Appendix 11M Yolo and Sutter Bypass Flow and Weir Spill Analysis

11M.1 Introduction

This appendix includes methods and results for quantifying inundated floodplain habitat in the Yolo and Sutter Bypasses and inundated side-channel habitat in the Sacramento River for the No Action Alternative (NAA)[1] and Alternatives 1, 2, and 3. Inundated floodplain habitat is created by flows that spill from the Sacramento River into the Yolo Bypass at the Fremont and Sacramento Weirs and into the Sutter Bypass at Ord Ferry and at the Moulton, Colusa, and Tisdale Weirs. Inundated side-channel habitat is created by high flows in the Sacramento River that flood side channels along the main river channel. In addition to estimating acreage of suitable habitat in different months and water year types available under the NAA and Alternatives 1, 2, and 3, this appendix provides analyses for the Yolo and Sutter Bypasses of the frequency and duration of inundation events of different acreages and of weir spill events of different flows. Inundated floodplain and side-channel habitat habitats are important for early life stages of several fish species in the Sacramento River and its tributaries, especially Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss irideus*), and Sacramento splittail (*Pogonichthys macrolepidotus*). Juvenile Chinook salmon and steelhead use inundated habitat for juvenile rearing, and Sacramento splittail use it for spawning and for larval and juvenile rearing. The appendix includes an analysis of the carrying capacity of the inundated rearing habitat for rearing juvenile Chinook salmon available under the NAA and Alternatives 1, 2, and 3. The analysis of weir spills provides information on the possibility of fish entering the bypasses via weir spills, which is the principal means by which juvenile salmonid access the bypasses (Acierto et al. 2014). Because of their regulatory importance and their heavy reliance on inundated off-channel habitat, this appendix focuses on the three species listed above.

11M.2 Methods

11M.2.1 Bypass and Side-Channel Inundated Habitat Area

This analysis examines the surface area of suitable inundated floodplain and side-channel habitat that would be available under the NAA and Alternatives 1, 2, and 3. Inundated habitat with depths up to 1 meter, which correspond to optimal depths for rearing salmonids and steelhead in the Sacramento River drainage, was considered suitable for rearing salmonids and Sacramento splittail (Aceituno 1993; Hampton 1997; Sommer et al. 2002; U.S. Fish and Wildlife Service

[1] The term *NAA*, which is identical to the No Project Alternative, is used throughout Chapter 11, *Aquatic Biological Resources*, and associated aquatic resources appendices in the presentation of modeled results and represents no material difference from the No Project Alternative, as discussed in Chapter 3, *Environmental Analysis*.

2005; Merced Irrigation District 2013; Whipple et al. 2019). Note that splittail also spawn on inundated floodplains and side channels with depths from about 0.5 meter to 2 meters (Moyle 2002:149; Merced Irrigation District 2013). Flow velocity was not explicitly modeled because previous modeling showed that almost all inundated habitat in the bypasses has flows less than 1.5 feet per second (Appendix 11M1, *Acres of Yolo Bypass with Limiting Habitat Suitability Criteria (Depth < 1 meter deep and/or Flow Velocity < 1.5 feet per second) for Rearing Salmonids under Three Different Fremont Weir Spills Levels*), which is optimal for rearing salmonids and splittail (U.S. Fish and Wildlife Service 2005; Merced Irrigation District 2013; Whipple et al. 2019).

Daily estimates of the surface area of suitable inundated habitat were generated from HEC-RAS model runs using daily flow data (Upper Sacramento River Daily Operations Model [USRDOM]) for the NAA and Alternatives 1, 2, and 3. Yolo Bypass habitat area was estimated from flow spills at the Fremont and Sacramento Weirs, plus monthly westside stream flows disaggregated into daily flows using the historical flow patterns. Sutter Bypass habitat area was estimated using flows entering the Sutter Bypass from creeks on the east side of the bypass and from the Sacramento River at Ord Ferry and the Moulton, Colusa, and Tisdale Weirs on the west side. Inundated side-channel habitat was estimated for three reaches of the upper Sacramento River: Reach 1—Bend Bridge to Hamilton City; Reach 2—Hamilton City to Colusa; and Reach 3—Colusa to Knights Landing. The Reach 1 flow was computed as the flow at Bend Bridge minus the diversion flows at Red Bluff and Hamilton City. The Reach 2 and Reach 3 flows are the flows at Hamilton City and Colusa, respectively. Valley tributary inflow was not considered. A velocity criterion was not included for the side-channel habitat analysis. As such, suitable habitat area may be overestimated during low-flow periods when water velocity could be a limiting factor.

Flow versus habitat area curves were developed from the HEC-RAS modeling results (Figure 11M-1 through Figure 11M-5). The HEC-RAS modeling of habitat inundation area uses steady state-like flow conditions lasting 8 days or more. As a result, daily inundation areas were calculated based on the 8-day running averages of flow throughout the 82-year simulated flow data record, excluding the first 8 days. Note that suitable habitat plateaus in the Yolo Bypass at flows between about 4,000 cubic feet per second (cfs) and 11,000 cfs and in the Sutter Bypass at flows between 1,000 cfs and 3,000 cfs. Higher flows reduce the acreage of suitable habitat as the area of inundation with depth less than 1 meter declines. Note also that HEC-RAS modeling was focused on high-flow conditions to evaluate flow over Fremont Weir and was not tailored to low-flow conditions. For details on model development, calibration, and validation, see CH2M HILL Engineers, Inc. (2017).

In addition to the estimates of daily habitat acreage, frequencies of inundation events of different acreages and durations were estimated for the NAA and Alternatives 1, 2, and 3. For durations, the events were grouped into ranges: 8–17 days; 18–24 days; and over 24 days. For acreages, the events were grouped into different ranges for the three different regions (Yolo Bypass, Sutter Bypass, and Sacramento River side channels) analyzed, with the Yolo Bypass having categories with the largest acreages and the Sacramento River having categories with the smallest acreages.

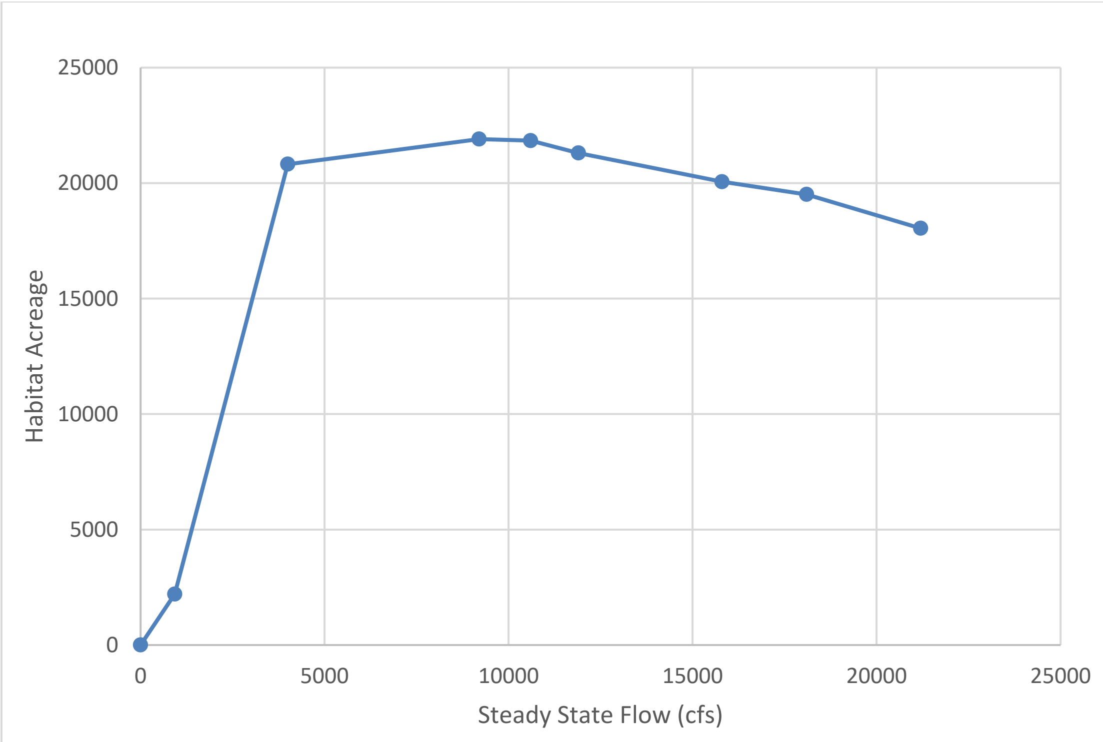

Figure 11M-1. Yolo Bypass Suitable (<1 Meter Deep) Habitat Acreage versus Total Bypass Flow.

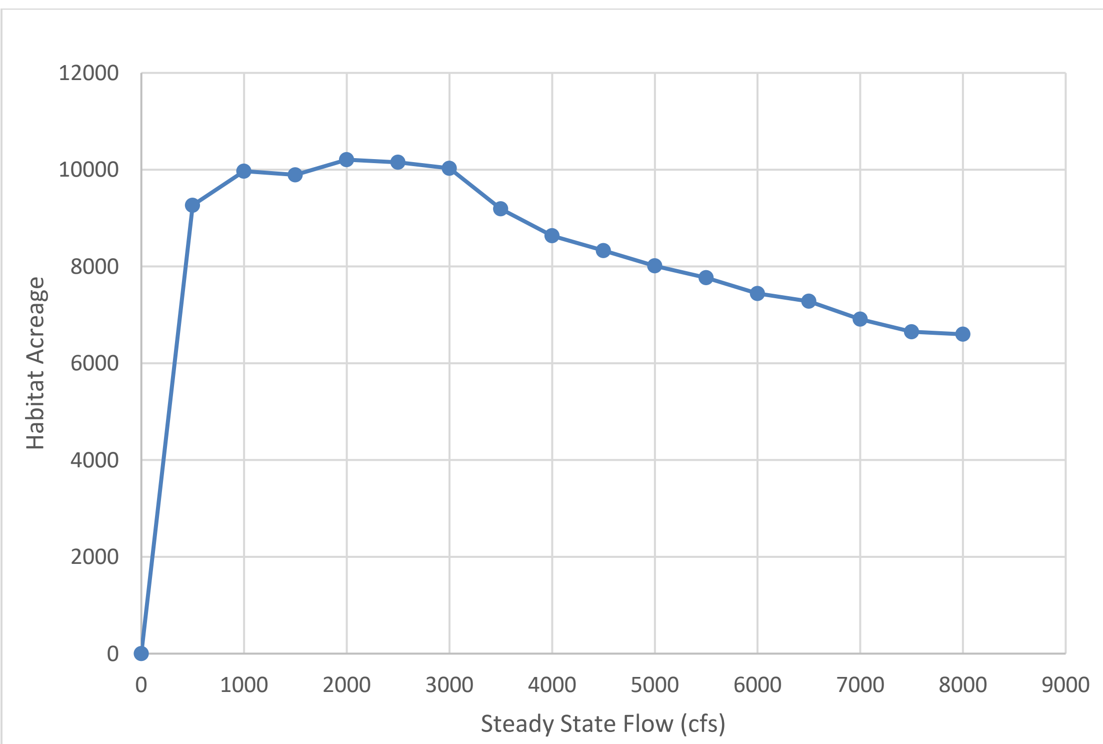

Figure 11M-2. Sutter Bypass Suitable (<1 Meter Deep) Habitat Acreage versus Total Bypass Flow.

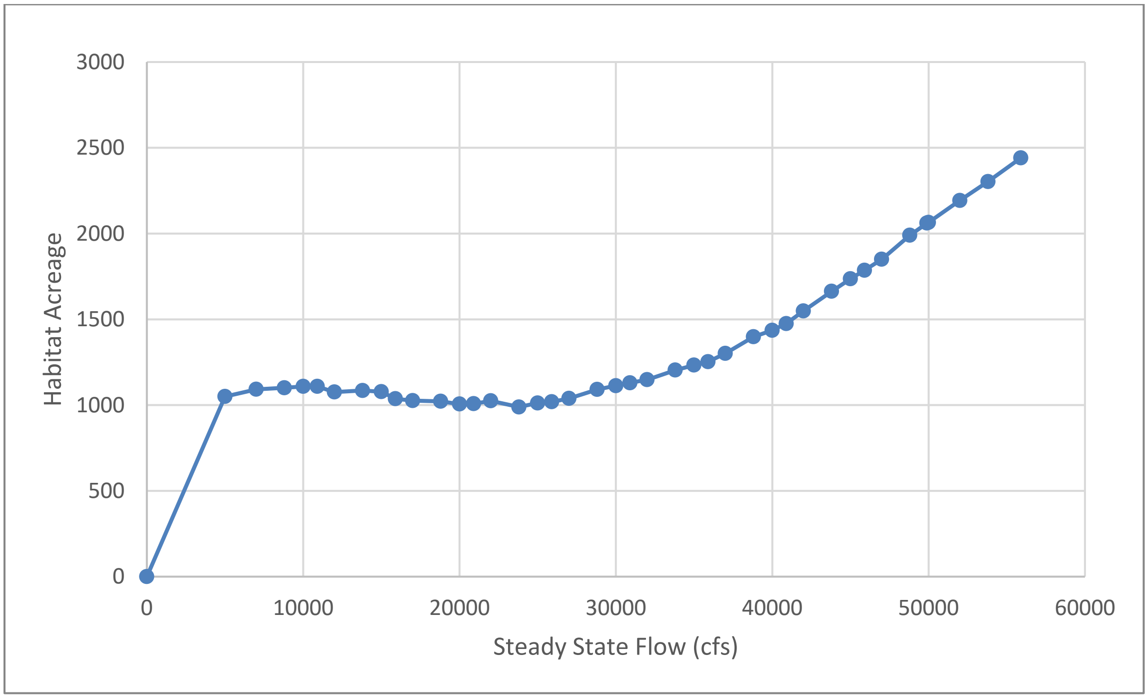

Figure 11M-3. Sacramento River Reach 1 (Bend Bridge to Hamilton City) Side-Channel Suitable (<1 Meter Deep) Habitat Acreage versus Bend Bridge Flow (minus Red Bluff and Hamilton City Diversions).

