

# 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](https://watershed.ucdavis.edu/files/biblio/NOAA-TM-NMFS-SWFSC-586_Final.pdf)

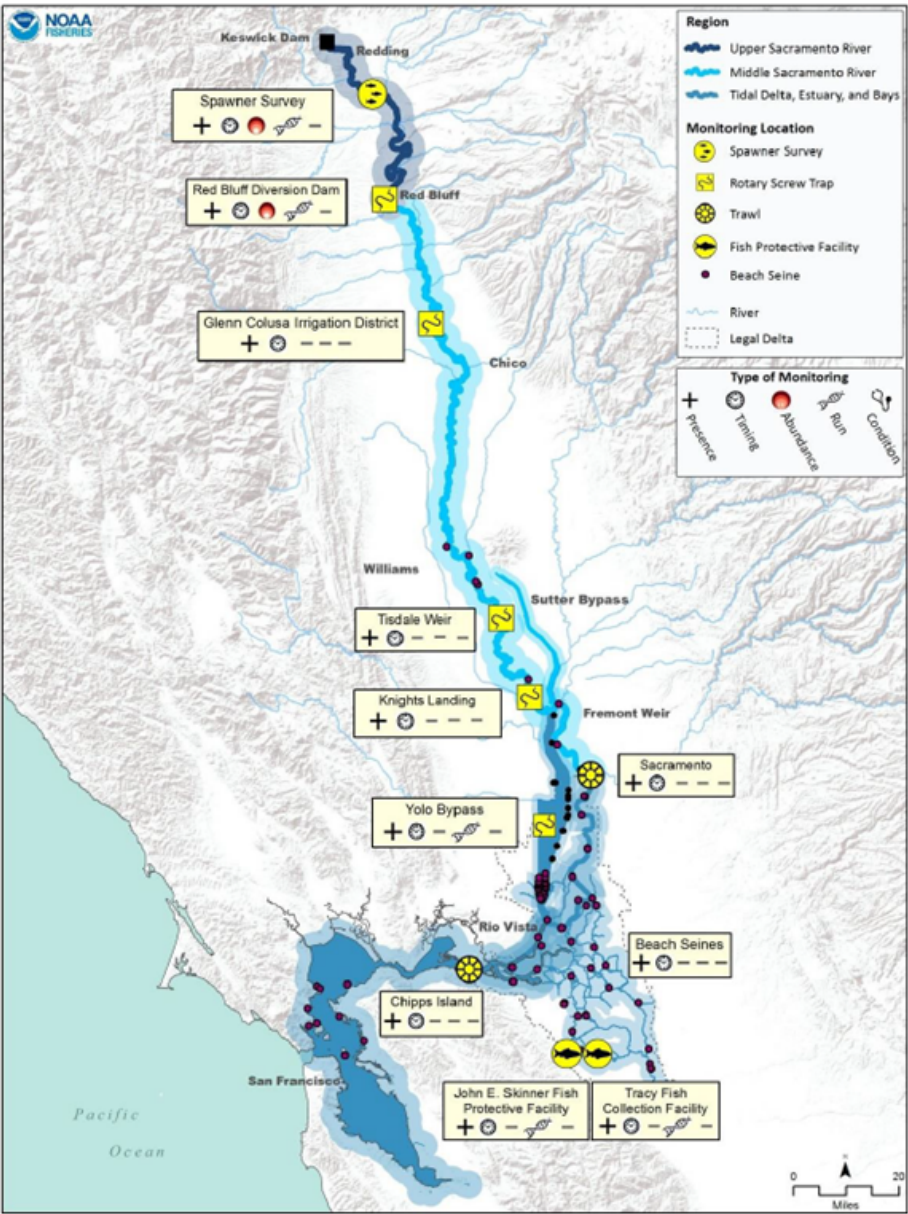


Figure 1.1: “distribution map”

