

Brood Year 2021 Winter-Run Chinook Salmon Report

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Chapter 1

About

We summarize environmental and habitat conditions in 2021 and assess the 2021 brood year of Sacramento winter-run Chinook salmon (WRCS; *Oncorhynchus tshawytscha*) (**BY 2021**). We used data available online to generate this report. This report follows the format of the BY 2019 WRCS Report written by Anchor QEA (@ref(<https://www.anchorqea.com/news/brood-year-2019-winter-run-chinook-salmon-operations-and-monitoring-assessment/>)). The assessment was in collaboration with the Sacramento River Science Partnership.

1.1 WR Chinook Salmon Life History

Sacramento River WRCS begin their spawning migration in November, traveling from the San Francisco Bay to the upper Sacramento River, and spawning between mid-April to August. Juvenile WRCS emigrate downstream between July-March, and are present in the Delta between September-June.

1.2 WR Chinook Salmon Threats

WRCS historically spawned in cold-water reaches of the McCloud, Pit, and Sacramento Rivers. The construction of Shasta and Keswick Dams blocked WRCS from returning to the cooler spawning grounds, and the population is now limited to spawning below Keswick Dam, which experiences higher water temperatures and lower flows.

WRCS were listed under the California Endangered Species Act (CESA) in 1989, and were listed under the Federal Endangered Species Act as endangered on January 4, 1994.

1.3 Spatial Distribution

1.4 Conceptual Model

Metrics selected in this report are based on a conceptual model developed by Windell et al. (2017).

1.5 References

- <https://wildlife.ca.gov/Conservation/Fishes/Chinook-Salmon/Winter-run>
- Moyle P.B. 2002. Inland Fishes of California, University of California Press.
- National Marine Fisheries Service (NMFS). 2014. Recovery Plan for Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct population Segment of California Central Valley Steelhead. California Central Valley Area Office, July 2014.
- Windell, S., P.L. Brandes, J.L. Conrad, J.W. Ferguson, P.A.L. Goertler, B.N. Harvey, J. Heublein, J.A. Israel, D.W. Kratville, J.E. Kirsch, R.W. Perry, J. Pisciotto, W.R. Poytress, K. Reece, B.G. Swart, and R.C. Johnson, 2017. Scientific Framework for Assessing Factors Influencing Endangered Sacramento River WinterRun Chinook Salmon (*Oncorhynchus tshawytscha*) Across the Life Cycle. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFSC-586. August 2017. Available at: https://watershed.ucdavis.edu/files/biblio/NOAA-TM-NMFS-SWFSC-586_Final.pdf

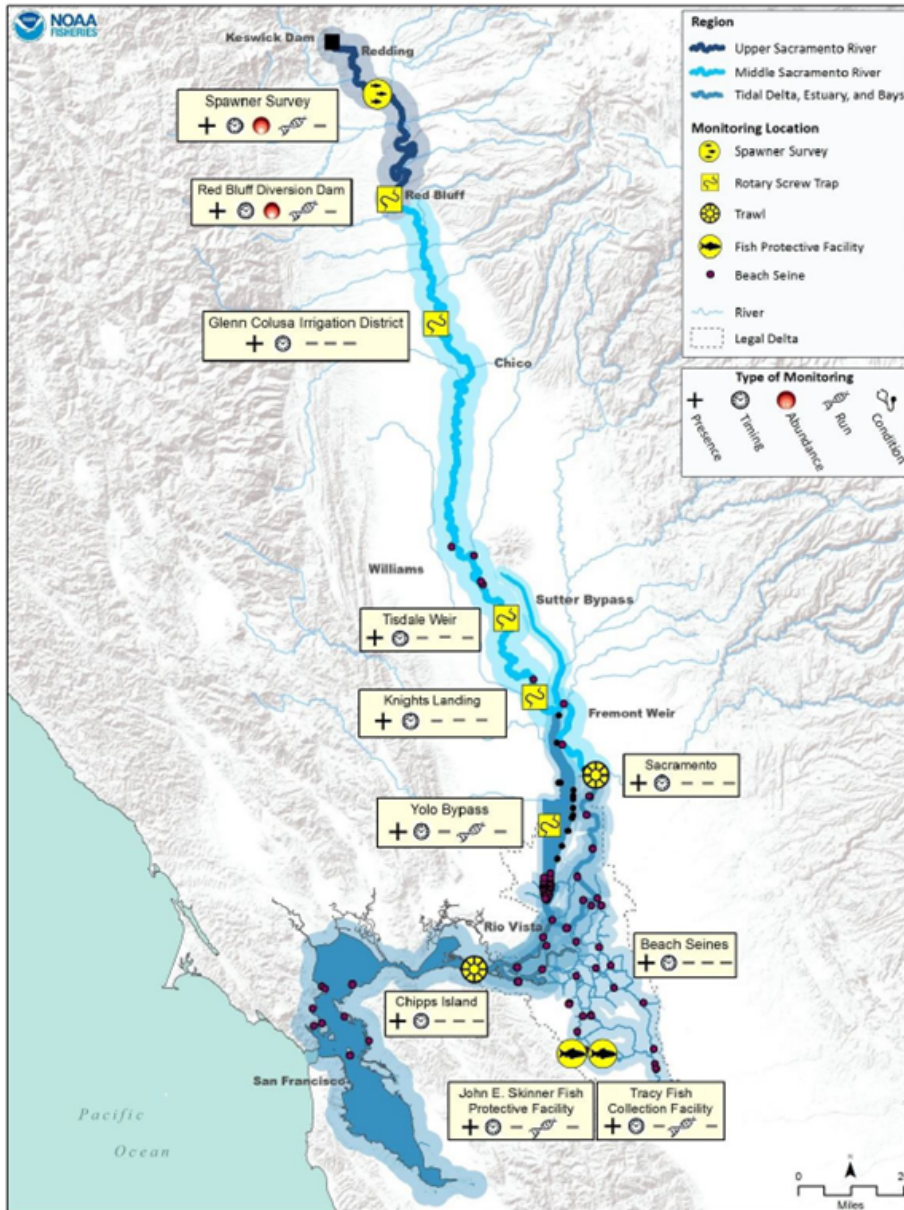


Figure 1.1: “distribution map”

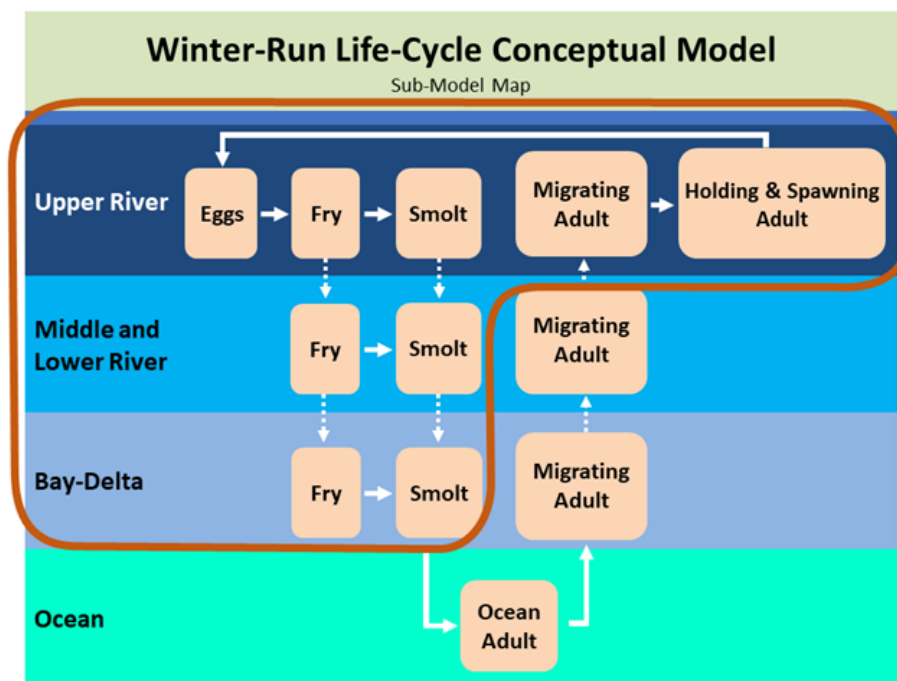


Figure 1.2: “conceptual model”

Chapter 2

Spawning Adults

This section describes environmental attributes associated with and responses during the spawning adult life stage

2.1 Environmental Drivers

2021 was a **Critical** water year type and 2020 was a **Dry** water year type.

2.1.1 Storage and Flow

2.1.1.1 Shasta Storage

Flows in the Sacramento River are dependent on Shasta storage. Adult WR Chinook Salmon rely on flows for migration cues.

2.1.1.2 Flow Conditions on the Upper Sacramento River

Summary

- In 2021, storage was consistently below the 10-year average (Figure 2.1), with peak storage at **2.4** TAF in **4**.
- **Keswick:** Peak flows were 1.08×10^4 cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.

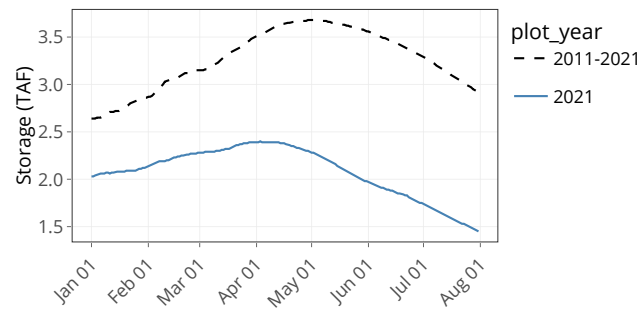


Figure 2.1: Daily Shasta Dam Storage (SHA) in 2021 and over the 10-year average.

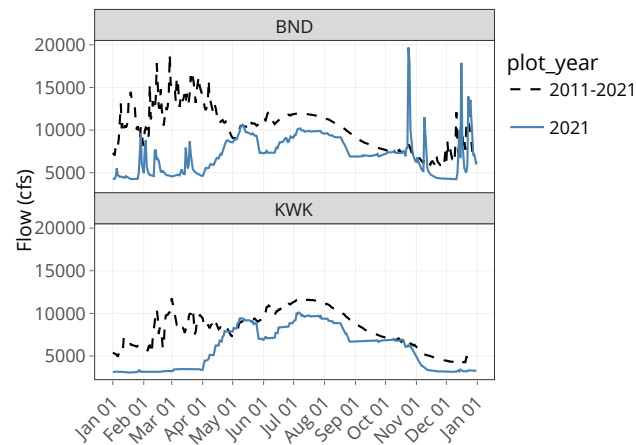


Figure 2.2: Daily Flows (cfs) at Sacramento Rier at Keswick (KWK) and Sacramento River at Bend Bridge (BND) in 2021 and over the 10-year average

Table 2.1: Mean, Maximum, Minimum Monthly Flows (cfs) at Sacramento River at Keswick (KWK) and Sacramento River at Bend Bridge (BND) in 2021

Year	Month	Station	Mean	Min	Max
2021	January	BND	6982.1	4220	12300
2021	February	BND	7358.0	4560	13500
2021	March	BND	7048.8	4540	10100
2021	April	BND	6666.7	4590	8920
2021	May	BND	8858.0	7170	10800
2021	June	BND	8328.5	7180	9330
2021	July	BND	9642.1	9030	10600
2021	August	BND	8334.2	6840	9670
2021	September	BND	7072.0	6840	7300
2021	October	BND	13618.0	6220	36800
2021	November	BND	8279.9	4260	17700
2021	December	BND	10327.5	4220	26600
2021	January	KWK	3217.4	2970	3700
2021	February	KWK	3157.9	2900	3520
2021	March	KWK	3405.0	3170	3640
2021	April	KWK	5682.5	3280	8050
2021	May	KWK	8369.6	6800	9870
2021	June	KWK	7882.3	6570	9390
2021	July	KWK	9510.2	8740	10800
2021	August	KWK	8102.0	6610	9500
2021	September	KWK	6899.8	5310	8500
2021	October	KWK	6160.1	5120	7330
2021	November	KWK	4027.1	3070	5080
2021	December	KWK	3431.0	3040	3970

- **Bend Bridge:** Peak flows were 3.68×10^4 cfs and occurred in **10**. The highest mean flows were 1.3618×10^4 cfs and occurred in **10**.
-

2.1.2 Water Temperature

2.1.2.1 Temperature Threshold Analysis

The temperature compliance point (location of compliance to daily average temperature (DAT) of 56°F) varies annually based on USBR's Temperature Management Plan.

- Conditions in 2021 indicated it was to be a Tier 4 temperature management season.
- Temperature compliance points existed on the Sacramento River at the SAC and CCR gauges and varied by month.
- See <https://www.usbr.gov/mp/bdo/lto/archive/apr.html> for more details.

2.1.2.2 Water Temperature at Balls Ferry Bridge and Clear Creek

Summary

- Water temperatures were warmer than average and warmer than 56°F in 2021 (Figure 2.3).
 - **Sac R at Balls Ferry Bridge:** Maximum water temperature was **66.9** degrees F and occurred in **8**. The highest mean water temperature was **59.9** degrees F and occurred in **5**.
 - **Sac R upstream from Confluence with Clear Creek:** Maximum water temperature was **64.5** degrees F and occurred in **5**. The highest mean water temperature was **59.7** degrees F and occurred in **10**.
 - **Sac R upstream of Hwy 44:** Maximum water temperature was **62.8** degrees F and occurred in **5**. The highest mean water temperature was **59.2** degrees F and occurred in **10**.
-

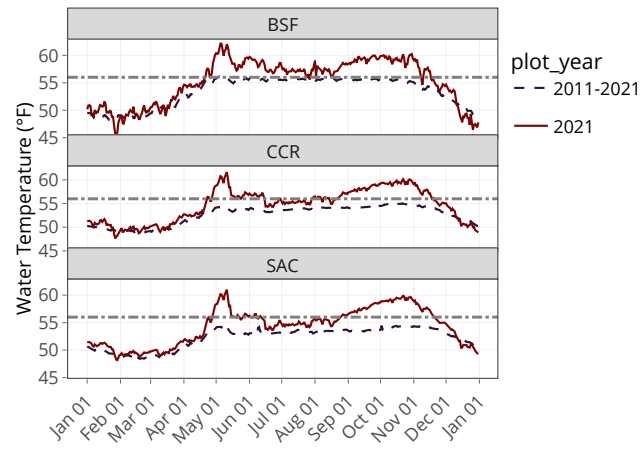


Figure 2.3: Daily Average Water Temperature at Sacramento River at Clear Creek (CCR) and Sacramento River at Balls Ferry Bridge (BSF) in 2021 and over the 10-year average

Table 2.2: Mean, Maximum, Minimum Monthly Water Temperature (°F) at Sacramento River at Balls Ferry Bridge (BSF), Sacramento River upstream from Confluence with Clear Creek (CCR), and Sacramento River Upstream of Hwy 44 (SAC) in 2021

Year	Month	Station	Mean	Min	Max
2021	January	BSF	48.6	44.2	52.4
2021	February	BSF	49.2	46.2	52.1
2021	March	BSF	51.7	47.2	56.2
2021	April	BSF	56.6	51.3	62.4
2021	May	BSF	59.9	54.8	65.4
2021	June	BSF	58.2	53.8	62.7
2021	July	BSF	57.6	54.6	60.7
2021	August	BSF	57.8	54.5	66.9
2021	September	BSF	59.0	56.2	61.9
2021	October	BSF	59.3	56.9	61.7
2021	November	BSF	56.4	52.3	60.5
2021	December	BSF	50.7	46.0	55.4
2021	January	CCR	50.0	46.5	53.2
2021	February	CCR	50.1	47.8	52.4
2021	March	CCR	51.6	47.9	55.4
2021	April	CCR	55.3	50.1	61.0
2021	May	CCR	59.4	54.7	64.5
2021	June	CCR	56.3	53.0	59.6
2021	July	CCR	56.0	53.9	58.1
2021	August	CCR	57.1	54.3	60.1
2021	September	CCR	58.6	55.9	61.4
2021	October	CCR	59.7	57.3	62.1
2021	November	CCR	57.0	53.4	61.0
2021	December	CCR	52.4	48.1	56.7
2021	January	SAC	49.9	47.7	52.1
2021	February	SAC	49.8	48.3	51.2
2021	March	SAC	50.9	48.1	53.6
2021	April	SAC	55.0	50.5	59.8
2021	May	SAC	58.6	54.8	62.8
2021	June	SAC	55.4	52.7	58.0
2021	July	SAC	55.0	53.5	56.6
2021	August	SAC	56.0	53.9	58.0
2021	September	SAC	57.9	55.6	60.1
2021	October	SAC	59.2	57.6	60.8
2021	November	SAC	57.1	54.5	59.9
2021	December	SAC	52.1	47.8	55.7

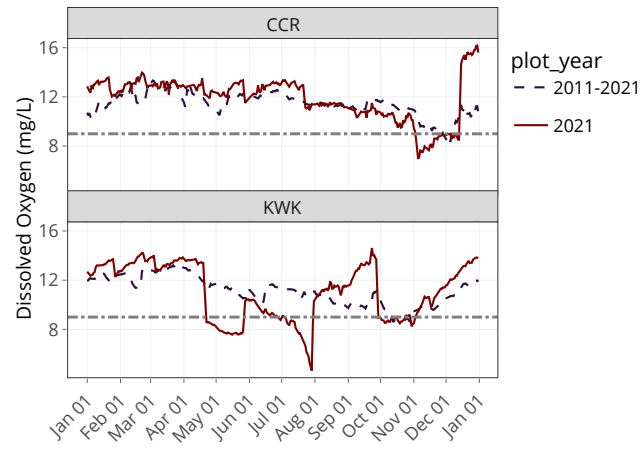


Figure 2.4: Daily Dissolved Oxygen (mg/L) at Sacramento River at Keswick Dam (KWK) and Sacramento River upstream from Confluence with Clear Creek (CCR).

Table 2.3: Mean, Maximum, Minimum Monthly Dissolved Oxygen (mg/L) at Sacramento River at Keswick (KWK) and Sacramento River upstream from Confluence with Clear Creek (CCR) in 2021

Year	Month	Station	Mean	Min	Max
2021	January	CCR	13.0	11.2	14.8
2021	February	CCR	13.5	8.8	15.9
2021	March	CCR	13.4	11.5	15.4
2021	April	CCR	12.9	11.1	14.8
2021	May	CCR	12.7	10.4	14.9
2021	June	CCR	12.9	10.6	15.2
2021	July	CCR	12.8	10.3	15.3
2021	August	CCR	11.6	10.0	13.1
2021	September	CCR	11.4	9.1	13.8
2021	October	CCR	10.8	8.7	12.8
2021	November	CCR	8.3	6.6	10.1
2021	December	CCR	13.3	8.3	17.3
2021	January	KWK	13.1	12.1	14.0
2021	February	KWK	13.6	12.6	14.6
2021	March	KWK	13.3	12.3	14.4
2021	April	KWK	10.8	8.2	14.1
2021	May	KWK	8.9	7.4	10.7
2021	June	KWK	9.6	8.5	10.7
2021	July	KWK	7.2	2.5	11.0
2021	August	KWK	11.1	10.0	12.1
2021	September	KWK	12.7	8.6	15.8
2021	October	KWK	8.7	7.8	9.4
2021	November	KWK	10.0	8.4	11.6
2021	December	KWK	12.7	11.4	14.0

2.1.3 Dissolved Oxygen Conditions at Keswick Dam and Clear Creek

Summary

- **Keswick:** Minimum dissolved oxygen was **2.5** mg/L and occurred in **7**. The lowest mean dissolved oxygen was **7.2** mg/L and occurred in **7**.
 - **Clear Creek:** Minimum dissolved oxygen was **6.6** mg/L and occurred in **11**. The lowest mean dissolved oxygen was **8.3** mg/L and occurred in **11**.
-

2.2 Biological Response

2.2.1 Adult Survival

In-river escapement decreased after the construction of the Red Bluff Diversion Dam (RBDD) in the 1960s.