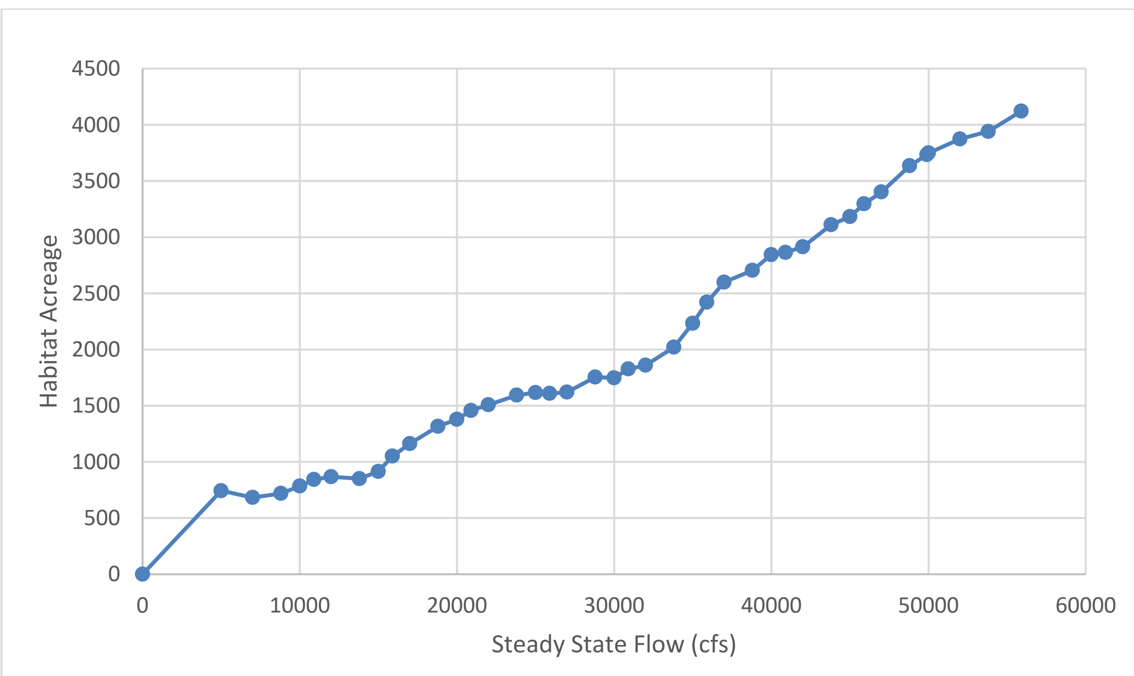

Figure 11M-4. Sacramento River Reach 2 (Hamilton City to Colusa) Side-Channel Suitable (<1 Meter Deep) Habitat Acreage versus Hamilton City Flow.

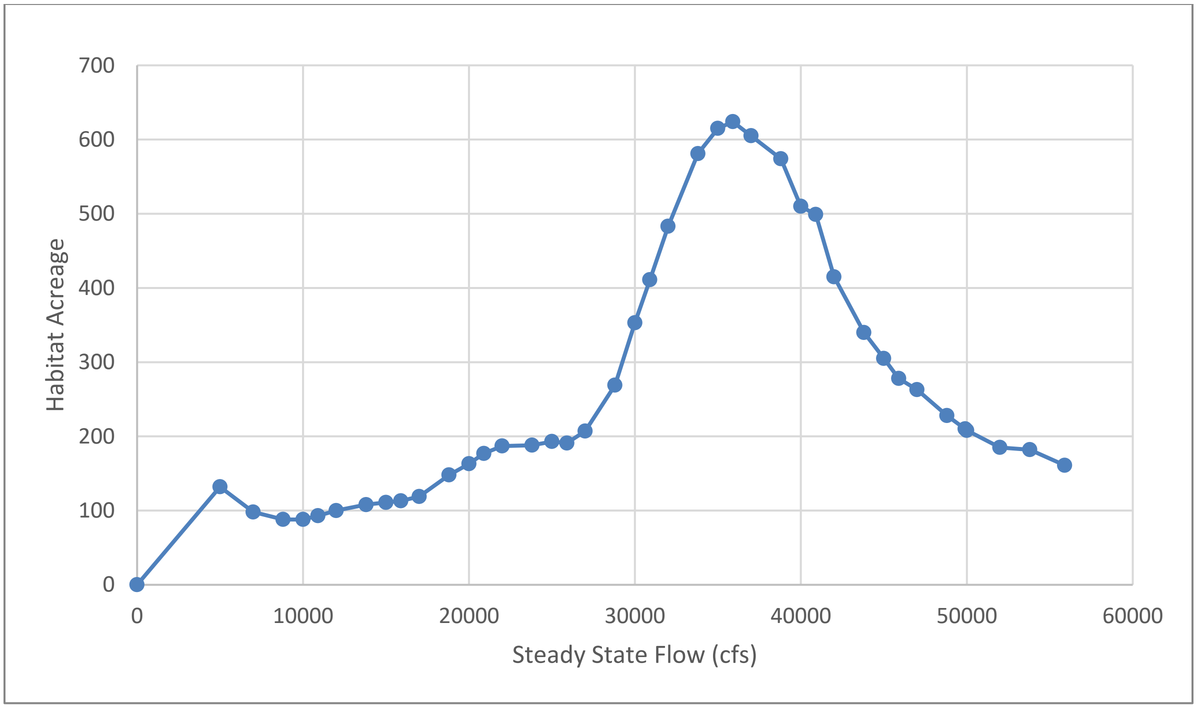

Figure 11M-5. Sacramento River Reach 3 (Colusa to Knights Landing) Side-Channel Suitable (<1 Meter Deep) Habitat Acreage versus Colusa Flow.

11M.2.2 Lower Sutter Bypass Inundated Habitat from Sacramento River Backflow

The lower Sutter Bypass is defined as the portion of the Sutter Bypass that extends from Nelson Slough to the Sacramento River. The Sutter Bypass joins the Sacramento River about 2 kilometers downstream of the Fremont Weir, which sits at the head of the Yolo Bypass. Portions of the lower Sutter Bypass may be inundated when elevated Sacramento River flow backs up into the bypass at its confluence with the river, potentially creating habitat for fish, including juvenile salmonids (Cordoleani et al. 2019). Upstream diversion of Sacramento River flow has the potential to reduce the flow of the river at its confluence with the lower bypass. If flow at the confluence would otherwise have been high enough to inundate the lower Sutter Bypass, such a reduction in river flow would potentially reduce the area of habitat with suitable depth for fish habitat.

The potential effects of Alternatives 1, 2, and 3 on inundation of the lower Sutter Bypass were evaluated by assessing their effects on the stage of the Sacramento River at Verona, which is located at the confluence of the bypass and the river. When river stage at Verona is high, changes in the stage may affect the surface area of bypass inundation (Cordoleani et al. 2019). Daily-patterned CALSIM II output of daily flow of the Sacramento River at Verona under the NAA and Alternatives 1, 2, and 3 were converted to estimates of river stage using the stage versus discharge rating table for the California Data Exchange Center gage at Verona (California Data Exchange Center 2022). The stage data were converted to NAVD88 to match the elevation data obtained from the California Department of Water Resources (DWR) for the lower Sutter Bypass. The surface area of the bypass inundated at different rivers stages was estimated from

DWR LiDAR, which provide ground elevation estimates for many locations within the lower bypass. The elevation and location data were converted to lower bypass surface areas for a range of elevations using GIS. The estimates of Sacramento River stage, converted to NAVD88 elevations, were used to estimate surface area inundated in the lower Sutter Bypass for any given flow at Verona (Figure 11M-6). Inundation increases rapidly with flow at Verona until about 50,000 cfs. Above this flow the Fremont Weir begins to spill and the rate of inundation increase slows (Cordoleani et al. 2019).

As described previously (Section 11M.2.1, *Bypass and Side-Channel Inundated Habitat Area*), suitable floodplain habitat for rearing juvenile salmonids is defined as inundated floodplain less than 1 meter deep. Surface areas of suitable habitat, therefore, were computed by subtracting the surface area of habitat for a depth 1 meter below the depth at the Verona gage from the total surface area of inundation computed for the depth at the gage. Suitable habitat acreage peaks when Sacramento River at Verona reaches about 50,000 cfs (Figure 11M-6).

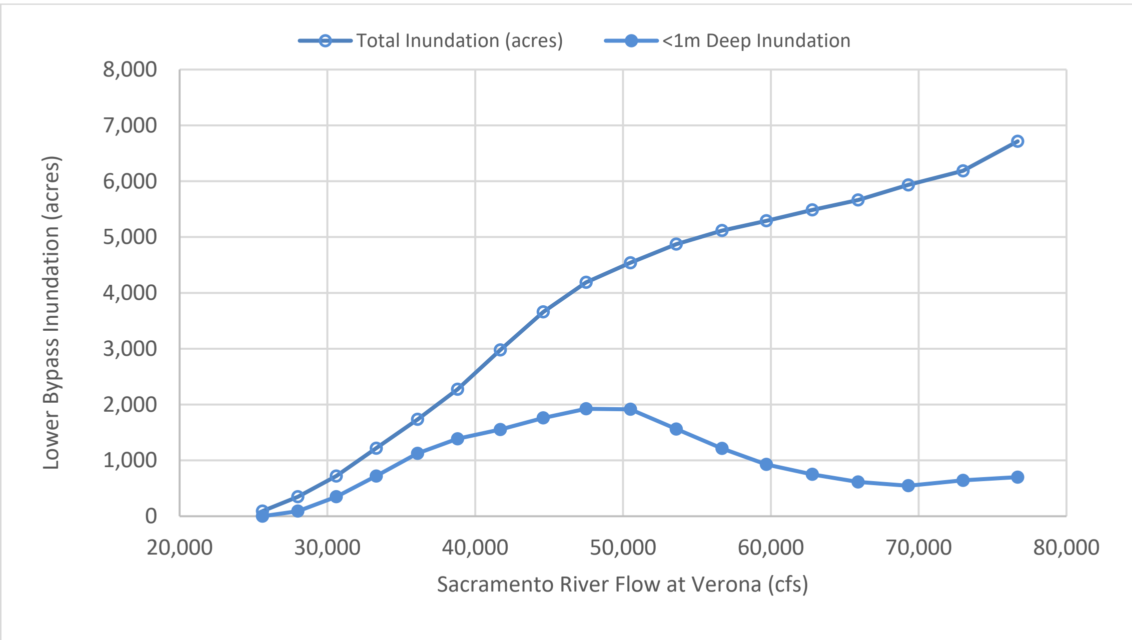

Figure 11M-6. Lower Sutter Bypass Total Inundated Acreage (open circles) and Inundated Acreage less than 1 Meter Deep versus Sacramento River Flow at Verona, Assuming No Inflow from the Upstream Portion of Sutter Bypass.

11M.2.3 Bypass Flow and Weir Spill

As discussed in the introduction, most juvenile salmonids likely enter the bypasses via weir spills (Acierto et al. 2014). The frequency, duration, and volume of the spills characterize the frequency and size of juvenile salmonid movements into the bypasses via the weir spills, although the exact relationship is uncertain. Note that the total flow in the bypass is not always a good indicator of suitable rearing habitat availability, as shown in Figures 11M-1 and 11M-2.

11M.2.3.1. Yolo Bypass

Daily Fremont Weir spill output from CALSIM II was used in the analysis of Fremont Weir spill events. Daily outputs from CALSIM II were based on a monthly-to-daily flow mapping technique applied in the model for a better representation of flows and spills along the Sacramento River between Red Bluff and Freeport. More information regarding CALSIM II's incorporation of daily variability is included in Appendix 5A7, *Daily Pattern Development for the Estimation of Daily Flows and Weir Spills in CALSIM II*. The number of years in the 82-year simulation period with at least one Fremont Weir spill event of varying sizes (0; 2,000; 4,000; 6,000; 8,000; and 10,000 cfs) with a duration of 0–10 days, 11–20 days, 21–30 days, 31–45 days, and over 45 days are calculated from the daily flow results. This analysis was limited to the October through April period in which most juvenile salmonids and spawning splittail would be present in the Yolo Bypass.

Daily total Yolo Bypass flow results used in the current analysis were estimated using the daily CALSIM II outputs of flow spills at Fremont and Sacramento Weirs, and monthly westside stream flows disaggregated into daily flows using the historical flow patterns.

11M.2.3.2. Sutter Bypass

Similar to the methodology used for the Yolo Bypass, modeled daily spill into the Sutter Bypass from the Sacramento River at Ord Ferry and the Moulton, Colusa, and Tisdale Weirs was used to examine the frequency, duration, and flow of total spill into the Sutter Bypass that could provide rearing habitat for salmonids and splittail. Spill (flow) at Ord Ferry, Moulton Weir, and Colusa Weir were combined to assess potential changes in the northern portion of the Sutter Bypass; total spill at Ord Ferry and the Moulton, Colusa, and Tisdale Weirs was combined to assess potential impacts in the central portion of the bypass; and total flow through the bypass was used as an indicator of potential changes in floodplain habitat in the southern portion of the bypass. The number of years where there is at least one event of spill over the weirs into the Sutter Bypass of varying amounts (0; 2,000; 4,000; 6,000; 8,000; and 10,000 cfs) with a duration of 0–10 days, 11–20 days, 21–30 days, 31–45 days, and greater than 45 days was calculated from the daily results. This analysis was limited to the October through April period in which juvenile salmonids are anticipated to enter the Sutter Bypass.

11M.2.4 Juvenile Chinook Salmon Rearing Habitat Carrying Capacity of Inundated Habitat Areas

A carrying capacity analysis was conducted to estimate and compare the number of rearing juvenile Chinook salmon that could be supported by the inundated rearing habitat available under the NAA and Alternatives 1, 2, and 3. This carrying capacity analysis is based on following data:

1) Acreages of inundated side-channel and floodplain habitat in the Sacramento River mainstem and Sutter and Yolo Bypasses.

2) The relationship between juvenile Chinook salmon size (i.e., length) and territory size.

3) The timing of entry of each of the four runs of Chinook salmon (winter, spring, fall, and late fall) to the study reach.

Daily acreages of inundated habitat in the Sacramento River mainstem, Sutter Bypass, and Yolo Bypass were quantified based on the methods described in Section 11M.2.1. The timing of juvenile Chinook salmon in the study area was estimated using the 10 most recent years of daily catch data from the U.S. Fish and Wildlife Service (USFWS) screw traps (available on SacPAS http://www.cbr.washington.edu/sacramento/, accessed 10/20/2022).

Predicted territory size need for individual juvenile Chinook salmon on each day was estimated from data on the size of juvenile Chinook salmon captured in USFWS screw traps (available on SacPAS http://www.cbr.washington.edu/sacramento/) and the length-territory size equation published in Grant and Kramer (1990):

$$Territory\ size\ (m^2) = 2.61 log_{10}(length) - 2.83$$

The mean length for each run of Chinook salmon captured was averaged each day to obtain the length value used in the equation above. The total acres of habitat available was converted to square meters and the carrying capacity was calculated as:

$$C_{i,j} = H_{i,j}/T_j$$

where $C_{i,j}$ is the carrying capacity of habitat i on day j, $H_{i,j}$ is the square meters of floodplain habitat available in habitat i on day j and T_j is the territory size needed by individual juvenile Chinook salmon on day j.

The mean monthly carrying capacity for all juvenile Chinook salmon races combined was computed for each of the major habitat areas (Yolo and Sutter Bypasses and Sacramento River mainstem) and for all the habitat areas combined. Results are provided for November through May, the months during which most rearing of juvenile salmon on floodplain habitats occurs.

