Brood Year 2021 Winter-Run Chinook Salmon Report

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Contents

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

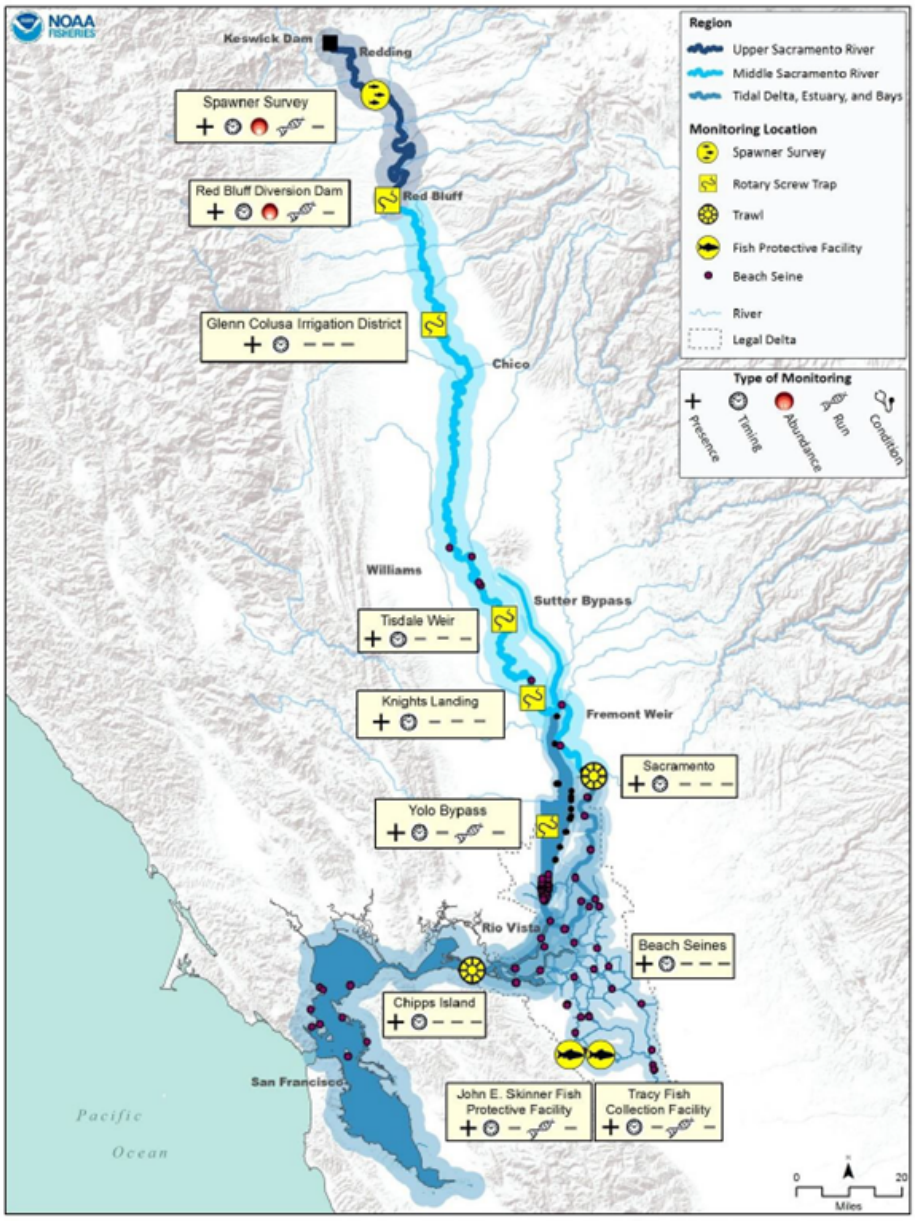

Figure 1.1: “distribution map”

