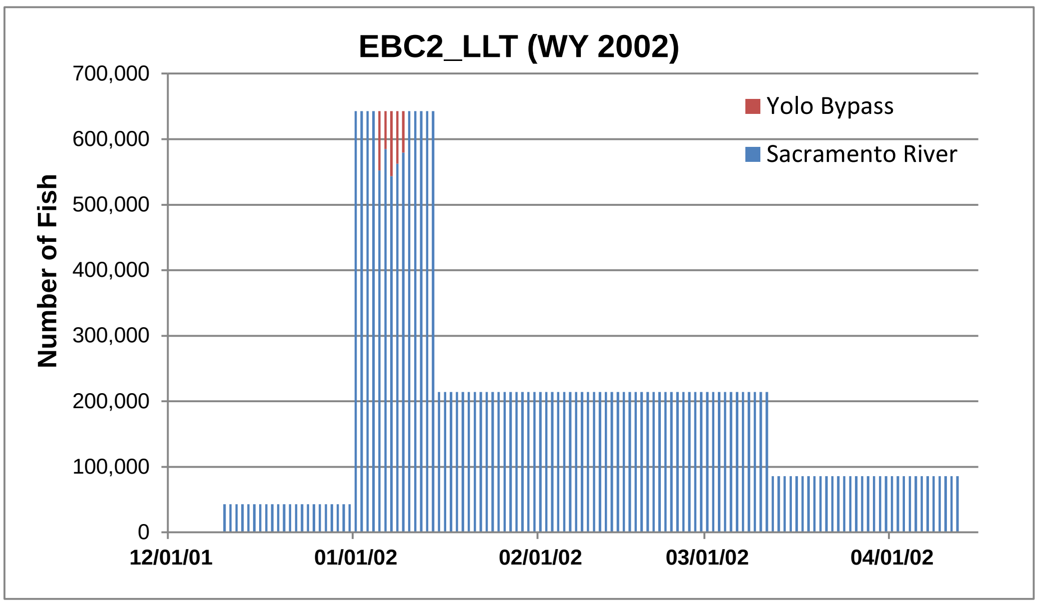
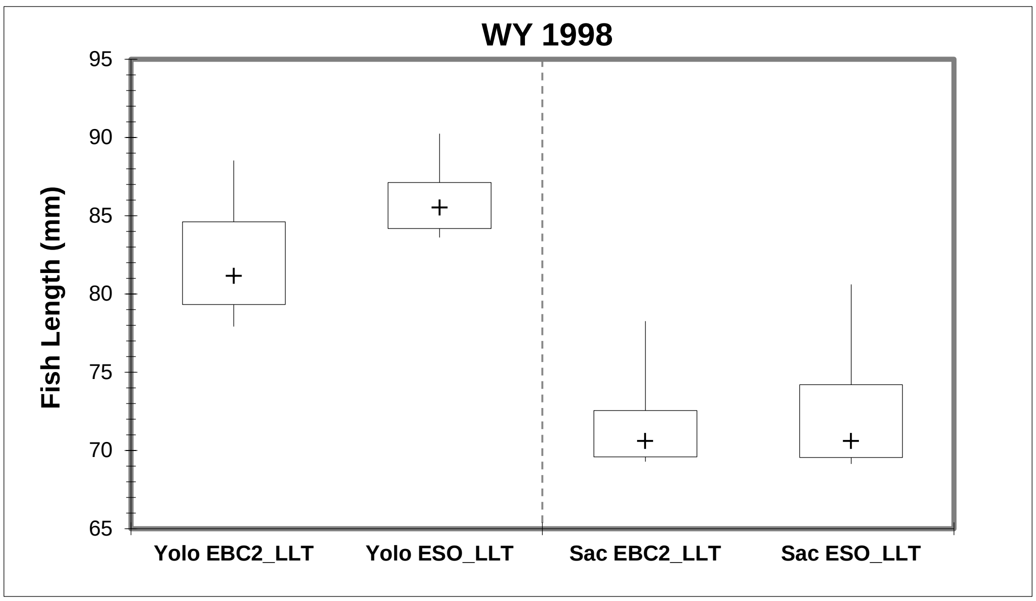


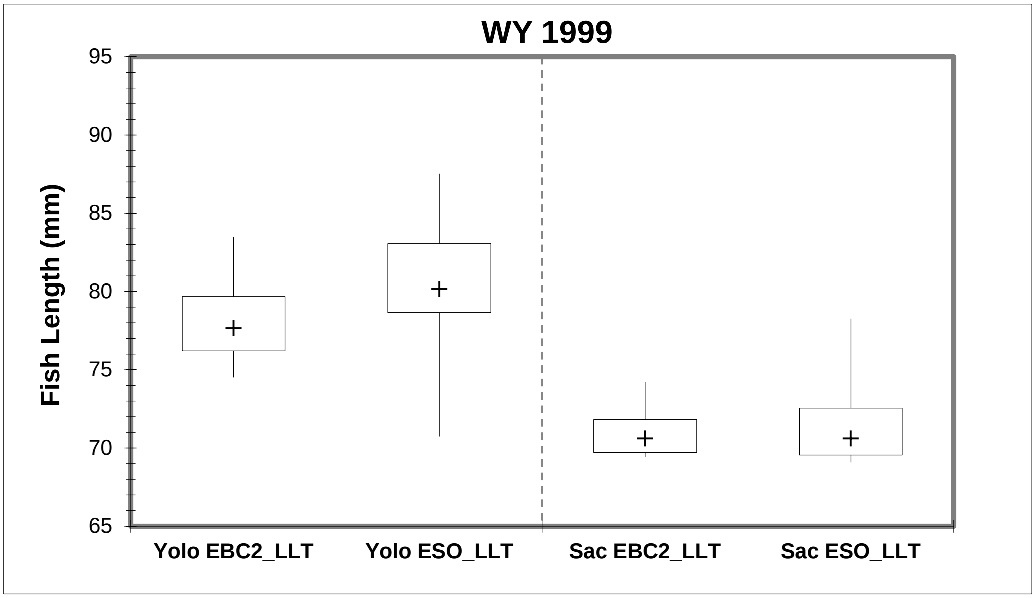

**Figure 5C.5.4-44. Number of Fall-Run Chinook Salmon Fry Staying in the Sacramento River or Entering the Yolo Bypass at the Fremont Weir under the EBC2_LLT Scenario (Water Year 2002)**

Figure 5C.5.4-45, Figure 5C.5.4-46, Figure 5C.5.4-47, Figure 5C.5.4-48, and Figure 5C.5.4-49 compare the size distributions (mean lengths) of Chinook salmon juveniles (smolts) entering the estuary from the Yolo Bypass and lower Sacramento River under the ESO_LLT and EBC2_LLT. The results are only for those cohorts of fry that arrived at the Fremont Weir on days when spills were ≥3,000 cfs to more clearly illustrate the differences in potential growth of juveniles related to migration route. Consequently, the differences in sizes of fish among years and between scenarios can be attributed primarily to differences in the timing and duration of spills and floodplain inundation in the Yolo Bypass during the fry emigration period. These differences were most pronounced in 1998 under the ESO_LLT when continuous spills and flooding of the Yolo Bypass over much of the emigration period allowed fry to rear for up to 18 weeks on the floodplain, compared to 12 weeks under the EBC2_LLT. Median sizes of juveniles that reared in the Yolo Bypass were 86 mm (84–90 mm) under the ESO_LLT and 81 mm (range: 78–89 mm) under the EBC_LLT, compared to 71 mm (range: 69–81 mm) for juveniles that reared in the Sacramento River. Under the ESO_LLT, differences in mean size related to migration route were magnified by operation of the proposed notch, which extended the duration of floodplain inundation by up to 6 weeks (depending on the timing of entry into the Yolo Bypass).



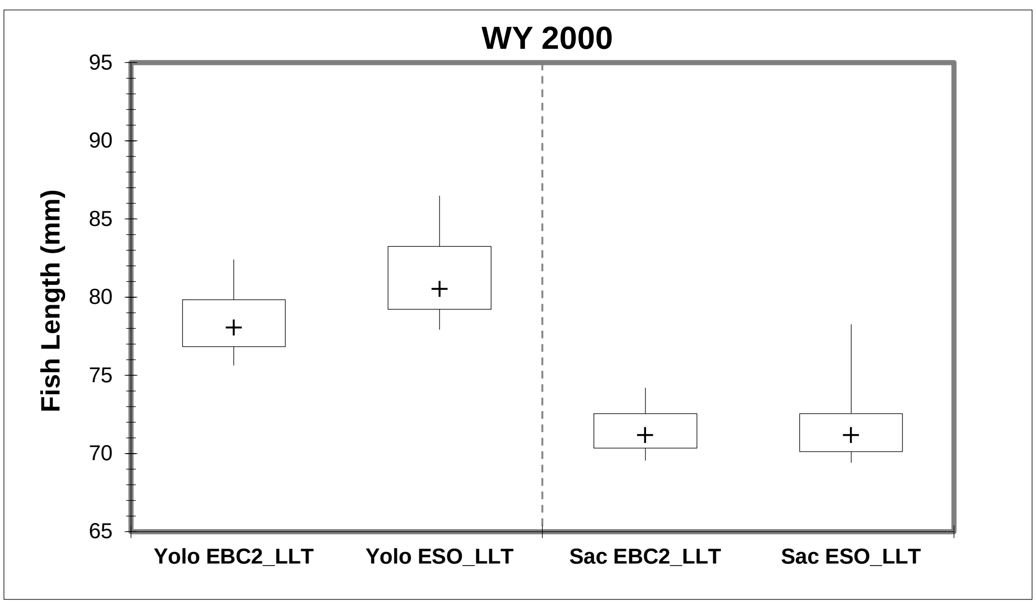

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of sizes of fish by modeled scenario.

**Figure 5C.5.4-45. Size Distributions (Mean Lengths) of Fall-Run Chinook Salmon Entering the Estuary from the Yolo Bypass and Lower Sacramento River under EBC2_LLT and ESO_LLT Scenarios (Water Year 1998)**



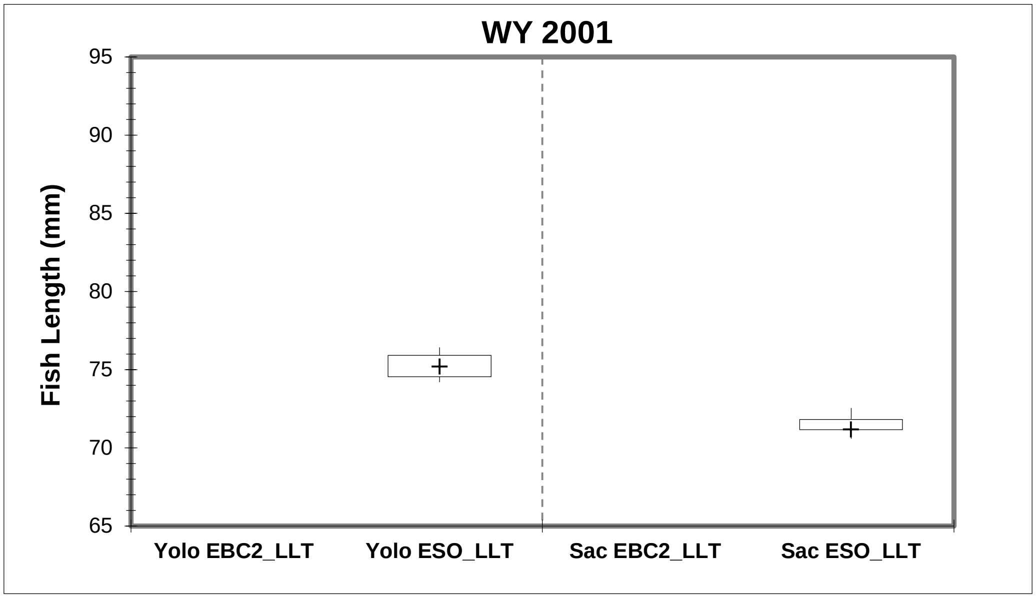

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of sizes of fish by modeled scenario.

**Figure 5C.5.4-46. Size Distributions (Mean Lengths) of Fall-Run Chinook Salmon Entering the Estuary from the Yolo Bypass and Lower Sacramento River under EBC2_LLT and ESO_LLT Scenarios (Water Year 1999)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of sizes of fish by modeled scenario.

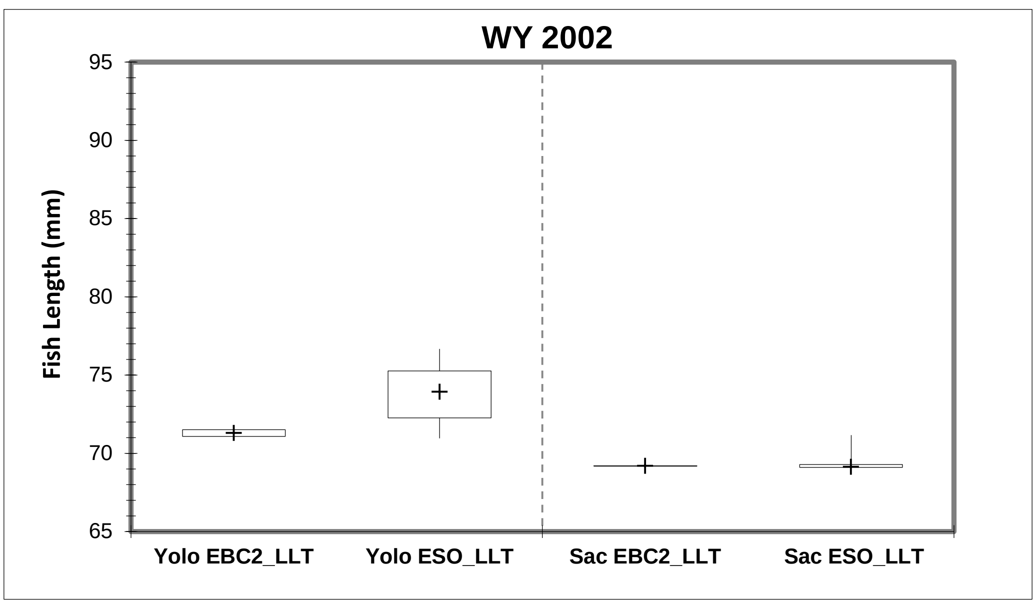
**Figure 5C.5.4-47. Size Distributions (Mean Lengths) of Fall-Run Chinook Salmon Entering the Estuary from the Yolo Bypass and Lower Sacramento River under EBC2_LLT and ESO_LLT Scenarios (Water Year 2000)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of sizes of fish by modeled scenario.

Note: No spills of 3,000 cfs or more occurred under the EBC2_LLT; see text.

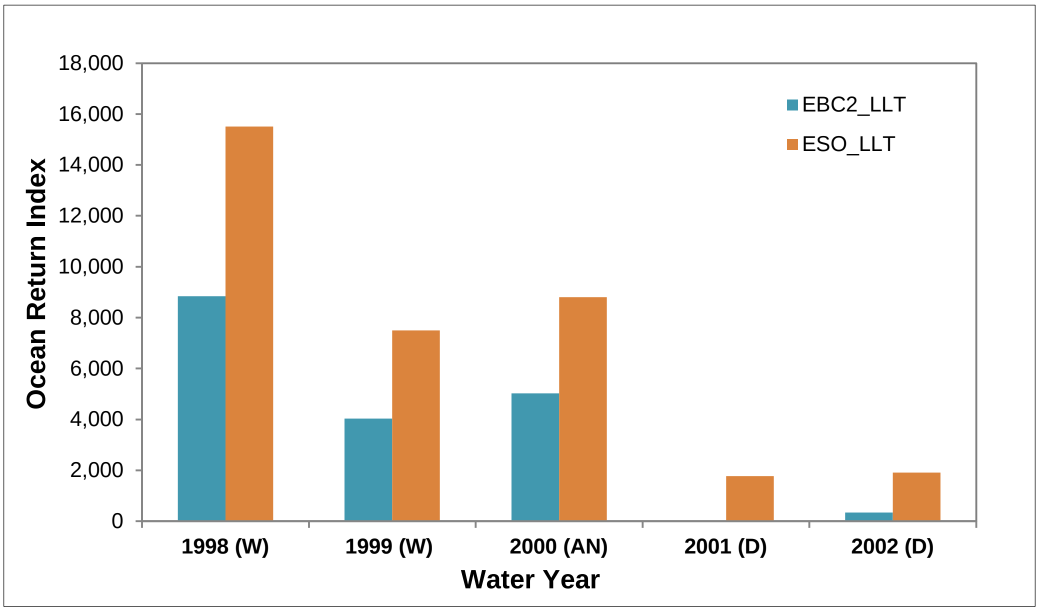
**Figure 5C.5.4-48. Size Distributions (Mean Lengths) of Fall-Run Chinook Salmon Entering the Estuary from the Yolo Bypass and Lower Sacramento River under EBC2_LLT and ESO_LLT Scenarios (Water Year 2001)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of sizes of fish by modeled scenario.

**Figure 5C.5.4-49. Size Distributions (Mean Lengths) of Fall-Run Chinook Salmon Entering the Estuary from the Yolo Bypass and Lower Sacramento River under EBC2_LLT and ESO_LLT Scenarios (Water Year 2002)**

Figure 5C.5.4-50 presents the differences in the number of fry that survived to the ocean fishery (in terms of fishery return indices) between the ESO_LLT and EBC2_LLT for the year classes that emigrated in water years 1998–2002 (based on a fixed total of 30 million juvenile fall-run Chinook population at the Fremont Weir each year). These results reflect the combined effects of hydrologic and operational conditions on the percentage of juveniles that emigrated as fry from the upper Sacramento River, the percentage of fry that entered the Yolo Bypass, the duration of floodplain rearing in the Yolo Bypass floodplain, and overall effects of these factors on growth and survival of fry to the estuary and ocean fishery. Among these years, operation of the proposed notch at the Fremont Weir would be expected to have the greatest growth and survival benefits in 1998, 1999, and 2000. The more pronounced difference in ocean return indices in 1998 is due to the larger numbers and longer residence time of fry on the Yolo Bypass floodplain as well as the resulting larger size of juveniles that entered the estuary.



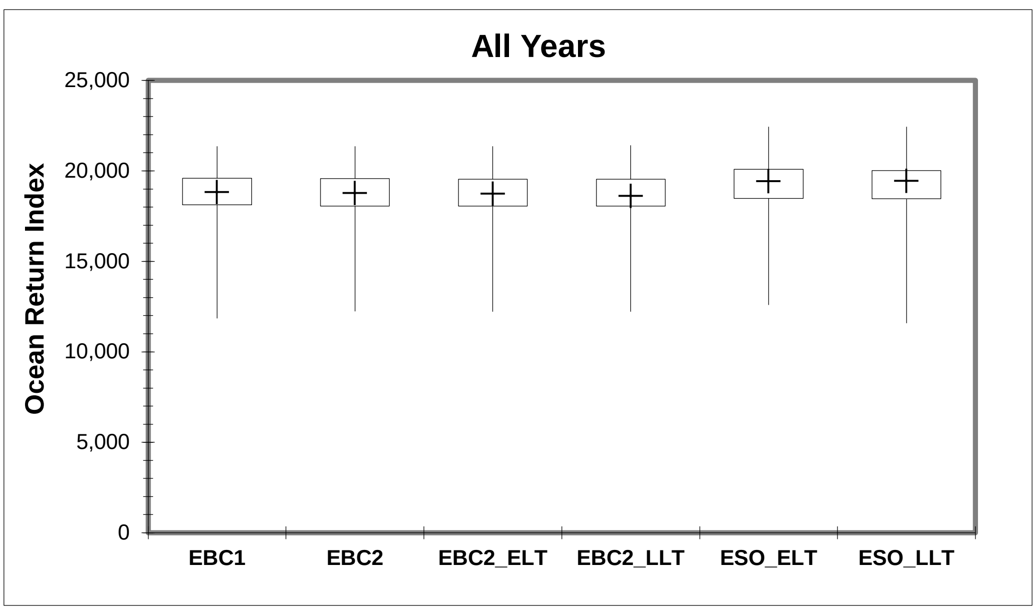

Water-year types: W = wet; AN = above normal; D = dry.

**Figure 5C.5.4-50. Ocean Return Indices of Fall-Run Chinook Salmon Fry under EBC2_LLT and ESO_LLT Scenarios (Water Years 1998–2002)**

## Winter-Run Chinook Salmon

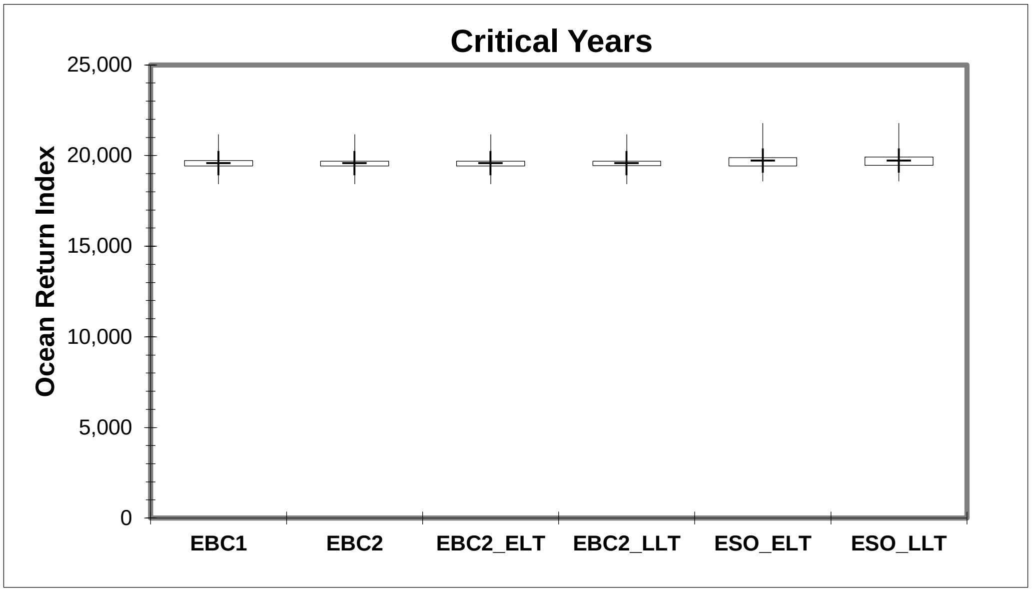
### *Ocean Fishery Returns*

Figure 5C.5.4-51, Figure 5C.5.4-52, Figure 5C.5.4-53, Figure 5C.5.4-54, Figure 5C.5.4-55, and Figure 5C.5.4-56 summarize the differences in annual ocean returns (ocean return indices) of winter-run among the modeled scenarios for the 82-year simulation period and by water-year type. Median annual returns were approximately 18,300 fish under the ESO scenarios (range: 18,279–18,324) and 17,800 fish under the EBC scenarios (range: 17,677–17,860), representing a 3% increase in annual fishery returns under the ESO scenarios (Figure 5C.5.4-24). As observed for fall-run, the model indicates that the potential benefits of operating the proposed notch under the ESO scenarios are lowest in critical and dry water years and increase in wetter years (Figure 5C.5.4-52, Figure 5C.5.4-53, Figure 5C.5.4-54, Figure 5C.5.4-55, and Figure 5C.5.4-56). However, the average differences in returns between the ESO and EBC scenarios are relatively small over all water-year types, ranging from 1% more fish in critical years to 8% more fish under the ESO scenarios. An examination of the daily modeling results for individual years reveals that, in many years, a large percentage of the winter-run are triggered to move before the Fremont Weir spills (with or without the proposed notch) (Figure 5C.5.4-57, Figure 5C.5.4-58, and Figure 5C.5.4-59). This accounts to a large extent for the relatively small differences in modeled winter-run recruitment to the ocean fishery under the EBC and ESO scenarios. While this effect may be exaggerated by limiting peak movement of winter-run to a single pulse in response to the first spill event of the season, it suggests that a large percentage of the population may often move past the weir during nonspill periods early in the season and thereby reduce the proportion of the population able to take advantage of floodplain rearing later in the season. This also suggests that potential benefits of *CM2 Yolo Bypass Fisheries Enhancement* to winter-run could be increased through coordinated flow management and/or notch operations to increase passage and rearing opportunities in the Yolo Bypass (e.g., increasing early season access through design or operational modifications of the proposed notch).



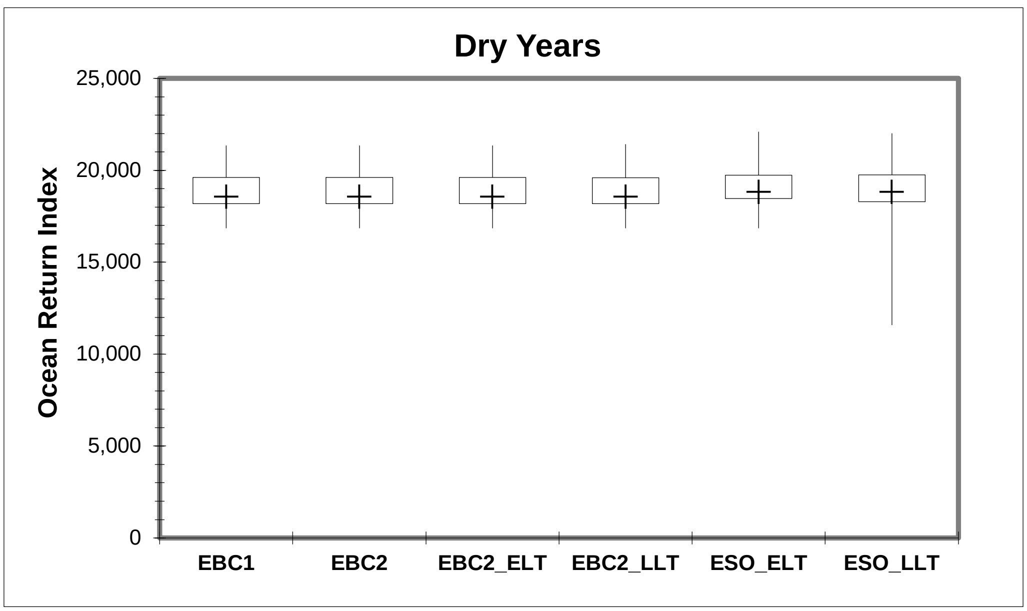

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-51. Winter-Run Chinook Salmon Ocean Return Indices (All Modeled Years)**



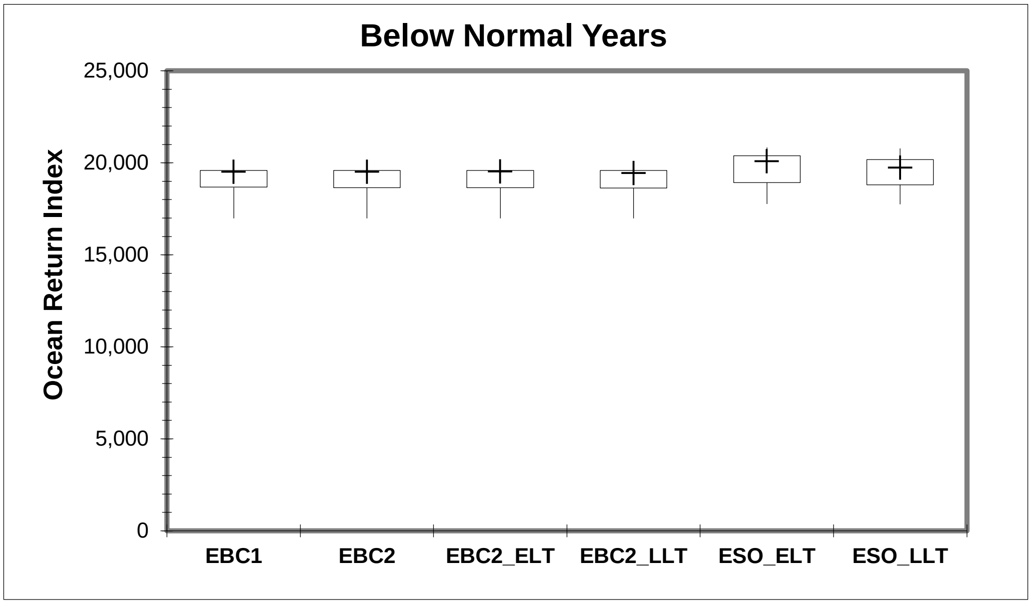

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-52. Winter-Run Chinook Salmon Ocean Return Indices (Critical Years)**



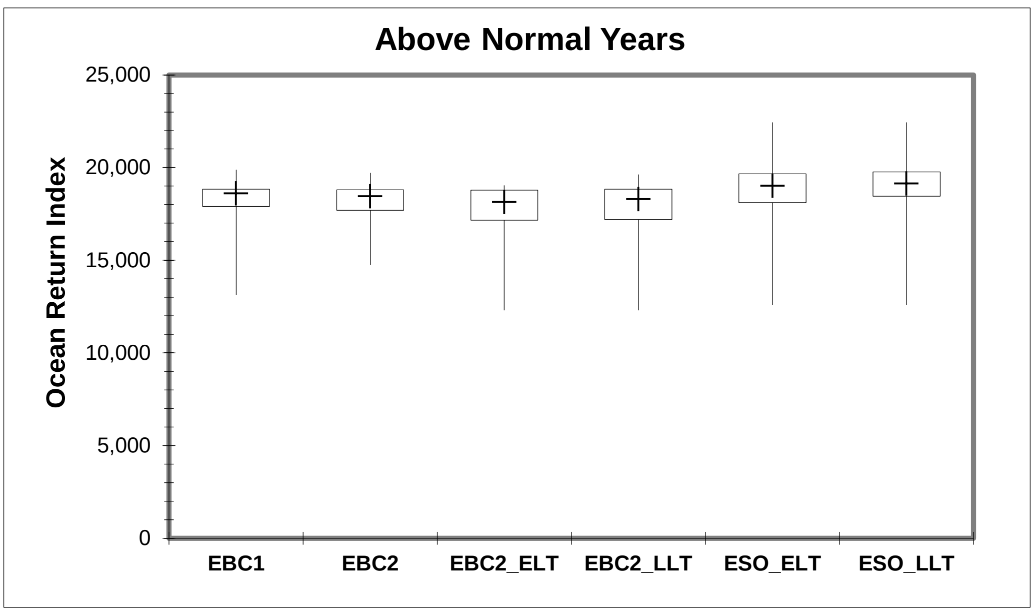

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-53. Winter-Run Chinook Salmon Ocean Return Indices (Dry Years)**



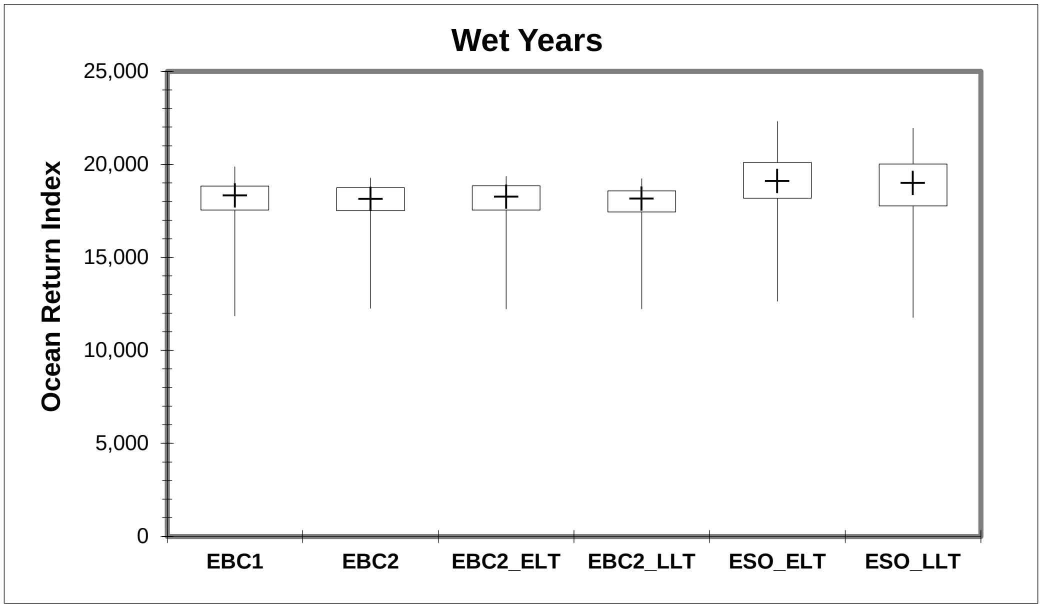

Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-54. Winter-Run Chinook Salmon Ocean Return Indices (Below Normal Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-55. Winter-Run Chinook Salmon Ocean Return Indices (Above Normal Years)**




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-56. Winter-Run Chinook Salmon Ocean Return Indices (Wet Years)**

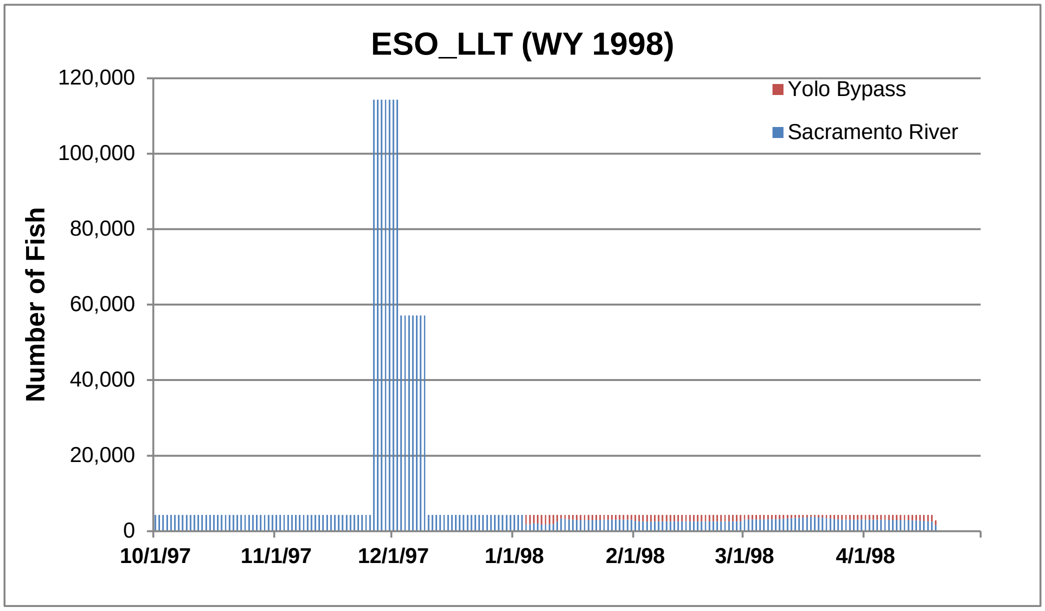



**Figure 5C.5.4-57. Number of Winter-Run Chinook Salmon Staying in the Sacramento River or Entering the Yolo Bypass at Fremont Weir under ESO_LLT Scenario (Water Year 1998)**