11M.3 Results

11M.3.1 Yolo Bypass Weir Spill Events and Inundated Floodplain Habitat Area

Results for Yolo Bypass Fremont Weir spill events are provided in Appendix 11M2, *Yolo Bypass Spill Events*, Table 1. The results show that Alternatives 1, 2, and 3 would have fewer days of Fremont Weir spill than the NAA. Opportunities for juvenile salmonids to enter the Yolo Bypass for rearing are therefore somewhat reduced under Alternatives 1, 2, and 3 relative to the NAA.

Takata et al. (2017) examined various juvenile Chinook salmon biological responses to Yolo Bypass flooding, which they defined as the number of days from January through June with daily mean flows at the downstream end of Yolo Bypass greater than 4,000 cfs; this is the flow at which floodplain inundation occurs. Takata et al. (2017) found that growth and floodplain residence of coded-wire-tagged juvenile Chinook salmon and catch per unit effort of wild juvenile Chinook salmon are significantly positively related to the annual duration of Yolo

Bypass flooding (Takata et al. 2017:Figures 3 and 4c). Daily-downscaled CALSIM II modeling suggests that operations under Alternatives 1, 2, and 3 may reduce Yolo Bypass inundation from January through June by approximately 1 day across most water year types (Table 11M-1). A similar analysis was carried out for the September through June period to include other months in which juvenile salmonids, including winter-run Chinook salmon, might enter the Yolo Bypass. This analysis found reductions of no more than 2 days across all water year types. Given the variability in the observed biological relationships indicated by the spread in the data (Takata et al. 2017:Figures 3 and 4c), and no significant difference in survival to capture in ocean fisheries between coded-wire-tagged juvenile Chinook salmon released in the Yolo Bypass and those released at the same time in the Sacramento River (Takata et al. 2017), the small differences in Yolo Bypass inundation indicated by the CALSIM II modeling suggest that Alternatives 1, 2, and 3 are limited in their potential for negative effects on juvenile Chinook salmon, including winter-run.

Table 11M-1. Mean Annual Number of Days in January–June With Yolo Bypass Floodplain Inundation by Alternative and Water Year Type.

Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Wet	71	70 (-2%)	70 (-2%)	70 (-2%)	70 (-2%)
Above Normal	52	51 (-2%)	51 (-2%)	51 (-2%)	52 (-1%)
Below Normal	19	18 (-4%)	18 (-4%)	18 (-4%)	18 (-4%)
Dry	8	7 (-7%)	7 (-7%)	7 (-7%)	7 (-7%)
Critically Dry	4	4 (-2%)	4 (-2%)	4 (-2%)	4 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to NAA. Floodplain inundation is Yolo Bypass flow >4,000 cfs per Takata et al. (2017).

The modeling results of Yolo Bypass inundated habitat show considerable increases in mean inundation acreage under Alternatives 1, 2, and 3 relative to the NAA during August through October, including up to 805 acres for September of Above Normal Water Years under Alternatives 1A and 1B (Table 11M-2). These increases are the result of planned agricultural flow releases from Sites Reservoir. The releases reach the Yolo Bypass via the Colusa Basin Drain, entirely bypassing the Sacramento River. For this reason and because of the months in which they occur, these summer–fall increases in inundated acreage have no effect on most of the fish species of management concern that use the Yolo Bypass for spawning and rearing habitat in the winter and spring. Also, these summer increases may be overestimated because the HEC-RAS model used for the inundation evaluation was focused on high-flow conditions to evaluate flow over Fremont Weir and was not tailored to summer low-flow conditions.

For November through June, the model results range from no change to moderate reductions in Yolo Bypass mean daily habitat acreage under Alternatives 1, 2, and 3 (Table 11M-2). Absolute acreage reductions for this period range from minimums of no change during April of Critically Dry Water Years and May and June of all but Wet Water Years to maximums of over 426 to 457 acres during December of Below Normal Water Years under Alternatives 1, 2, and 3 (Table 11M-2). Almost all changes during this period consist of reductions in acreage. The majority of the reductions during December through March exceed 100 acres (Table 11M-2).The largest percentage reductions in acreage, 12%, occur in November of Below Normal Water Years under Alternatives 1, 2, and 3. In Table 11M-2, the habitat acreages (but not the differences) are reported in thousands of acres to save space in the table.

Table 11M-2. Estimated Mean Daily Inundated Habitat (Thousands of Acres <1 Meter Deep) for Juvenile Salmonids in the Yolo Bypass and Absolute Differences (Acres, in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	14.52	14.36 (-156)	14.28 (-237)	14.36 (-156)	14.28 (-238)
	Above Normal	10.65	10.36 (-286)	10.36 (-285)	10.36 (-284)	10.38 (-268)
	Below Normal	6.19	6.05 (-146)	6.02 (-174)	6.04 (-157)	6.01 (-182)
	Dry	1.79	1.76 (-34)	1.75 (-41)	1.76 (-34)	1.75 (-39)
	Critically Dry	1.42	1.37 (-45)	1.37 (-45)	1.37 (-45)	1.38 (-44)
	All	7.78	7.66 (-129)	7.62 (-161)	7.65 (-130)	7.62 (-160)
February	Wet	17.26	17.23 (-33)	17.23 (-33)	17.22 (-43)	17.22 (-42)
	Above Normal	17.22	16.95 (-264)	16.97 (-249)	16.94 (-274)	16.89 (-324)
	Below Normal	10.58	10.38 (-197)	10.4 (-177)	10.38 (-196)	10.42 (-153)
	Dry	4.58	4.37 (-217)	4.35 (-236)	4.37 (-217)	4.35 (-238)
	Critically Dry	1.34	1.3 (-31)	1.31 (-30)	1.31 (-30)	1.3 (-31)
	All	10.92	10.78 (-133)	10.79 (-132)	10.78 (-138)	10.78 (-141)
March	Wet	14.62	14.59 (-34)	14.57 (-53)	14.59 (-33)	14.68 (64)
	Above Normal	14.51	14.32 (-196)	14.31 (-205)	14.33 (-183)	14.3 (-216)
	Below Normal	5.33	5.08 (-243)	5.1 (-230)	5.09 (-241)	5.09 (-240)
	Dry	3.78	3.61 (-176)	3.6 (-178)	3.61 (-175)	3.62 (-166)
	Critically Dry	1.37	1.33 (-44)	1.33 (-44)	1.33 (-44)	1.33 (-44)
	All	8.63	8.5 (-125)	8.5 (-130)	8.51 (-122)	8.53 (-94)
April	Wet	11.37	11.24 (-132)	11.24 (-130)	11.24 (-132)	11.16 (-210)
	Above Normal	5.07	5.14 (67)	5.13 (64)	5.14 (66)	5.13 (58)
	Below Normal	1.31	1.3 (-3)	1.3 (-3)	1.3 (-3)	1.3 (-3)
	Dry	1.20	1.2 (-2)	1.2 (-2)	1.2 (-2)	1.2 (0)
	Critically Dry	0.52	0.52 (0)	0.52 (0)	0.52 (0)	0.52 (0)
	All	4.91	4.87 (-34)	4.87 (-34)	4.87 (-35)	4.85 (-60)
May	Wet	2.76	2.64 (-113)	2.64 (-111)	2.64 (-112)	2.65 (-110)
	Above Normal	0.82	0.82 (0)	0.82 (0)	0.82 (0)	0.82 (0)
	Below Normal	0.46	0.46 (0)	0.46 (0)	0.46 (0)	0.46 (0)
	Dry	0.27	0.27 (0)	0.27 (0)	0.27 (0)	0.27 (0)
	Critically Dry	0.17	0.17 (0)	0.17 (0)	0.17 (0)	0.17 (0)
	All	1.16	1.12 (-37)	1.12 (-36)	1.12 (-36)	1.12 (-36)
June	Wet	0.78	0.75 (-29)	0.75 (-28)	0.75 (-28)	0.75 (-28)
	Above Normal	0.16	0.16 (0)	0.16 (0)	0.16 (0)	0.16 (0)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Below Normal	0.16	0.16 (0)	0.16 (0)	0.16 (0)	0.16 (0)
	Dry	0.16	0.16 (0)	0.16 (0)	0.16 (0)	0.16 (0)
	Critically Dry	0.16	0.16 (0)	0.16 (0)	0.16 (0)	0.16 (0)
	All	0.36	0.35 (-9)	0.35 (-9)	0.35 (-9)	0.35 (-9)
July	Wet	0.12	0.11 (-12)	0.11 (-12)	0.11 (-12)	0.11 (-12)
	Above Normal	0.11	0.1 (-13)	0.1 (-13)	0.1 (-14)	0.1 (-13)
	Below Normal	0.11	0.1 (-6)	0.1 (-6)	0.1 (-7)	0.1 (-5)
	Dry	0.11	0.11 (-5)	0.11 (-5)	0.11 (-5)	0.11 (-5)
	Critically Dry	0.12	0.12 (-1)	0.12 (-1)	0.11 (-6)	0.12 (-1)
	All	0.12	0.11 (-9)	0.11 (-9)	0.11 (-10)	0.11 (-9)
August	Wet	0.32	1.02 (702)	1.02 (703)	1.02 (701)	1.02 (703)
	Above Normal	0.22	0.91 (685)	0.91 (685)	0.99 (762)	0.91 (685)
	Below Normal	0.25	0.62 (364)	0.62 (367)	0.68 (425)	0.56 (304)
	Dry	0.14	0.47 (324)	0.46 (313)	0.44 (302)	0.46 (318)
	Critically Dry	0.13	0.22 (91)	0.22 (93)	0.47 (343)	0.21 (78)
	All	0.23	0.69 (467)	0.69 (465)	0.75 (520)	0.68 (454)
September	Wet	0.21	1 (793)	0.97 (766)	1.03 (827)	0.95 (744)
	Above Normal	0.17	0.98 (805)	0.98 (805)	1.05 (878)	0.94 (773)
	Below Normal	0.28	0.63 (353)	0.55 (269)	0.64 (366)	0.57 (297)
	Dry	0.16	0.28 (116)	0.3 (134)	0.31 (146)	0.29 (129)
	Critically Dry	0.16	0.2 (37)	0.2 (33)	0.31 (147)	0.17 (9)
	All	0.20	0.65 (456)	0.63 (436)	0.7 (502)	0.62 (425)
October	Wet	0.24	1 (756)	0.93 (686)	1.02 (775)	0.83 (592)
	Above Normal	0.09	0.71 (625)	0.7 (608)	0.86 (768)	0.53 (439)
	Below Normal	0.64	0.95 (311)	0.9 (265)	0.96 (321)	0.91 (271)
	Dry	0.11	0.17 (67)	0.17 (67)	0.23 (123)	0.22 (116)
	Critically Dry	0.10	0.18 (75)	0.11 (3)	0.12 (11)	0.1 (0)
	All	0.24	0.65 (407)	0.6 (363)	0.68 (437)	0.56 (322)
November	Wet	1.34	1.36 (25)	1.34 (1)	1.37 (28)	1.34 (-4)
	Above Normal	1.20	1.25 (50)	1.25 (48)	1.27 (64)	1.25 (48)
	Below Normal	1.36	1.19 (-163)	1.19 (-163)	1.19 (-162)	1.2 (-161)
	Dry	0.66	0.6 (-61)	0.6 (-56)	0.6 (-55)	0.62 (-38)
	Critically Dry	0.05	0.06 (8)	0.05 (0)	0.05 (0)	0.05 (0)
	All	0.98	0.96 (-26)	0.95 (-34)	0.96 (-23)	0.95 (-31)
December	Wet	5.02	4.93 (-97)	4.92 (-109)	4.93 (-98)	4.92 (-101)
	Above Normal	5.89	5.59 (-297)	5.63 (-256)	5.6 (-292)	5.7 (-187)
	Below Normal	6.84	6.38 (-457)	6.41 (-426)	6.38 (-457)	6.4 (-433)
	Dry	4.85	4.84 (-7)	4.75 (-96)	4.84 (-7)	4.87 (24)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Critically Dry	0.92	0.91 (-10)	0.91 (-10)	0.91 (-10)	0.91 (-10)
	All	4.81	4.65 (-153)	4.64 (-166)	4.65 (-153)	4.68 (-128)

[1] Water year type sorting by hydrologic water years

A further summary of Yolo Bypass inundated habitat acreages gives the net effect of all the November through May changes between the NAA and Alternatives 1, 2, and 3 in habitat acreage (Table 11M-3). For this summary, the monthly means were computed for all daily habitat acreages from November through May for all water year types combined. The largest difference is a reduction of 164 acres for December under Alternative 1B, or 3.4% of the NAA acreage, and the largest difference for the entire November through May period is a reduction of 98 acres under Alternative 1B, a 1.8% reduction of the NAA acreage (Table 11M-3).

Table 11M-3. Mean Daily November through May Inundated Habitat (Acres <1 Meter Deep) for Juvenile Salmonids in the Yolo Bypass and the Absolute Differences (in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
November	970	945 (-25)	937 (-34)	948 (-22)	939 (-31)
December	4,760	4,609 (-151)	4,597 (-164)	4,609 (-151)	4,633 (-127)
January	7,949	7,825 (-125)	7,793 (-157)	7,823 (-126)	7,791 (-158)
February	10,897	10,765 (-132)	10,766 (-131)	10,760 (-137)	10,757 (-140)
March	8,526	8,402 (-124)	8,397 (-129)	8,405 (-122)	8,433 (-93)
April	4,950	4,916 (-34)	4,916 (-33)	4,916 (-34)	4,891 (-59)
May	1,261	1,225 (-36)	1,226 (-35)	1,225 (-36)	1,226 (-35)
All (Nov–May)	5,616	5,527 (-90)	5,519 (-98)	5,527 (-90)	5,524 (-92)

The fish species of management concern most likely to be affected by the changes in Yolo Bypass inundated suitable habitat are Chinook salmon, steelhead, and Sacramento splittail. Recent studies have shown that, when inundated by high flows in the winter and spring, the Yolo Bypass provides good rearing habitat for juvenile salmonids, as demonstrated by increased growth rates (Sommer et al. 2001a; Sommer et al. 2005; Hinkelman et al. 2017; Katz et al. 2017; Bellido-Leiva et al. 2021). Additionally, the Yolo Bypass is the most important spawning, nursery, and juvenile rearing habitat for Sacramento splittail (Sommer et al. 2001b, 2002, 2008; Moyle et al. 2004; Feyrer et al. 2006a, 2006b). These species use the Yolo Bypass during the winter and spring, the natural period for seasonal floodplain inundation in the Sacramento River Basin. By late summer and early fall, when Alternatives 1, 2, and 3 are expected to result in the largest percentage increases in Yolo Bypass inundation (Table 11M-2), rearing salmonids and Sacramento splittail have emigrated from the bypass, except for the relatively few trapped in pools (Sommer et al. 2005). Most of the fish species remaining in the bypass after mid-summer are nonnative species, including black bass (*Micropterus* spp.) and striped bass (*Morone saxatilis*), which are fish species (or species groups) of management concern (Sommer et al. 2001b, 2004).