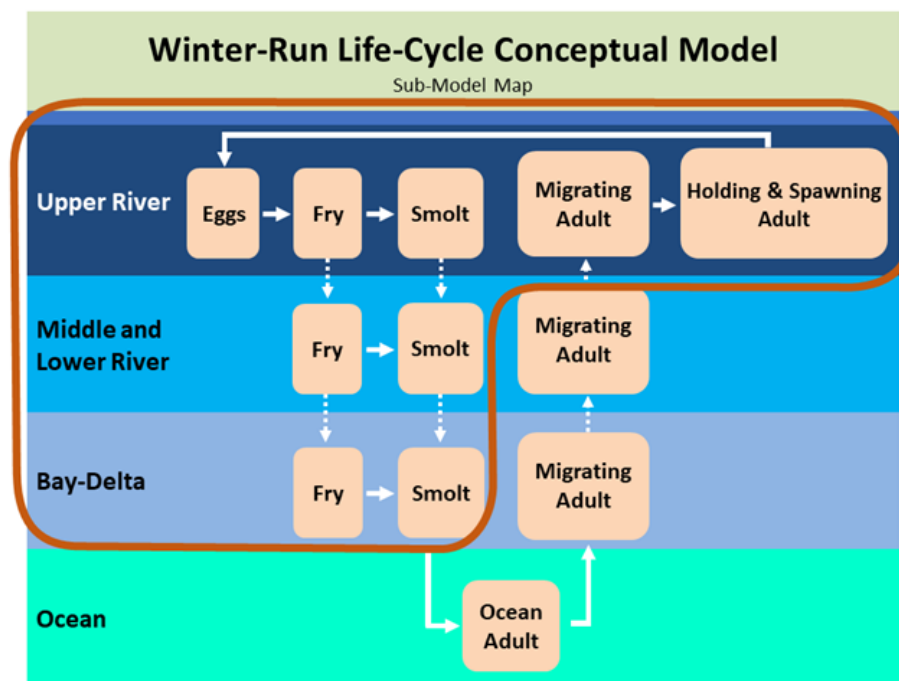


Figure 1.2: “conceptual model”



# Chapter 2

## Adults

This section describes environmental attributes associated with and responses during the adult life stage (ocean harvest, migration, spawning)

### 2.1 Habitat Attributes

1. Hatchery Influence (Proportion of hatchery return)
2. Hatchery Pathogens/Disease
3. In-River Pathogens/Disease
4. Spawning Habitat Capacity (SIT model)

### 2.2 Environmental Drivers

- 2021 was a Critical water year type.

#### 2.2.1 Storage and Flow

##### 2.2.1.1 Shasta Storage

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

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

### 2.2.1.2 Flow Conditions on the Upper Sacramento River

Daily Flows (cfs) at Sacramento River 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

<b>year</b>	<b>Month</b>	<b>Station</b>	<b>Mean (cfs)</b>	<b>Min (cfs)</b>	<b>Max (cfs)</b>
2021	January	BND	6,982.1	4,220	12,300
2021	February	BND	7,358.0	4,560	13,500
2021	March	BND	7,048.8	4,540	10,100
2021	April	BND	6,666.7	4,590	8,920
2021	May	BND	8,858.0	7,170	10,800
2021	June	BND	8,328.5	7,180	9,330
2021	July	BND	9,642.1	9,030	10,600
2021	August	BND	8,334.2	6,840	9,670
2021	September	BND	7,072.0	6,840	7,300
2021	October	BND	13,618.0	6,220	36,800
2021	November	BND	8,279.9	4,260	17,700
2021	December	BND	10,327.5	4,220	26,600
2021	January	KWK	3,217.4	2,970	3,700
2021	February	KWK	3,157.9	2,900	3,520
2021	March	KWK	3,405.0	3,170	3,640
2021	April	KWK	5,682.5	3,280	8,050
2021	May	KWK	8,369.6	6,800	9,870
2021	June	KWK	7,882.3	6,570	9,390
2021	July	KWK	9,510.2	8,740	10,800
2021	August	KWK	8,102.0	6,610	9,500
2021	September	KWK	6,899.8	5,310	8,500
2021	October	KWK	6,160.1	5,120	7,330
2021	November	KWK	4,027.1	3,070	5,080

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 (cfs)	Min (cfs)	Max (cfs)
2021	December	KWK	3,431.0	3,040	3,970

### Summary

- In 2021, storage was consistently below the 10-year average (Figure 2.2.1.1), with peak storage at **2.4** TAF in **4**.
- **Keswick:** Peak flows were  $1.08 \times 10^4$  cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.
- **Bend Bridge:** Peak flows were  $3.68 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.3618 \times 10^4$  cfs and occurred in **10**.