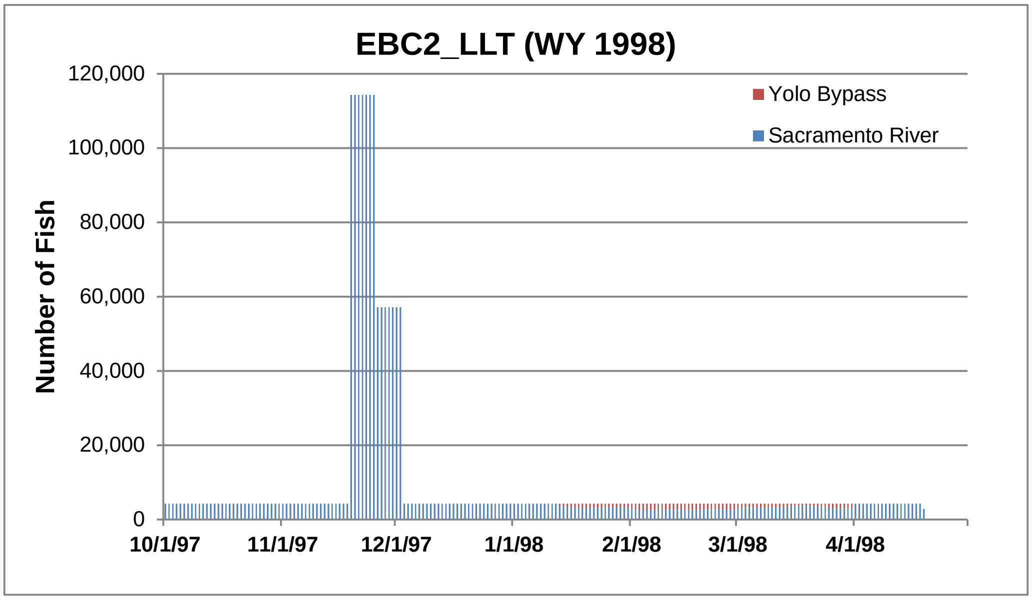



**Figure 5C.5.4-58. Number of Winter-Run Chinook Salmon Staying in the Sacramento River or Entering the Yolo Bypass at Fremont Weir under EBC2_LLT Scenario (Water Year 1998)**

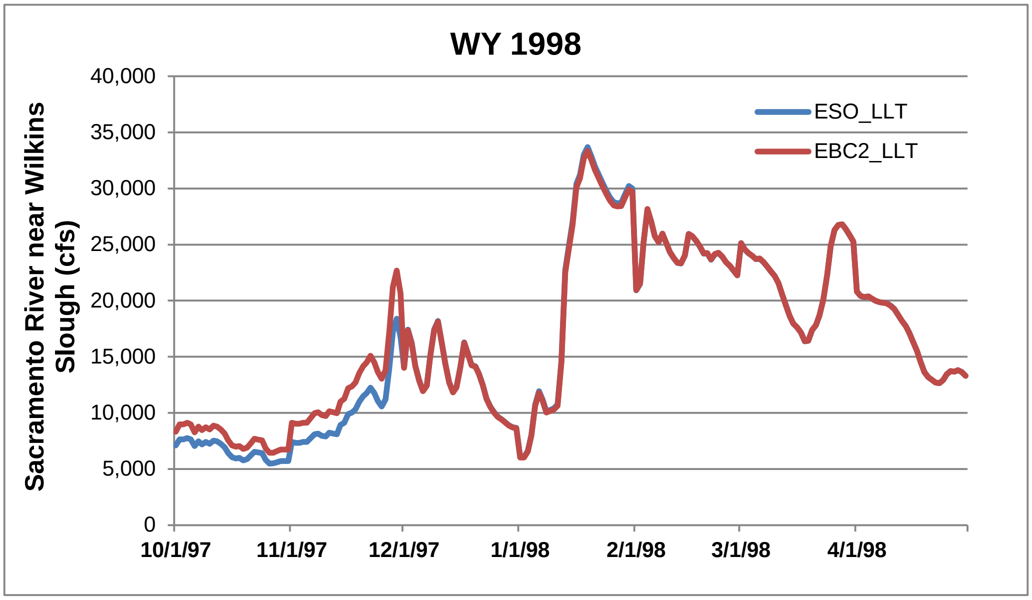



**Figure 5C.5.4-59. Modeled Daily Flow in the Sacramento River near Wilkins Slough under ESO_LLT and EBC2_LLT Scenarios (October 1, 1997–April 30, 1998)**

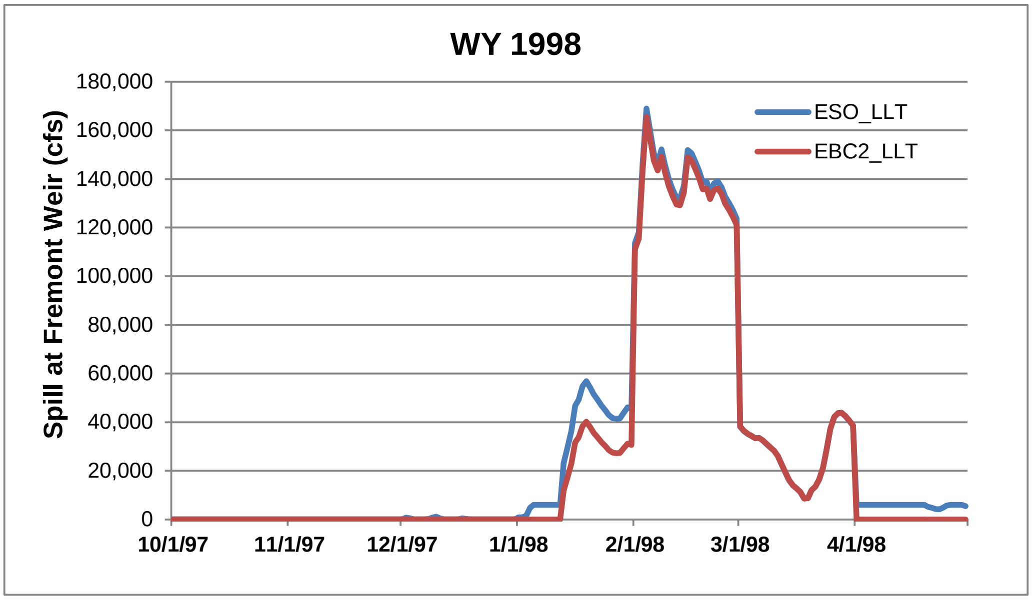



**Figure 5C.5.4-60. Modeled Daily Spills at Fremont Weir under ESO_LLT and EBC2_LLT Scenarios (October 1, 1997–April 30, 1998)**

**Model Sensitivity to Changes in Fry Survival in Sacramento River**

A sensitivity analysis was performed to evaluate the potential effects of changes in fry survival in the lower Sacramento River on overall benefits associated with implementation of proposed Fremont Weir modifications under *CM2 Yolo Bypass Fisheries Enhancement*. This analysis was performed to evaluate the potential negative effects of other covered activities on overall fry survival related to lower flows and higher diversion-related losses in the lower Sacramento River. The sensitivity analysis was applied to fall-run and the ESO_LLT and EBC2_LLT scenarios. Model sensitivity under the ESO_LLT was evaluated by reducing survival in the lower Sacramento River in 1% increments from 8.0% to 5.0% (while holding fry survival in the Yolo Bypass constant at 12.5%) and examining the results in terms of changes in ocean fishery returns relative to the EBC2_LLT.

Figure 5C.5.4-61 presents the incremental effects of changes in fall-run fry survival in the lower Sacramento River under the ESO_LLT on average ocean fishery returns (ocean fishery return indices) relative to average fishery returns under the EBC2_LLT. The results indicate that a 1% reduction in survival in the lower Sacramento River (i.e., from 8% to 7% or a relative change of 12.5%) would reduce the benefits by 65% (i.e., 2,300 to 800 fish), and that a 1.5% reduction in fry survival (i.e., from 8% to 6.5% or a relative change of 19%) would fully offset the benefits associated with implementation of proposed Fremont Weir modifications under CM2 (i.e., no change relative to baseline conditions).

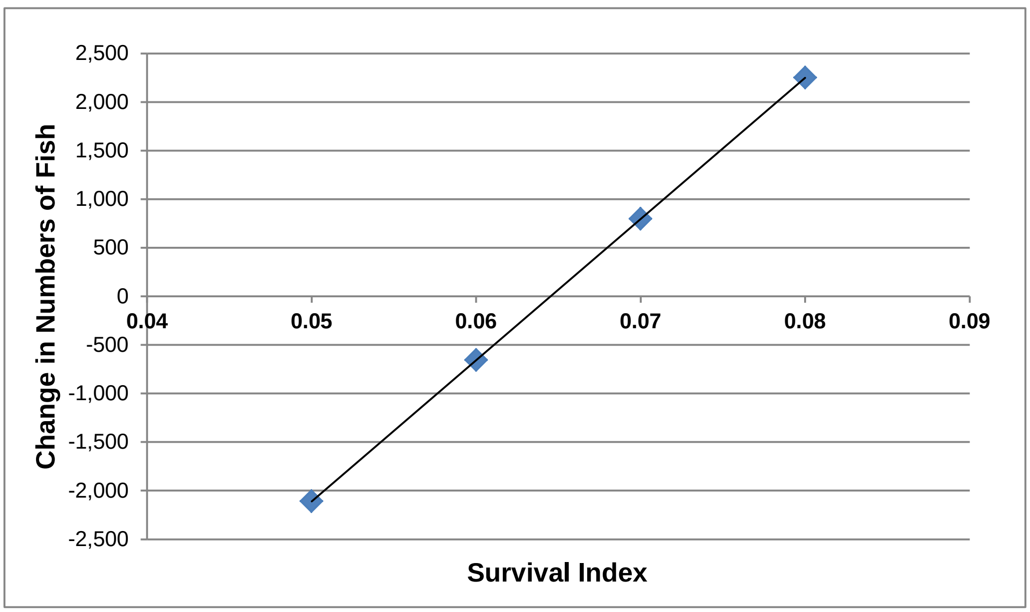
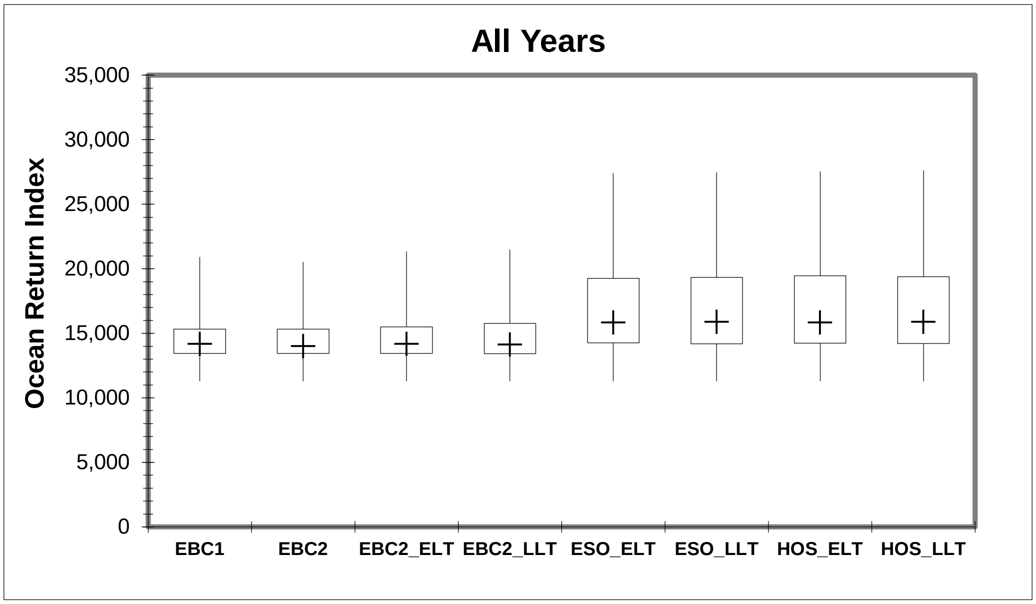



**Figure 5C.5.4-61. Average Change in Ocean Fishery Returns of Fall-Run Chinook Salmon under ESO_LLT (Relative to EBC_LLT) in Response to Changes in Fry Survival in the Lower Sacramento River between Fremont Weir and Chipps Island (All Modeled Years)**

**High Outflow Scenario**

Application of the YBFR model to the HOS_ELT and HOS_LLT scenarios indicated that the benefits associated with proposed modifications of the Fremont Weir under the HOS scenarios would be similar to those achieved under the ESO scenarios (Figure 5C.5.4-62). Minimum, median, and maximum ocean return indices under the HOS and ELT scenarios differed by less than 1%, indicating little change in the proportion of fry entering the bypass and the duration of floodplain rearing under these two scenarios.




Box and whisker plots show minimum, 25th, 50th (denoted by +), 75th, and maximum percentiles of indices by modeled scenario.

**Figure 5C.5.4-62. Fall-Run Chinook Salmon Ocean Return Indices for EBC, ESO, and HOS Scenarios (All Modeled Years)**

### 5C.5.4.1.5 Lower Sutter Bypass Inundation

The results of the lower Sutter Bypass inundation analysis show very little difference among the scenarios in daily average surface area inundated (Table 5C.5.4-4 and Table 5C.5.4-5). Only one of the differences is greater than 10%. The differences are especially small (<4%) when climate change effects are taken into account (i.e., ESO_ELT vs. EBC2_ELT and ESO_LLT vs. EBC2_LLT).

**Table 5C.5.4-4. Daily Average (December–June) Lower Sutter Bypass Inundation under EBC and ESO Scenarios (acres)**

| Scenario[a] | Water-Year Type: Wet | Above Normal | Below Normal | Dry | Critical | All |
|---|---|---|---|---|---|---|
| EBC1 | 2,364 | 1,335 | 333 | 138 | 26 | 1,036 |
| EBC2 | 2,306 | 1,286 | 297 | 133 | 26 | 1,003 |
| EBC2_ELT | 2,334 | 1,342 | 310 | 132 | 26 | 1,022 |
| EBC2_LLT | 2,269 | 1,342 | 290 | 129 | 27 | 998 |
| ESO_ELT | 2,330 | 1,389 | 307 | 134 | 26 | 1,028 |
| ESO_LLT | 2,282 | 1,384 | 296 | 126 | 27 | 1,008 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-5. Differences[a] between ESO Scenarios and EBC Scenarios in Daily Average (December–June) of Lower Sutter Bypass Inundation (acres)**

| Scenario[a] Comparison | Water-Year Type: Wet | | Above Normal | | Below Normal | | Dry | | Critical | | All | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESO_ELT vs. EBC1 | -35 | (-1.5%) | 55 | (4.1) | -26 | (-7.8%) | -4 | (-2.8%) | 1 | (2.8%) | 1 | (0.1%) |
| ESO_LLT vs. EBC1 | -83 | (-3.5%) | 49 | (3.7) | -37 | (-11.0%) | -12 | (-8.7%) | 1 | (5.3%) | 1 | (0.1%) |
| ESO_ELT vs. EBC2 | 24 | (1.0%) | 104 | (8.1) | 10 | (3.2%) | 1 | (1.0%) | 0 | (0.7%) | 0 | (0.0%) |
| ESO_LLT vs. EBC2 | -24 | (-1.0%) | 98 | (7.6) | -1 | (-0.3%) | -7 | (-5.2%) | 1 | (3.2%) | 1 | (0.1%) |
| ESO_ELT vs. EBC2_ELT | -4 | (-0.2%) | 47 | (3.5) | -3 | (-0.9%) | 3 | (2.0%) | 0 | (1.2%) | 0 | (0.0%) |
| ESO_LLT vs. EBC2_LLT | 13 | (0.6%) | 42 | (3.1) | 6 | (2.0%) | -3 | (-2.5%) | 0 | (0.8%) | 0 | (0.0%) |

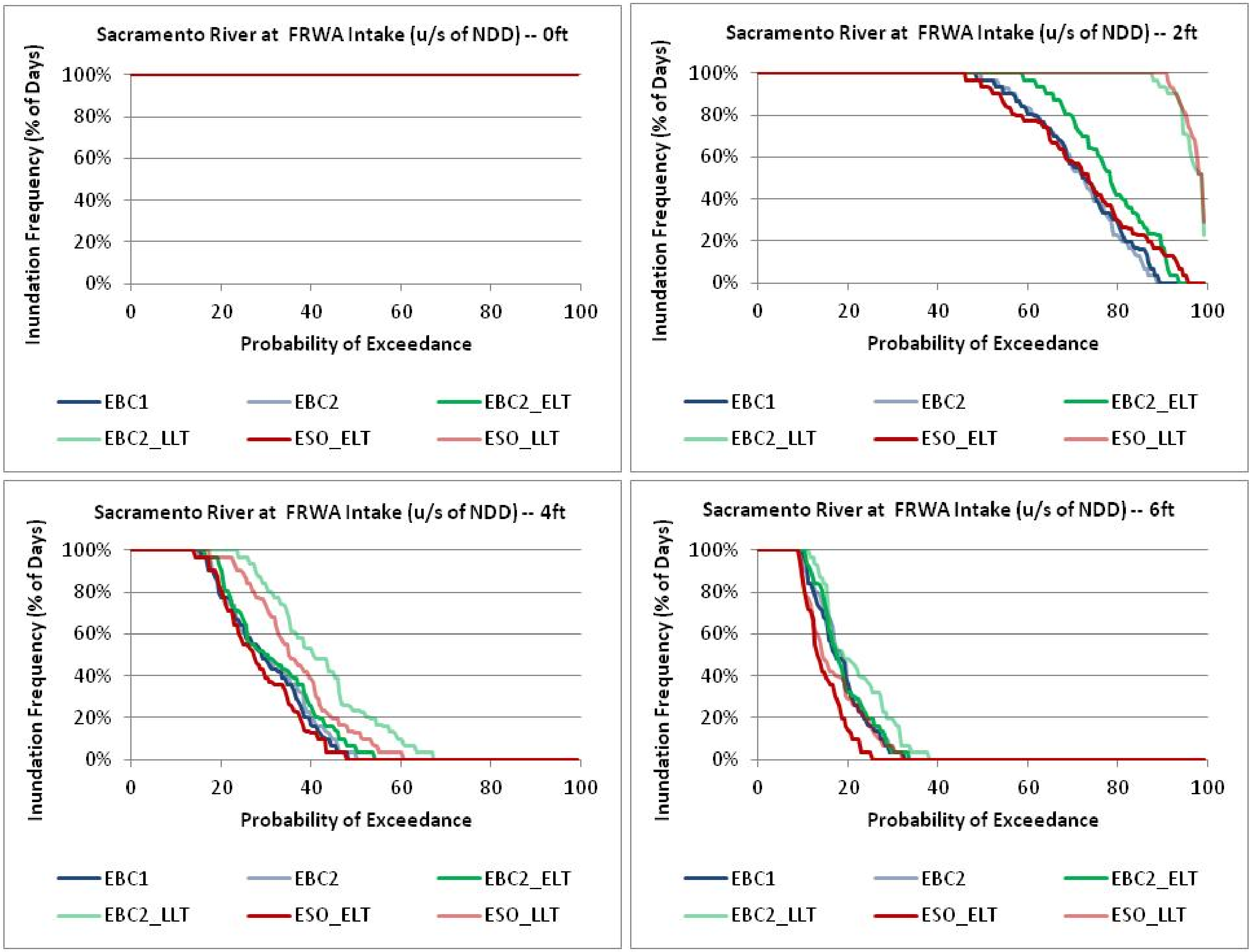
[a] Positive value indicates greater inundation under ESO than under EBC.
[b] See Table 5C.0-1 for definitions of scenarios.

Two important limitations of the analysis used to evaluate effects of the scenarios on lower Sutter Bypass inundation should be noted. The first limitation is that the analysis assumes no pre-existing inundation from upstream sources. This assumption leads to substantial underestimation of the areas in the lower bypass that would be inundated. However, it is expected that the underestimates would be roughly similar for all the scenarios and, therefore, the comparisons among scenarios accurately portray the potential BDCP effects. The second limitation is that the analysis treats each day of the simulation independently, whereas, in fact, inundation from one day would likely affect the level of inundation that occurred the following day. Again, this limitation likely affects all the scenarios more or less equally and, therefore, probably has little effect on the overall conclusion that the scenarios are expected to result in only minor differences in lower Sutter Bypass inundation.

## 5C.5.4.2 Wetland Bench Inundation

*[Herein ICF presents the results of the Wetland Bench Inundation analysis as described in the Methods. Discussion during the late-2012 species working group meetings suggested that there may be issues with the datums used from DSM2 in comparison with the datum for the blueprints for the sites that NMFS provided. ICF will verify this. ICF will work with agency partners to develop more detailed information on the bench restoration, i.e., the inundation frequency criteria for wetland and riparian benches, in order to assess potential changes under the BDCP].*

The frequency of inundation of habitat benches along eight sites on the Sacramento River was explored under each model scenario to assess the effect of the evaluated starting operations. Inundation was determined from DMS2 daily model output at the node nearest to each bench. The distribution of inundation frequency for each model scenario at each habitat bench and elevation is presented as the percent exceedance for all years (Figure 5C.5.4-63 through Figure 5C.5.4-70), and by month (Figure 5C.5.4-71 through Figure 5C.5.4-78) to capture seasonal dynamics of flows. Exceedance frequencies showed that inundation under the ESO scenarios was generally similar to or greater than EBC1 and EBC2 scenarios for both time periods (ELT and LLT). Especially at elevations of 0 feet and 2 feet, flow exceedances were highest for ESO_LLT, but were often among the lowest for ESO_ELT. Variation in inundation frequency was high among sites. At higher elevations (4 feet and 6 feet), the highest inundation was generally under the EBC2 scenario. However, at higher elevations, the range of inundation exceedances was markedly reduced, suggesting little difference among model scenarios. It should be noted that these analyses are based on total inundation frequency (i.e., where the minimum stage of the river at the particular site exceeded the chosen elevation) and did not capture days during which a bench was partially inundated (i.e., where the maximum stage exceeded bench elevation). There is considerable variability in the inundation dynamics of habitat benches, and this variability is likely greater than the variance observed among scenarios, especially at higher elevations. The annual dynamics of inundation of habitat benches by month supported similar conclusions.




u/s of NDD = upstream of north Delta diversions.

**Figure 5C.5.4-63. Exceedance Plots for Inundation Frequency (Percent of Total Days) for Four Elevations, Sacramento River at Freeport Regional Water Authority Intake**

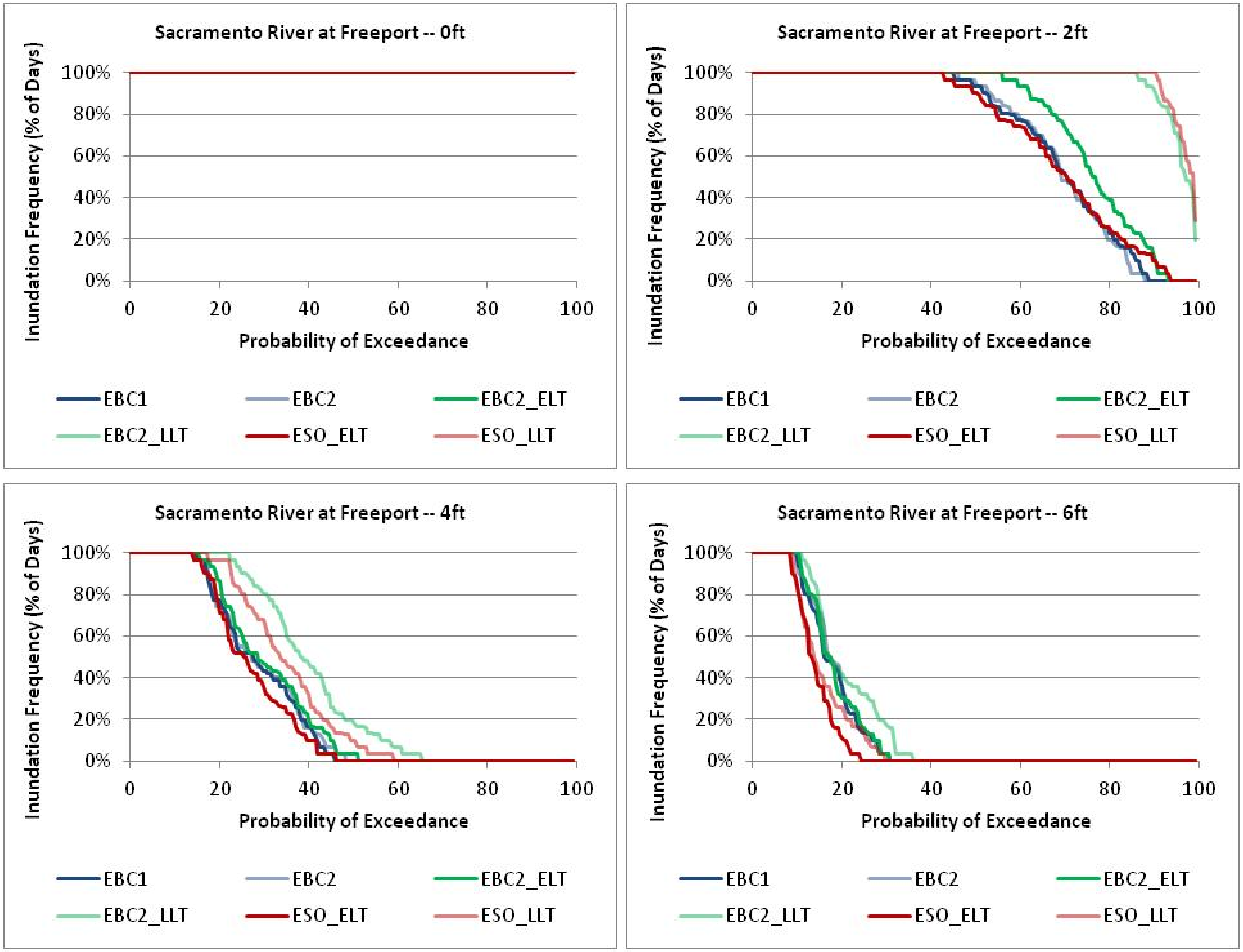
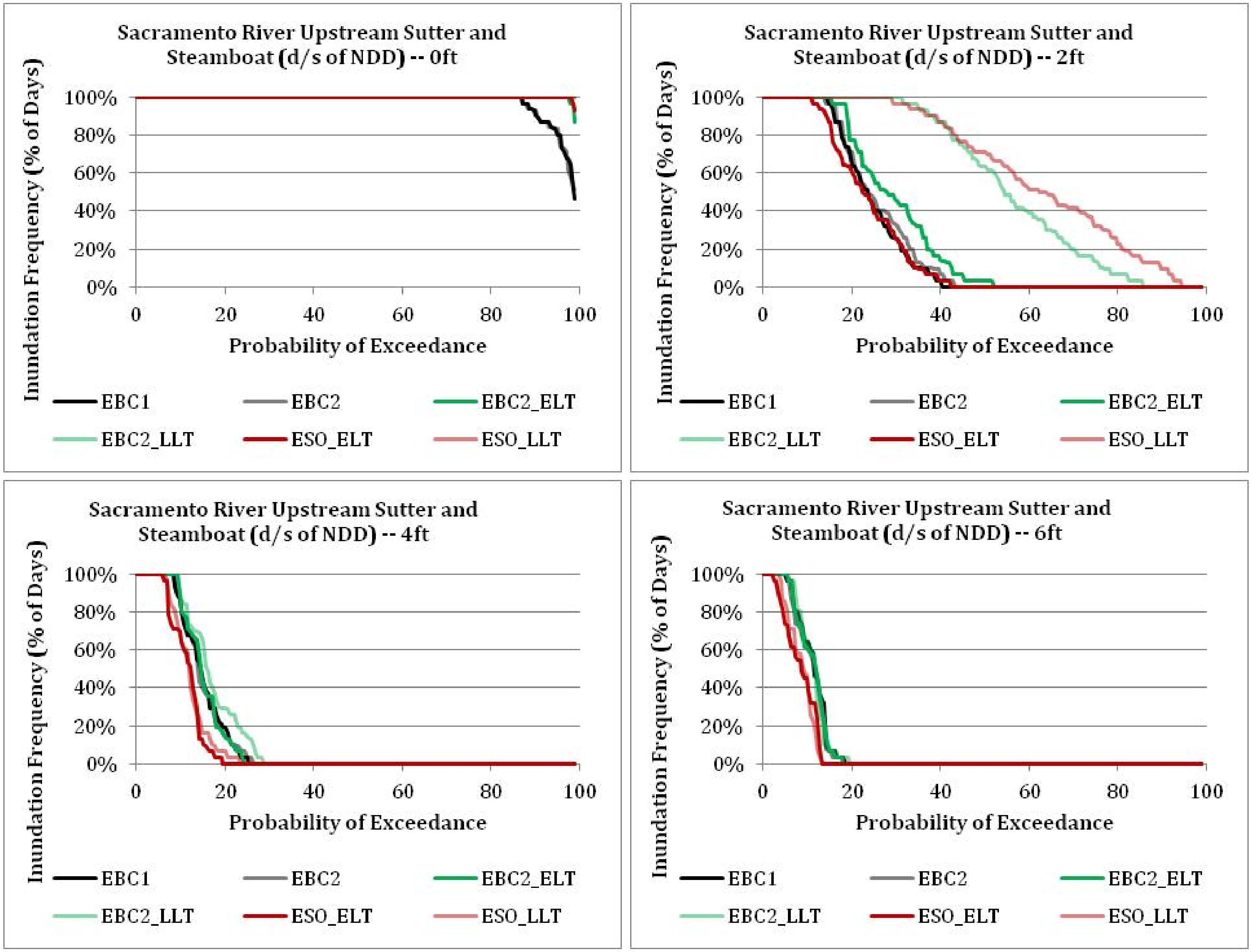



**Figure 5C.5.4-64. Exceedance Plots for Inundation Frequency (Percent of Total Days) for Four Elevations, Sacramento River at Freeport**




d/s of NDD = downstream of north Delta diversions.

