Long-Term Operation – Initial Alternatives

Appendix C – Species Spatial-Temporal Domains

Central Valley Project, California

Interior Region 10 – California-Great Basin

U.S. Department of the Interior September 2022

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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1. Introduction

This document describes the timing for the potential presence of listed species by life stage and geographic region to inform whether individuals may experience stressors that require evaluation due to the Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP). Sources of data in existing species timing tables were reviewed or aggregated to evaluate each species in different locations.

Variability in the timing of species present requires consideration of a broader window than conditions on average or in any single year. For example, if fish may start migrating as early as November or as late as January, then the analyses considered the migration as potentially starting in November so that the potential stressors would be evaluated. Differences in abundance were categorized, as described below, with approximate percentages based on the National Marine Fisheries Service (NMFS) 2019 Biological Opinion (National Marine Fisheries Service 2019):

- Low – no specific consideration of stressors: ~1% of the population may be present
- Medium – some considerations needed: ~>5% of the population may be present
- High – considerations needed: ~>10% of the population may be present

These analyses inform the risks and potential benefits of calendar-based versus real-time strategies. To illustrate spatiotemporal occurrence, tables in this document are presented in terms of “First” occurrence, percent passing (from the monitoring location), and “Last” occurrence.

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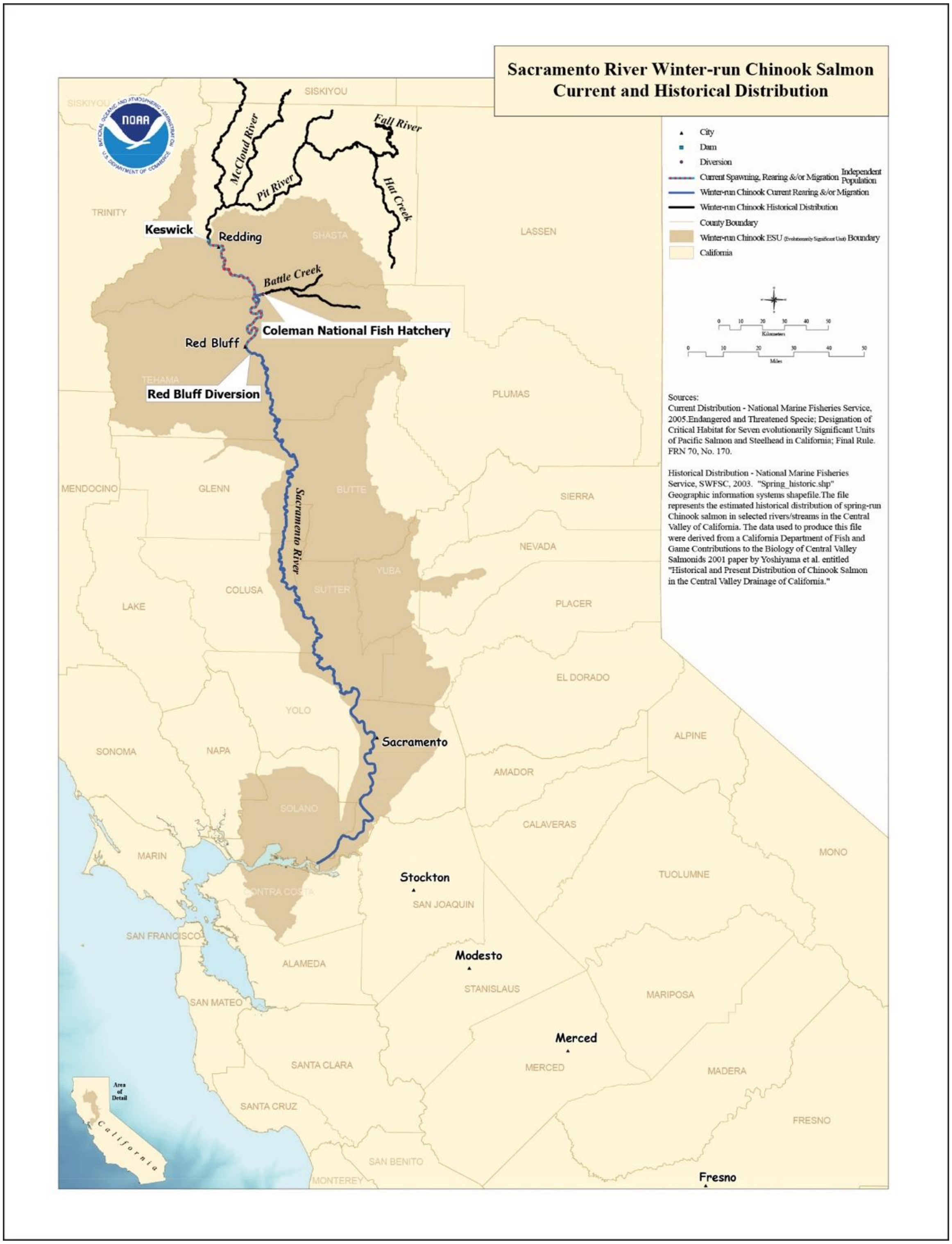
2. Winter-Run Chinook Salmon

Windell et al. (2017) describes life stages and geographic locations for winter-run Chinook salmon.

During the winter months, adults return from the ocean through San Francisco Bay to the Sacramento River and travel to the extent of their current range, below Keswick Dam (Figure 1). All known winter-run Chinook salmon production occurs either in the mainstem Sacramento River or Livingston Stone National Fish Hatchery, although a nascent reintroduction effort in Battle Creek led to the return of at least 700 subadults and adults in 2020 (U.S. Fish and Wildlife Service 2020).

Current spawning is confined to the mainstem of the Sacramento River, above Red Bluff Diversion Dam (RBDD), and below Keswick Dam during the summer months (National Marine Fisheries Service 2014). Access to historical habitat in upper Sacramento River tributaries is no longer available (Figure 1). Following spawning, fry and juvenile downstream movement begins in July/August, as shown by monitoring at RBDD (Table 4). In addition to the Sacramento River, juveniles have also been found to rear in areas such as the lower American River, lower Feather River, Battle Creek, Mill Creek, Deer Creek, and the Delta before emigrating to the ocean (Phillis et al. 2018).

Summaries of the temporal life-history domains for winter-run Chinook salmon can be found below on Figure 1.



Source: National Marine Fisheries Service 2014.

Figure 1. Current and Historical Sacramento River Winter-Run Chinook Salmon Distribution.

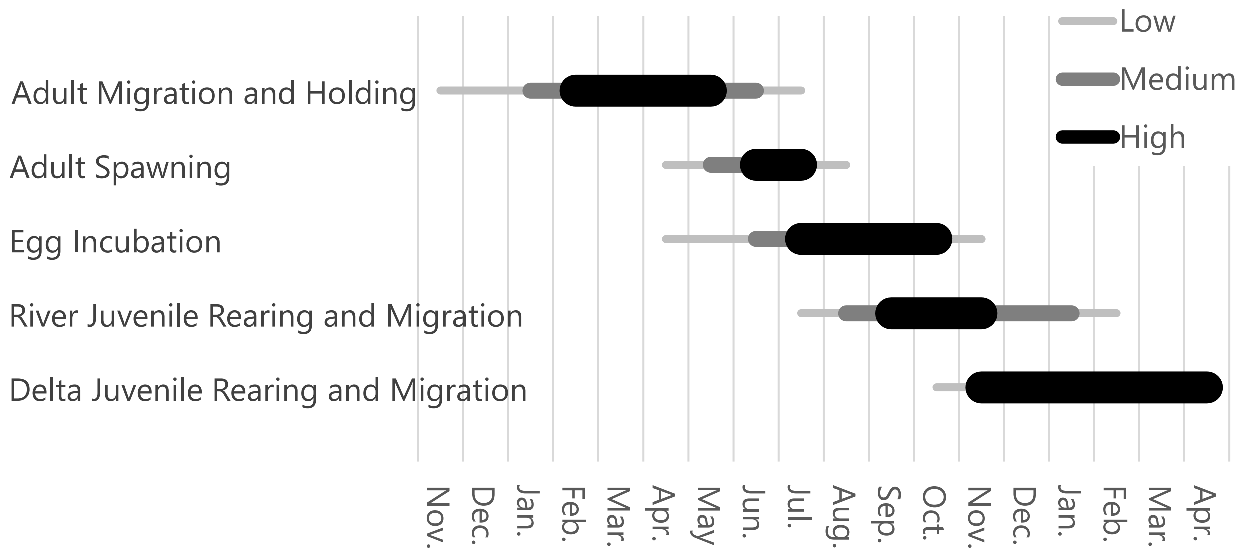


Figure 2. Summary of Temporal Life Stage Domains for Winter-Run Chinook Salmon.