## 2.2.2 Water Temperature

### 2.2.2.1 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.

```
# knitr::include_graphics("https://www.cbr.washington.edu/sacramento/tmp/tc_sacramento_1704298322")
```

### Summary

- The compliance point at X was met X percent of days (??).

### 2.2.2.2 Water Temperature at Balls Ferry Bridge and Clear Creek

Daily 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) and Sacramento River upstream from Confluence with Clear Creek (CCR) in 2021

<b>year</b>	<b>Month</b>	<b>Station</b>	<b>Mean (°F)</b>	<b>Min (°F)</b>	<b>Max (°F)</b>
2,021	January	BSF	48.6	44.2	52.4
2,021	February	BSF	49.2	46.2	52.1
2,021	March	BSF	51.7	47.2	56.2
2,021	April	BSF	56.6	51.3	62.4
2,021	May	BSF	59.9	54.8	65.4
2,021	June	BSF	58.2	53.8	62.7
2,021	July	BSF	57.6	54.6	60.7
2,021	August	BSF	57.8	54.5	66.9
2,021	September	BSF	59.0	56.2	61.9
2,021	October	BSF	59.3	56.9	61.7
2,021	November	BSF	56.4	52.3	60.5
2,021	December	BSF	50.7	46.0	55.4
2,021	January	CCR	50.0	46.5	53.2
2,021	February	CCR	50.1	47.8	52.4
2,021	March	CCR	51.6	47.9	55.4
2,021	April	CCR	55.3	50.1	61.0
2,021	May	CCR	59.4	54.7	64.5
2,021	June	CCR	56.3	53.0	59.6
2,021	July	CCR	56.0	53.9	58.1
2,021	August	CCR	57.1	54.3	60.1
2,021	September	CCR	58.6	55.9	61.4
2,021	October	CCR	59.7	57.3	62.1
2,021	November	CCR	57.0	53.4	61.0
2,021	December	CCR	52.4	48.1	56.7

### Summary

- Water temperatures were warmer than average and warmer than 56°F in 2021 (Figure 2.2.2.2).
- **Balls Ferry:** 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**.
- **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**.

### 2.2.3 Dissolved Oxygen Conditions at Keswick Dam and Clear Creek

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 (mg/L)	Min (mg/L)	Max (mg/L)
2,021	January	CCR	13.0	11.2	14.8
2,021	February	CCR	13.5	8.8	15.9
2,021	March	CCR	13.4	11.5	15.4
2,021	April	CCR	12.9	11.1	14.8
2,021	May	CCR	12.7	10.4	14.9
2,021	June	CCR	12.9	10.6	15.2
2,021	July	CCR	12.8	10.3	15.3
2,021	August	CCR	11.6	10.0	13.1
2,021	September	CCR	11.4	9.1	13.8
2,021	October	CCR	10.8	8.7	12.8
2,021	November	CCR	8.3	6.6	10.1
2,021	December	CCR	13.3	8.3	17.3
2,021	January	KWK	13.1	12.1	14.0
2,021	February	KWK	13.6	12.6	14.6
2,021	March	KWK	13.3	12.3	14.4
2,021	April	KWK	10.8	8.2	14.1

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 (mg/L)	Min (mg/L)	Max (mg/L)
2,021	May	KWK	8.9	7.4	10.7
2,021	June	KWK	9.6	8.5	10.7
2,021	July	KWK	7.2	2.5	11.0
2,021	August	KWK	11.1	10.0	12.1
2,021	September	KWK	12.7	8.6	15.8
2,021	October	KWK	8.7	7.8	9.4
2,021	November	KWK	10.0	8.4	11.6
2,021	December	KWK	12.7	11.4	14.0

### 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**.

## 2.3 Biological Response

### 2.3.1 Adult Survival

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

1. Ocean Harvest Rates (PFMC)
2. Adults to Hatchery (GrandTab)
3. Estimated Total Mainstem In-River Spawners of Natural and Hatchery Origin (GrandTab)
  - Downstream RBDD
  - Upstream RBDD
  - Clear Creek

