Appendix A. Drought in the Delta Report - Supplemental Information

Drought MAST. 2022. Ecological Impacts of Drought on the Sacramento-San Joaquin Delta. Preliminary report. Interagency Ecological Program for the San Francisco Estuary. Technical Report #XX. Sacramento, CA. 230 p.

Contents

Sacramento Hydrologic Water Year Index definition

Copied from: https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

Sacramento River Runoff is the sum (in maf) of Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, andAmerican River inflow to Folsom Lake.

The WY sum is also known as the Sacramento River Index, and was previously referred to as the "4 River Index" or "4 Basin Index". It was previously used to determine year type classifications under State Water Resources Control Board (SWRCB) Decision 1485.

Sacramento Valley Water Year Index = 0.4 * Current Apr-Jul Runoff Forecast (in maf) + 0.3 * Current Oct-Mar Runoff in (maf) + 0.3 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 10.0, then 10.0 is used).

This index, originally specified in the 1995 SWRCB Water Quality Control Plan, is used to determine the Sacramento Valley water year type as implemented in SWRCB D-1641. Year types are set by first of month forecasts beginning in February. Final determination is based on the May 1 50% exceedence forecast.

Sacramento Valley Water Year Hydrologic Classification:

Year Type:	Water Year Index:
Wet	Equal to or greater than 9.2
Above Normal	Greater than 7.8, and less than 9.2
Below Normal	Greater than 6.5, and equal to or less than 7.8
Dry	Greater than 5.4, and equal to or less than 6.5
Critical	Equal to or less than 5.4

Statistical Inference in a Bayesian Framework

Statistical inference in a Bayesian framework differs from more common frequentist methods; however, while Bayesian methods may be complex, the results are incredibly intuitive and, generally speaking, just a different way to think about probabilities. Bayesian inference, in short, is a way to simply asks “what is the probability of our hypothesis given our data?” (Ellison 2004; Quintana and Williams 2018). In our case, for example, we will ask the question, "what is the probability that Threadfin Shad catch during multiple drought water-year conditions is less that catch during multiple wet water-years given 43 years of FMWT survey data (spoiler alert, it is 0.999). We will be using two metrics to discuss Bayesian statistical inference: 1) the Probability of Direction and 2) Bayes Factor.

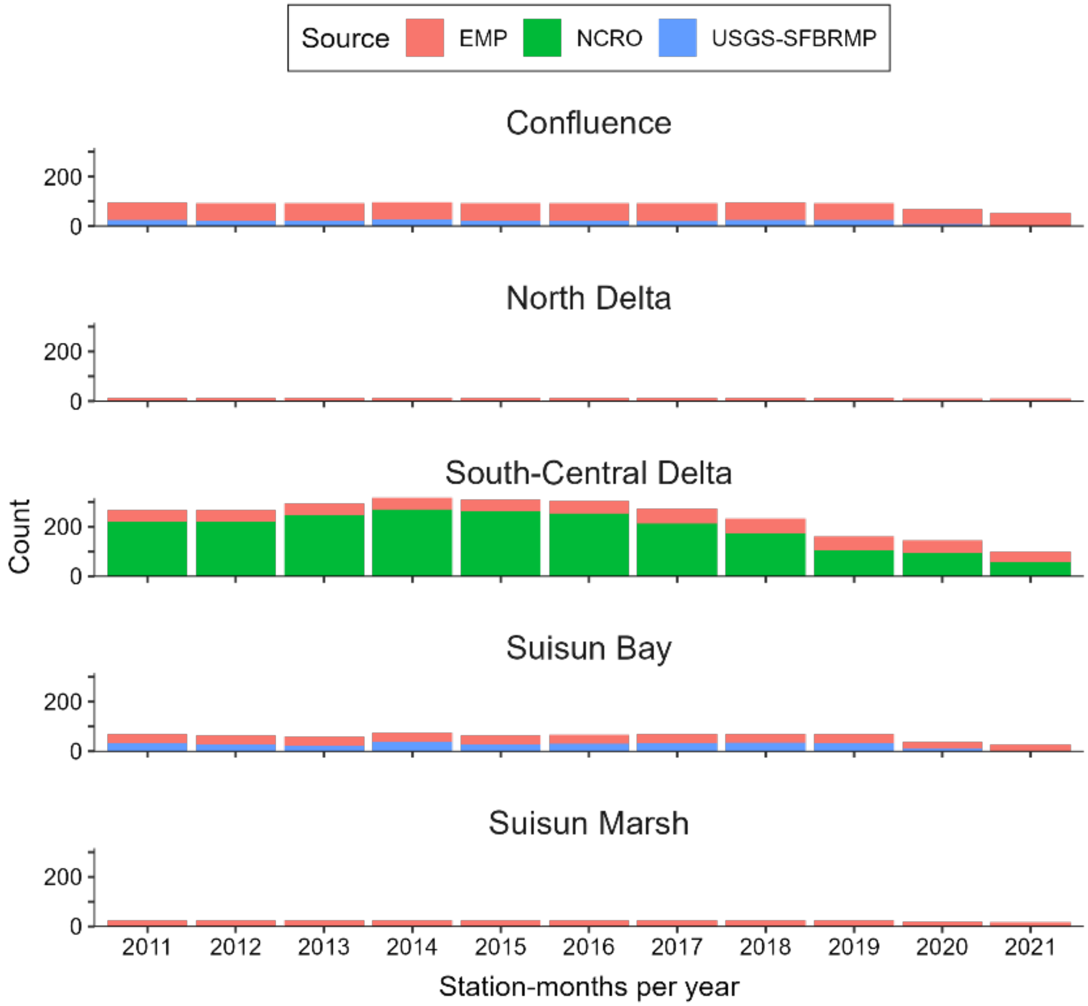
The Probability of Direction is a form of Null-Hypothesis Significance Testing in which we ask what is the probability that a parameter or model prediction (known as the posterior distribution) is positive or negative (i.e., different than zero) (Makowski et al. 2019a; Makowski et al. 2019b). For example, if we subtract the posterior distribution of Threadfin Shad catch during multiple drought water-year conditions from catch during multiple wet water-years conditions, we would expect the values to be centered at zero if the posterior distributions perfectly overlapped (i.e., if catch during multiple drought water-years was the same as during multiple wet water-years). The Probability of Direction, would, therefore be 0.5: 50% of the values were ≥zero and 50% were ≤zero. In our case, however, we observed a Probability of Direction of 0.999: 99.9% of the posterior distribution of Threadfin Shad catch during multiple drought water-year conditions was less than catch during multiple wet water-year conditions.

The Bayes Factor can also be used for Null-Hypothesis Significance Testing as it is a metric describing the difference between the posterior distribution and the null value(s), indicating whether or not the likelihood of the null hypothesis is more or less likely given our data (Makowski et al. 2019a; Makowski et al. 2019b). Continuing with the example of Threadfin Shad during multiple drought and multiple wet years, the null hypothesis is that the difference between the two posterior distributions is zero. We can compare the posterior distribution of the difference between the two water-year types we observed and a distribution that is centered around zero (i.e., a normal distribution with a mean of zero and a standard distribution of one). The Bayes factor metric can be converted into a classification of confidence using Table 4, which is modified from Lee and Wagenmakers (2014) as per Stefan et al. (2019).

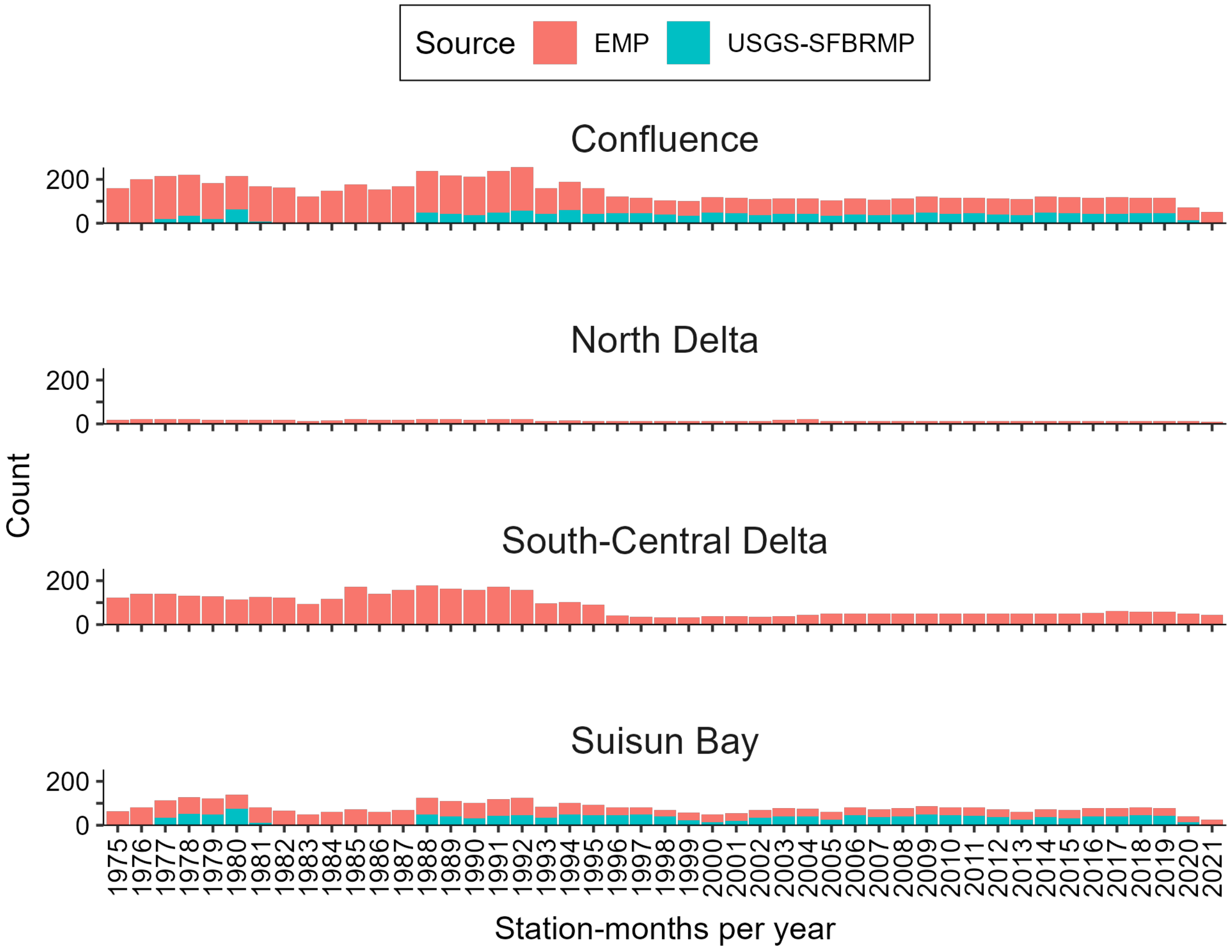
Supplemental table 1. Bayes factor classification where H_0 is the null hypothesis of no difference between posterior distributions and H_1 being the alternative hypothesis of a difference between the posterior distributions.