**Figure 5C.5.4-65. Exceedance Plots for Inundation Frequency (Percent of Total Days) for Four Elevations, Sacramento River Upstream of Sutter and Steamboat Sloughs**

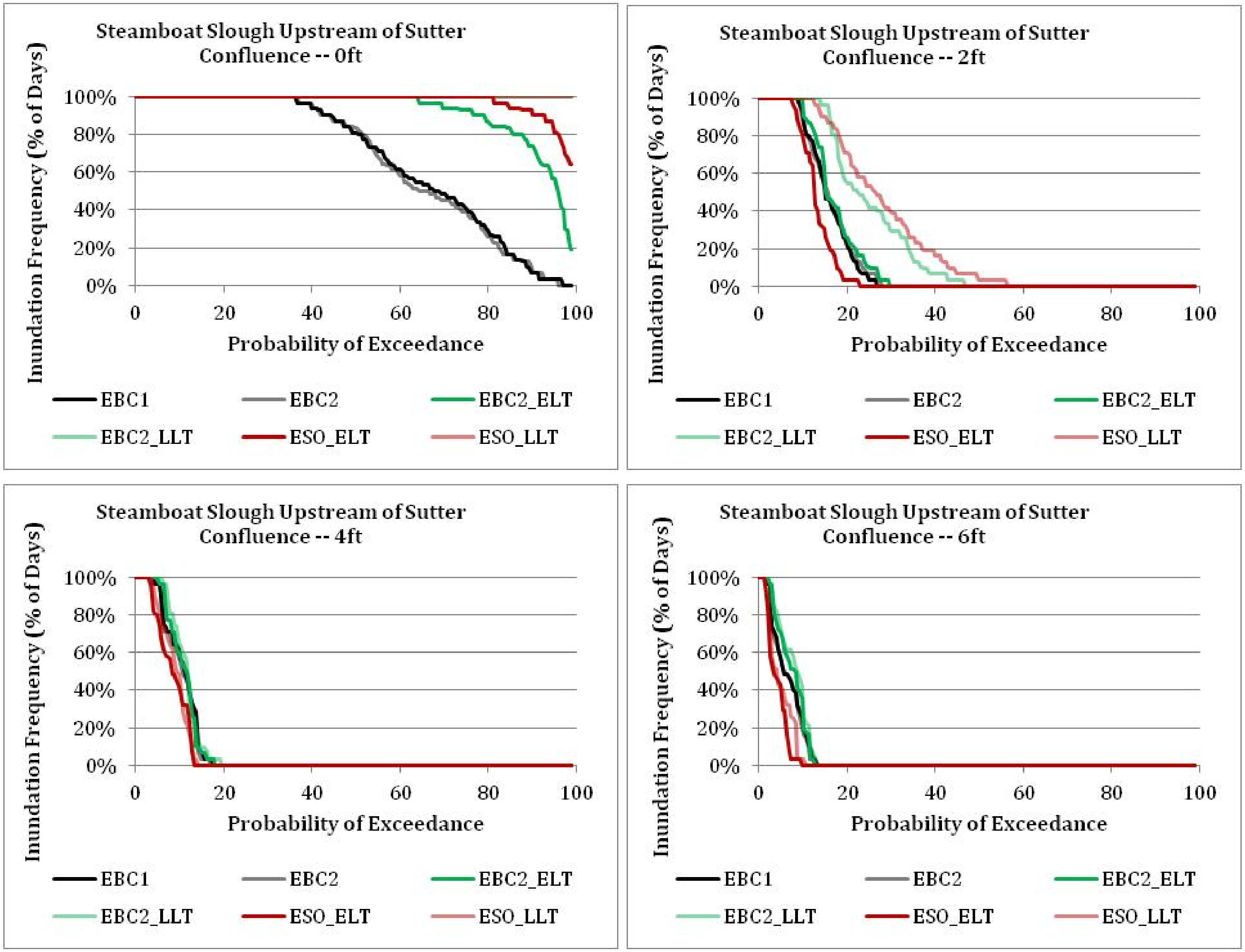



**Figure 5C.5.4-66. Exceedance Plots for Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Steamboat Slough Upstream of Sutter Slough Confluence**

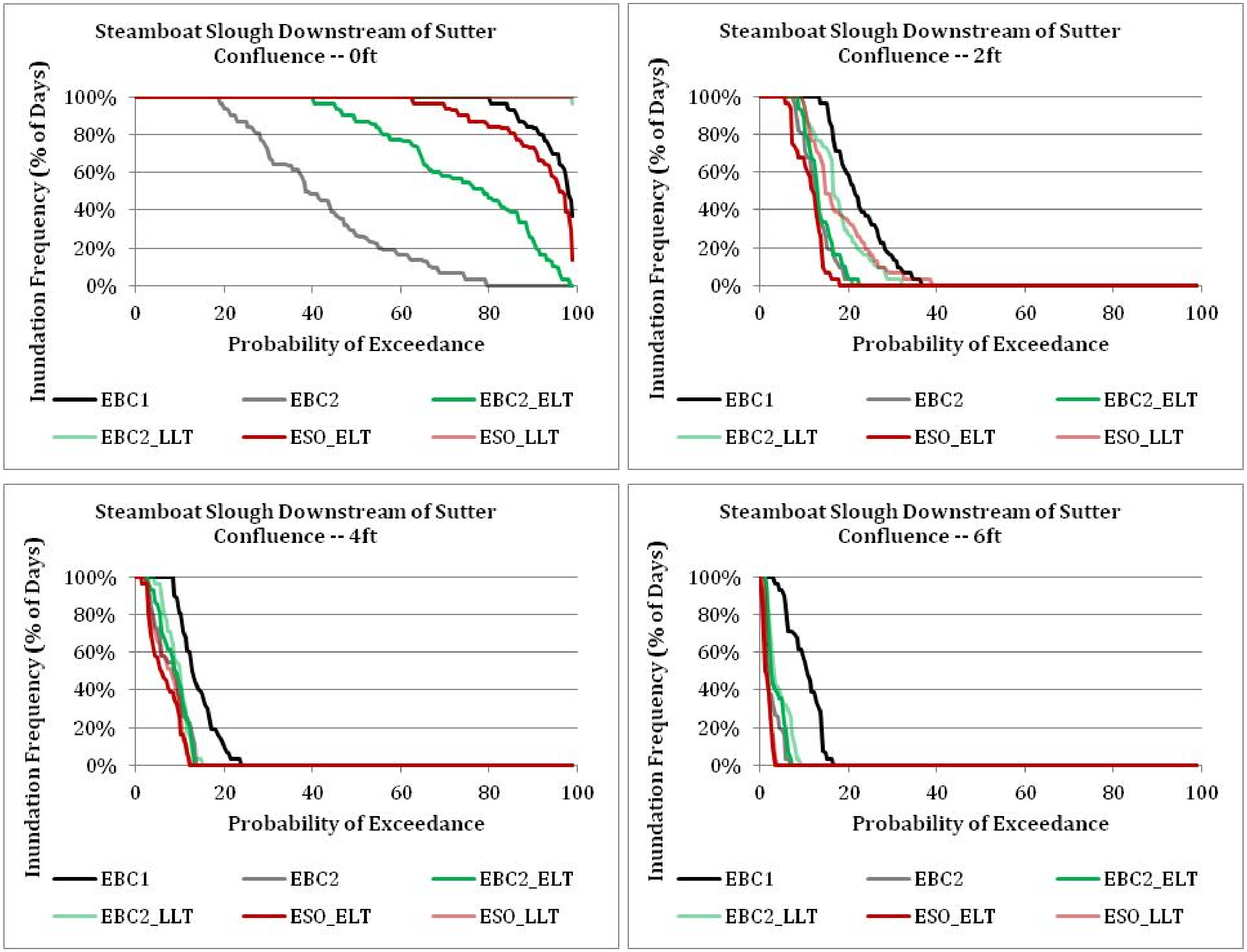



**Figure 5C.5.4-67. Exceedance Plots for Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Steamboat Slough Downstream of Sutter Slough Confluence**

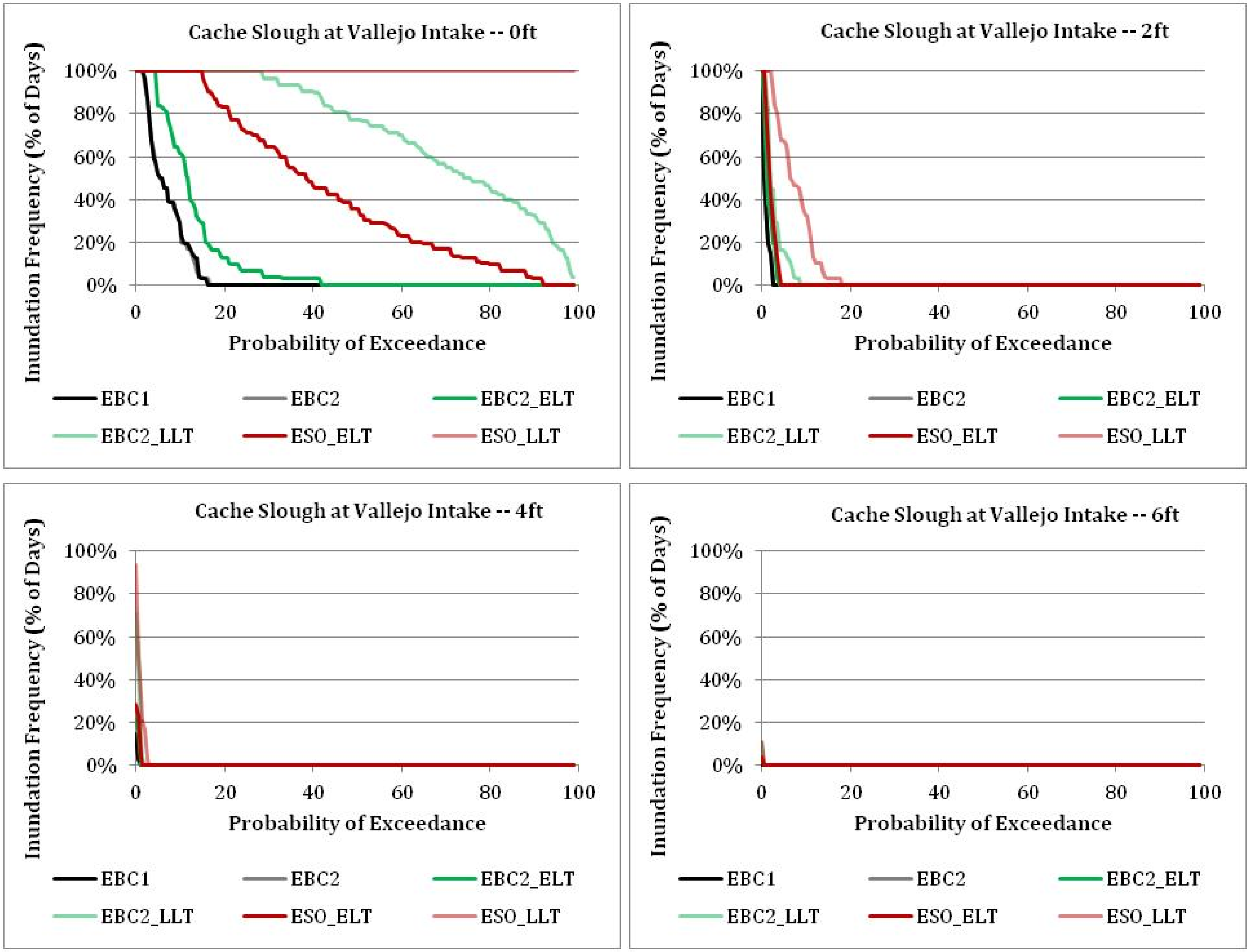



**Figure 5C.5.4-68. Exceedance Plots for Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Cache Slough at Vallejo Intake**

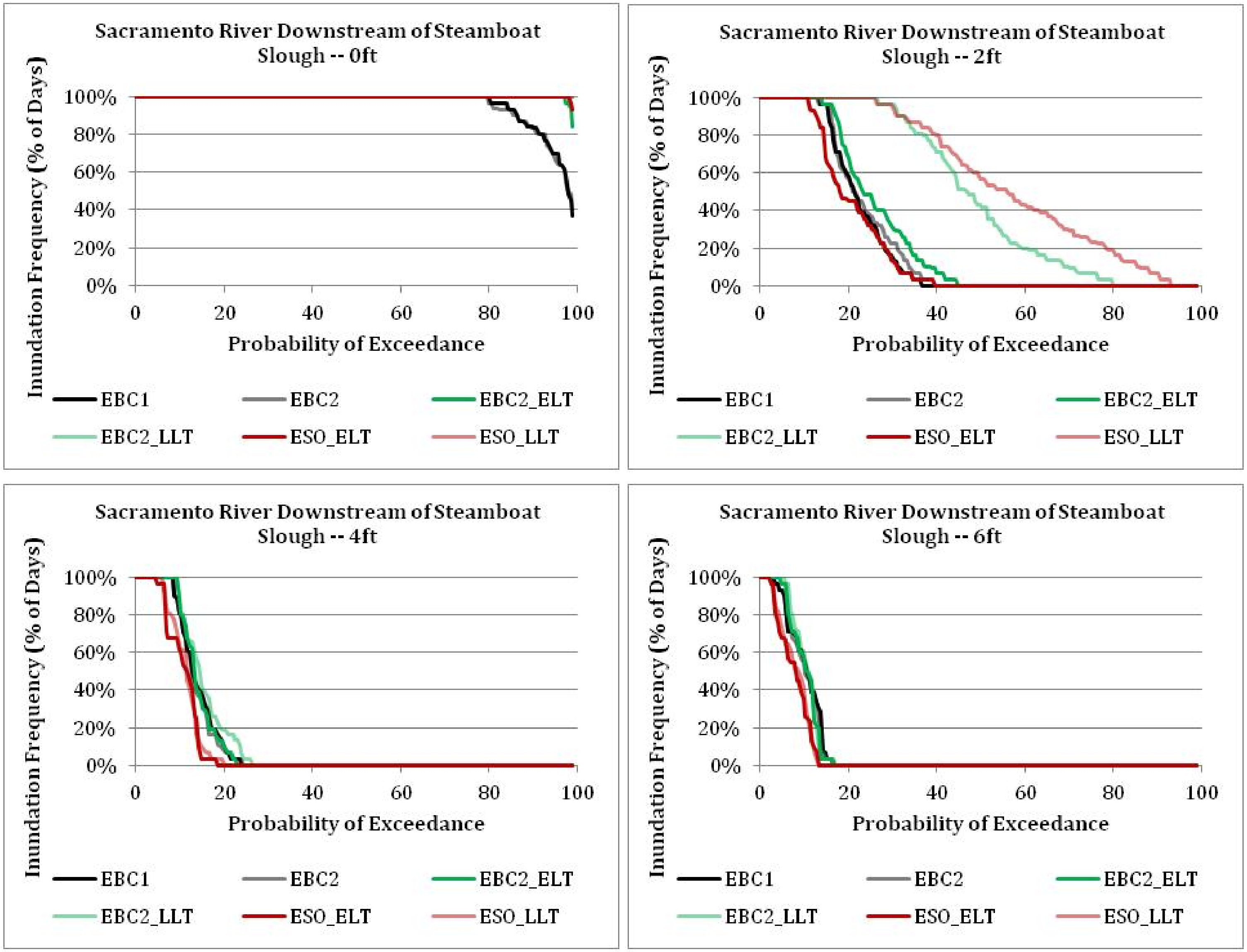



**Figure 5C.5.4-69. Exceedance Plots for Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River Downstream of Steamboat Slough**

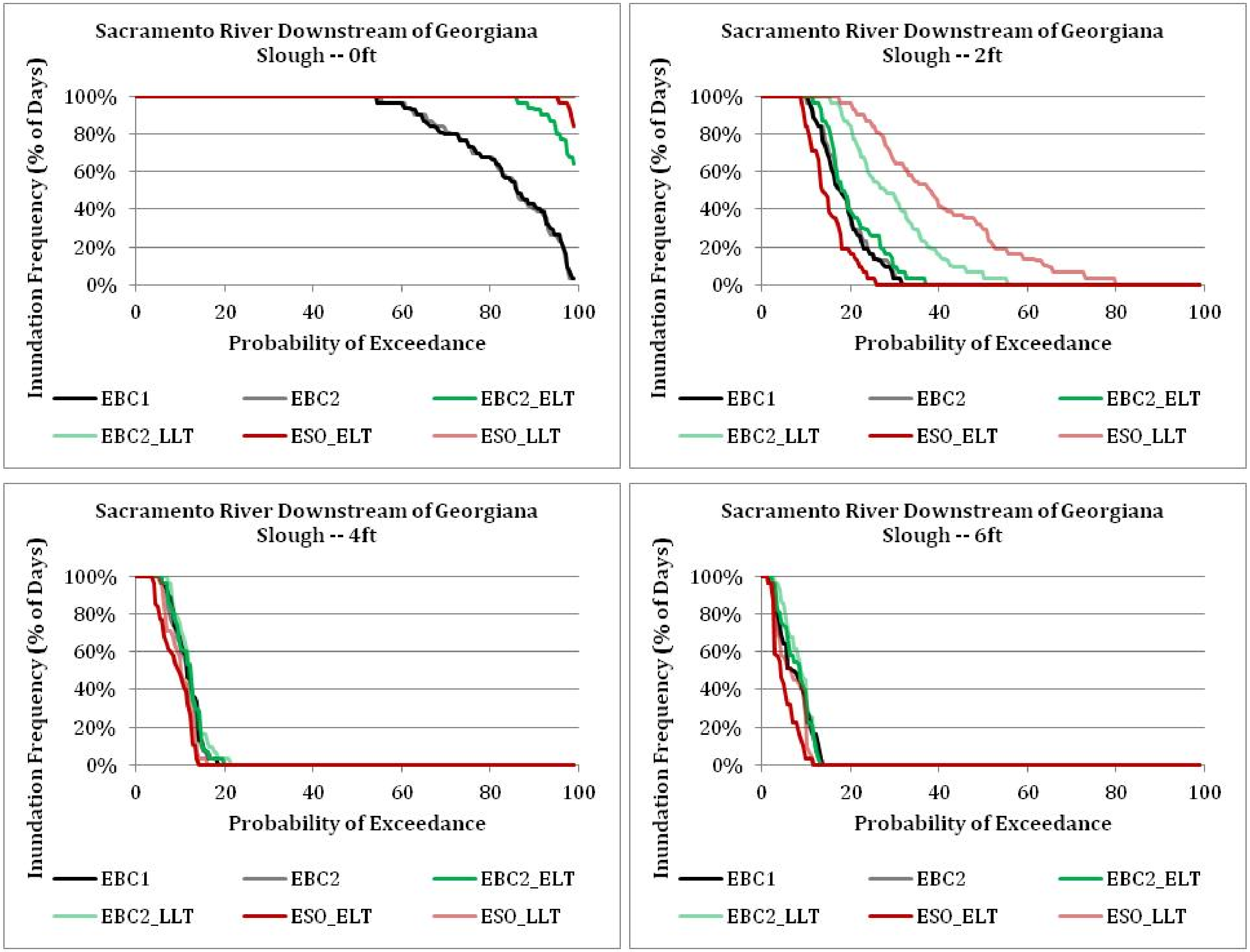
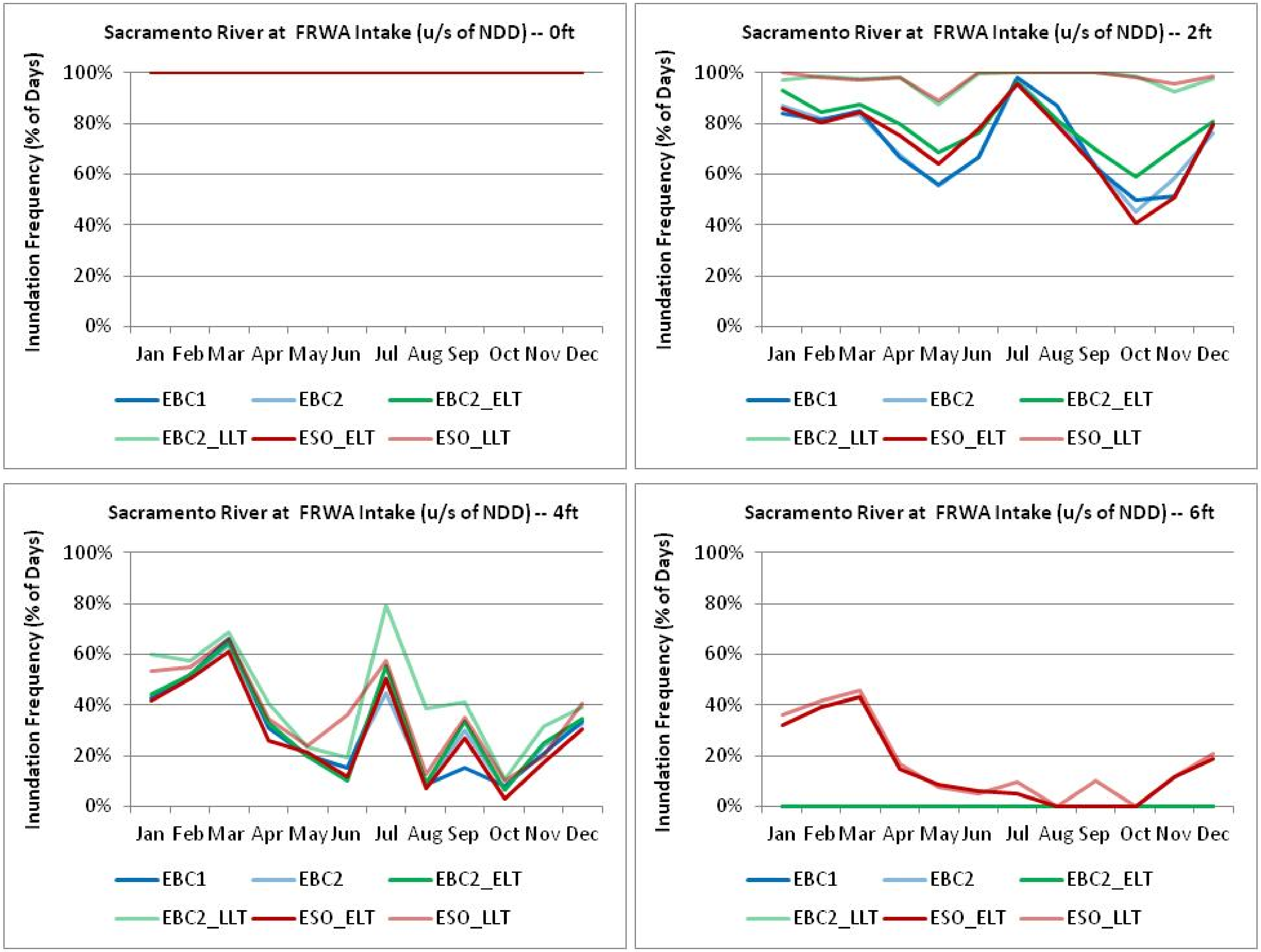



**Figure 5C.5.4-70. Exceedance Plots for Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River Downstream of Georgiana Slough**




u/s of NDD = upstream of north Delta diversions.

**Figure 5C.5.4-71. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River at Freeport Regional Water Authority Intake**

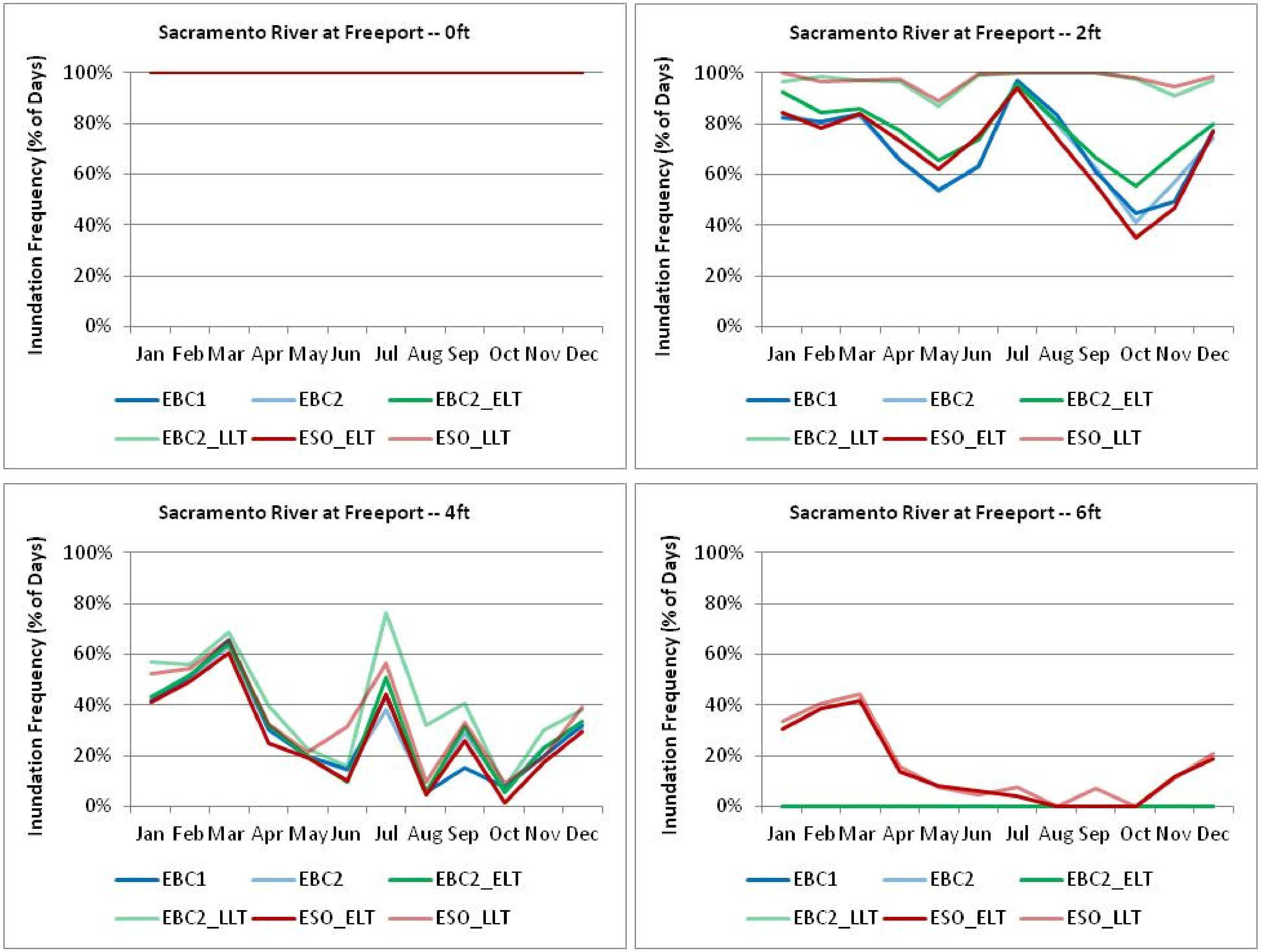
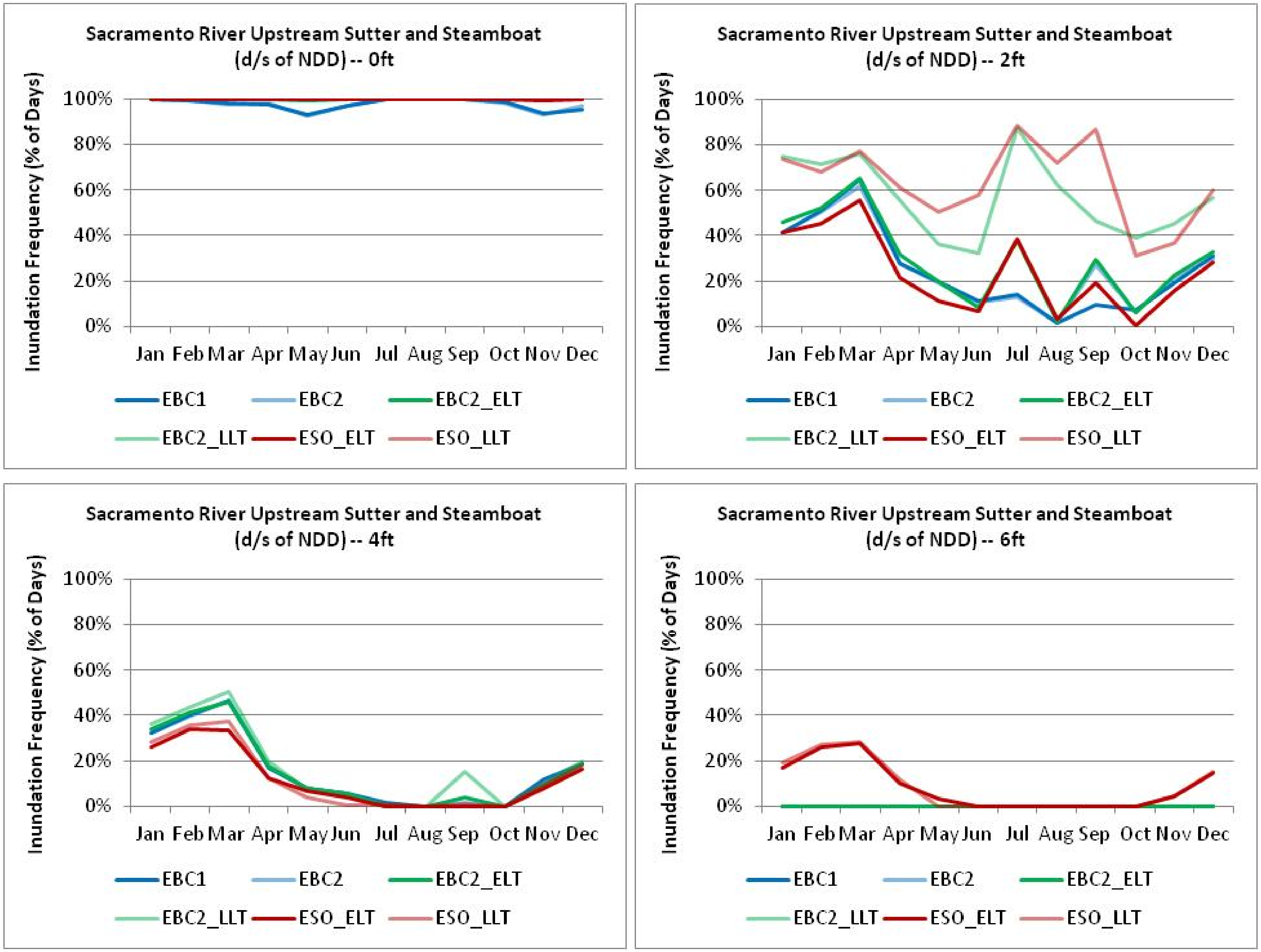



**Figure 5C.5.4-72. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River at Freeport**




d/s of NDD = downstream of north Delta diversions.

**Figure 5C.5.4-73. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River Upstream of Sutter and Steamboat Sloughs**

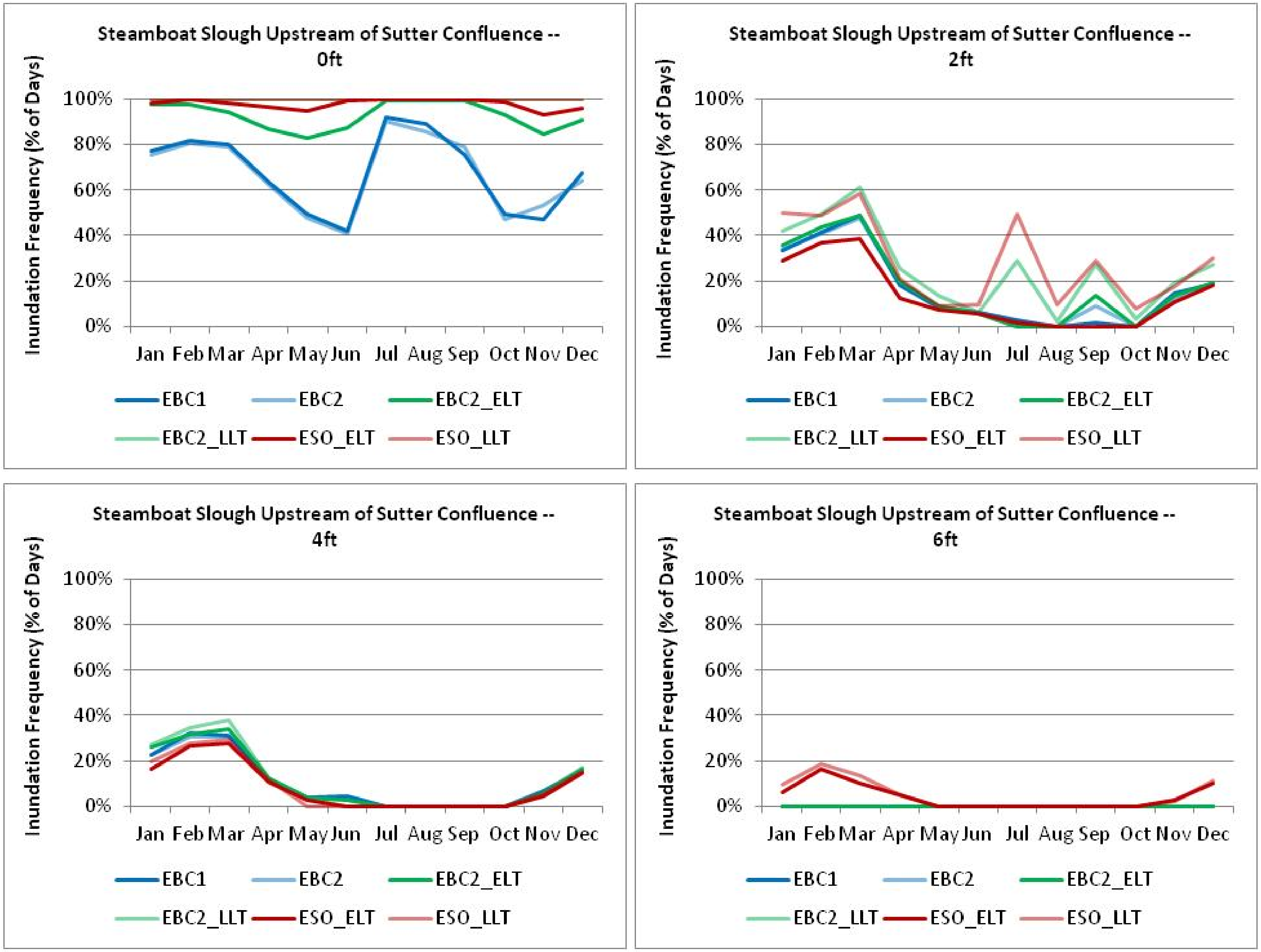



**Figure 5C.5.4-74. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Steamboat Slough Upstream of Sutter Slough Confluence**

