Appendix J, Spring Delta Outflow

Attachment J.2 Sturgeon Year Class Index and Delta Outflow

J.2.1 Model Overview

This analysis assesses potential effects of the proposed project and alternatives on white or green sturgeon year-class index (YCI) using a correlative relationship between Sacramento–San Joaquin Delta (Delta) outflow and white sturgeon YCI based on Fish (2010). The analysis uses historical Delta outflow and white sturgeon YCI data to establish the relationships. Modeled Delta outflow values from CalSim 3 are then used as input to these relationships to estimate white sturgeon YCI. White sturgeon YCI is used as a surrogate to estimate green sturgeon YCI.

J.2.2 Model Development

J.2.2.1 Methods

This analysis was originally used by ICF International (2016) to assess potential effects of the California WaterFix project on white and green sturgeon. The analysis was updated for the current document to include new white sturgeon YCI and Delta outflow data through 2020 (Table J.2-1). Annual white sturgeon YCI data obtained from the California Department of Fish and Wildlife (CDFW) San Francisco Bay Study (California Department of Fish and Wildlife unpublished data) and historical daily Delta outflow data were extracted from the California Department of Water Resources Dayflow data (https://data.cnra.ca.gov/dataset/dayflow). Daily outflow data were averaged for each year for either March–July or April–May. White sturgeon YCI data were regressed against mean Delta outflow data for March–July and April–May (Figure 1) to establish the relationships between YCI and Delta outflow. The updated relationships used are:

$$Log_{10}(YCI+1) = [0.0000227 * \text{Delta Outflow (Apr–May)}] + 0.246,\ r^2 = 0.56,\ P<0.0001$$

$$Log_{10}(YCI+1) = [0.0000275 * \text{Delta Outflow (Mar–Jul)}] + 0.169,\ r^2 = 0.59,\ P<0.0001$$

Table J.2-1. Historical Data Used to Develop Regressions of White Sturgeon Year-Class Strength versus Mean Delta Outflow Data (cfs) for March–July and April–May.

Year	Year-Class Index	March-July Delta Outflow (cfs)	April-May Delta Outflow (cfs)
1980	11.1	35,060	24,652
1981	21.8	11,478	10,375
1983	599.6	119,942	108,220
1984	40.7	15,798	12,836
1985	44.0	6,911	7,072
1986	23.5	49,947	30,923
1987	8.5	8,261	5,517
1988	0	5,451	7,983
1989	0	14,130	9,497
1990	0	5,248	6,826
1991	0	7,946	3,783
1992	0	5,854	4,732
1993	72.5	33,974	34,585
1994	0	7,006	8,044
1995	348.6	92,926	94,501
1996	161.0	40,478	44,059
1997	46.7	15,662	13,266
1998	327.7	72,580	77,724
1999	18.2	30,309	28,753
2000	0	31,258	24,678
2001	0	11,539	10,942
2002	0	11,153	12,762
2003	0	20,299	32,159
2004	19.1	20,857	17,137
2005	0	31,406	40,624
2006	234.6	84,048	129,578
2007	30.2	9,580	10,327
2008	0	8,193	8,867
2009	0	12,255	13,994
2010	0	17,082	22,611
2011	48.8	59,129	65,740
2012	11.1	15,209	20,012

Year	Year-Class Index	March-July Delta Outflow (cfs)	April-May Delta Outflow (cfs)
2013	0	9,165	11,444
2014	0	6,863	6,013
2015	No index	N/A	N/A
2016	No index	N/A	N/A
2017	284.0	66,842	85,730
2018	0	19,282	27,057
2019	66.0	59,427	67,608
2020	0	8,470	10,200

cfs = cubic feet per second.

Modeled monthly Delta outflow from CalSim 3 for the full simulation period (1922-2021) are used as inputs to the analysis. Since the model is used to predict new values of YCI, not just assess the goodness of fit to the historical data, cross-validation to assess its predictive ability was completed to estimate the predictive error using a repeated k-fold approach (5-fold, repeated 4 times). For the March-July outflow relationship the Root Mean Square Error (RMSE) value was 0.66, multiple R^2 value was 0.63, and Mean Absolute Error value was 0.57. This translated into an average prediction error of 3 to 4 YCI for a historical average of 80+/-165 (standard deviation). For the April-May outflow relationship, RMSE was 0.67, Multiple R^2 was 0.6 and MAE was 0.6. Outputs from the analysis are white sturgeon YCI for each modeled scenario. The regression operates at an annual time step. The analysis was conducted using R statistical software (R Core Team 2023).