Bayes factor $BF_{1,0}$	**Bayes Factor Classification**
>100	Extreme evidence: H_1
30 - 100	Very strong evidence: H_1
10 - 30	Strong evidence: H_1
3 - 10	Moderate evidence: H_1
1 - 3	Anecdotal evidence: H_1
1	No evidence
1/3 - 1	Anecdotal evidence: H_0
1/10 - 1/3	Moderate evidence: H_0
1/30 - 1/10	Strong evidence: H_0
1/100 - 1/30	Very strong evidence: H_0
<1/100	Extreme evidence: H_0

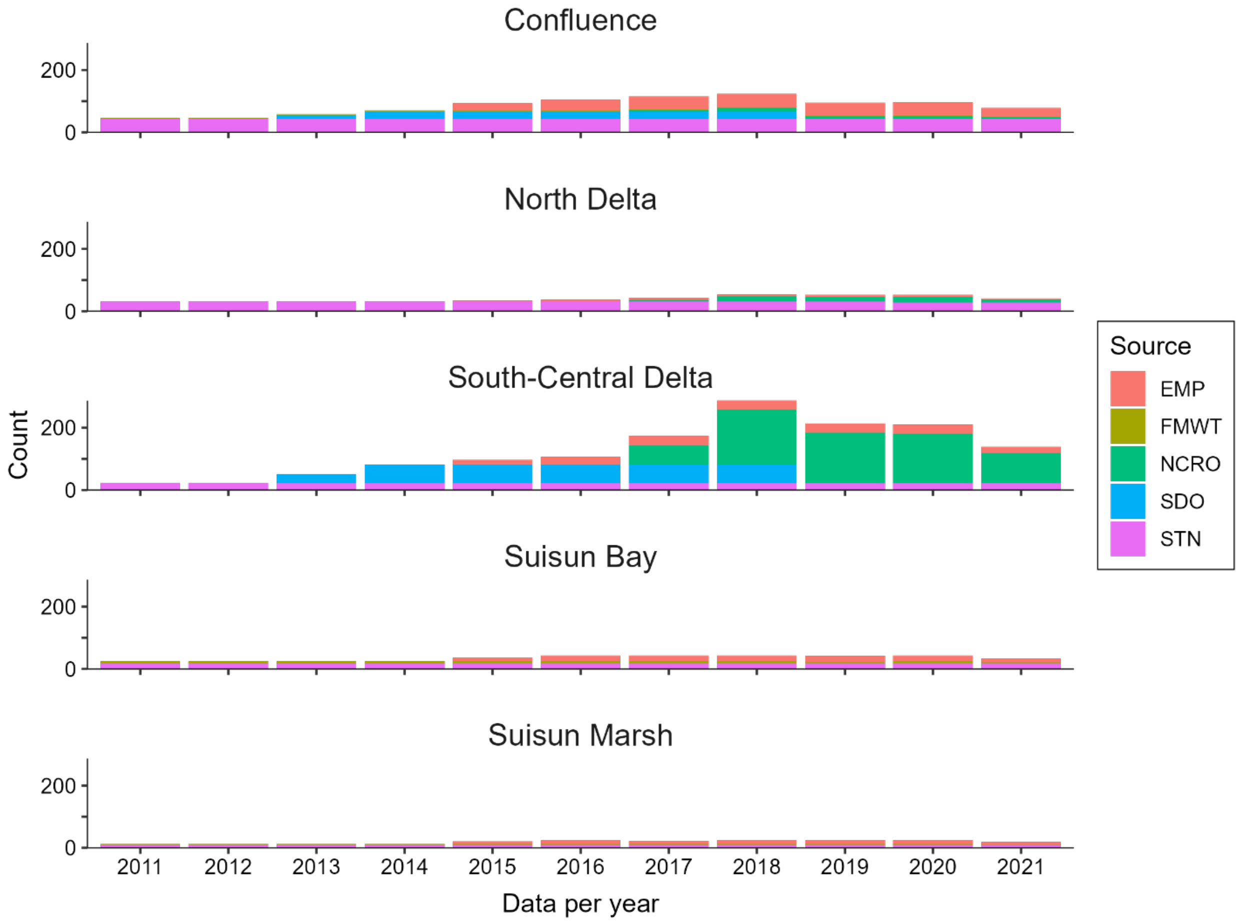
Supplemental Results



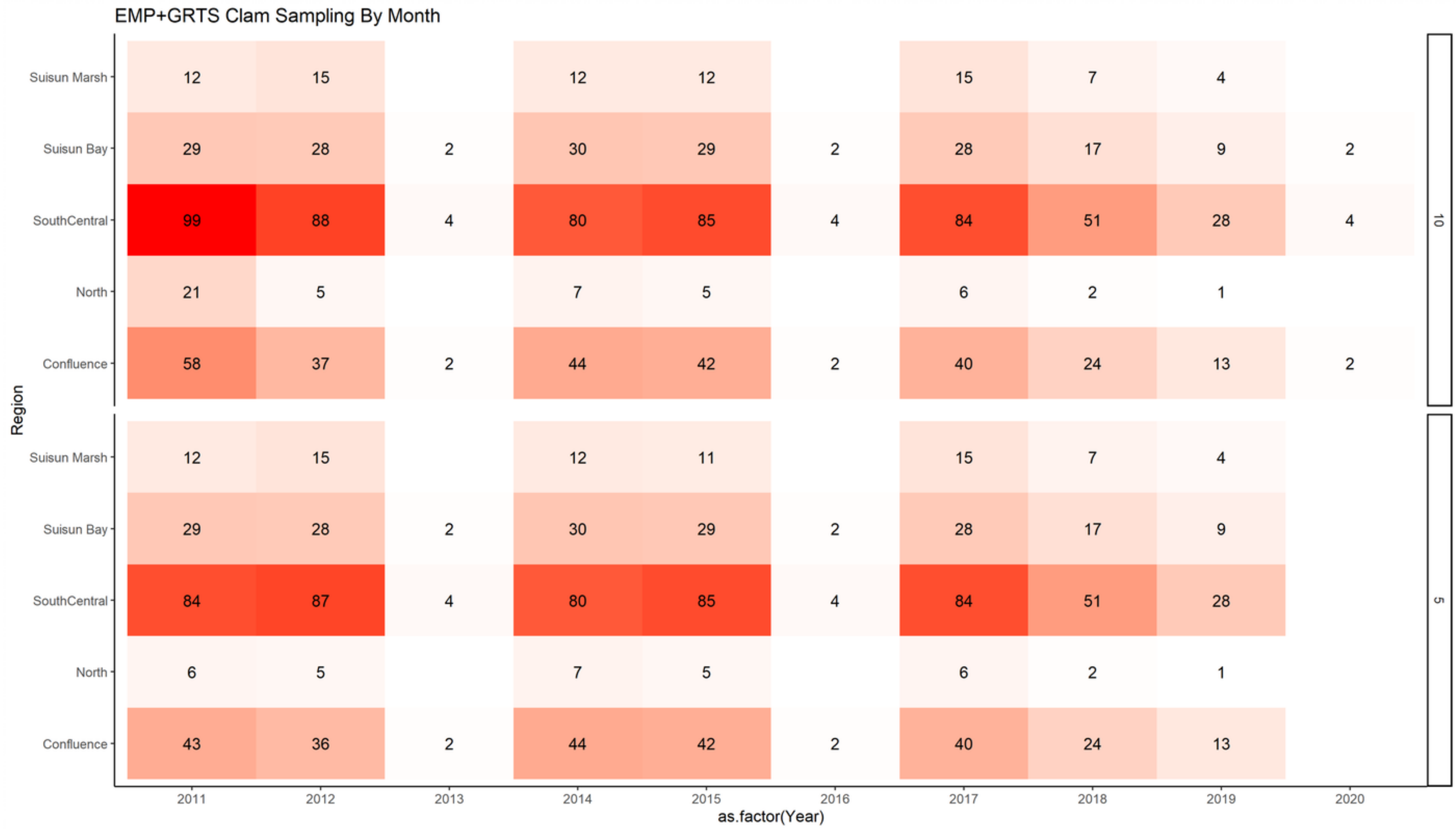
Supplemental Figure 1. The number of chlorophyll-a samples collected by monitoring or research programs used in the short-term (2011- 2021) data analysis.