- Battle Creek
4. Adult Condition (Carcass Surveys)
    - Male Fork Lengths (Histogram)
    - Female Fork Lengths (Histogram)
    - Age Distribution
    - Thiamine Deficiency
    - Pre-spawn mortality (in-text current year and 10-yr average, compare with other years)
  5. Spawn Timing (Carcass Surveys)
    - Percent spawning by week - line plot of percent of carcasses by week (current year, 10 year and 20 year average)
    - Peak spawning week - line plot of peak spawning week by year (annual, rolling 5-year avg, 10-year avg)
  6. Number of Winter-Run Chinook Salmon Redds (aerial redd surveys, Cal-fish)
    - line plot of count by year with average horizontal line
  7. Distribution of Winter-Run Chinook Salmon Redds - location of redds (aerial redd surveys, Calfish)
    - map of locations
    - bar plot of percent redds by location (historical and this year)
    - bar plot of female spawner carcasses by location
  8. Hatchery Fecundity (JPE Letters)
    - in text, comparison with previous 10 years
  9. Hatchery Influence (Hatchery report?)
    - in text percentage of hatchery fish/natural spawning pop
  10. Cohort Replacement Rate (GrandTab)
    - line plot of CRR by year





## Chapter 3

# Egg to Fry Emergence

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

### 3.1 Habitat Attributes

1. Redd Dewatering

- count by year
- location
- water depth
- flow

### 3.2 Environmental Drivers

#### 3.2.1 Storage and Flow

##### 3.2.1.1 Shasta Storage

- See 2.2.1.1 for summary of storage conditions.

##### 3.2.1.2 Flow Conditions on the Upper Sacramento River

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 (cfs)	Min (cfs)	Max (cfs)
2021	KWK	May	8,369.6	6,800	9,870
2021	KWK	June	7,882.3	6,570	9,390
2021	KWK	July	9,510.2	8,740	10,800
2021	KWK	August	8,102.0	6,610	9,500
2021	KWK	September	6,899.8	5,310	8,500
2021	KWK	October	6,160.1	5,120	7,330
2021	KWK	November	4,027.1	3,070	5,080
2021	BND	May	8,858.0	7,170	10,800
2021	BND	June	8,328.5	7,180	9,330
2021	BND	July	9,642.1	9,030	10,600
2021	BND	August	8,334.2	6,840	9,670
2021	BND	September	7,072.0	6,840	7,300
2021	BND	October	13,618.0	6,220	36,800
2021	BND	November	8,279.9	4,260	17,700

- **Keswick:** Peak flows were  $1.08 \times 10^4$  cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.
- **Bend Bridge:** Peak flows were  $3.68 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.3618 \times 10^4$  cfs and occurred in **10**.

### 3.2.2 Water Temperature on the Upper Sacramento River

- See 2.2.2.1 for discussion around temperature threshold analysis.

### 3.2.3 Dissolved Oxygen Conditions on the Upper Sacramento River

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 (mg/L)	Min (mg/L)	Max (mg/L)
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

#### 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**.

#### 3.2.4 Air Temperature

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

### 3.3 Biological Response

#### 1. Egg Count

- line plot of potential eggs by year with averages (JPE letter?)