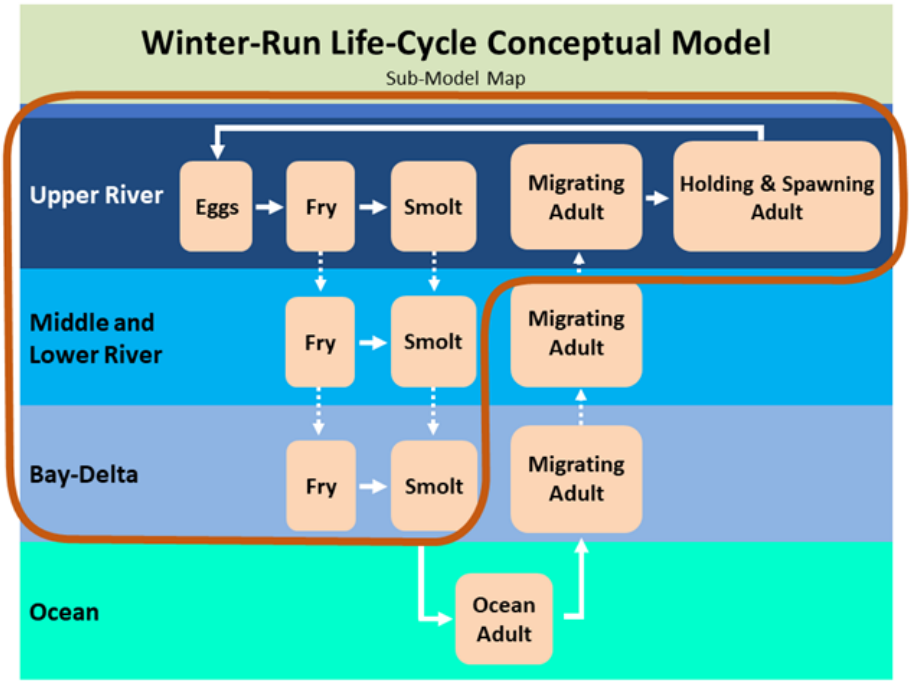

Figure 1.2: "conceptual model"

Chapter 2

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 reply on flows for migration cues.

```
shasta_max <-  shasta_data %>% filter(plot_year == "2021")
max_storage_sha <- max(shasta_max$Storage_TAF)
max_storage_sha_month <- shasta_max %>% filter(Storage_TAF == max_storage_sha) %>% select(Month)
```

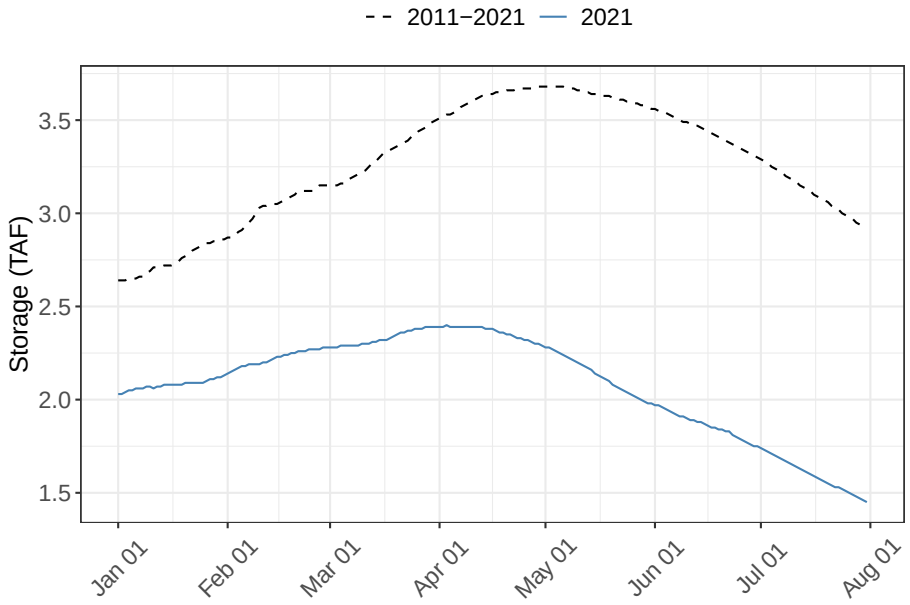

Figure 2.1: Shasta Dam Storage (SHA).