Supplemental Figure 2. The number of samples collected for each year between 1975 and 2021 by region and sampling program used for the long-term chlorophyll-a analysis.



Supplemental Figure 3. The number of Microcystis visual index samples collected by monitoring and research programs between 2011- 2021 used in the analyses of data between 2011 and 2021.



EMP+GRTS Clam Sampling By Month

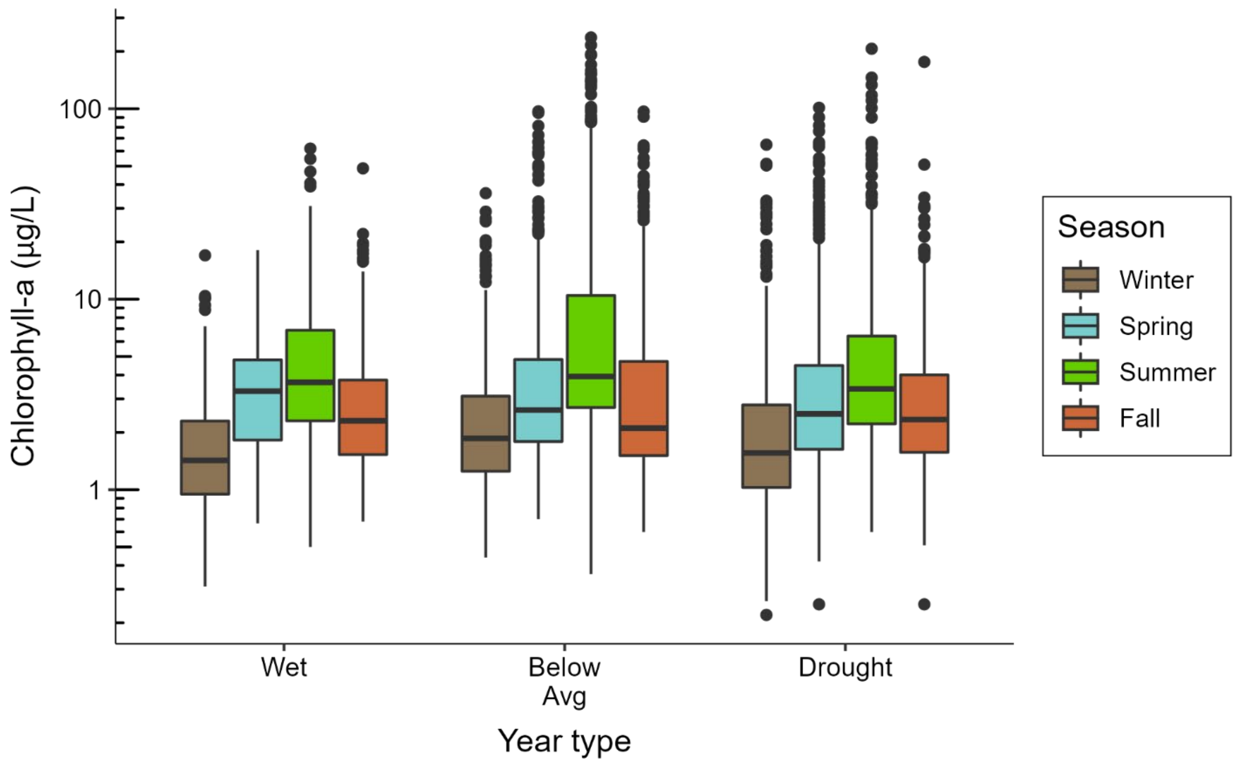
10

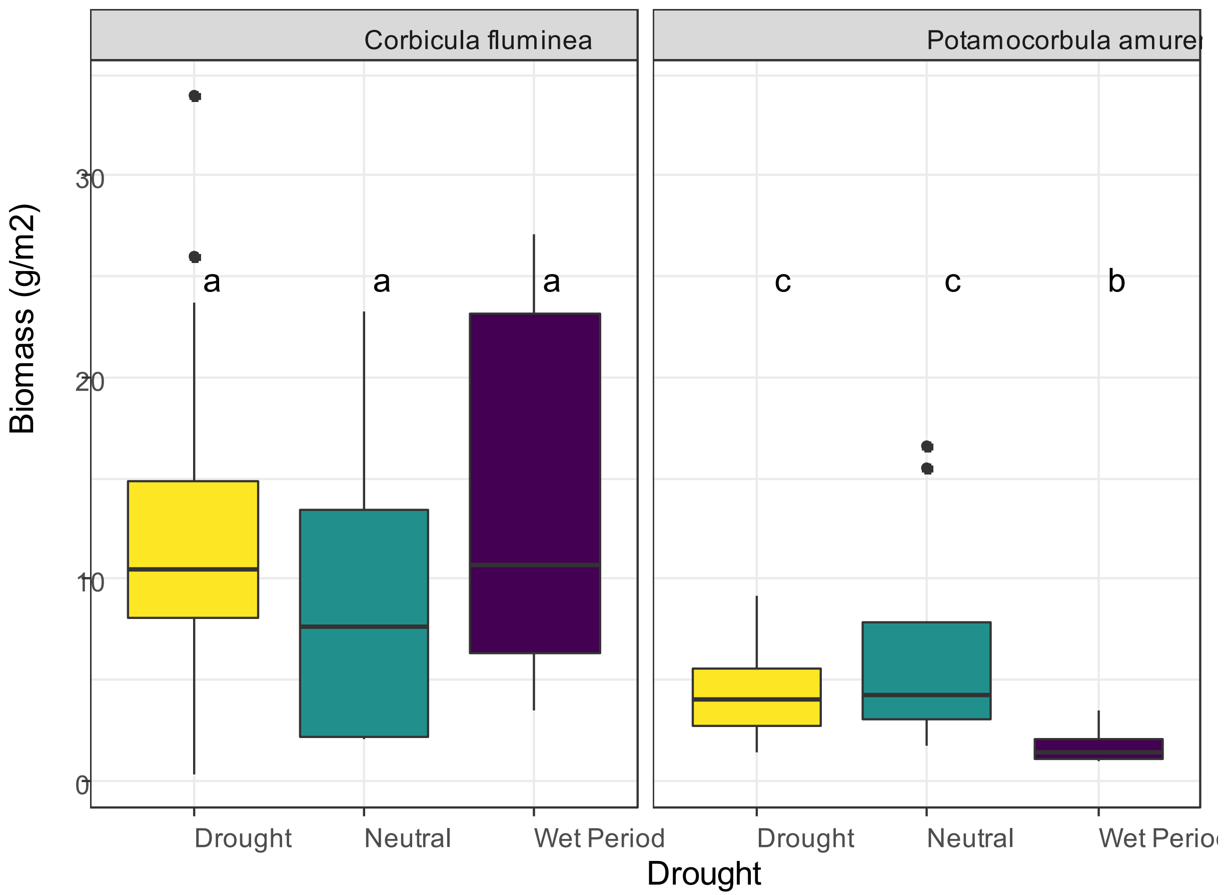
Region	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Suisun Marsh	12	15		12	12		15	7	4	
Suisun Bay	29	28	2	30	29	2	28	17	9	2
SouthCentral	99	88	4	80	85	4	84	51	28	4
North	21	5		7	5		6	2	1	
Confluence	58	37	2	44	42	2	40	24	13	2