Salmon and steelhead juveniles are most likely to enter the Yolo Bypass while rearing in and emigrating from the lower Sacramento River. California Department of Water Resources has a rotary screw trap (RST) at Knights Landing that is 8 kilometers upstream of Fremont Weir and provides the most reliable information on when the juveniles are most likely to access the Yolo Bypass, assuming the Fremont Weir is spilling (Acierto et al. 2014). Most of the catch of juvenile salmon and steelhead at Knights Landing occurs during October through May (Appendix 11A1, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*). Significant spilling of the Fremont Weir generally begins in November or December and may occur as late as May. One race or another of juvenile Chinook salmon or steelhead is likely to enter the Yolo Bypass during most of this period. Based on the Knights Landing RST data, the presence of the different races and species of juvenile salmon and steelhead near the Fremont Weir generally occurs as follows: winter-run from October through March, spring-run from December through April, fall-run from January through April, late fall–run from April through January, and steelhead from January through May. Once on the Yolo Bypass, the juveniles may remain for a month or more, depending on conditions (Sommer et al. 2005). On this basis, the March and April reductions in suitable habitat expected to result from Alternatives 1, 2, and 3 would potentially affect rearing juveniles of all four salmon races and steelhead. The largest differences in mean acreage for March and April are reductions of 230 to 243 acres (about 4.5%) during March of Below Normal Water Years under Alternatives 1, 2, and 3 (Table 11M-2). As noted above, almost all changes during December through March consist of reductions and many of the reductions exceed 100 acres, so Alternatives 1, 2, and 3 are expected to have a cumulative negative effect on habitat availability (Table 11M-2). However, when the changes in mean monthly acreage between the NAA and Alternatives 1, 2, and 3, irrespective of water year type, are examined, all reductions are less than 200 acres or 3.5% (Table 11M-3). The net effect on the Chinook salmon and steelhead rearing habitat is not expected to be substantial.

Of the three fish species of management concern, Sacramento splittail may benefit most from inundated floodplain habitat (Sommer et al. 2001b, Feyrer et al. 2005). Adult splittail begin their upstream spawning migrations from the Delta during winter and spring and spawn on the Yolo Bypass from late winter to late spring in years when the bypass is inundated. Timing of spawning depends on the timing of inundation, but most often peaks during March (Feyrer et al. 2006a). Egg incubation and larval development require a few weeks to a month, depending on water temperature (Moyle et al. 2004). The juveniles rear in the bypass for as long as conditions are suitable and typically return to the Delta from April through July (Feyrer et al. 2005),

Splittail benefit from Yolo Bypass inundation primarily during the spawning and rearing periods, which typically run from February through April or May. This period largely overlaps the timing of the greatest and most consistent habitat reductions associated with Alternatives 1, 2, and 3 (Table 11M-2). However, as noted above, the net effect of all daily differences between the NAA and Alternatives 1, 2, and 3 are small reductions in habitat acreage (Table 11M-3). Therefore, the habitat reductions are not expected to substantially affect Sacramento splittail spawning and rearing habitat.

As noted in the Section 11M.2, *Methods,* in addition to evaluating effects of Alternatives 1, 2, and 3 on mean daily habitat acreage, this report also examines effects of Alternatives 1, 2, and 3 on the frequency, duration and acreage of inundation events. This analysis is important because the value of inundated habitat varies with its duration and total acreage, and the value may be species-specific. For instance, the productivity of inundated floodplain habitat for juvenile salmonids is maximized after about 18 days of inundation and begins to diminish by about 24 days (Whipple et al. 2019). In contrast, Sacramento splittail require at least 30 days of inundation for completion of spawning, egg incubation, and larval development, after which the juveniles are large and strong enough to emigrate more safely from the floodplain (Feyrer et al. 2006a).

The results of the frequency analysis of inundation of events for the Yolo Bypass generally show only minor difference between Alternatives 1, 2, and 3 and the NAA (Figure 11M-7). However, there are reductions in frequency for Alternatives 1, 2, and 3 compared to the NAA for events of 15,000 to 20,000 acres lasting 8 to 17 days, with frequencies ranging from once per 3.8 years for Alternative 1A to once per 2.9 years for the NAA. There are increases for Alternatives 1A and 1B for events of >20,000 acres lasting 18 to 24 days, with frequencies ranging from once per 4.7 years for the NAA to once per 4.3 years for Alternatives 1B. As noted above, inundation lasting 18–24 days has been shown to result in maximum habitat productivity for juvenile salmonids in field studies (Whipple et al. 2019). The differences in frequencies of inundation events of varying duration and acreage show no consistent differences between the NAA and Alternatives 1, 2, and 3. Tables providing the results plotted in Figure 11M-7 and frequency of inundation tables for every month are provided in Appendix 11M3, *Average Monthly and Average Annual Number of Yolo Bypass Inundation Events with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3*.

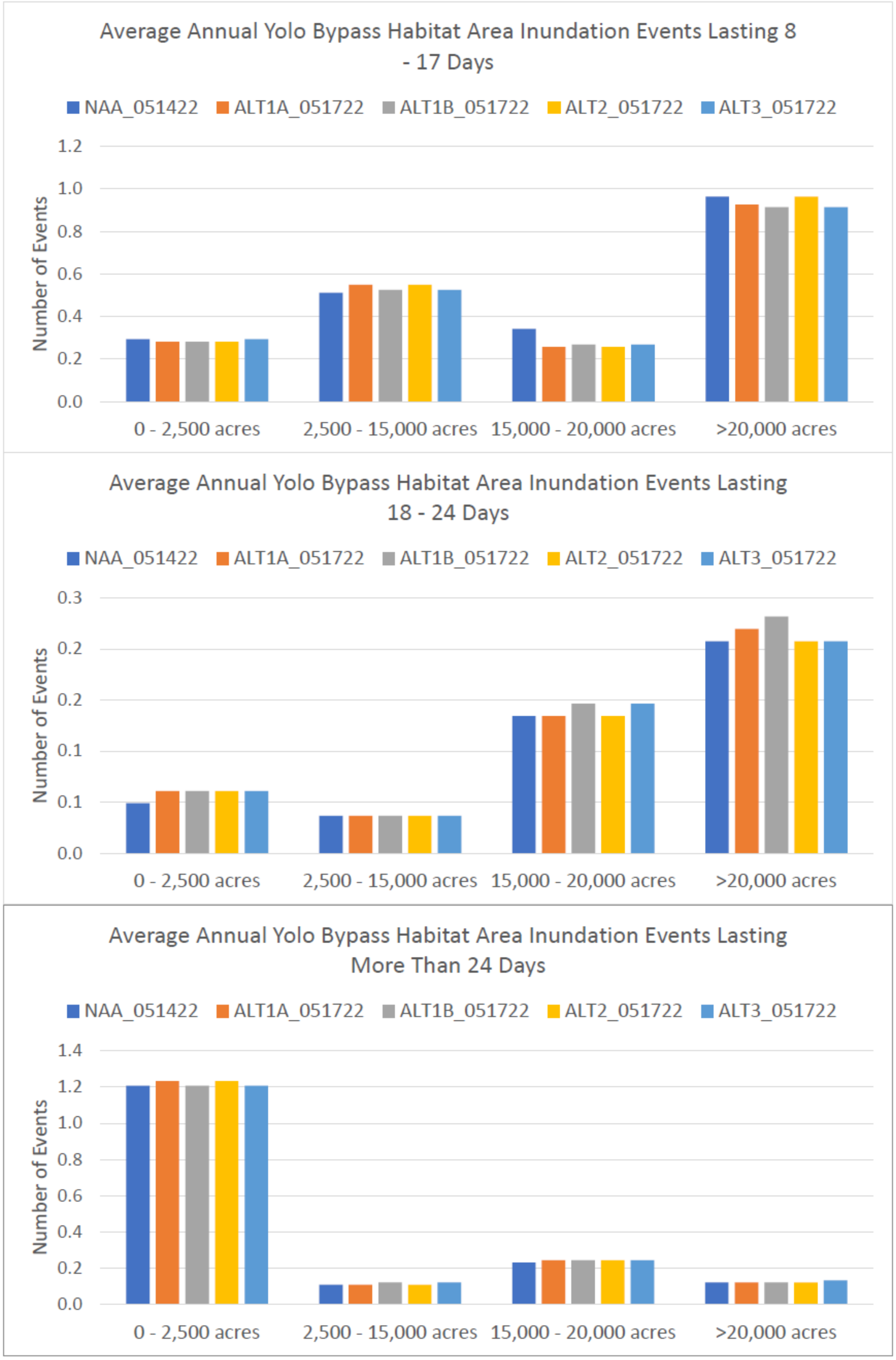

Figure 11M-7. Average Annual Number of Yolo Bypass Inundation Events with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

11M.3.2 Sutter Bypass Weir Spill Events and Inundated Floodplain Habitat Area

Results for the Sutter Bypass weir spill events are provided in Appendix 11M4, *Sutter Bypass Weir Spill Events*, Tables 1 through 4. The results indicate that there would be fewer weir spill events into the Sutter Bypass under Alternatives 1, 2, and 3 than the NAA, especially for spills lasting 30–45 days and spills lasting more than 45 days. This result indicates that opportunities for juvenile salmonids to enter the Sutter Bypass for rearing would be lower under Alternatives 1, 2, and 3 relative to the NAA. Note that flow in the Sutter Bypass greater than 3,000 cfs results in reduction of suitable habitat (Figure 11M-2).

The Sutter Bypass when inundated, as discussed for the Yolo Bypass, provides important rearing habitat for juvenile Chinook salmon and steelhead and spawning and rearing habitat for Sacramento splittail (Moyle et al. 2004; Feyrer et al. 2006b; Cordoleani et al. 2020a; Bellido-Leiva et al. 2021). For the Sutter Bypass, the modeling results indicate that Alternatives 1, 2, and 3 would produce very little change in suitable habitat compared to the NAA (Table 11M-4). The largest differences are increases of 42 acres for January of Above Normal Water Years under Alternatives 1, 2, and 3 and increases of about 45 acres for February of Above Normal Water Years under Alternatives 1A, 1B, and 2. The largest reduction is 17 acres for December of Dry Water Years under Alternative 3. All differences are less than 1%. The results of the frequency analysis of inundation events similarly show little to no differences between the NAA and Alternatives 1, 2, and 3 (Figure 11M-8). The largest differences are 6% to 10% increases in frequency of events under Alternatives 1, 2, and 3 for 6,500- to 8,000-acre events lasting 18–24 days, and 6% reductions for the same range of acreages lasting over 24 days. Tables providing the results plotted in Figure 11M-8 and frequency of inundation tables for every month are provided in Appendix 11M5, *Average Monthly and Average Annual Number of Sutter Bypass Inundation Events with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3*. Alternatives 1, 2, and 3 are expected to have little effect on availability of suitable inundated fish habitat in the Sutter Bypass.

Table 11M-4. Estimated Mean Daily Inundated Habitat (Acres <1 Meter Deep) for Juvenile Salmonids in the Sutter Bypass and the Absolute Differences (Acres, in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	7,992	8,004 (12)	8,007 (15)	8,004 (12)	8,007 (15)
	Above Normal	8,093	8,135 (42)	8,135 (42)	8,135 (42)	8,135 (42)
	Below Normal	8,373	8,390 (17)	8,386 (13)	8,391 (18)	8,387 (14)
	Dry	8,308	8,314 (6)	8,313 (5)	8,314 (6)	8,312 (4)
	Critically Dry	7,688	7,695 (7)	7,695 (7)	7,695 (7)	7,695 (7)
	All	8,097	8,112 (15)	8,112 (15)	8,112 (15)	8,112 (15)
February	Wet	7,578	7,608 (30)	7,608 (30)	7,604 (26)	7,613 (35)
	Above Normal	7,748	7,792 (44)	7,793 (45)	7,792 (44)	7,763 (15)
	Below Normal	8,703	8,730 (27)	8,730 (27)	8,730 (27)	8,729 (26)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	8,727	8,751 (24)	8,751 (24)	8,751 (24)	8,751 (24)
	Critically Dry	8,536	8,545 (9)	8,545 (9)	8,545 (9)	8,545 (9)
	All	8,194	8,220 (26)	8,220 (26)	8,219 (25)	8,218 (24)
March	Wet	7,997	8,007 (10)	8,017 (20)	8,003 (6)	8,020 (23)
	Above Normal	8,160	8,185 (25)	8,187 (27)	8,184 (24)	8,192 (32)
	Below Normal	9,094	9,120 (26)	9,121 (27)	9,120 (26)	9,135 (41)
	Dry	9,165	9,170 (5)	9,193 (28)	9,170 (5)	9,168 (3)
	Critically Dry	9,041	9,042 (1)	9,042 (1)	9,042 (1)	9,042 (1)
	All	8,623	8,635 (12)	8,644 (21)	8,634 (11)	8,643 (20)
April	Wet	8,243	8,257 (14)	8,257 (14)	8,257 (14)	8,262 (19)
	Above Normal	9,047	9,063 (16)	9,057 (10)	9,058 (11)	9,057 (10)
	Below Normal	9,508	9,516 (8)	9,516 (8)	9,516 (8)	9,516 (8)
	Dry	9,455	9,455 (0)	9,467 (12)	9,455 (0)	9,456 (1)
	Critically Dry	8,791	8,791 (0)	8,791 (0)	8,791 (0)	8,791 (0)
	All	8,921	8,929 (8)	8,931 (10)	8,929 (8)	8,930 (9)
May	Wet	9,203	9,209 (6)	9,209 (6)	9,209 (6)	9,210 (7)
	Above Normal	9,608	9,608 (0)	9,608 (0)	9,608 (0)	9,608 (0)
	Below Normal	9,371	9,368 (-3)	9,368 (-3)	9,368 (-3)	9,369 (-2)
	Dry	9,018	9,018 (0)	9,018 (0)	9,018 (0)	9,018 (0)
	Critically Dry	8,166	8,166 (0)	8,166 (0)	8,166 (0)	8,166 (0)
	All	9,092	9,094 (2)	9,094 (2)	9,094 (2)	9,095 (3)
June	Wet	9,273	9,274 (1)	9,274 (1)	9,274 (1)	9,274 (1)
	Above Normal	8,816	8,816 (0)	8,816 (0)	8,816 (0)	8,816 (0)
	Below Normal	8,358	8,358 (0)	8,358 (0)	8,358 (0)	8,358 (0)
	Dry	7,755	7,755 (0)	7,755 (0)	7,755 (0)	7,755 (0)
	Critically Dry	6,736	6,736 (0)	6,736 (0)	6,736 (0)	6,736 (0)
	All	8,340	8,340 (0)	8,340 (0)	8,340 (0)	8,340 (0)
July	Wet	8,213	8,213 (0)	8,213 (0)	8,213 (0)	8,213 (0)
	Above Normal	7,299	7,299 (0)	7,299 (0)	7,299 (0)	7,299 (0)
	Below Normal	6,271	6,271 (0)	6,271 (0)	6,271 (0)	6,271 (0)
	Dry	5,254	5,254 (0)	5,254 (0)	5,254 (0)	5,254 (0)
	Critically Dry	4,118	4,118 (0)	4,118 (0)	4,118 (0)	4,118 (0)
	All	6,489	6,489 (0)	6,489 (0)	6,489 (0)	6,489 (0)
August	Wet	7,187	7,187 (0)	7,187 (0)	7,187 (0)	7,187 (0)
	Above Normal	5,838	5,838 (0)	5,838 (0)	5,838 (0)	5,838 (0)
	Below Normal	4,257	4,257 (0)	4,257 (0)	4,257 (0)	4,257 (0)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	3,204	3,204 (0)	3,204 (0)	3,204 (0)	3,204 (0)
	Critically Dry	2,447	2,447 (0)	2,447 (0)	2,447 (0)	2,447 (0)
	All	4,910	4,910 (0)	4,910 (0)	4,910 (0)	4,910 (0)
September	Wet	6,644	6,644 (0)	6,644 (0)	6,644 (0)	6,644 (0)
	Above Normal	5,553	5,553 (0)	5,553 (0)	5,553 (0)	5,553 (0)
	Below Normal	3,682	3,682 (0)	3,682 (0)	3,682 (0)	3,682 (0)
	Dry	3,385	3,385 (0)	3,385 (0)	3,385 (0)	3,385 (0)
	Critically Dry	2,346	2,346 (0)	2,346 (0)	2,346 (0)	2,346 (0)
	All	4,623	4,623 (0)	4,623 (0)	4,623 (0)	4,623 (0)
October	Wet	7,048	7,048 (0)	7,048 (0)	7,048 (0)	7,048 (0)
	Above Normal	6,642	6,642 (0)	6,642 (0)	6,642 (0)	6,642 (0)
	Below Normal	5,333	5,337 (4)	5,336 (3)	5,337 (4)	5,336 (3)
	Dry	4,842	4,842 (0)	4,842 (0)	4,842 (0)	4,842 (0)
	Critically Dry	3,325	3,325 (0)	3,325 (0)	3,325 (0)	3,325 (0)
	All	5,655	5,655 (0)	5,655 (0)	5,655 (0)	5,655 (0)
November	Wet	8,197	8,197 (0)	8,197 (0)	8,197 (0)	8,195 (-2)
	Above Normal	7,549	7,549 (0)	7,549 (0)	7,549 (0)	7,549 (0)
	Below Normal	7,141	7,141 (0)	7,141 (0)	7,141 (0)	7,142 (1)
	Dry	6,597	6,597 (0)	6,597 (0)	6,597 (0)	6,597 (0)
	Critically Dry	6,001	6,001 (0)	6,001 (0)	6,001 (0)	6,001 (0)
	All	7,245	7,246 (1)	7,246 (1)	7,246 (1)	7,245 (0)
December	Wet	8,294	8,314 (20)	8,316 (22)	8,314 (20)	8,315 (21)
	Above Normal	8,020	8,042 (22)	8,044 (24)	8,042 (22)	8,015 (-5)
	Below Normal	7,449	7,481 (32)	7,480 (31)	7,481 (32)	7,466 (17)
	Dry	7,745	7,758 (13)	7,742 (-3)	7,757 (12)	7,728 (-17)
	Critically Dry	7,447	7,447 (0)	7,447 (0)	7,447 (0)	7,447 (0)
	All	7,863	7,881 (18)	7,878 (15)	7,881 (18)	7,868 (5)