- Sacramento River system-wide total adult escapement (currently GrandTab): 10165 90% Confidence Interval: []
 - 10-year average: 4416
 - 20-year average: 5612
- Total mainstem in-river spawner estimate: 9998,
 - 10-year average: 4302
 - 20-year average: 5555
- Mainstem natural-origin spawners (Killam): 100 %
- Mainstem hatchery-origin spawners (Killam): %
 - 10-year average:
- Fish to hatchery broodstock (Killam):
 - In-river mainstem transferred to Livingston Stone National Fish Hatchery (LSNFH): 298
 - In-river mainstem transferred to Coleman National Fish Hatchery (CNFH): 58

Table 2.4: Escapement by Reach

Year	Downstream RBDD	Upstream RBDD	Clear Creek	Battle Creek	Total
2021	0	9998	0	167	10165
2020	0	6199	0	942	7141
2019	0	7853	0	21	7874
2018	0	2458	0	1	2459
2017	0	797	2	0	799
2016	0	1411	1	0	1412
2015	0	3182	NA	0	3182
2014	0	2627	NA	0	2627
2013	0	5922	NA	0	5922
2012	0	2578	NA	0	2578
2011	0	738	NA	1	739
2010	0	1533	NA	0	1533
2009	0	4416	NA	0	4416
2008	0	2725	NA	0	2725
2007	0	2487	NA	0	2487
2006	48	17149	NA	6	17203
2005	0	15730	NA	0	15730
2004	0	7784	NA	0	7784
2003	28	8105	NA	0	8133
2002	12	7325	NA	0	7337
2001	35	8085	NA	0	8120
2000	0	1261	NA	2	1263
1999	0	3264	NA	NA	3264
1998	62	2831	NA	NA	2893
1997	0	836	NA	44	880
1996	0	1012	NA	325	1337
1995	7	1159	NA	88	1254
1994	0	144	NA	NA	144
1993	9	369	NA	NA	378
1992	44	1159	NA	NA	1203
1991	0	177	NA	NA	177
1990	28	384	NA	NA	412
1989	14	635	NA	NA	649
1988	728	2129	NA	NA	2857
1987	97	2068	NA	NA	2165
1986	NA	2566	NA	NA	2566
1985	1445	3686	NA	NA	5131
1984	NA	2662	NA	NA	2662
1983	NA	1827	NA	NA	1827
1982	39	1233	NA	NA	1272
1981	2756	19795	NA	NA	22551
1980	NA	1142	NA	NA	1142
1979	NA	2339	NA	NA	2339
1978	NA	24735	NA	NA	24735
1977	NA	16470	NA	NA	16470
1976	NA	33029	NA	NA	33029
1975	NA	22579	NA	NA	22579
1974	NA	21389	NA	NA	21389
1973	NA	22651	NA	NA	22651
1972	NA	35929	NA	NA	35929
1971	NA	53089	NA	NA	53089

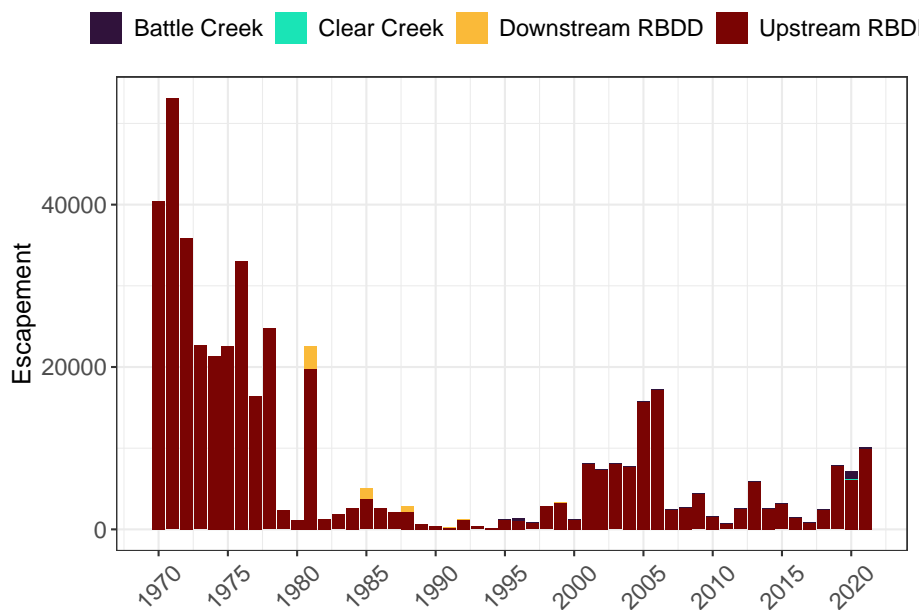


Figure 2.5: Estimated Total Mainstem In-River Spawners in 2021 by reach. Data from SacPAS.

- Tributary in-river spawners (Killam):
 - Battle Creek: 167
 - Clear Creek: 0

2.2.2 Fish Condition and Age Class

- Pre-spawn mortality: 4.9%
 - 10-year average:
 - 10-year maximum:
 - 20-year average:
 - 20-year maximum:
- Fecundity: 5312 eggs per female
 - 10-year average: 4812 eggs per female
 - 20-year average: 4998 eggs per female (only goes to 2005)
- Age classes based on size:

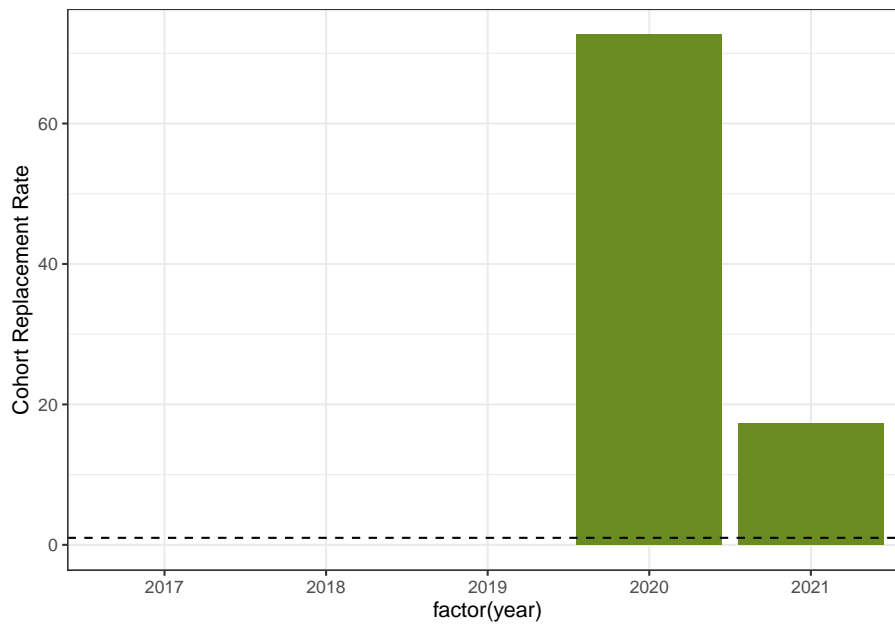


Figure 2.6: Cohort Replacement Rate. Current year female spawners are divided by number of female spawners from 3 years ago. Horizontal line is at 1.0.

- Jacks and Jills = Age-2 fish
- Percent Adult Female (≥ 610 millimeters [mm]): 73.7%
- Percent Jills (< 610 mm): 0.7%
- Percent Adult Male (≥ 680 mm): 23%
- Percent Jacks (< 680 mm): 2.3%

Table 2.5: Carcass Data Summary. Fork length cutoffs are 610 mm for Females and 680 mm for Males based on Killam 2021

Age Class	Count	Mean FL (mm)	SD	Min FL (mm)	Max FL (mm)
Female Adult	1606	748	45	610	911
Jack	50	587	52	469	679
Jill	15	568	50	412	604
Male Adult	501	854	62	680	1053

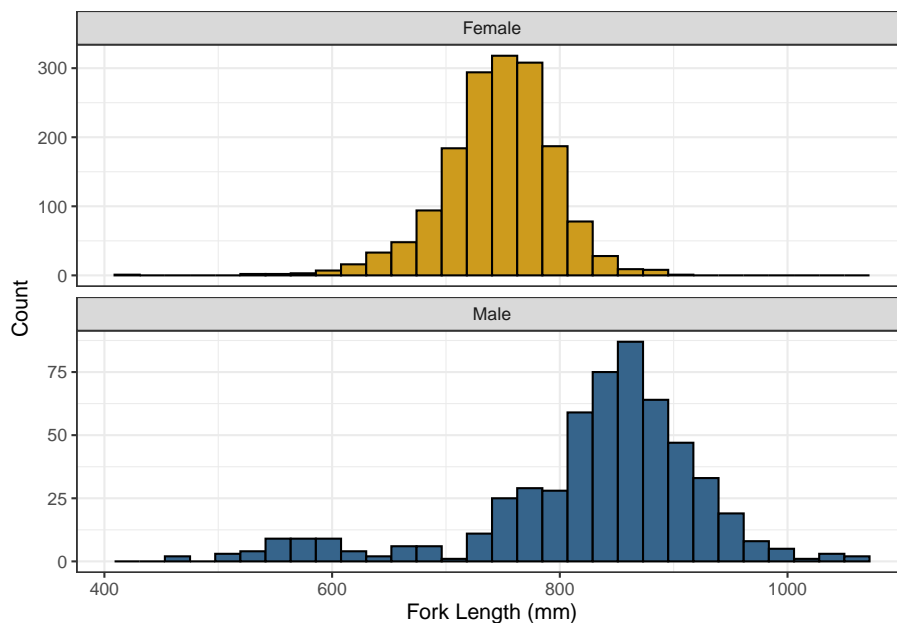


Figure 2.7: Carcass Data Fork Length Distribution. Plots are separated by Sex.

2.2.3 Migration and Spawn Timing

WRCS migration usually occurs between December through April, while spawning occurs between April and September.

2.2.3.1 Spawn Timing

- First redd observed by aerial survey:
- Spawning start week: May 02 (Week 19)
 - Historical Median: Week 2017 to 2021): 20
- Peak spawning week: July 11 (Week 29) 10-Year median: 20-Year median:

Add 10-year and 20-year average to this plot if we have access to the data.

Expand data to include more years (should have 10-year median and 20-year median)

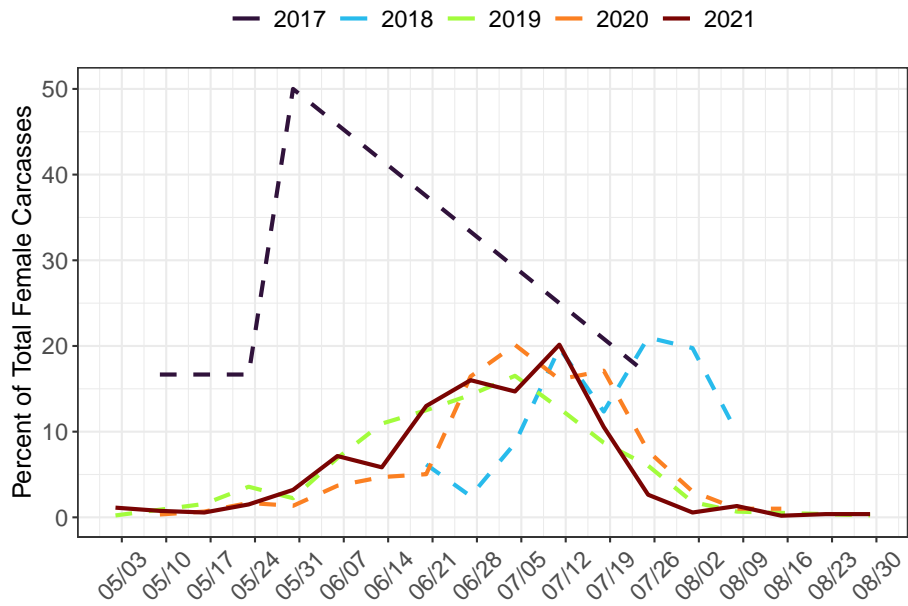


Figure 2.8: Spawn Timing, 2017 through 2021

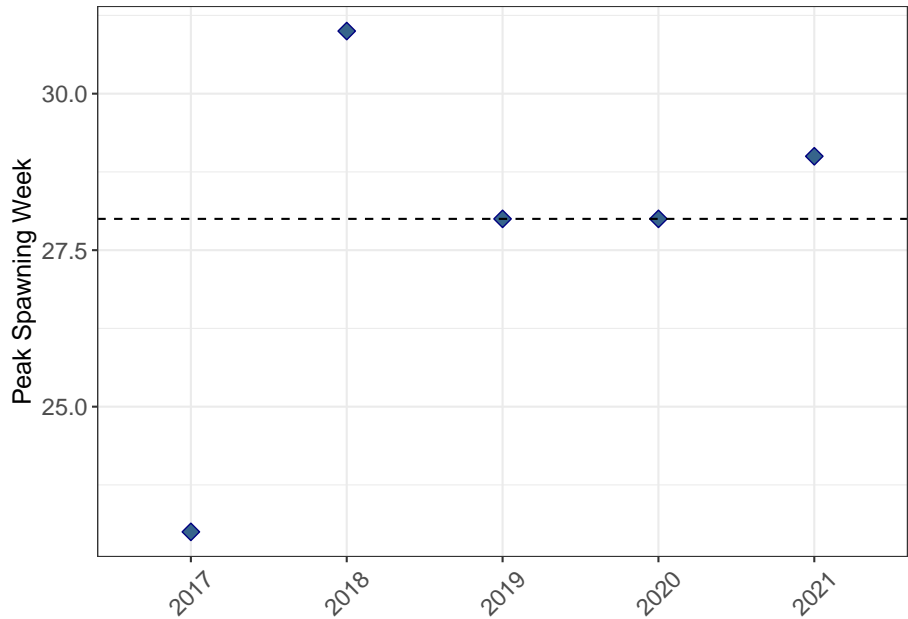


Figure 2.9: Peak Spawning Week from 2000 to 2021

Table 2.6: Redd Abundance by Section in 2021

Section	Section Name	Count	Percent	Average
1	A.C.I.D. Dam to Keswick Dam	NA	NA	8.00%
2	Hwy 44 Brg to A.C.I.D Dam	484	100.00%	85.00%
3	Clear Crk. Powerlines to Hwy 44 Brg	NA	NA	10.00%
4	Balls Ferry Brg to Clear Crk Powerlines	NA	NA	0.00%
7	Bend Brg to Jellys Brg	NA	NA	1.00%

Table 2.7: Carcass Abundance by Section in 2021

Section Name	Section	Count	Percent	Average
Keswick to ACID (RM 302-298)	1	202	36.0%	22.0%
ACID to Hwy 44 Bridge (RM 298-296)	2	132	24.0%	25.0%
Hwy 44 Bridge to Clear Creek PLs (RM 296-288)	3	163	29.0%	40.0%
Clear Creek PLs to Balls Ferry Bridge (RM 288-276)	4	58	10.0%	23.0%

2.2.4 Carcass and Redd Abundance and Distribution

2.2.4.1 Redd Abundance

2.2.4.2 Carcass Abundance

It would be nice to include here a map of each reach

2.2.4.3 Redd Distribution

2.2.4.4 Carcass Distribution

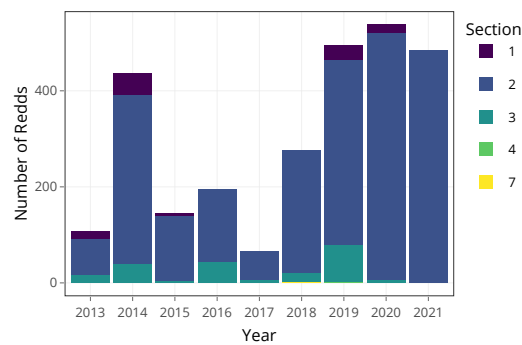


Figure 2.10: Redd Counts by Year. Dashed line indicates average from 2013 to 2021

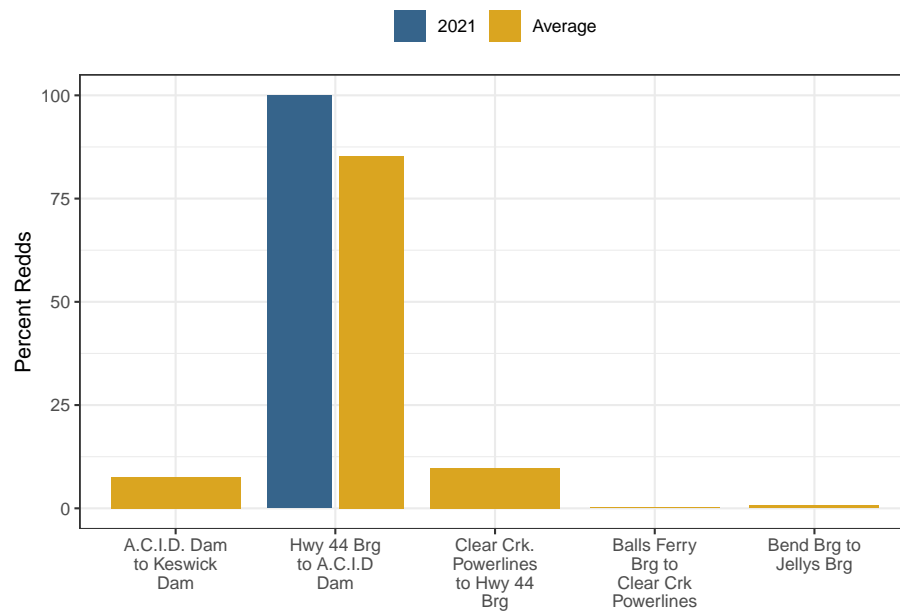


Figure 2.11: Distribution of Winter Run Redds in 2021 and Average between 2013 and 2021

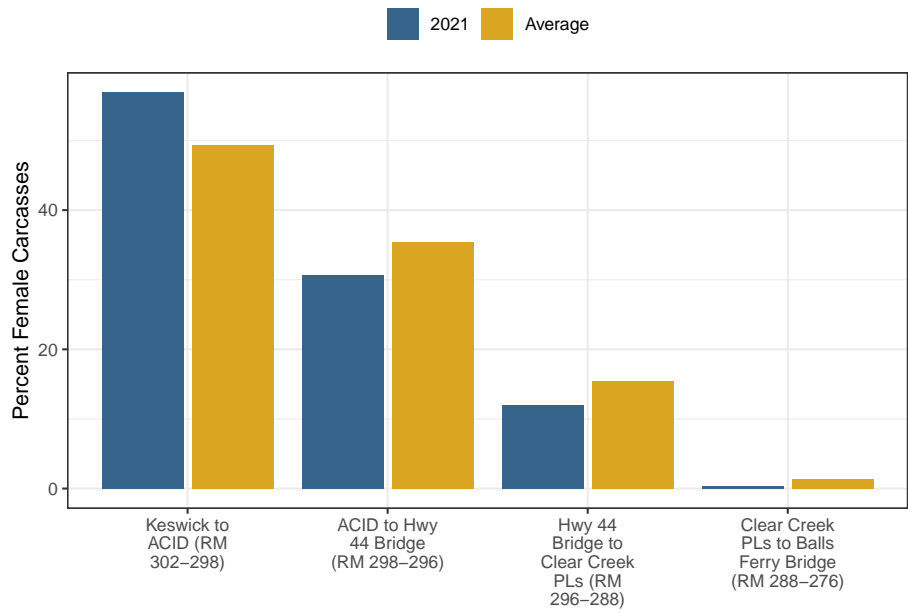


Figure 2.12: Female Carcass Distribution for 2021 and Average from 2017 to 2021

Chapter 3

Egg to Fry Emergence

This section describes environmental attributes associated with and responses during the egg-to-fry life stage.