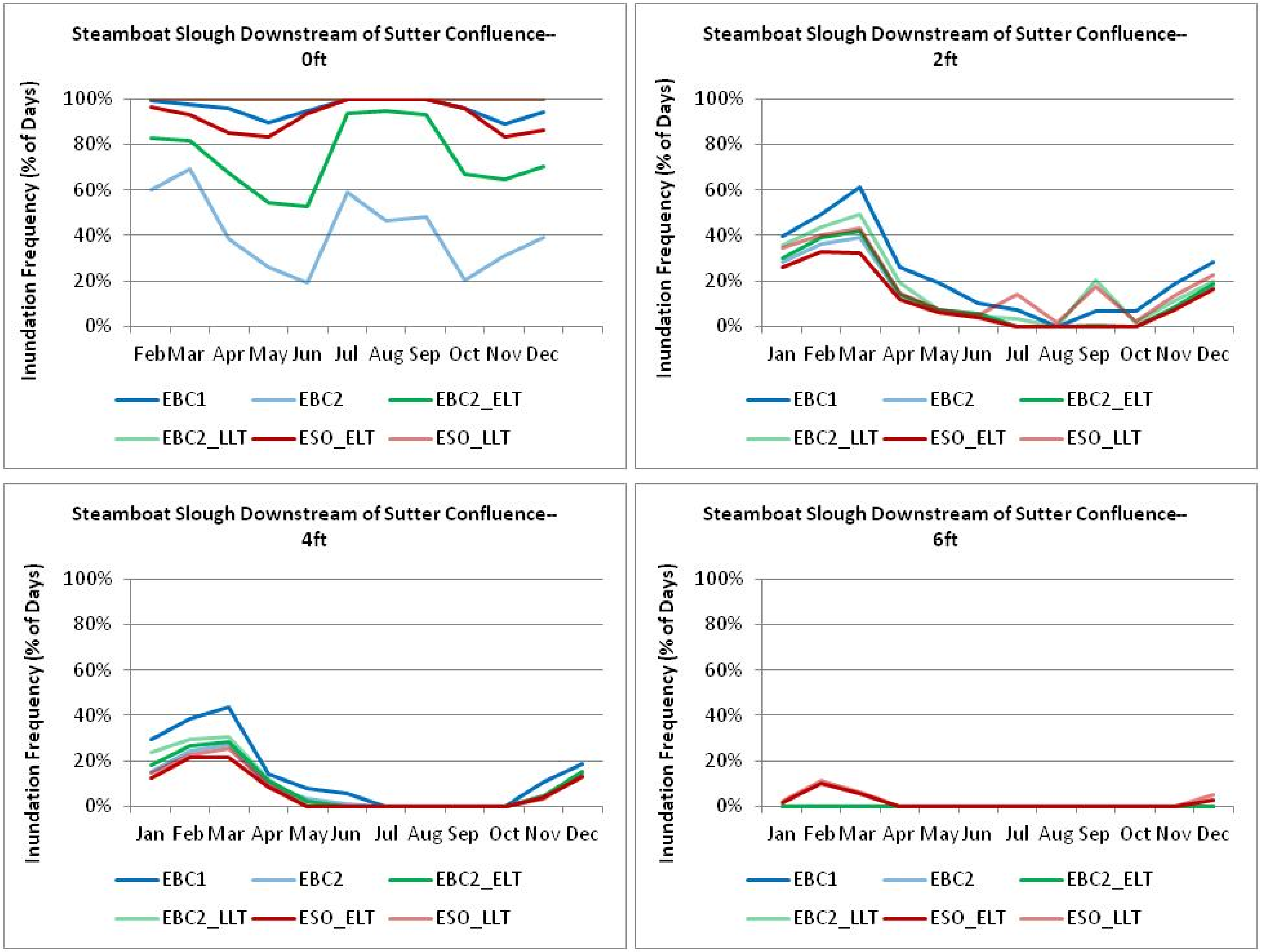



**Figure 5C.5.4-75. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Steamboat Slough Downstream of Sutter Slough Confluence**

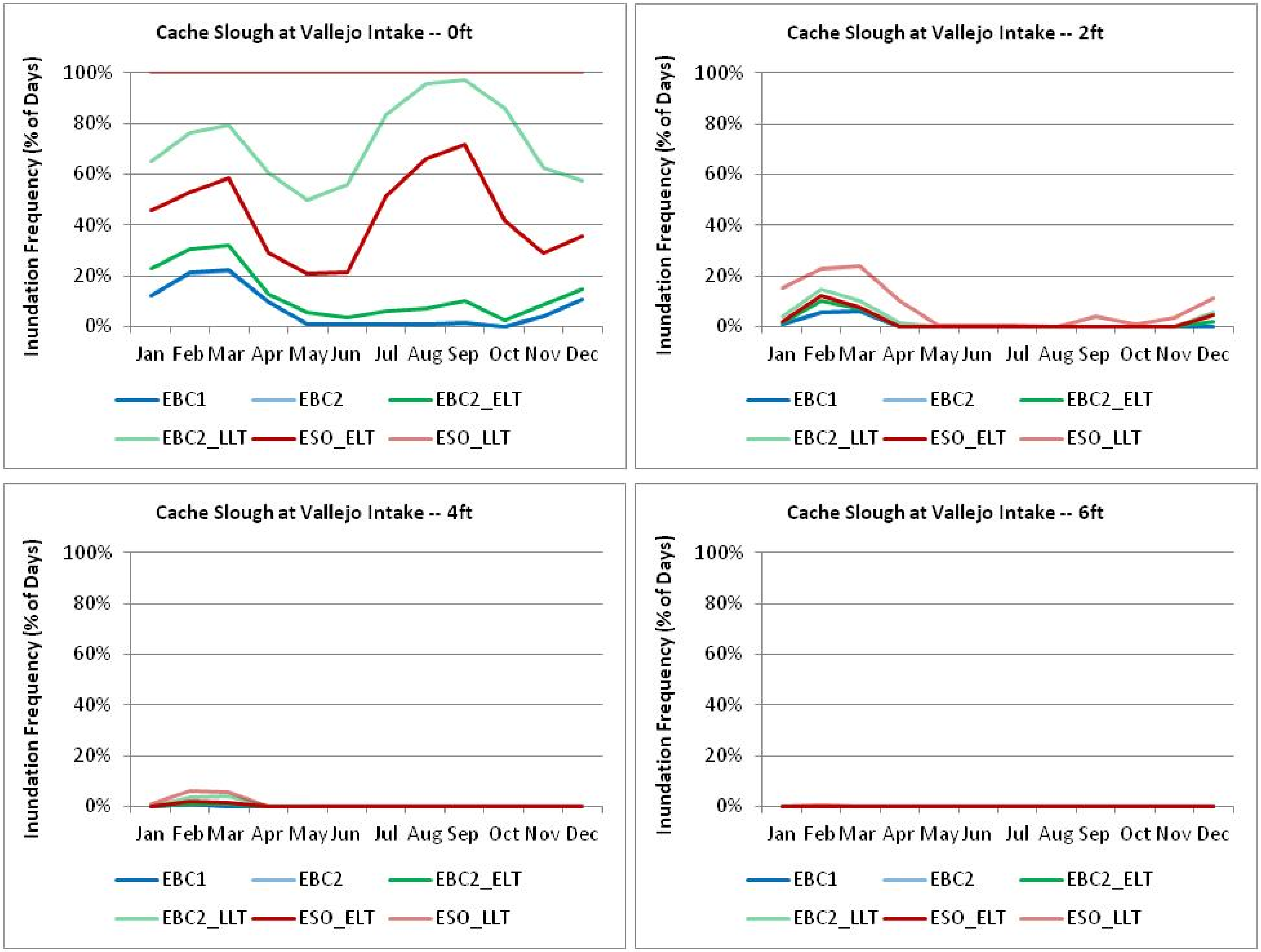



**Figure 5C.5.4-76. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Cache Slough at Vallejo Intake**

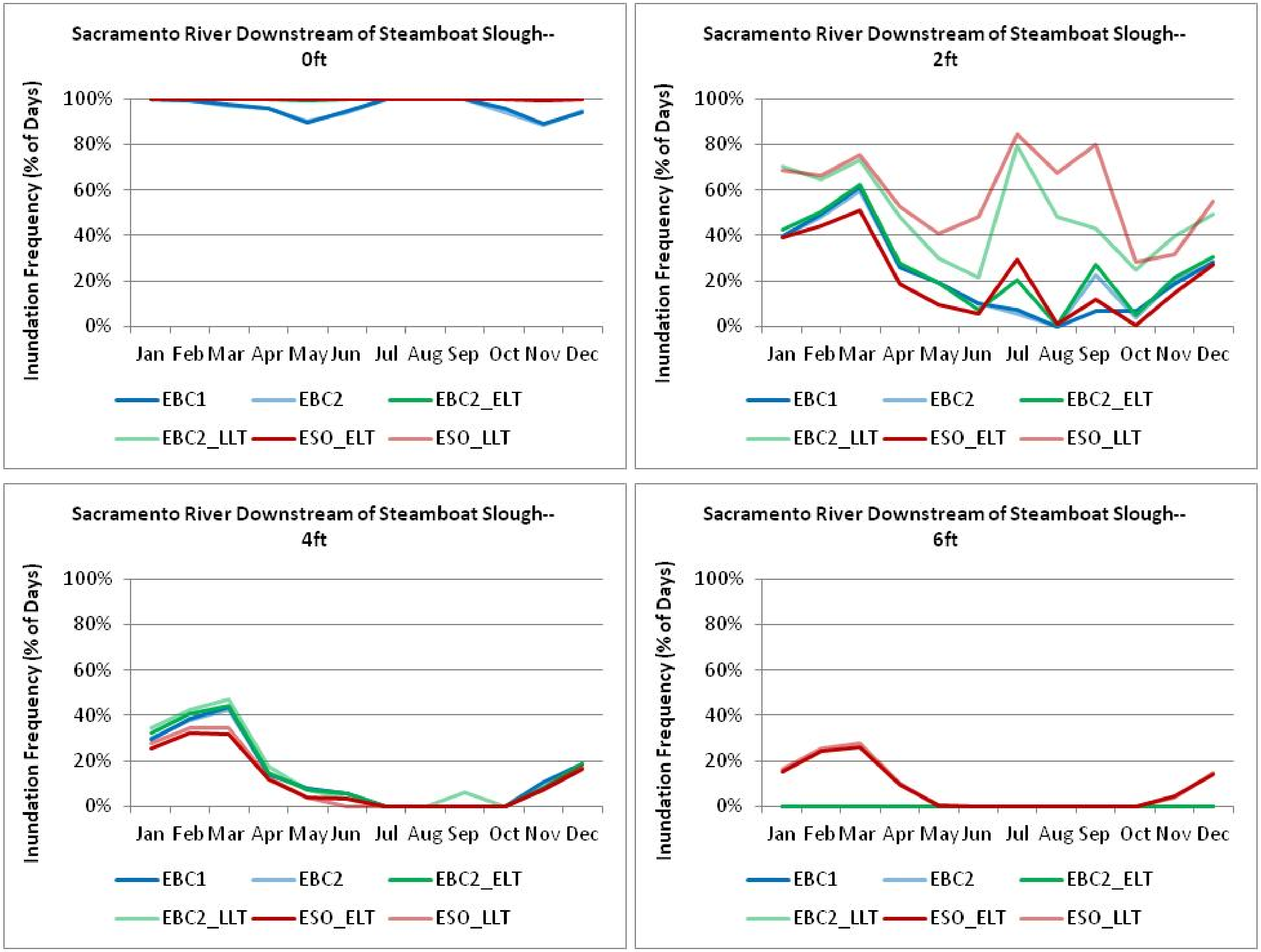



**Figure 5C.5.4-77. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River Downstream of Steamboat Slough**

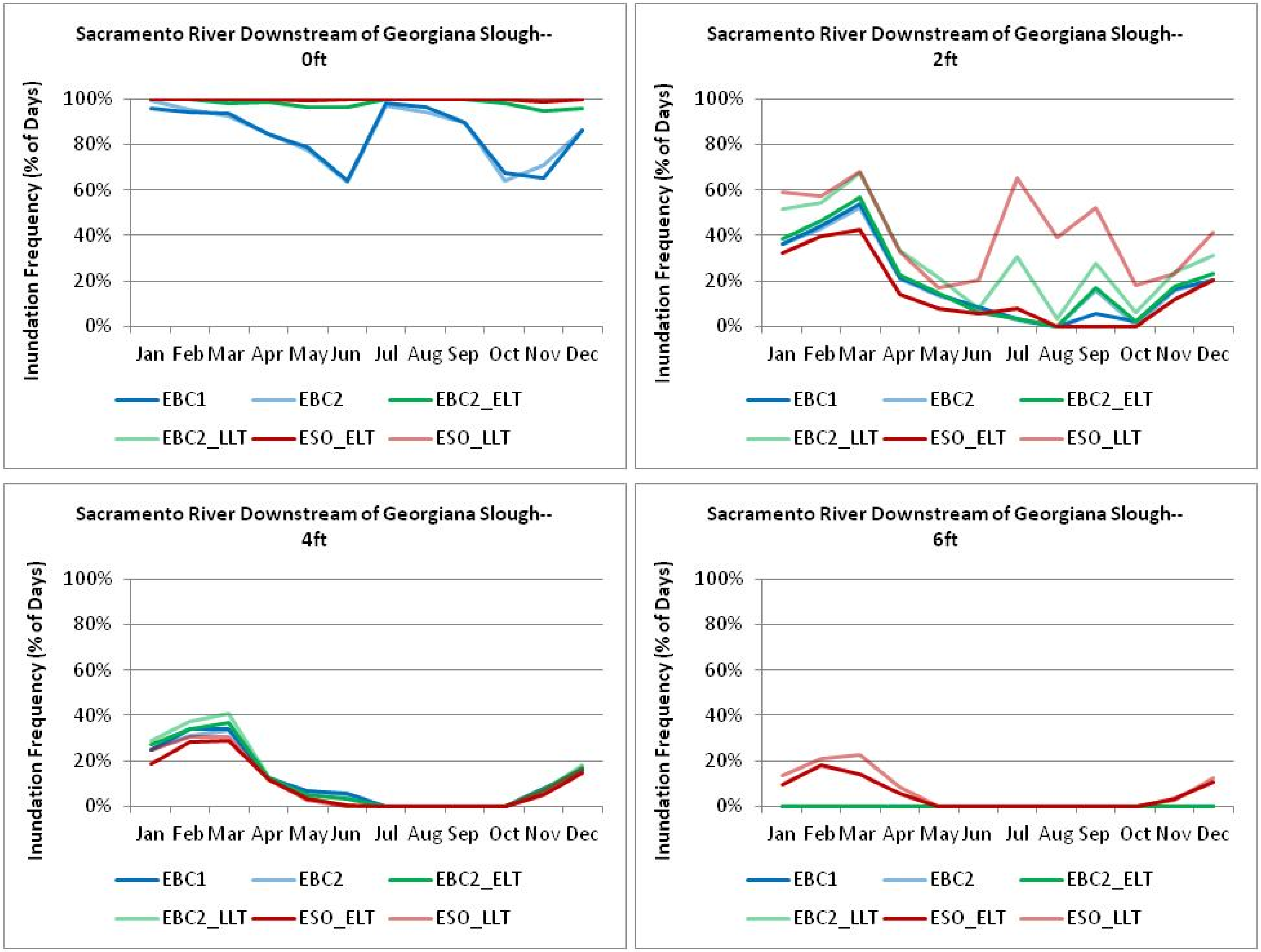



**Figure 5C.5.4-78. Average Monthly Inundation Frequency (Percent of Total Days) of Hypothetical Habitat Benches at Four Elevations, Sacramento River Downstream of Georgiana Slough**

# 5C.5.4.3 Dissolved Oxygen

The simulations of dissolved oxygen (DO) concentrations in eight subregions of the Delta for the six different scenarios using DSM-QUAL found only minor differences among the scenarios. The greatest difference in the mean DO value for any day of the year was 0.95 milligrams per liter (mg/L) in Suisun Marsh during March. For most of the subregions, differences due to climate change were larger than those due to the effects of the evaluated starting operations. Furthermore, except for the evaluated starting operations in the San Joaquin River portion of the South Delta subregion, differences due to climate change were consistently negative while those due to the evaluated starting operations were positive or close to zero. There were no estimates of daily mean DO below 4.85 mg/L, an assumed threshold for increased stress for sturgeons.

## 5C.5.4.3.1 Cache Slough Subregion

The lowest DO concentration for the Cache Slough subregion under any of the BDCP scenarios is 7.8 mg/L, for both the existing biological conditions in the late long-term (EBC2_LLT) and the evaluated starting operations in the late long-term (ESO_LLT). This DO value exceeds the Basin Plan objectives for all areas of the Delta. Most of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-79). The two late long-term scenarios, EBC2_LLT and ESO_LLT, consistently show lower values for any given probability of exceedance than the other scenarios, whereas the evaluated starting operations in the early long-term (ESO_ELT) generally shows the highest value. The largest difference among all scenarios is about 0.8 mg/L.

Figure 5C.5.4-80 shows the daily DO concentrations in the Cache Slough subregion for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations are similar for all scenarios, with the lowest values occurring in late July (Figure 5C.5.4-80). The two late long-term scenarios, EBC2_LLT and ESO_LLT, exhibit the lowest mean DO values during most of the year. ESO_ELT shows the highest value during the majority of days. The greatest difference among all scenarios for any day is about 0.5 mg/L.

For the Cache Slough subregion, differences in the mean daily DO values resulting from climate change are greater than those resulting from the evaluated starting operations (Table 5C.5.4-6). The changes due to climate change for both the evaluated starting operations (from ESO_ELT to ESO_LLT) and existing biological conditions (from EBC2_ELT to EBC2_LLT) are greater than those due to the evaluated starting operations for both the early long-term (from EBC2_ELT to ESO_ELT) and the late long-term (from EBC2_LLT to ESO_LLT). Also, the changes due to the evaluated starting operations are positive, whereas those due to climate change are negative (Table 5C.5.4-6).

**Table 5C.5.4-6. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, Cache Slough**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.036 |
| From EBC2_LLT to ESO_LLT | 0.148 |
| From ESO_ELT to ESO_LLT | -0.180 |
| From EBC2_ELT to EBC2_LLT | -0.292 |

[a] See Table 5C.0-1 for definitions of scenarios.

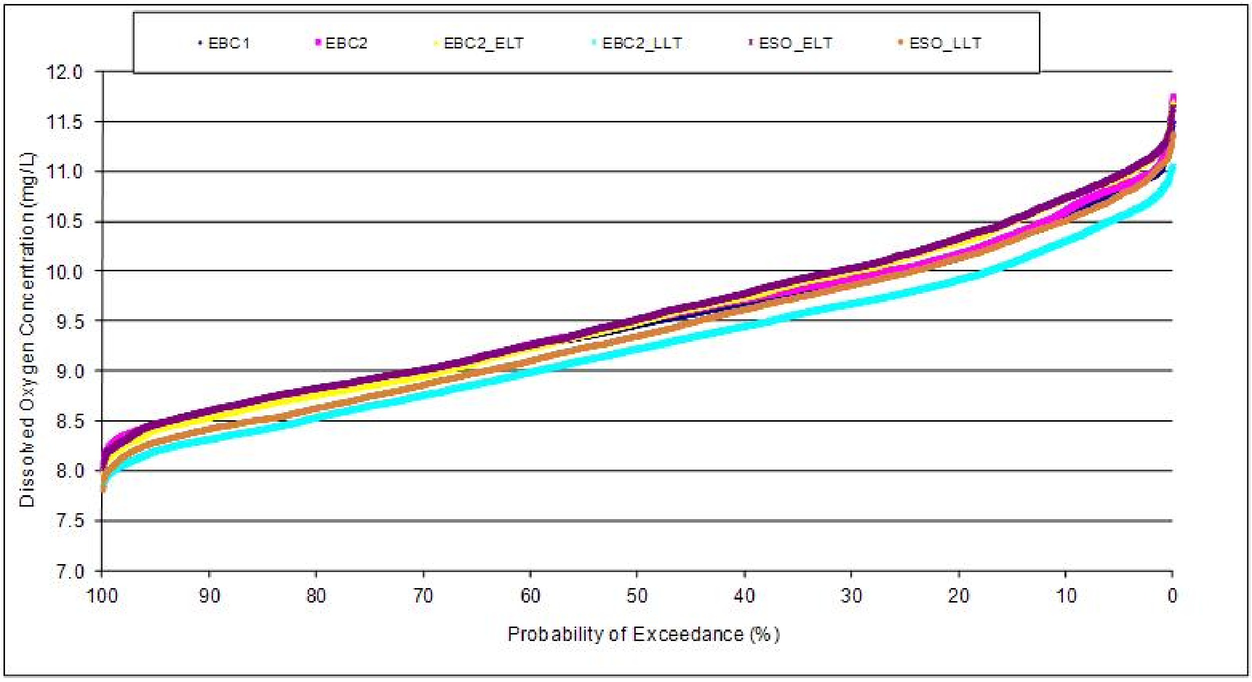



**Figure 5C.5.4-79. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Cache Slough**

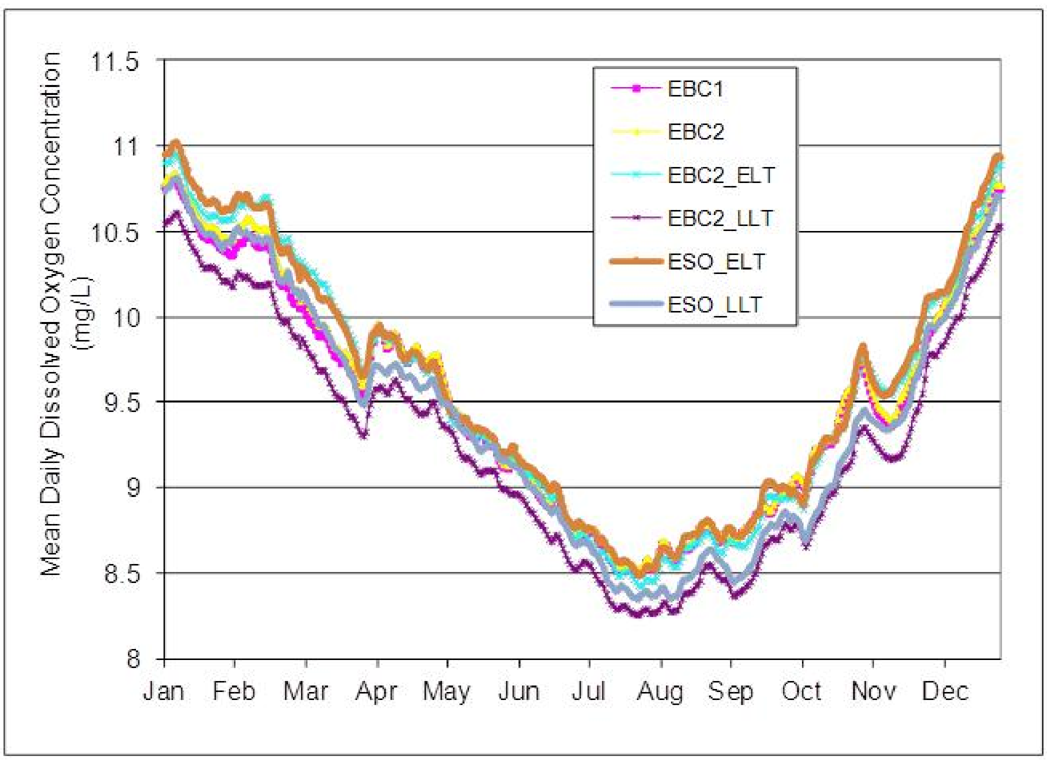



**Figure 5C.5.4-80. Mean Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Cache Slough**

#### 5C.5.4.3.2 North Delta Subregion

The lowest DO concentration for the North Delta subregion under any of the BDCP scenarios is 7.1 mg/L, for the existing biological conditions in the late long-term (EBC2_LLT). This DO value exceeds the Basin Plan objectives for all areas of the Delta. Most of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-81). The two late long-term scenarios, EBC2_LLT and ESO_LLT, consistently show lower values for any given probability of exceedance than the other scenarios, whereas there is essentially no difference among the other scenarios. The largest difference among all scenarios is only about 0.3 mg/L.

Figure 5C.5.4-82 shows the daily DO concentrations in the North Delta subregion for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations are similar for all scenarios, with the lowest values occurring in late August or early September (Figure 5C.5.4-82). The two late long-term scenarios, EBC2_LLT and ESO_LLT, exhibit the lowest mean DO values during most of the year. There is little difference among the other scenarios. The greatest difference among all scenarios for any day is about 0.4 mg/L.

For the North Delta subregion, differences in mean daily DO values resulting from climate change are greater than those resulting from the evaluated starting operations (Table 5C.5.4-7). The changes due to climate change for both the evaluated starting operations (from ESO_ELT to ESO_LLT) and existing biological conditions (from EBC2_ELT to EBC2_LLT) are greater than those due to the evaluated starting operations for both the early long-term (from EBC2_ELT to ESO_ELT) and the late long-term (from EBC2_LLT to ESO_LLT). The changes due to climate change are negative, whereas those due to the evaluated starting operations are close to zero (Table 5C.5.4-7).

**Table 5C.5.4-7. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, North Delta**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.005 |
| From EBC2_LLT to ESO_LLT | -0.005 |
| From ESO_ELT to ESO_LLT | -0.143 |
| From EBC2_ELT to EBC2_LLT | -0.133 |

[a] See Table 5C.0-1 for definitions of scenarios.

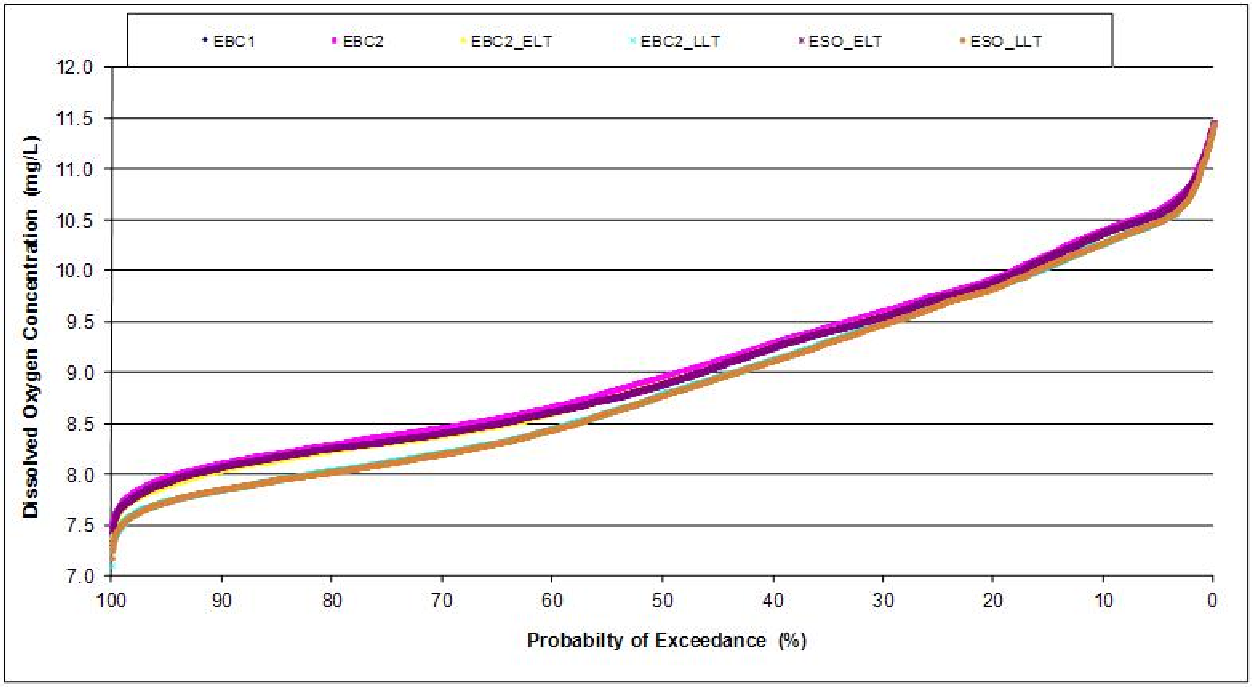



**Figure 5C.5.4-81. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, North Delta**

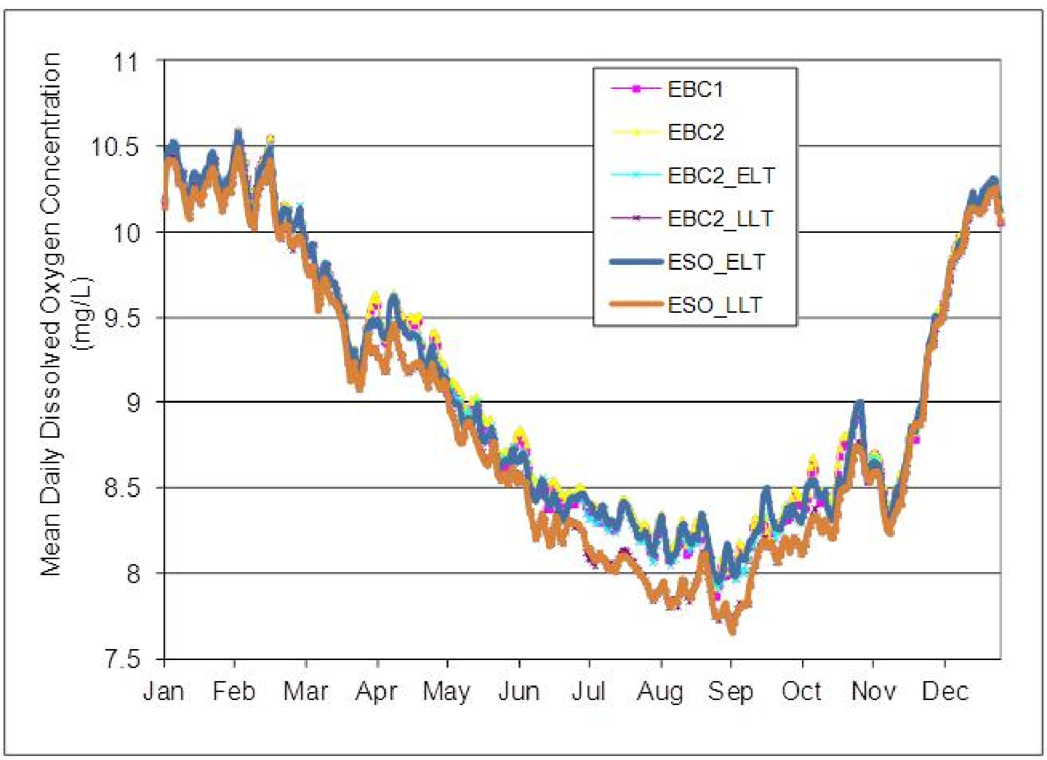



**Figure 5C.5.4-82. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, North Delta**

### 5C.5.4.3.3 East Delta Subregion

The lowest DO concentration for the East Delta subregion under any of the BDCP scenarios is 7.0 mg/L, for the existing biological conditions in the late long-term (EBC2_LLT). This DO value meets the Basin Plan objectives for all areas of the Delta. Most of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-83). EBC2_LLT consistently shows the lowest value for any given probability of exceedance, whereas the evaluated starting operations in the early long-term (ESO_ELT) consistently shows the highest value. The largest difference among all scenarios is about 0.8 mg/L.

Figure 5C.5.4-84shows the daily DO concentrations in the East Delta subregion for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations vary among scenarios, with the low values occurring from late July to early September for existing biological conditions in the late long-term (EBC2_LLT), in late August and early November for the other three existing biological conditions scenarios (EBC1, EBC2, and EBC2_ELT), from late July through early November for the evaluated starting operations in the late long-term (ESO_LLT), and in late July and early November for the evaluated starting operations in the early long-term (ESO_ELT) (Figure 5C.5.4-84). EBC2_LLT exhibits the lowest mean DO values during most of the year, whereas ESO_ELT has the highest value on most days. The greatest difference among all scenarios is about 0.9 mg/L between ESO_ELT and EBC2_LLT on September 5.

For the East Delta subregion, unlike most other regions, differences in mean daily DO values resulting from climate change are smaller than those resulting from the evaluated starting operations (Table 5C.5.4-8). The changes due to climate change for both the evaluated starting operations (from ESO_ELT to ESO_LLT) and existing biological conditions (from EBC2_ELT to EBC2_LLT) are smaller than those due to the evaluated starting operations for both the early long-term (from EBC2_ELT to ESO_ELT) and the late long-term (from EBC2_LLT to ESO_LLT). The changes due to climate change are negative and those due to the project are positive (Table 5C.5.4-8).

**Table 5C.5.4-8. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, East Delta**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.360 |
| From EBC2_LLT to ESO_LLT | 0.325 |
| From ESO_ELT to ESO_LLT | -0.106 |
| From EBC2_ELT to EBC2_LLT | -0.072 |

[a] See Table 5C.0-1 for definitions of scenarios.