Summary

- In 2021, storage was consistently below the 10-year average (Figure 2.1), with peak storage at **2.4** TAF in **4**.

2.2.1.2 Flow Conditions on the Sacramento River at Keswick (KWK) and Sacramento River at Bend Bridge (BND)

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

Month	Station	Mean (cfs)	Min (cfs)	Max (cfs)
Jan	BND	6,982.1	4,220	12,300
Feb	BND	7,358.0	4,560	13,500
Mar	BND	7,048.8	4,540	10,100
Apr	BND	6,666.7	4,590	8,920
May	BND	8,858.0	7,170	10,800

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

Month	Station	Mean (cfs)	Min (cfs)	Max (cfs)
Jun	BND	8,328.5	7,180	9,330
Jul	BND	9,642.1	9,030	10,600
Aug	BND	8,334.2	6,840	9,670
Sep	BND	7,072.0	6,840	7,300
Oct	BND	13,618.0	6,220	36,800
Nov	BND	8,279.9	4,260	17,700
Dec	BND	10,327.5	4,220	26,600
Jan	KWK	3,217.4	2,970	3,700
Feb	KWK	3,157.9	2,900	3,520
Mar	KWK	3,405.0	3,170	3,640
Apr	KWK	5,682.5	3,280	8,050
May	KWK	8,369.6	6,800	9,870
Jun	KWK	7,882.3	6,570	9,390
Jul	KWK	9,510.2	8,740	10,800
Aug	KWK	8,102.0	6,610	9,500
Sep	KWK	6,899.8	5,310	8,500
Oct	KWK	6,160.1	5,120	7,330
Nov	KWK	4,027.1	3,070	5,080
Dec	KWK	3,431.0	3,040	3,970

Summary

- **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**.
- **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**.