J.2.2.2 Assumptions / Uncertainty

A primary assumption of this analysis is that the correlation between white sturgeon YCI and Delta outflow is causal such that Delta outflow drives white sturgeon YCI. Although this assumption of causality is reasonable, there is little evidence that Delta outflow itself drives the YCI. The two variables, Delta outflow and white sturgeon YCI, may both vary in response to another variable. As a result, there is moderate uncertainty in the results of this analysis.

Another assumption of this analysis is that, because no green sturgeon YCI has been developed, white sturgeon is an appropriate surrogate species for green sturgeon. Although the two sturgeon species share several life history traits, the spatial and temporal use of upstream and Delta habitat, as well as their movement within their ranges, differ between the species. Therefore, the results of the analysis for green sturgeon YCI have higher uncertainty than those for white sturgeon YCI.

J.2.2.3 Code and Data Repository

Code, input, and output files for this analysis can be found at: https://icfonline.sharepoint.com/:f:/r/sites/EP/USBR_2021LTO/Public%20Draft%20Alternatives/Appendix%20J.%20Spring%20Delta%20Outflow%20Attachments/J.%20Sturgeon%20YCI%20and%20outflow/Data%20and%20Code?csf=1&web=1&e=Zc0MZW

J.2.3 Results

These results describe potential effects to white sturgeon, although they are applied similarly to green sturgeon.

Table J.2-2. Year-Class Strength of Green Sturgeon Based on April–May Regression with Delta Outflow.

WYT	EXP 1	EXP 3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	139.1	58.2	30.3	29.0	29.0	29.5	29.7
AN	16.9	8.5	5.8	5.1	5.2	5.4	6.0
BN	8.8	4.7	3.5	3.2	3.3	3.4	3.8
D	3.4	2.3	2.2	2.2	2.2	2.2	2.4
C	1.7	1.6	1.4	1.6	1.5	1.6	1.7
All	46.6	20.2	11.2	10.7	10.7	10.9	11.2

Table only includes annual mean responses and does not consider model uncertainty.
WYT = Water Year Type, W = Wet, AN = Above Normal, BN = Below Normal, D = Dry, C= Critically Dry.

The average YCI by water year type based on the April-May regression with Delta-Outflow are presented in Table J.2-2. Excluding Exp 1 and Exp 3, the average overall YCI values would generally be similar across all alternatives, with the highest average values obtained for the NAA and PA Without TUCP Systemwide VA at 11.2 and the lowest average values obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA at 10.7. This pattern would hold true across water year types with ranges (min-max) of average YCI going from 0.3 in Critically Dry years to 1.3 in Wet years. In Critically Dry years, the lowest average YCI would be obtained for the NAA (1.4) and the highest for PA Without TUCP Systemwide VA (1.7). In Dry years, the average YCI would be very consistent across alternatives with PA Without TUCP Systemwide VA at 2.4 and all others (excluding Exp 1 and Exp 3) at 2.2. In Below Normal years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA (3.2) and the highest for PA Without TUCP Systemwide VA (3.8). In Above Normal years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA (5.1) and the highest for PA Without TUCP Systemwide VA (6). In Wet years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA (29) and the highest for the NAA (30.3). Exp 1 and Exp 3 unsurprisingly would follow the same patterns of increasing average YCI from Critically Dry years to Wet years, with values ranging from 1.7 to 139.1 and 1.6 to 58.2, respectively.

Table J.2-3. Year-Class Strength of Green Sturgeon Based on March–July Regression with Delta Outflow.