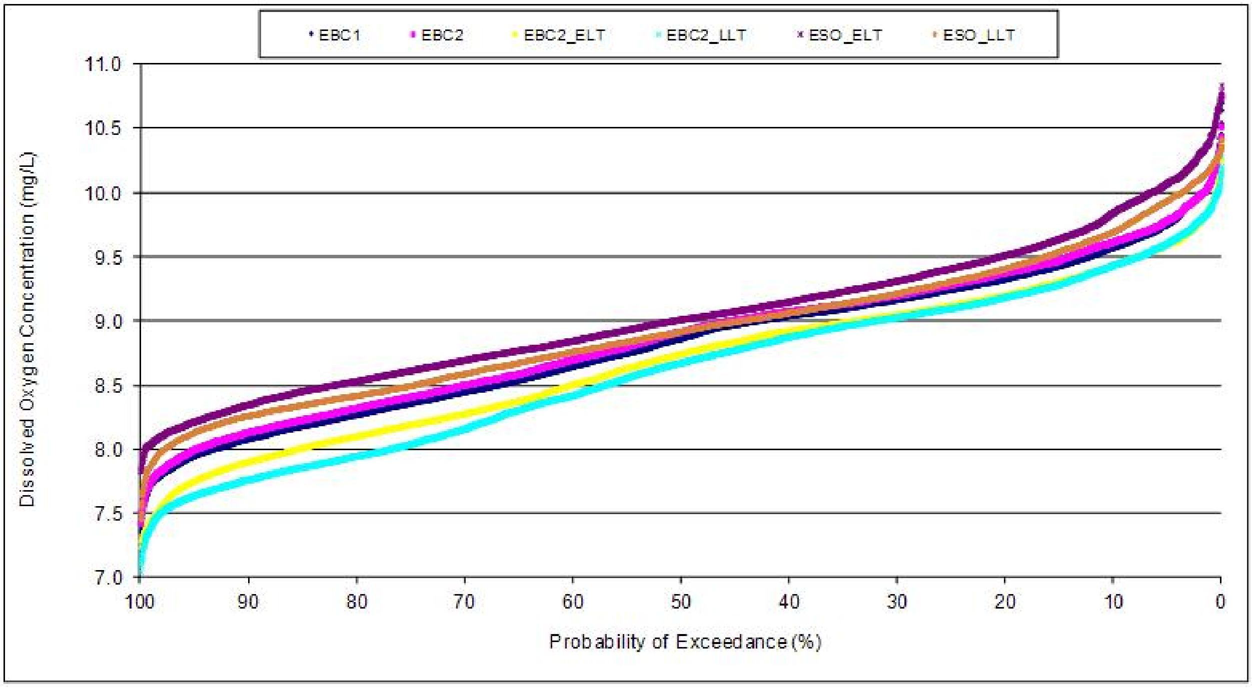



**Figure 5C.5.4-83. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, East Delta**

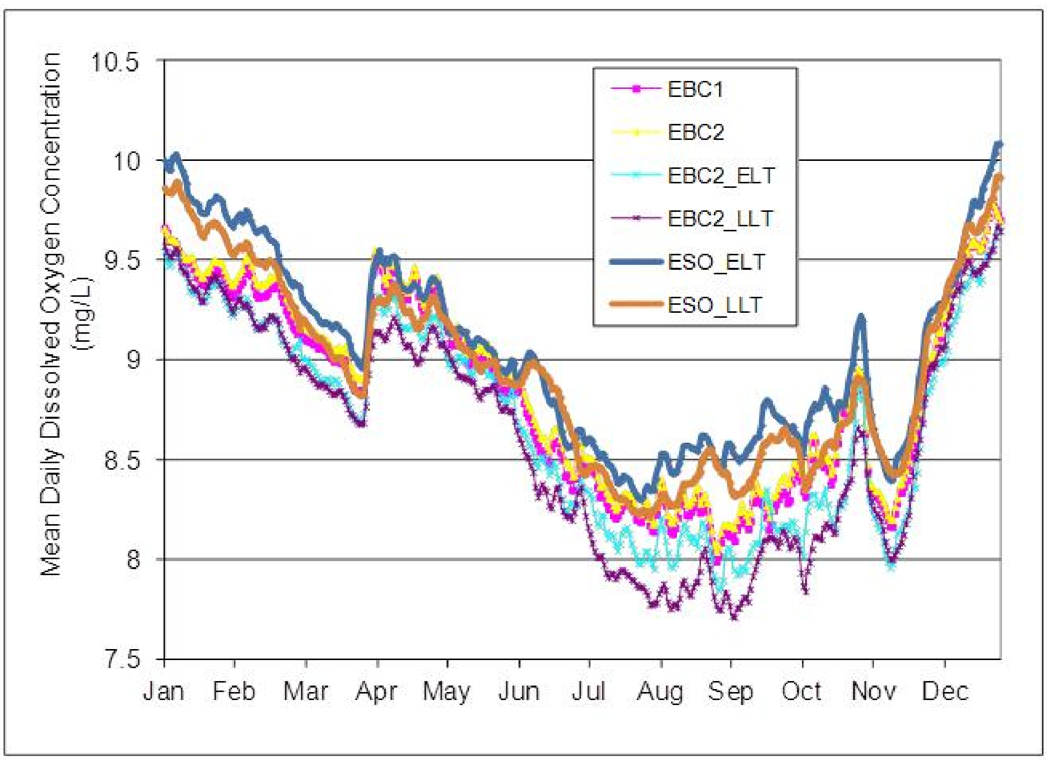



**Figure 5C.5.4-84. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, East Delta**

### 5C.5.4.3.4 South Delta Subregion

The lowest DO concentration for the South Delta subregion (exclusing the San Joaquin River, which is analyzed separately below) under any of the BDCP scenarios is 7.0 mg/L, for the existing biological conditions in the late long-term (EBC2_LLT). This DO value meets the Basin Plan objectives for all areas of the Delta. Most of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-85). EBC2_LLT consistently shows the lowest values for any given probability of exceedance, but the existing biological conditions in the early long-term (EBC2_ELT) generally shows similar or slightly higher values. The evaluated starting operations in the late long-term (ESO_LLT) generally shows the highest value, although differences among the four scenarios other than EBC2_LLT and EBC_ELT are small. The largest difference among all scenarios is about 0.5 mg/L.

Figure 5C.5.4-86shows the daily DO concentrations in the South Delta subregion for the BDCPscenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations vary among scenarios, with the lowest values occurring in November for all the existing biological conditions scenarios (EBC1, EBC2, EBC2_ELT, and EBC2_LLT), in late July for the evaluated starting operations in the early long-term (ESO_ELT), and in September for the evaluated starting operations in the late long-term (ESO_LLT) (Figure 5C.5.4-86). The existing biological conditions in the late long-term (EBC2_LLT) exhibits the lowest mean DO values during almost every day of the year. There is no consistent ranking among the other scenarios. The greatest difference among all scenarios for any day is about 0.7 mg/L.

For the South Delta subregion, results with regard to the relative effect of the evaluated starting operations and climate change on DO value were inconsistent (Table 5C.5.4-9). The largest difference between means, 0.286 mg/L, is between the existing biological conditions and the evaluated starting operations in the late long-term (from EBC2_LLT to ESO_LLT), while the second largest, -0.141 mg/L, is between the existing biological conditions and the evaluated starting operations in the early long-term (from EBC2_ELT to ESO_ELT). The other two changes are both closer to zero (Table 5C.5.4-9). The difference for the existing biological conditions between the early and late long-terms (from (EBC2_ELT to EBC2_LLT) is negative, while the differences for the other comparisons are positive (Table 5C.5.4-9).

**Table 5C.5.4-9. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, South Delta**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.141 |
| From EBC2_LLT to ESO_LLT | 0.286 |
| From ESO_ELT to ESO_ELT | 0.062 |
| From EBC2_ELT to EBC2_LLT | -0.083 |

[a] See Table 5C.0-1 for definitions of scenarios.

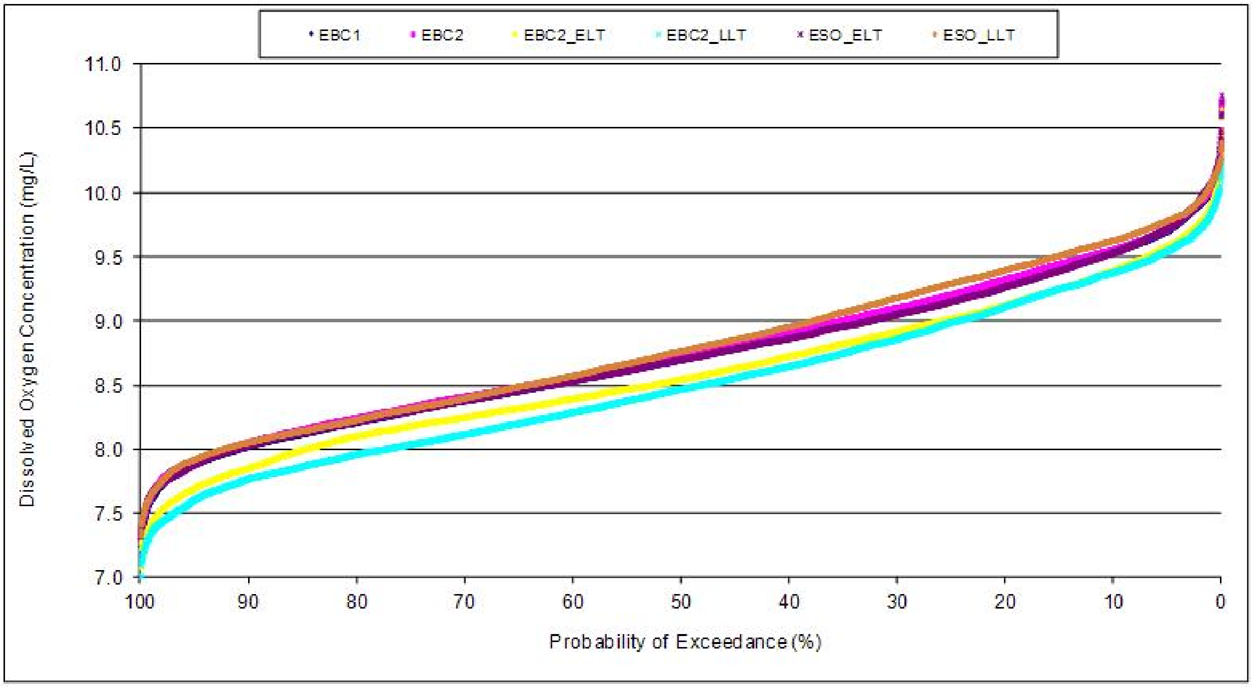



**Figure 5C.5.4-85. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, South Delta**

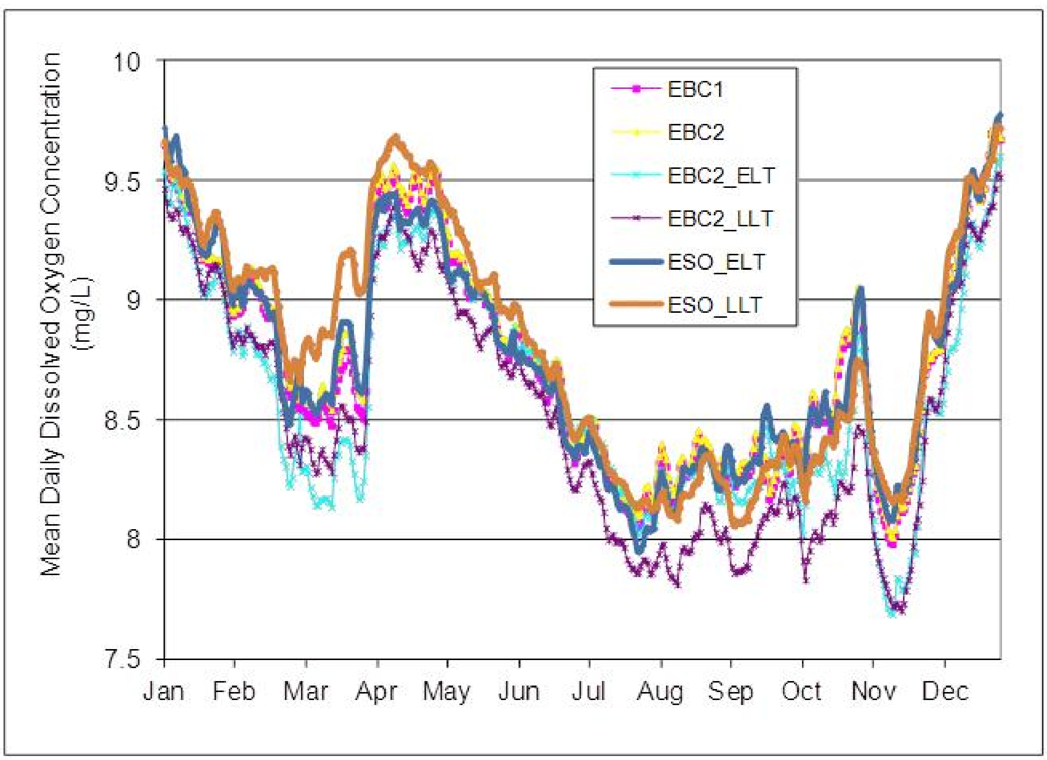



**Figure 5C.5.4-86. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, South Delta**

#### 5C.5.4.3.5 West Delta Subregion

The lowest DO concentration for the West Delta subregion under any of the BDCP scenarios is 7.4 mg/L, for the existing conditions in the late long-term (EBC2_LLT). This DO value exceeds the Basin Plan objectives for all areas of the Delta. Most of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-87). EBC2_LLT consistently shows the lowest values for any given probability of exceedance, and the evaluated starting operations in the late long-term (ESO_LLT) consistently shows the second-lowest values. The largest difference among all scenarios is only about 0.4 mg/L.

Figure 5C.5.4-88shows the daily DO concentrations in the West Delta subregion for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations are similar for all scenarios, with the lowest values occurring in late July for all of the scenarios, and also in early August and early September for the two late long-term scenarios (EBC2_LLT and ESO_LLT) (Figure 5C.5.4-88). EBC2_LLT exhibits the lowest mean DO values during the entire year. The greatest difference among all scenarios for any day is about 0.5 mg/L.

For the West Delta subregion, differences in mean daily DO values resulting from climate change (from EBC2_ELT to EBC2_LLT and from ESO_ELT to ESO_LLT) are greater than the difference resulting from the evaluated starting operations in the early long-term (from EBC2_ELT to ESO_ELT), but similar to the difference resulting from the evaluated starting operations in the late long-term (from EBC2_LLT to ESO_LLT) (Table 5C.5.4-10). The changes due to climate change are negative, whereas those due to the evaluated starting operations are positive (Table 5C.5.4-10).

**Table 5C.5.4-10. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, West Delta**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.038 |
| From EBC2_LLT to ESO_LLT | 0.134 |
| From ESO_ELT to ESO_LLT | -0.113 |
| From EBC2_ELT to EBC2_LLT | -0.208 |
| [a] See Table 5C.0-1 for definitions of scenarios. | |

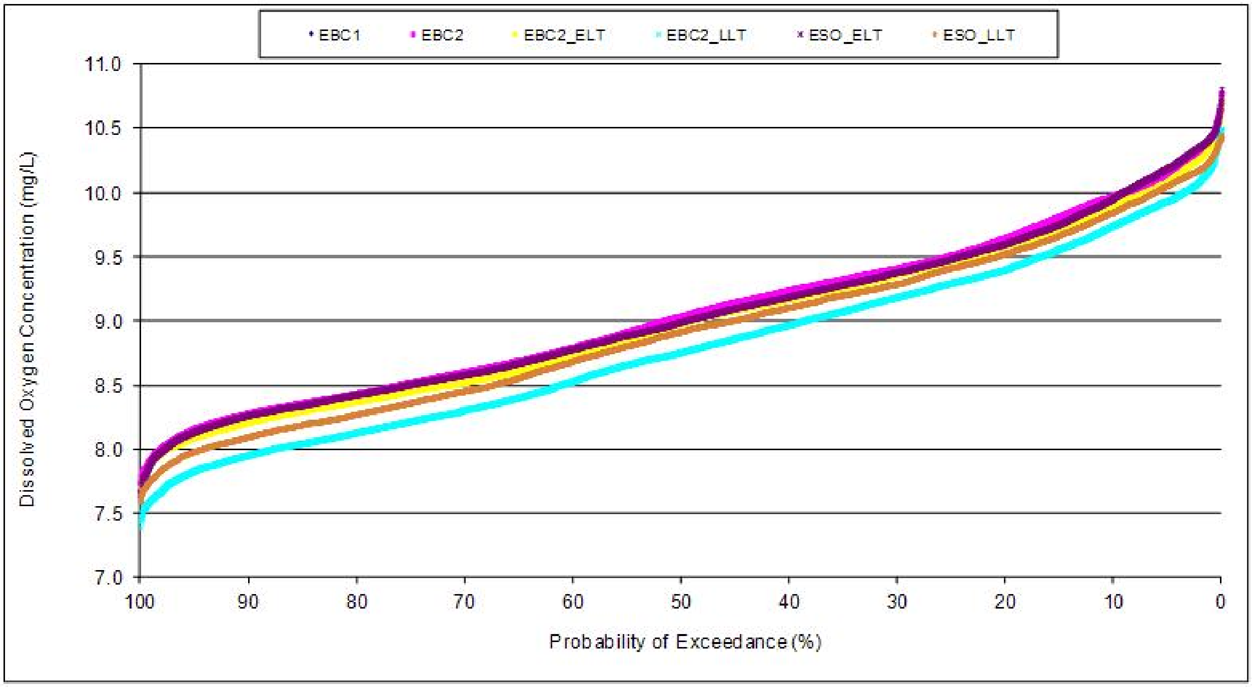



**Figure 5C.5.4-87. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, West Delta**

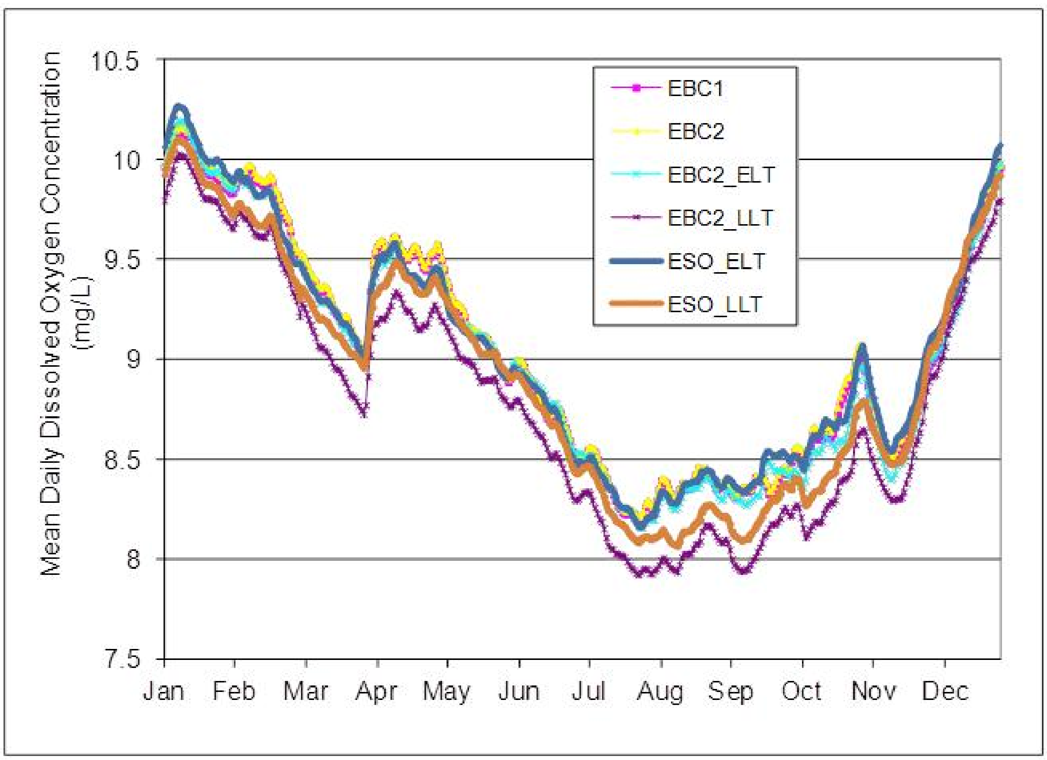



**Figure 5C.5.4-88. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, West Delta**

### 5C.5.4.3.6 Suisun Marsh Subregion

The lowest DO concentration for the Suisun Marsh subregion under any of the BDCP scenarios is 6.6 mg/L, for the existing biological conditions in the late long-term (EBC2_LLT). This DO value falls below the Basin Plan objective of 7.0 mg/L for all waters of the Delta west of the Antioch Bridge. The existing biological conditions in the early long-term scenario (EBC2_ELT) also has several DO values below 7.0 mg/L, but for both scenarios 99.8% of the DO values are greater than 7.0 mg/L. The majority of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-89). EBC2_LLT consistently shows the lowest values for any given probability of exceedance. The largest difference among all scenarios is about 0.6 mg/L.

Figure 5C.5.4-90shows the daily DO concentrations in Suisun Marsh for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations varied among the scenarios. The lowest values for both existing biological conditions in the near-term scenarios (EBC1 and EBC2) and both late long-term scenarios (EBC2_LLT and ESO_LLT) fall in September, while the lowest values for both early long-term scenarios (EBC2_ELT and ESO_ELT) occur in late July (Figure 5C.5.4-90). EBC2_LLT exhibits the lowest mean DO values during most of the year. All of the scenarios show a rapid drop and recovery in DO concentration during March, although the DO values remain above 8.0 mg/L. The greatest difference among all scenarios for any day, about 0.95 mg/L, occurs during this month.

For Suisun Marsh, differences in mean daily DO values resulting from climate change are similar in magnitude to those resulting from the evaluated starting operations (Table 5C.5.4-11). However, the changes due to climate change (from ESO_ELT to ESO_LLT and from EBC2_ELT to EBC2_LLT) are negative, while those due to the evaluated starting operations are positive (from EBC2_ELT to ESO_ELT and from EBC2_LLT to ESO_LLT).

**Table 5C.5.4-11. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, Suisun Marsh**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.110 |
| From EBC2_LLT to ESO_LLT | 0.175 |
| From ESO_ELT to ESO_LLT | -0.103 |
| From EBC2_ELT to EBC2_LLT | -0.168 |

[a] See Table 5C.0-1 for definitions of scenarios.

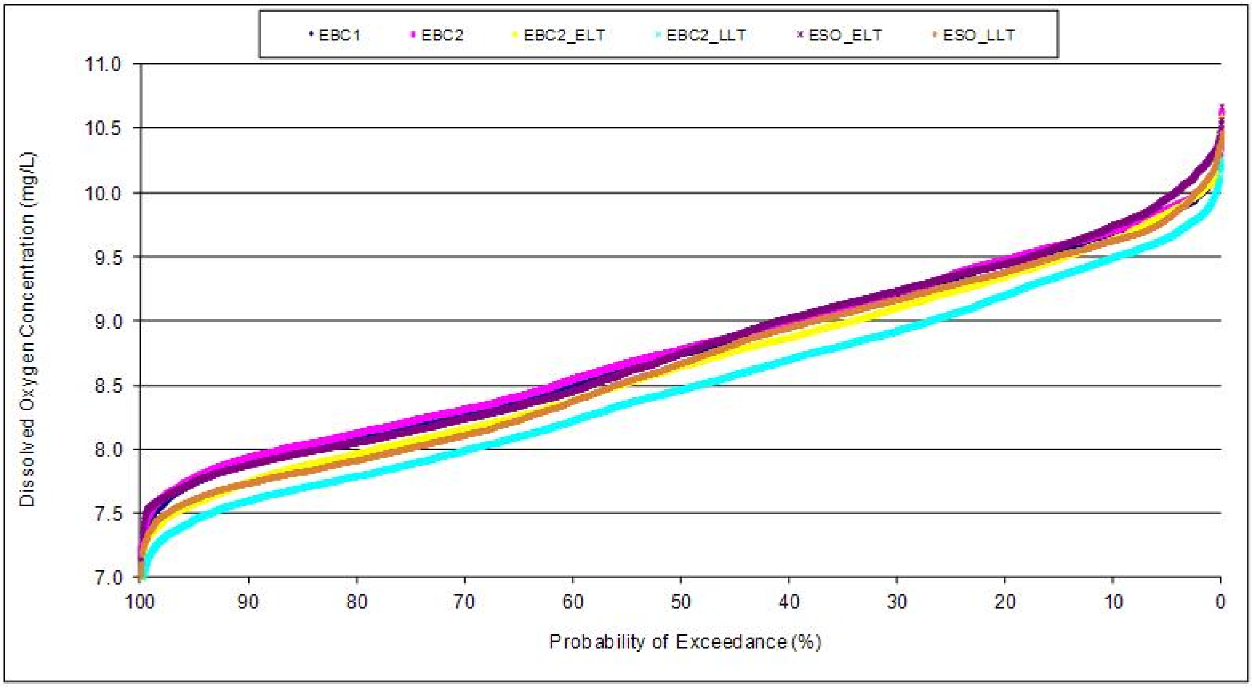



Figure 5C.5.4-89. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Suisun Marsh

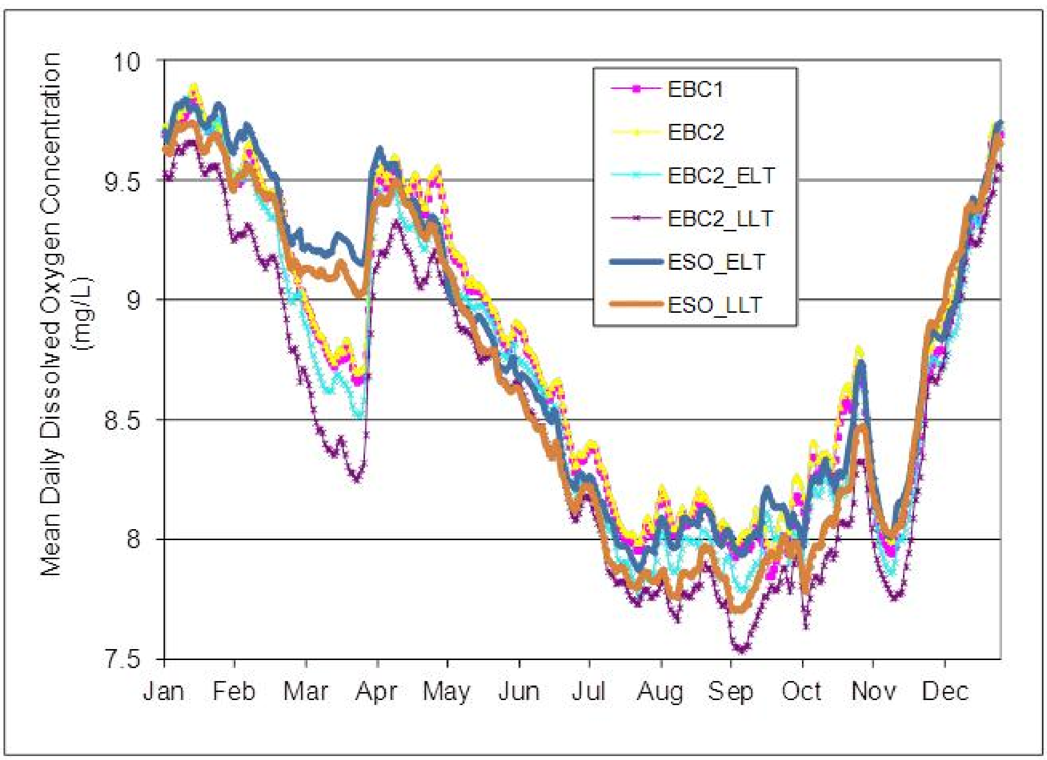



Figure 5C.5.4-90. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Suisun Marsh

### 5C.5.4.3.7 Suisun Bay Subregion

The lowest DO concentration for the Suisun Bay subregion under any of the BDCP scenarios is 7.3 mg/L, for the existing biological conditions in the both the early and the late long-term (EBC2_ELT and EBC2_LLT) and the evaluated starting operations in the early long-term (ESO_ELT). This DO value exceeds the Basin Plan objectives of 7.0 mg/L for all waters of the Delta west of the Antioch Bridge. The majority of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-91). EBC2_LLT consistently shows the lowest values for any given probability of exceedance, although there is little difference among the scenarios (<0.3 mg/L).

Figure 5C.5.4-92 shows the daily DO concentrations in Suisun Bay for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations are similar for all scenarios, with the lowest values occurring in late July through early September for all of the scenarios (Figure 5C.5.4-92). EBC2_LLT and ESO_LLT exhibit the lowest mean DO values during most of the year. The greatest difference among all scenarios for any day is only about 0.3 mg/L.

For Suisun Bay, differences in mean daily DO values resulting from climate change are greater than those resulting from the evaluated starting operations, although all of the changes are small (Table 5C.5.4-12). The changes due to climate change are negative and those due to the preliminary proposal are positive, although close to zero (Table 5C.5.4-12).

**Table 5C.5.4-12. Mean Changes between Scenarios[a] in Dissolved Oxygen Concentrations, Suisun Bay**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT | 0.037 |
| From EBC2_LLT to ESO_LLT | 0.048 |
| From ESO_ELT to ESO_LLT | -0.062 |
| From EBC2_ELT to EBC2_LLT | -0.073 |

[a] See Table 5C.0-1 for definitions of scenarios.

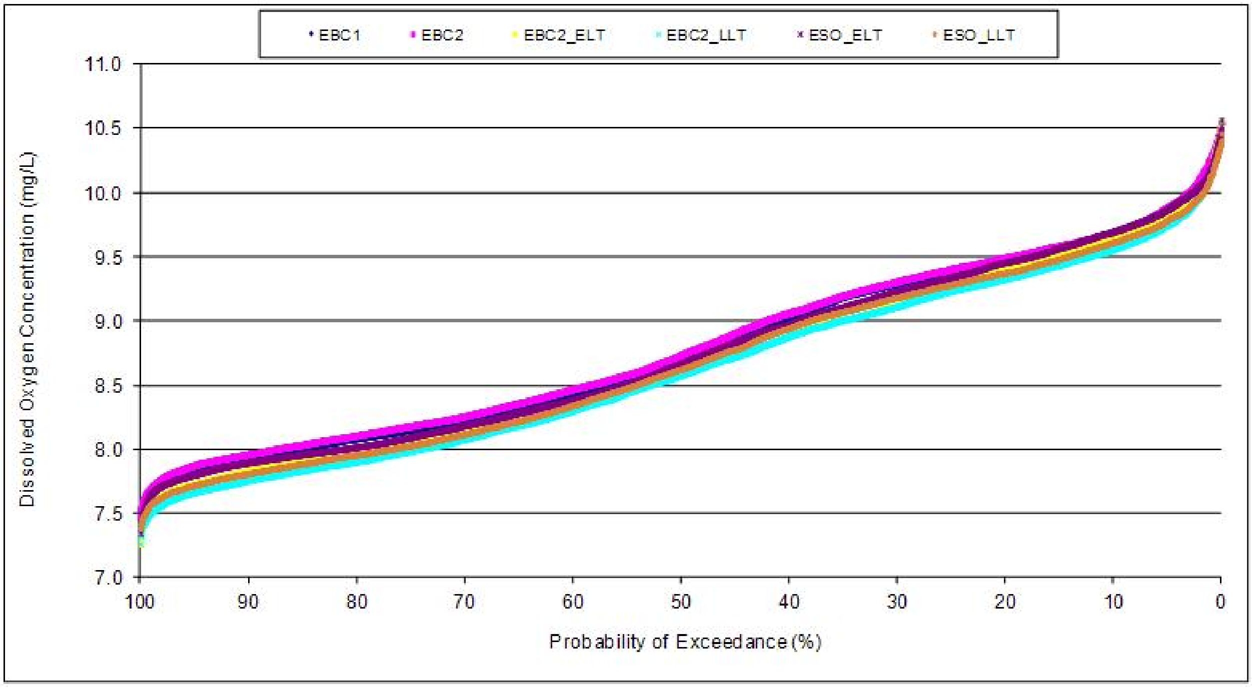



**Figure 5C.5.4-91. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Suisun Bay**

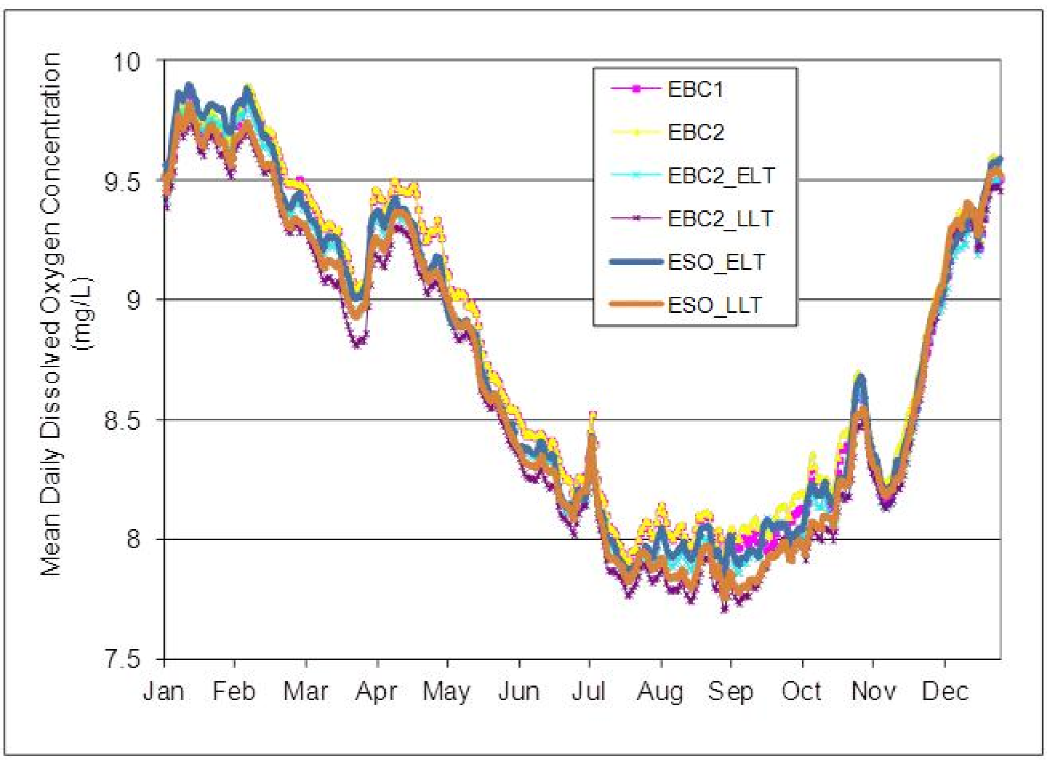



**Figure 5C.5.4-92. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, Suisun Bay**

### 5C.5.4.3.8 San Joaquin River

The lowest DO concentration for the San Joaquin River portion of the South Delta subregion under any of the BDCP scenarios is 6.8 mg/L, for the evaluated starting operations in the early long-term (ESO_ELT). This DO value exceeds the Basin Plan objectives of 6.0 mg/L for the San Joaquin River (between Turner Cut and Stockton from September 1 through November 30) and 5.0 mg/L for all Delta waters other than the Sacramento River and the Delta west of the Antioch Bridge. The majority of the DO values for all the scenarios are above 8 mg/L (Figure 5C.5.4-93). EBC2_LLT shows the lowest DO values for all probability of exceedances, except for the lowest 2% of the values, for which ESO_ELT has the lowest values. The largest difference among all scenarios is about 0.5 mg/L.

Figure 5C.5.4-94shows the daily DO concentrations in the San Joaquin River region for the BDCP scenarios, averaged by day of the month over the 16-year period of simulation. Seasonal variations in the mean daily DO concentrations varied among the scenarios. The lowest values for both existing biological conditions in the near-term scenarios (EBC1 and EBC2) fall in August and September, the lowest for the evaluated starting operations in the early long-term (ESO_ELT) fall in November, the lowest for the evaluated starting operations in the late long-term (ESO_LLT) occur in late July and early August, and the lowest values for the existing biological conditions in both the early long-term and late long-term (EBC2_ELT and EBC2_LLT) are in August (Figure 5C.5.4-94). EBC2_LLT and ESO_ELT exhibit the lowest mean DO values during most of the year. All of the scenarios show a rapid drop in DO concentration from late February to early March, followed by a sharp recovery in late March, although the DO values remain above 8.0 mg/L. The greatest difference among all scenarios for any day, about 0.7 mg/L, occurs during December.