[1] Water year type sorting by hydrologic water years

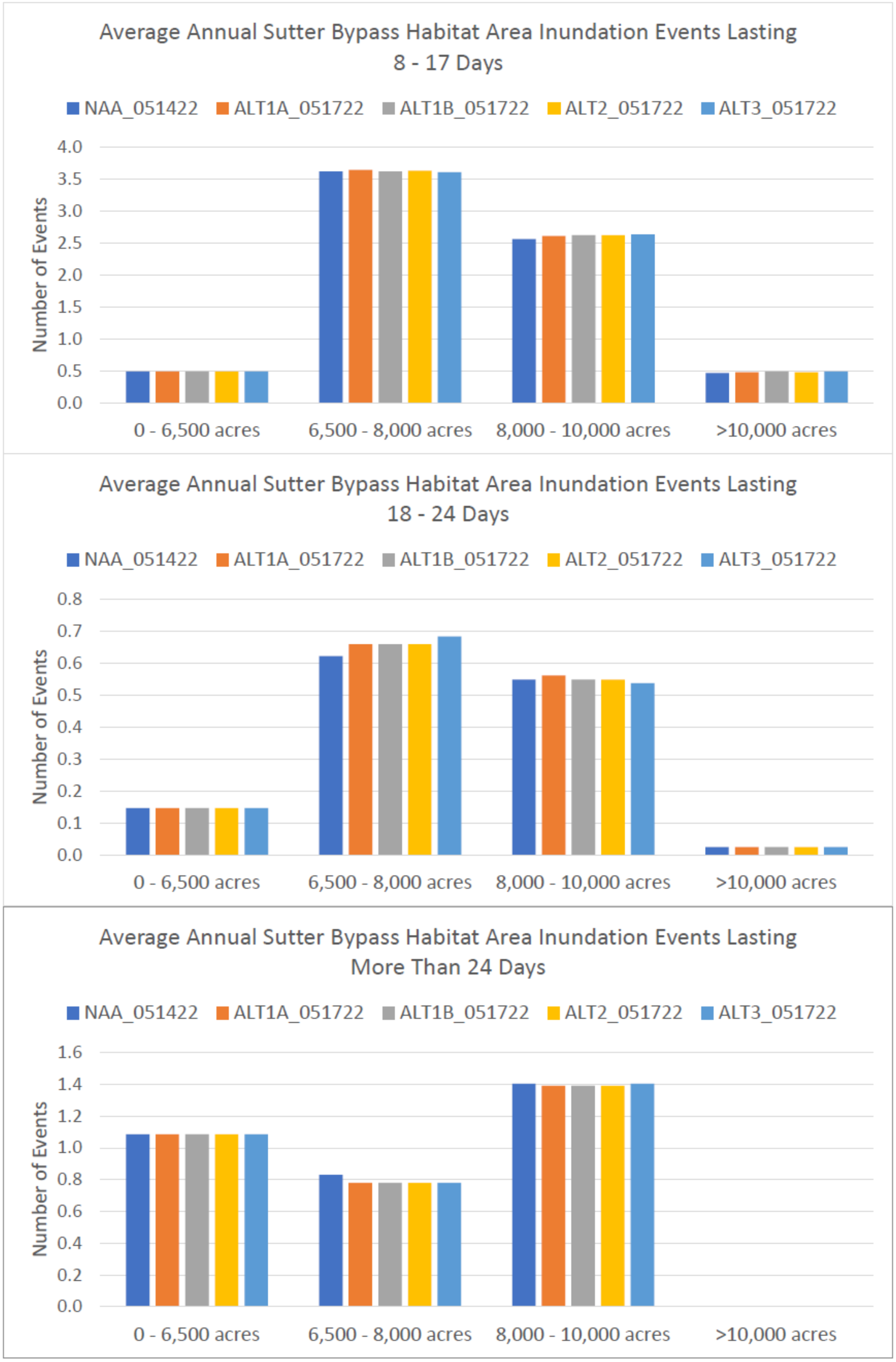

Figure 11M-8. Average Annual Number of Sutter Bypass Inundation Events with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

11M.3.3 Lower Sutter Bypass Inundated Habitat

As described in Section 11M.2.2, *Lower Sutter Bypass Inundated Habitat from Sacramento River Backflow*, portions of the lower Sutter Bypass may be inundated when elevated Sacramento River flow backs up into the bypass at its confluence with the river, potentially creating habitat for fish, including juvenile salmonids. The results of the lower Sutter Bypass suitable habitat analysis show that suitable habitat acreage under all the alternatives is greatest in Wet Water Years and lowest in Critically Dry Water Years, as expected (Table 11M-5). The acreages for inundation at all depths (not shown) are typically several times as high as those for suitable habitat (<1 meter deep) alone. The highest acreages of suitable habitat occur during January through March in all water year types. In general, the acreages of suitable habitat produced in the lower Sutter Bypass are small relative to those created by inundation of the upper Sutter Bypass (Table 11M-4) or the Yolo Bypass (Table 11M-2). As discussed above in Section 11M.3.1, *Yolo Bypass Weir Spill Events and Inundated Floodplain Habitat Area*, most of the catch of juvenile salmon and steelhead at Knights Landing occurs during October through May, so this is considered the most important period for juvenile salmonid rearing in the lower Sutter Bypass.

The acreage of suitable habitat in the lower Bypass is lower under Alternatives 1, 2, and 3 than under the NAA in most water year types and months for which there are differences (Table 11M-5). Reductions in means are three and a half times more frequent than increases. The largest reductions in acreage are about 50 acres in February of Above Normal Water Years under Alternative 3 and about 40 acres in January of Above Normal Water Years under all the alternatives. Reductions of more than 30 acres also occur under all the alternatives in December of Wet Water Years, March of Below Normal Water Years, and February of Dry Water Years (Table 11M-5). The largest increases in acreage are between 10 and 20 acres for Alternatives 1, 2, and 3 in February of Wet Water Years and April of Above Normal Water Years. The habitat reductions predicted for the lower Sutter Bypass are small relative to the habitat acreages available in the upper Sutter Bypass (Table 11M-4) and the Yolo Bypass (Table 11M-2).

In general, these results indicate that lower Sutter Bypass suitable habitat created by Sacramento River backflow would be lower under the Alternatives 1, 2, and 3 than the NAA. However, these differences are relatively small and unlikely to affect overall salmonid or splittail production. As noted above, the amount of suitable habitat created on the lower Sutter Bypass under the NAA and Alternatives 1, 2, and 3 is low compared to most other areas of inundated habitat.

Table 11M-5. Mean Lower Sutter Bypass Inundated Suitable Habitat (acres) for the NAA and Alternatives 1, 2, and 3 and the Absolute Differences in Acres (in parentheses).

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Wet	January	804	789 (-14.9)	778 (-25.9)	789 (-14.9)	776 (-28.6)
	February	942	955 (13.6)	957 (14.9)	954 (12)	953 (11.7)
	March	889	882 (-7.2)	875 (-13.5)	880 (-9)	900 (10.8)
	April	777	774 (-2.6)	774 (-2.6)	774 (-2.9)	777 (0.1)

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	May	565	558 (-6.3)	558 (-6.2)	559 (-6.1)	559 (-6.1)
	June	203	204 (0.8)	204 (0.7)	204 (0.8)	204 (0.7)
	July	7	7 (0)	8 (0.2)	7 (0)	8 (0.2)
	August	0	0 (0)	0 (0)	0 (0)	0 (0)
	September	23	23 (0.7)	24 (1)	24 (1.2)	24 (1.1)
	October	21	9 (-12.3)	9 (-12)	9 (-12.3)	10 (-11.2)
	November	136	119 (-17.2)	118 (-17.9)	119 (-17.2)	121 (-15.4)
	December	530	495 (-35.4)	496 (-34.1)	495 (-35.1)	497 (-32.9)
	All	405	398 (-6.9)	397 (-8.2)	398 (-7.1)	399 (-6)
Above Normal	January	619	580 (-39.9)	579 (-40)	580 (-39.9)	583 (-36.7)
	February	898	865 (-32.9)	872 (-26.6)	861 (-37)	848 (-50.5)
	March	788	778 (-10.1)	767 (-20.6)	778 (-10.1)	755 (-33)
	April	337	356 (18.7)	357 (20.2)	353 (16.2)	349 (12.1)
	May	231	230 (-0.5)	230 (-0.6)	230 (-0.5)	230 (-0.7)
	June	32	32 (0)	32 (0)	32 (0)	32 (0)
	July	21	21 (0)	23 (1.8)	21 (0)	25 (3.7)
	August	0	0 (0)	0 (0)	0 (0)	0 (0)
	September	30	30 (-0.1)	31 (0.8)	30 (0)	33 (2.7)
	October	0	0 (0)	0 (0)	0 (0)	0 (0)
	November	32	25 (-7.3)	25 (-7.3)	25 (-7.3)	25 (-7.4)
	December	210	199 (-10.7)	201 (-9.2)	199 (-10.7)	194 (-15.5)
	All	264	257 (-6.8)	257 (-6.8)	256 (-7.3)	253 (-10.3)
Below Normal	January	160	140 (-20.7)	133 (-27.5)	137 (-23.5)	133 (-27.2)
	February	523	490 (-33.2)	501 (-22.4)	488 (-35.6)	514 (-9.2)
	March	147	112 (-35)	112 (-35)	113 (-34.7)	111 (-36.5)
	April	110	101 (-9)	103 (-7.7)	101 (-9)	100 (-10.1)
	May	21	21 (0)	21 (0)	21 (0)	21 (0)
	June	0	0 (0)	0 (0)	0 (0)	0 (0)
	July	0	0 (0)	0 (0)	0 (0)	0 (0)
	August	5	5 (0.3)	5 (0.3)	5 (0.2)	5 (0.1)
	September	4	4 (0.1)	4 (0.5)	4 (0.1)	4 (0.3)
	October	0	0 (0)	0 (0)	0 (0)	0 (0)
	November	0	0 (0)	0 (0)	0 (0)	0 (0)
	December	80	75 (-5.6)	75 (-5.6)	75 (-5.6)	75 (-5.6)
	All	85	77 (-8.5)	77 (-8.1)	76 (-8.9)	78 (-7.4)

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Dry	January	60	54 (-6)	54 (-6.2)	54 (-6)	54 (-6.3)
	February	206	175 (-31.3)	175 (-31.1)	175 (-31.3)	175 (-31.3)
	March	166	142 (-24.4)	141 (-24.7)	142 (-24.4)	141 (-25.5)
	April	12	12 (0.1)	12 (0.1)	12 (0.1)	12 (0.1)
	May	0	0 (0)	0 (0)	0 (0)	0 (0)
	June	0	0 (0)	0 (0)	0 (0)	0 (0)
	July	1	1 (0)	1 (-0.1)	1 (0)	2 (0.1)
	August	0	0 (0)	0 (0)	0 (0)	0 (0)
	September	0	0 (0)	0 (0)	0 (0)	0 (0)
	October	0	0 (0)	0 (0)	0 (0)	0 (0)
	November	2	1 (-1.6)	0 (-2.3)	1 (-1.5)	0 (-2.2)
	December	8	2 (-5.8)	5 (-3.3)	2 (-5.8)	8 (-0.4)
	All	37	32 (-5.6)	32 (-5.5)	32 (-5.6)	32 (-5.3)
Critical	January	2	1 (-1.2)	1 (-1.2)	1 (-1.2)	1 (-1.2)
	February	61	46 (-14.3)	46 (-14.3)	46 (-14.3)	46 (-14.3)
	March	19	12 (-7.8)	12 (-7.8)	12 (-7.8)	12 (-7.8)
	April	0	0 (0)	0 (0)	0 (0)	0 (0)
	May	0	0 (0)	0 (0)	0 (0)	0 (0)
	June	0	0 (0)	0 (0)	0 (0)	0 (0)
	July	0	0 (0)	0 (0)	0 (0)	0 (0)
	August	0	0 (0)	0 (0)	0 (0)	0 (0)
	September	0	0 (0)	0 (0)	0 (0)	0 (0)
	October	0	0 (0)	0 (0)	0 (0)	0 (0)
	November	0	0 (0)	0 (0)	0 (0)	0 (0)
	December	0	0 (0)	0 (0)	0 (0)	0 (0)
	All	7	5 (-1.9)	5 (-1.9)	5 (-1.9)	5 (-1.9)

The frequency of inundation creating suitable habitat (<1 meter deep) in the lower Sutter Bypass was determined for each month and water year type (Table 11M-6). The frequencies are the percent of days in each water year type and month with any suitable habitat inundation. These frequencies are similar to those for any level of inundation because inundation < 1 meter deep is absent in the lower bypass only at the very highest Sacramento River flows at Verona. Frequencies are especially high (> 50% of days) for January, February, and March of Wet and Above Normal Water Years (Table 11M-6). In Critically Dry Water Years, the percent of days with inundation is low (<5%) in January, February and March, while no inundation occurs during the rest of the year.