WYT	EXP 1	EXP 3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	159.6	90.0	48.9	47.9	47.9	48.3	48.3
AN	14.5	9.9	6.7	6.2	6.3	6.5	6.9
BN	5.5	3.8	2.9	2.8	2.8	2.9	3.1
D	2.8	2.3	2.0	1.9	1.9	2.0	2.1
C	1.4	1.4	1.2	1.3	1.2	1.3	1.4
All	51.7	29.7	16.7	16.3	16.3	16.6	16.7

Table only includes annual mean responses and does not consider model uncertainty.
WYT = Water Year Type, W = Wet, AN = Above Normal, BN = Below Normal, D = Dry, C= Critically Dry.

The average YCI by water year type based on the March-July regression with Delta-Outflow are presented in Table J.2-3. Excluding Exp 1 and Exp 3, the average overall YCI values would generally be similar across all alternatives, with the highest average values obtained for the NAA and PA Without TUCP Systemwide VA at 16.7 and the lowest average values obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA at 16.3. This pattern would hold true across water year types with ranges (min-max) of average YCI going from 0.2 in Critically Dry years to 1 in Wet years. In Critically Dry years, the lowest average YCI would be obtained for the NAA and PA Without TUCP Without VA (1.2) and the highest for PA Without TUCP Systemwide VA (1.4). In Dry years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA (1.9) and the highest for PA Without TUCP Systemwide VA (2.1). In Below Normal years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA (2.8) and the highest for PA Without TUCP Systemwide VA (3.1). In Above Normal years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA (6.2) and the highest for PA Without TUCP Systemwide VA (6.9). In Wet years, the lowest average YCI would be obtained for Alt2 With TUCP Without VA and PA Without TUCP Without VA (47.9) and the highest for the NAA (48.9). Exp 1 and Exp 3 unsurprisingly would follow the same patterns of increasing average YCI from Critically Dry years to Wet years, with values ranging from 1.4 to 159.6 and 1.4 to 90, respectively.

Table J.2-4. Year-Class Strength of White Sturgeon (Percent Difference from NAA) Based on April–May Regression with Delta Outflow.

WYT	NAA	Alt 1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt 3	Alt 4
W	30.3	29.1 (-4.2%)	29 (-4.5%)	29 (-4.4%)	29.5 (-2.8%)	29.7 (-2%)	50.2 (65.5%)	29 (-4.2%)
AN	5.8	5.1 (-12.2%)	5.1 (-10.9%)	5.2 (-10.7%)	5.4 (-6%)	6 (4.6%)	9.2 (58.6%)	5.2 (-10.7%)
BN	3.5	3.2 (-8.9%)	3.2 (-7%)	3.3 (-6.4%)	3.4 (-3.3%)	3.8 (9.2%)	4.6 (30.9%)	3.2 (-7.1%)
D	2.2	2.2 (-3.3%)	2.2 (-3.4%)	2.2 (-2.9%)	2.2 (-1.5%)	2.4 (7.5%)	2.6 (17.3%)	2.2 (-2.9%)
C	1.4	1.6 (10.3%)	1.6 (11.7%)	1.5 (1.8%)	1.6 (11.4%)	1.7 (16.2%)	1.7 (16.1%)	1.5 (2.1%)
All	11.2	10.7 (-4.6%)	10.7 (-4.7%)	10.7 (-4.7%)	10.9 (-2.7%)	11.2 (-0.1%)	18 (59.9%)	10.7 (-4.6%)

Table only includes annual mean responses and does not consider model uncertainty.
WYT = Water Year Type, W = Wet, AN = Above Normal, BN = Below Normal, D = Dry, C= Critically Dry.