For the San Joaquin River Region, results with regard to the relative effect of the evaluated starting operations and climate change on changes in DO value were inconsistent (Table 5C.5.4-13). The largest difference between means, 0.283 mg/L, is between the existing biological conditions and the evaluated starting operations in the late long-term (from EBC2_LLT to ESO_LLT). The second largest difference, 0.194 mg/L, is between the evaluated starting operations in the early and late long-terms (from ESO_ELT to ESO_LLT). This difference was the only positive change due to climate change found in this analysis of BDCP effects on DO (see Table 5C.5.4-6 through Table 5C.5.4-13). The other San Joaquin River difference due to climate change, from the existing biological conditions in the early long-term to the late long-term (from EBC2_ELT to EBC2_LLT), was -0.012.

**Table 5C.5.4-13. Mean Changes between Scenarios in Dissolved Oxygen Concentrations, San Joaquin River**

| Change | Difference (mg/L) |
|---|---|
| From EBC2_ELT to ESO_ELT[a] | 0.078 |
| From EBC2_LLT to ESO_LLT | 0.283 |
| From ESO_ELT to ESO_LLT | 0.194 |
| From EBC2_ELT to EBC2_LLT | -0.012 |
| [a] See Table 5C.0-1 for definitions of scenarios. | |

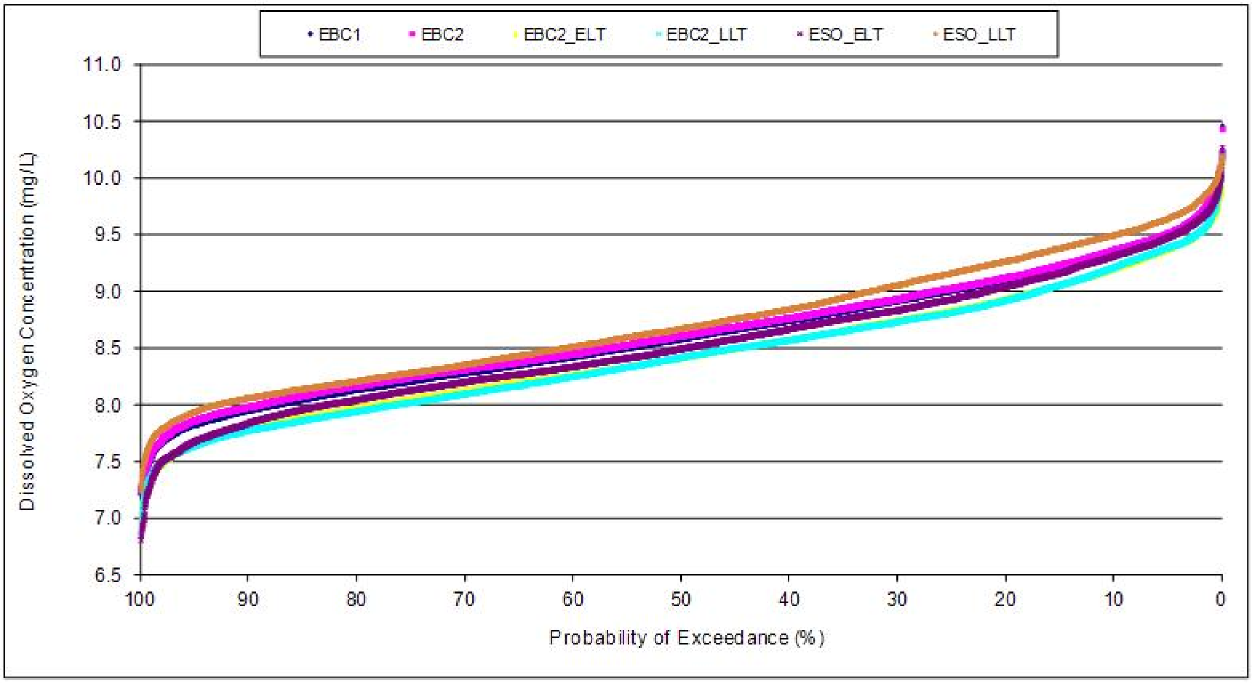



**Figure 5C.5.4-93. Probability of Exceedances of Daily Dissolved Oxygen Concentrations for EBC and ESO Scenarios, San Joaquin River**

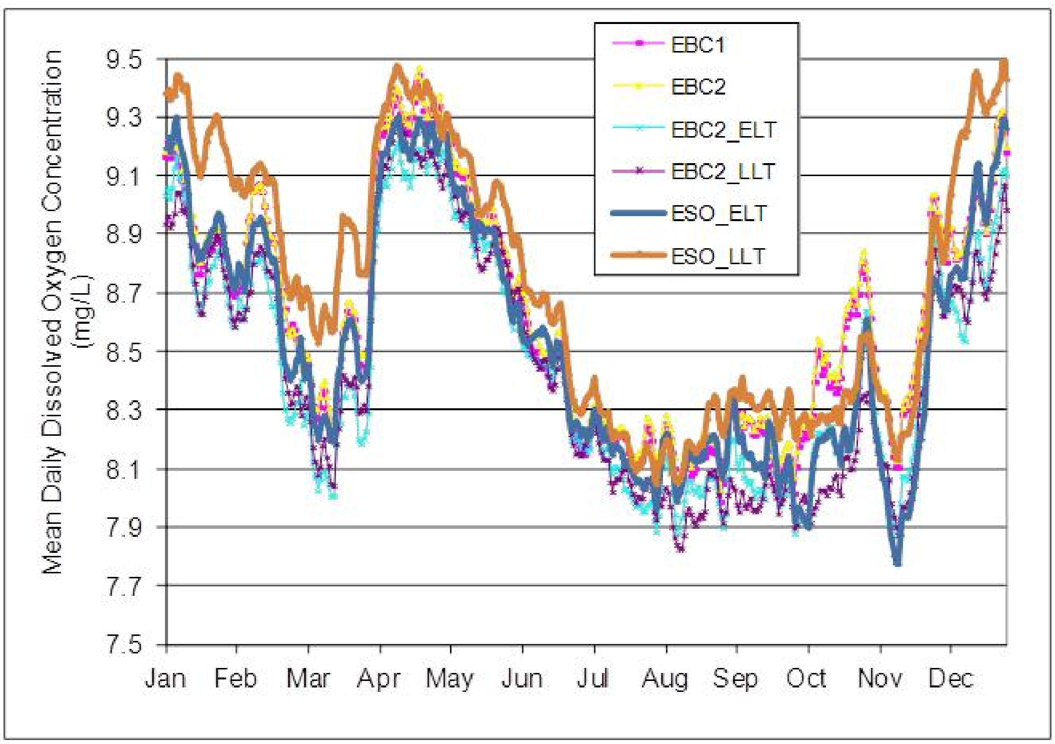



**Figure 5C.5.4-94. Daily Average Dissolved Oxygen Concentrations for EBC and ESO Scenarios, San Joaquin River**

# 5C.5.4.4 Residence Time (DSM2-PTM)

## 5C.5.4.4.1 EBC vs. ESO Scenarios

Residence time potentially affects several ecologically important factors in the Delta, including foodweb productivity and water quality (see Chapter 5, Section 5.3.3.2.2, *Residence Time*). The effects of the evaluated starting operations on the residence time of water flowing through different subregions of the Plan Area in different seasons was estimated using DSM2-PTM results. Table 5C.5.4-14 shows for EBC and ESO scenarios the average residence times for particles starting within different subregions of the Plan Area for each of the four seasons and the full year (all seasons combined). The residence time is defined as the time by which 50% of the simulated particles at a given starting location have left the Plan Area (by exiting the west end at Martinez, CVP/SWP exports, or agricultural diversions). Residence times vary widely with hydrologic conditions because of the strong association of residence time with flow rates and south Delta exports. The residence times given in the table are the averages of the modeling results for several different starting locations within each Plan Area subregion using hydrological conditions from several different months and years. Caution should be used in interpreting the model results because, while the year and month periods used for DSM2 simulation are generally representative of most hydrologic conditions, they do not represent the entire hydrologic history of the Plan Area. For example, based on the entire 82-year period of hydrologic data, the DSM2 hydrologic period does not include the most extreme scenarios in terms of river flows.

Seasonal patterns of average residence times differ greatly for the different subregions of the Plan Area (Table 5C.5.4-14). The longest residence times for the North Delta, Cache Slough, and the West Delta subregions occur during the summer/fall, with these patterns generally being consistent across scenarios. The longest residence times for the East Delta subregion occur during spring, although fall residence times are appreciably greater under ESO scenarios than under EBC scenarios (and are similar to spring residence times). In the Suisun Marsh subregion, residence times are greatest for summer and spring under the EBC scenarios, whereas residence time under the ESO scenarios has less seasonal variability. For the South Delta subregion, the longest residence times occur during the spring for all the EBC2 scenarios, but occur during the fall for the two ESO scenarios. The shortest residence times in the South Delta subregion are in the winter and summer for the ESO scenarios.

The ESO scenarios generally are estimated to result in similar or longer average residence time than EBC2 scenarios for all subregions of the Plan Area during all seasons of the year. This pattern results from several factors under the ESO compared to EBC scenarios: generally less Sacramento River flow (because of the north Delta intakes), more habitat area (causing particles to spread out and give longer residence time), and less south Delta pumping. The main exceptions to the general pattern were for the Suisun Marsh subregion, wherein average residence time in spring and summer was less under ESO scenarios than under EBC scenarios in the LLT (Table 5C.5.4-14 and Table 5C.5.4-15). The largest differences in residence time, both in number of days and percent change, are in the Cache Slough subregion during summer (18–22 days/~90–110% greater in the ELT and LLT), in the South Delta subregion in the fall (23–27 days/~270–290% greater in the ELT and LLT), and in Suisun Marsh during the winter and fall (15–31 days/~80–350% greater in the ELT and LLT). Differences in spring residence time between ESO and EBC scenarios generally were quite low, except for Cache Slough (12–15 days/~65–80% greater in the ELT and LLT) and Suisun Marsh (21 days/40% less in the LLT).

**Table 5C.5.4-14. Average Residence Time (Number of Days[a] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Plan Area under EBC and ESO Scenarios**

| | | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|---|
| **Subregion** | **Season** | **EBC1** | **EBC2** | **EBC2_ELT** | **EBC2_LLT** | **ESO_ELT** | **ESO_LLT** |
| North Delta | Winter (Dec–Feb) | 35 | 35 | 36 | 37 | 37 | 38 |
| | Spring (Mar–May) | 30 | 30 | 31 | 32 | 32 | 34 |
| | Summer (Jun–Aug) | 32 | 33 | 36 | 37 | 37 | 38 |
| | Fall (Sep–Nov) | 48 | 48 | 49 | 49 | 54 | 56 |
| | All months | 35 | 35 | 36 | 37 | 38 | 39 |
| Cache Slough | Winter (Dec–Feb) | 23 | 25 | 25 | 26 | 33 | 31 |
| | Spring (Mar–May) | 17 | 17 | 18 | 19 | 32 | 31 |
| | Summer (Jun–Aug) | 18 | 18 | 19 | 20 | 41 | 38 |
| | Fall (Sep–Nov) | 28 | 30 | 30 | 29 | 43 | 38 |
| | All months | 21 | 22 | 22 | 23 | 36 | 34 |
| West Delta | Winter (Dec–Feb) | 18 | 18 | 19 | 20 | 20 | 20 |
| | Spring (Mar–May) | 18 | 18 | 18 | 19 | 20 | 21 |
| | Summer (Jun–Aug) | 21 | 22 | 25 | 23 | 26 | 27 |
| | Fall (Sep–Nov) | 25 | 25 | 25 | 27 | 28 | 30 |
| | All months | 20 | 20 | 21 | 22 | 23 | 24 |
| East Delta | Winter (Dec–Feb) | 26 | 26 | 28 | 30 | 34 | 38 |
| | Spring (Mar–May) | 38 | 37 | 39 | 41 | 44 | 47 |
| | Summer (Jun–Aug) | 20 | 22 | 26 | 24 | 28 | 30 |
| | Fall (Sep–Nov) | 15 | 27 | 28 | 32 | 41 | 45 |
| | All months | 27 | 29 | 31 | 33 | 37 | 40 |
| South Delta | Winter (Dec–Feb) | 9 | 9 | 10 | 10 | 11 | 15 |
| | Spring (Mar–May) | 23 | 22 | 23 | 24 | 22 | 24 |
| | Summer (Jun–Aug) | 7 | 8 | 9 | 9 | 12 | 13 |
| | Fall (Sep–Nov) | 5 | 8 | 8 | 10 | 30 | 37 |
| | All months | 13 | 13 | 14 | 14 | 18 | 21 |
| Suisun Marsh | Winter (Dec–Feb) | 9 | 9 | 9 | 9 | 40 | 27 |
| | Spring (Mar–May) | 45 | 45 | 49 | 51 | 45 | 30 |
| | Summer (Jun–Aug) | 51 | 52 | 54 | 58 | 58 | 35 |
| | Fall (Sep–Nov) | 17 | 18 | 19 | 19 | 49 | 34 |
| | All months | 33 | 33 | 35 | 37 | 48 | 31 |

[a] Data rounded to whole days.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-15. Differences[a] between EBC and ESO Scenarios in Average Residence Time (Number of Days[b] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Delta**

| Subregion | Season | Scenario[c] EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
|---|---|---|---|---|---|---|---|
| North Delta | Winter (Dec–Feb) | 2 (5%)[b] | 3 (8%) | 2 (6%) | 3 (9%) | 1 (3%) | 1 (4%) |
| | Spring (Mar–May) | 2 (7%) | 4 (14%) | 2 (6%) | 4 (13%) | 1 (4%) | 2 (5%) |
| | Summer (Jun–Aug) | 5 (17%) | 6 (19%) | 4 (11%) | 4 (12%) | 1 (1%) | 1 (3%) |
| | Fall (Sep–Nov) | 6 (12%) | 8 (16%) | 6 (13%) | 8 (17%) | 5 (11%) | 6 (13%) |
| | All months | 4 (10%) | 5 (14%) | 3 (9%) | 4 (13%) | 2 (5%) | 2 (6%) |
| Cache Slough | Winter (Dec–Feb) | 10 (44%) | 8 (36%) | 9 (35%) | 7 (27%) | 8 (33%) | 6 (22%) |
| | Spring (Mar–May) | 15 (88%) | 14 (83%) | 15 (88%) | 14 (82%) | 15 (82%) | 12 (66%) |
| | Summer (Jun–Aug) | 23 (132%) | 20 (116%) | 23 (122%) | 20 (107%) | 22 (111%) | 18 (87%) |
| | Fall (Sep–Nov) | 14 (50%) | 10 (34%) | 12 (40%) | 8 (25%) | 12 (40%) | 9 (32%) |
| | All months | 16 (77%) | 13 (66%) | 15 (69%) | 13 (58%) | 14 (65%) | 11 (51%) |
| West Delta | Winter (Dec–Feb) | 1 (7%) | 2 (11%) | 2 (8%) | 2 (12%) | 1 (4%) | 1 (3%) |
| | Spring (Mar–May) | 2 (13%) | 4 (22%) | 2 (12%) | 4 (21%) | 2 (8%) | 2 (11%) |
| | Summer (Jun–Aug) | 5 (25%) | 6 (27%) | 4 (19%) | 5 (20%) | 2 (8%) | 3 (14%) |
| | Fall (Sep–Nov) | 3 (14%) | 5 (21%) | 3 (13%) | 5 (21%) | 3 (11%) | 3 (11%) |
| | All months | 3 (15%) | 4 (20%) | 3 (13%) | 4 (19%) | 2 (8%) | 2 (10%) |
| East Delta | Winter (Dec–Feb) | 8 (29%) | 12 (46%) | 8 (30%) | 12 (47%) | 6 (22%) | 8 (28%) |
| | Spring (Mar–May) | 6 (16%) | 10 (26%) | 6 (17%) | 10 (27%) | 5 (13%) | 6 (15%) |
| | Summer (Jun–Aug) | 8 (39%) | 10 (49%) | 7 (31%) | 9 (40%) | 2 (9%) | 6 (26%) |
| | Fall (Sep–Nov) | 27 (179%) | 30 (203%) | 14 (54%) | 18 (67%) | 14 (50%) | 13 (39%) |
| | All months | 10 (39%) | 14 (52%) | 8 (28%) | 12 (40%) | 6 (20%) | 8 (24%) |
| South Delta | Winter (Dec–Feb) | 2 (22%) | 5 (57%) | 2 (24%) | 6 (60%) | 2 (20%) | 5 (48%) |
| | Spring (Mar–May) | 0 (-2%) | 2 (7%) | 0 (0%) | 2 (9%) | 0 (-2%) | 0 (1%) |
| | Summer (Jun–Aug) | 5 (71%) | 6 (84%) | 5 (62%) | 6 (74%) | 3 (34%) | 4 (51%) |
| | Fall (Sep–Nov) | 26 (534%) | 32 (662%) | 22 (271%) | 28 (346%) | 23 (287%) | 27 (274%) |
| | All months | 6 (47%) | 9 (69%) | 5 (42%) | 8 (63%) | 5 (36%) | 7 (48%) |
| Suisun Marsh | Winter (Dec–Feb) | 31 (336%) | 18 (192%) | 31 (331%) | 18 (188%) | 31 (348%) | 18 (205%) |
| | Spring (Mar–May) | 0 (1%) | -15 (-32%) | 0 (0%) | -15 (-33%) | -4 (-8%) | -21 (-40%) |
| | Summer (Jun–Aug) | 7 (13%) | -16 (-31%) | 6 (12%) | -16 (-32%) | 4 (7%) | -23 (-39%) |
| | Fall (Sep–Nov) | 33 (198%) | 17 (104%) | 31 (172%) | 16 (87%) | 31 (163%) | 15 (80%) |
| | All months | 15 (46%) | -2 (-5%) | 14 (43%) | -2 (-6%) | 13 (36%) | -6 (-15%) |

[a] Positive values indicates greater residence time under ESO than under EBC.
[b] Days and percentages are rounded to whole numbers, but percentages are calculated with unrounded data for improved accuracy.
[c] See Table 5C.0-1 for definitions of scenarios.

Of relevance to consideration of changes in residence time is the ultimate fate of particles (e.g., entrainment versus downstream movement). The fate of particles during the simulation periods used for the residence time analyses generally suggested that similar or lower percentages of particles were entrained under the ESO scenarios than under the EBC scenarios, both for 30-day (Table 5C.5.4-16 and Table 5C.5.4-17) and 60-day (Table 5C.5.4-18 and Table 5C.5.4-19) fates.

Specific results differed by season and subregion. For example, for 30-day fate, differences between scenarios ranged from around 1–3% (6–>50% relative difference) more spring (March–May) North Delta subregion entrainment under ESO_ELT and ESO_LLT scenarios compared with EBC2_ELT and EBC2_LLT scenarios, to 26–29% (44–50% relative difference) less Cache Slough summer entrainment ESO_ELT and ESO_LLT scenarios compared with EBC2_ELT and EBC2_LLT scenarios (Table 5C.5.4-17). Note that Suisun Marsh data were not analyzed for this comparison because very few particles from this subregion are entrained at any of the water diversions modeled in DSM2-PTM (i.e., south and north Delta export facilities, in-Delta agriculture, and North Bay Aqueduct).

**Table 5C.5.4-16. Average Percentage of Particles Entrained after 30 Days from Different Subregions of the Plan Area under EBC and ESO Scenarios, Using Same Data as for Residence Time Analysis**

| | | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|---|
| **Subregion** | **Season** | **EBC1** | **EBC2** | **EBC2_ELT** | **EBC2_LLT** | **ESO_ELT** | **ESO_LLT** |
| North Delta | Winter (Dec–Feb) | 11[a] | 10 | 8 | 7 | 6 | 4 |
| | Spring (Mar–May) | 6 | 6 | 5 | 5 | 8 | 8 |
| | Summer (Jun–Aug) | 25 | 24 | 21 | 21 | 24 | 22 |
| | Fall (Sep–Nov) | 23 | 10 | 9 | 7 | 7 | 6 |
| | All months | 15 | 12 | 10 | 10 | 11 | 11 |
| Cache Slough | Winter (Dec–Feb) | 38 | 36 | 36 | 35 | 13 | 17 |
| | Spring (Mar–May) | 47 | 46 | 46 | 45 | 21 | 24 |
| | Summer (Jun–Aug) | 61 | 60 | 59 | 58 | 30 | 33 |
| | Fall (Sep–Nov) | 45 | 33 | 32 | 40 | 16 | 24 |
| | All months | 48 | 45 | 44 | 45 | 20 | 24 |
| West Delta | Winter (Dec–Feb) | 18 | 18 | 15 | 13 | 11 | 9 |
| | Spring (Mar–May) | 4 | 4 | 3 | 3 | 3 | 3 |
| | Summer (Jun–Aug) | 23 | 20 | 16 | 18 | 16 | 17 |
| | Fall (Sep–Nov) | 31 | 14 | 13 | 10 | 4 | 4 |
| | All months | 17 | 13 | 11 | 10 | 8 | 8 |
| East Delta | Winter (Dec–Feb) | 43 | 42 | 38 | 32 | 28 | 22 |
| | Spring (Mar–May) | 12 | 12 | 10 | 9 | 9 | 9 |
| | Summer (Jun–Aug) | 66 | 61 | 53 | 58 | 45 | 45 |
| | Fall (Sep–Nov) | 82 | 45 | 45 | 33 | 12 | 13 |
| | All months | 45 | 37 | 34 | 31 | 23 | 22 |
| South Delta | Winter (Dec–Feb) | 82 | 82 | 81 | 79 | 78 | 69 |
| | Spring (Mar–May) | 45 | 44 | 43 | 42 | 47 | 45 |
| | Summer (Jun–Aug) | 89 | 87 | 83 | 84 | 76 | 76 |
| | Fall (Sep–Nov) | 97 | 88 | 89 | 82 | 29 | 24 |
| | All months | 74 | 72 | 70 | 69 | 59 | 55 |

[a] Data rounded to whole percentages.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-17. Differences[a] between EBC and ESO scenarios in Average Percentage of Particles Entrained after 30 Days from Different Subregions of the Plan Area, Using Same Data as for Residence Time Analysis**

| Subregion | Season | Scenario[c] | | | | | |
|---|---|---|---|---|---|---|---|
| | | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| North Delta | Winter (Dec–Feb) | -4 (-41%)[b] | -6 (-58%) | -4 (-38%) | -6 (-56%) | -2 (-21%) | -2 (-34%) |
| | Spring (Mar–May) | 2 (35%) | 2 (34%) | 2 (37%) | 2 (35%) | 3 (52%) | 3 (57%) |
| | Summer (Jun–Aug) | -1 (-5%) | -3 (-11%) | 0 (2%) | -1 (-5%) | 3 (16%) | 1 (6%) |
| | Fall (Sep–Nov) | -16 (-70%) | -17 (-72%) | -3 (-33%) | -4 (-38%) | -2 (-23%) | -1 (-13%) |
| | All months | -3 (-23%) | -4 (-29%) | -1 (-6%) | -2 (-13%) | 1 (9%) | 1 (6%) |
| Cache Slough | Winter (Dec–Feb) | -25 (-65%) | -20 (-54%) | -23 (-64%) | -19 (-53%) | -22 (-63%) | -17 (-50%) |
| | Spring (Mar–May) | -26 (-55%) | -23 (-49%) | -26 (-55%) | -23 (-49%) | -25 (-55%) | -22 (-48%) |
| | Summer (Jun–Aug) | -31 (-51%) | -28 (-46%) | -31 (-51%) | -28 (-46%) | -29 (-50%) | -26 (-44%) |
| | Fall (Sep–Nov) | -28 (-64%) | -20 (-45%) | -17 (-51%) | -8 (-26%) | -16 (-50%) | -16 (-39%) |
| | All months | -27 (-57%) | -23 (-49%) | -25 (-55%) | -21 (-46%) | -24 (-54%) | -21 (-46%) |
| West Delta | Winter (Dec–Feb) | -7 (-39%) | -9 (-51%) | -7 (-39%) | -9 (-52%) | -4 (-26%) | -4 (-32%) |
| | Spring (Mar–May) | -1 (-24%) | -1 (-28%) | -1 (-24%) | -1 (-28%) | 0 (9%) | 0 (10%) |
| | Summer (Jun–Aug) | -7 (-31%) | -6 (-26%) | -5 (-24%) | -4 (-18%) | 0 (-3%) | -1 (-7%) |
| | Fall (Sep–Nov) | -26 (-87%) | -27 (-87%) | -10 (-71%) | -10 (-71%) | -9 (-69%) | -6 (-60%) |
| | All months | -8 (-50%) | -9 (-52%) | -5 (-37%) | -5 (-40%) | -3 (-23%) | -2 (-22%) |
| East Delta | Winter (Dec–Feb) | -15 (-35%) | -21 (-49%) | -15 (-34%) | -20 (-48%) | -10 (-27%) | -10 (-32%) |
| | Spring (Mar–May) | -3 (-22%) | -3 (-24%) | -3 (-22%) | -3 (-24%) | -1 (-6%) | 0 (-3%) |
| | Summer (Jun–Aug) | -20 (-31%) | -20 (-31%) | -16 (-26%) | -16 (-26%) | -8 (-15%) | -12 (-22%) |
| | Fall (Sep–Nov) | -70 (-85%) | -69 (-84%) | -33 (-73%) | -33 (-72%) | -33 (-73%) | -20 (-61%) |
| | All months | -21 (-48%) | -23 (-51%) | -14 (-37%) | -15 (-41%) | -10 (-31%) | -9 (-29%) |
| South Delta | Winter (Dec–Feb) | -4 (-5%) | -13 (-16%) | -4 (-4%) | -13 (-16%) | -3 (-4%) | -10 (-13%) |
| | Spring (Mar–May) | 3 (6%) | 1 (2%) | 3 (7%) | 1 (2%) | 4 (10%) | 3 (8%) |
| | Summer (Jun–Aug) | -13 (-15%) | -13 (-15%) | -11 (-13%) | -11 (-13%) | -6 (-8%) | -8 (-10%) |
| | Fall (Sep–Nov) | -68 (-70%) | -73 (-75%) | -58 (-66%) | -64 (-73%) | -59 (-67%) | -59 (-71%) |
| | All months | -15 (-20%) | -18 (-25%) | -12 (-17%) | -16 (-23%) | -11 (-16%) | -13 (-19%) |

[a] Positive values indicates greater entrainment under ESO than under EBC.
[b] Percentage entrainment and percentage differences are rounded to whole numbers, but percentage differences are calculated with unrounded data for improved accuracy.
[c] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-18. Average Percentage of Particles Entrained after 60 Days from Different Subregions of the Plan Area under EBC and ESO Scenarios, Using Same Data as for Residence Time Analysis**

| Subregion | Season | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| North Delta | Winter (Dec–Feb) | 15[a] | 15 | 13 | 11 | 10 | 7 |
| | Spring (Mar–May) | 11 | 11 | 10 | 10 | 14 | 14 |
| | Summer (Jun–Aug) | 38 | 36 | 32 | 32 | 35 | 33 |
| | Fall (Sep–Nov) | 35 | 17 | 16 | 15 | 11 | 10 |
| | All months | 23 | 19 | 17 | 17 | 17 | 16 |
| Cache Slough | Winter (Dec–Feb) | 41 | 40 | 39 | 38 | 18 | 27 |
| | Spring (Mar–May) | 52 | 52 | 52 | 51 | 26 | 31 |
| | Summer (Jun–Aug) | 70 | 70 | 68 | 68 | 40 | 43 |
| | Fall (Sep–Nov) | 52 | 44 | 44 | 44 | 21 | 32 |
| | All months | 54 | 52 | 51 | 51 | 27 | 33 |
| West Delta | Winter (Dec–Feb) | 22 | 22 | 19 | 17 | 15 | 12 |
| | Spring (Mar–May) | 5 | 5 | 4 | 4 | 4 | 4 |
| | Summer (Jun–Aug) | 29 | 27 | 22 | 24 | 22 | 24 |
| | Fall (Sep–Nov) | 39 | 18 | 18 | 15 | 6 | 7 |
| | All months | 21 | 17 | 15 | 14 | 12 | 12 |
| East Delta | Winter (Dec–Feb) | 58 | 57 | 55 | 52 | 44 | 39 |
| | Spring (Mar–May) | 20 | 20 | 20 | 18 | 20 | 19 |
| | Summer (Jun–Aug) | 78 | 74 | 68 | 70 | 63 | 66 |
| | Fall (Sep–Nov) | 88 | 61 | 64 | 56 | 23 | 27 |
| | All months | 55 | 50 | 48 | 46 | 37 | 37 |
| South Delta | Winter (Dec–Feb) | 88 | 88 | 88 | 87 | 85 | 79 |
| | Spring (Mar–May) | 53 | 53 | 52 | 51 | 57 | 54 |
| | Summer (Jun–Aug) | 94 | 92 | 90 | 91 | 85 | 88 |
| | Fall (Sep–Nov) | 98 | 92 | 93 | 90 | 49 | 45 |
| | All months | 80 | 78 | 78 | 76 | 70 | 67 |

[a] Data rounded to whole percentages.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-19. Differences[a] between EBC and ESO scenarios in Average Percentage of Particles Entrained after 60 Days from Different Subregions of the Plan Area, Using Same Data as for Residence Time Analysis**

| Subregion | Season | Scenario[c] | | | | | |
|---|---|---|---|---|---|---|---|
| | | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| North Delta | Winter (Dec–Feb) | -6 (-37%)[b] | -8 (-51%) | -5 (-34%) | -7 (-49%) | -3 (-24%) | -4 (-35%) |
| | Spring (Mar–May) | 3 (23%) | 2 (22%) | 3 (23%) | 2 (22%) | 3 (31%) | 3 (34%) |
| | Summer (Jun–Aug) | -3 (-7%) | -5 (-13%) | -1 (-2%) | -3 (-9%) | 3 (8%) | 0 (1%) |
| | Fall (Sep–Nov) | -24 (-69%) | -25 (-72%) | -7 (-38%) | -7 (-42%) | -5 (-34%) | -5 (-33%) |
| | All months | -5 (-23%) | -7 (-29%) | -2 (-9%) | -3 (-15%) | 0 (0%) | -1 (-4%) |
| Cache Slough | Winter (Dec–Feb) | -22 (-55%) | -13 (-33%) | -22 (-54%) | -13 (-32%) | -21 (-53%) | -11 (-28%) |
| | Spring (Mar–May) | -26 (-50%) | -22 (-41%) | -26 (-50%) | -21 (-41%) | -26 (-50%) | -21 (-40%) |
| | Summer (Jun–Aug) | -31 (-43%) | -28 (-39%) | -30 (-43%) | -27 (-39%) | -28 (-42%) | -25 (-37%) |
| | Fall (Sep–Nov) | -30 (-59%) | -19 (-38%) | -23 (-52%) | -12 (-27%) | -23 (-52%) | -12 (-26%) |
| | All months | -27 (-50%) | -21 (-38%) | -25 (-49%) | -19 (-37%) | -25 (-48%) | -18 (-35%) |
| West Delta | Winter (Dec–Feb) | -8 (-34%) | -10 (-45%) | -8 (-34%) | -10 (-45%) | -5 (-24%) | -5 (-29%) |
| | Spring (Mar–May) | -1 (-11%) | -1 (-15%) | -1 (-12%) | -1 (-15%) | 0 (7%) | 0 (11%) |
| | Summer (Jun–Aug) | -8 (-26%) | -5 (-18%) | -5 (-20%) | -3 (-11%) | -1 (-3%) | 0 (0%) |
| | Fall (Sep–Nov) | -32 (-84%) | -32 (-83%) | -12 (-66%) | -12 (-65%) | -12 (-66%) | -9 (-58%) |
| | All months | -9 (-45%) | -9 (-45%) | -5 (-32%) | -5 (-32%) | -3 (-22%) | -3 (-18%) |
| East Delta | Winter (Dec–Feb) | -14 (-24%) | -19 (-33%) | -13 (-23%) | -18 (-32%) | -11 (-21%) | -14 (-26%) |
| | Spring (Mar–May) | 0 (-2%) | -1 (-4%) | 0 (-1%) | -1 (-3%) | 0 (-2%) | 1 (6%) |
| | Summer (Jun–Aug) | -16 (-20%) | -12 (-15%) | -12 (-16%) | -8 (-10%) | -5 (-8%) | -4 (-5%) |
| | Fall (Sep–Nov) | -65 (-74%) | -62 (-70%) | -37 (-62%) | -34 (-56%) | -41 (-64%) | -29 (-52%) |
| | All months | -18 (-33%) | -18 (-33%) | -13 (-25%) | -12 (-25%) | -11 (-23%) | -9 (-19%) |
| South Delta | Winter (Dec–Feb) | -4 (-4%) | -10 (-11%) | -3 (-4%) | -9 (-10%) | -3 (-4%) | -8 (-10%) |
| | Spring (Mar–May) | 4 (7%) | 1 (3%) | 4 (8%) | 2 (4%) | 4 (8%) | 4 (7%) |
| | Summer (Jun–Aug) | -9 (-10%) | -6 (-7%) | -7 (-8%) | -4 (-4%) | -5 (-5%) | -2 (-3%) |
| | Fall (Sep–Nov) | -49 (-50%) | -52 (-54%) | -44 (-47%) | -47 (-51%) | -45 (-48%) | -44 (-49%) |
| | All months | -10 (-13%) | -12 (-15%) | -8 (-11%) | -11 (-13%) | -8 (-10%) | -9 (-12%) |

[a] Positive values indicates greater entrainment under ESO than under EBC.

[b] Percentage entrainment and percentage differences are rounded to whole numbers, but percentage differences are calculated with unrounded data for improved accuracy.

[c] See Table 5C.0-1 for definitions of scenarios.