## 2. Egg to fry survival

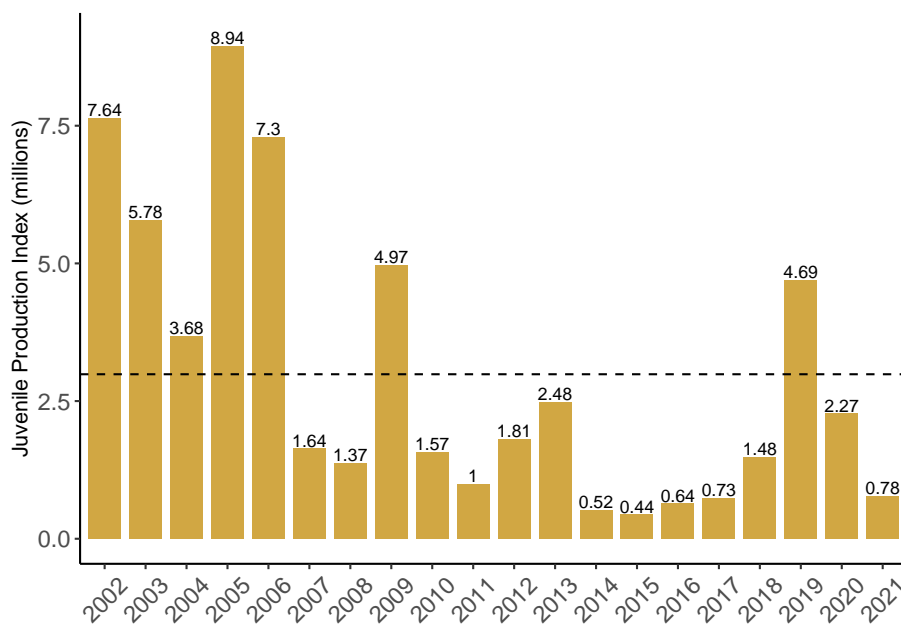


Figure 3.1: Annual JPI from 2002 to 2021

## Summary

- **Juvenile Production Index** JPI in 2021 was below the average JPI between 2002 and 2021 at 0.779427.
- **Egg to Fry Survival** ETF in 2021 was below the average ETF between 2002 and 2021 at 2.5.
- egg-to-fry survival from fish model (fish model)

## 3. Emergence Timing (fish model)

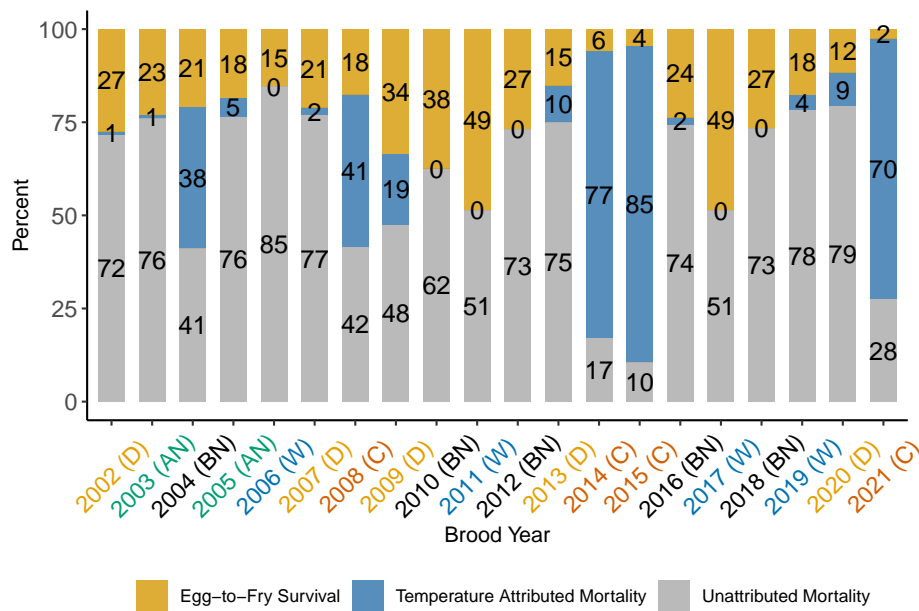


Figure 3.2: Annual Percent of Egg to Fry Survival, Temperature-Dependent Mortality, and Unattributed Survival from 2002 to 2021



## 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

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 Decemeber 2021

<b>year</b>	<b>Month</b>	<b>Station</b>	<b>Mean (cfs)</b>	<b>Min (cfs)</b>	<b>Max (cfs)</b>
2021	July	BND	9,642.1	9,030	10,600
2021	August	BND	8,334.2	6,840	9,670
2021	September	BND	7,072.0	6,840	7,300
2021	October	BND	13,618.0	6,220	36,800

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 (cfs)	Min (cfs)	Max (cfs)
2021	November	BND	8,279.9	4,260	17,700
2021	December	BND	10,327.5	4,220	26,600
2021	July	KWK	9,510.2	8,740	10,800
2021	August	KWK	8,102.0	6,610	9,500
2021	September	KWK	6,899.8	5,310	8,500
2021	October	KWK	6,160.1	5,120	7,330
2021	November	KWK	4,027.1	3,070	5,080
2021	December	KWK	3,431.0	3,040	3,970

- **Keswick:** Peak flows were  $1.08 \times 10^4$  cfs and occurred in **7**. The highest mean flows were **9510.2** cfs and occurred in **7**.
- **Bend Bridge:** Peak flows were  $3.68 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.3618 \times 10^4$  cfs and occurred in **10**.