The average YCI by water year type based on the April-May regression with Delta-Outflow are presented in Table J.2-4. The average overall YCI values would be generally similar across all alternatives except Alt 3, which would be substantially higher at 18 (+59.9% compared to the NAA). Except for Alt 3, they would range from 10.7 for Alt 1, Alt2 With TUCP Without VA, Alt2 Without TUCP Without VA and Alt 4 (-4.6% difference with the NAA) to 11.2 for Alt2 Without TUCP Systemwide VA, which would be essentially similar to the NAA. This general pattern would be most pronounced for Wet and Above Normal years with Alt 3 yielding the highest average YCI across all alternatives at 50.2 and 9.2, respectively, far exceeding the average YCI of 30.3 and 5.8 obtained for the NAA (a difference of +65.5% and 58.6%, respectively). In those wetter years, the average absolute YCI values for all other alternatives considered would be mostly similar or slightly lower compared to the NAA. In Wet years, they would range from 29 for Alt2 With TUCP Without VA, Alt2 Without TUCP Without VA and Alt 4 to 29.7 for Alt2 Without TUCP Systemwide VA (differences of -4.5% to -2% compared to the NAA). The average YCI would vary a bit more in Above Normal years for those other alternatives, ranging from 5.1 for Alt 1 and Alt2 With TUCP Without VA to 6 for Alt2 Without TUCP Systemwide VA (differences of -12.2% to + 4.6% compared to the NAA), although these relative differences would still be well within the variation observed among individual Above Normal years for any given alternative besides Alt 3 (yearly AN YCI ranging from about 2.1 to 11.4). While less pronounced, these differences between alternatives would still be detected for Below Normal years, ranging from slightly lower than the NAA for Alt 1 at 3.1 (-8.9%) to slightly higher than the NAA for Alt2 Without TUCP Systemwide VA at 3.8 (+9.2%), or substantially higher than the NAA for Alt 3 at 4.6 (+30.9%). In Dry years, Alt2 Without TUCP Systemwide VA and Alt 3 may yield small positive relative differences compared to the NAA (+7.5 and +16.3%, respectively), while the YCI for all other alternatives would be virtually indistinguishable from those obtained for the NAA. In Critically Dry Years, all alternatives would lead to either no detectable difference in average YCI with the NAA (Alt2 Without TUCP Without VA and Alt 4) or possibly small positive differences (from +10.3% for Alt 1 to +16.2% for Alt2 Without TUCP Systemwide VA). However, it is important to keep in mind that in dryer years (D and CD): 1) historical (observed) yearly YCI were most often at zero or relatively low (and then almost exclusively when immediately following wetter years), with no to little

sturgeons detected in the monitoring programs, leading to low average predicted YCI and low absolute differences between alternatives and the NAA compared to the variation between individual years for a given alternative and water year type, and 2) the linear model predictive performance is expectedly low for low Delta outflow values, with considerable uncertainty in the predicted YCI. For April-May Delta outflow values of less than 25,000 cfs, there are likely strong limitations to the ability of the monitoring programs to reliably detect and estimate abundances of sturgeons, and/or additional mechanisms controlling sturgeons' recruitment/YCI that are not directly linked to Delta outflow.

Table J.2-5. Year-Class Strength of White Sturgeon (Percent Difference from NAA) Based on March–July Regression with Delta Outflow.

WYT	NAA	Alt 1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt 3	Alt 4
W	48.9	48.5 (-0.9%)	47.9 (-2%)	47.9 (-1.9%)	48.3 (-1.1%)	48.3 (-1.1%)	66.4 (35.9%)	47.9 (-2.1%)
AN	6.7	5.9 (-12.1%)	6.2 (-7.9%)	6.3 (-6.3%)	6.5 (-2.7%)	6.9 (2.3%)	8.3 (24.2%)	6.3 (-6.3%)
BN	2.9	2.6 (-9.6%)	2.8 (-4.1%)	2.8 (-3.8%)	2.9 (0.3%)	3.1 (6.8%)	3.5 (19.7%)	2.8 (-4%)
D	2.0	1.9 (-5%)	1.9 (-0.5%)	1.9 (-1.4%)	2 (2.5%)	2.1 (7.7%)	2.3 (18.7%)	1.9 (-1.6%)
C	1.2	1.3 (9.1%)	1.3 (12.2%)	1.2 (1.3%)	1.3 (12.4%)	1.4 (15.4%)	1.4 (20.5%)	1.2 (1.3%)
All	16.7	16.4 (-1.7%)	16.3 (-2.2%)	16.3 (-2.2%)	16.6 (-0.9%)	16.7 (-0.3%)	22.4 (34.2%)	16.3 (-2.3%)

Table only includes annual mean responses and does not consider model uncertainty.
WYT = Water Year Type, W = Wet, AN = Above Normal, BN = Below Normal, D = Dry, C= Critically Dry.