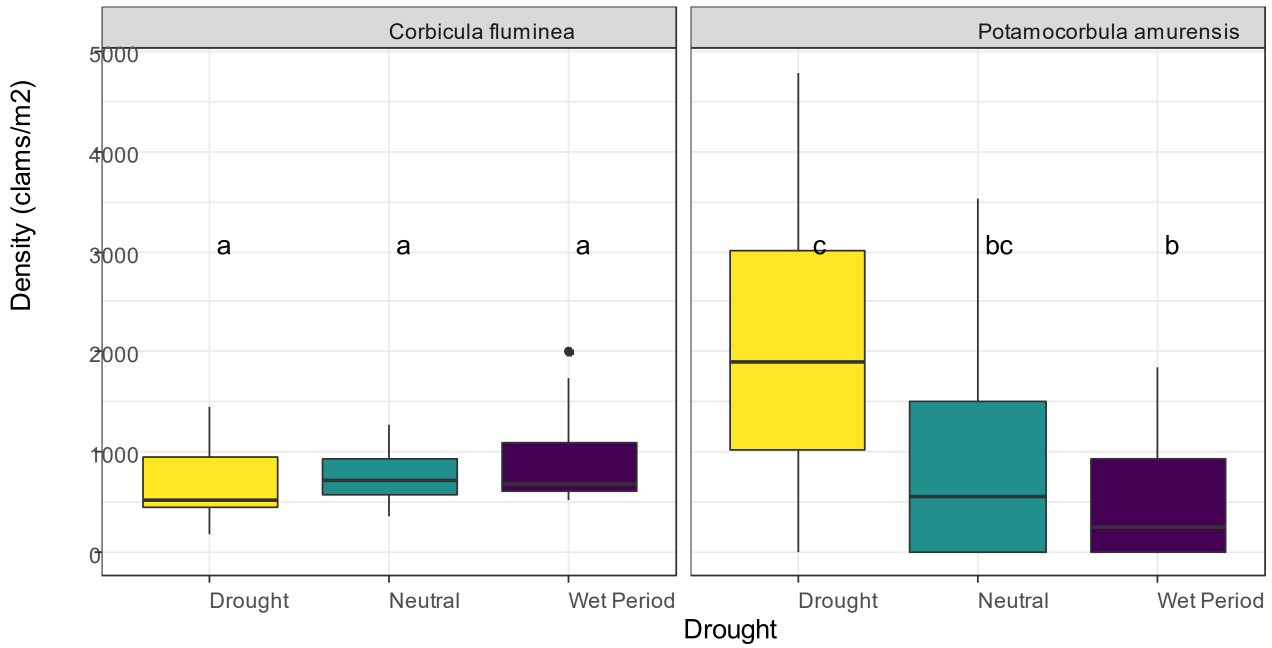
5

Region	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Suisun Marsh	12	15		12	11		15	7	4	
Suisun Bay	29	28	2	30	29	2	28	17	9	
SouthCentral	84	87	4	80	85	4	84	51	28	
North	6	5		7	5		6	2	1	
Confluence	43	36	2	44	42	2	40	24	13	

as.factor(Year)


Chlorophyll-a (µg/L)
100
10
1
Wet
Below
Avg
Drought
Year type
Season
Winter
Spring
Summer
Fall

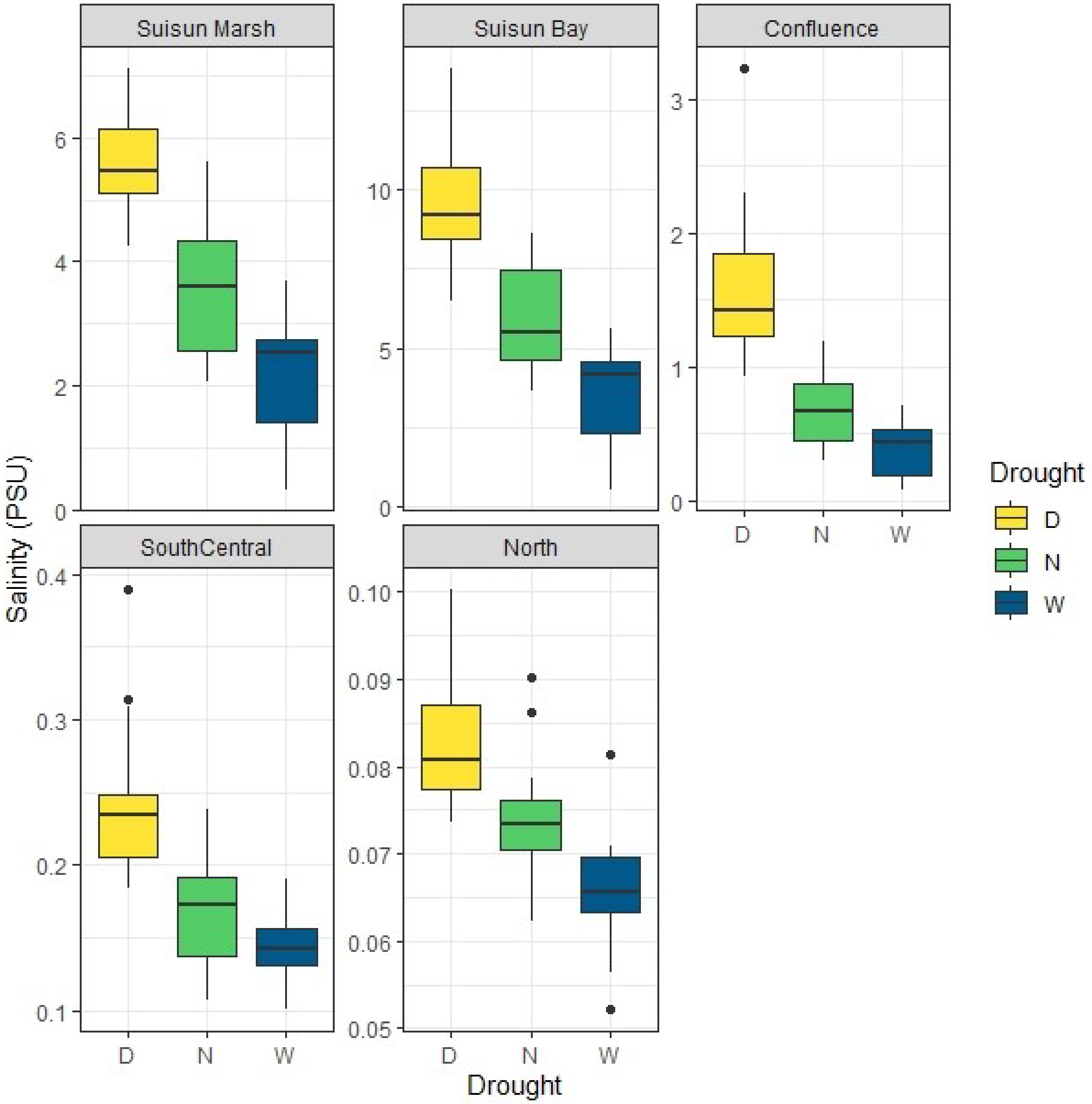

Corbicula fluminea
Potamocorbula amure
Biomass (g/m2)
0
10
20
30
a
a
a
c
c
b
Drought
Neutral
Wet Period
Drought
Neutral
Wet Perio
Drought


Corbicula fluminea
Potamocorbula amurensis
Density (clams/m2)
5000
4000
3000
2000
1000
0
a
a
a
c
bc
b
Drought
Neutral
Wet Period
Drought
Neutral
Wet Period
Drought

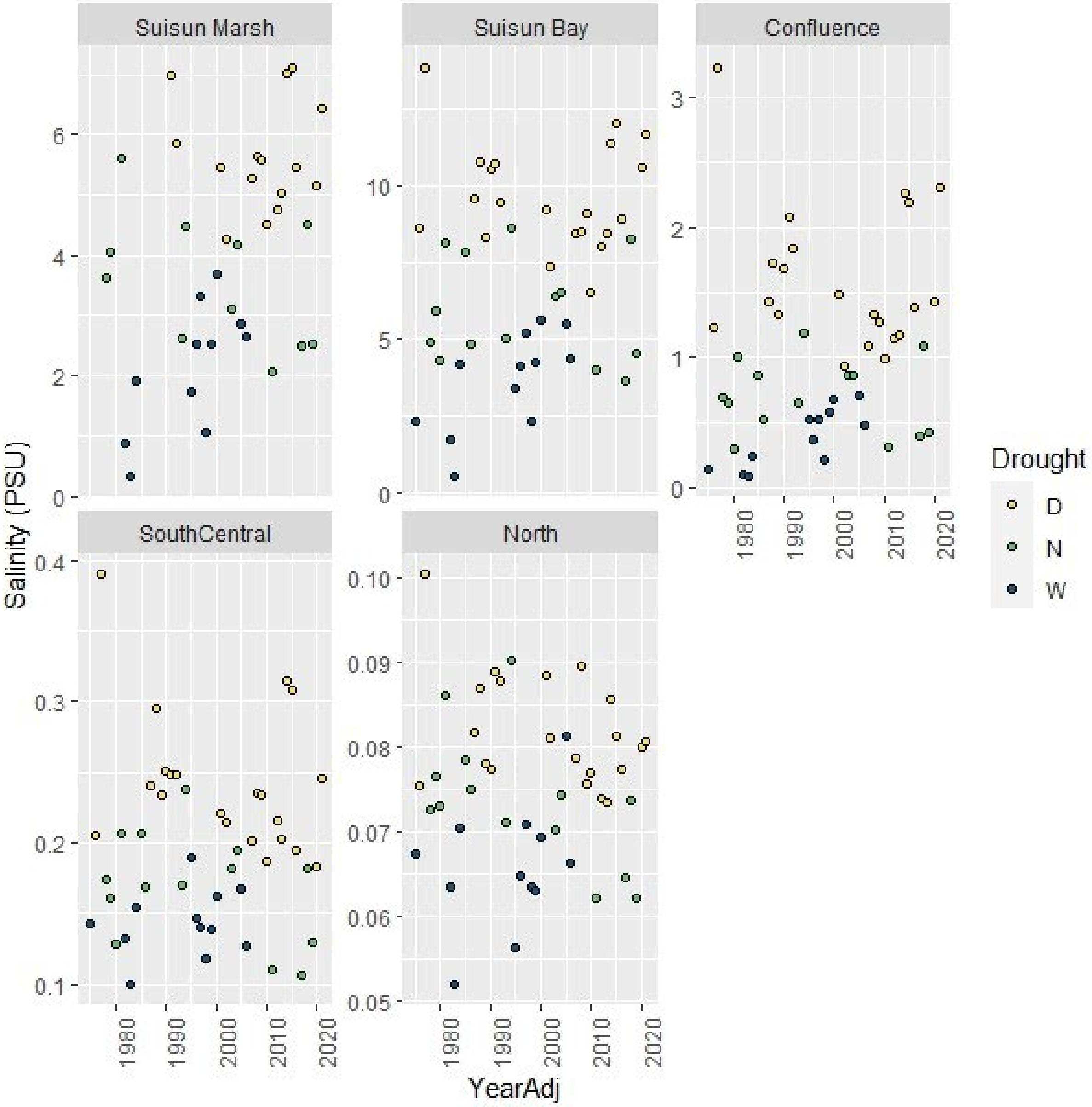
Supplemental Table 2. Anova output of both year-seasonal and seasonal-drought models for the short term Dayflow Outflow and USGS Outflow comparison