#### 4.2.2 Stranding

#### 4.2.3 Water Temperature

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

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 (degF)	Min (degF)	Max (degF)
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



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 (degF)	Min (degF)	Max (degF)
2021	December	BND	50.4	45.6	55.6

#### 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**.

#### 4.2.4 Dissolved Oxygen

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

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 (cfs)	Min (mg/L)	Max (mg/L)	Days < 6 mg/L
2021	July	BND	11.8	1.2	17.5	
2021	August	BND	10.3	1.7	29.7	1
2021	September	BND	3.5	0.1	10.9	3
2021	October	BND	10.3	0.3	13.5	
2021	November	BND	10.9	3.4	15.5	
2021	December	BND	12.2	11.1	13.6	

#### 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**.

### 4.2.5 Turbidity

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 (cfs)	Min (cfs)	Max (cfs)
2021	July	BND	76.0	0.5	2,565.5
2021	August	BND	30.3	0.1	1,310.7
2021	September	BND	741.1	0.1	2,621.3
2021	October	BND	182.8	1.3	1,140.2
2021	November	BND	46.9	1.0	1,138.1
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

### 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.
- **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

1. Fry abundance (Fry-equivalent JPI)

- By year
- RBDD RST Data

2. Condition/ Growth

- Fork length by year

3. Migration Timing

- RBDD RST Data

4. Fry-to-Smolt Survival

- Model?



## 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

##### 5.1.1.1 Flow Conditions on the Middle and Lower Sacramento River

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 (cfs)	Min (cfs)	Max (cfs)
2021	September	HMC	5,885.7	5,590	6,182
2021	October	HMC	13,842.8	5,945	47,509
2021	November	HMC	7,181.8	3,983	17,544
2021	December	HMC	11,421.0	3,400	29,442
2022	January	HMC	7,669.2	4,678	12,005
2022	February	HMC	4,326.8	3,744	4,934
2022	March	HMC	3,983.1	3,615	4,333
2021	September	WLK	5,605.0	5,290	5,920
2021	October	WLK	11,000.4	5,650	25,100
2021	November	WLK	7,160.0	4,370	12,700
2021	December	WLK	9,375.3	3,990	20,600
2022	January	WLK	7,715.4	5,190	12,000
2022	February	WLK	4,732.0	4,060	5,400
2022	March	WLK	4,200.0	3,930	4,470
2021	September	VON	7,827.2	7,160	8,420
2021	October	VON	18,089.0	7,110	35,500
2021	November	VON	8,051.0	5,480	12,900
2021	December	VON	15,431.8	5,500	31,900
2022	January	VON	14,467.4	9,010	23,200
2022	February	VON	10,197.1	9,610	11,500
2022	March	VON	8,856.6	7,490	11,200

### Summary

- **Hamilton City:** Peak flows were  $4.7509 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.38428 \times 10^4$  cfs and occurred in **10**.
- **Wilkins Slough:** Peak flows were  $2.51 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.10004 \times 10^4$  cfs and occurred in **10**.

- **Verona:** Peak flows were  $3.55 \times 10^4$  cfs and occurred in **10**. The highest mean flows were  $1.8089 \times 10^4$  cfs and occurred in **10**.

## 5.1.2 Environmental Drivers

### 5.1.2.1 Turbidity

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 (FNU)	Min (FNU)	Max (FNU)
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

### 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

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 (°F)	Min (°F)	Max (°F)	Days > 63°F
2021	September	WLK	69.5	63.8	90.7	30
2021	October	WLK	61.2	57.3	71.7	20
2021	November	WLK	56.8	52.4	62.0	10
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	10

#### 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**.

#### 5.1.2.3 Dissolved Oxygen



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

### 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)

1. Abundance (Count) (IEP Monitoring)

- Natural JPE
- Hatchery JPE
- SacPAS Fish Model (emerged fry)

2. Condition

- Growth/ Size

3. Migration Timing

- SacPAS style plots of historical and current year?