3.1 Environmental Drivers

3.1.1 Storage and Flow

3.1.1.1 Shasta Storage

- See Section 2.1.1.1 for a summary of storage conditions.

3.1.1.2 Flow Conditions on the Upper Sacramento River

- **Keswick:** Peak flows were **10800** cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.
 - **Bend Bridge:** Peak flows were **36800** cfs and occurred in **10**. The highest mean flows were **13618** cfs and occurred in **10**.
-

3.1.2 Water Temperature on the Upper Sacramento River

- See Section 2.1.2.1 for discussion around temperature threshold analysis.
-

Table 3.1: Mean, Maximum, Minimum Monthly Flows (cfs) at Sacramento River at Keswick (KWK) and Sacramento River at Bend Bridge (BND) between May and November 2021

Year	Station	Month	Mean	Min	Max
2021	KWK	May	8369.6	6800	9870
2021	KWK	June	7882.3	6570	9390
2021	KWK	July	9510.2	8740	10800
2021	KWK	August	8102.0	6610	9500
2021	KWK	September	6899.8	5310	8500
2021	KWK	October	6160.1	5120	7330
2021	KWK	November	4027.1	3070	5080
2021	BND	May	8858.0	7170	10800
2021	BND	June	8328.5	7180	9330
2021	BND	July	9642.1	9030	10600
2021	BND	August	8334.2	6840	9670
2021	BND	September	7072.0	6840	7300
2021	BND	October	13618.0	6220	36800
2021	BND	November	8279.9	4260	17700

3.1.3 Dissolved Oxygen Conditions on the Upper Sacramento River

Summary

- **Keswick:** Minimum dissolved oxygen was **2.5** mg/L and occurred in **7**. The lowest mean dissolved oxygen was **7.2** mg/L and occurred in **7**.
- **Clear Creek:** Minimum dissolved oxygen was **6.6** mg/L and occurred in **11**. The lowest mean dissolved oxygen was **8.3** mg/L and occurred in **11**.

3.1.4 Air Temperature

3.2 Biological Response

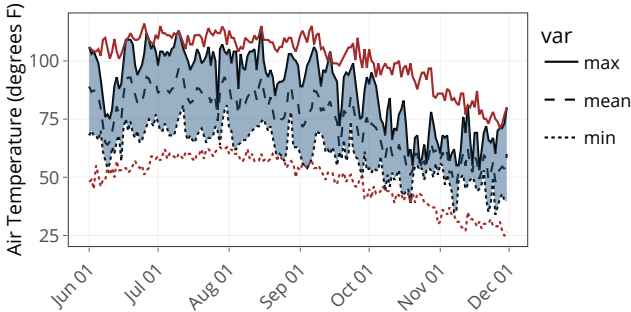


Figure 3.1: Daily Air Temperature (deg F) at Redding Municipal Airport from May 2021 through November 2021 and maximum and minimum temperatures since 2003

Table 3.2: Mean, Maximum, Minimum Monthly Dissolved Oxygen (mg/L) at Sacramento River at Keswick (KWK) and Sacramento River upstream from Confluence with Clear Creek (CCR) between May and November 2021

Year	Station	Month	Mean	Min	Max
2021	KWK	May	8.9	7.4	10.7
2021	KWK	June	9.6	8.5	10.7
2021	KWK	July	7.2	2.5	11.0
2021	KWK	August	11.1	10.0	12.1
2021	KWK	September	12.7	8.6	15.8
2021	KWK	October	8.7	7.8	9.4
2021	KWK	November	10.0	8.4	11.6
2021	CCR	May	12.7	10.4	14.9
2021	CCR	June	12.9	10.6	15.2
2021	CCR	July	12.8	10.3	15.3
2021	CCR	August	11.6	10.0	13.1
2021	CCR	September	11.4	9.1	13.8
2021	CCR	October	10.8	8.7	12.8
2021	CCR	November	8.3	6.6	10.1

3.2.1 Egg to Fry Survival

Right now reading from internal spreadsheet and JPE letter SacPAS page. Final ETF survival is in USFWS RBDD spreadsheet.

Egg-to-Fry Metrics

- **Total potential eggs:** 31,128,320 eggs
 - **10-year average:** 12,855,143 eggs
 - **20-year average:** 16,534,741 eggs
- **Fry-equivalents at RBDD (JPE Letter):** 798,183.
 - **10-year average:** 1,430,698 including 2011, 2014-2017, 2021
- **Egg to Fry Survival (ETF Survival; JPI-based):** ETF Survival in 2021 was below the 10-year average ETF and below the 20-year average ETF (Figure 3.2).
 - **10-year average:** 18.3%
 - **20-year average:** 22.3%

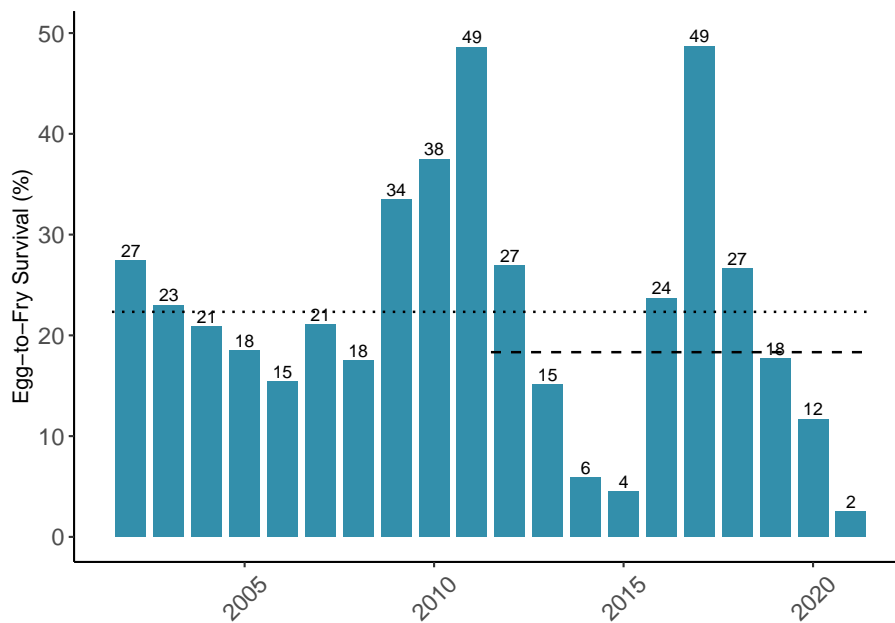


Figure 3.2: Egg to Fry Survival

3.2.1.1 SacPAS Fish Model

The SacPAS Fish Model was developed by the University of Washington Columbia Basin Research center. The model, along with additional method and usage details, are available on: “the SacPAS website”.

The user-selected inputs to the model include:

- 2021 carcass survey, temperature, and flow data
- Stage-dependent, spatially-dependent survival (Anderson 2018) model
- Observed Keswick (KWK) flows redd dewatering option

Results

- Redds exposed to $T_{critical} = 11.82^{\circ}\text{C}$ (53.28°F) are shown in Figure \ref{fig:fishmodel-ha}
- **Pre-hatching exposure:** 99.9%
- **Pre-emergence exposure:** 100%

- **Estimated total egg-to-fry emergence survival:** 4.54%
 - **Temperature-dependent survival:** 95.2%
 - **Temperature-dependent mortality (TDM):** 4.8%

Table 3.3: SacPAS Fish Model Estimated Survival by Reach for BY 2021

Reach	Redd Counts	Total Survival
RKM483	1104	4.2%
RKM479	493	4.5%
RKM474	71	7.7%

- **Spawner density-based mortality:** 65.6%
- **Background mortality:** 49.7%
- **Dewater-based mortality:** 1%
- Survival by reach is shown in Table ??

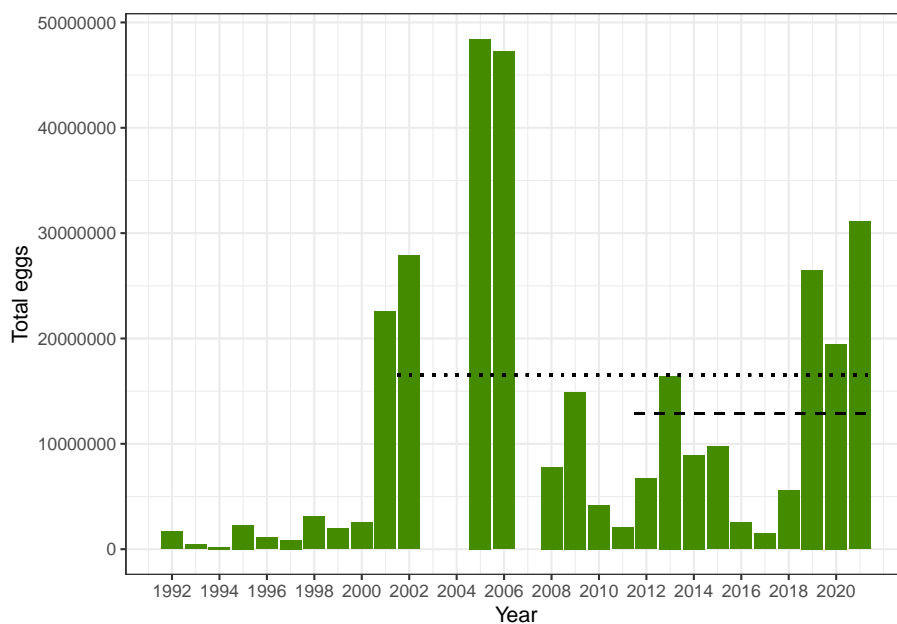


Figure 3.3: Potential Total Eggs in the Upper Sacramento

3.2.2 Emergence Timing

SacPAS fish model estimates for emergence:

- **First occupancy:** 118

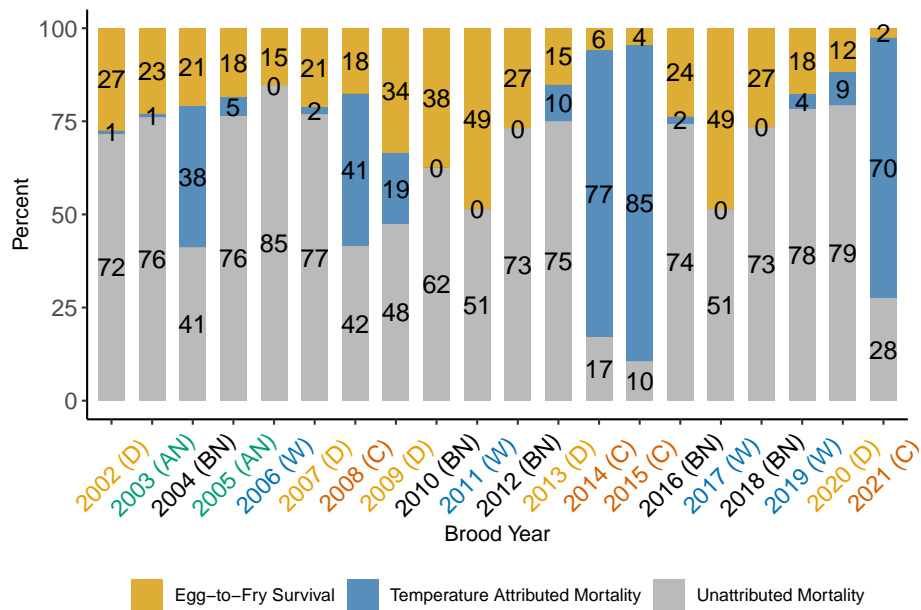


Figure 3.4: Annual Percent of Egg to Fry Survival, Temperature-Dependent Mortality, and Unattributed Survival from 2002 to 2021. Labels in parentheses indicate Water Year Type.

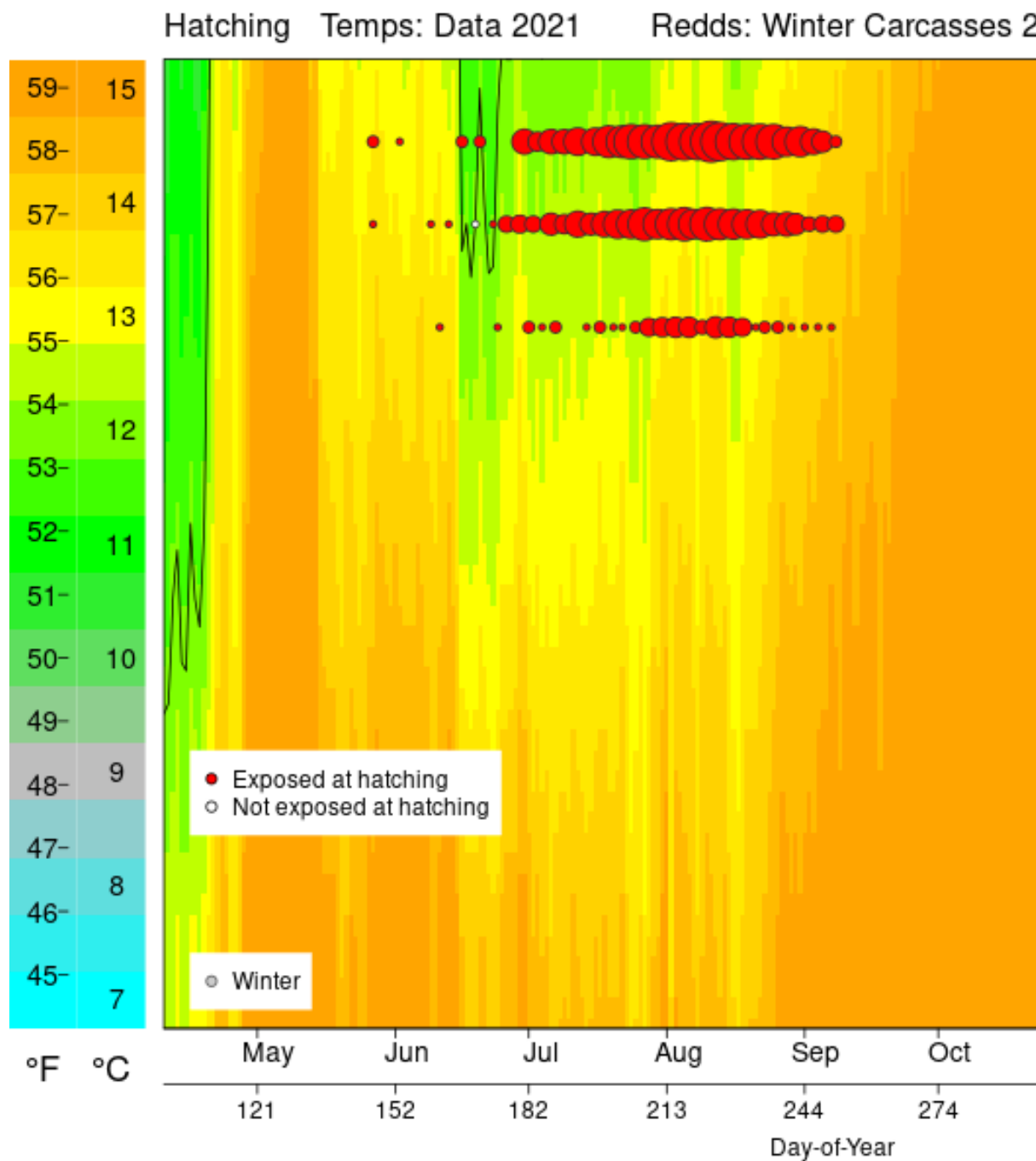


Figure 3.5: SacPAS Fish Model v3.0 Results for BY2021 Temperature Exposure for Hatching. Redds are represented by filled circles, with larger circles indicating more numerous redds. Redd data from CDFW Carcass Surveys.

Table 3.4: Dewatered Redds in 2021

Date	River Mile	River Section	Water Depth	Flow at Keswick Dam (cfs)
2021-08-25	297.5	Hwy 44 Brg to A.C.I.D Dam	0	7290
2021-08-25	297.5	Hwy 44 Brg to A.C.I.D Dam	0	7290

- **Emergence:**
 - **First:** 192
 - **Mean:** 255.2
 - **Last:** 291

3.2.3 Redd Dewatering

I don't know if these two are the same redd (redd ID has 2 numbers switched around) What is the unit for water depth?

- 2 redds were dewatered in 2021 (Table ??).

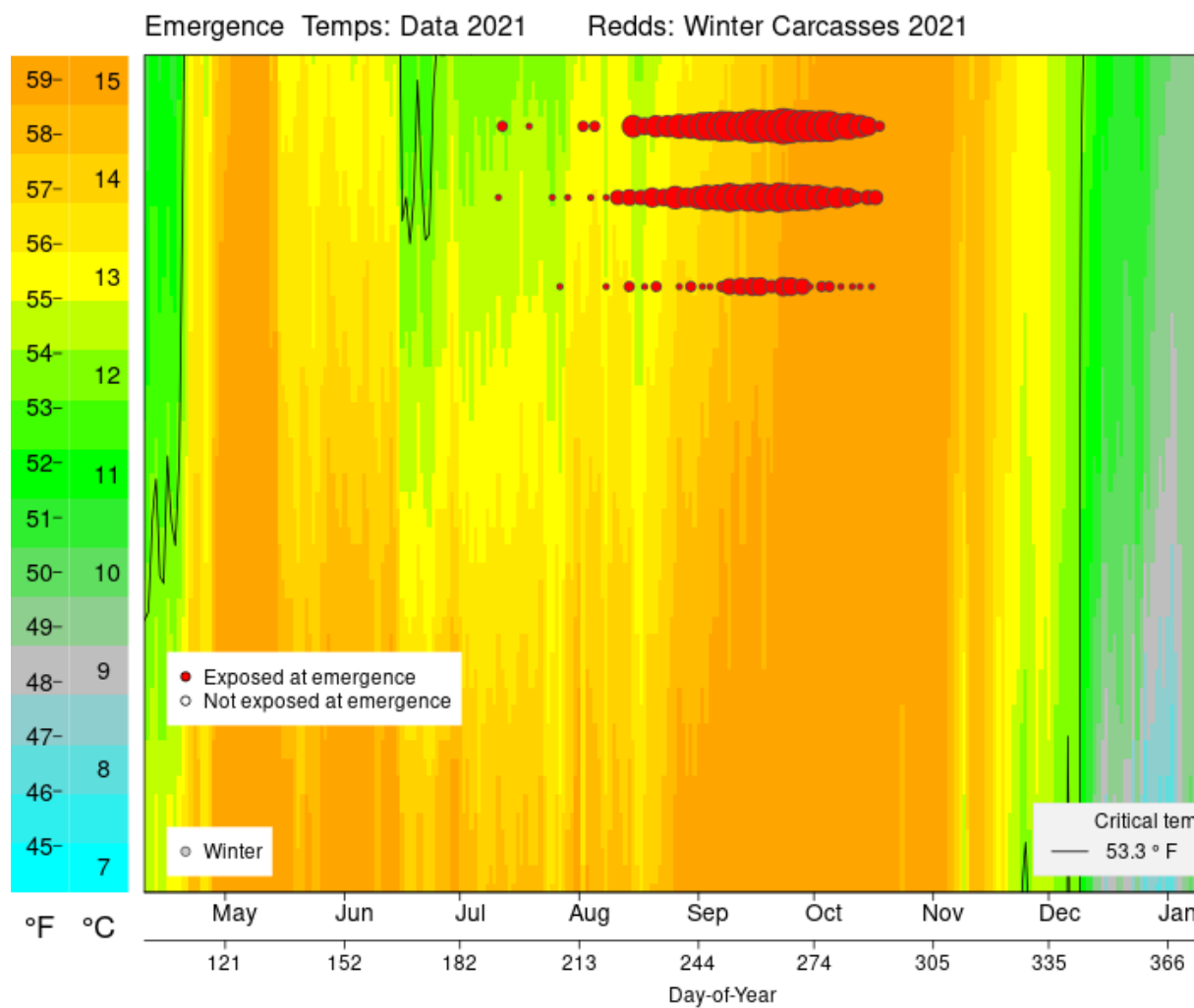


Figure 3.6: SacPAS Fish Model v3.0 Results for BY2021 Temperature Exposure for Emergence. Redds are represented by filled circles, with larger circles indicating more numerous redds. Redd data from CDFW Carcass Surveys.