The average YCI by water year type based on the March-July regression with Delta-Outflow are presented in Table J.2-5. The average overall YCI values would generally be similar across all alternatives except Alt 3, which would be substantially higher at 22.4 (+34.2% compared to the NAA). Except for Alt 3, they would range from 16.3 for Alt2 With TUCP Without VA, Alt2 Without TUCP Without VA and Alt 4 (+2.2% difference with the NAA) to 16.7 for Alt2 Without TUCP Systemwide VA, which would essentially be similar to the NAA. This general pattern would be slightly more pronounced for Wet and Above Normal years with Alt 3 yielding the highest average YCI across all alternatives at 66.4 and 8.3, respectively, exceeding the average YCI of 48.9 and 6.7 obtained for the NAA (a difference of +35.9% and +24.2%, respectively). In those wetter years, the average absolute YCI values for all other alternatives considered would be mostly similar or slightly lower compared to the NAA. In Wet years, they would range from 47.9 for Alt2 With TUCP Without VA, Alt2 Without TUCP Without VA and Alt 4 to 48.5 for Alt 1 (differences of -2.1% to -0.9% compared to the NAA). The average YCI would vary a bit more in Above Normal years for those other alternatives, ranging from 5.9 for Alt 1 to 6.9 for Alt2 Without TUCP Systemwide VA (differences of -12.1% to + 2.3% compared to the NAA, although these relative differences would still be well within the variation observed among individual Above Normal years for any given alternative besides Alt 3 (yearly AN YCI ranging from about 2.6 to 13.9). While less pronounced, these differences between alternatives

would still be detected for Below Normal years, ranging from 9.6% lower than the NAA for Alt 1 at 2.6 to 6.8% higher than the NAA for Alt2 Without TUCP Systemwide VA at 3.1 or 19.7% higher than the NAA for Alt 3 at 3.5. In Dry years, Alt2 Without TUCP Systemwide VA and Alt 3 may yield small positive relative differences compared to the NAA (+7.7 and +18.7%, respectively), while the YCI for all other alternatives would be virtually indistinguishable from those obtained for the NAA. In Critically Dry Years, all alternatives would lead to either no detectable difference in average YCI with the NAA (Alt2 Without TUCP Without VA and Alt 4) or possibly small positive differences (from +9.1% for Alt 1 to +20.5% for Alt 3). However, it is important again to keep in mind that in dryer years (D and CD): 1) historical (observed) yearly YCI were most often at zero or relatively low (and then almost exclusively when immediately following wetter years) with no to little sturgeons detected in the monitoring programs, leading to low average modeled YCI and low absolute differences between alternatives and the NAA compared to the variation between individual years for a given alternative and water year type, and 2) the linear model predictive performance is expectedly low for low Delta outflow values, with considerable uncertainty in the predicted YCI. For March-July Delta outflow values of less than 35,000 cfs, there are likely strong limitations to the ability of the monitoring programs to reliably detect and estimate abundances of sturgeons, and/or additional mechanisms controlling sturgeon's recruitment/YCI that are not directly linked to Delta outflow.

Reserve the following text for the EIS appendix:

Using the April-May regression, mean white sturgeon YCI would be 5% lower under Alt 2 v1 w TUCP and Alt 2 v1 wo TUCP compared to the NAA (Table J.2-2). Mean white sturgeon YCI under Alt 2 v1 w TUCP and Alt 2 v1 wo TUCP would range from 10% and 10% lower, respectively, in above normal water years, to 10% and 3% higher, respectively, in critically dry water years compared to the NAA.

Using the March-July regression, mean white sturgeon YCI would be 2% lower under Alt 2 v1 w TUCP and Alt 2 v1 wo TUCP compared to the NAA (Table J.2-2). Mean white sturgeon YCI under Alt 2 v1 w TUCP and Alt 2 v1 wo TUCP would range from 6% and 6% lower, respectively, in above normal water years, to 10% and 2% higher, respectively, in critically dry water years compared to the NAA.

J.2.4 References

California Department of Fish and Wildlife unpublished data

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