The frequency of inundation in the lower Bypass is lower under Alternatives 1, 2, and 3 than under the NAA in most water year types and months for which there are differences (Table 11M-6). As is true for the inundation acreages, reductions in means are much more frequent than increases. The largest reductions in the inundation frequencies are about 5% in March of Below Normal Water Years under Alternatives 1, 2, and 3. Most of the reductions are less than 1%.

Table 11M-6. Frequency of Occurrence (% of days) of Lower Sutter Bypass Inundation Creating Suitable Habitat for the NAA and Alternatives 1, 2, and 3 and Absolute Differences in Percentage (in parentheses).

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Wet	January	74.7	73.8 (-0.87)	72.6 (-2.11)	73.8 (-0.87)	72.7 (-1.99)
	February	89.2	89.2 (0)	89.2 (0)	89.2 (0)	89.2 (0)
	March	77.2	76.8 (-0.37)	76.7 (-0.5)	76.8 (-0.37)	76.6 (-0.62)
	April	60.5	60.5 (0)	60.5 (0)	60.4 (-0.13)	60.5 (0)
	May	50.4	50.4 (0)	50.4 (0)	50.4 (0)	50.4 (0)
	June	21.9	22.2 (0.26)	22.2 (0.26)	22.2 (0.26)	22.2 (0.26)
	July	2.7	2.7 (0)	2.7 (0)	2.7 (0)	2.7 (0)
	August	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	September	3.2	3.2 (0)	3.1 (-0.13)	3.2 (0)	3.1 (-0.13)
	October	3.5	3.1 (-0.37)	3.1 (-0.37)	3.1 (-0.37)	3.5 (0)
	November	11.7	11.3 (-0.38)	11.3 (-0.38)	11.3 (-0.38)	11.4 (-0.26)
	December	50.9	48.6 (-2.23)	49.1 (-1.74)	48.8 (-2.11)	49.4 (-1.49)
	All	36.9	36.5 (-0.34)	36.5 (-0.42)	36.5 (-0.34)	36.5 (-0.36)
Above Normal	January	54.0	50.5 (-3.49)	50.5 (-3.49)	50.5 (-3.49)	50.3 (-3.76)
	February	74.4	71.5 (-2.94)	71.5 (-2.94)	71.5 (-2.94)	69.4 (-5)
	March	71.8	69.4 (-2.42)	69.1 (-2.69)	69.4 (-2.42)	68.8 (-2.96)
	April	34.4	35.6 (1.11)	35.6 (1.11)	35.6 (1.11)	34.7 (0.28)
	May	17.5	17.5 (0)	17.5 (0)	17.5 (0)	17.5 (0)
	June	5.0	5 (0)	5 (0)	5 (0)	5 (0)
	July	3.5	3.5 (0)	3.5 (0)	3.5 (0)	3.8 (0.27)
	August	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	September	5.6	5.6 (0)	5.6 (0)	5.6 (0)	6.4 (0.83)
	October	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	November	3.6	3.6 (0)	3.6 (0)	3.6 (0)	3.6 (0)
	December	16.7	15.6 (-1.08)	15.6 (-1.08)	15.6 (-1.08)	15.3 (-1.34)
	All	23.6	22.9 (-0.73)	22.9 (-0.75)	22.9 (-0.73)	22.7 (-0.96)
Below Normal	January	18.7	14.7 (-3.92)	14.1 (-4.61)	14.5 (-4.15)	14.3 (-4.38)
	February	49.0	48.2 (-0.76)	48.2 (-0.76)	48.2 (-0.76)	48.2 (-0.76)

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	March	21.7	16.6 (-5.07)	16.6 (-5.07)	16.8 (-4.84)	15.7 (-5.99)
	April	11.4	11 (-0.48)	11 (-0.48)	11 (-0.48)	11 (-0.48)
	May	3.7	3.7 (0)	3.7 (0)	3.7 (0)	3.7 (0)
	June	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	July	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	August	1.2	1.2 (0)	1.2 (0)	1.2 (0)	1.2 (0)
	September	0.5	0.5 (0)	0.5 (0)	0.5 (0)	0.5 (0)
	October	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	November	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	December	6.0	6 (0)	6 (0)	6 (0)	6 (0)
	All	9.1	8.3 (-0.86)	8.2 (-0.92)	8.3 (-0.86)	8.1 (-0.98)
Dry	January	6.6	6.6 (0)	6.6 (0)	6.6 (0)	6.6 (0)
	February	20.5	19.3 (-1.18)	19.3 (-1.18)	19.3 (-1.18)	19.3 (-1.18)
	March	15.4	12.5 (-2.87)	12.5 (-2.87)	12.5 (-2.87)	12.5 (-2.87)
	April	1.1	1.1 (0)	1.1 (0)	1.1 (0)	1.1 (0)
	May	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	June	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	July	0.4	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)
	August	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	September	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	October	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	November	0.6	0.4 (-0.19)	0.2 (-0.37)	0.4 (-0.19)	0.2 (-0.37)
	December	2.7	1.1 (-1.61)	2.3 (-0.36)	1.1 (-1.61)	3 (0.36)
	All	3.8	3.4 (-0.49)	3.5 (-0.4)	3.4 (-0.49)	3.5 (-0.33)
Critical	January	1.1	0.3 (-0.81)	0.3 (-0.81)	0.3 (-0.81)	0.3 (-0.81)
	February	4.7	4.4 (-0.29)	4.4 (-0.29)	4.4 (-0.29)	4.4 (-0.29)
	March	3.0	1.1 (-1.88)	1.1 (-1.88)	1.1 (-1.88)	1.1 (-1.88)
	April	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	May	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	June	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	July	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	August	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	September	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	October	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	November	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	December	0.0	0 (0)	0 (0)	0 (0)	0 (0)

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	All	0.7	0.5 (-0.25)	0.5 (-0.25)	0.5 (-0.25)	0.5 (-0.25)

Two important limitations of the lower Sutter Bypass inundation analysis should be noted. The first limitation is that the analysis assumes no pre-existing inundation from upstream sources in the Sutter Bypass. This assumption potentially leads to underestimation of the total areas in the lower bypass that would be inundated, especially in wetter years. On the other hand, with regard to suitable inundated habitat (<1 meter deep), the assumption potentially leads to overestimation of acreage. As shown in Figure 11M-2, suitable habitat in the Sutter Bypass is maximized at bypass flows of about 1,000 cfs to 3,000 cfs and flows greater than 3,000 cfs produce less habitat. This is because higher flows result in smaller proportions of the surface area inundated having depths less than 1 meter, as required for suitable rearing habitat. Pre-existing inundation from upstream sources potentially results in habitat depths in the lower bypass that exceed 1 meter. Under such circumstances, a reduction in Sacramento River flow that led to reduced backflow effects on the lower bypass could result in reductions in the depths of inundated areas in the lower bypass leading to increased suitable habitat.

The second limitation of the lower Sutter Bypass inundated habitat analysis is that it treats each day of the simulation independently. In fact, inundation from 1 day would generally affect the level of inundation that occurred the following day. This limitation likely affects all the scenarios more or less equally and therefore probably has little effect on conclusions regarding differences between the NAA and Alternatives 1, 2, and 3 in lower Sutter Bypass inundation.

11M.3.4 Sacramento River Side-Channel Habitat Area

Like the floodplain habitat of the Yolo and Sutter Bypasses, inundated side-channel habitat in the Sacramento River provides important habitat for several fish species, including Chinook salmon, steelhead, and Sacramento splittail. Juvenile salmon and steelhead use inundated side-channel habitat for rearing and Sacramento splittail use it for spawning and rearing (Moyle et al. 2004, 2015; Feyrer et al. 2005; Limm and Marchetti 2009; Bellido-Leiva et al. 2021). Rearing juvenile salmon and steelhead use side-channel habitat, when it is available and water temperature is suitable, along the full length of the lower Sacramento River from Keswick Dam to the Delta. Adult Sacramento splittail have been found as far upstream as Red Bluff Pumping Plant[2], although juveniles have not been found upstream of about Colusa, so the upstream limit of splittail spawning is uncertain (Moyle et al. 2004; Feyrer et al. 2005).

The modeling results for acreage of suitable side-channel habitat in the three reaches of the Sacramento River analyzed indicate that Alternatives 1, 2, and 3 would produce minor changes in mean daily suitable habitat as compared to the NAA in all three reaches (Table 11M-7, Table 11M-8, and Table 11M-9). None of the differences in any of the reaches are greater than 4%. In all reaches and alternatives, reductions in mean monthly habitat acreage are two to four times more frequent than increases. The average annual differences by reach in acreage, encompassing

[2] The Red Bluff Diversion Dam, which was decommissioned in 2013, and the Red Bluff Pumping Plant are co-located, and the names may be used interchangeably when referring to the geographic location.

all months and water years types, are: (1) Reach 1: -6 acres for Alternatives 1A and 2 and -5 acres for Alternatives 1B and 3; (2) Reach 2: -13 acres for Alternatives 1A, 1B, and 2 and -12 acres for Alternative 3; and (3) Reach 3: -2 acres for Alternatives 1, 2, and 3. The maximum increases and reductions in acreage over all reaches and alternatives are an increase of 34 acres for Alternative 1A in September of Critically Dry Water Years in Reach 1, and a reduction of 87 acres for Alternative 3 in March of Above Normal Water Years in Reach 2.

Table 11M-7. Estimated Mean Daily Side-Channel Habitat (Acres <1 Meter Deep) for Juvenile Salmonids in the Sacramento River Reach 1 (Bend Bridge to Hamilton City) and the Absolute Differences (in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	1,367	1,334 (-33)	1,335 (-32)	1,334 (-33)	1,338 (-29)
	Above Normal	1,112	1,083 (-29)	1,081 (-31)	1,083 (-29)	1,084 (-28)
	Below Normal	1,094	1,089 (-5)	1,086 (-8)	1,088 (-6)	1,086 (-8)
	Dry	1,037	1,032 (-5)	1,033 (-4)	1,032 (-5)	1,034 (-3)
	Critically Dry	1,020	1,016 (-4)	1,017 (-3)	1,017 (-3)	1,022 (2)
	All	1,160	1,143 (-17)	1,143 (-17)	1,143 (-17)	1,145 (-15)
February	Wet	1,480	1,461 (-19)	1,459 (-21)	1,465 (-15)	1,452 (-28)
	Above Normal	1,209	1,188 (-21)	1,191 (-18)	1,185 (-24)	1,200 (-9)
	Below Normal	1,109	1,092 (-17)	1,091 (-18)	1,092 (-17)	1,091 (-18)
	Dry	1,053	1,050 (-3)	1,051 (-2)	1,050 (-3)	1,052 (-1)
	Critically Dry	1,054	1,047 (-7)	1,047 (-7)	1,047 (-7)	1,047 (-7)
	All	1,221	1,207 (-14)	1,207 (-14)	1,208 (-13)	1,206 (-15)
March	Wet	1,338	1,327 (-11)	1,328 (-10)	1,329 (-9)	1,322 (-16)
	Above Normal	1,320	1,261 (-59)	1,261 (-59)	1,262 (-58)	1,260 (-60)
	Below Normal	1,074	1,067 (-7)	1,067 (-7)	1,067 (-7)	1,064 (-10)
	Dry	1,055	1,047 (-8)	1,049 (-6)	1,047 (-8)	1,043 (-12)
	Critically Dry	1,055	1,052 (-3)	1,054 (-1)	1,052 (-3)	1,054 (-1)
	All	1,185	1,170 (-15)	1,171 (-14)	1,171 (-14)	1,167 (-18)
April	Wet	1,197	1,182 (-15)	1,181 (-16)	1,182 (-15)	1,173 (-24)
	Above Normal	1,138	1,121 (-17)	1,124 (-14)	1,124 (-14)	1,111 (-27)
	Below Normal	1,011	1,010 (-1)	1,012 (1)	1,010 (-1)	1,011 (0)
	Dry	982	979 (-3)	981 (-1)	979 (-3)	981 (-1)
	Critically Dry	966	967 (1)	969 (3)	966 (0)	971 (5)
	All	1,075	1,067 (-8)	1,068 (-7)	1,067 (-8)	1,064 (-11)
May	Wet	1,046	1,027 (-19)	1,031 (-15)	1,027 (-19)	1,029 (-17)
	Above Normal	1,011	1,005 (-6)	1,004 (-7)	1,005 (-6)	1,010 (-1)
	Below Normal	994	994 (0)	997 (3)	994 (0)	995 (1)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	1,005	1,006 (1)	1,015 (10)	1,006 (1)	1,016 (11)
	Critically Dry	1,024	1,017 (-7)	1,020 (-4)	1,017 (-7)	1,021 (-3)
	All	1,020	1,012 (-8)	1,016 (-4)	1,012 (-8)	1,017 (-3)
June	Wet	1,081	1,080 (-1)	1,081 (0)	1,080 (-1)	1,081 (0)
	Above Normal	1,087	1,087 (0)	1,085 (-2)	1,087 (0)	1,085 (-2)
	Below Normal	1,085	1,083 (-2)	1,083 (-2)	1,083 (-2)	1,083 (-2)
	Dry	1,086	1,085 (-1)	1,085 (-1)	1,085 (-1)	1,087 (1)
	Critically Dry	1,090	1,087 (-3)	1,088 (-2)	1,087 (-3)	1,087 (-3)
	All	1,085	1,084 (-1)	1,084 (-1)	1,084 (-1)	1,084 (-1)
July	Wet	1,096	1,096 (0)	1,096 (0)	1,096 (0)	1,096 (0)
	Above Normal	1,092	1,092 (0)	1,092 (0)	1,092 (0)	1,092 (0)
	Below Normal	1,094	1,095 (1)	1,094 (0)	1,095 (1)	1,094 (0)
	Dry	1,099	1,099 (0)	1,099 (0)	1,099 (0)	1,100 (1)
	Critically Dry	1,091	1,091 (0)	1,091 (0)	1,091 (0)	1,091 (0)
	All	1,095	1,095 (0)	1,095 (0)	1,095 (0)	1,095 (0)
August	Wet	1,098	1,098 (0)	1,098 (0)	1,098 (0)	1,098 (0)
	Above Normal	1,098	1,097 (-1)	1,097 (-1)	1,097 (-1)	1,096 (-2)
	Below Normal	1,093	1,093 (0)	1,093 (0)	1,093 (0)	1,093 (0)
	Dry	1,091	1,095 (4)	1,094 (3)	1,095 (4)	1,094 (3)
	Critically Dry	1,076	1,087 (11)	1,086 (10)	1,086 (10)	1,084 (8)
	All	1,093	1,095 (2)	1,094 (1)	1,095 (2)	1,094 (1)
September	Wet	1,099	1,098 (-1)	1,098 (-1)	1,098 (-1)	1,098 (-1)
	Above Normal	1,095	1,095 (0)	1,095 (0)	1,095 (0)	1,100 (5)
	Below Normal	1,042	1,039 (-3)	1,044 (2)	1,039 (-3)	1,043 (1)
	Dry	997	1,011 (14)	1,013 (16)	1,010 (13)	1,008 (11)
	Critically Dry	980	1,014 (34)	1,010 (30)	1,012 (32)	1,004 (24)
	All	1,048	1,056 (8)	1,056 (8)	1,055 (7)	1,055 (7)
October	Wet	1,091	1,089 (-2)	1,090 (-1)	1,089 (-2)	1,089 (-2)
	Above Normal	1,073	1,074 (1)	1,077 (4)	1,074 (1)	1,084 (11)
	Below Normal	1,041	1,040 (-1)	1,043 (2)	1,041 (0)	1,054 (13)
	Dry	966	974 (8)	976 (10)	976 (10)	998 (32)
	Critically Dry	999	1,027 (28)	1,024 (25)	1,025 (26)	1,023 (24)
	All	1,038	1,044 (6)	1,045 (7)	1,044 (6)	1,052 (14)
November	Wet	1,084	1,082 (-2)	1,082 (-2)	1,082 (-2)	1,081 (-3)
	Above Normal	1,113	1,104 (-9)	1,107 (-6)	1,104 (-9)	1,114 (1)
	Below Normal	1,047	1,024 (-23)	1,028 (-19)	1,024 (-23)	1,034 (-13)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	1,007	986 (-21)	992 (-15)	983 (-24)	1,004 (-3)
	Critically Dry	1,043	1,012 (-31)	1,013 (-30)	1,010 (-33)	1,012 (-31)
	All	1,058	1,043 (-15)	1,046 (-12)	1,042 (-16)	1,050 (-8)
December	Wet	1,116	1,110 (-6)	1,110 (-6)	1,110 (-6)	1,112 (-4)
	Above Normal	1,086	1,057 (-29)	1,059 (-27)	1,053 (-33)	1,049 (-37)
	Below Normal	1,102	1,090 (-12)	1,091 (-11)	1,090 (-12)	1,097 (-5)
	Dry	1,115	1,109 (-6)	1,110 (-5)	1,109 (-6)	1,112 (-3)
	Critically Dry	993	992 (-1)	993 (0)	991 (-2)	992 (-1)
	All	1,091	1,082 (-9)	1,083 (-8)	1,081 (-10)	1,083 (-8)