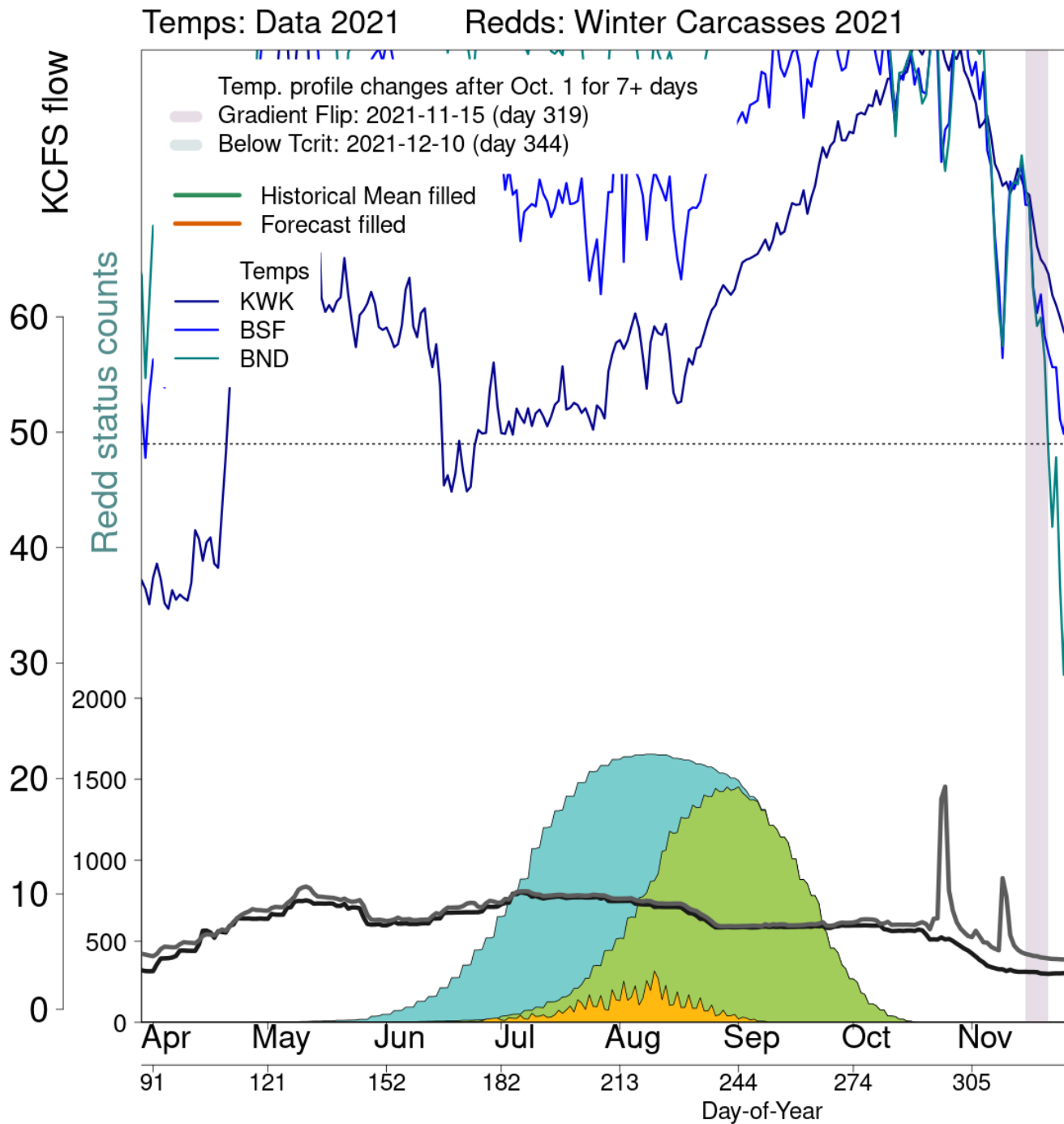


Figure 3.7: SacPAS Fish Model v3.0 Results for BY2021 Temperature Exposure for Redd Occupation and Emergence Timing. Temperature data at Sacramento River at Keswick (KWK), Sacramento River at Balls Ferry Bridge (BSF), and BND (Sacramento River at Bend Bridge) Redd data from CDFW Carcass Surveys.

Chapter 4

Upper Sacramento Juveniles

This section describes environmental attributes associated with and responses during the out-migrating juvenile life stage in the Upper Sacramento River.

4.1 Habitat Attributes

4.2 Environmental Drivers

4.2.1 Flow

- **Keswick:** Peak flows were **10800** cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.
 - **Bend Bridge:** Peak flows were **36800** cfs and occurred in **10**. The highest mean flows were **13618** cfs and occurred in **10**.
-

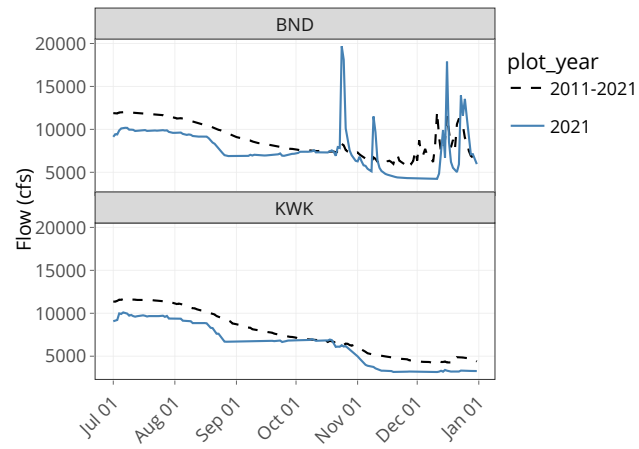


Figure 4.1: Daily Flows (cfs) at Sacramento River at Keswick (KWK) and Sacramento River at Bend Bridge (BND) in July through September 2021 and over the 10-year average

Table 4.1: Mean, Maximum, Minimum Monthly Flows (cfs) at Sacramento River at Keswick (KWK) and Sacramento River at Bend Bridge (BND) in July through December 2021

Year	Month	Station	Mean	Min	Max
2021	July	BND	9642.1	9030	10600
2021	August	BND	8334.2	6840	9670
2021	September	BND	7072.0	6840	7300
2021	October	BND	13618.0	6220	36800
2021	November	BND	8279.9	4260	17700
2021	December	BND	10327.5	4220	26600
2021	July	KWK	9510.2	8740	10800
2021	August	KWK	8102.0	6610	9500
2021	September	KWK	6899.8	5310	8500
2021	October	KWK	6160.1	5120	7330
2021	November	KWK	4027.1	3070	5080
2021	December	KWK	3431.0	3040	3970

Table 4.2: Mean, Maximum, Minimum Monthly Water Temperature (degF) at Sacramento River at Bend Bridge (BND) in July through December 2021

Year	Month	Station	Mean	Min	Max
2021	July	BND	59.3	55.9	62.6
2021	August	BND	59.2	56.0	62.2
2021	September	BND	60.9	58.7	63.0
2021	October	BND	59.5	57.1	61.8
2021	November	BND	54.0	45.2	60.6
2021	December	BND	50.4	45.6	55.6

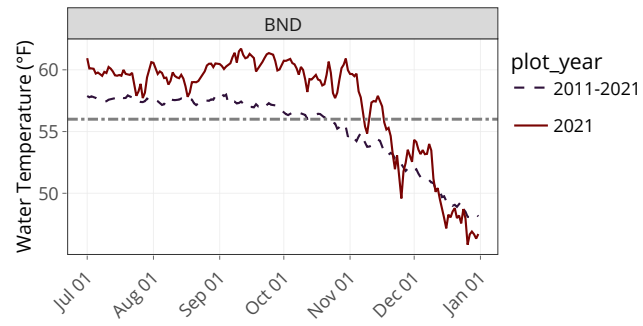


Figure 4.2: Daily Water Temperature (degF) at Sacramento River at Bend (BND) in 2021 and 10-year average between July and December.

Table 4.3: Mean, Maximum, Minimum Monthly Dissolved Oxygen (mg/L) at Sacramento River at Bend Bridge (BND) in July through December 2021 . Days less than 6 mg/L indicates the number of days per month that experienced at least 1 hour where DO was less than 6 mg/L.

Year	Month	Station	Mean	Min	Max	Days < 6mg/L
2021	July	BND	11.8	1.2	17.5	2
2021	August	BND	10.3	1.7	29.7	12
2021	September	BND	3.5	0.1	10.9	30
2021	October	BND	10.3	0.3	13.5	5
2021	November	BND	10.9	3.4	15.5	1
2021	December	BND	12.2	11.1	13.6	0

4.2.2 Water Temperature

Summary

- In 2021 water temperature was below average for most of the season between July and December.
 - **Sacramento River at Bend Bridge:** Maximum water temperature was **63** degrees F and occurred in **9**. The highest mean water temperature was **60.9** degrees F and occurred in **9**.
-

4.2.3 Dissolved Oxygen

Summary

- **Sacramento River at Bend Bridge:** Minimum dissolved oxygen was **0.1** mg/L and occurred in **9**. The lowest mean dissolved oxygen was **3.5** mg/L and occurred in **9**.
-

4.2.4 Turbidity

Summary

- **Sacramento River at Bend Bridge:** Minimum turbidity was **0.1** FNU and occurred in **8** and **9**. The lowest mean turbidity was **30.3** FNU and occurred in **8**. Turbidity was below average in parts of August and September and similar at other times of the season.

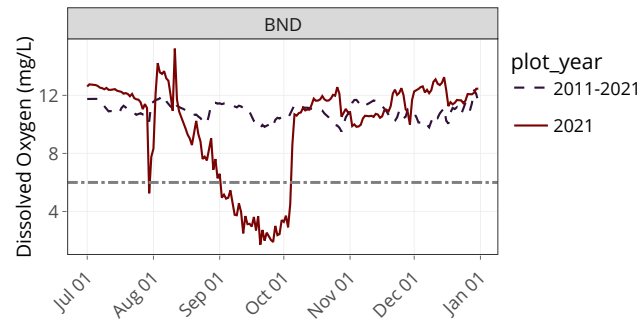


Figure 4.3: Daily Dissolved Oxygen (mg/L) at Sacramento River at Bend Bridge (BND) in July through December 2021 and 10-year average.

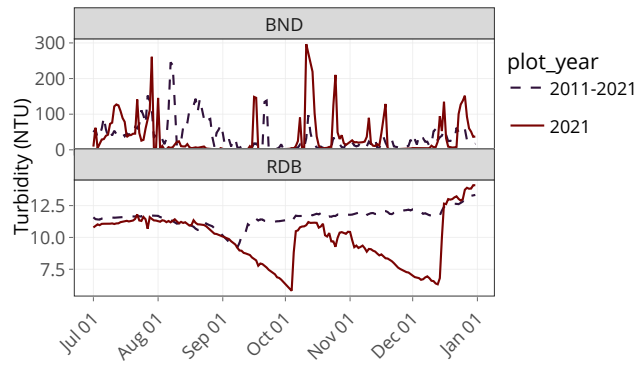


Figure 4.4: Daily Turbidity at Sacramento River at Bend Bridge (BND) and Red Bluff Diversion Dam (RDB) in 2021 and 10-year average between July and December. Turbidity data have not undergone QC, other than values filtered to less than 300 NTU.

Table 4.4: Mean, Maximum, Minimum Monthly Turbidity (NTU) at Sacramento River at Bend Bridge (BND) and Red Bluff Diversion Dam (RDB) in July through December 2021

Year	Month	Station	Mean	Min	Max
2021	July	BND	76.0	0.5	2565.5
2021	August	BND	30.3	0.1	1310.7
2021	September	BND	741.1	0.1	2621.3
2021	October	BND	182.8	1.3	1140.2
2021	November	BND	46.9	1.0	1138.1
2021	December	BND	73.8	3.6	990.1
2021	July	RDB	11.6	9.6	13.5
2021	August	RDB	11.1	9.0	13.2
2021	September	RDB	8.8	6.0	11.5
2021	October	RDB	9.5	5.2	13.2
2021	November	RDB	8.6	6.4	10.9
2021	December	RDB	10.2	5.9	14.4

- **Red Bluff Diversion Dam:** Minimum turbidity was **5.2** FNU and occurred in **10**. The lowest mean turbidity was **8.6** FNU and occurred in **11**. Turbidity was below average between September and mid-December and similar at other times of the season

4.3 Biological Response

4.3.1 Fry abundance

Fry abundance (JPI) is calculated by Red Bluff USFWS by calculating the sum of: - fry passage from rotary screw trap data, and - estimated smolts and pre-smolts that pass RBDD, which are converted to fry-equivalents by applying the inverse of the fry-to-smolt survival rate (new method used as of BY2019; Voss and Poytress 2022).

4.3.1.1 Fry-equivalent JPI

Information from the RBDD Annual Report:

- Fry-to-smolt survival rate:
- Estimated Passage:
 - Fry-sized juveniles:
 - Pre-smolts and smolt passage:
- Percent fry passage to juvenile passage (fry/fry+smolts):
 - **10-year average:**
 - **20-year average:**
- Fry-equivalent JPI:
 - **Juvenile Production Index** JPI in 2021 was below the average JPI between 2002 and 2021 at 0.779427.
 - **10-year average:**
 - **20-year average:**

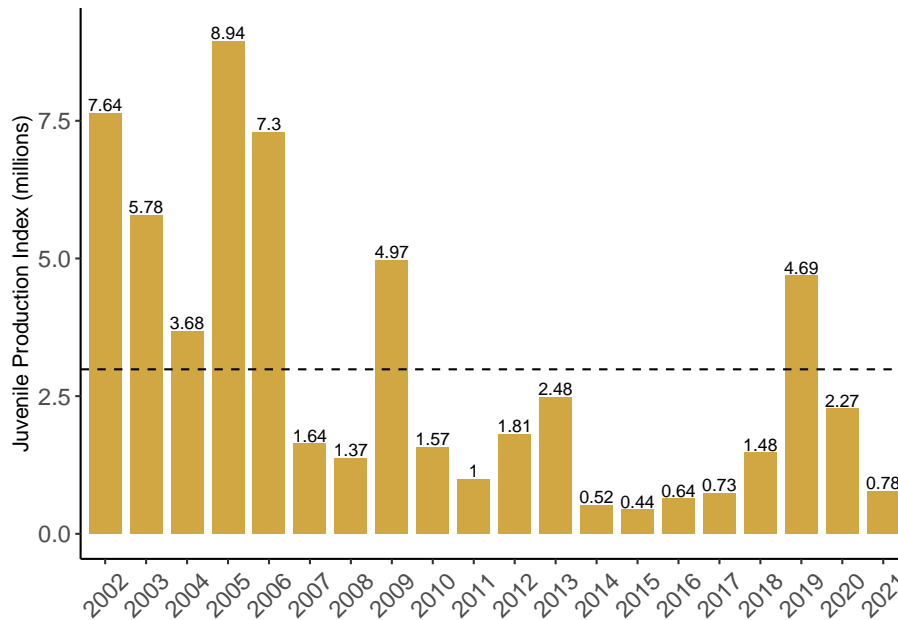


Figure 4.5: Annual JPI from 2002 to 2021

4.3.2 Telemetry Studies

Include a subset of the data

Table of telemetry release groups Reach-specific survival to below RBDD

4.3.3 Migration Timing

Passage at RBDD:

- **First:**
 - BY2021: July 02, 2021
 - 10-year median: July 06
 - **Middle 50% (25% to 75%):**
 - BY2021: September 16, 2021 to October 13, 2021
 - 10-year median: September 23 to November 01
 - **Last:**
 - BY2021: May 25, 2022
 - 10-year median: May 02
-

4.3.4 Stranding

A total of 383 juveniles were stranded.