2.1 Adult Migration and Holding

Adult Sacramento River winter-run Chinook salmon enter the San Francisco Bay in November to begin their spawning migration and continue upstream from December through July to the extent of anadromy at the base of Keswick Dam (Figure 2). Hallock and Fisher (1985) observed winter-run Chinook salmon adult fish passage at RBDD during November through July. Holding occurs in the upper 10 to 15 river miles of the Sacramento River below Keswick Dam for up to 8 months (Windell et al. 2017; National Marine Fisheries Service 2011; Table 1). Winter-run Chinook salmon employ a different life-history strategy than fall-run Chinook salmon because they typically enter the system with undeveloped gametes and move into the upper Sacramento River, where they hold until ready to spawn (Windell et al. 2017). Historically, Fisher (1994) and the U.S. Fish and Wildlife Service (USFWS; 1995) described adult immigration between December and July, with a peak in spawning during March. Fisher (1994) and USFWS (1995) do not cite any data or personal communication; it is assumed this periodicity is based on the timing of adult passage through Red Bluff Diversion Dam.

Table 1. Summary Winter-Run Chinook Salmon Passage at RBDD, 1982–1986

First	5% Passing	10% Passing	90% Passing	95% Passing
NA	January Week 2	February Week 1	June Week 1	June Week 3

Source: USFWS Red Bluff Diversion Dam (RBDD) fish ladder passage.

2.2 Adult Spawning and Egg Incubation

Hallock and Fisher (1985) observed winter-run Chinook salmon spawning in the Sacramento River, upstream of RBDD, between mid-April and mid-August, with the bulk of spawning occurring in May and June. Fisher (1994) described spawning between late April and early August, with a peak in spawning activity during early June. USFWS (1995) described spawning occurring between April and July, with peak spawning in May and June. Fisher (1994) and USFWS (1995) do not cite any data or personal communication; it is assumed this periodicity is based on biologist observations of spawning and carcasses. USFWS (2006) summarized 5 years of carcass surveys before RBDD was removed. In some years, peak abundance of hatchery-origin carcasses was delayed, relative to natural-origin carcasses, although the spatial distribution of hatchery and natural-origin carcasses were nearly identical and consistent across years.

The California Department of Fish and Wildlife (CDFW) provides summaries of redd and carcass surveys, which are available on the CalFish website (https://www.calfish.org; 2020). Table 2 shows carcass survey data for winter-run Chinook salmon spawning in the upper Sacramento River between 2004–2020. CDFW biologists estimate that it takes approximately 10–14 days for a carcass to be observed after spawning, so spawning timing is estimated to occur 10–14 days prior to carcass observations (CDFW pers. comm.). The first carcass is detected in May, peak spawning occurs throughout June and July, by August 95% of the carcasses have been observed, and the last of the carcasses have been observed in September. Spawning was proxied by the 10–14 day estimate by CDFW biologists, and follows a similar trajectory as the carcass data, but with a slight temporal shift for the 5% passing and 90% passing (Table 2). USFWS (1995) described winter-run Chinook salmon egg incubation as occurring between April and October, with peak incubation between July and October (Table 2). Carcass and redd surveys on the upper Sacramento River start in May, so it is likely that spawning occurs in April, before the first survey, along with egg incubation as noted by USFWS (1995). Yoshiyama et al. (1998) described winter-run Chinook salmon juvenile emergence between July and October.

Table 2. Winter-Run Chinook Salmon Carcass Survey Detections and Median Estimates of Spawning and Incubation Based on Carcass Distributions, 2004–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	May 15	Jun 14	Jun 23	Aug 4	Aug 11	Sep 3
2019	May 13	Jun 9	Jun 15	Aug 2	Aug 8	Sep 1
2018	May 8	Jun 13	Jun 28	Aug 12	Aug 20	Sep 5
2017	May 2	Jun 1	Jun 5	Aug 15	Aug 19	Sep 2
2016	May 4	May 22	Jun 6	Aug 5	Aug 11	Aug 26
2015	May 12	Jun 3	Jun 14	Aug 4	Aug 10	Aug 25
2014	May 17	Jun 12	Jun 21	Aug 5	Aug 8	Aug 20
2013	May 22	Jun 12	Jul 1	Aug 9	Aug 15	Aug 30
2012	May 11	Jun 16	Jun 25	Aug 6	Aug 12	Aug 24
2011	May 6	Jun 15	Jun 24	Aug 8	Aug 11	Aug 26

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2010	May 5	May 22	Jun 3	Jul 28	Aug 3	Aug 21
2009	May 18	Jun 8	Jun 14	Jul 22	Jul 26	Aug 10
2008	May 7	Jun 2	Jun 11	Jul 23	Jul 29	Aug 13
2007	May 8	May 25	Jun 8	Jul 29	Aug 3	Aug 18
2006	May 10	Jun 2	Jun 9	Jul 25	Aug 1	Aug 16
2005	May 15	Jun 10	Jun 17	Aug 1	Aug 6	Aug 22
2004	May 3	Jun 5	Jun 18	Jul 30	Aug 5	Aug 20
Carcass Median	May	June	June	August	August	August
Spawning Median	May	May	June	July	August	August
Incubation Median	April	June	July	October	October	October

Source: CalFish 2020.

2.3 River Juvenile Rearing and Migration

Winter-run Chinook salmon juvenile rearing and migration can be described based on observations in the upper Sacramento River at the RBDD rotary screw trap and in the lower Sacramento River at the Knights Landing rotary screw trap. Hallock and Fisher (1985) observed fry migration past RBDD in early August and continuing through October. The peak was reported between mid-September to mid-October. Fisher (1994) described juvenile emergence between July and October and ocean entry between November and May. USFWS (1995) describe winter-run Chinook salmon rearing in freshwater between July and May, with smolt emigration from January through May. Martin et al. (2001) summarized RBDD rotary screw trap total passage and found that winter-run Chinook salmon fry were predominantly captured in July through October, which aligns with recent catch data available in the Sacramento Prediction and Assessment of Salmon (SacPAS) online database (Table 4). According to Martin et al. (2001), fry passage through August was observed to be low, with most fry passing by September, and all passing by November. Pre-smolt/smolt winter-run Chinook salmon passage was greatest in November. The data available on SacPAS combine all juvenile stages and shows the last passage in June, and the median last passage in May (Figure 2, Table 3 and Table 4). At Knights Landing, first passage occurs in October, peaks in December and January, and ends by April (Figure 3, Table 5, and Table 3).

In addition to the mainstem Sacramento River, juvenile winter-run Chinook salmon have also been found to rear in Sacramento River tributaries, such as the lower American River, Battle Creek, and in the Delta (Phillis et al. 2018). Lower American River catch data is readily available through the Pacific States Marine Fisheries Commission (PSMFC) on http://CalFish.org. At the rotary screw traps located near the Watt Ave Bridge, PSMFC reports small numbers of winter-run Chinook salmon passage, suggesting use of the area as rearing habitat. All Chinook salmon are assigned a run at the time of capture, using length-at-date criteria for the Sacramento River that Greene (1992; PSMFC 2013–2020) developed. Detections start in January and end in March, with 90% of juvenile passage by March (Table 6).

Table 3. Summary of Juvenile Winter-Run Chinook Salmon Passage in the Sacramento River by Median Month from USFWS Raw Catch Data, 2003–2021

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
RBDD	July	August	September	November	December	May
KNL	October	October	October	January	February	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.
RBDD = Red Bluff Diversion Dam; KNL = Knights Landing

Table 4. Red Bluff Diversion Dam Rotary Screw Trap Winter-Run Chinook Salmon Juvenile Passage, 2004–2021