### 5C.5.4.4.2 EBC vs. HOS and LOS Scenarios

Overall, average residence times for the HOS scenarios (Table 5C.5.4-20) and their differences from the average residence times under the EBC scenarios (Table 5C.5.4-21) were similar to the corresponding ESO average residence times (Table 5C.5.4-14) and ESO-EBC average residence time differences (Table 5C.5.4-15). In relation to the difference in average residence time between ESO vs. EBC scenarios, somewhat greater summer average residence time differences under the HOS_LLT scenario compared to the EBC2_LLT scenario existed in several of the subregions of the Plan Area: North Delta subregion (4 days/10% more under HOS compared to ESO), Cache Slough subregion (3 days/15% more), West Delta subregion (3 days/12% more), East Delta subregion (5 days/20% more), and South Delta subregion (3 days/31% more).

Average residence time for LOS scenarios (Table 5C.5.4-22) and difference in average residence time between LOS scenarios and EBC scenarios (Table 5C.5.4-23) generally was similar to ESO average residence times (Table 5C.5.4-14) and EBC–ESO average residence time differences (Table 5C.5.4-15). However, there were some differences in the fall that were related to the LOS scenarios not including the USFWS (2008) BiOp Fall X2 criteria. Thus, whereas fall residence times in the East Delta and South Delta subregions were appreciably greater under ESO scenarios compared to EBC scenarios, there was relatively little difference in residence time between LOS and EBC scenarios (e.g., average of 1 day or 11–12% different in ELT and LLT in the South Delta subregion; Table 5C.5.4-23). In the West Delta and Suisun Marsh subregions, fall residence time under LOS scenarios was greater than under ESO scenarios and therefore even greater relative to EBC scenarios, as a result of less outflow caused by greater south Delta pumping under the LOS scenarios.

**Table 5C.5.4-20. Average Residence Time (Number of Days[a] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Plan Area under EBC and HOS Scenarios**

| | | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|---|
| **Subregion** | **Season** | **EBC1** | **EBC2** | **EBC2_ELT** | **EBC2_LLT** | **HOS_ELT** | **ESO_LLT** |
| North Delta | Winter (Dec–Feb) | 35 | 35 | 36 | 37 | 37 | 38 |
| | Spring (Mar–May) | 30 | 30 | 31 | 32 | 30 | 32 |
| | Summer (Jun–Aug) | 32 | 33 | 36 | 37 | 38 | 41 |
| | Fall (Sep–Nov) | 48 | 48 | 49 | 49 | 53 | 54 |
| | All months | 35 | 35 | 36 | 37 | 38 | 40 |
| Cache Slough | Winter (Dec–Feb) | 23 | 25 | 25 | 26 | 34 | 32 |
| | Spring (Mar–May) | 17 | 17 | 18 | 19 | 32 | 30 |
| | Summer (Jun–Aug) | 18 | 18 | 19 | 20 | 43 | 41 |
| | Fall (Sep–Nov) | 28 | 30 | 30 | 29 | 46 | 42 |
| | All months | 21 | 22 | 22 | 23 | 38 | 35 |
| West Delta | Winter (Dec–Feb) | 18 | 18 | 19 | 20 | 20 | 20 |
| | Spring (Mar–May) | 18 | 18 | 18 | 19 | 19 | 20 |
| | Summer (Jun–Aug) | 21 | 22 | 25 | 23 | 28 | 30 |
| | Fall (Sep–Nov) | 25 | 25 | 25 | 27 | 28 | 29 |
| | All months | 20 | 20 | 21 | 22 | 23 | 24 |
| East Delta | Winter (Dec–Feb) | 26 | 26 | 28 | 30 | 34 | 39 |
| | Spring (Mar–May) | 38 | 37 | 39 | 41 | 43 | 48 |
| | Summer (Jun–Aug) | 20 | 22 | 26 | 24 | 31 | 35 |
| | Fall (Sep–Nov) | 15 | 27 | 28 | 32 | 41 | 44 |
| | All months | 27 | 29 | 31 | 33 | 37 | 42 |
| South Delta | Winter (Dec–Feb) | 9 | 9 | 10 | 10 | 13 | 16 |
| | Spring (Mar–May) | 23 | 22 | 23 | 24 | 24 | 27 |
| | Summer (Jun–Aug) | 7 | 8 | 9 | 9 | 14 | 16 |
| | Fall (Sep–Nov) | 5 | 8 | 8 | 10 | 34 | 36 |
| | All months | 13 | 13 | 14 | 14 | 20 | 23 |
| Suisun Marsh | Winter (Dec–Feb) | 9 | 9 | 9 | 9 | 40 | 27 |
| | Spring (Mar–May) | 45 | 45 | 49 | 51 | 40 | 28 |
| | Summer (Jun–Aug) | 51 | 52 | 54 | 58 | 59 | 37 |
| | Fall (Sep–Nov) | 17 | 18 | 19 | 19 | 49 | 33 |
| | All months | 33 | 33 | 35 | 37 | 46 | 31 |

[a] Data rounded to whole days.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-21. Differences[a] between EBC and HOS Scenarios in Average Residence Time (Number of Days[b] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Delta**

| Subregion | Season | Scenario[c] | | | | | |
|---|---|---|---|---|---|---|---|
| | | EBC1 vs. HOS_ELT | EBC1 vs. HOS_LLT | EBC2 vs. HOS_ELT | EBC2 vs. HOS_LLT | EBC2_ELT vs. HOS_ELT | EBC2_LLT vs. HOS_LLT |
| North Delta | Winter (Dec–Feb) | 2 (5%)[b] | 3 (9%) | 2 (5%) | 3 (9%) | 1 (2%) | 2 (4%) |
| | Spring (Mar–May) | 0 (1%) | 3 (9%) | 0 (0%) | 2 (8%) | 0 (-2%) | 0 (1%) |
| | Summer (Jun–Aug) | 7 (21%) | 10 (31%) | 5 (14%) | 8 (23%) | 2 (5%) | 5 (13%) |
| | Fall (Sep–Nov) | 5 (11%) | 6 (13%) | 6 (12%) | 6 (13%) | 5 (10%) | 4 (9%) |
| | All months | 3 (9%) | 5 (15%) | 3 (7%) | 5 (13%) | 1 (3%) | 2 (6%) |
| Cache Slough | Winter (Dec–Feb) | 11 (49%) | 9 (41%) | 10 (39%) | 8 (32%) | 9 (37%) | 7 (26%) |
| | Spring (Mar–May) | 15 (87%) | 13 (75%) | 15 (87%) | 13 (74%) | 14 (81%) | 11 (59%) |
| | Summer (Jun–Aug) | 25 (142%) | 23 (133%) | 24 (131%) | 23 (123%) | 23 (120%) | 21 (102%) |
| | Fall (Sep–Nov) | 18 (63%) | 13 (47%) | 16 (52%) | 11 (37%) | 16 (52%) | 13 (44%) |
| | All months | 17 (82%) | 15 (71%) | 16 (75%) | 14 (64%) | 16 (70%) | 13 (56%) |
| West Delta | Winter (Dec–Feb) | 1 (7%) | 2 (12%) | 1 (8%) | 2 (13%) | 1 (3%) | 1 (4%) |
| | Spring (Mar–May) | 1 (7%) | 3 (16%) | 1 (7%) | 3 (16%) | 0 (3%) | 1 (6%) |
| | Summer (Jun–Aug) | 7 (31%) | 8 (40%) | 5 (25%) | 7 (33%) | 3 (13%) | 6 (26%) |
| | Fall (Sep–Nov) | 3 (13%) | 5 (19%) | 3 (12%) | 5 (18%) | 2 (10%) | 3 (9%) |
| | All months | 3 (14%) | 4 (22%) | 3 (13%) | 4 (20%) | 2 (7%) | 2 (11%) |
| East Delta | Winter (Dec–Feb) | 8 (29%) | 12 (48%) | 8 (30%) | 13 (48%) | 6 (22%) | 9 (29%) |
| | Spring (Mar–May) | 6 (15%) | 10 (27%) | 6 (15%) | 10 (27%) | 4 (11%) | 6 (15%) |
| | Summer (Jun–Aug) | 11 (53%) | 15 (72%) | 10 (44%) | 13 (62%) | 5 (20%) | 11 (45%) |
| | Fall (Sep–Nov) | 26 (178%) | 30 (199%) | 14 (53%) | 17 (65%) | 13 (49%) | 12 (37%) |
| | All months | 11 (41%) | 15 (57%) | 9 (30%) | 13 (44%) | 7 (21%) | 9 (28%) |
| South Delta | Winter (Dec–Feb) | 3 (33%) | 7 (71%) | 3 (35%) | 7 (74%) | 3 (31%) | 6 (61%) |
| | Spring (Mar–May) | 2 (8%) | 4 (19%) | 2 (10%) | 5 (21%) | 2 (7%) | 3 (13%) |
| | Summer (Jun–Aug) | 6 (90%) | 9 (121%) | 6 (80%) | 8 (109%) | 4 (49%) | 7 (81%) |
| | Fall (Sep–Nov) | 29 (598%) | 31 (642%) | 25 (308%) | 27 (334%) | 26 (326%) | 26 (264%) |
| | All months | 8 (62%) | 10 (83%) | 7 (56%) | 10 (76%) | 7 (49%) | 9 (60%) |
| Suisun Marsh | Winter (Dec–Feb) | 31 (333%) | 18 (194%) | 31 (328%) | 18 (191%) | 31 (345%) | 18 (207%) |
| | Spring (Mar–May) | -5 (-10%) | -16 (-36%) | -5 (-11%) | -17 (-37%) | -9 (-18%) | -22 (-44%) |
| | Summer (Jun–Aug) | 7 (14%) | -14 (-28%) | 7 (13%) | -15 (-28%) | 4 (8%) | -21 (-36%) |
| | Fall (Sep–Nov) | 32 (195%) | 17 (100%) | 31 (170%) | 15 (83%) | 30 (160%) | 14 (77%) |
| | All months | 13 (41%) | -2 (-5%) | 13 (38%) | -2 (-7%) | 11 (31%) | -6 (-16%) |

[a] Positive values indicates greater residence time under HOS than under EBC.

[b] Days and percentages are rounded to whole numbers, but percentages are calculated with unrounded data for improved accuracy.

[c] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-22. Average Residence Time (Number of Days[a] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Plan Area under EBC and LOS Scenarios**

| | | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|---|
| **Subregion** | **Season** | **EBC1** | **EBC2** | **EBC2_ELT** | **EBC2_LLT** | **LOS_ELT** | **LOS_LLT** |
| North Delta | Winter (Dec–Feb) | 35 | 35 | 36 | 37 | 36 | 39 |
| | Spring (Mar–May) | 30 | 30 | 31 | 32 | 32 | 34 |
| | Summer (Jun–Aug) | 32 | 33 | 36 | 37 | 38 | 37 |
| | Fall (Sep–Nov) | 48 | 48 | 49 | 49 | 57 | 61 |
| | All months | 35 | 35 | 36 | 37 | 39 | 41 |
| Cache Slough | Winter (Dec–Feb) | 23 | 25 | 25 | 26 | 32 | 32 |
| | Spring (Mar–May) | 17 | 17 | 18 | 19 | 33 | 29 |
| | Summer (Jun–Aug) | 18 | 18 | 19 | 20 | 41 | 36 |
| | Fall (Sep–Nov) | 28 | 30 | 30 | 29 | 44 | 45 |
| | All months | 21 | 22 | 22 | 23 | 37 | 34 |
| West Delta | Winter (Dec–Feb) | 18 | 18 | 19 | 20 | 19 | 21 |
| | Spring (Mar–May) | 18 | 18 | 18 | 19 | 20 | 21 |
| | Summer (Jun–Aug) | 21 | 22 | 25 | 23 | 27 | 26 |
| | Fall (Sep–Nov) | 25 | 25 | 25 | 27 | 34 | 35 |
| | All months | 20 | 20 | 21 | 22 | 24 | 25 |
| East Delta | Winter (Dec–Feb) | 26 | 26 | 28 | 30 | 35 | 38 |
| | Spring (Mar–May) | 38 | 37 | 39 | 41 | 43 | 48 |
| | Summer (Jun–Aug) | 20 | 22 | 26 | 24 | 30 | 30 |
| | Fall (Sep–Nov) | 15 | 27 | 28 | 32 | 34 | 34 |
| | All months | 27 | 29 | 31 | 33 | 36 | 39 |
| South Delta | Winter (Dec–Feb) | 9 | 9 | 10 | 10 | 12 | 15 |
| | Spring (Mar–May) | 23 | 22 | 23 | 24 | 22 | 25 |
| | Summer (Jun–Aug) | 7 | 8 | 9 | 9 | 13 | 13 |
| | Fall (Sep–Nov) | 5 | 8 | 8 | 10 | 9 | 10 |
| | All months | 13 | 13 | 14 | 14 | 15 | 17 |
| Suisun Marsh | Winter (Dec–Feb) | 9 | 9 | 9 | 9 | 37 | 28 |
| | Spring (Mar–May) | 45 | 45 | 49 | 51 | 45 | 30 |
| | Summer (Jun–Aug) | 51 | 52 | 54 | 58 | 59 | 35 |
| | Fall (Sep–Nov) | 17 | 18 | 19 | 19 | 56 | 39 |
| | All months | 33 | 33 | 35 | 37 | 48 | 32 |

[a] Data rounded to whole days.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-23. Differences[a] between EBC and LOS Scenarios in Average Residence Time (Number of Days[b] to When 50% of Particles Leave the Delta) for Particles Starting from Different Subregions of the Delta**

| | | Scenario[c] | | | | | |
|---|---|---|---|---|---|---|---|
| **Subregion** | **Season** | **EBC1 vs. LOS_ELT** | **EBC1 vs. LOS_LLT** | **EBC2 vs. LOS_ELT** | **EBC2 vs. LOS_LLT** | **EBC2_ELT vs. LOS_ELT** | **EBC2_LLT vs. LOS_LLT** |
| North Delta | Winter (Dec–Feb) | 1 (2%) | 4 (12%) | 1 (2%) | 4 (12%) | 0 (0%) | 3 (7%) |
| | Spring (Mar–May) | 2 (7%) | 4 (14%) | 2 (7%) | 4 (13%) | 1 (4%) | 2 (5%) |
| | Summer (Jun–Aug) | 7 (21%) | 5 (16%) | 5 (14%) | 3 (9%) | 2 (5%) | 0 (0%) |
| | Fall (Sep–Nov) | 10 (20%) | 13 (28%) | 10 (21%) | 13 (28%) | 9 (19%) | 12 (24%) |
| | All months | 4 (12%) | 6 (17%) | 4 (10%) | 5 (16%) | 2 (6%) | 3 (9%) |
| Cache Slough | Winter (Dec–Feb) | 9 (40%) | 9 (40%) | 8 (31%) | 8 (31%) | 7 (29%) | 6 (25%) |
| | Spring (Mar–May) | 16 (92%) | 12 (68%) | 16 (92%) | 12 (67%) | 15 (86%) | 10 (52%) |
| | Summer (Jun–Aug) | 24 (136%) | 18 (103%) | 23 (125%) | 17 (94%) | 22 (114%) | 15 (75%) |
| | Fall (Sep–Nov) | 16 (56%) | 17 (59%) | 14 (46%) | 15 (48%) | 14 (45%) | 16 (56%) |
| | All months | 16 (79%) | 13 (65%) | 15 (71%) | 13 (58%) | 15 (67%) | 11 (51%) |
| West Delta | Winter (Dec–Feb) | 1 (4%) | 3 (15%) | 1 (5%) | 3 (16%) | 0 (1%) | 1 (6%) |
| | Spring (Mar–May) | 2 (13%) | 4 (22%) | 2 (13%) | 4 (21%) | 2 (9%) | 2 (11%) |
| | Summer (Jun–Aug) | 6 (30%) | 5 (23%) | 5 (23%) | 4 (17%) | 3 (12%) | 3 (11%) |
| | Fall (Sep–Nov) | 10 (39%) | 11 (43%) | 10 (38%) | 11 (43%) | 9 (36%) | 9 (32%) |
| | All months | 4 (21%) | 5 (25%) | 4 (19%) | 5 (23%) | 3 (13%) | 3 (14%) |
| East Delta | Winter (Dec–Feb) | 8 (32%) | 12 (46%) | 8 (33%) | 12 (47%) | 7 (25%) | 8 (28%) |
| | Spring (Mar–May) | 6 (15%) | 10 (27%) | 6 (15%) | 10 (28%) | 4 (11%) | 7 (16%) |
| | Summer (Jun–Aug) | 9 (45%) | 10 (48%) | 8 (37%) | 9 (39%) | 4 (14%) | 6 (25%) |
| | Fall (Sep–Nov) | 19 (131%) | 19 (128%) | 7 (27%) | 7 (25%) | 7 (24%) | 1 (4%) |
| | All months | 9 (36%) | 12 (45%) | 7 (25%) | 10 (34%) | 5 (17%) | 6 (18%) |
| South Delta | Winter (Dec–Feb) | 2 (24%) | 5 (56%) | 2 (26%) | 5 (58%) | 2 (23%) | 5 (46%) |
| | Spring (Mar–May) | -1 (-4%) | 2 (9%) | -1 (-2%) | 2 (11%) | -1 (-4%) | 1 (3%) |
| | Summer (Jun–Aug) | 5 (74%) | 6 (82%) | 5 (65%) | 6 (73%) | 3 (37%) | 4 (50%) |
| | Fall (Sep–Nov) | 5 (96%) | 5 (101%) | 1 (15%) | 1 (18%) | 2 (19%) | 0 (-1%) |
| | All months | 2 (19%) | 4 (34%) | 2 (14%) | 4 (29%) | 1 (10%) | 2 (17%) |
| Suisun Marsh | Winter (Dec–Feb) | 28 (305%) | 19 (203%) | 28 (301%) | 19 (199%) | 28 (317%) | 19 (216%) |
| | Spring (Mar–May) | 0 (1%) | -15 (-33%) | 0 (0%) | -15 (-33%) | -4 (-8%) | -21 (-41%) |
| | Summer (Jun–Aug) | 7 (15%) | -16 (-32%) | 7 (14%) | -17 (-32%) | 5 (8%) | -23 (-40%) |
| | Fall (Sep–Nov) | 39 (237%) | 22 (133%) | 38 (208%) | 20 (113%) | 37 (197%) | 20 (106%) |
| | All months | 16 (47%) | -1 (-2%) | 15 (45%) | -1 (-3%) | 13 (37%) | -5 (-13%) |

[a] Positive values indicates greater residence time under LOS than under EBC.
[b] Days and percentages are rounded to whole numbers, but percentages are calculated with unrounded data for improved accuracy.
[c] See Table 5C.0-1 for definitions of scenarios.

# 5C.5.4.5 Analyses Related to Decision Tree Outcomes

As described in Chapter 3, *Conservation Strategy*, *CM1 Water Facilities and Operation* includes alternative outcomes related to spring and fall outflow operations. These are driven by the decision tree process, in which scientific investigation will lead to reduced uncertainty about the effects of outflow on longfin smelt in the spring and delta smelt in the fall, and the operations will be managed accordingly. There are two potential outcomes for spring outflow and two potential outcomes for fall outflow. Consequently, there are four potential CM1 operations. In addition to the ESO, which represents high fall outflow coupled with low spring outflow, this effects analysis includes analysis of the high outflow and low outflow scenarios in the early and late long-term (HOS_ELT, HOS_LLT, LOS_ELT, and LOS_LLT scenarios). The high outflow scenario includes high fall and spring outflow and the low outflow scenario includes low fall and spring outflow.

The following section specifically evaluates the different outcomes of the decision tree process relative to longfin smelt and delta smelt using methods that include outflow as a driver of abundance and habitat quantity and value.

## 5C.5.4.5.1 Delta Smelt Fall Abiotic Habitat Index

This section analyzes differences between EBC and ESO scenarios in the delta smelt fall abiotic habitat index with (Section 5C.5.4.5.1.2) and without (Section 5C.5.4.5.1.1) BDCP tidal wetland restoration. An evaluation of differences in the fall abiotic habitat index between EBC2 and HOS or LOS scenarios is also included in each section. Note that in the discussion included here, October–December have been grouped with the previous water year (based on the Sacramento Valley 40-30-30 system) to account for the management regime that occurs with implementation of the Fall X2 RPA from the USFWS (2008) OCAP BiOp. Note also that this analysis includes only existing areas that are covered by the Feyrer et al. (2011) abiotic habitat index as well as proposed tidal habitat restoration in the Suisun Marsh and West Delta ROAs under BDCP; it does not include other delta smelt habitat areas, such as within the Cache Slough subregion and the Cache Slough ROA.

### 5C.5.4.5.1.1 Abiotic Habitat without Restoration

The results of the delta smelt fall abiotic habitat index analyses based on the method of Feyrer and coauthors (2011) suggested that the abiotic habitat index under the evaluated starting operations (ESO_ELT and ESO_LLT) scenarios would be similar to EBC1 for the lowest 40% of predicted habitat index exceedance levels, but would be similar to EBC2, EBC2_ELT, and EBC2_LLT in all years (Figure 5C.5.4-95). There was estimated to be less than a 2% difference in the habitat index at the 80% exceedance level between the evaluated starting operations scenarios and EBC1 and the three EBC2 scenarios, reflecting that the Fall X2 action is implemented only in wet and above normal years. For the upper 50% exceedance levels, the evaluated starting operations had an approximately 31 to 55% higher abiotic habitat index than EBC1 (Table 5C.5.4-24 and Table 5C.5.4-25), reflecting implementation of Fall X2 in the wet and above normal years of ESO and not in EBC1.

Relative to the EBC2 scenarios, the abiotic habitat index under the evaluated starting operations differed by less than 10% under all percent exceedance levels (Figure 5C.5.4-95). Note that the range of the habitat index exceedances (frequencies) corresponds roughly to water year hydrologies, with the driest years having the highest exceedance levels. Expressed by water-year type, the average abiotic habitat index under ESO scenarios was around 5,000 (ranging from an average of 3,000 in critical years to around 7,000 in wet years) and was on average 1,000–1,150 higher than the average habitat index under EBC1 (which was around 4,000 on average, ranging from 3,000 in critical years to 4,700 in wet years) (Table 5C.5.4-26, Table 5C.5.4-27). Note that the abiotic habitat index is computed as a habitat surface area weighted by habitat value parameters—although plots such as Figure 5C.5.4-95 refer to the index in hectares, these should be more properly thought of as habitat units.

The average habitat index under the ESO scenarios was little different from the average habitat index under EBC1 for critical, dry and below normal water-year types, but was much greater for above normal and wet year types, for which the ESO habitat indices were on average 1,700–2,500 (45–53%) greater (Table 5C.5.4-26, Table 5C.5.4-27). The average habitat index for the ESO scenarios was similar to that for the three EBC2 scenarios for all water-year types together, wet, above normal, and critical years (Table 5C.5.4-27). The ESO scenarios had marginally greater (up to 9%) average abiotic habitat indices than EBC2 scenarios in below normal and dry years. The results reflect the inclusion of the Fall X2 requirement under EBC2 and ESO scenarios.

The delta smelt fall abiotic habitat index with no BDCP restoration averaged ~5,000 under the HOS scenarios and ~4,000 under LOS scenarios (Table 5C.5.4-28). Relative differences between the HOS or LOS scenarios and EBC2 scenarios were intuitive given the operational assumptions associated with each scenario. Because both the HOS and ESO scenarios include the Fall X2 management measure, the pattern of difference between HOS and EBC2 scenarios (Table 5C.5.4-29) and ESO and EBC2 scenarios (Table 5C.5.4-27) was similar, i.e., little difference overall with slightly greater indices under the HOS scenarios in below normal and dry years. The overall average LOS abiotic habitat indices were around 1,000 (20%) lower than the average EBC2 scenarios, which was because of little difference in averages for below normal, dry, and critical years and 30–40% lower indices under the LOS scenarios in wet and above normal years (Table 5C.5.4-29).

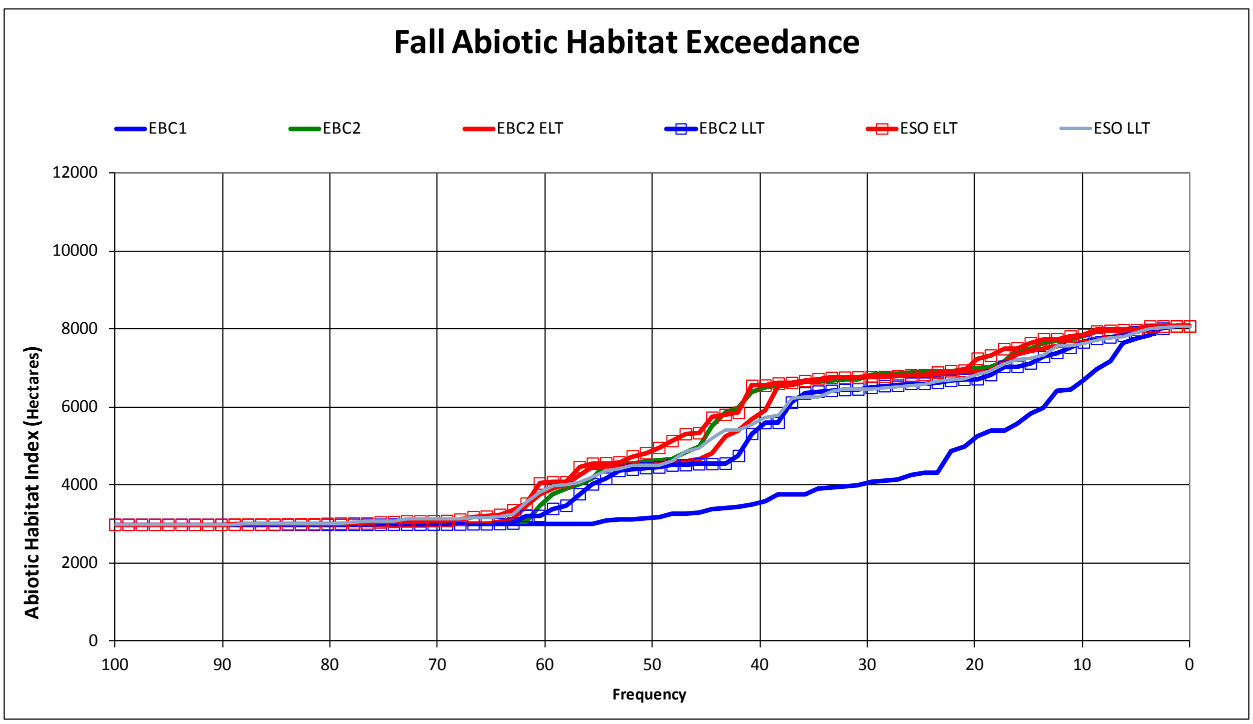



**Figure 5C.5.4-95. Exceedance Plot of Delta Smelt Fall Abiotic Habitat Index (Hectares) without Restoration, September through December**

1 **Table 5C.5.4-24. Delta Smelt Fall Abiotic Habitat Index without Considering Restoration**

| Percent Exceedance | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| 80th | 2,987 | 2,987 | 2,987 | 2,987 | 3,014 | 3,031 |
| 50th | 3,160 | 4,626 | 4,530 | 4,448 | 4,888 | 4,501 |
| 20th | 5,190 | 6,995 | 6,881 | 6,713 | 7,183 | 6,822 |

[a] See Table 5C.0-1 for definitions of scenarios.

2

3 **Table 5C.5.4-25. Differences[a] between ESO and EBC Scenarios in Delta Smelt Fall Abiotic Habitat Index**
4 **without Considering Restoration (Percent)**

| Percent Exceedance | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|
| | ESO_ELT vs. EBC1 | ESO_LLT vs. EBC1 | ESO_ELT vs. EBC2 | ESO_LLT vs. EBC2 | ESO_ELT vs. EBC2_ELT | ESO_LLT vs. EBC2_LLT |
| 80th | 0.9 | 1.5 | 0.9 | 1.5 | 0.0 | 1.5 |
| 50th | 54.7 | 42.4 | 5.7 | -2.7 | 7.9 | 1.2 |
| 20th | 38.4 | 31.4 | 2.7 | -2.5 | 4.4 | 1.6 |

[a] Positive values indicate higher habitat indices under ESO scenarios.
[b] See Table 5C.0-1 for definitions of scenarios.

5

6 **Table 5C.5.4-26. Delta Smelt Fall Abiotic Index under ESO without Considering Restoration, Averaged**
7 **by Water-Year Type**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| All | 3,979 | 5,035 | 5,031 | 4,865 | 5,129 | 4,981 |
| Wet | 4,704 | 7,253 | 7,143 | 6,900 | 7,182 | 6,887 |
| Above normal | 3,823 | 5,644 | 5,768 | 5,491 | 5,836 | 5,541 |
| Below normal | 4,138 | 4,090 | 4,177 | 3,990 | 4,409 | 4,223 |
| Dry | 3,566 | 3,559 | 3,555 | 3,475 | 3,716 | 3,788 |
| Critical | 2,987 | 2,987 | 2,987 | 2,987 | 2,996 | 3,011 |

[a] See Table 5C.0-1 for definitions of scenarios.

8

**Table 5C.5.4-27. Differences[a] in Delta Smelt Fall Abiotic Index between ESO and EBC Scenarios, without Consering Restoration under ESO, Averaged by Water-Year Type**

| Water-Year Type | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| All | 1,150 (29%) | 1,002 (25%) | 94 (2%) | -54 (-1%) | 99 (2%) | 116 (2%) |
| Wet | 2,478 (53%) | 2,183 (46%) | -72 (-1%) | -366 (-5%) | 38 (1%) | -13 (0%) |
| Above normal | 2,013 (53%) | 1,718 (45%) | 192 (3%) | -103 (-2%) | 68 (1%) | 50 (1%) |
| Below normal | 182 (4%) | -5 (0%) | 319 (8%) | 133 (3%) | 232 (6%) | 233 (6%) |
| Dry | 150 (4%) | 222 (6%) | 157 (4%) | 229 (6%) | 161 (5%) | 313 (9%) |
| Critical | 9 (0%) | 24 (1%) | 9 (0%) | 23 (1%) | 9 (0%) | 23 (1%) |

[a] Negative values indicate lower habitat indices under ESO than under EBC.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-28. Delta Smelt Fall Abiotic Index under EBC2, HOS and LOS Scenarios, without Considering Restoration, Averaged by Water-Year Type**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC2_ELT | EBC2_LLT | HOS_ELT | HOS_LLT | LOS_ELT | LOS_LLT |
| All | 5,031 | 4,865 | 5,163 | 5,013 | 4,021 | 3,839 |
| Wet | 7,143 | 6,900 | 7,189 | 6,896 | 4,510 | 4,047 |
| Above Normal | 5,768 | 5,491 | 5,855 | 5,562 | 4,128 | 3,836 |
| Below Normal | 4,177 | 3,990 | 4,492 | 4,294 | 4,301 | 4,170 |
| Dry | 3,555 | 3,475 | 3,778 | 3,848 | 3,714 | 3,833 |
| Critical | 2,987 | 2,987 | 2,998 | 3,020 | 2,996 | 3,014 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-29. Differences[a] between EBC2 Scenarios and HOS and LOS Scenarios in Delta Smelt Fall Abiotic Index, without Considering Restoration, Averaged by Water-Year Type**

| Water-Year Type | Scenario[b] | | | |
|---|---|---|---|---|
| | HOS_ELT v EBC2_ELT | HOS_LLT v EBC2_LLT | LOS_ELT v EBC2_ELT | LOS_LLT v EBC2_LLT |
| All | 132 (3%) | 153 (3%) | -1,010 (-20%) | -1,022 (-21%) |
| Wet | 46 (1%) | -4 (0%) | -2,633 (-37%) | -2,853 (-41%) |
| Above Normal | 88 (2%) | 72 (1%) | -1,639 (-28%) | -1,655 (-30%) |
| Below Normal | 316 (8%) | 303 (8%) | 125 (3%) | 180 (5%) |
| Dry | 222 (6%) | 373 (11%) | 159 (4%) | 358 (10%) |
| Critical | 11 (0%) | 33 (1%) | 9 (0%) | 26 (1%) |

[a] Positive values indicate a higher index under HOS or LOS than under EBC2.
[b] See Table 5C.0-1 for definitions of scenarios.

#### 5C.5.4.5.1.2 Delta Smelt Fall Abiotic Habitat Index with Restoration

As described in the methods section, differences in the fall abiotic habitat index between EBC and ESO, HOS, or LOS were also conducted assuming that areas of hypothetical restored tidal habitat under BDCP would have similar abiotic value to adjacent existing areas, with this value varying according to fall Delta outflow (X2). The potential for delta smelt's actual occupation of this habitat is uncertain and so sensitivity analyses were conducted to test varying assumptions of potential use, from 25 to 100%. Note that the term "100% use"' in effect means that the restored habitat would have equal value (functionally equivalent) to that of the adjacent existing area; likewise, "25% use" is computationally equivalent to assuming that the restored habitat has 25% of the functional value of the existing adjacent habitat.

When assuming augmentation of the delta smelt fall abiotic habitat index by habitat restoration in the Suisun Marsh and West Delta ROAs under the BDCP (other subregions in which tidal wetland restoration is proposed are not included in this method), implementation of the evaluated starting operations was estimated to provide a greater abiotic habitat index than EBC1. The magnitude of this difference in habitat index exceeded 4,000 (30% level of exceedance) and was generally high over the range from the 40% to the 20% exceedance levels , depending on assumed use of restored habitat (Figure 5C.5.4-96, Table 5C.5.4-30, Table 5C.5.4-31). Relative to EBC2, the abiotic habitat index was estimated to range from no difference (40% exceedance level) to about 46% greater (60% exceedance) under the ESO_LLT over the full range of habitat index exceedance levels, depending on the assumed use of restored habitat by delta smelt. The greatest difference (about 2,400) was at the 0% exceedance level, while the greatest percentage difference (about 46%) was, as noted above, at about the 60% exceedance level.