4.3.5 Condition

4.3.5.1 RBDD Size

- **Average daily fork length**
 - Early migration (July to August): 29 to 49 mm
 - Middle 50% of cumulative (September 16 to October 13): 84 to 178 mm
 - Late migration: 84 to 178 mm
- 74 % of fish migrated past RBDD as fry (<46 mm FL)
- Average daily fork length in 2021 was 32 to 178mm compared with the 10-year average daily fork length (29.5 to 237 mm)

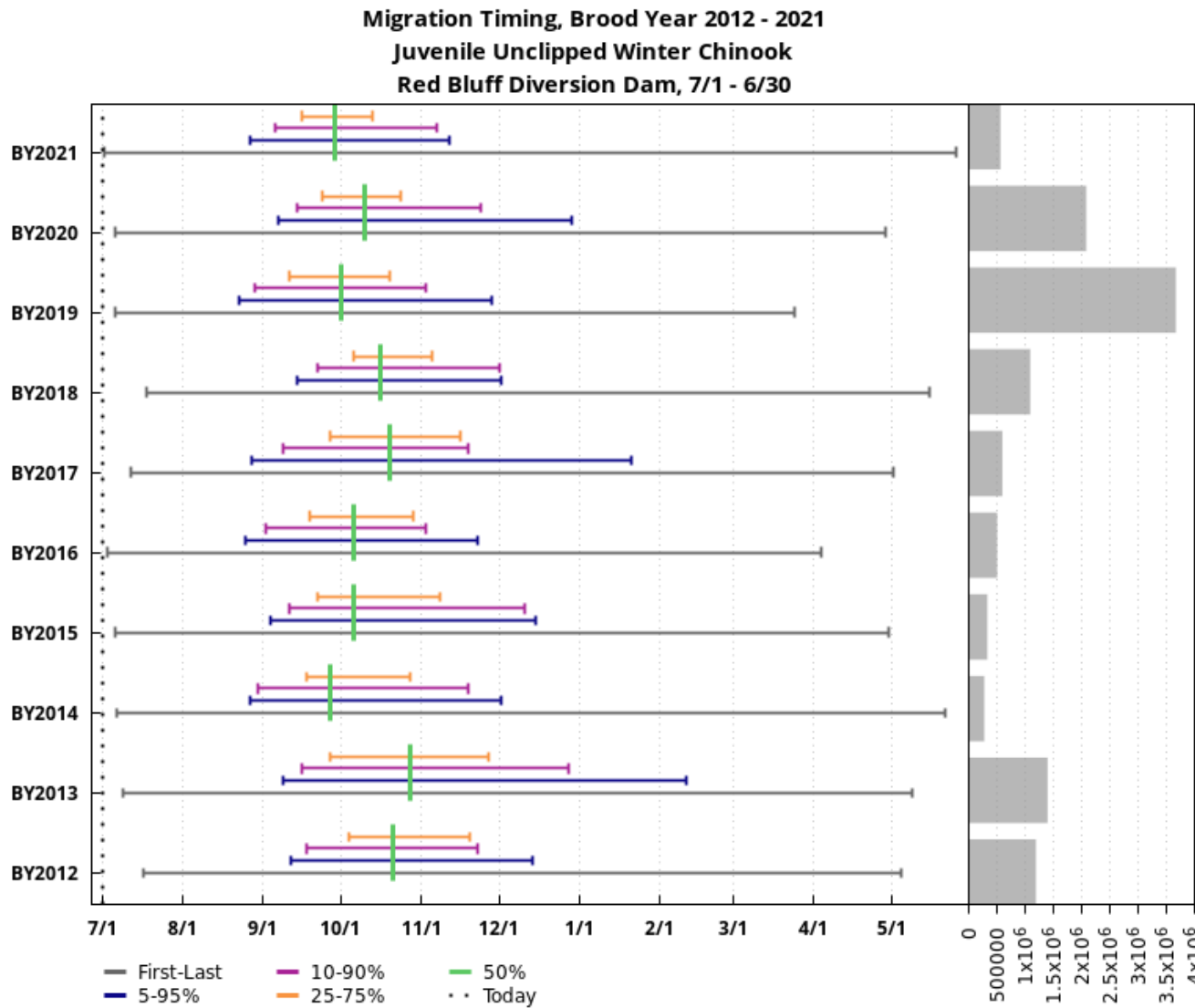


Figure 4.6: Red Bluff Diversion Dam Migration Timing

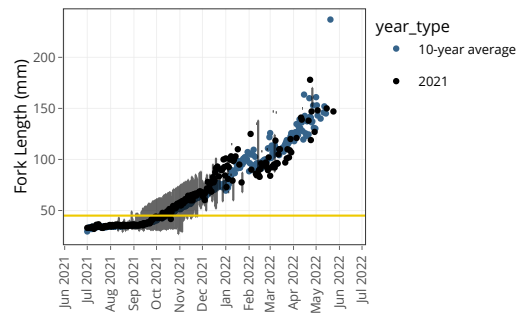


Figure 4.7: Fork Length Distribution in 2021 and 10-year average at RBDD RST. The yellow line at 45 mm indicates the length transition from fry to smolt.

Table 4.5: Juvenile Stranding in 2021

Date	Section Number	Section Name	River Miles	Count	Flow (cfs)	Flow (cfs)
2021-08-26	2	Hwy 44 Brg to A.C.I.D Dam	298-296	4	6699	KW
2021-11-08	2	Hwy 44 Brg to A.C.I.D Dam	298-296	34	3751	KW
2021-11-09	2	Hwy 44 Brg to A.C.I.D Dam	298-296	65	3747	KW
2021-11-01	3	Clear Crk. Powerlines to Hwy 44 Brg	296-288	12	4982	KW
2021-10-28	4	Balls Ferry Brg to Clear Crk Powerlines	288-276	9	5761	KW
2021-11-03	4	Balls Ferry Brg to Clear Crk Powerlines	288-276	75	4458	KW
2021-11-10	4	Balls Ferry Brg to Clear Crk Powerlines	288-276	27	3582	KW
2021-11-18	4	Balls Ferry Brg to Clear Crk Powerlines	288-276	11	3268	KW
2021-10-27	8	RBDD to Bend Brg	257-242	71	8500	BN
2021-11-01	8	RBDD to Bend Brg	257-242	20	6268	BN
2021-11-02	8	RBDD to Bend Brg	257-242	46	6824	BN
2021-11-04	8	RBDD to Bend Brg	257-242	1	5814	BN
2021-11-16	8	RBDD to Bend Brg	257-242	4	4723	BN
2021-12-18	8	RBDD to Bend Brg	257-242	2	6198	BN
2021-12-27	8	RBDD to Bend Brg	257-242	2	8980	BN

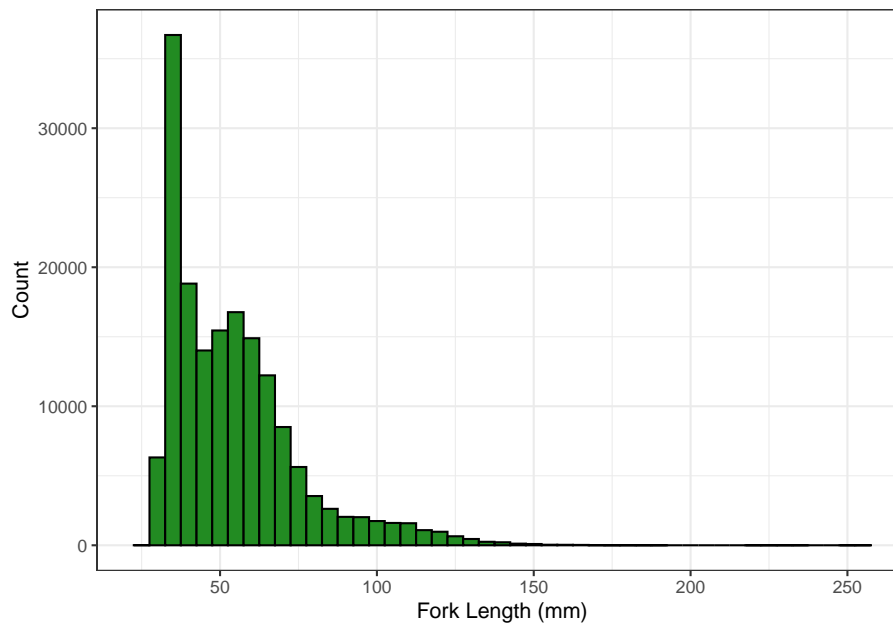


Figure 4.8: Fork Length Distribution over Time, RBDD RST

Chapter 5

Middle and Lower Sacramento Juveniles

This section describes environmental attributes associated with and responses during the out-migrating juvenile life stage in the Lower and Middle Sacramento River.

5.1 Habitat Attributes

1. Habitat Capacity (Floodplain Connectivity)
 2. Habitat Capacity: Depth/Shallow Water
 3. In-Stream Habitat Capacity
-

5.1.1 Storage and Flows

1. Shasta Storage/Hydrology
2. Flows: Migration Cues

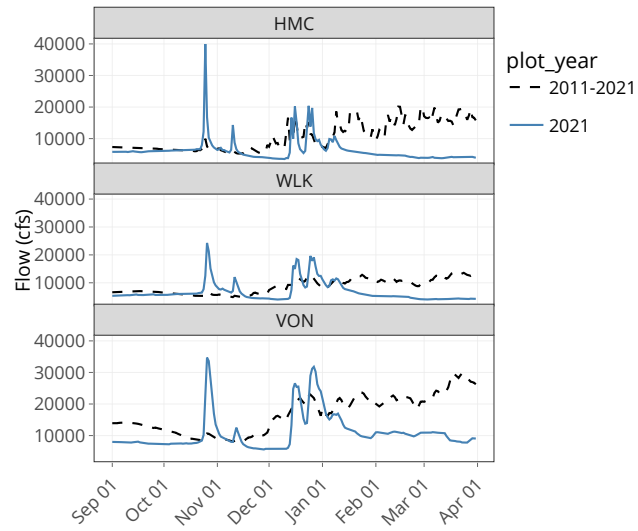


Figure 5.1: Daily Flows (cfs) at Sacramento River at Hamilton City (HMC), Sacramento River at Wilkins Slough (WLK) and Sacramento River at Verona (VON) from September 2021 through March 2022 and over the 10-year average

Table 5.1: Mean, Maximum and Minimum Monthly Flows (cfs) at Sacramento River at Hamilton City (HMC), Sacramento River at Wilkins Slough (WLK) and Sacramento River at Verona (VON) from September 2021 through March 2022

Year	Month	Station	Mean	Min	Max
2021	September	HMC	5885.7	5590	6182
2021	October	HMC	13842.8	5945	47509
2021	November	HMC	7181.8	3983	17544
2021	December	HMC	11421.0	3400	29442
2022	January	HMC	7669.2	4678	12005
2022	February	HMC	4326.8	3744	4934
2022	March	HMC	3983.1	3615	4333
2021	September	WLK	5605.0	5290	5920
2021	October	WLK	11000.4	5650	25100
2021	November	WLK	7160.0	4370	12700
2021	December	WLK	9375.3	3990	20600
2022	January	WLK	7715.4	5190	12000
2022	February	WLK	4732.0	4060	5400
2022	March	WLK	4200.0	3930	4470
2021	September	VON	7827.2	7160	8420
2021	October	VON	18089.0	7110	35500
2021	November	VON	8051.0	5480	12900
2021	December	VON	15431.8	5500	31900
2022	January	VON	14467.4	9010	23200
2022	February	VON	10197.1	9610	11500
2022	March	VON	8856.6	7490	11200

5.1.1.1 Flow Conditions on the Middle and Lower Sacramento River

5.1.1.2 Juvenile WRCS Rescued During Stranding Surveys

Fish were not stranded in the Middle to Lower Sacramento River for Brood Year 2021.

Summary

- **Hamilton City:** Peak flows were **47509** cfs and occurred in **10**. The highest mean flows were **13842.8** cfs and occurred in **10**.
 - **Wilkins Slough:** Peak flows were **25100** cfs and occurred in **10**. The highest mean flows were **11000.4** cfs and occurred in **10**.
 - **Verona:** Peak flows were **35500** cfs and occurred in **10**. The highest mean flows were **18089** cfs and occurred in **10**.
-

5.1.2 Environmental Drivers

5.1.2.1 Turbidity

Summary

- **Red Bluff Diversion Dam:** Minimum turbidity was **4.3** FNU and occurred in **3**. The lowest mean turbidity was **8.6** FNU and occurred in **11**.
 - **Sacramento River at Freeport:** Minimum turbidity was **0.8** FNU and occurred in **9**. The lowest mean turbidity was **2.6** FNU and occurred in **9**.
-

5.1.2.2 Water Temperature

Summary

- Maximum water temperature was **90.7** degrees F and occurred in **9**. The highest mean water temperature was **69.5** degrees F and occurred in **9**.
 - The month with greatest days exceeding 63 degrees F (**30** days) was **9**.
-

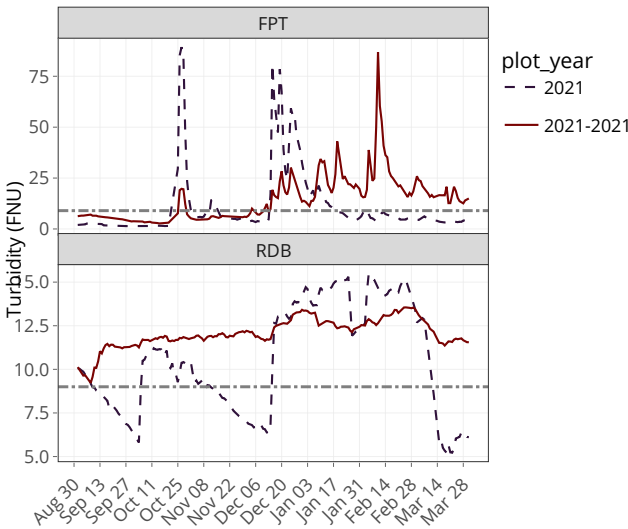


Figure 5.2: Daily Turbidity at Red Bluff Diversion Dam (RDB) and Sacramento River at Freeport (FPT) from September 2021 through March 2022

Table 5.2: Mean, Maximum, Minimum Monthly Flows (cfs) at Red Bluff Diversion Dam (RDB) and Sacramento River at Freeport (FPT) from September 2021 through March 2022

Year	Month	Station	Mean	Min	Max
2021	September	RDB	8.8	6.0	11.5
2021	October	RDB	9.5	5.2	13.2
2021	November	RDB	8.6	6.4	10.9
2021	December	RDB	10.3	5.9	14.5
2022	January	RDB	14.0	11.1	16.9
2022	February	RDB	14.4	11.4	17.3
2022	March	RDB	9.7	4.3	15.3
2021	September	FPT	2.6	0.8	5.2
2021	October	FPT	47.7	1.0	123.0
2021	November	FPT	10.1	3.4	24.0
2021	December	FPT	44.2	2.3	107.0
2022	January	FPT	14.5	1.6	30.3
2022	February	FPT	7.3	3.0	11.8
2022	March	FPT	5.1	1.8	10.1

Table 5.3: Mean, Maximum, Minimum Monthly Water Temperature (°F) at Sacramento River Below Wilkins Slough (WLK) in September 2021 through March 2022 . Days > 63°F indicates the number of days per month that experienced at least 1 hour where Water Temperature was greater than 63°F.

Year	Month	Station	Mean	Min	Max	Water Temp > 63 Degf
2021	September	WLK	69.5	63.8	90.7	30
2021	October	WLK	61.2	57.3	71.7	8
2021	November	WLK	56.8	52.4	62.0	0
2021	December	WLK	49.7	45.1	54.9	0
2022	January	WLK	48.7	44.8	51.0	0
2022	February	WLK	51.9	47.0	56.7	0
2022	March	WLK	58.8	53.0	66.7	8

Table 5.4: Mean, Maximum, Minimum Monthly Flows (cfs) at Red Bluff Diversion Dam (RDB) and Sacramento River at Hood (SRH) in 2021 - 2022 . Days less than 6 mg/L indicates the number of days per month that experienced at least 1 hour where DO was less than 6 mg/L.

Year	Month	Station	Mean	Min	Max	Do < 6mg/L
2021	September	RDB	8.4	6.0	11.5	0
2021	October	RDB	9.9	5.2	13.2	5
2021	November	RDB	8.5	6.4	10.9	0
2021	December	RDB	10.2	5.9	14.5	1
2022	January	RDB	14.2	11.1	16.9	0
2022	February	RDB	14.5	11.4	17.3	0
2022	March	RDB	8.3	4.3	15.3	17
2021	September	SRH	8.2	7.6	9.2	0
2021	October	SRH	8.8	6.4	10.0	0
2021	November	SRH	8.9	7.1	10.1	0
2021	December	SRH	10.1	9.5	10.7	0
2022	January	SRH	11.0	10.6	11.4	0
2022	February	SRH	10.9	10.2	11.7	0
2022	March	SRH	9.9	8.5	11.1	0

5.1.2.3 Dissolved Oxygen

Summary

- **Sacramento River at Bend Bridge:** Minimum dissolved oxygen was **4.3** mg/L and occurred in **3**. The lowest mean dissolved oxygen was **8.3** mg/L and occurred in **3**.
- **Sacramento River at Hood:** Minimum dissolved oxygen was **6.4** mg/L and occurred in **10**. The lowest mean dissolved oxygen was **8.2** mg/L and occurred in **9**.

5.2 Biological Response

Monitoring Sources for abundance, growth/size, migration timing/duration

- Sac Trawl
- Tisdale Weir
- Knights Landing
- GCID

- DJFMP
- Yolo Bypass
- Chipps Island Trawl (Exit)
- Genetic (Chipps, SWP/CVP, Knights Landing, Yolo Bypass)

Data Sources

- JPE, Smolt survival from JPE Letters ([link](#))

5.2.1 Juvenile Production Estimate (Abundance)

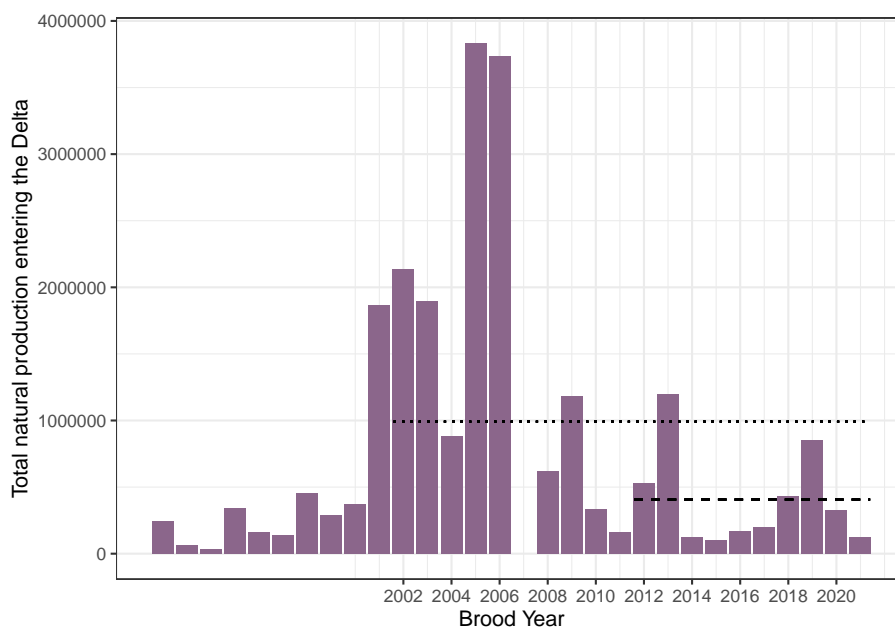


Figure 5.3: Total Natural production entering the Delta (JPE)

5.2.2 Smolt Survival

5.2.2.1 JPE Letter

Natural-origin smolt survival is calculated at the Tower Bridge from acoustically tagged hatchery fish that are released at RBDD.