Metric	Parameter	Sum Sq	Df	F value	Pr(>F)	model
log(USGS_outflow)	factor(YearAdj)	97.61146	46	11.48986	< 0.001	Year_Season
log(USGS_outflow)	Season	72.68083	3	131.1808	< 0.001	Year_Season
log(USGS_outflow)	Residuals	25.48634	138			Year_Season
log(USGS_outflow)	Drought	10.48026	1	30.07238	< 0.001	Season_Drought
log(USGS_outflow)	Season	9.882239	3	9.45213	< 0.001	Season_Drought
log(USGS_outflow)	Residuals	13.59155	39			Season_Drought
log(Outflow)	factor(YearAdj)	97.61146	46	11.48986	< 0.001	Year_Season
log(Outflow)	Season	72.68083	3	131.1808	< 0.001	Year_Season
log(Outflow)	Residuals	25.48634	138			Year_Season
log(Outflow)	Drought	12.55061	1	42.73595	< 0.001	Season_Drought

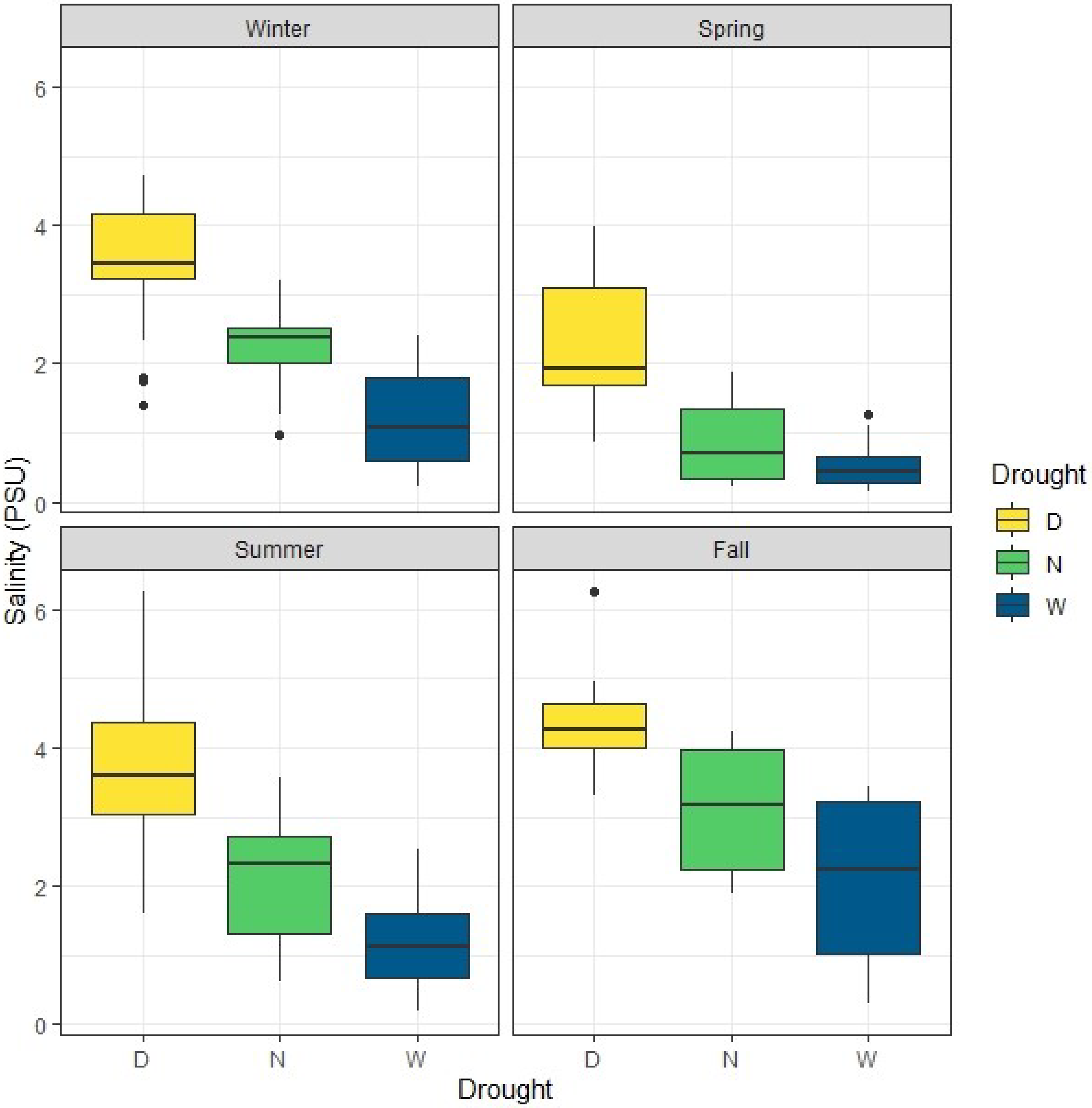
log(Outflow)	Season	12.96424	3	14.71479	< 0.001	Season_Drought
log(Outflow)	Residuals	11.45344	39			Season_Drought



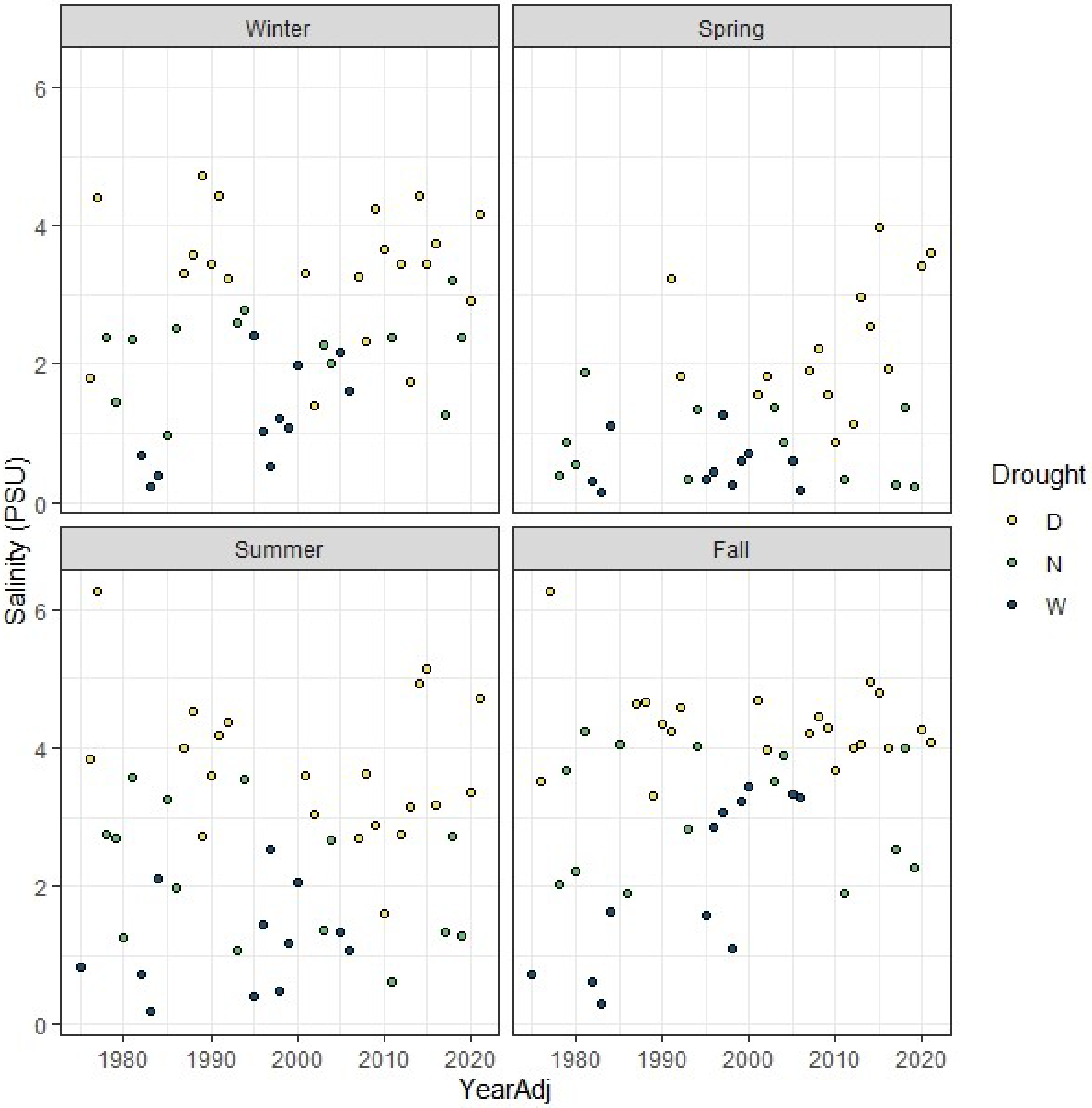
Supplemental Figure 8. Regional salinity by Drought year classification since 1975



Supplemental Figure 9. Salinities observed across all regions during “Wet” years appeared to fall in the lower range of observed values while “Drought” years showed salinity values occurred in the upper range of observed values, and “Neutral” years showed values interspersed largely through the center range of observed values (Supplemental Figure 8). A regional pattern is visible across the three drought year index types showing Suisun Bay had the highest salinity values, followed by Suisun Marsh, then Confluence, then South Central, and finally, North (Supplemental Figure 9, Supplemental Figure 10 and Supplemental Figure 11). There appears to be a slight upward trend in salinity across each region since 1975 (Supplemental Figure 11).