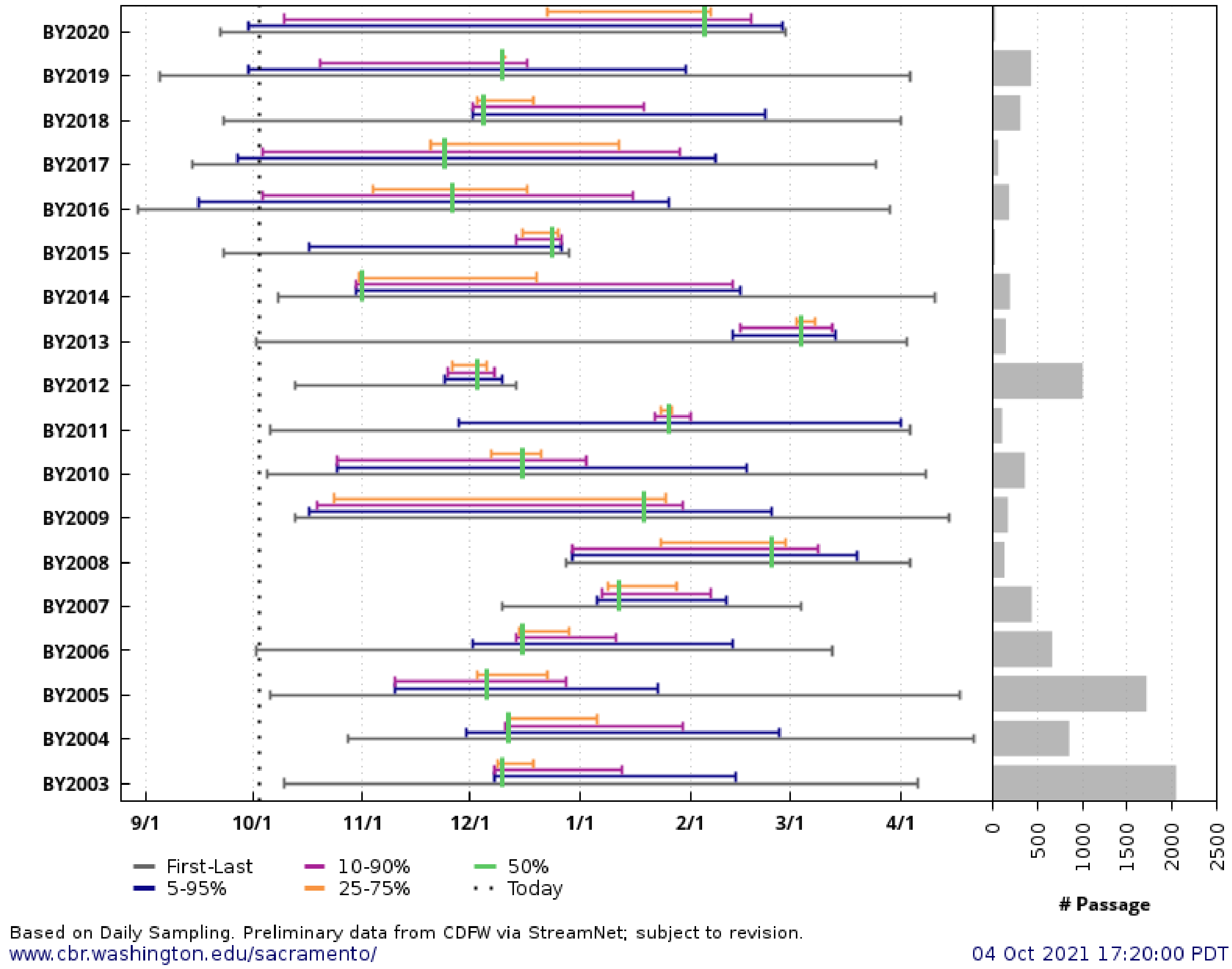
Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2021	Jul 2	Aug 27	Sept 6	Nov 7	Nov 12	May 25
2020	Jul 5	Sep 6	Sep 13	Nov 23	Dec 28	Apr 28
2019	Jul 6	Aug 23	Aug 29	Nov 3	Nov 28	Mar 23
2018	Jul 18	Sep 14	Sep 22	Dec 1	Dec 2	May 15
2017	Jul 12	Aug 28	Sep 9	Nov 19	Jan 20	May 1
2016	Jul 2	Aug 24	Sep 1	Nov 2	Nov 22	Apr 3
2015	Jul 6	Sep 4	Sep 11	Dec 11	Dec 15	Apr 28
2014	Jul 7	Aug 27	Aug 30	Nov 19	Dec 2	May 21
2013	Jul 9	Sep 9	Sep 16	Dec 28	Feb 10	May 8
2012	Jul 16	Sep 11	Sep 17	Nov 22	Dec 13	May 4
2011	Aug 3	Sep 15	Sep 19	Dec 1	Dec 13	Apr 18
2010	Jul 13	Aug 27	Sep 5	Nov 16	Dec 13	Apr 27
2009	Jul 6	Aug 20	Aug 25	Oct 17	Oct 20	May 4
2008	Jul 15	Aug 22	Aug 24	Nov 4	Dec 3	May 14
2007	Jul 17	Aug 21	Sep 3	Nov 20	Dec 8	Apr 20
2006	Jul 4	Aug 19	Aug 26	Nov 15	Dec 2	Jun 7
2005	Jul 11	Sep 3	Sep 9	Oct 21	Nov 8	Apr 22
2004	Jul 10	Aug 23	Sep 1	Oct 21	Oct 31	May 11
Median	July	August	September	November	December	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 5. Winter-Run Chinook Salmon Migration Timing Passing Knights Landing, 2003–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Sep 21	Sep 29	Oct 9	Feb 17	Feb 26	Feb 27
2019	Sep 5	Sep 30	Oct 20	Dec 17	Jan 30	Apr 2
2018	Sep 23	Dec 2	Dec 2	Jan 18	Feb 21	Mar 31
2017	Sep 14	Sep 27	Oct 4	Jan 28	Feb 7	Mar 24
2016	Aug 29	Sep 15	Oct 3	Jan 15	Jan 25	Mar 28
2015	Sep 23	Oct 17	Dec 14	Dec 27	Dec 27	Dec 29
2014	Oct 8	Oct 30	Oct 30	Feb 12	Feb 14	Apr 10
2013	Oct 2	Feb 12	Feb 14	Mar 12	Mar 13	Apr 2
2012	Oct 12	Nov 23	Nov 24	Dec 7	Dec 9	Dec 13
2011	Oct 6	Nov 28	Jan 21	Jan 31	Mar 30	Apr 2
2010	Oct 5	Oct 25	Oct 25	Jan 2	Feb 16	Apr 7
2009	Oct 13	Oct 17	Oct 19	Jan 29	Feb 23	Apr 14
2008	Dec 27	Dec 29	Dec 29	Mar 8	Mar 19	Apr 3
2007	Dec 10	Jan 5	Jan 6	Feb 6	Feb 10	Mar 2
2006	Oct 2	Dec 2	Dec 14	Jan 10	Feb 12	Mar 12
2005	Oct 6	Nov 10	Nov 10	Dec 28	Jan 22	Apr 17
2004	Oct 27	Nov 29	Dec 10	Jan 29	Feb 25	Apr 21
Median Month	October	October	October	January	February	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

Figure 3. Winter-Run Chinook Salmon Migration Timing Passing Knights Landing, 2003–2020.

Table 6. Summary of Juvenile Winter-Run Chinook Salmons Catch, Passage In the Lower American River Screw Trap, 2013–2021

Observation Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2022	No winter-run detected at screw trap.					
2021	Feb 4	Feb 4	Feb 4	Mar 26	Mar 26	Mar 26
2020	Jan 16	Jan 31	Feb 3	Mar 21	Mar 23	Mar 26
2019	Jan 14	Jan 14	Jan 14	Jan 31	Feb 1	Feb 1
2018	Jan 15	Jan 15	Jan 16	Mar 5	Mar 13	Mar 13
2017	No winter-run detected at screw trap.					

Observation Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2016	One winter-run detected March 3, 2016.					
2015	Jan 11	Jan 14	Jan 16	Mar 2	Mar 8	Mar 26
2014	Feb 17	Feb 17	Feb 17	Mar 16	Apr 8	Apr 8
2013	Jan 26	Jan 28	Jan 30	Mar 28	Mar 28	Mar 30
Median Month	January	January	January	March	March	March

Source: CalFish 2020.