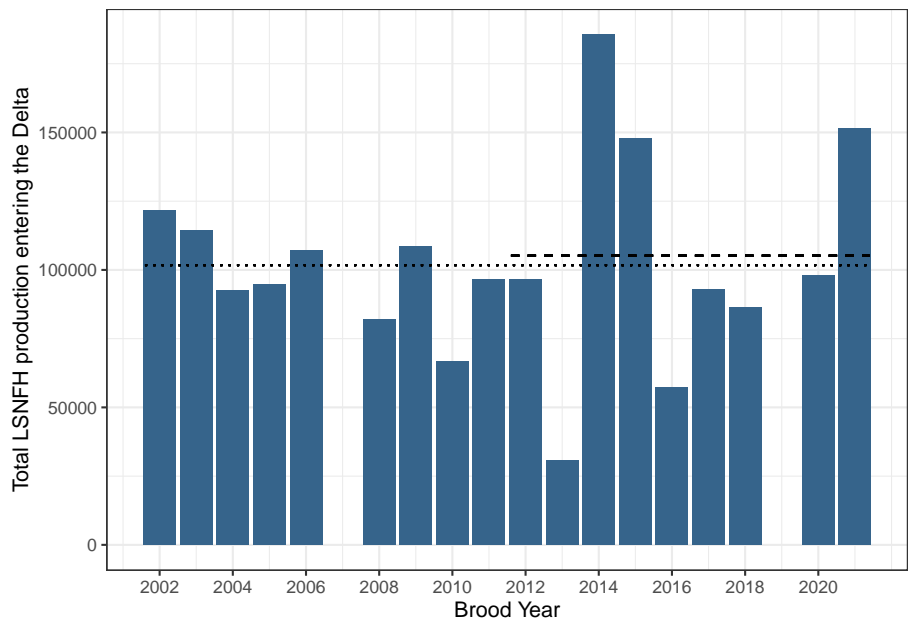
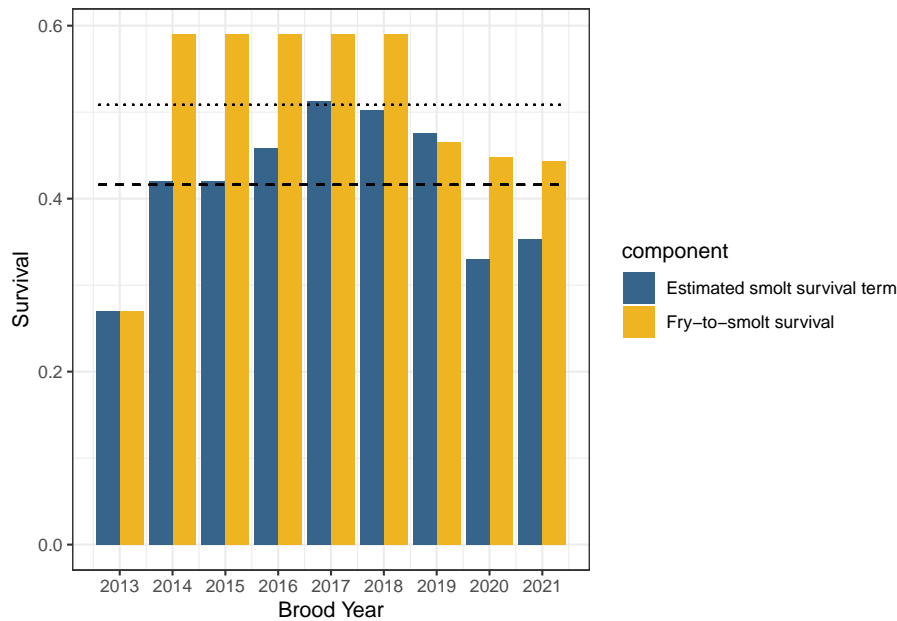


Figure 5.4: Total Hatchery Production entering the Delta (Hatchery JPE)

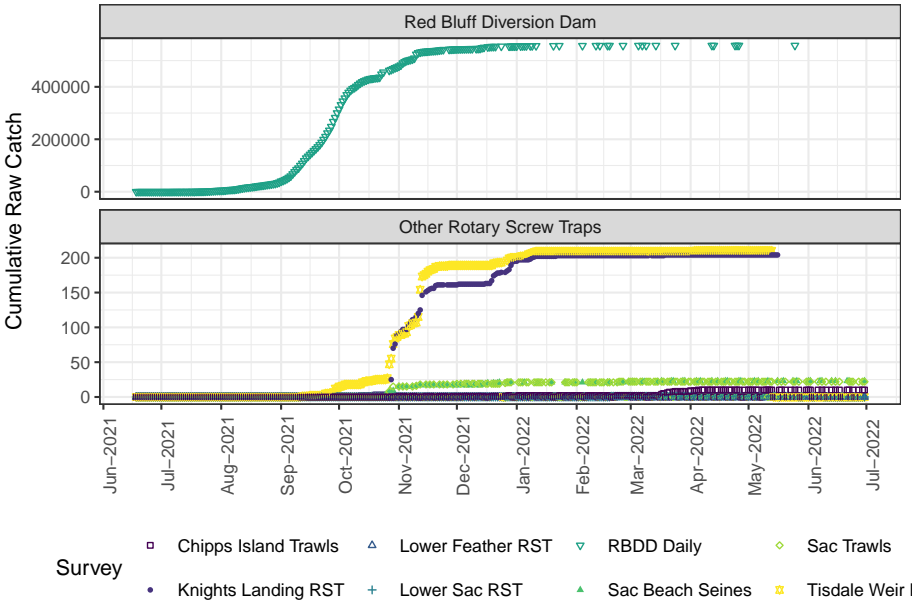


Acoustic Tagging

Reach-specific survival

5.2.3 Migration Timing

Cumulative Raw Catch: RBDD, Chipps, Tisdale, Knights, Sac Beach Seines,



Sac Trawls

Median Passage Dates

Migration Timing

5.2.4 Condition

Do we want FL on any surveys?

Table 5.5: Table of Hatchery WR Juvenile Survival

rel_date	reach_start	reach_end	rkm_start	ReachSurvival	CumulativeSurvival
2022-02-10	Caldwell_Park_Rel	Blw_Cypress	551	0.995 (0.988, 0.998)	1 (0, 0)
2022-02-10	Blw_Cypress	Blw_ClearCr	544	0.999 (0.994, 1)	0.964 (0.92, 0.98)
2022-02-10	Blw_ClearCr	BlwCowCr	536	0.999 (0.996, 1)	0.957 (0.91, 0.98)
2022-02-10	BlwCowCr	Battle_Conf	521	0.999 (0.995, 1)	0.95 (0.9, 0.98)
2022-02-10	Battle_Conf	Blw_Paynes_Ck	507	0.997 (0.995, 0.999)	0.935 (0.88, 0.97)
2022-02-10	Blw_Paynes_Ck	Blw_Salt	476	0.996 (0.992, 0.998)	0.863 (0.8, 0.91)
2022-02-10	Blw_Salt	Mill_Ck_Conf	457	0.999 (0.99, 1)	0.799 (0.72, 0.86)
2022-02-10	Mill_Ck_Conf	Ord	441	0.992 (0.989, 0.994)	0.782 (0.7, 0.85)
2022-02-10	Ord	Colusa AC2	372	0.989 (0.984, 0.993)	0.449 (0.36, 0.54)
2022-02-10	Colusa AC2	AbvColusaBr	319	0.998 (0.978, 1)	0.252 (0.19, 0.33)
2022-02-10	AbvColusaBr	Colusa BC2	308	0.998 (0.947, 1)	0.245 (0.18, 0.32)
2022-02-10	Colusa BC2	AbvTisdale	296	0.997 (0.988, 0.999)	0.241 (0.18, 0.32)
2022-02-10	AbvTisdale	Knights_RST	269	0.995 (0.99, 0.998)	0.224 (0.16, 0.3)
2022-02-10	Knights_RST	Abv_FremontWeir	222	0.995 (0.952, 0.999)	0.18 (0.12, 0.25)
2022-02-10	Abv_FremontWeir	SacFeather	215	0.995 (0.965, 0.999)	0.174 (0.12, 0.25)
2022-02-10	SacFeather	Blw_Elkhorn_GS1	206	1 (1, 1)	0.165 (0.11, 0.24)
2022-02-10	Blw_Elkhorn_GS1	TowerBridge	192	0.998 (0.984, 1)	0.165 (0.11, 0.24)
2022-02-10	TowerBridge	SacTrawl	172	1 (1, 1)	0.158 (0.11, 0.23)
2022-02-10	NA	NA	167	NA (NA, NA)	0.158 (0.11, 0.23)
2022-02-10	Freeport	Abv_Clarksburg	152	1 (1, 1)	0.137 (0.09, 0.2)
2022-02-10	Abv_Clarksburg	Hood	148	1 (1, 1)	0.137 (0.09, 0.2)
2022-02-10	Hood	Chippis	138	0.992 (0.984, 0.996)	0.137 (0.09, 0.2)
2022-02-10	Chippis	Benicia	71	0.989 (0.959, 0.997)	0.08 (0.04, 0.14)
2022-02-10	Benicia	GoldenGateE	52	1 (1, 1)	0.065 (0.03, 0.12)
2022-02-10	NA	NA	2	NA (NA, NA)	0.065 (0.03, 0.12)
2022-03-02	Caldwell_Park_Rel	Blw_Cypress	551	0.996 (0.993, 0.998)	1 (0, 0)
2022-03-02	Blw_Cypress	Blw_ClearCr	544	0.999 (0.997, 1)	0.972 (0.95, 0.98)
2022-03-02	Blw_ClearCr	BlwCowCr	536	1 (0.999, 1)	0.963 (0.94, 0.98)
2022-03-02	BlwCowCr	Battle_Conf	521	0.998 (0.997, 0.999)	0.958 (0.94, 0.97)
2022-03-02	Battle_Conf	Blw_Paynes_Ck	507	0.997 (0.996, 0.998)	0.935 (0.91, 0.96)
2022-03-02	Blw_Paynes_Ck	Blw_Salt	476	0.997 (0.995, 0.998)	0.856 (0.82, 0.89)
2022-03-02	Blw_Salt	Mill_Ck_Conf	457	0.993 (0.99, 0.996)	0.8 (0.76, 0.84)
2022-03-02	Mill_Ck_Conf	Ord	441	0.988 (0.986, 0.99)	0.722 (0.67, 0.77)
2022-03-02	Ord	Colusa AC2	372	0.991 (0.988, 0.994)	0.315 (0.27, 0.36)
2022-03-02	Colusa AC2	AbvColusaBr	319	0.99 (0.981, 0.995)	0.198 (0.16, 0.24)
2022-03-02	AbvColusaBr	Colusa BC2	308	0.997 (0.987, 0.999)	0.178 (0.14, 0.22)
2022-03-02	Colusa BC2	AbvTisdale	296	0.999 (0.995, 1)	0.171 (0.14, 0.21)
2022-03-02	AbvTisdale	Knights_RST	269	0.998 (0.996, 0.999)	0.166 (0.13, 0.2)
2022-03-02	Knights_RST	Abv_FremontWeir	222	0.998 (0.981, 1)	0.153 (0.12, 0.19)
2022-03-02	Abv_FremontWeir	SacFeather	215	0.998 (0.985, 1)	0.151 (0.12, 0.19)
2022-03-02	SacFeather	Blw_Elkhorn_GS1	206	0.996 (0.989, 0.999)	0.149 (0.12, 0.19)
2022-03-02	Blw_Elkhorn_GS1	TowerBridge	192	0.994 (0.987, 0.997)	0.142 (0.11, 0.18)
2022-03-02	TowerBridge	SacTrawl	172	0.985 (0.961, 0.994)	0.126 (0.1, 0.16)
2022-03-02	NA	NA	167	NA (NA, NA)	0.116 (0.09, 0.15)
2022-03-02	Freeport	Abv_Clarksburg	152	0.991 (0.964, 0.998)	0.107 (0.08, 0.14)
2022-03-02	Abv_Clarksburg	Hood	148	0.995 (0.981, 0.999)	0.102 (0.08, 0.14)
2022-03-02	Hood	Chippis	138	0.993 (0.989, 0.996)	0.098 (0.07, 0.13)
2022-03-02	Chippis	Benicia	71	0.994 (0.981, 0.998)	0.063 (0.04, 0.09)
2022-03-02	Benicia	GoldenGateE	52	1 (1, 1)	0.056 (0.04, 0.08)
2022-03-02	NA	NA	2	NA (NA, NA)	0.056 (0.04, 0.08)

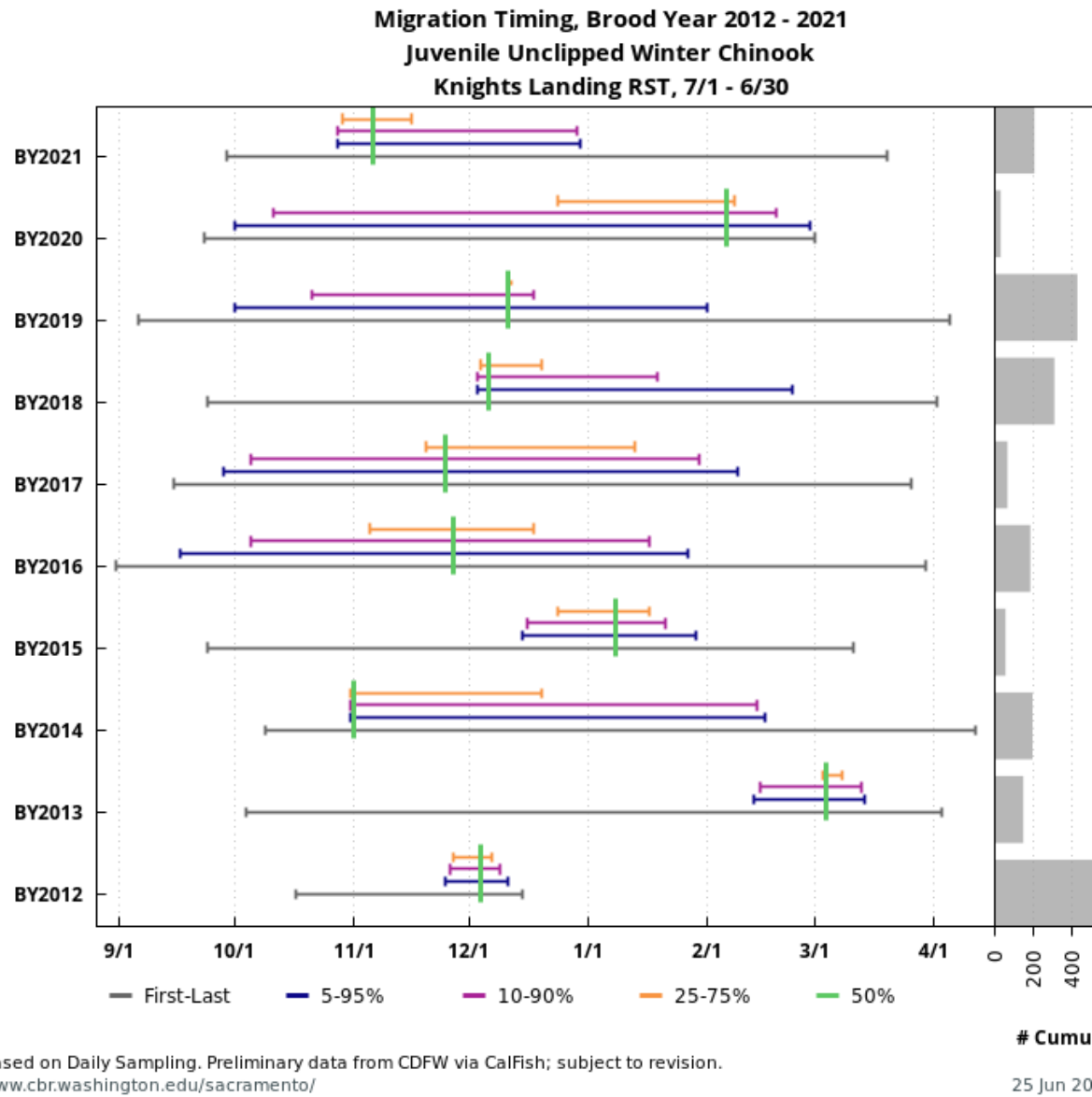


Figure 5.5: Knights Landing Rotary Screw Trap Migration Timing

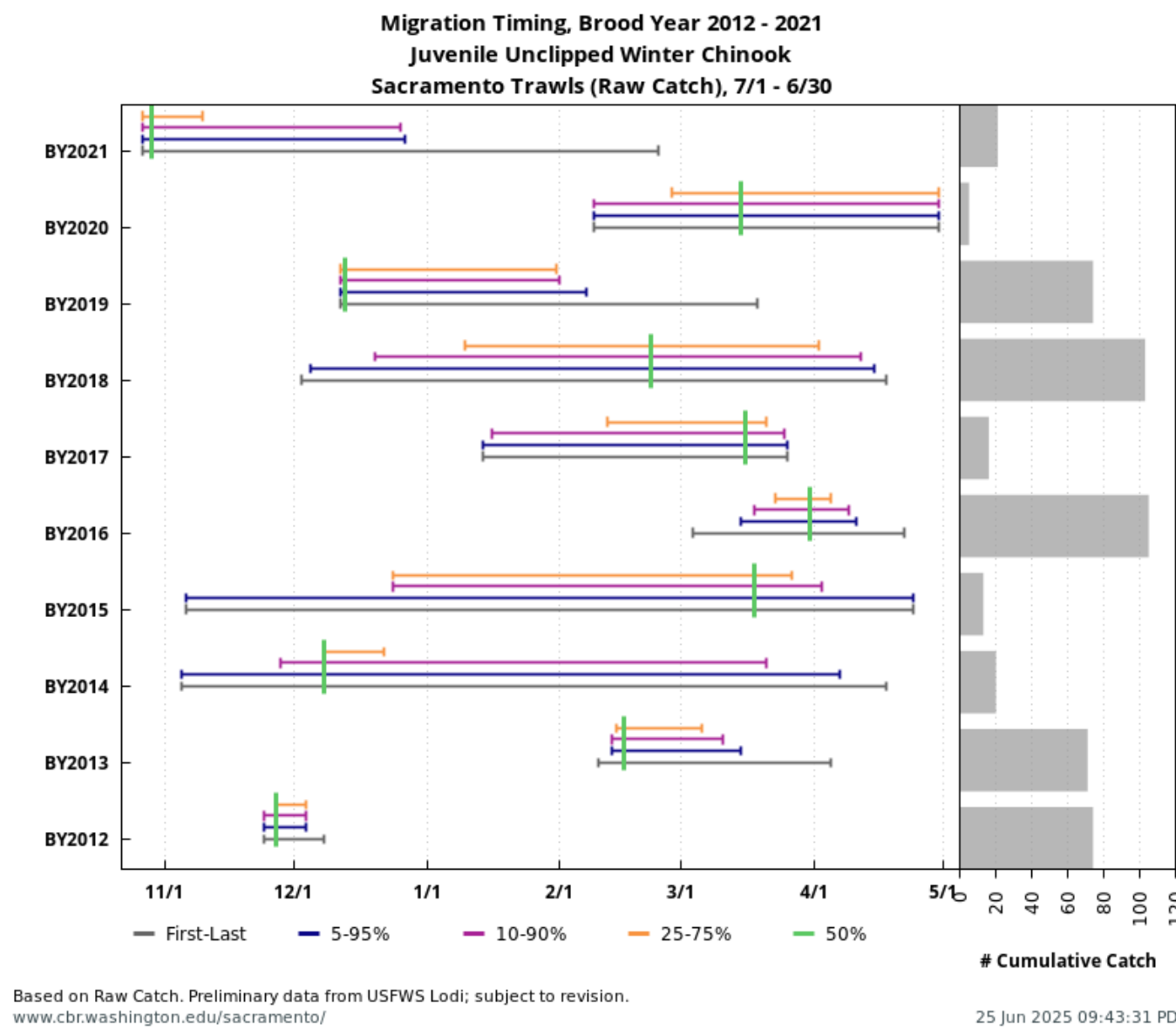


Figure 5.6: Sacramento Trawl Timing

Chapter 6

Sacramento-San Joaquin Delta Juveniles

This section describes environmental attributes associated with and responses during the out-migrating juvenile life stage in the Sacramento-San Joaquin Delta.