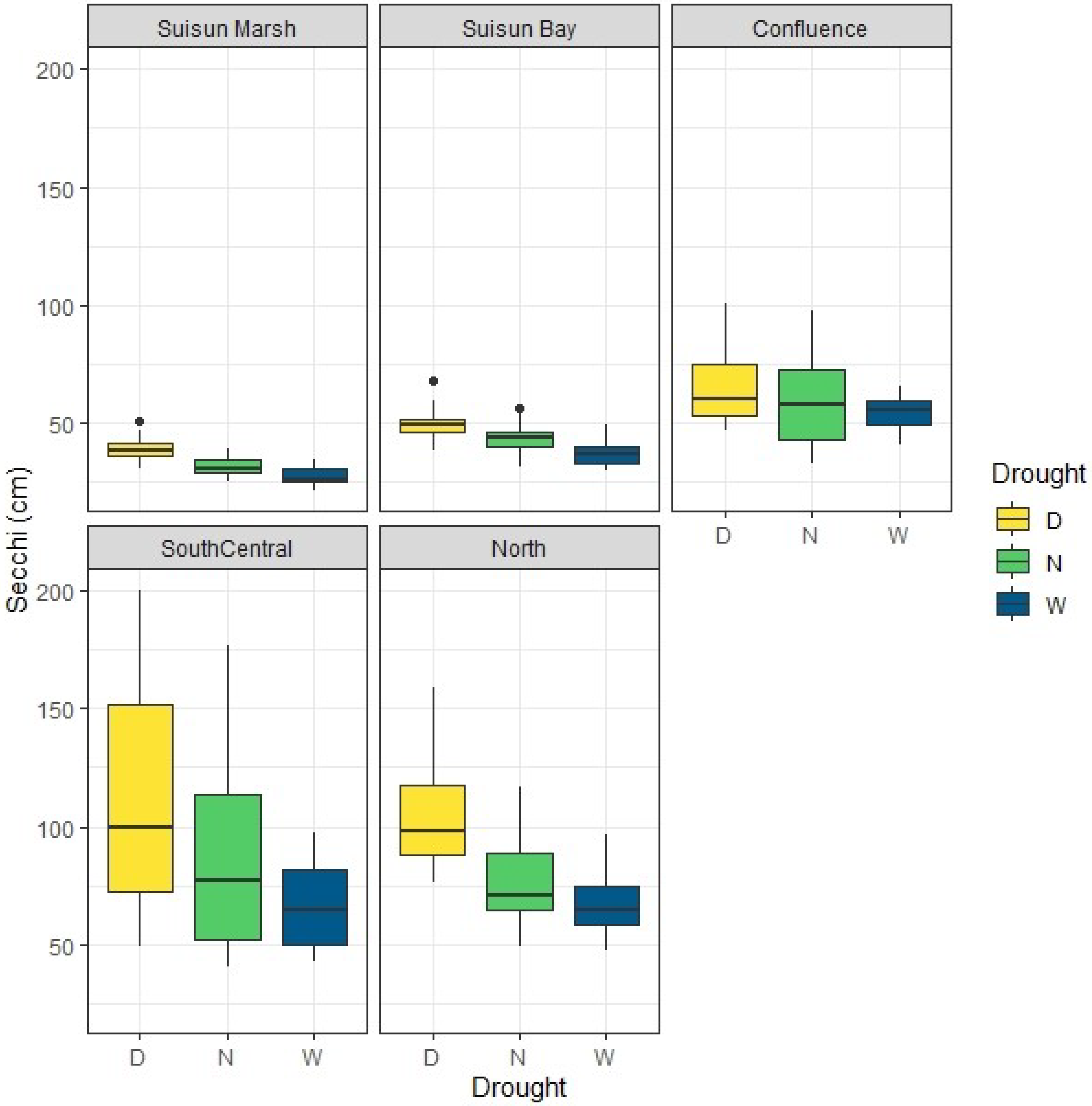


Supplemental Figure 10. Seasonal salinity by Drought year classification since 1975

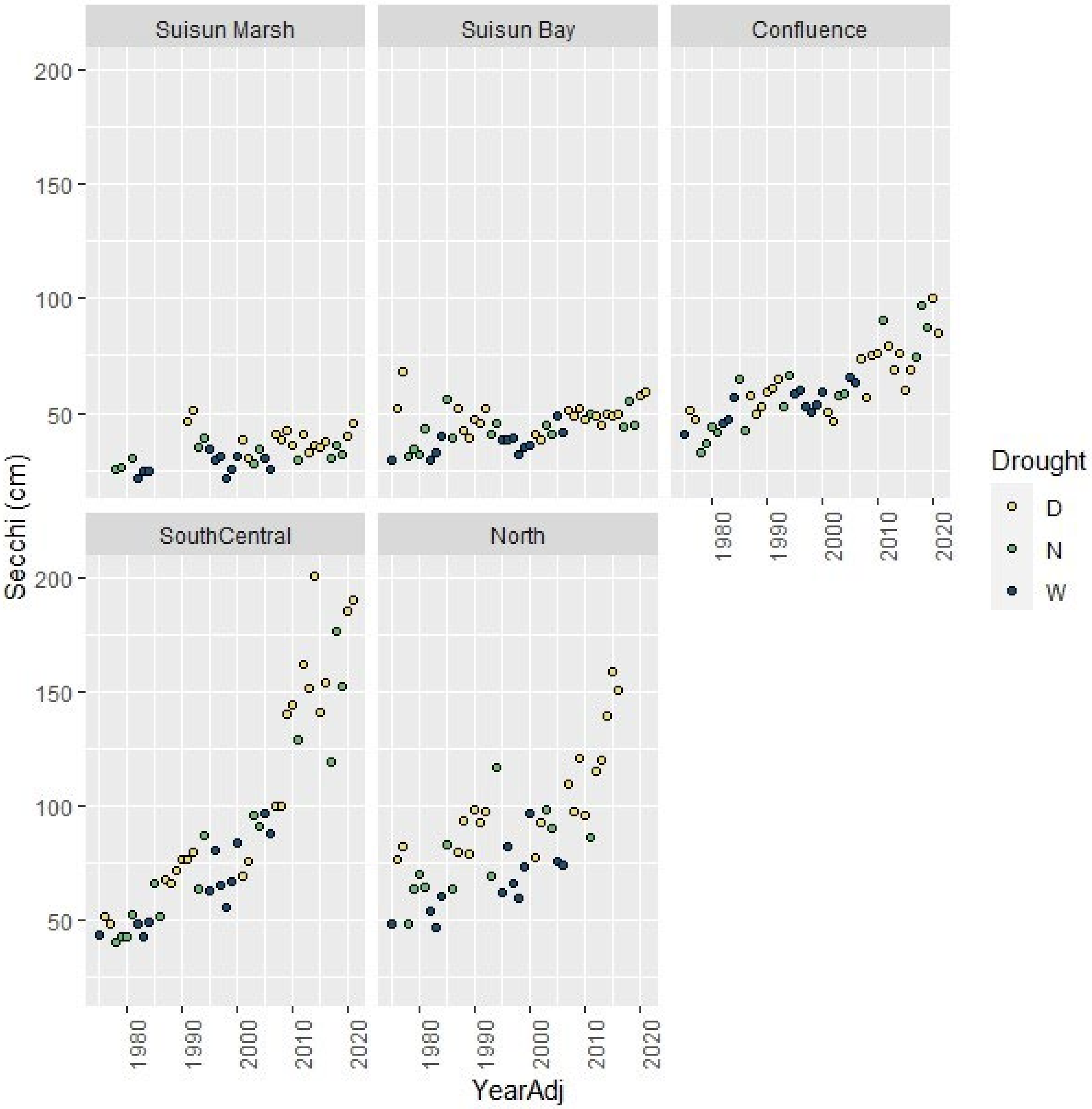


Supplemental Figure 11. Seasonal salinity by year since 1975

Salinity observed across all seasons during “Wet” years appeared to fall in the lower range of observed values while “Drought” years showed salinity values occurring in the upper range of observed values, and “Neutral” years showed values interspersed largely through the center range of observed values (Figure 8). A seasonal pattern is present across all drought year index types and showed the spring season had the lowest salinity, with salinity rarely exceeding 2 PSU (and virtually not at all prior to 2008), winter and summer having higher and more similar salinity than spring, while the fall season had the highest salinity (Figure 8 and Figure 9). There is a slight upward trend in salinity across each of the seasons since 1975, being most pronounced in fall and winter, which both showed a greater incidence of salinity values exceeding 2 PSU over the last 15 years (Figure 9).