[1] Water year type sorting by hydrologic water years

Table 11M-8. Estimated Mean Daily Side-Channel Habitat (Acres <1 Meter Deep) for Juvenile Salmonids in the Sacramento River Reach 2 (Hamilton City to Colusa) and the Absolute Differences (in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	1,942	1,905 (-37)	1,896 (-46)	1,907 (-35)	1,895 (-47)
	Above Normal	1,371	1,299 (-72)	1,297 (-74)	1,299 (-72)	1,301 (-70)
	Below Normal	994	969 (-25)	968 (-26)	967 (-27)	966 (-28)
	Dry	791	784 (-7)	785 (-6)	784 (-7)	785 (-6)
	Critically Dry	755	743 (-12)	743 (-12)	744 (-11)	744 (-11)
	All	1,269	1,240 (-29)	1,237 (-32)	1,240 (-29)	1,237 (-32)
February	Wet	2,423	2,361 (-62)	2,361 (-62)	2,371 (-52)	2,353 (-70)
	Above Normal	1,721	1,642 (-79)	1,653 (-68)	1,638 (-83)	1,671 (-50)
	Below Normal	1,084	1,049 (-35)	1,046 (-38)	1,050 (-34)	1,061 (-23)
	Dry	948	908 (-40)	909 (-39)	908 (-40)	912 (-36)
	Critically Dry	773	764 (-9)	764 (-9)	764 (-9)	764 (-9)
	All	1,523	1,476 (-47)	1,477 (-46)	1,479 (-44)	1,480 (-43)
March	Wet	1,927	1,895 (-32)	1,892 (-35)	1,904 (-23)	1,880 (-47)
	Above Normal	1,843	1,765 (-78)	1,764 (-79)	1,767 (-76)	1,756 (-87)
	Below Normal	938	904 (-34)	906 (-32)	907 (-31)	907 (-31)
	Dry	895	856 (-39)	853 (-42)	857 (-38)	857 (-38)
	Critically Dry	744	735 (-9)	740 (-4)	735 (-9)	742 (-2)
	All	1,340	1,304 (-36)	1,303 (-37)	1,307 (-33)	1,299 (-41)
April	Wet	1,554	1,520 (-34)	1,520 (-34)	1,521 (-33)	1,510 (-44)
	Above Normal	1,145	1,114 (-31)	1,121 (-24)	1,121 (-24)	1,123 (-22)
	Below Normal	779	767 (-12)	769 (-10)	767 (-12)	766 (-13)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	728	726 (-2)	725 (-3)	726 (-2)	730 (2)
	Critically Dry	697	691 (-6)	692 (-5)	691 (-6)	691 (-6)
	All	1,054	1,036 (-18)	1,037 (-17)	1,037 (-17)	1,034 (-20)
May	Wet	880	865 (-15)	866 (-14)	865 (-15)	865 (-15)
	Above Normal	741	740 (-1)	740 (-1)	740 (-1)	739 (-2)
	Below Normal	740	744 (4)	745 (5)	744 (4)	741 (1)
	Dry	708	708 (0)	711 (3)	708 (0)	709 (1)
	Critically Dry	702	696 (-6)	698 (-4)	696 (-6)	698 (-4)
	All	772	767 (-5)	769 (-3)	767 (-5)	767 (-5)
June	Wet	809	807 (-2)	807 (-2)	807 (-2)	807 (-2)
	Above Normal	729	730 (1)	728 (-1)	727 (-2)	729 (0)
	Below Normal	724	725 (1)	725 (1)	725 (1)	721 (-3)
	Dry	735	736 (1)	737 (2)	736 (1)	737 (2)
	Critically Dry	714	713 (-1)	712 (-2)	712 (-2)	709 (-5)
	All	753	753 (0)	752 (-1)	752 (-1)	751 (-2)
July	Wet	761	762 (1)	761 (0)	762 (1)	761 (0)
	Above Normal	798	797 (-1)	795 (-3)	796 (-2)	798 (0)
	Below Normal	765	764 (-1)	766 (1)	763 (-2)	767 (2)
	Dry	751	766 (15)	764 (13)	766 (15)	765 (14)
	Critically Dry	726	737 (11)	735 (9)	736 (10)	731 (5)
	All	759	764 (5)	763 (4)	764 (5)	764 (5)
August	Wet	734	734 (0)	734 (0)	734 (0)	734 (0)
	Above Normal	731	725 (-6)	731 (0)	725 (-6)	733 (2)
	Below Normal	707	704 (-3)	706 (-1)	704 (-3)	707 (0)
	Dry	707	713 (6)	711 (4)	713 (6)	710 (3)
	Critically Dry	714	714 (0)	712 (-2)	711 (-3)	710 (-4)
	All	720	720 (0)	720 (0)	720 (0)	720 (0)
September	Wet	781	779 (-2)	773 (-8)	779 (-2)	773 (-8)
	Above Normal	726	717 (-9)	723 (-3)	718 (-8)	718 (-8)
	Below Normal	698	699 (1)	702 (4)	699 (1)	701 (3)
	Dry	675	682 (7)	684 (9)	682 (7)	684 (9)
	Critically Dry	661	683 (22)	681 (20)	684 (23)	678 (17)
	All	718	721 (3)	721 (3)	721 (3)	719 (1)
October	Wet	739	738 (-1)	737 (-2)	738 (-1)	737 (-2)
	Above Normal	717	717 (0)	715 (-2)	717 (0)	717 (0)
	Below Normal	728	723 (-5)	723 (-5)	724 (-4)	721 (-7)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	673	676 (3)	677 (4)	676 (3)	691 (18)
	Critically Dry	679	692 (13)	690 (11)	690 (11)	687 (8)
	All	710	712 (2)	711 (1)	712 (2)	714 (4)
November	Wet	738	734 (-4)	733 (-5)	734 (-4)	735 (-3)
	Above Normal	854	853 (-1)	857 (3)	853 (-1)	865 (11)
	Below Normal	753	738 (-15)	737 (-16)	738 (-15)	742 (-11)
	Dry	739	733 (-6)	735 (-4)	731 (-8)	740 (1)
	Critically Dry	721	702 (-19)	702 (-19)	701 (-20)	701 (-20)
	All	754	746 (-8)	746 (-8)	745 (-9)	750 (-4)
December	Wet	1,088	1,062 (-26)	1,070 (-18)	1,063 (-25)	1,076 (-12)
	Above Normal	1,009	983 (-26)	980 (-29)	979 (-30)	976 (-33)
	Below Normal	1,126	1,081 (-45)	1,082 (-44)	1,081 (-45)	1,108 (-18)
	Dry	1,055	1,023 (-32)	1,025 (-30)	1,024 (-31)	1,055 (0)
	Critically Dry	743	743 (0)	744 (1)	744 (1)	743 (0)
	All	1,025	999 (-26)	1,002 (-23)	999 (-26)	1,014 (-11)

[1] Water year type sorting by hydrologic water years

Table 11M-9. Estimated Mean Daily Side-Channel Habitat (Acres <1 Meter Deep) for Juvenile Salmonids in the Sacramento River Reach 3 (Colusa to Knights Landing) and the Absolute Differences (in parentheses) for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	251	246 (-5)	245 (-6)	247 (-4)	245 (-6)
	Above Normal	200	188 (-12)	188 (-12)	188 (-12)	188 (-12)
	Below Normal	136	133 (-3)	132 (-4)	132 (-4)	132 (-4)
	Dry	120	119 (-1)	119 (-1)	119 (-1)	119 (-1)
	Critically Dry	116	114 (-2)	114 (-2)	114 (-2)	114 (-2)
	All	175	171 (-4)	171 (-4)	171 (-4)	170 (-5)
February	Wet	324	317 (-7)	317 (-7)	317 (-7)	317 (-7)
	Above Normal	255	239 (-16)	239 (-16)	239 (-16)	241 (-14)
	Below Normal	158	150 (-8)	151 (-7)	150 (-8)	153 (-5)
	Dry	143	136 (-7)	136 (-7)	136 (-7)	137 (-6)
	Critically Dry	111	111 (0)	110 (-1)	111 (0)	110 (-1)
	All	214	207 (-7)	207 (-7)	207 (-7)	207 (-7)
March	Wet	256	253 (-3)	253 (-3)	255 (-1)	251 (-5)
	Above Normal	254	243 (-11)	242 (-12)	244 (-10)	241 (-13)
	Below Normal	129	124 (-5)	125 (-4)	125 (-4)	127 (-2)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	124	118 (-6)	117 (-7)	118 (-6)	118 (-6)
	Critically Dry	105	104 (-1)	103 (-2)	104 (-1)	104 (-1)
	All	182	177 (-5)	177 (-5)	178 (-4)	177 (-5)
April	Wet	231	224 (-7)	224 (-7)	224 (-7)	223 (-8)
	Above Normal	157	153 (-4)	154 (-3)	154 (-3)	156 (-1)
	Below Normal	112	108 (-4)	108 (-4)	108 (-4)	108 (-4)
	Dry	108	108 (0)	108 (0)	108 (0)	109 (1)
	Critically Dry	114	113 (-1)	114 (0)	114 (0)	113 (-1)
	All	156	152 (-4)	152 (-4)	152 (-4)	152 (-4)
May	Wet	119	117 (-2)	117 (-2)	117 (-2)	116 (-3)
	Above Normal	112	112 (0)	112 (0)	112 (0)	111 (-1)
	Below Normal	120	121 (1)	121 (1)	121 (1)	120 (0)
	Dry	115	115 (0)	115 (0)	115 (0)	115 (0)
	Critically Dry	113	113 (0)	114 (1)	114 (1)	115 (2)
	All	117	116 (-1)	116 (-1)	116 (-1)	116 (-1)
June	Wet	117	117 (0)	117 (0)	117 (0)	117 (0)
	Above Normal	106	106 (0)	108 (2)	106 (0)	108 (2)
	Below Normal	107	107 (0)	108 (1)	107 (0)	108 (1)
	Dry	105	106 (1)	105 (0)	106 (1)	104 (-1)
	Critically Dry	108	109 (1)	109 (1)	109 (1)	110 (2)
	All	110	110 (0)	110 (0)	110 (0)	110 (0)
July	Wet	97	97 (0)	97 (0)	97 (0)	97 (0)
	Above Normal	95	95 (0)	95 (0)	95 (0)	98 (3)
	Below Normal	98	97 (-1)	97 (-1)	96 (-2)	98 (0)
	Dry	96	95 (-1)	95 (-1)	95 (-1)	95 (-1)
	Critically Dry	109	107 (-2)	107 (-2)	107 (-2)	107 (-2)
	All	98	98 (0)	98 (0)	98 (0)	98 (0)
August	Wet	98	98 (0)	98 (0)	98 (0)	98 (0)
	Above Normal	99	100 (1)	100 (1)	100 (1)	100 (1)
	Below Normal	107	107 (0)	107 (0)	107 (0)	107 (0)
	Dry	107	101 (-6)	103 (-4)	101 (-6)	103 (-4)
	Critically Dry	114	106 (-8)	106 (-8)	106 (-8)	110 (-4)
	All	104	102 (-2)	102 (-2)	102 (-2)	103 (-1)
September	Wet	95	94 (-1)	94 (-1)	94 (-1)	94 (-1)
	Above Normal	94	94 (0)	94 (0)	95 (1)	91 (-3)
	Below Normal	116	118 (2)	117 (1)	118 (2)	119 (3)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	119	118 (-1)	119 (0)	118 (-1)	119 (0)
	Critically Dry	116	116 (0)	116 (0)	117 (1)	118 (2)
	All	107	107 (0)	107 (0)	107 (0)	107 (0)
October	Wet	98	98 (0)	98 (0)	98 (0)	98 (0)
	Above Normal	109	109 (0)	107 (-2)	109 (0)	104 (-5)
	Below Normal	118	118 (0)	117 (-1)	118 (0)	113 (-5)
	Dry	117	117 (0)	117 (0)	117 (0)	120 (3)
	Critically Dry	116	117 (1)	117 (1)	117 (1)	116 (0)
	All	110	110 (0)	110 (0)	110 (0)	109 (-1)
November	Wet	106	107 (1)	107 (1)	107 (1)	107 (1)
	Above Normal	125	125 (0)	124 (-1)	124 (-1)	125 (0)
	Below Normal	115	112 (-3)	111 (-4)	112 (-3)	110 (-5)
	Dry	118	118 (0)	118 (0)	117 (-1)	120 (2)
	Critically Dry	119	116 (-3)	115 (-4)	115 (-4)	115 (-4)
	All	115	114 (-1)	114 (-1)	114 (-1)	114 (-1)
December	Wet	159	154 (-5)	155 (-4)	154 (-5)	156 (-3)
	Above Normal	148	149 (1)	148 (0)	149 (1)	146 (-2)
	Below Normal	167	159 (-8)	159 (-8)	159 (-8)	163 (-4)
	Dry	147	143 (-4)	143 (-4)	143 (-4)	149 (2)
	Critically Dry	115	115 (0)	115 (0)	115 (0)	116 (1)
	All	150	146 (-4)	146 (-4)	146 (-4)	148 (-2)