6.1 Habitat Attributes

1. Rearing Habitat Capacity (Floodplain Connectivity)
 - Weir overtopping
-

6.1.1 Food Availability

Macrozooplankton currently lacking 2022 data

6.2 Environmental Drivers

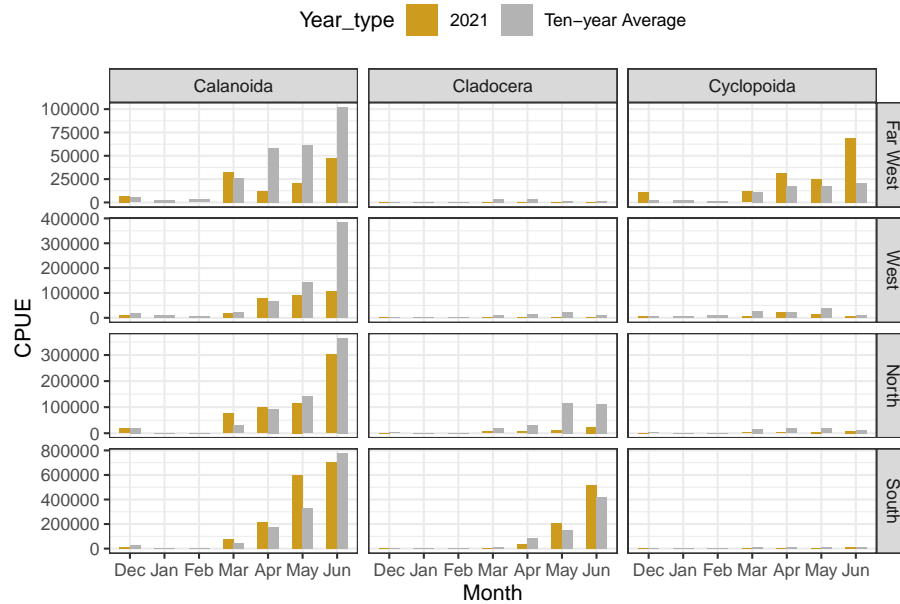


Figure 6.1: Zooplankton Abundance in the Delta, December 2021 - June 2022 and 10-year average CPUE

6.2.1 Sacramento River Flow and Delta Outflow

Summary

- **Sacramento River at Freeport:** Peak flows were **36600** cfs and occurred in **12**. The highest mean flows were **12824.9** cfs and occurred in **1**. Flow was generally lower than average.
- **Delta Outflow:** Peak Delta outflow was **45494** cfs and occurred in **12**. The highest mean Delta outflow was **18383.4** cfs and occurred in **12**. Flow was generally lower than average.
- **OMR:** The most negative OMR flows were **-9193** cfs and occurred in **12**. The most negative mean OMR flows were **-4493.8** cfs and occurred in **1**. OMR was generally similar to average.

6.2.2 Water Temperature

Summary

Table 6.1: Sacramento River at Freeport (FPT), Delta Outflow (DTO), Old and Middle River (OMR) Mean, Maximum, Minimum Monthly Flows (cfs) in 2021 - 2022

Year	Month	Station	Mean	Min	Max
2021	December	FPT	8616.8	-5360	36600
2022	January	FPT	12824.9	1370	32600
2022	February	FPT	8173.3	2880	17200
2022	March	FPT	6008.5	-1390	17000
2022	April	FPT	4295.7	-3630	15700
2022	May	FPT	3310.5	-4040	15300
2022	June	FPT	4553.0	-2710	18300
2021	December	DTO	18383.4	2674	45494
2022	January	DTO	13135.7	5266	33374
2022	February	DTO	11724.5	11150	12147
2022	March	DTO	9559.9	5712	12035
2022	April	DTO	7716.9	4865	11825
2022	May	DTO	4553.6	3082	5697
2022	June	DTO	4936.1	3937	6935
2021	December	OMR	-2738.9	-9193	-86
2022	January	OMR	-4493.8	-5631	-1289
2022	February	OMR	-1688.3	-4780	-389
2022	March	OMR	-1919.8	-3776	191
2022	April	OMR	-981.3	-2710	2423
2022	May	OMR	-1690.0	-3774	2519
2022	June	OMR	-1922.2	-3400	2523

Table 6.2: FPT (Sacramento River at Freeport), SUS (Steamboat Slough below Sutter Slough), SWE (Sacramento River at Walnut Grove), GSS (Georgiana Slough at Sacramento River), MAL (Sacramento River at Mallard Island) Mean, Maximum, Minimum Monthly Water Temperature (°F) in 2021 - 2022

Year	Month	Station	Mean	Min	Max	Days < 63 Degf
2021	December	FPT	49.6	45.9	55.4	0
2022	January	FPT	48.6	45.7	50.0	0
2022	February	FPT	51.6	47.5	55.0	0
2022	March	FPT	57.9	52.9	64.9	5
2022	April	FPT	62.7	58.8	67.6	16
2022	May	FPT	68.8	62.2	75.2	31
2022	June	FPT	73.3	69.6	77.9	29
2021	December	SUS	50.2	45.9	54.7	0
2022	January	SUS	48.8	45.7	50.5	0
2022	February	SUS	51.8	47.7	55.8	0
2022	March	SUS	58.2	51.8	64.9	7
2022	April	SUS	63.1	59.9	68.0	23
2022	May	SUS	69.2	63.7	75.2	31
2022	June	SUS	74.1	70.9	77.9	30
2021	December	SWE	50.1	45.9	54.5	0
2022	January	SWE	48.7	45.7	50.4	0
2022	February	SWE	51.7	47.8	54.5	0
2022	March	SWE	57.9	52.0	64.0	5
2022	April	SWE	62.8	59.9	66.7	17
2022	May	SWE	68.8	63.9	73.4	31
2022	June	SWE	73.6	70.7	76.8	30
2021	December	GSS	50.2	46.0	54.7	0
2022	January	GSS	48.9	45.9	55.4	0
2022	February	GSS	51.9	47.8	55.2	0
2022	March	GSS	58.0	52.0	64.2	6
2022	April	GSS	63.0	56.3	66.9	19
2022	May	GSS	69.0	64.0	75.9	31
2022	June	GSS	73.8	70.9	77.0	30
2021	December	MAL	52.4	47.6	57.8	0
2022	January	MAL	49.2	47.1	51.7	0
2022	February	MAL	51.9	49.6	54.9	0
2022	March	MAL	57.0	53.0	61.3	0
2022	April	MAL	61.5	59.0	64.1	7
2022	May	MAL	64.6	61.0	71.1	27
2022	June	MAL	70.1	66.3	75.1	30

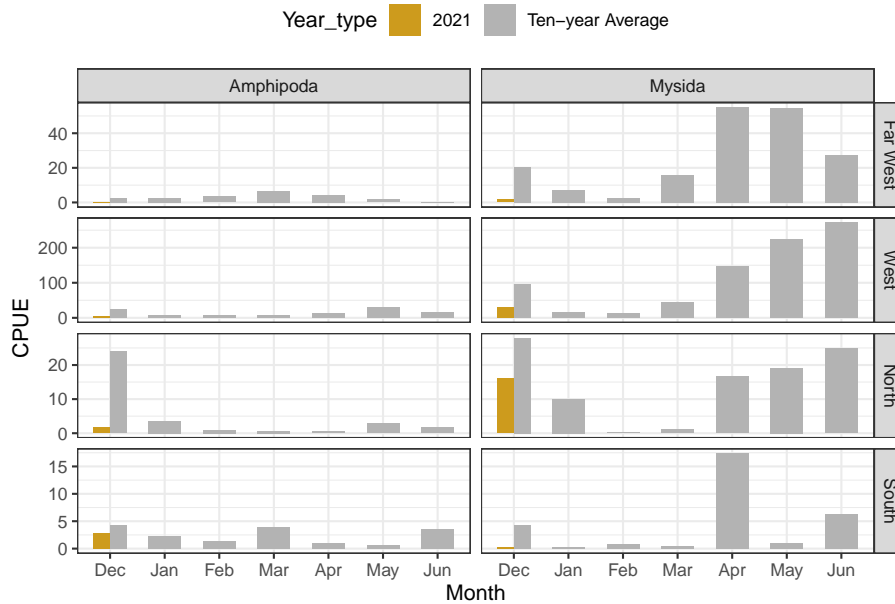


Figure 6.2: Amphipod and Mysid Abundance in the Delta, December 2021 - June 2022 and 10-year average CPUE

- Maximum water temperature was **77.9** degrees F and occurred in **6**. The highest mean water temperature was **73.3** degrees F and occurred in **6**.
- Maximum water temperature was **77.9** degrees F and occurred in **6**. The highest mean water temperature was **74.1** degrees F and occurred in **6**.
- Maximum water temperature was **77** degrees F and occurred in **6**. The highest mean water temperature was **73.8** degrees F and occurred in **6**.
- Maximum water temperature was **75.1** degrees F and occurred in **6**. The highest mean water temperature was **70.1** degrees F and occurred in **6**.

6.2.3 Dissolved Oxygen

Summary

- Maximum water temperature was **11.7** degrees F and occurred in **2**. The highest mean water temperature was **11** degrees F and occurred in **1**.
- Maximum water temperature was **12.5** degrees F and occurred in **2** and **3**. The highest mean water temperature was **10.9** degrees F and occurred in **2**.

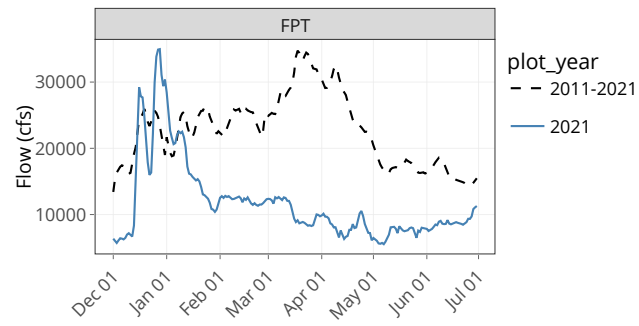


Figure 6.3: Freeport (FPT) Average Flows (cfs) in 2021 and over the 10-year average

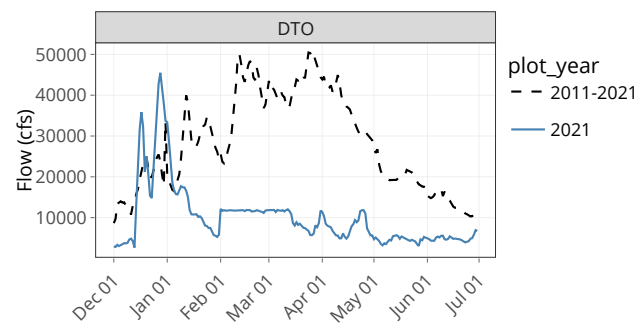


Figure 6.4: Delta Outflow (DTO) in 2021 and over the 10-year average

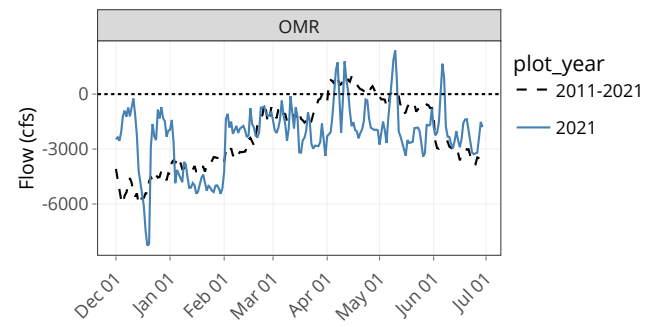


Figure 6.5: OMR Flow (OMR) (cfs) in 2021 and over the 10-year average

Table 6.3: SRH (Sacramento River at Hood), SXS (Steamboat Slough near Sacramento River), BLP (Blind Point), MAL (Sacramento River at Mallard Island) Mean, Maximum, Minimum Monthly DO (mg/L) in 2021 - 2022

Year	Month	Station	Mean	Min	Max	Days < 6 Mg/L
2021	December	SRH	10.1	9.5	10.7	0
2022	January	SRH	11.0	10.6	11.4	0
2022	February	SRH	10.9	10.2	11.7	0
2022	March	SRH	9.9	8.5	11.1	0
2022	April	SRH	9.0	8.3	9.6	0
2022	May	SRH	8.5	7.9	10.5	0
2022	June	SRH	8.1	7.5	9.1	0
2021	December	SXS	9.7	9.2	10.4	0
2022	January	SXS	10.7	10.2	11.2	0
2022	February	SXS	10.9	9.7	12.5	0
2022	March	SXS	10.3	8.5	12.5	0
2022	April	SXS	9.4	8.6	10.7	0
2022	May	SXS	8.9	7.5	11.9	0
2022	June	SXS	8.1	7.1	9.2	0
2021	December	BLP	9.5	8.3	10.4	0
2022	January	BLP	9.8	9.3	10.5	0
2022	February	BLP	10.6	9.8	10.9	0
2022	March	BLP	10.3	9.2	11.2	0
2022	April	BLP	9.4	8.6	10.4	0
2022	May	BLP	9.0	8.0	10.1	0
2022	June	BLP	8.4	7.7	9.9	0
2021	December	MAL	9.4	8.2	10.4	0
2022	January	MAL	10.1	9.6	10.6	0
2022	February	MAL	10.3	9.8	10.6	0
2022	March	MAL	10.1	9.3	10.9	0
2022	April	MAL	9.3	8.8	10.0	0
2022	May	MAL	8.9	8.3	9.4	0
2022	June	MAL	8.4	7.7	9.1	0

Table 6.4: Table of Hatchery WR Juvenile Survival

rel_date	reach_start	reach_end	rkm_start	ReachSurvival	Cumulat
2022-02-10	Abv_FremontWeir	SacFeather	215	0.995 (0.965, 0.999)	0.174 (0.
2022-02-10	SacFeather	Blw_Elkhorn_GS1	206	1 (1, 1)	0.165 (0.
2022-02-10	Blw_Elkhorn_GS1	TowerBridge	192	0.998 (0.984, 1)	0.165 (0.
2022-02-10	TowerBridge	SacTrawl	172	1 (1, 1)	0.158 (0.
2022-02-10	Freeport	Abv_Clarksburg	152	1 (1, 1)	0.137 (0.
2022-02-10	Abv_Clarksburg	Hood	148	1 (1, 1)	0.137 (0.
2022-02-10	Hood	Chipps	138	0.992 (0.984, 0.996)	0.137 (0.
2022-02-10	Chipps	Benicia	71	0.989 (0.959, 0.997)	0.08 (0.0
2022-02-10	Benicia	GoldenGateE	52	1 (1, 1)	0.065 (0.
2022-03-02	Abv_FremontWeir	SacFeather	215	0.998 (0.985, 1)	0.151 (0.
2022-03-02	SacFeather	Blw_Elkhorn_GS1	206	0.996 (0.989, 0.999)	0.149 (0.
2022-03-02	Blw_Elkhorn_GS1	TowerBridge	192	0.994 (0.987, 0.997)	0.142 (0.
2022-03-02	TowerBridge	SacTrawl	172	0.985 (0.961, 0.994)	0.126 (0.
2022-03-02	Freeport	Abv_Clarksburg	152	0.991 (0.964, 0.998)	0.107 (0.
2022-03-02	Abv_Clarksburg	Hood	148	0.995 (0.981, 0.999)	0.102 (0.
2022-03-02	Hood	Chipps	138	0.993 (0.989, 0.996)	0.098 (0.
2022-03-02	Chipps	Benicia	71	0.994 (0.981, 0.998)	0.063 (0.
2022-03-02	Benicia	GoldenGateE	52	1 (1, 1)	0.056 (0.

- Maximum water temperature was **11.2** degrees F and occurred in **3**. The highest mean water temperature was **10.6** degrees F and occurred in **2**.
- Maximum water temperature was **10.9** degrees F and occurred in **3**. The highest mean water temperature was **10.3** degrees F and occurred in **2**.

6.3 Biological Response

6.3.1 Survival

6.3.2 Abundance

Catch for all surveys

Summary

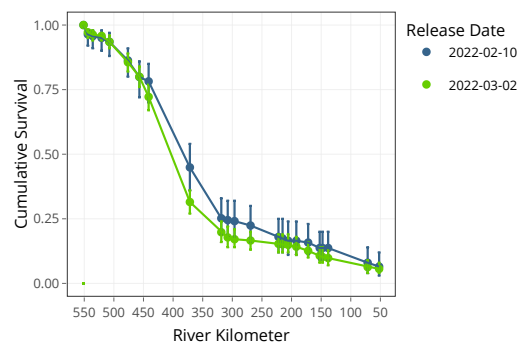


Figure 6.6: Cumulative Survival by River Kilometer

- Juvenile WRCS cumulative total catch:
 - Sacramento Trawls at Sherwood Harbor: **22** (Index = **22**)
 - Sacramento Beach Seines: **23** (Index = **50.2**)
 - Chipps Island Trawl: **10**

- Migration Timing:
 - Delta Entry (Sacramento Trawls at Sherwood Harbor):
 - * First: **October 27, 2021**
 - * Median: **June 18, 2021**
 - * Last: **February 23, 2022**
 - Delta Exit (Chipps Island Trawl):
 - * First: **November 01, 2021**
 - * Median: **June 18, 2021**
 - * Last: **April 05, 2022**

6.3.3 Migration Timing

Sac Trawl Data (Raw Catch by Day or Week?)