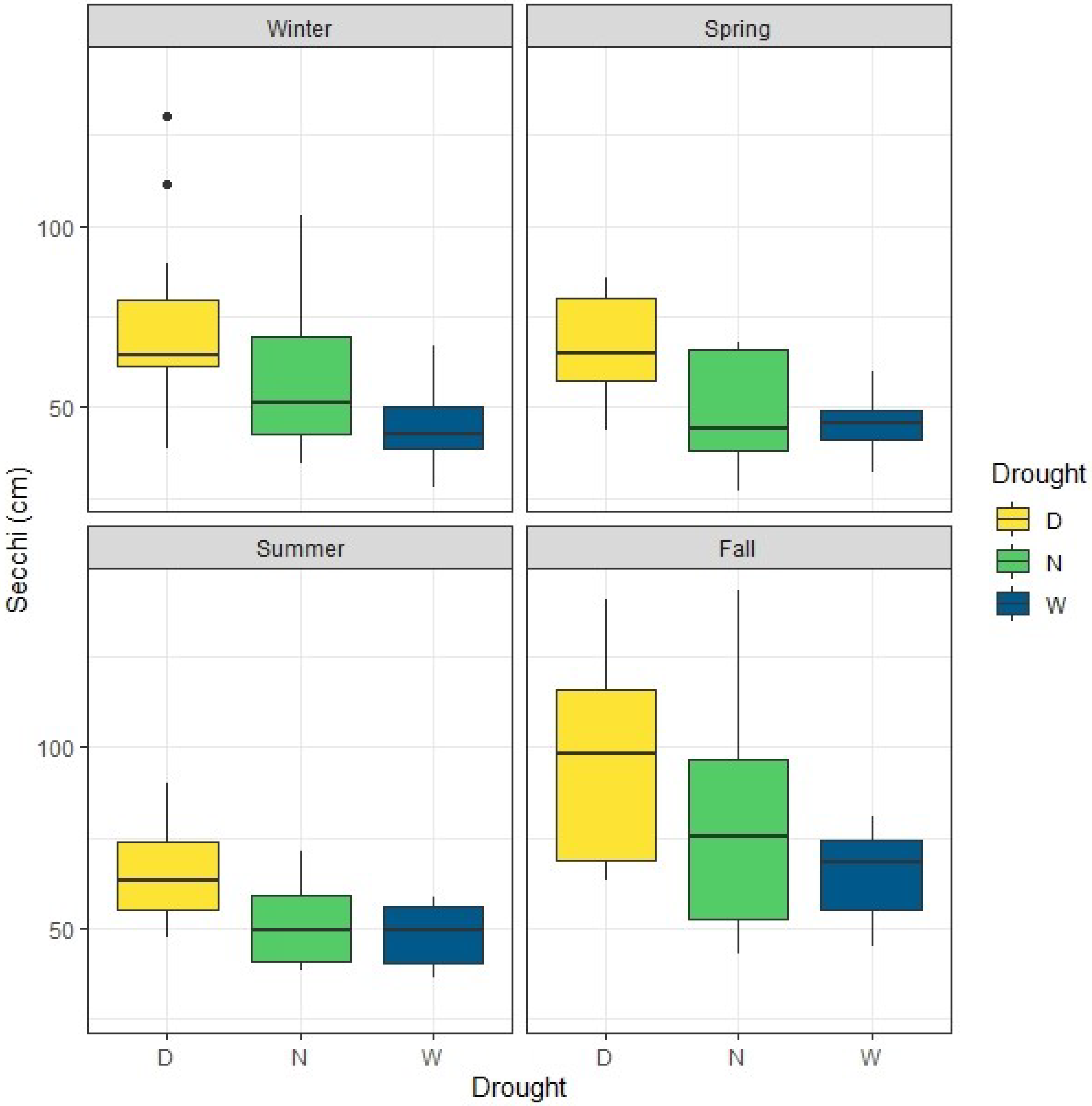


Supplemental Figure 12. Regional secchi depth by Drought year classification since 1975

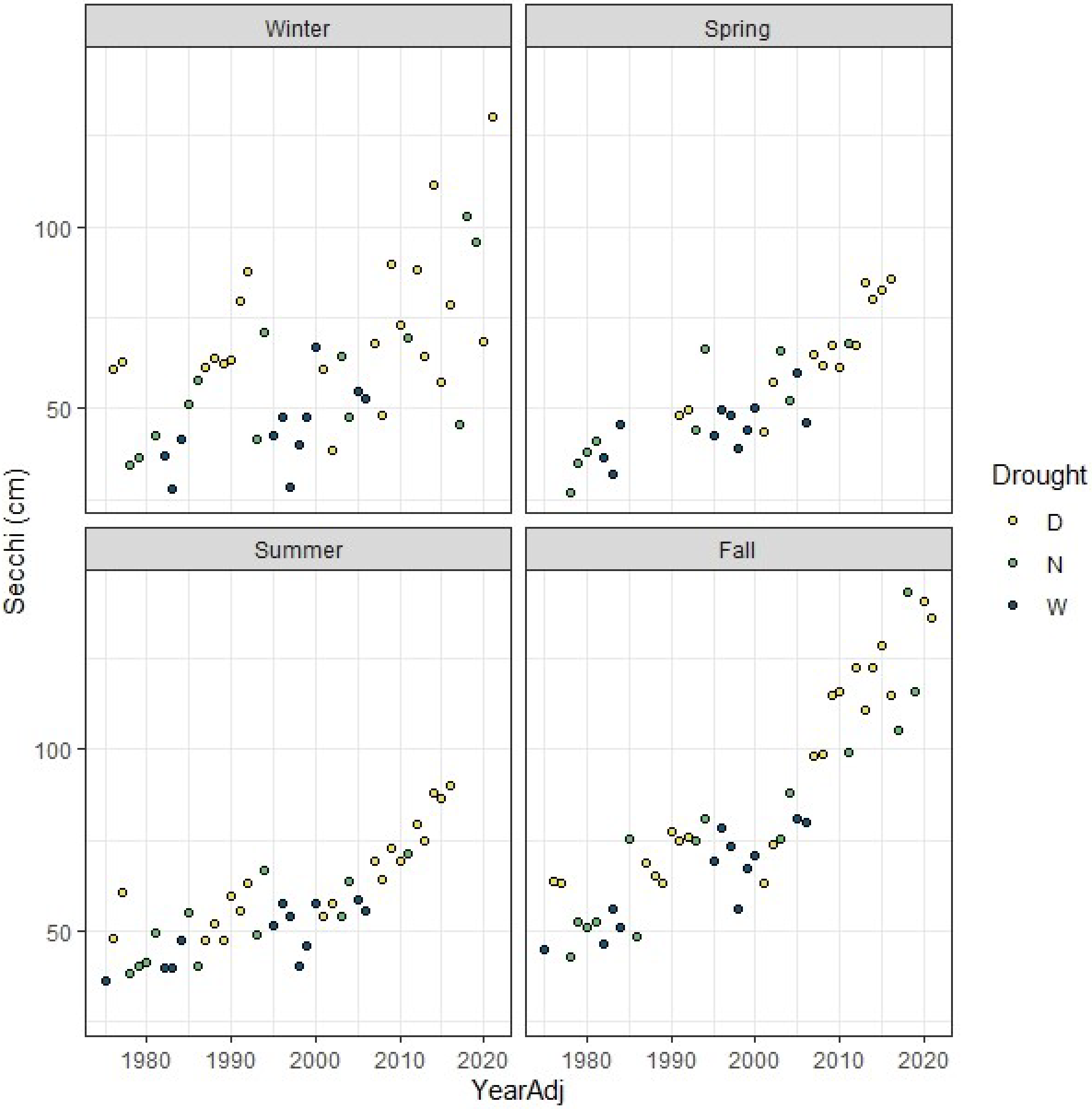


Supplemental Figure 13 Regional secchi depth by year since 1975

Secchi depth measurements across all regions during “Wet” years appeared to fall in the lower range of observed values while “Drought” years showed secchi measurements occurred in the upper range of observed values, and “Neutral” years showed values interspersed largely through the center range of observed values (Supplemental Figure 5). A regional pattern is visible across the three drought year index types showing Suisun Marsh had the lowest secchi values, followed by Suisun Bay, then Confluence, then North, and finally, South Central (Supplemental Figure 12, Supplemental Figure 13). There is an upward trend in secchi depth across each region since 1975 and is most pronounced in the South Central region.