2.2.2 Water Temperature

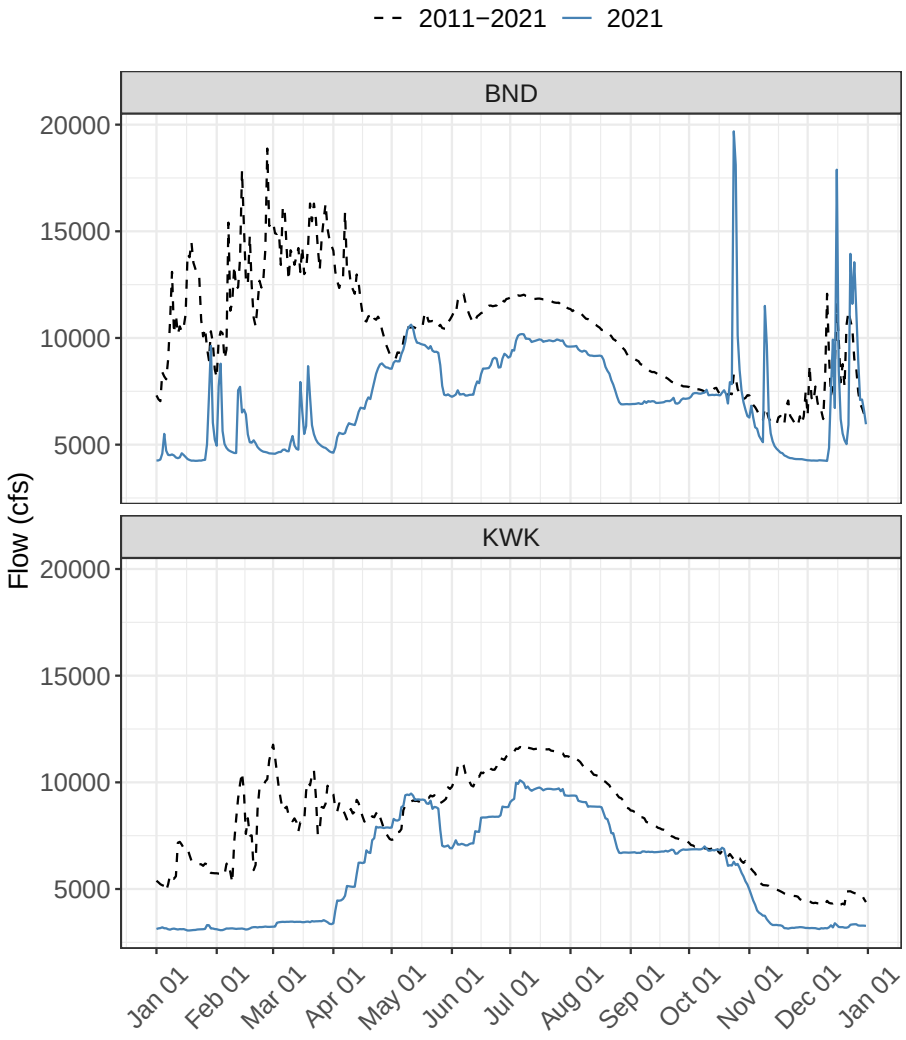

Figure 2.2: Keswick (KWK) and Bend Bridge (BND) Average Flows (cfs) in 2021 and over the 10-year average

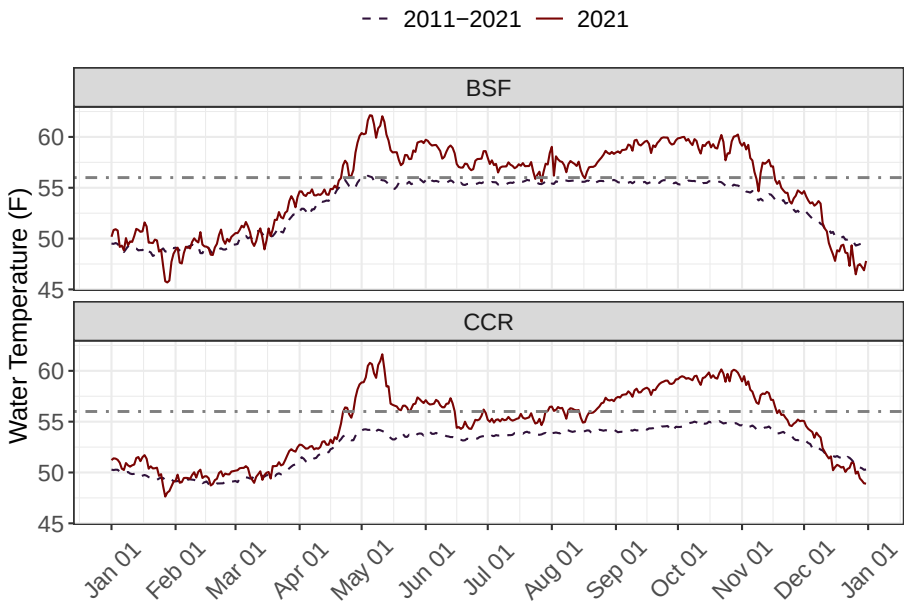

Figure 2.3: Historical Comparison of Sacramento River Water Temperature at Clear Creek (CCR) and Balls Ferry Bridge (BSF).