2.4 Delta Juvenile Rearing and Migration

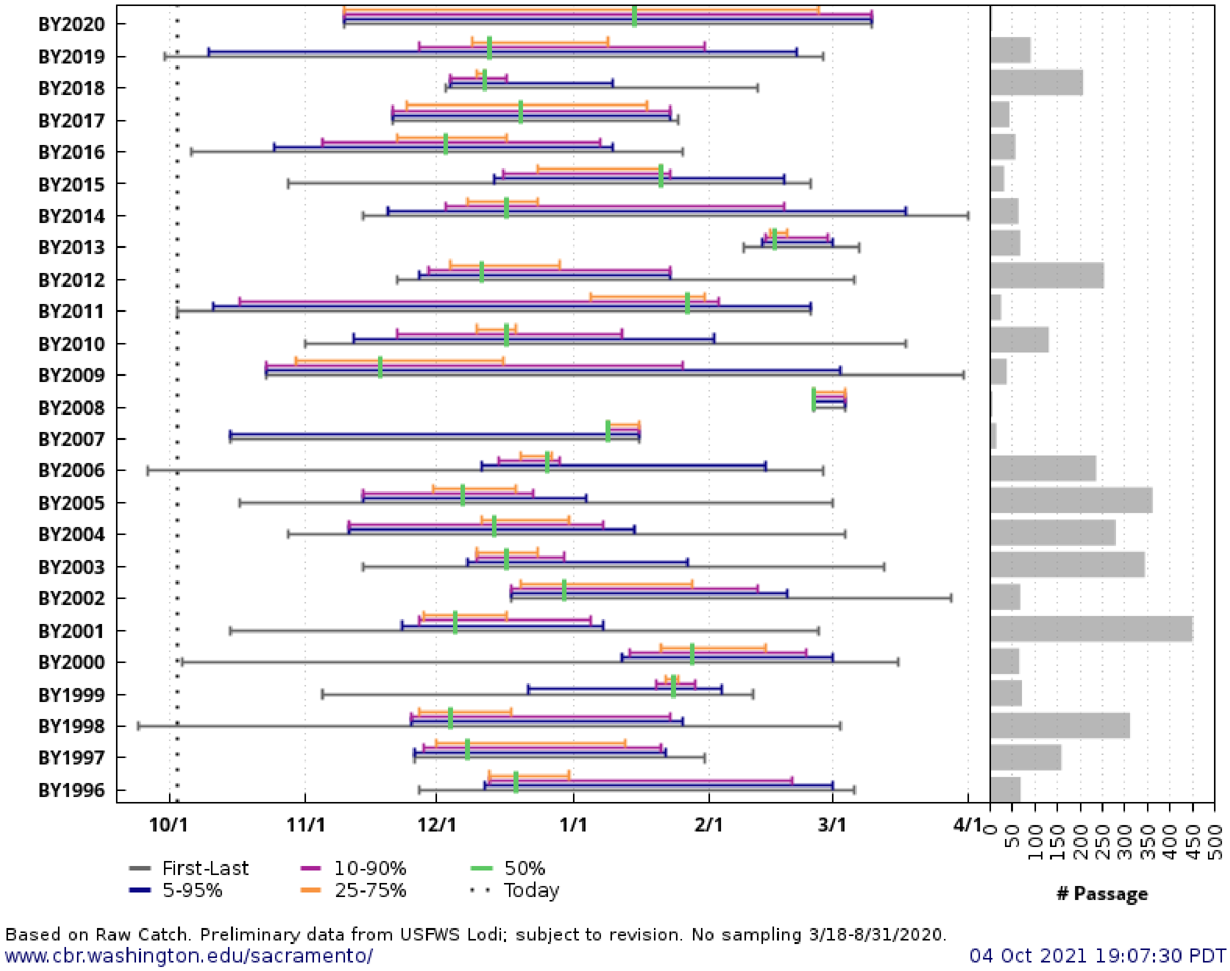
The lower reaches of the Sacramento River, the Delta, and San Francisco Bay serve as migration corridors for both smolts and adults and are thought to serve as juvenile rearing habitat. Juvenile winter-run Chinook salmon begin to enter the Delta in October, and smolt outmigration continues until April. Timing of smolt movement is thought to be strongly correlated with winter rain events that result in pulse flows in the Sacramento River (del Rosario et al. 2013; Hassrick et al. 2022). In addition to monitoring salvage of winter-run Chinook salmon at the Tracy Fish Collection Facility and the John E. Skinner Delta Fish Protective Facility in the south Delta, temporal occurrence of each life stage in the project area is monitored using screw-trapping data in the rivers, trawls, and beach seines in the estuary and, more recently, acoustic tagging using a network of receivers located throughout the extent of their range, from Keswick Dam to Golden Gate Bridge (e.g., Klimley et al. 2017). USFWS-conducted long-term fish monitoring surveys provide observations of when juvenile winter-run Chinook salmon enter and exit the Delta. Entrance can be inferred from data collected by the Sacramento Beach Seine and Trawl surveys, and Delta exit can be inferred from data collected by the Chipps Island trawl survey. Catch data are compiled on the SacPAS database (https://www.cbr.washington.edu/sacramento/data/juv_monitoring.html). Based on catch data from USFWS, passage in the Delta starts in October, peaks in December through April, and individuals exit the Delta by May (Table 7 through Table 10, Figure 4 through Figure 6). Salvage data from the CVP facilities show a similar temporal pattern as the Chipps Island trawl, with the first occurrence in December and last occurrence in May (Table 11 and Figure 7).

Table 7. Summary of Juvenile Winter-Run Chinook Passage in the Delta by Median Month from USFWS Raw Catch, 1996–2020

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
Sacramento Seine	October	October	November	February	February	March
Sacramento Trawl	November	November	December	April	April	April
Chipps Trawl	December	February	February	April	April	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.
USFWS = U.S. Fish and Wildlife Service.

2.4.1 Delta – Sacramento Beach Seines



Source: Source: University of Washington, School of Aquatic and Fishery Science 2022.

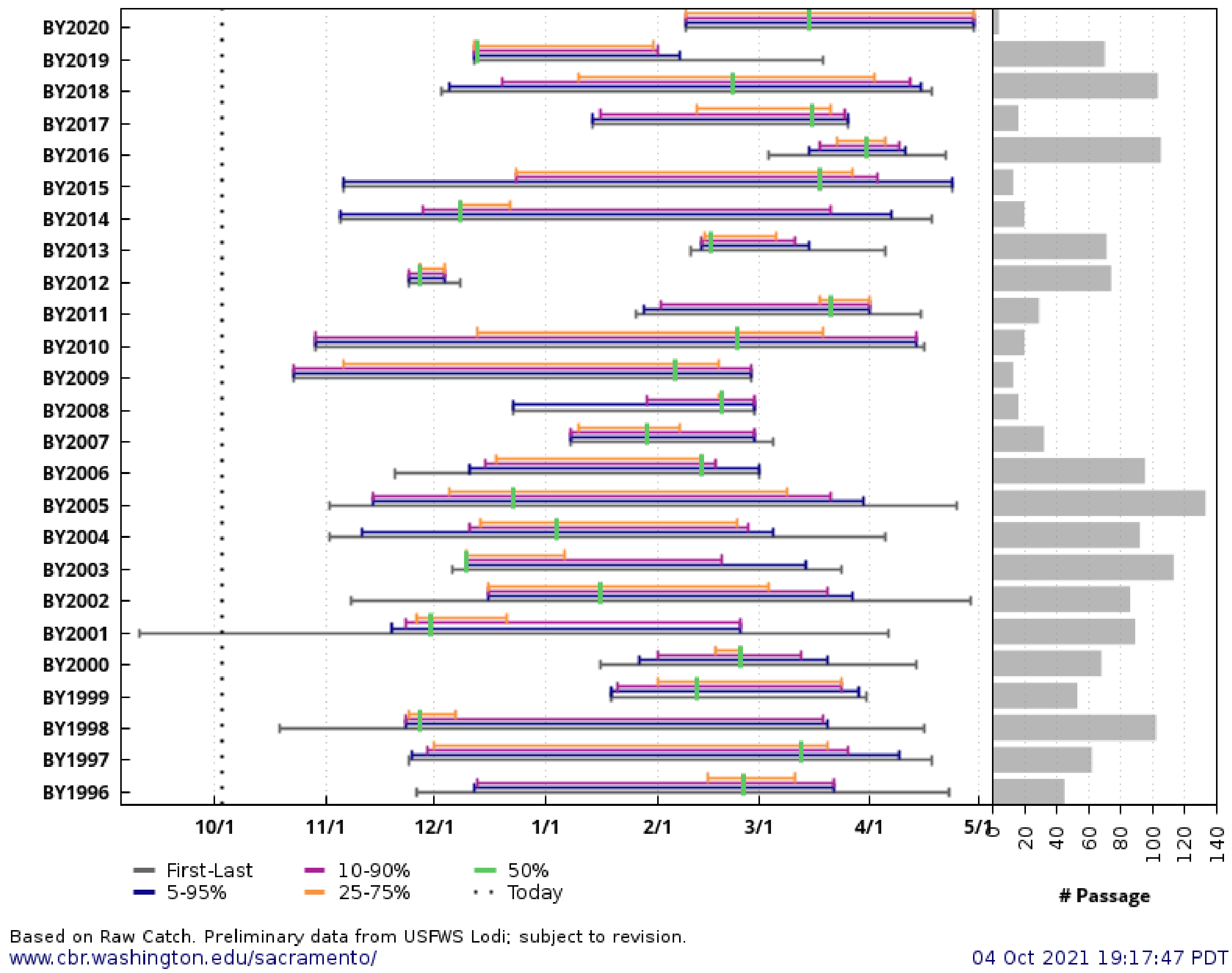
Figure 4. Winter-Run Chinook Juvenile Migrating Timing, Sacramento Beach Seines, 1996–2020.