4. 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

## 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
2. Entrainment Risk
3. Food Availability

### 6.2 Environmental Drivers

#### 6.2.1 Sacramento River Flow and Delta Outflow

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

Year	Month	Station	Mean (cfs)	Min (cfs)	Max (cfs)
2021	December	FPT	8,616.8	-5,360	36,600
2022	January	FPT	12,824.9	1,370	32,600
2022	February	FPT	8,173.3	2,880	17,200
2022	March	FPT	6,008.5	-1,390	17,000
2022	April	FPT	4,295.7	-3,630	15,700
2022	May	FPT	3,310.5	-4,040	15,300
2022	June	FPT	4,553.0	-2,710	18,300
2021	December	DTO	18,383.4	2,674	45,494
2022	January	DTO	13,135.7	5,266	33,374
2022	February	DTO	11,724.5	11,150	12,147
2022	March	DTO	9,559.9	5,712	12,035
2022	April	DTO	7,716.9	4,865	11,825
2022	May	DTO	4,553.6	3,082	5,697
2022	June	DTO	4,936.1	3,937	6,935
2021	December	OMR	-2,738.9	-9,193	-86
2022	January	OMR	-4,493.8	-5,631	-1,289
2022	February	OMR	-1,688.3	-4,780	-389
2022	March	OMR	-1,919.8	-3,776	191
2022	April	OMR	-981.3	-2,710	2,423
2022	May	OMR	-1,690.0	-3,774	2,519
2022	June	OMR	-1,922.2	-3,400	2,523

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

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

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

#### Summary

- **Sacramento River at Freeport:** Peak flows were  $3.66 \times 10^4$  cfs and

occurred in **12**. The highest mean flows were  $1.28249 \times 10^4$  cfs and occurred in **1**. Flow was generally lower than average.

- **Delta Outflow:** Peak Delta outflow was  $4.5494 \times 10^4$  cfs and occurred in **12**. The highest mean Delta outflow was  $1.83834 \times 10^4$  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

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 (°F)	Min (°F)	Max (°F)	Days > 63°
2021	December	FPT	49.6	45.9	55.4	
2022	January	FPT	48.6	45.7	50.0	
2022	February	FPT	51.6	47.5	55.0	
2022	March	FPT	57.9	52.9	64.9	
2022	April	FPT	62.7	58.8	67.6	1
2022	May	FPT	68.8	62.2	75.2	3
2022	June	FPT	73.3	69.6	77.9	2
2021	December	SUS	50.2	45.9	54.7	
2022	January	SUS	48.8	45.7	50.5	
2022	February	SUS	51.8	47.7	55.8	
2022	March	SUS	58.2	51.8	64.9	
2022	April	SUS	63.1	59.9	68.0	2
2022	May	SUS	69.2	63.7	75.2	3
2022	June	SUS	74.1	70.9	77.9	3
2021	December	SWE	50.1	45.9	54.5	
2022	January	SWE	48.7	45.7	50.4	

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 (°F)	Min (°F)	Max (°F)
2022	February	SWE	51.7	47.8	54.5
2022	March	SWE	57.9	52.0	64.0
2022	April	SWE	62.8	59.9	66.7
2022	May	SWE	68.8	63.9	73.4
2022	June	SWE	73.6	70.7	76.8
2021	December	GSS	50.2	46.0	54.7
2022	January	GSS	48.9	45.9	55.4
2022	February	GSS	51.9	47.8	55.2
2022	March	GSS	58.0	52.0	64.2
2022	April	GSS	63.0	56.3	66.9
2022	May	GSS	69.0	64.0	75.9
2022	June	GSS	73.8	70.9	77.0
2021	December	MAL	52.4	47.6	57.8
2022	January	MAL	49.2	47.1	51.7
2022	February	MAL	51.9	49.6	54.9
2022	March	MAL	57.0	53.0	61.3
2022	April	MAL	61.5	59.0	64.1
2022	May	MAL	64.6	61.0	71.1
2022	June	MAL	70.1	66.3	75.1