Expressed in terms of water-year types, the average delta smelt abiotic habitat index under the ESO_LLT scenario ranged from approximately 3,200 in critical water years assuming 25% habitat use to 8,800 in wet years assuming 100% habitat use (Table 5C.5.4-32). For all water-year types combined, this was between 1,323 and 2,335 more than under EBC1, depending on assumed habitat use by delta smelt and between 267 and 1,279 more than the average under EBC2 (Table 5C.5.4-33). The average abiotic habitat index under ESO_LLT was between 2,665 (57%) and 4,072 (87%) higher than EBC1 in wet water years and higher than EBC1 in above normal, below normal, dry, and critical water years by 190 to 3,227 (6% to 84%), depending on assumed percent habitat use by delta smelt. The average abiotic habitat index under ESO_LLT was higher than EBC2 and EBC2_LLT in all water-year types, ranging from 190 (6%) more in critical year types to 1,876 (21%) more in wet year types, depending on assumed percent habitat use by delta smelt. In terms of percent difference, the index ranged from 2% higher for wet year types (25% percent habitat use) to 38% higher for critical year types (100% habitat use).

Average fall abiotic habitat indices under the HOS_LLT scenario ranged from ~3,200 in critical years (25% restored habitat use) to ~8,600 in wet years (100% restored habitat use) (Table 5C.5.4-34). Average fall abiotic habitat indices under the LOS_LLT scenario ranged from ~3,200 in critical years (25% restored habitat use) to ~5,300 in below normal years (100% restored habitat use) (Table 5C.5.4-34).The relative differences in average abiotic habitat indices between the HOS_LLT and EBC2_LLT scenarios (Table 5C.5.4-35) was very similar to the differences between the ESO_LLT scenario and EBC2_LLT scenarios (Table 5C.5.4-33). The overall difference between the average LOS_LLT and average EBC2_LLT abiotic habitat indices across all water years ranged from essentially no difference when assuming 100% use of restored habitat to 16% lower under the LOS_LLT scenario when assuming 25% use of restored habitat (Table 5C.5.4-35). By water-year type, relative differences between LOS_LLT and EBC2_LLT scenarios ranged from a 38% lower abiotic habitat index under the LOS_LLT scenario in wet water years (25% use of restored habitat) to a 38% higher abiotic habitat index in dry water-year types (100% use of restored habitat) (Table 5C.5.4-35).

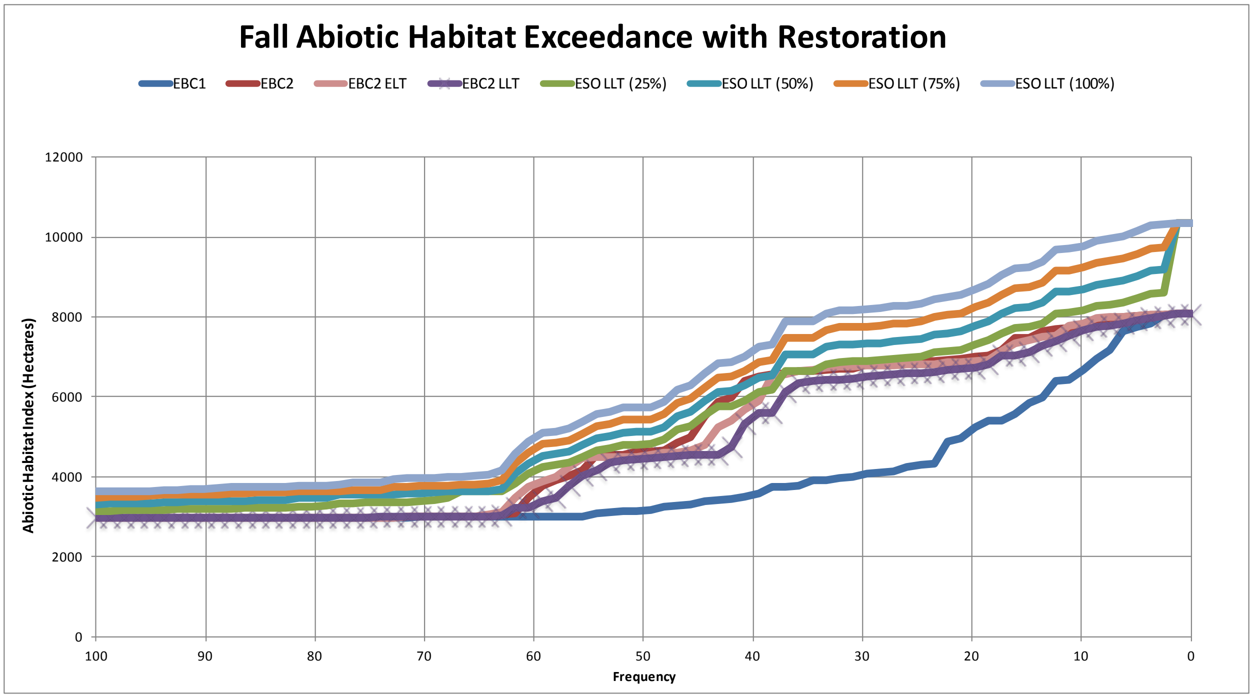



**Figure 5C.5.4-96. Exceedance Plot of Fall Abiotic Habitat Index with Restoration, September through December**

**Table 5C.5.4-30. Delta Smelt Fall Abiotic Habitat Index under EBC Scenarios and under ESO Scenarios with Restoration Considered**

| Percent Exceedance | Scenario[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_LLT | ESO_LLT (25% Use)[b] | ESO_LLT (50% Use) | ESO_LLT (75% Use) | ESO_LLT (100% Use) |
| 80th | 2,987 | 2,987 | 2,987 | 3,265 | 3,462 | 3,642 | 3,787 |
| 50th | 3,160 | 4,626 | 4,448 | 4,813 | 5,124 | 5,435 | 5,747 |
| 20th | 5,190 | 6,995 | 6,713 | 7,283 | 7,745 | 8,207 | 8,669 |

[a] See Table 5C.0-1 for definitions of scenarios.

[b] Assumed percent use of restored habitat by delta smelt.

**Table 5C.5.4-31. Differences[a] in Delta Smelt Fall Abiotic Habitat Index between EBC Scenarios and ESO_LLT, with Restoration Considered (Percent)**

| | Scenario[b] | | |
|---|---|---|---|
| **Percent Exceedance** | **ESO_LLT vs. EBC1** | **ESO_LLT vs. EBC2** | **ESO_LLT vs. EBC2_LLT** |
| **25% Use of Restored Habitat by Delta Smelt** | | | |
| 80th | 9.3 | 9.3 | 9.3 |
| 50th | 52.3 | 4.0 | 8.2 |
| 20th | 40.3 | 4.1 | 8.5 |
| **50% Use of Restored Habitat by Delta Smelt** | | | |
| 80th | 15.9 | 15.9 | 15.9 |
| 50th | 62.1 | 10.8 | 15.2 |
| 20th | 49.2 | 10.7 | 15.4 |
| **75% Use of Restored Habitat by Delta Smelt** | | | |
| 80th | 21.9 | 21.9 | 21.9 |
| 50th | 72.0 | 17.5 | 22.2 |
| 20th | 58.1 | 17.3 | 22.3 |
| **100% Use of Restored Habitat by Delta Smelt** | | | |
| 80th | 26.8 | 26.8 | 26.8 |
| 50th | 81.8 | 24.2 | 29.2 |
| 20th | 67.0 | 23.9 | 29.1 |

[a] Positive values indicate higher habitat indices under ESO scenarios.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-32. Delta Smelt Fall Abiotic Index under EBC and ESO Scenarios, with Restoration Considered, Averaged by Water-Year Type**

| | Scenario[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Water-Year Type** | **EBC1** | **EBC2** | **EBC2_LLT** | **ESO_LLT (25% Use)[b]** | **ESO_LLT (50% Use)[b]** | **ESO_LLT (75% Use)[b]** | **ESO_LLT (100% Use)[b]** |
| All | 3,979 | 5,035 | 4,865 | 5,302 | 5,639 | 5,977 | 6,314 |
| Wet | 4,704 | 7,253 | 6,900 | 7,369 | 7,838 | 8,307 | 8,776 |
| Above normal | 3,823 | 5,644 | 5,491 | 5,939 | 6,309 | 6,680 | 7,050 |
| Below normal | 4,138 | 4,090 | 3,990 | 4,482 | 4,775 | 5,067 | 5,360 |
| Dry | 3,566 | 3,559 | 3,475 | 3,995 | 4,258 | 4,520 | 4,783 |
| Critical | 2,987 | 2,987 | 2,987 | 3,177 | 3,357 | 3,536 | 3,716 |

[a] See Table 5C.0-1 for definitions of scenarios.
[b] Assumed percent use of restored habitat by delta smelt.

**Table 5C.5.4-33. Differences [a] in Delta Smelt Fall Abiotic Index between EBC Scenarios and ESO_LLT, with Restoration Considered, Averaged by Water-Year Type**

| Water-Year Type | Scenario[b] | | |
|---|---|---|---|
| | EBC1 vs. ESO_LLT | EBC2 vs. ESO_LLT | EBC2_LLT vs. ESO_LLT |
| **25% Use of Restored Habitat by Delta Smelt** | | | |
| All | 1,323 (33%) [b] | 267 (5%) | 437 (9%) |
| Wet | 2,665 (57%) | 116 (2%) | 469 (7%) |
| Above normal | 2,116 (55%) | 295 (5%) | 448 (8%) |
| Below normal | 344 (8%) | 392 (10%) | 492 (12%) |
| Dry | 429 (12%) | 436 (12%) | 520 (15%) |
| Critical | 190 (6%) | 190 (6%) | 190 (6%) |
| **50% Use of Restored Habitat by Delta Smelt** | | | |
| All | 1,660 (42%) | 604 (12%) | 774 (16%) |
| Wet | 3,134 (67%) | 585 (8%) | 938 (14%) |
| Above normal | 2,486 (65%) | 665 (12%) | 818 (15%) |
| Below normal | 637 (15%) | 685 (17%) | 785 (20%) |
| Dry | 692 (19%) | 699 (20%) | 783 (23%) |
| Critical | 370 (12%) | 370 (12%) | 370 (12%) |
| **75% Use of Restored Habitat by Delta Smelt** | | | |
| All | 1,998 (50%) | 942 (19%) | 1,112 (23%) |
| Wet | 3,603 (77%) | 1,054 (15%) | 1,407 (20%) |
| Above normal | 2,857 (75%) | 1,036 (18%) | 1,189 (22%) |
| Below normal | 929 (22%) | 977 (24%) | 1,077 (27%) |
| Dry | 954 (27%) | 961 (27%) | 1,045 (30%) |
| Critical | 549 (18%) | 549 (18%) | 549 (18%) |
| **100% Use of Restored Habitat by Delta Smelt** | | | |
| All | 2,335 (59%) | 1,279 (25%) | 1,449 (30%) |
| Wet | 4,072 (87%) | 1,523 (21%) | 1,876 (27%) |
| Above normal | 3,227 (84%) | 1,406 (25%) | 1,559 (28%) |
| Below normal | 1,222 (30%) | 1,270 (31%) | 1,370 (34%) |
| Dry | 1,217 (34%) | 1,224 (34%) | 1,308 (38%) |
| Critical | 729 (24%) | 729 (24%) | 729 (24%) |

[a] Positive values indicate higher habitat indices under ESO scenarios.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-34. Delta Smelt Fall Abiotic Index under EBC, HOS, and LOS Scenarios, with Restoration Considered, Averaged by Water-Year Type**

| Water-Year Type | Scenario[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | EBC2_LLT | HOS_LLT (25% Use)[b] | HOS_LLT (50% Use)[b] | HOS_LLT (75% Use)[b] | HOS_LLT (100% Use)[b] | LOS_LLT (25% Use)[b] | LOS_LLT (50% Use)[b] | LOS_LLT (75% Use)[b] | LOS_LLT (100% Use)[b] |
| A | 4,865 | 5,327 | 5,641 | 5,954 | 6,268 | 4,079 | 4,320 | 4,560 | 4,800 |
| W | 6,900 | 7,325 | 7,754 | 8,184 | 8,613 | 4,296 | 4,545 | 4,794 | 5,043 |
| AN | 5,491 | 5,940 | 6,318 | 6,696 | 7,073 | 4,097 | 4,358 | 4,619 | 4,880 |
| BN | 3,990 | 4,581 | 4,868 | 5,156 | 5,443 | 4,450 | 4,730 | 5,010 | 5,290 |
| D | 3,475 | 4,094 | 4,341 | 4,587 | 4,834 | 4,077 | 4,321 | 4,565 | 4,809 |
| C | 2,987 | 3,156 | 3,291 | 3,427 | 3,562 | 3,165 | 3,316 | 3,467 | 3,617 |

A = all; W = wet; AN = above normal; BN = below normal; D = dry; C = critical.
[a] See Table 5C.0-1 for definitions of scenarios. [b] Assumed percent use of restored habitat by delta smelt.

**Table 5C.5.4-35. Differences[a] in Delta Smelt Fall Abiotic Index between EBC2_LLT Scenario and HOS and LOS Scenarios, with Restoration Considered under HOS and LOS, Averaged by Water-Year Type**

| Water-Year Type | Scenario[b] | |
|---|---|---|
| | EBC2_LLT vs. HOS_LLT | EBC2_LLT vs. LOS_LLT |
| **25% Use of Restored Habitat by Delta Smelt** | | |
| All | 462 (9%) | -786 (-16%) |
| Wet | 425 (6%) | -2,604 (-38%) |
| Above normal | 449 (8%) | -1,394 (-25%) |
| Below normal | 591 (15%) | 460 (12%) |
| Dry | 619 (18%) | 602 (17%) |
| Critical | 168 (6%) | 177 (6%) |
| **50% Use of Restored Habitat by Delta Smelt** | | |
| All | 776 (16%) | -545 (-11%) |
| Wet | 854 (12%) | -2,355 (-34%) |
| Above normal | 827 (15%) | -1,132 (-21%) |
| Below normal | 878 (22%) | 740 (19%) |
| Dry | 866 (25%) | 846 (24%) |
| Critical | 304 (10%) | 328 (11%) |
| **75% Use of Restored Habitat by Delta Smelt** | | |
| All | 1,089 (22%) | -305 (-6%) |
| Wet | 1,283 (19%) | -2,106 (-31%) |
| Above normal | 1,205 (22%) | -871 (-16%) |
| Below normal | 1,166 (29%) | 1,020 (26%) |
| Dry | 1,112 (32%) | 1,090 (31%) |
| Critical | 439 (15%) | 479 (16%) |
| **100% Use of Restored Habitat by Delta Smelt** | | |
| All | 1,403 (29%) | -65 (-1%) |
| Wet | 1,712 (25%) | -1,857 (-27%) |
| Above normal | 1,583 (29%) | -610 (-11%) |
| Below normal | 1,453 (36%) | 1,300 (33%) |
| Dry | 1,359 (39%) | 1,334 (38%) |
| Critical | 575 (19%) | 630 (21%) |

[a] Positive value indicate higher habitat index under HOS or LOS than under EBC2.
[b] See Table 5C.0-1 for definitions of scenarios.

### 5C.5.4.5.2 X2 Relative-Abundance Regressions (Longfin Smelt)

Kimmerer et al. 's (2009) regressions use average January through June X2 and longfin smelt relative abundance from trawl survey data to assess potential effects of the evaluated starting operations, high outflow, and low outflow scenarios in relation to existing biological conditions. While this method estimates absolute abundance as a function of winter-spring outflow, it does not account for potential changes in food production or changes in available habitat area because of restoration activities, and therefore best represents the hypothesis that requires spring outflow for BDCP to meet its biological goals and objectives for longfin smelt. Kimmerer et al. (2009:385) noted:

> [A]lthough increases in quantity of habitat may contribute, the mechanism chiefly responsible for the X2 relationship for longfin smelt remains unknown. It may be related to the shift by young fish toward greater depth at higher salinity…, possibly implying a retention mechanism.

Results from the analysis using the Kimmerer et al. (2009) regressions showed that differences between EBC and ESO scenarios were greatest when comparing across time periods (i.e., comparisons of ESO scenarios with EBC1 or EBC2) and that differences were greater at the 80th-percentile exceedance than at the 20th-percentile exceedances (Table 5C.5.4-36 and Table 5C.5.4-37). The 20th and 80th percentile exceedances serve as useful endpoints for the most manageable range of outflows. For the 20th-percentile exceedances compared across time periods, the differences between scenarios ranged from 5% lower under ESO_ELT compared to EBC2 for fall midwater trawl to just over 20% lower when comparing ESO_LLT to EBC1/EBC2 for bay midwater and otter trawls. There was little difference between EBC2_ELT and ESO_ELT or between EBC2_LLT and ESO_LLT at the 20th-percentile exceedance, i.e., when the effect of climate change had been removed, likely a reflection of the fact that across all scenarios, drier years are very similar.

For the 80th-percentile exceedances compared across time periods, the difference in relative abundance between scenarios ranged from 25% lower under ESO_ELT compared to EBC2 for fall midwater trawl to around 40% lower when comparing ESO_LLT to EBC1/EBC2 for bay midwater and otter trawls. Relative abundance under the ESO_ELT scenario was 14-16% lower than the EBC2_ELT scenario for the three trawl types. There was little difference between EBC2_LLT and ESO_LLT at the 80th-percentile exceedance. Results for the HOS and LOS are described below.

**Table 5C.5.4-36. Estimated Longfin Smelt Relative Abundance Using the X2 Abundance Regression, December through May X2, 20th and 80th Exceedance Percentiles, Based on Trawl Data**

| | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| **Percentile** | **EBC1** | **EBC2** | **EBC2_ELT** | **EBC2_LLT** | **ESO_ELT** | **ESO_LLT** |
| **Fall Midwater Trawl** | | | | | | |
| 20th percentile | 1,659 | 1,640 | 1,588 | 1,357 | 1,550 | 1,331 |
| 80th percentile | 14,069 | 13,818 | 12,064 | 9,148 | 10,405 | 9,121 |
| **Bay Midwater Trawl** | | | | | | |
| 20th percentile | 2,910 | 2,869 | 2,760 | 2,286 | 2,682 | 2,234 |
| 80th percentile | 37,836 | 37,030 | 31,462 | 22,575 | 26,343 | 22,494 |
| **Bay Otter Trawl** | | | | | | |
| 20th percentile | 3,664 | 3,612 | 3,474 | 2,877 | 3,376 | 2,812 |
| 80th percentile | 47,632 | 46,618 | 39,608 | 28,420 | 33,164 | 28,318 |
| [a] See Table 5C.0-1 for definitions of scenarios. | | | | | | |

**Table 5C.5.4-37. Differences between EBC and ESO Scenarios for Longfin Smelt Estimated Relative Abundance Due to Differences in X2[a], Based on Trawl Survey Results**

| Percentile | Comparison[b] | Scenarios[c] EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
|---|---|---|---|---|---|---|---|
| **Fall Midwater Trawl** | | | | | | | |
| 20th | Difference | -109[b] | -328 | -90 | -309 | -38 | -26 |
| | Percent difference | -7% | -20% | -5% | -19% | -2% | -2% |
| 80th | Difference | -3,664 | -4,947 | -3,414 | -4,697 | -1,659 | -27 |
| | Percent difference | -26% | -35% | -25% | -34% | -14% | 0% |
| **Bay Midwater Trawl** | | | | | | | |
| 20th | Difference | -229 | -676 | -187 | -635 | -78 | -52 |
| | Percent difference | -8% | -23% | -7% | -22% | -3% | -2% |
| 80th | Difference | -11,492 | -15,342 | -10,687 | -14,536 | -5,119 | -81 |
| | Percent difference | -30% | -41% | -29% | -39% | -16% | 0% |
| **Bay Otter Trawl** | | | | | | | |
| 20th | Difference | -288 | -852 | -236 | -800 | -98 | -65 |
| | Percent difference | -8% | -23% | -7% | -22% | -3% | -2% |
| 80th | Difference | -14,468 | -19,314 | -13,454 | -18,300 | -6,444 | -102 |
| | Percent difference | -30% | -41% | -29% | -39% | -16% | 0% |

[a] Based on Kimmerer et al. (2009) January–June X2-abundance relationships.
[b] Negative values indicate lower longfin smelt abundance under ESO.
[c] See Table 5C.0-1 for definitions of scenarios.

Summaries of estimated longfin smelt relative abundance and differences between ESO and EBC scenarios based on this method averaged by water-year type from the X2-relative abundance regressions are provided in Table 5C.5.4-38, Table 5C.5.4-39, Table 5C.5.4-40, Table 5C.5.4-41, Table 5C.5.4-42, and Table 5C.5.4-43. Differences in relative abundance between ESO and EBC scenarios for the three trawls were greatest when comparing ESO_LLT scenarios to EBC2: The differences ranged from 22–26% lower under ESO_LLT in critical years to 34–40% lower under ESO_LLT in below normal years. Differences between ESO_ELT and EBC2 scenarios generally were around half of the difference between ESO_LLT and EBC2 scenarios. Accounting for climate change by comparing within the same time period, there was appreciably less difference between ESO and EBC2 scenarios. Averaged across all water years, the ESO_ELT scenario had 6–7% lower relative abundance than EBC2_ELT for the three trawls, with differences by water-year type ranging from 10% lower in below normal years to 1% lower in critical years. Averaged across all water years, the ESO_LLT scenario was little different (within 1–3%) from EBC2_LLT for the three trawls, with differences by water-year type ranging from 9 to 11% lower under ESO_LLT in below normal years to 5–7% higher under ESO_LLT in wet years.

**Table 5C.5.4-38. Estimated Longfin Smelt Relative Abundance in the Fall Midwater Trawl Based on the X2–Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| All | 8,897 | 8,754 | 7,871 | 5,861 | 7,395 | 5,938 |
| Wet | 18,917 | 18,621 | 16,631 | 11,880 | 15,722 | 12,493 |
| Above Normal | 10,059 | 9,889 | 9,060 | 7,063 | 8,375 | 6,795 |
| Below Normal | 4,478 | 4,344 | 3,954 | 3,141 | 3,624 | 2,850 |
| Dry | 2,313 | 2,290 | 2,051 | 1,799 | 1,917 | 1,694 |
| Critical | 1,057 | 1,084 | 999 | 887 | 992 | 849 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-39. Estimated Differences[a] between EBC and ESO Scenarios for Longfin Smelt Relative Abundance in the Fall Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| All | -1,502 (-17%) | -2,959 (-33%) | -1,359 (-16%) | -2,816 (-32%) | -475 (-6%) | 77 (1%) |
| Wet | -3,195 (-17%) | -6,423 (-34%) | -2,898 (-16%) | -6,127 (-33%) | -909 (-5%) | 614 (5%) |
| Above normal | -1,684 (-17%) | -3,264 (-32%) | -1,514 (-15%) | -3,094 (-31%) | -685 (-8%) | -267 (-4%) |
| Below normal | -855 (-19%) | -1,629 (-36%) | -721 (-17%) | -1,495 (-34%) | -331 (-8%) | -291 (-9%) |
| Dry | -396 (-17%) | -619 (-27%) | -373 (-16%) | -597 (-26%) | -134 (-7%) | -106 (-6%) |
| Critical | -65 (-6%) | -208 (-20%) | -92 (-9%) | -236 (-22%) | -7 (-1%) | -38 (-4%) |

[a] Negative values indicate lower longfin smelt abundance under ESO.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-40. Estimated Longfin Smelt Relative Abundance in the Bay Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| All | 24,195 | 23,738 | 20,908 | 14,503 | 19,509 | 14,935 |
| Wet | 55,411 | 54,378 | 47,576 | 31,675 | 44,801 | 33,943 |
| Above Normal | 25,643 | 25,160 | 22,683 | 16,796 | 20,629 | 16,096 |
| Below Normal | 9,695 | 9,372 | 8,393 | 6,355 | 7,527 | 5,638 |
| Dry | 4,404 | 4,352 | 3,811 | 3,252 | 3,500 | 3,017 |
| Critical | 1,717 | 1,771 | 1,600 | 1,384 | 1,585 | 1,311 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-41. Estimated Differences [a] between EBC and ESO Scenarios for Longfin Smelt Relative Abundance in the Bay Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| All | -4,686 (-19%) | -9,261 (-38%) | -4,229 (-18%) | -8,804 (-37%) | -1,399 (-7%) | 432 (3%) |
| Wet | -10,611 (-19%) | -21,468 (-39%) | -9,578 (-18%) | -20,435 (-38%) | -2,775 (-6%) | 2,268 (7%) |
| Above Normal | -5,014 (-20%) | -9,546 (-37%) | -4,530 (-18%) | -9,063 (-36%) | -2,054 (-9%) | -700 (-4%) |
| Below Normal | -2,168 (-22%) | -4,057 (-42%) | -1,845 (-20%) | -3,734 (-40%) | -866 (-10%) | -717 (-11%) |
| Dry | -904 (-21%) | -1,387 (-31%) | -852 (-20%) | -1,335 (-31%) | -311 (-8%) | -235 (-7%) |
| Critical | -132 (-8%) | -406 (-24%) | -186 (-10%) | -460 (-26%) | -15 (-1%) | -74 (-5%) |

[a] Negative values indicate lower longfin smelt abundance under ESO.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-42. Estimated Longfin Smelt Relative Abundance in the Bay Otter Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009).**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 | EBC2 | EBC2_ELT | EBC2_LLT | ESO_ELT | ESO_LLT |
| All | 30,460 | 29,885 | 26,322 | 18,258 | 24,561 | 18,802 |
| Wet | 69,759 | 68,458 | 59,895 | 39,877 | 56,401 | 42,732 |
| Above Normal | 32,282 | 31,674 | 28,557 | 21,145 | 25,971 | 20,264 |
| Below Normal | 12,205 | 11,798 | 10,566 | 8,000 | 9,476 | 7,098 |
| Dry | 5,545 | 5,479 | 4,797 | 4,094 | 4,406 | 3,798 |
| Critical | 2,162 | 2,230 | 2,015 | 1,743 | 1,996 | 1,650 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-43. Estimated Differences [a] between EBC and ESO Scenarios for Longfin Smelt Relative Abundance in the Bay Otter Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[b] | | | | | |
|---|---|---|---|---|---|---|
| | EBC1 vs. ESO_ELT | EBC1 vs. ESO_LLT | EBC2 vs. ESO_ELT | EBC2 vs. ESO_LLT | EBC2_ELT vs. ESO_ELT | EBC2_LLT vs. ESO_LLT |
| All | -5,899 (-19%) | -11,658 (-38%) | -5,324 (-18%) | -11,083 (-37%) | -1,761 (-7%) | 544 (3%) |
| Wet | -13,358 (-19%) | -27,026 (-39%) | -12,057 (-18%) | -25,726 (-38%) | -3,494 (-6%) | 2,856 (7%) |
| Above normal | -6,312 (-20%) | -12,018 (-37%) | -5,703 (-18%) | -11,410 (-36%) | -2,586 (-9%) | -881 (-4%) |
| Below normal | -2,729 (-22%) | -5,107 (-42%) | -2,322 (-20%) | -4,701 (-40%) | -1,090 (-10%) | -903 (-11%) |
| Dry | -1,139 (-21%) | -1,747 (-31%) | -1,072 (-20%) | -1,680 (-31%) | -391 (-8%) | -295 (-7%) |
| Critical | -166 (-8%) | -511 (-24%) | -234 (-10%) | -580 (-26%) | -19 (-1%) | -93 (-5%) |

[a] Negative values indicate lower longfin smelt abundance under ESO.
[b] See Table 5C.0-1 for definitions of scenarios.

The analysis for HOS and LOS was limited to the fall midwater trawl and bay midwater trawl X2-abundance regressions because the bay midwater trawl and bay otter trawl regression equations are very similar and yield virtually identical relative differences between scenarios. The EBC2_ELT vs. LOS_ELT and EBC2_LLT vs. LOS_LLT comparisons (Table 5C.5.4-44, Table 5C.5.4-45, Table 5C.5.4-46, Table 5C.5.4-47) yielded very similar results to the comparisons of EBC2_ELT vs. ESO_ELT and EBC2_LLT vs. ESO_LLT (Table 5C.5.4-38, Table 5C.5.4-39, Table 5C.5.4-40, and Table 5C.5.4-41), as would be expected given the generally similar January-June outflow under ESO and LOS. Averaged across all water-year types, HOS_ELT had 5% greater relative abundance than EBC2_ELT for the fall midwater trawl, and by water-year type the average relative abundance ranged from similar in critical years to 18% greater under the HOS_ELT scenario in below normal years (Table 5C.5.4-45). Also for the fall midwater trawl, the HOS_LLT scenario had 12% greater relative abundance than the EBC2_LLT scenario averaged across all years; this was driven by 12-14% greater average relative abundance in wet, above normal, and below normal years, whereas there was little or no difference in dry and critical years (Table 5C.5.4-45). Patterns of differences between HOS scenarios and EBC2 scenarios for the bay midwater trawl were similar to those for the fall midwater trawl, although the relative differences were slightly more pronounced because of the steeper X2-abundance regression slope for the bay midwater trawl (-0.06) compared to the fall midwater trawl (-0.05).

**Table 5C.5.4-44. Estimated Longfin Smelt Relative Abundance in the Fall Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009) for HOS, LOS, and EBC Scenarios**

| | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| **Water-Year Type** | **EBC2_ELT** | **EBC2_LLT** | **HOS_ELT** | **HOS_LLT** | **LOS_ELT** | **LOS_LLT** |
| All | 7,871 | 5,861 | 8,275 | 6,589 | 7,494 | 6,018 |
| Wet | 16,631 | 11,880 | 17,035 | 13,558 | 15,922 | 12,619 |
| Above normal | 9,060 | 7,063 | 10,009 | 7,999 | 8,490 | 6,991 |
| Below normal | 3,954 | 3,141 | 4,654 | 3,532 | 3,662 | 2,920 |
| Dry | 2,051 | 1,799 | 2,126 | 1,794 | 1,936 | 1,687 |
| Critical | 999 | 887 | 1,005 | 835 | 1,042 | 858 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-45. Differences[a] between EBC Scenarios and HOS and LOS Scenarios in Estimated Longfin Smelt Relative Abundance in the Fall Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| | Scenario[b] | | | |
|---|---|---|---|---|
| **Water-Year Type** | **EBC2_ELT vs. HOS_ELT** | **EBC2_LLT vs. HOS_LLT** | **EBC2_ELT vs. LOS_ELT** | **EBC2_LLT vs. LOS_LLT** |
| All | 404 (5%) | 727 (12%) | -377 (-5%) | 157 (3%) |
| Wet | 404 (2%) | 1,678 (14%) | -709 (-4%) | 739 (6%) |
| Above normal | 949 (10%) | 936 (13%) | -571 (-6%) | -72 (-1%) |
| Below normal | 699 (18%) | 391 (12%) | -292 (-7%) | -220 (-7%) |
| Dry | 75 (4%) | -6 (0%) | -115 (-6%) | -113 (-6%) |
| Critical | 6 (1%) | -51 (-6%) | 43 (4%) | -29 (-3%) |

[a] Negative values indicate lower longfin smelt abundance under ESO.
[b] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-46. Estimated Longfin Smelt Relative Abundance in the Bay Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009) for HOS, LOS, and EBC Scenarios**

| Water-Year Type | Scenario[a] | | | | | |
|---|---|---|---|---|---|---|
| | EBC2_ELT | EBC2_LLT | HOS_ELT | HOS_LLT | LOS_ELT | LOS_LLT |
| All | 20,908 | 14,503 | 22,075 | 16,778 | 19,804 | 15,167 |
| Wet | 47,576 | 31,675 | 48,786 | 37,069 | 45,467 | 34,349 |
| Above normal | 22,683 | 16,796 | 25,643 | 19,601 | 20,941 | 16,618 |
| Below normal | 8,393 | 6,355 | 10,205 | 7,345 | 7,613 | 5,797 |
| Dry | 3,811 | 3,252 | 3,990 | 3,250 | 3,540 | 3,003 |
| Critical | 1,600 | 1,384 | 1,610 | 1,289 | 1,681 | 1,328 |

[a] See Table 5C.0-1 for definitions of scenarios.

**Table 5C.5.4-47. Differences[a] between EBC Scenarios and HOS and LOS Scenarios in Estimated Longfin Smelt Relative Abundance in the Bay Midwater Trawl Based on the X2–Relative Abundance Regression of Kimmerer et al. (2009)**

| Water-Year Type | Scenario[b] | | | |
|---|---|---|---|---|
| | EBC2_ELT vs. HOS_ELT | EBC2_LLT vs. HOS_LLT | EBC2_ELT vs. LOS_ELT | EBC2_LLT vs. LOS_LLT |
| All | 1,167 (6%) | 2,275 (16%) | -1,104 (-5%) | 664 (5%) |
| Wet | 1,210 (3%) | 5,393 (17%) | -2,109 (-4%) | 2,674 (8%) |
| Above Normal | 2,960 (13%) | 2,805 (17%) | -1,743 (-8%) | -178 (-1%) |
| Below Normal | 1,812 (22%) | 990 (16%) | -780 (-9%) | -558 (-9%) |
| Dry | 180 (5%) | -2 (0%) | -270 (-7%) | -249 (-8%) |
| Critical | 10 (1%) | -96 (-7%) | 80 (5%) | -57 (-4%) |

[a] Negative values indicate lower longfin smelt abundance under ESO.
[b] See Table 5C.0-1 for definitions of scenarios.

It is possible that the nature of the Kimmerer et al. (2009) X2-relative abundance relationship could change as a result of BDCP conservation measures and non-BDCP actions. It has been recognized that the intercept of such regressions between longfin smelt and X2 or outflow has moved downward over time perhaps because of lower prey availability or other factors (Baxter et al. 2010), as represented by the step change included by Kimmerer et al. (2009). The inclusion of the post-1987 step change that was found by Kimmerer et al. (2009) was not required for the BDCP effects analysis as it would not change the relative difference between scenarios, given that the slope of the regression did not change. However, an upward shift in the regression's intercept as a result of BDCP or other actions would result in increase in the abundance of fish for a given outflow, which will be considered as part of the spring outflow decision tree process.