Table 8. Winter-Run Chinook Salmon Juvenile Migrating Timing, Sacramento Beach Seines, 1996–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Nov 9	Nov 9	Nov 9	Mar 9	Mar 9	Mar 9
2019	Sep 30	Oct 10	Nov 27	Jan 30	Feb 20	Feb 26
2018	Dec 3	Dec 4	Dec 4	Dec 17	Jan 9	Feb 11
2017	Nov 21	Nov 21	Nov 21	Jan 22	Jan 22	Jan 24
2016	Oct 5	Oct 24	Nov 4	Jan 6	Jan 9	Jan 25
2015	Oct 28	Dec 14	Dec 16	Jan 22	Feb 17	Feb 23

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2014	Nov 14	Nov 20	Dec 3	Feb 17	Mar 17	Mar 31
2013	Feb 8	Feb 12	Feb 13	Feb 27	Feb 28	Mar 6
2012	Nov 21	Nov 26	Nov 28	Jan 22	Jan 22	Mar 5
2011	Oct 3	Oct 11	Oct 17	Feb 2	Feb 23	Feb 23
2010	Nov 1	Nov 12	Nov 22	Jan 11	Feb 1	Mar 17
2009	Oct 23	Oct 23	Oct 23	Jan 25	Mar 2	Mar 30
2008	Feb 24	Feb 24	Feb 24	Mar 3	Mar 3	Mar 3
2007	Oct 15	Oct 15	Jan 8	Jan 15	Jan 15	Jan 15
2006	Sep 26	Dec 11	Dec 15	Dec 29	Feb 13	Feb 26
2005	Oct 17	Nov 14	Nov 14	Dec 23	Jan 3	Feb 28
2004	Oct 27	Nov 10	Nov 10	Jan 7	Jan 14	Mar 3
2003	Nov 14	Dec 8	Dec 10	Dec 30	Jan 26	Mar 11
2002	Dec 18	Dec 18	Dec 18	Feb 11	Feb 18	Mar 27
2001	Oct 15	Nov 23	Nov 27	Jan 4	Jan 7	Feb 25
2000	Oct 3	Jan 11	Jan 13	Feb 22	Feb 28	Mar 15
1999	Nov 5	Dec 22	Jan 19	Jan 28	Feb 3	Feb 10
1998	Sep 24	Nov 25	Nov 25	Jan 22	Jan 25	Mar 2
1997	Nov 26	Nov 26	Nov 28	Jan 20	Jan 21	Jan 30
1996	Nov 26	Dec 11	Dec 12	Feb 19	Feb 28	Mar 5
Median Month	October	October	November	February	February	March

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

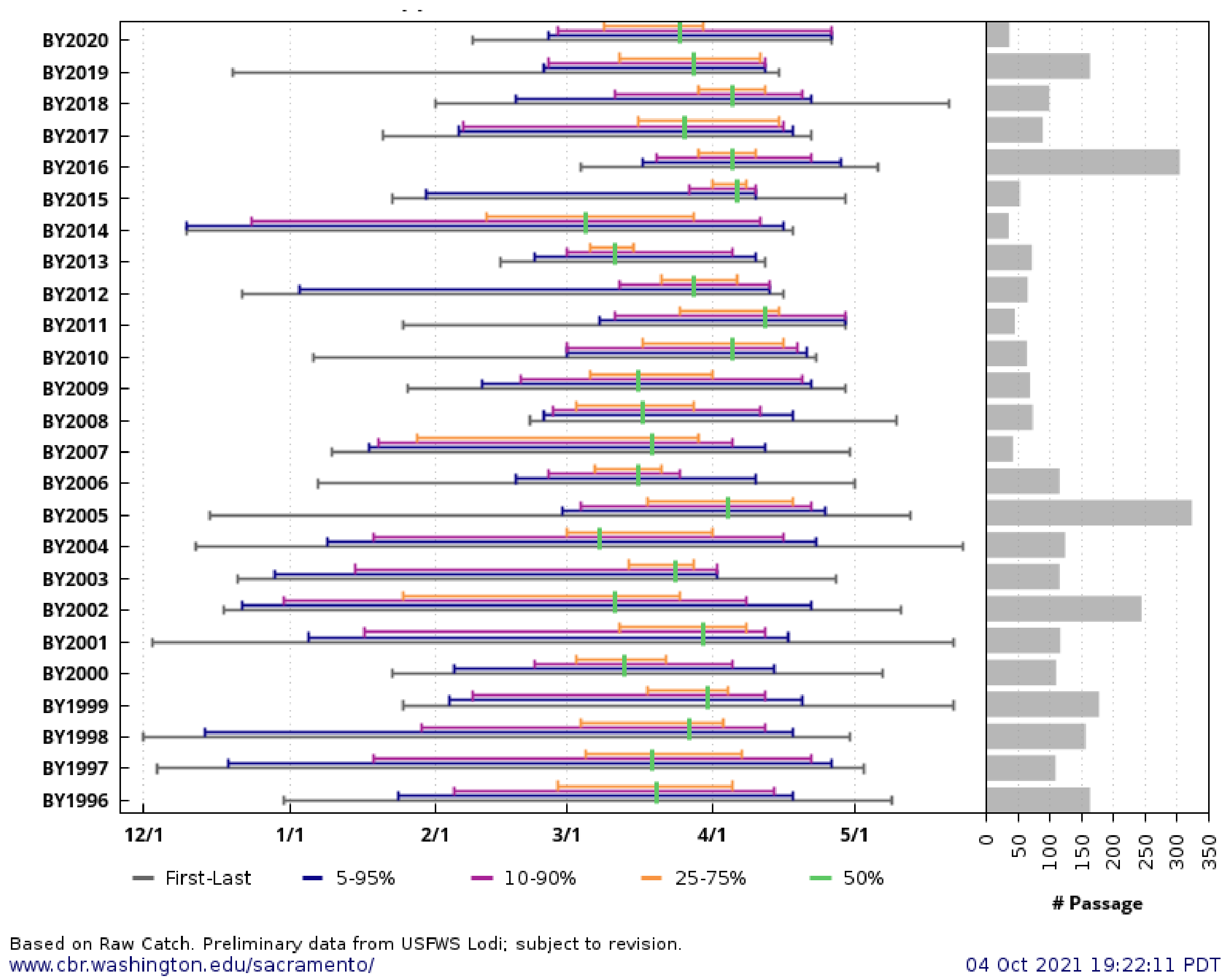
Figure 5. Winter-Run Chinook Salmon Juvenile Migrating Timing, Sacramento Trawl at Sherwood Harbor, 1996–2020.

Table 9. Winter-Run Chinook Salmon Juvenile Migrating Timing, Sacramento Trawl at Sherwood Harbor, 1996–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Feb 8	Feb 8	Feb 8	Apr 29	Apr 29	Apr 29
2019	Dec 12	Dec 12	Dec 12	Jan 31	Feb 6	Mar 17
2018	Dec 3	Dec 5	Dec 20	Apr 11	Apr 14	Apr 17
2017	Jan 13	Jan 13	Jan 15	Mar 24	Mar 25	Mar 25
2016	Mar 3	Mar 14	Mar 17	Apr 8	Apr 10	Apr 21
2015	Nov 6	Nov 6	Dec 24	Apr 1	Apr 22	Apr 22
2014	Nov 5	Nov 5	Nov 28	Mar 20	Apr 6	Apr 17

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2013	Feb 9	Feb 12	Feb 12	Mar 10	Mar 14	Apr 4
2012	Nov 23	Nov 23	Nov 23	Dec 3	Dec 3	Dec 7
2011	Jan 25	Jan 27	Feb 1	Mar 30	Mar 30	Apr 13
2010	Oct 29	Oct 29	Oct 29	Apr 13	Apr 13	Apr 15
2009	Oct 23	Oct 23	Oct 23	Feb 26	Feb 26	Feb 26
2008	Dec 22	Dec 22	Jan 28	Feb 27	Feb 27	Feb 27
2007	Jan 7	Jan 7	Jan 7	Feb 27	Feb 27	Mar 3
2006	Nov 20	Dec 11	Dec 15	Feb 16	Feb 28	Feb 28
2005	Nov 2	Nov 14	Nov 14	Mar 20	Mar 29	Apr 24
2004	Nov 1	Nov 10	Dec 10	Feb 25	Mar 4	Apr 4
2003	Dec 6	Dec 10	Dec 10	Feb 18	Mar 12	Mar 22
2002	Nov 8	Dec 16	Dec 16	Mar 19	Mar 26	Apr 28
2001	Sep 10	Nov 19	Nov 23	Feb 23	Feb 23	Apr 5
2000	Jan 15	Jan 26	Jan 31	Mar 12	Mar 19	Apr 13
1999	Jan 18	Jan 18	Jan 20	Mar 22	Mar 27	Mar 29
1998	Oct 19	Nov 23	Nov 23	Mar 18	Mar 19	Apr 15
1997	Nov 24	Nov 25	Nov 29	Mar 25	Apr 8	Apr 17
1996	Nov 25	Dec 11	Dec 12	Mar 21	Mar 21	Apr 22
Median Month	October	November	November	April	April	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