### Summary

- 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

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

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

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 (mg/L)	Min (mg/L)	Max (mg/L)
2021	December	MAL	9.4	8.2	10.4
2022	January	MAL	10.1	9.6	10.6
2022	February	MAL	10.3	9.8	10.6
2022	March	MAL	10.1	9.3	10.9
2022	April	MAL	9.3	8.8	10.0
2022	May	MAL	8.9	8.3	9.4
2022	June	MAL	8.4	7.7	9.1

### 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**.
- 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

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 Farell et al. 2018)
  - Hatchery Origin Smolt survival
  - Modeled: \*\* Juvenile: STARS \*\* Fish Model
  - Survival to Delta: Production (Hatchery JPE, Modeled JPE)
7. Loss and Salvage (Salvage)
  - Take Limit
  - Model



## Chapter 7

# Abbreviations

CM = Conceptual Model WRCS = Winter Run Chinook Salmon



# Chapter 8

## Useful info

### 8.1 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.

### 8.2 Footnotes and citations

#### 8.2.1 Footnotes

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

#### 8.2.2 Citations

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

For example, we are using the **bookdown** package [Xie, 2023] (check out the last code chunk in index.Rmd to see how this citation key was added) in this

---

<sup>1</sup>This 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>

## 8.3 Blocks

### 8.3.1 Equations

Here is an equation.

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k} \quad (8.1)$$

You may refer to using `\@ref(eq:binom)`, like see Equation (8.1).

### 8.3.2 Theorems and proofs

Labeled theorems can be referenced in text using `\@ref(thm:tri)`, for example, check out this smart theorem 8.1.

**Theorem 8.1.** *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>.

### 8.3.3 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>

## 8.4 Cross-references

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

### 8.4.1 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 8.4.
  - If you prefer text as the link instead of a numbered reference use: any text you want can go here.

### 8.4.2 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 8.1.

```
par(mar = c(4, 4, .1, .1))
plot(pressure, type = 'b', pch = 19)
```

Don't miss Table 8.1.

```
knitr::kable(
  head(pressure, 10), caption = 'Here is a nice table!',
  booktabs = TRUE
)
```

## 8.5 Sharing your book

### 8.5.1 Publishing

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

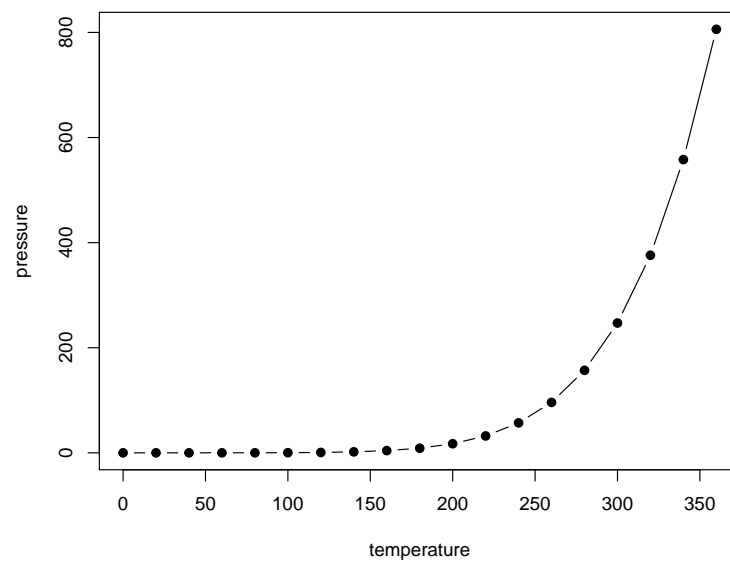


Figure 8.1: Here is a nice figure!

Table 8.1: 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



### 8.5.2 404 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.

### 8.5.3 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:

```
?bookdown::gitbook
```

## 8.6 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:

```
bookdown::render_book()
```

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/>.

## 8.7 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:

```
bookdown::serve_book()
```

## 8.8 Footnotes and citations

### 8.8.1 Footnotes

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

### 8.8.2 Citations

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

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

For example, we are using the **bookdown** package [Xie, 2023] (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>

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<sup>2</sup>This is a footnote.

# 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.

Yihui Xie. *bookdown: Authoring Books and Technical Documents with R Markdown*, 2023. URL <https://CRAN.R-project.org/package=bookdown>. R package version 0.34.