Table 2.2: Balls Ferry Bridge (BSF) and Clear Creek (CCR) Mean, Maximum, Minimum Monthly Water Temperature (°F) in 2021

Month	Station	Mean (°F)	Min (°F)	Max (°F)
Jan	BSF	48.6	44.2	52.4
Feb	BSF	49.2	46.2	52.1
Mar	BSF	51.7	47.2	56.2
Apr	BSF	56.6	51.3	62.4
May	BSF	59.9	54.8	65.4
Jun	BSF	58.2	53.8	62.7
Jul	BSF	57.6	54.6	60.7
Aug	BSF	57.8	54.5	66.9
Sep	BSF	59.0	56.2	61.9
Oct	BSF	59.3	56.9	61.7
Nov	BSF	56.4	52.3	60.5
Dec	BSF	50.7	46.0	55.4
Jan	CCR	50.0	46.5	53.2
Feb	CCR	50.1	47.8	52.4
Mar	CCR	51.6	47.9	55.4
Apr	CCR	55.3	50.1	61.0
May	CCR	59.4	54.7	64.5
Jun	CCR	56.3	53.0	59.6
Jul	CCR	56.0	53.9	58.1
Aug	CCR	57.1	54.3	60.1
Sep	CCR	58.6	55.9	61.4
Oct	CCR	59.7	57.3	62.1
Nov	CCR	57.0	53.4	61.0
Dec	CCR	52.4	48.1	56.7

Summary

- Water temperatures were warmer than average and warmer than 56°F in 2021 (Figure 2.3).

- **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

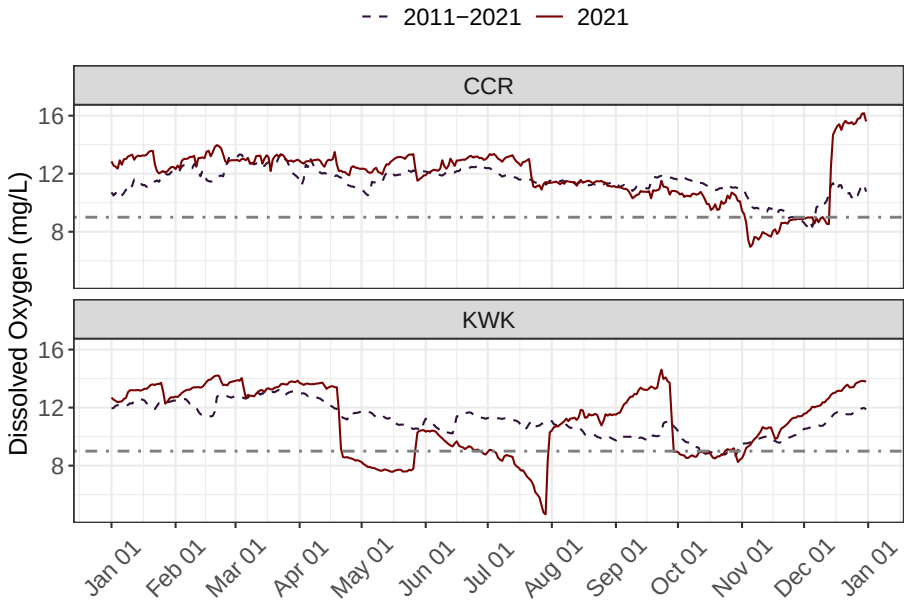

Figure 2.4: Dissolved Oxygen at Keswick Dam (KWK) and Sacramento River upstream from Confluence with Clear Creek (CCR).

Table 2.3: Keswick (KWK) and Clear Creek (CCR) Mean, Maximum, Minimum Monthly Dissolved Oxygen (mg/L) in 2021

Month	Station	Mean (mg/L)	Min (mg/L)	Max (mg/L)
Jan	CCR	13.0	11.2	14.8
Feb	CCR	13.5	8.8	15.9
Mar	CCR	13.4	11.5	15.4
Apr	CCR	12.9	11.1	14.8

Table 2.3: Keswick (KWK) and Clear Creek (CCR) Mean, Maximum, Minimum Monthly Dissolved Oxygen (mg/L) in 2021