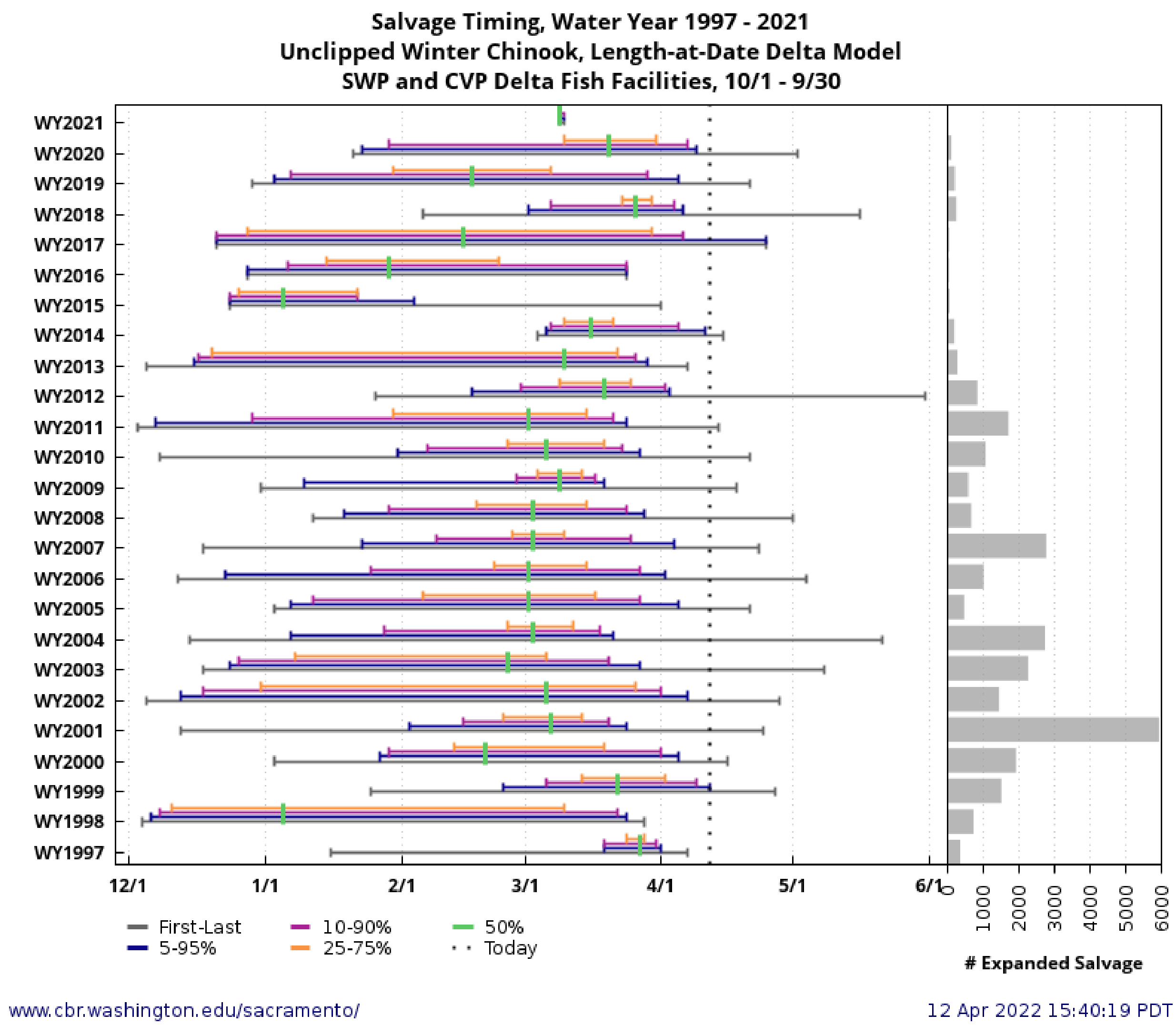
Figure 6. Winter-Run Chinook Salmon Juvenile Migrating Timing, Chipps Island Trawl, 1996–2020.

Table 10. Winter-Run Chinook Salmon Juvenile Migrating Timing, Chipps Island Trawl, 1996–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Feb 8	Feb 24	Feb 26	Apr 25	Apr 25	Apr 25
2019	Dec 20	Feb 23	Feb 24	Apr 10	Apr 10	Apr 13
2018	Jan 31	Feb 17	Mar 10	Apr 19	Apr 21	May 20
2017	Jan 20	Feb 5	Feb 6	Apr 15	Apr 17	Apr 21
2016	Mar 3	Mar 16	Mar 19	Apr 21	Apr 27	May 5
2015	Jan 22	Jan 29	Mar 25	Apr 8	Apr 8	Apr 27
2014	Dec 10	Dec 10	Dec 24	Apr 10	Apr 15	Apr 17

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2013	Feb 14	Feb 21	Feb 28	Apr 4	Apr 9	Apr 11
2012	Dec 21	Jan 2	Mar 11	Apr 12	Apr 12	Apr 15
2011	Jan 24	Mar 6	Mar 9	Apr 27	Apr 27	Apr 27
2010	Jan 5	Feb 28	Feb 28	Apr 18	Apr 20	Apr 22
2009	Jan 25	Feb 10	Feb 18	Apr 19	Apr 21	Apr 28
2008	Feb 20	Feb 23	Feb 25	Apr 10	Apr 17	May 9
2007	Jan 9	Jan 17	Jan 19	Apr 3	Apr 10	Apr 28
2006	Jan 6	Feb 17	Feb 24	Mar 24	Apr 9	Apr 30
2005	Dec 15	Feb 27	Mar 3	Apr 21	Apr 24	May 12
2004	Dec 11	Jan 8	Jan 18	Apr 15	Apr 22	May 23
2003	Dec 21	Dec 29	Jan 14	Mar 31	Mar 31	Apr 25
2002	Dec 18	Dec 22	Dec 31	Apr 7	Apr 21	May 10
2001	Dec 3	Jan 4	Jan 16	Apr 11	Apr 16	May 21
2000	Jan 22	Feb 4	Feb 21	Apr 4	Apr 13	May 6
1999	Jan 24	Feb 3	Feb 8	Apr 10	Apr 18	May 20
1998	Dec 1	Dec 14	Jan 28	Apr 11	Apr 17	Apr 29
1997	Dec 4	Dec 19	Jan 18	Apr 21	Apr 25	May 2
1996	Dec 30	Jan 23	Feb 4	Apr 13	Apr 17	May 8
Median Month	December	February	February	April	April	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

Figure 7. Unclipped Winter-Run Chinook Salmon Juvenile Migration Timing, Salvage at CVP and SWP Fish Facilities, 1997–2021.

Table 11. Unclipped Winter-Run Chinook Salmon Juvenile Migration Timing, Salvage at CVP and SWP Fish Facilities, 1997–2021

Water Year	First	5%	10%	90%	95%	Last
2021	3/8/2021	3/8/2021	3/8/2021	3/9/2021	3/9/2021	3/9/2021
2020	1/20/2020	1/22/2020	1/28/2020	4/5/2020	4/7/2020	4/30/2020
2019	12/29/2018	1/2/2019	1/6/2019	3/28/2019	4/4/2019	4/20/2019
2018	2/5/2018	3/1/2018	3/6/2018	4/3/2018	4/5/2018	5/15/2018
2017	12/20/2016	12/20/2016	12/20/2016	4/5/2017	4/24/2017	4/24/2017
2016	12/28/2015	12/28/2015	1/5/2016	3/22/2016	3/22/2016	3/22/2016