[1] Water year type sorting by hydrologic water years

The results of the frequency analysis of inundation events for all three reaches combined also show some differences between the NAA and Alternatives 1, 2, and 3 (Figure 11M-9). For events of all three durations groupings (8–17 days, 18–24 days, and >24 days), inundations of 0 to 2,000 acres show increases in frequencies under Alternatives 1, 2, and 3 and inundations of 2,000 to 3,000 acres show reductions in frequencies under Alternatives 1, 2, and 3. Results for inundation events of 3,000 to 5,000 acres and >5,000 acres show little change. As previously noted, inundation lasting 18–24 days has been shown to result in maximum productivity for salmonids in field studies (Whipple et al. 2019). Tables providing the results plotted in Figure 11M-9 and frequency of inundation tables for every month are provided in Appendix 11M6, *Average Monthly and Average Annual of Sacramento River Side-Channel Inundation Events (Three River Reaches Combined) with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3*. Corresponding tables for each of the three reaches separately are provided in Appendix 11M7, *Sacramento River Side-Channel Inundation Events for Reach 1*; Appendix 11M8, *Sacramento River Side-Channel Inundation Events for Reach 2*; and Appendix 11M9, *Sacramento River Side-Channel Inundation Events for Reach 3*.

Alternatives 1, 2, and 3 would result in both reductions and increases in acreage and frequency of suitable inundated side-channel habitat in the Sacramento River, with reductions larger and more frequent than increases. On balance, the effects would not be large enough to substantially affect habitat availability for Chinook salmon, steelhead, and Sacramento splittail.

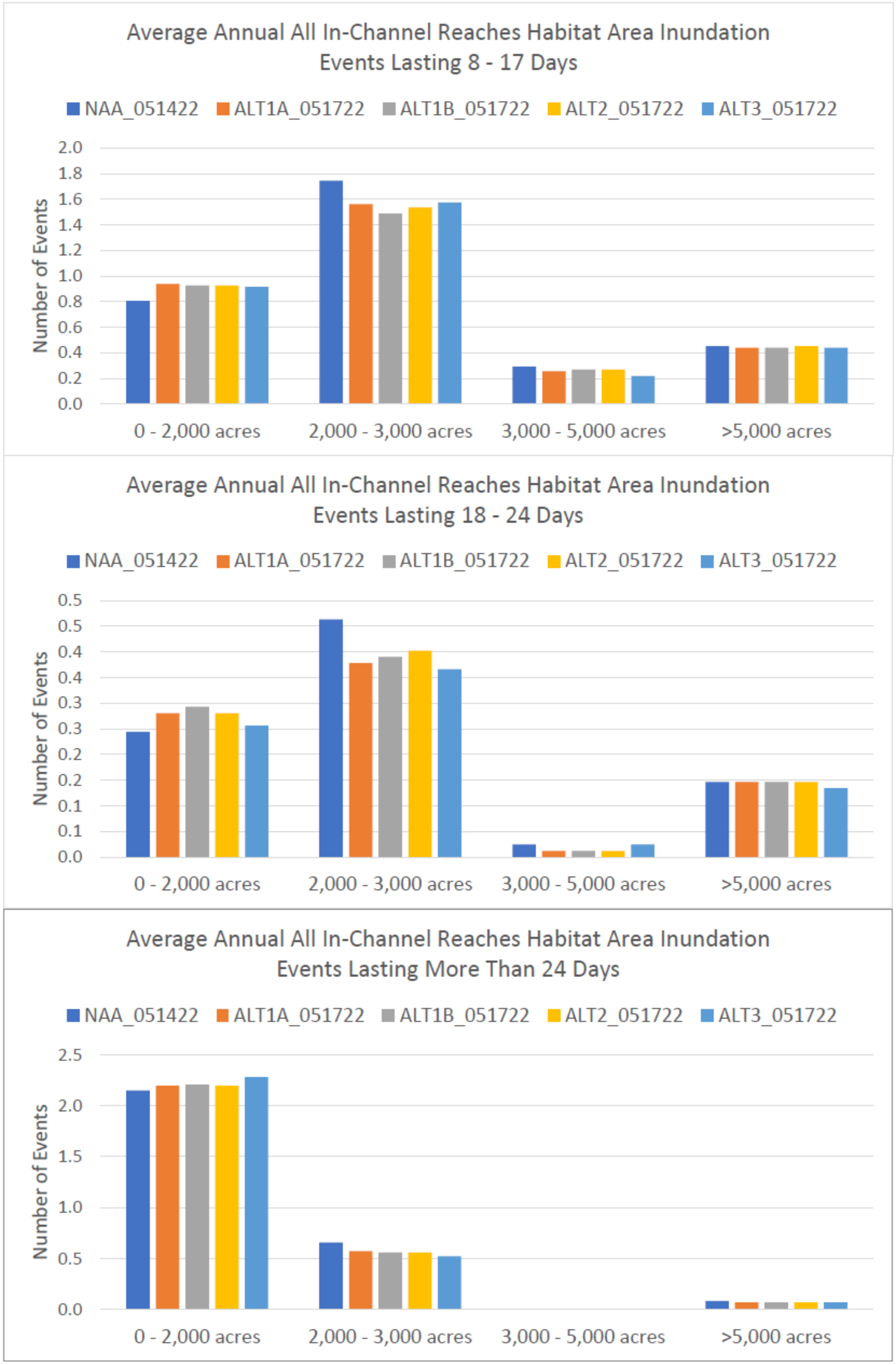

Figure 11M-9. Average Annual Number of Sacramento River Side-Channel Inundation Events (Three River Reaches Combined) with Three Different Ranges of Duration and Four Ranges of Suitable Habitat Acreages for the NAA and Alt 1A, Alt 1B, Alt 2, and Alt 3.

11M.3.5 Rearing Habitat Carrying Capacity of Inundated Habitat in the Yolo Bypass, the Sutter Bypass, and the Sacramento River Mainstem

Table 11M-10 gives the results of the juvenile salmonid rearing habitat carrying capacity analysis for inundated habitat in the Yolo Bypass, Sutter Bypass and Sacramento River side-channels combined. These results show that mean carrying capacity declined under Alternatives 1, 2, and 3 during the majority of months and water year types. The largest reductions, which range from 2.2% to 2.6%, occur for Alternatives 1, 2, and 3 in Above Normal Water Years during December. All increases in carrying capacity are less than 1%. This pattern of change is similar to that found for acreage of suitable habitat in the Yolo Bypass (Table 11M-2). The similarity reflects the larger influence of the Yolo Bypass on the total carrying capacity estimates as compared to the Sutter Bypass (Table 11M-4) and Sacramento River side-channels (Table 11M-7 through Table 11M-9) because of its much larger suitable habitat acreages.

The results of the carrying capacity analysis suggest that juvenile rearing habitat carrying capacity available under all the alternatives would be sufficient for current population sizes. Based on data from the USFWS trapping program at the Red Bluff Diversion Dam for 2002 to 2012, abundance of Chinook salmon juveniles for all races combined ranged from approximately 7.5 to 35 million juveniles (Poytress et al. 2014). The upper value of this range, 35 million, is well below the lowest mean carrying capacity in Table 11M-10 for any of the alternatives. However, carrying capacity at submonthly time intervals could result in bottlenecks, and both monthly and submonthly capacity must be sufficient to facilitate increased population sizes as populations recover from their depressed state. Furthermore, other habitat conditions that were not included in the analysis, including prey abundance and water temperature, may affect inundated rearing habitat carrying capacity. The total habitat carrying capacity estimates in Table 11M-10 are roughly similar to the sum of the carrying capacities for the Yolo Bypass, Sutter Bypass, and Sacramento River determined by Cordoleani et al. (2020b).

Table 11M-10. Total Carrying Capacity for Juvenile Chinook Salmon Rearing Habitat (millions of juveniles) in Inundated Floodplain Habitat of the Sacramento River and the Yolo and Sutter Bypasses and the Percent Differences (in parantheses) under the NAA and Alternatives 1, 2 and 3.

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Wet	November	509.2	505.8 (-0.7%)	505.9 (-0.6%)	506.1 (-0.6%)	507.7 (-0.3%)
	December	575.5	566.1 (-1.6%)	567.1 (-1.5%)	566.1 (-1.6%)	568.5 (-1.2%)
	January	391.8	388.6 (-0.8%)	387.3 (-1.2%)	388.6 (-0.8%)	387.3 (-1.2%)
	February	304.8	303.9 (-0.3%)	303.9 (-0.3%)	303.9 (-0.3%)	303.7 (-0.4%)
	March	254.3	253.7 (-0.2%)	253.6 (-0.3%)	253.8 (-0.2%)	254.4 (0%)
	April	258.3	256.3 (-0.8%)	256.3 (-0.8%)	256.3 (-0.8%)	255.2 (-1.2%)
	May	104.1	103 (-1%)	103.1 (-0.9%)	103 (-1%)	103.1 (-1%)
Above Normal	November	457.3	454.4 (-0.6%)	454.3 (-0.7%)	454.5 (-0.6%)	452.3 (-1.1%)
	December	354.4	345.8 (-2.4%)	345.9 (-2.4%)	345.8 (-2.4%)	345.2 (-2.6%)
	January	335.5	330.2 (-1.6%)	330.1 (-1.6%)	330.2 (-1.6%)	330.2 (-1.6%)
	February	288.0	284.7 (-1.1%)	285 (-1%)	284.5 (-1.2%)	284.3 (-1.3%)

Water Year Type	Month	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	March	240.0	236.9 (-1.3%)	236.9 (-1.3%)	237.1 (-1.2%)	236.8 (-1.3%)
	April	191.8	192.2 (0.2%)	192.2 (0.2%)	192.2 (0.2%)	192 (0.1%)
	May	94.3	94.3 (-0.1%)	94.3 (-0.1%)	94.3 (-0.1%)	94.3 (0%)
Below Normal	November	397.1	398.3 (0.3%)	397.9 (0.2%)	398.2 (0.3%)	398 (0.2%)
	December	301.7	300.7 (-0.3%)	300.7 (-0.3%)	300.7 (-0.3%)	300.6 (-0.4%)
	January	251.5	249.2 (-0.9%)	248.7 (-1.1%)	249 (-1%)	248.5 (-1.2%)
	February	225.1	222.6 (-1.1%)	222.8 (-1%)	222.6 (-1.1%)	223.2 (-0.8%)
	March	159.2	156.9 (-1.4%)	157 (-1.3%)	156.9 (-1.4%)	157.1 (-1.3%)
	April	143.4	143.3 (-0.1%)	143.3 (-0.1%)	143.3 (-0.1%)	143.3 (-0.1%)
	May	84.9	84.9 (0%)	85 (0.1%)	84.9 (0%)	84.9 (0%)
Dry	November	414.6	414.1 (-0.1%)	413.3 (-0.3%)	414.2 (-0.1%)	413.3 (-0.3%)
	December	300.6	302.2 (0.5%)	298.9 (-0.6%)	302.2 (0.5%)	302.7 (0.7%)
	January	181.7	181.2 (-0.3%)	181.1 (-0.4%)	181.2 (-0.3%)	181.1 (-0.3%)
	February	161.6	159 (-1.6%)	158.8 (-1.7%)	159 (-1.6%)	158.8 (-1.7%)
	March	146.1	143.9 (-1.5%)	144.1 (-1.3%)	143.9 (-1.5%)	144 (-1.4%)
	April	141.1	141 (-0.1%)	141.2 (0.1%)	141 (-0.1%)	141.1 (0%)
	May	80.7	80.7 (0%)	80.8 (0.1%)	80.7 (0%)	80.8 (0.1%)
Critically Dry	November	337.0	335.6 (-0.4%)	335.4 (-0.5%)	335.3 (-0.5%)	336 (-0.3%)
	December	234.0	233.2 (-0.4%)	233.2 (-0.4%)	233.1 (-0.4%)	233.4 (-0.3%)
	January	165.9	165.1 (-0.5%)	165.1 (-0.5%)	165.1 (-0.5%)	165.2 (-0.4%)
	February	122.3	121.9 (-0.3%)	121.9 (-0.3%)	121.9 (-0.3%)	121.9 (-0.3%)
	March	120.5	120.1 (-0.4%)	120.1 (-0.4%)	120.1 (-0.4%)	120.1 (-0.3%)
	April	126.1	126 (0%)	126 (0%)	126 (0%)	126 (0%)
	May	73.9	73.8 (-0.1%)	73.8 (-0.1%)	73.8 (-0.1%)	73.8 (0%)

11M.4 Conclusion

Except for the Sutter Bypass, the analyses indicated that during the winter and spring months, when inundated habitat is most important to Chinook salmon, steelhead, and Sacramento splittail, the mean daily acreages of suitable habitat are generally lower under Alternatives 1, 2, and 3 than under the NAA. However, the reductions are mostly small and unlikely to have substantial effects on the fish populations. The reductions were largest for the Yolo Bypass (Table 11M-2), but the net reduction for all January through April days was 107 acres or 1.3% (Table 11M-3). The Sutter Bypass results showed almost no reductions and many minor increases in daily habitat acreage under Alternatives 1, 2, and 3 (Table 11M-4). The lower Sutter Bypass results showed reductions of up to 50 acres under Alternative 3 (Table 11M-5). Acreages of Sacramento River inundated side-channel habitat was moderately reduced under Alternatives

1, 2, and 3 (Table 11-7 through Table 11-9). Overall, no consistent differences in the frequency of inundation events were found between the NAA and Alternatives 1, 2, and 3.

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