Month	Station	Mean (mg/L)	Min (mg/L)	Max (mg/L)
May	CCR	12.7	10.4	14.9
Jun	CCR	12.9	10.6	15.2
Jul	CCR	12.8	10.3	15.3
Aug	CCR	11.6	10.0	13.1
Sep	CCR	11.4	9.1	13.8
Oct	CCR	10.8	8.7	12.8
Nov	CCR	8.3	6.6	10.1
Dec	CCR	13.3	8.3	17.3
Jan	KWK	13.1	12.1	14.0
Feb	KWK	13.6	12.6	14.6
Mar	KWK	13.3	12.3	14.4
Apr	KWK	10.8	8.2	14.1
May	KWK	8.9	7.4	10.7
Jun	KWK	9.6	8.5	10.7
Jul	KWK	7.2	2.5	11.0
Aug	KWK	11.1	10.0	12.1
Sep	KWK	12.7	8.6	15.8
Oct	KWK	8.7	7.8	9.4
Nov	KWK	10.0	8.4	11.6
Dec	KWK	12.7	11.4	14.0

Summary

- **Keswick:** Minimum dissolved oxygen was **2900** mg/L and occurred in **2**. The lowest mean dissolved oxygen was **3157.9** mg/L and occurred in **2**.
- **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, Calfish)

- 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

1. Air Temperature
2. DO
3. Shasta Storage/Hydrology
4. Water Temperature

3.3 Biological Response

1. Egg Count

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

2. Egg to fry survival

- bar plot of percent survival by year (JPI calculation)
  - JPI = fry abundance/total viable eggs in JPE letter
- egg to fry survival by number of mainstem in-river spawners (JPI calculation)
- egg-to-fry survival from fish model (fish model)

3. Emergence Timing (fish model)

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

1. Hatchery Influence (Juvenile Releases)
2. Juvenile Stranding
3. Pathogens/Disease
4. Contaminants
5. Habitat Capacity (Floodplain Connectivity)
6. Habitat Capacity: Depth/Shallow Water
7. In-Stream Habitat Capacity

4.2 Environmental Drivers

1. Shasta Storage/Hydrology
2. Flows: Migration Cues
3. Flows at Keswick

4. Turbidity and DO
5. Water Temperature

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

5.2 Environmental Drivers

1. Shasta Storage/Hydrology
2. Flows: Migration Cues
3. Flows: In-River Flows
4. Turbidity
5. Water Temperature

5.3 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)

- 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 Farell 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

1. Shasta Storage/Hydrology
2. Flows: Sacramento River, Delta Outflow
3. Flows: Migration Cues and Routing
4. Turbidity
5. Water Temperature
6. DO

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 [1].

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

[1] 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.

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

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

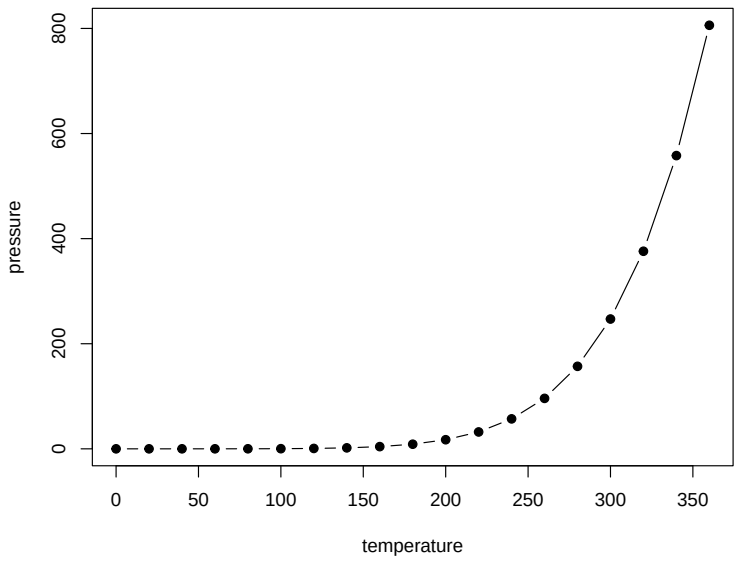

Figure 8.1: Here is a nice figure!

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 [2].

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

[2] 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.