Water Year	First	5%	10%	90%	95%	Last
2015	12/24/2014	12/24/2014	12/24/2014	1/21/2015	2/3/2015	3/31/2015
2014	3/3/2014	3/5/2014	3/6/2014	4/4/2014	4/10/2014	4/14/2014
2013	12/4/2012	12/15/2012	12/16/2012	3/25/2013	3/28/2013	4/6/2013
2012	1/25/2012	2/16/2012	2/27/2012	3/31/2012	4/1/2012	5/29/2012
2011	12/3/2010	12/7/2010	12/29/2010	3/20/2011	3/23/2011	4/13/2011
2010	12/8/2009	1/30/2010	2/6/2010	3/22/2010	3/26/2010	4/20/2010
2009	12/30/2008	1/9/2009	2/26/2009	3/16/2009	3/18/2009	4/17/2009
2008	1/11/2008	1/18/2008	1/28/2008	3/22/2008	3/26/2008	4/29/2008
2007	12/18/2006	1/22/2007	2/8/2007	3/24/2007	4/3/2007	4/22/2007
2006	12/12/2005	12/23/2005	1/24/2006	3/26/2006	4/1/2006	5/3/2006
2005	1/2/2005	1/6/2005	1/11/2005	3/26/2005	4/4/2005	4/20/2005
2004	12/15/2003	1/6/2004	1/27/2004	3/16/2004	3/19/2004	5/19/2004
2003	12/18/2002	12/24/2002	12/26/2002	3/19/2003	3/26/2003	5/7/2003
2002	12/5/2001	12/13/2001	12/18/2001	3/31/2002	4/6/2002	4/27/2002
2001	12/12/2000	2/2/2001	2/14/2001	3/19/2001	3/23/2001	4/23/2001
2000	1/2/2000	1/26/2000	1/28/2000	3/30/2000	4/3/2000	4/14/2000
1999	1/24/1999	2/23/1999	3/5/1999	4/8/1999	4/11/1999	4/26/1999
1998	12/4/1997	12/6/1997	12/8/1997	3/21/1998	3/23/1998	3/27/1998
1997	1/15/1997	3/18/1997	3/18/1997	3/30/1997	3/31/1997	4/6/1997
Median	December	January	January	March	March	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.
CVP = Central Valley Project; SWP = State Water Project.

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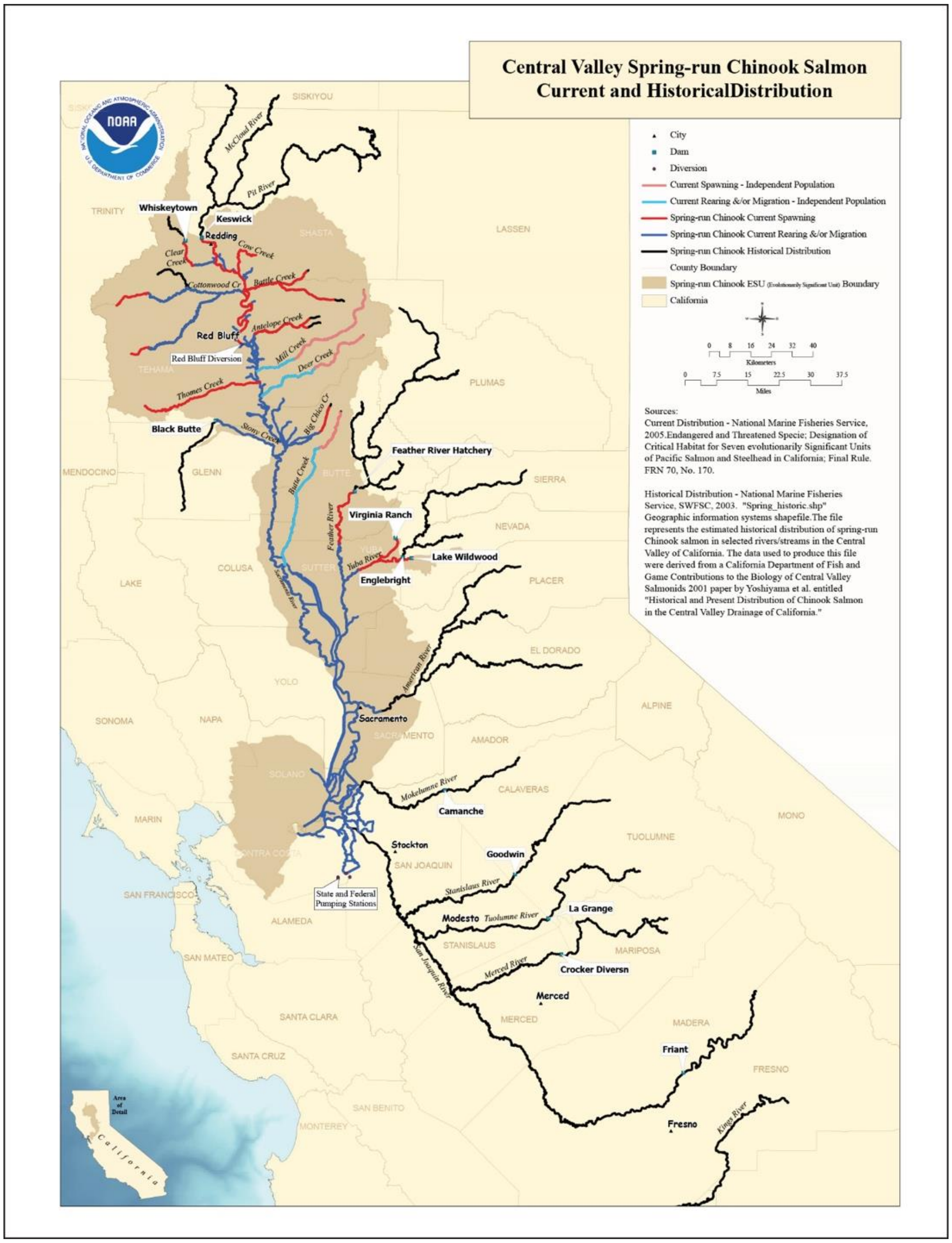
3. Spring-Run Chinook Salmon

Central Valley spring-run Chinook salmon have independent populations in Butte Creek, Mill Creek, and Deer Creek, with repopulation of a historically independent population in Battle Creek occurring; dependent populations occur in Antelope Creek, Big Chico Creek, Clear Creek, and Cottonwood/Beegum Creek (Figure 8; National Marine Fisheries Service 2016; Goertler et al. 2020). Of the tributaries of the Sacramento River, CVP uses Clear Creek and Battle Creek, which have monitoring efforts that can elucidate their spatiotemporal occurrences. Native spring-run Chinook salmon have been extirpated from the San Joaquin River watershed, which represented a large portion of their historical range. There are, however, San Joaquin River spring-run Chinook salmon as a result of reintroduction efforts, and spring-run Chinook salmon in San Joaquin River tributaries. Phenotypically spring-running Chinook salmon observed in the Tuolumne and Stanislaus Rivers in the last decade may represent strays from the Feather River hatchery (fall- or spring-run) or spring-run Chinook salmon produced in the Sacramento River Basin for reintroduction efforts in the San Joaquin River (National Marine Fisheries Service 2019:7).

Life history and habitat requirements are largely the same as those described for winter-run Chinook salmon, with differences primarily in the duration and time of year that spring-run adults and juveniles occupy freshwater habitat. Typically, adult spring-run Chinook salmon enter fresh water as sexually immature fish in the springtime, oversummer, and remain in deep, cold pools in proximity to spawning areas until late summer and early fall, when they are sexually mature and ready to spawn, depending on water temperatures.

Summaries of the temporal life-history domains for spring-run Chinook salmon can be found below, on Figure 9.



Source: National Marine Fisheries Service 2003.

Figure 8. Current and Historical Central Valley Spring-Run Chinook Salmon Distribution.