Supplemental Figure 14 Seasonal secchi depth by Drought year classification since 1975



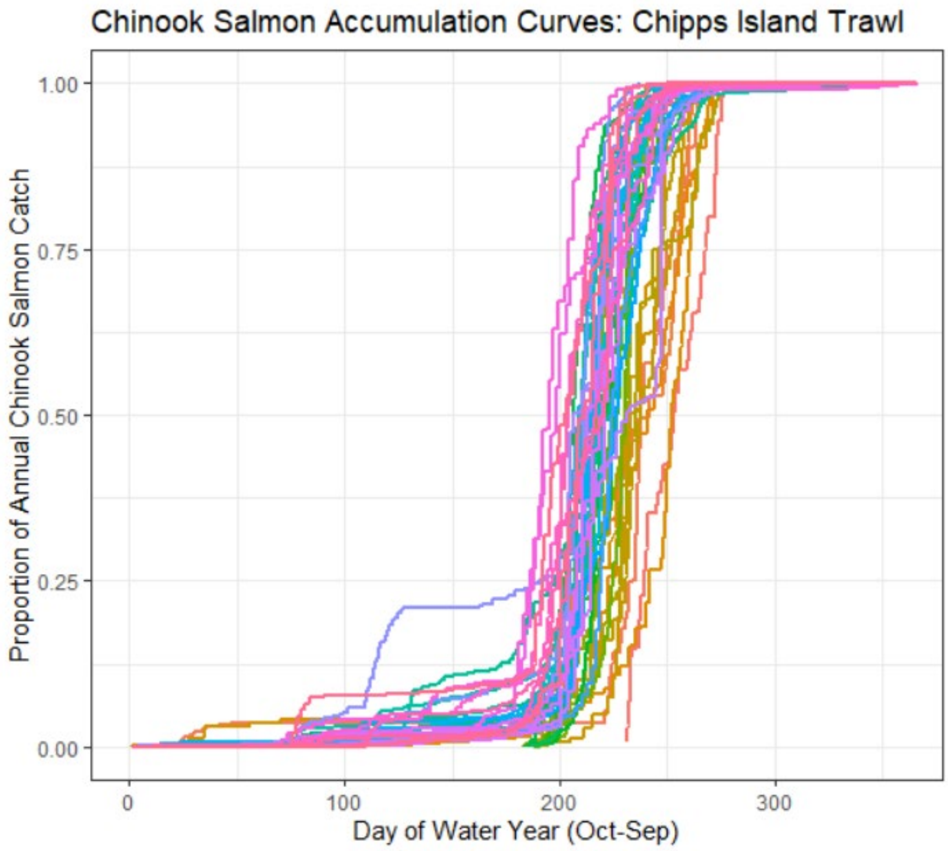
Supplemental Figure 15. Seasonal secchi by year since 1975

Secchi depth observed across all seasons during “Wet” years appeared to fall in the lower range of observed values while “Drought” years showed secchi values occurring in the upper range of observed values, and “Neutral” years showed values interspersed largely through the center range of observed values (Supplemental Figure 11). A seasonal pattern is difficult to discern, though it appears the fall season had the highest secchi across all Drought Indices, with secchi readings below 50 cm extremely rare during the fall and non-existent after 1986 (Supplemental Figure 12, and Supplemental Figure 13). Spring appeared to have lower secchi than summer and winter during "Neutral” years, while summer seemed to have generally higher secchi in

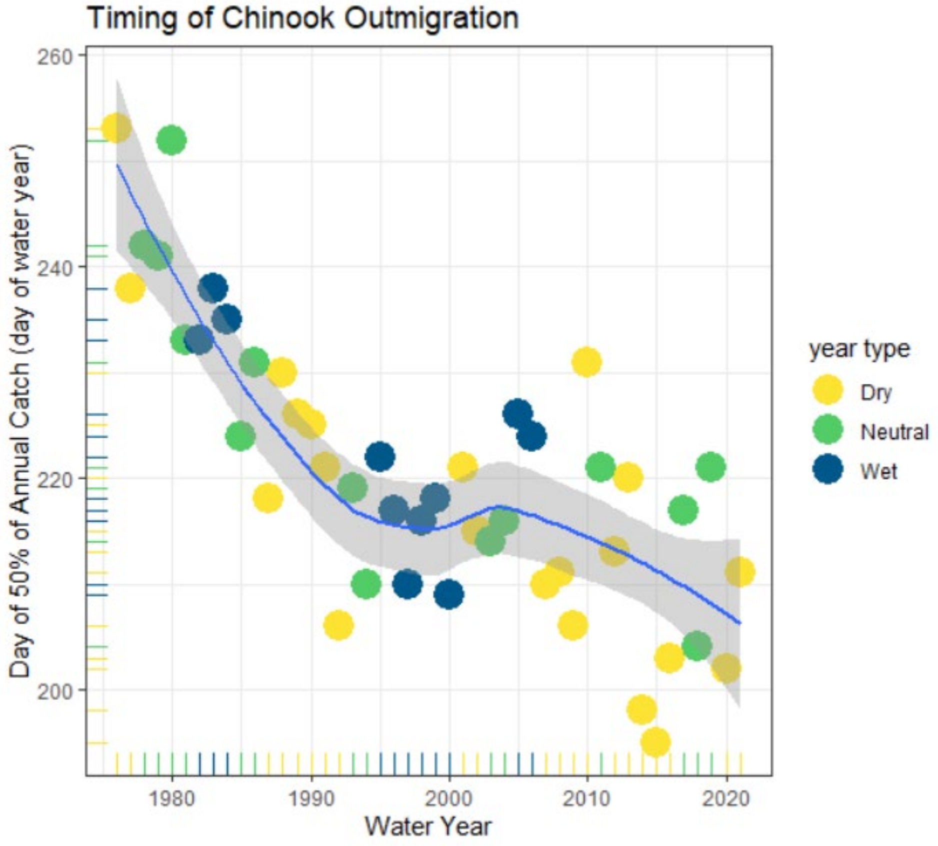
“Wet” and “Drought” years than winter or spring (Supplemental Figure 15). There is an upward trend in secchi depth across each of the seasons since 1975, being most pronounced in fall, spring, and summer, none of which have had secchi measurements below 50 cm since 2006 and none below 75 cm since 2013 (Supplemental Figure 15).

Catch accumulation curves

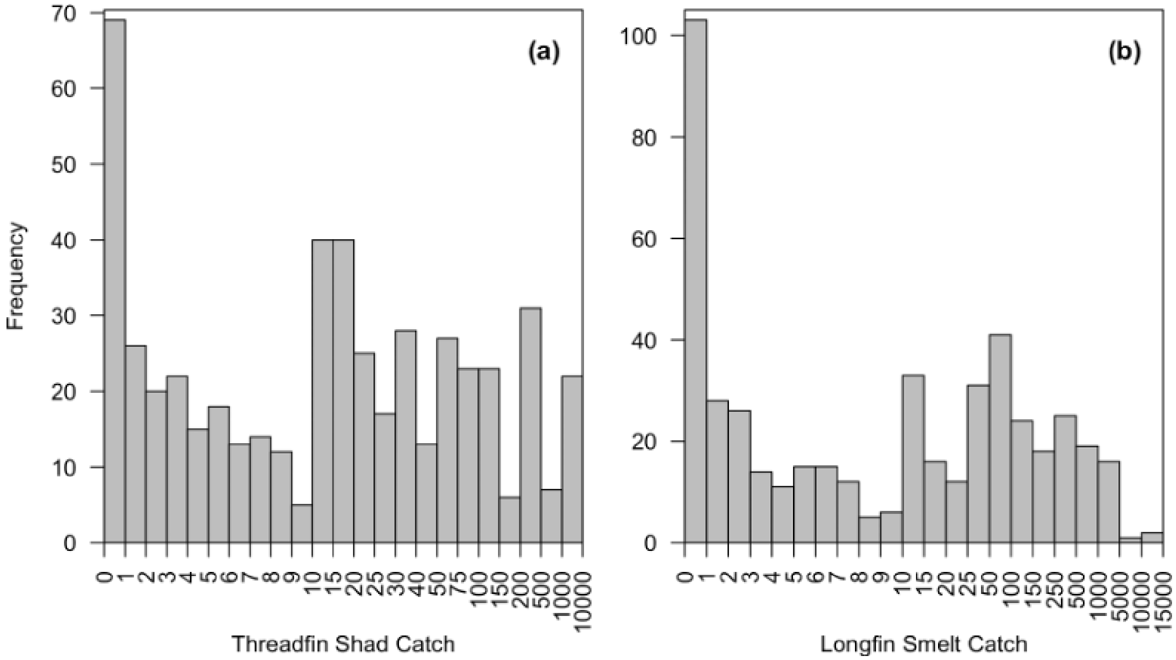
Chinook Salmon Catch accumulation curves from Chipps Island trawl data (all run-types combined) are shown from years 1976-2021 (Supplemental Figure 16). The day at which 50% of each year’s total catch was identified for each year, and categorized based on the year type (“Dry”, “Neutral”, “Wet”); plotted over the 40+ year period (1976-2021) these data show a shift in the timing of Chinook Salmon outmigration earlier in the water year (Supplemental Figure 17).



Supplemental Figure 16 **Central Valley Chinook Salmon (all runs combined) catch accumulation curves from 1976-2021. Colors identify distinct water years.**



Supplemental Figure 17. **Chinook Salmon outmigration at Chipps Island shifted to earlier in the water year from 1976-2021.**



Supplemental Figure 18. Histograms of (a) Threadfin Shad and (b) Longfin Smelt catch. Shown with varying bin widths to highlight the zero-inflated nature of the data.