SacPAS Migration Timing Table - LAD Median Dates, 10 Year Comparison
Sacramento Beach Seines, Trawls, Chipps Island Trawls

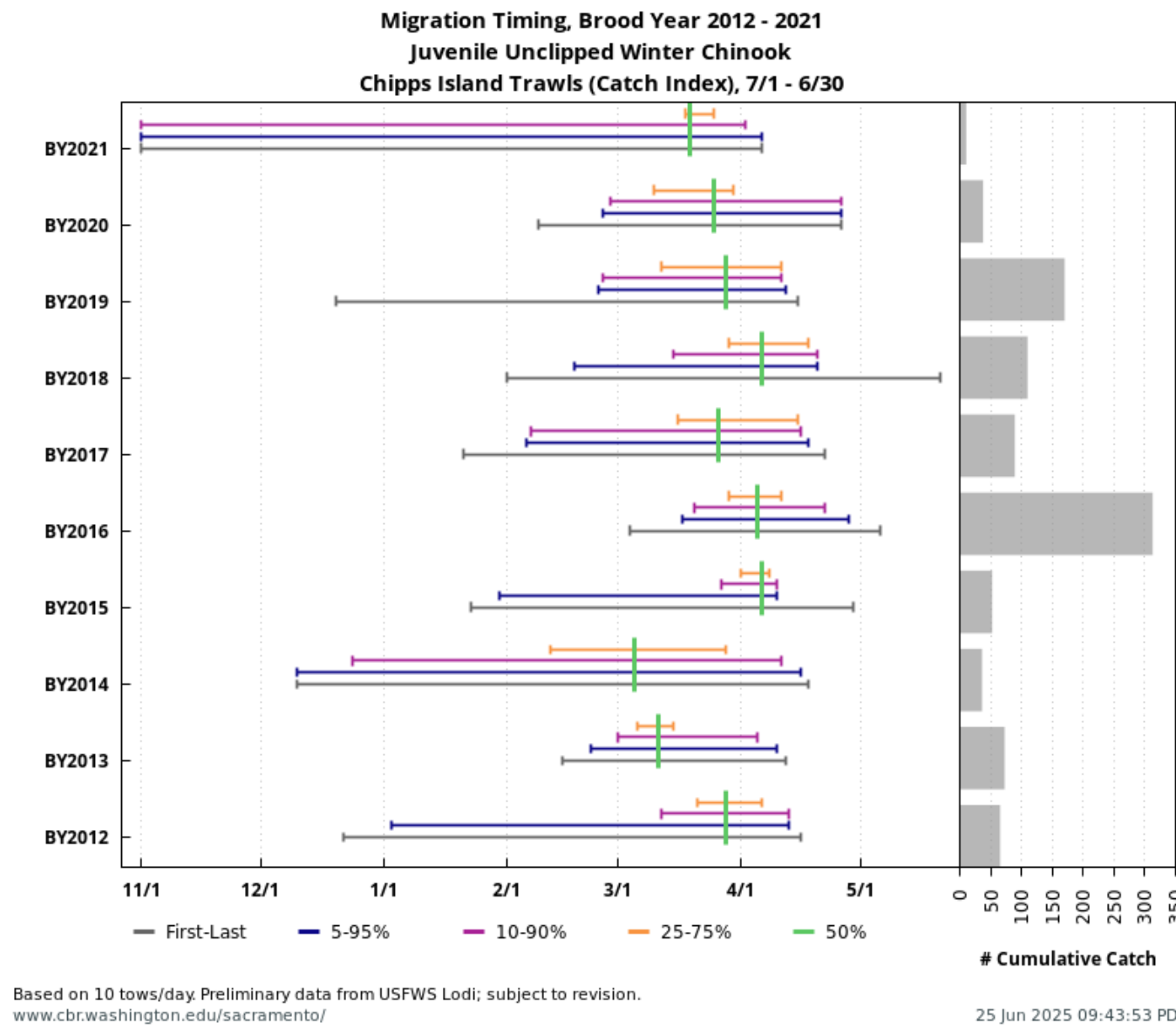
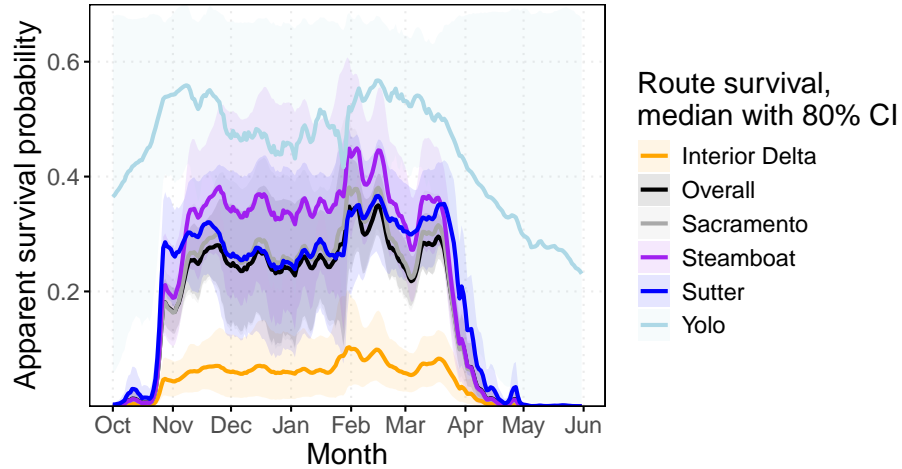


Figure 6.7: Delta Exit (Chippis Island) Migration Timing

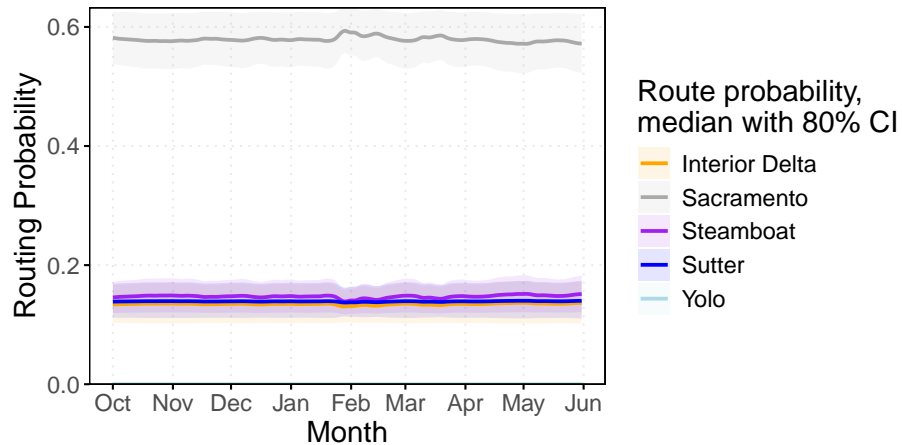
6.3.4 STARS Survival and Routing

WY2021 Survival: Median survival of daily cohorts by
Delta STARS Model –
Predicted Natural Winter-run Chinook Daily Cohorts Passage, k



ative Fisheries Ecology Section and deployed by SacPAS.

WY2021 Route-specific probability: Proportion of dail
Delta STARS Model –
Predicted Natural Winter-run Chinook Daily Cohorts Passage, k



ative Fisheries Ecology Section and deployed by SacPAS.

6.3.5 Condition

Plot of current year sizes for Salvage, Chipps, Sacramento Beach Seines, Sac Trawls at Sherwood

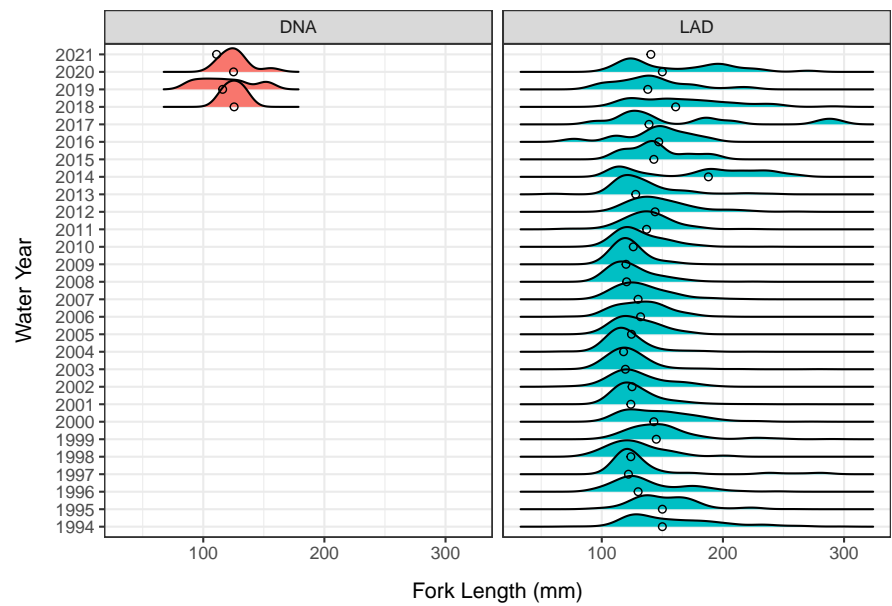


Figure 6.8: (#fig:salvage_fl-fig) Fork Lengths of Genetic and LAD Winter Run Chinook Salmon Juveniles at Salvage. Points indicate median fork length.

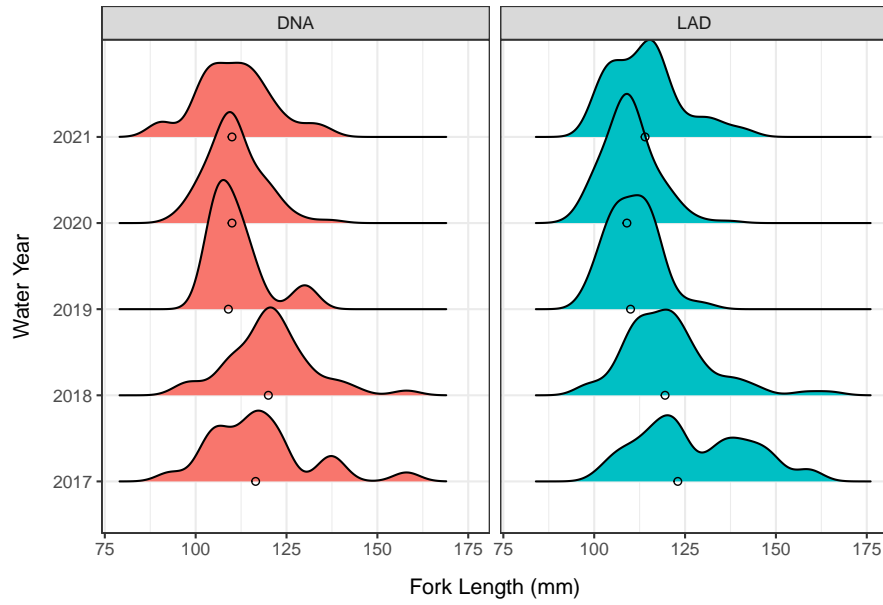
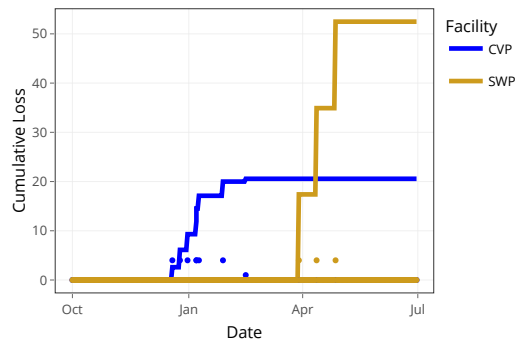


Figure 6.9: (#fig:chipps_fl-fig) Fork Lengths of Genetic and LAD Winter Run Chinook Salmon Juveniles at Chipps Trawl. Points indicate median fork length.

6.3.6 Loss



Winter-run Current and Historic Cumulative Salvage (Line plots)

Current + Historic Percent of JPE

Monitoring Sources for abundance, growth/size, migration timing/duration

- Sac Trawl

- Tisdale Weir
- Knights Landing
- GCID
- DJFMP
- Yolo Bypass
- Chipps Island Trawl (Exit)
- Genetic (Chipps, SWP/CVP, Knights Landing, Yolo Bypass)

1. Abundance (Count) (IEP Monitoring)
2. Condition (IEP Monitoring)

- FL

3. Migration Timing (IEP Monitoring)

- SacPAS style plots of historical and current year?

Chipps Trawl Timing

Sac Trawl Timing

Sac Beach Seine Timing

4. Migration Duration

- Calfish Track/ERDDAP

5. Migration Routing

6. Survival

- Hatchery real-time: Calfish Track/ERDDAP
- Natural Origin Smolt survival (O Farrell et al. 2018)
- Hatchery Origin Smolt survival
- Modeled: ** Juvenile: STARS ** Fish Model
- Survival to Delta: Production (Hatchery JPE, Modeled JPE)

Chapter 7

Abbreviations

CM = Conceptual Model WRCS = Winter Run Chinook Salmon

Chapter 8

Data Sources

8.1 Environmental Data

- CDEC
- USGS

8.2 Biological Data

8.2.1 Adults

- CDFW Carcass Data (https://www.cbr.washington.edu/sacramento/data/query_carcass_detail.html)
 - Data courtesy of CDFW
 - Metrics:
 - * Escapement
 - * Sex and Age class distribution
 - * Spawners
 - * % Spawned
 - * Spawn origin
 - * Spawn timing
 - * Spatial distribution
- Aerial Redd Data (https://www.cbr.washington.edu/sacramento/data/query_redd_aerial.html)
 - Data courtesy of CDFW
 - Metrics:
 - * Aerial Redd Count

- JPE Data (https://www.cbr.washington.edu/sacramento/data/jpe_data.html)
 - Data originally from JPE letters
 - Metrics:
 - * Pre-spawn mortality

8.2.2 Egg to Fry

8.2.3 Juveniles

Chapter 9

Useful info

9.1 Parts

You can add parts to organize one or more book chapters together. Parts can be inserted at the top of an .Rmd file, before the first-level chapter heading in that same file.

Add a numbered part: `# (PART) Act one {-}` (followed by `# A chapter`)

Add an unnumbered part: `# (PART*) Act one {-}` (followed by `# A chapter`)

Add an appendix as a special kind of un-numbered part: `# (APPENDIX) Other stuff {-}` (followed by `# A chapter`). Chapters in an appendix are prepended with letters instead of numbers.

9.2 Footnotes and citations

9.2.1 Footnotes

Footnotes are put inside the square brackets after a caret `^[]`. Like this one ¹.

9.2.2 Citations

Reference items in your bibliography file(s) using `@key`.

For example, we are using the **bookdown** package [Xie, 2024] (check out the last code chunk in index.Rmd to see how this citation key was added) in this

¹This is a footnote.

sample book, which was built on top of R Markdown and **knitr** [Xie, 2015] (this citation was added manually in an external file `book.bib`). Note that the `.bib` files need to be listed in the `index.Rmd` with the YAML `bibliography` key.

The RStudio Visual Markdown Editor can also make it easier to insert citations: <https://rstudio.github.io/visual-markdown-editing/#/citations>

9.3 Blocks

9.3.1 Equations

Here is an equation.

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k} \quad (9.1)$$

You may refer to using `\@ref{eq:binom}`, like see Equation (9.1).

9.3.2 Theorems and proofs

Labeled theorems can be referenced in text using `\@ref{thm:tri}`, for example, check out this smart theorem 9.1.

Theorem 9.1. *For a right triangle, if c denotes the length of the hypotenuse and a and b denote the lengths of the **other** two sides, we have*

$$a^2 + b^2 = c^2$$

Read more here <https://bookdown.org/yihui/bookdown/markdown-extensions-by-bookdown.html>.

9.3.3 Callout blocks

The R Markdown Cookbook provides more help on how to use custom blocks to design your own callouts: <https://bookdown.org/yihui/rmarkdown-cookbook/custom-blocks.html>

9.4 Cross-references

Cross-references make it easier for your readers to find and link to elements in your book.

9.4.1 Chapters and sub-chapters

There are two steps to cross-reference any heading:

1. Label the heading: `# Hello world {#nice-label}`.
 - Leave the label off if you like the automated heading generated based on your heading title: for example, `# Hello world = # Hello world {#hello-world}`.
 - To label an un-numbered heading, use: `# Hello world {-#nice-label}` or `{# Hello world .unnumbered}`.
2. Next, reference the labeled heading anywhere in the text using `\@ref(nice-label)`; for example, please see Chapter 9.4.
 - If you prefer text as the link instead of a numbered reference use: any text you want can go here.

9.4.2 Captioned figures and tables

Figures and tables *with captions* can also be cross-referenced from elsewhere in your book using `\@ref(fig:chunk-label)` and `\@ref(tab:chunk-label)`, respectively.

See Figure 9.1.

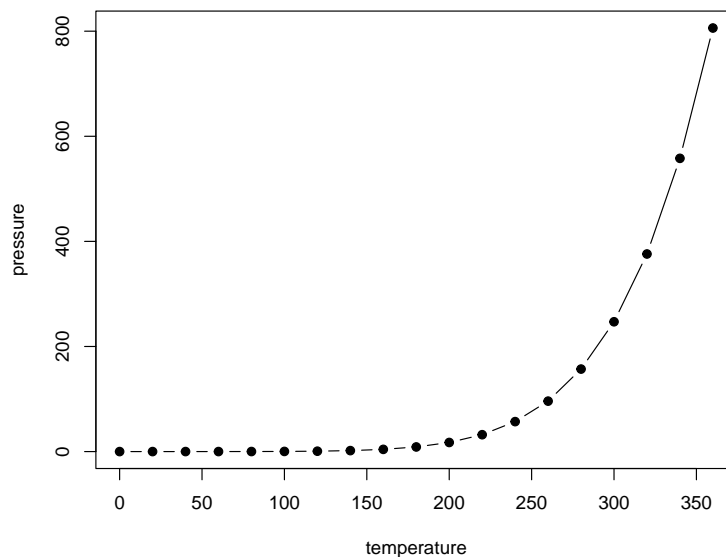


Figure 9.1: Here is a nice figure!

Don't miss Table 9.1.

Table 9.1: Here is a nice table!

temperature	pressure
0	0.0002
20	0.0012
40	0.0060
60	0.0300
80	0.0900
100	0.2700
120	0.7500
140	1.8500
160	4.2000
180	8.8000

9.5 Sharing your book

9.5.1 Publishing

HTML books can be published online, see: <https://bookdown.org/yihui/bookdown/publishing.html>

9.5.2 404 pages

By default, users will be directed to a 404 page if they try to access a webpage that cannot be found. If you'd like to customize your 404 page instead of using the default, you may add either a `_404.Rmd` or `_404.md` file to your project root and use code and/or Markdown syntax.

9.5.3 Metadata for sharing

Bookdown HTML books will provide HTML metadata for social sharing on platforms like Twitter, Facebook, and LinkedIn, using information you provide in the `index.Rmd` YAML. To setup, set the `url` for your book and the path to your `cover-image` file. Your book's `title` and `description` are also used.

This `gitbook` uses the same social sharing data across all chapters in your book—all links shared will look the same.

Specify your book's source repository on GitHub using the `edit` key under the configuration options in the `_output.yml` file, which allows users to suggest an edit by linking to a chapter's source file.

Read more about the features of this output format here:

<https://pkgs.rstudio.com/bookdown/reference/gitbook.html>

Or use:

9.6 Render book

You can render the HTML version of this example book without changing anything:

1. Find the **Build** pane in the RStudio IDE, and
2. Click on **Build Book**, then select your output format, or select “All formats” if you’d like to use multiple formats from the same book source files.

Or build the book from the R console:

To render this example to PDF as a `bookdown::pdf_book`, you’ll need to install XeLaTeX. You are recommended to install TinyTeX (which includes XeLaTeX): <https://yihui.org/tinytex/>.

9.7 Preview book

As you work, you may start a local server to live preview this HTML book. This preview will update as you edit the book when you save individual `.Rmd` files. You can start the server in a work session by using the RStudio add-in “Preview book”, or from the R console:

9.8 Footnotes and citations

9.8.1 Footnotes

Footnotes are put inside the square brackets after a caret `^[]`. Like this one ².

9.8.2 Citations

- <https://www.anchorqea.com/news/brood-year-2019-winter-run-chinook-salmon-operations-and-monitoring-assessment/>

²This is a footnote.

Reference items in your bibliography file(s) using `@key`.

For example, we are using the **bookdown** package [Xie, 2024] (check out the last code chunk in `index.Rmd` to see how this citation key was added) in this sample book, which was built on top of R Markdown and **knitr** [Xie, 2015] (this citation was added manually in an external file `book.bib`). Note that the `.bib` files need to be listed in the `index.Rmd` with the YAML `bibliography` key.

The RStudio Visual Markdown Editor can also make it easier to insert citations: <https://rstudio.github.io/visual-markdown-editing/#/citations>

Chapter 10

Key metrics

This section summarizes key metrics listed in the 3.3.3 of the Proposed Action (Annual Winter-run Chinook Salmon Broodyear Assessment)

10.1 Metrics

- greater than 30% TDM
- less than 20% ETF survival
- 25 percentile of historic JPE
- TMP compliance point was above CCR
- Adverse Population Viability Trends (per previous year's annual brood year report if there was an increase in any of the five criteria in Lindley et al. 2007)
- High risk of extinction (per 5 year status review)
- Outyear adult escapement forecast based on PFMC winter-run stock abundance analyses

The JPE Subteam will provide the broodyear assessment to Reclamation and the SHOT. If the broodyear assessment determines Adverse Conditions for Winter-run Chinook salmon and identifies that Shasta storage and hydrology are expected to result in continuing adverse conditions to the coming broodyear, the SHOT will report these conditions and proposed actions to the Directors and all reasonable actions will be taken to avoid continued adverse conditions. These indicators of broodyear strength can be revised by the SHOT with NMFS approval .

10.1.1 TDM**10.1.2 ETF survival****10.1.3 Percentile of historic JPE**

Bibliography

Yihui Xie. *Dynamic Documents with R and knitr*. Chapman and Hall/CRC, Boca Raton, Florida, 2nd edition, 2015. URL <http://yihui.org/knitr/>. ISBN 978-1498716963.

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