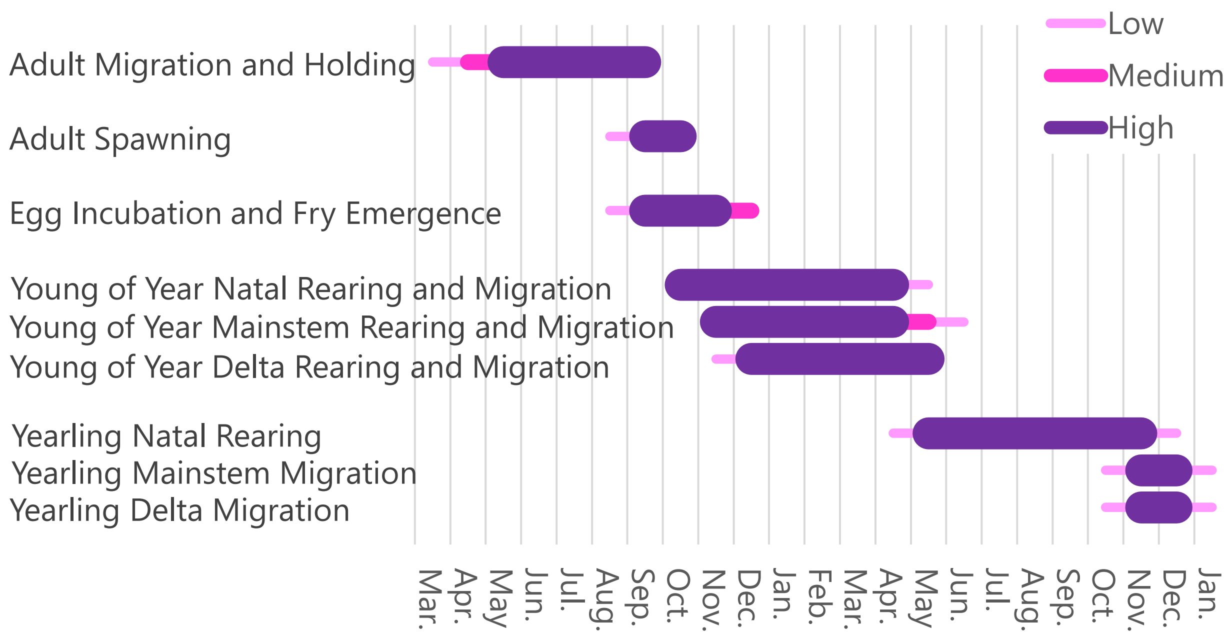


Figure 9. Summary of Temporal Life Stage Domains for Spring-Run Chinook Salmon

3.1 Adult Migration and Holding

Spring-run Chinook salmon populations historically occupied the headwaters of all major river systems in the Central Valley up to any natural barrier, such as an impassable waterfall (Yoshiyama et al. 1998). The Sacramento River was used by adults as a migratory corridor to spawning areas in upstream tributaries and headwater streams (California Department of Fish and Wildlife 1998). Adult passage data are limited, but the most complete historical record of spring-run Chinook salmon migration timing and spawning is contained in reports to the U.S. Fish Commissioners of Baird Hatchery operations on the McCloud River (California Department of Fish and Game 1998). Spring-run Chinook salmon migration in the upper Sacramento River and tributaries extended from mid-March through the end of July, with a peak in late May and early June. Baird Hatchery intercepted returning adults and spawned them from mid-August through late September. Peak spawning occurred during the first half of September. Historical timing from Baird Hatchery aligns with passage data collected at RBDD from 1970–1988, showing the first occurrence in March and last passage by September (Table 12).

Passage data is limited in the San Joaquin River basin, but unpublished data in the NMFS 5-year review (2016) revealed that adults began to return to tributaries, including the Mokelumne, Stanislaus, and Tuolumne Rivers, in February through June (Franks 2014; Workman 2003; FishBio 2015).

Table 12. Summary of Spring-Run Chinook Salmon Adult Passage at Red Bluff Diversion Dam, 1970–1988

First	5% Passage	10% Passage	90% Passage	95% Passage	Last
March	April	May	September	September	September

3.2 Adult Spawning and Egg Incubation

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water, which promotes higher oxygen levels and reduced deposition of fines. Adult spawning conditions, incubation, and emergence from gravel are dependent on cold water temperatures (Myrick and Cech 2004). Data on spring-run specific spawning are limited due to the temporal and spatial overlap of spawning with fall-run Chinook salmon. Williams (2006) reports first occurrence of spawning in late August, peaking from mid-September to early October, and finishing by October (Table 13). Fry emerge from gravels from November to March (Williams 2006). Post-emergent fry inhabit calm, shallow waters with fine substrates; fry depend on fallen trees, undercut banks, and overhanging riparian vegetation for refuge (Healey 1991).

Table 13. Summary of Spring-Run Chinook Salmon Spawning in the Sacramento River Basin

River or Tributary	5% Passage	Peak	95% Passage
Butte Creek	–	September–October	–
Deer Creek	August	September	October
Sacramento River[a]	August–September	September–October	October

Source: Williams 2006.
[a] Killam pers. comm.

3.3 River Juvenile Natal Rearing and Mainstem Migration

Identification of spring-run Chinook salmon juvenile can be challenging. The length-at-date approach used in the Central Valley has limited ability to differentiate spring-run Chinook salmon from other runs. Spring-run Chinook salmon juveniles show two rearing patterns in natal tributaries: (1) the majority of spring-run Chinook juveniles exit tributaries and emigrate through the Sacramento River and the Delta in the spring; and (2) a very small proportion of juveniles oversummer in natal habitats and exit with the first rainstorms on the fall or winter following their birth. These fish are typically called *older* or *yearling* juveniles. The outmigration period for spring-run Chinook salmon can extend from November to early May (National Marine Fisheries Service 2009:94) or June (California Department of Fish and Game 1998:III-9), with residency in the Delta probably lessening as the season progresses into the late-spring months

(California Department of Fish and Game 1998:III-9). Peak movement of yearling spring-run Chinook salmon occurs in October–December (Goertler et al. 2020:3).

Rotary screw trap data on spring-run Chinook salmon outmigration from Clear Creek show fish emigrating during late October through late April (Figure 10; Table 14 and Table 15; Schraml and Chamberlain 2019; Schraml et al. 2020). Peak emigration of spring-run Chinook salmon juveniles occurs in November, with few fish existing each week through the end of May (Figure 11). Yearlings are not observed in any significant fraction of the outmigration.

Review of spring-run Chinook salmon emigration from the upper Battle Creek rotary screw trap shows fish emigrating from late October through late May (Figure 11; Table 16; Schraml and Earley 2021, 2019). The trap is just upstream of the CNFH barrier weir. Capture of spring-run Chinook salmon juveniles begins in late October. Typically, the peak of spring-run Chinook salmon juveniles occurs during mid-November through early December, with few fish exiting every week through the end of May. Yearlings are not observed in any significant fraction of the outmigration.

On the mainstem Sacramento River, timing of spring-run Chinook salmon juvenile rearing and migration can be estimated from rotary screw traps at RBDD and Knights Landing. Fish emigrate during mid-October through July, with peak passage between December and April (Table 14, Table 16, Table 18, Table 21).

Table 14. Summary of Spring-Run Chinook Salmon Juvenile Natal Rearing and Mainstem Migration

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
RBDD	October	October	December	April	May	June
KNL	October	December	December	April	April	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

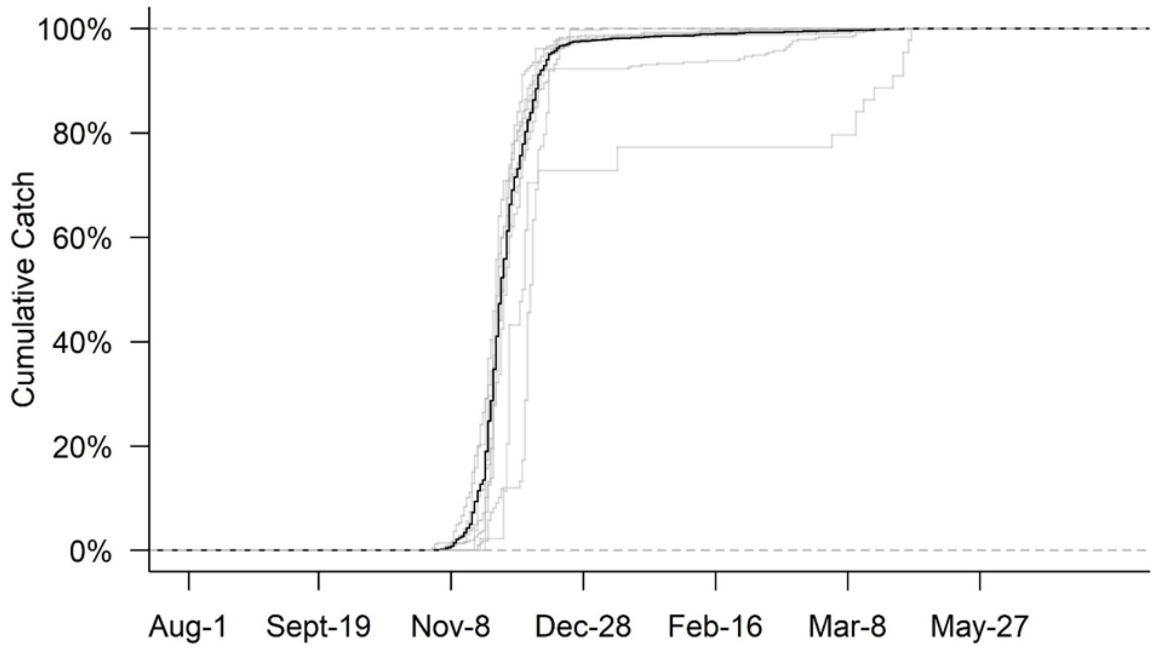


Figure 10. Lower Clear Creek Rotary Screw Trap Spring-Run Chinook Salmon Catch Timing, 2011–2018 Brood Years.

Table 15. Lower Clear Creek Catch, USFWS Life Stage: Yolk-Sac Fry to Smolt

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2018	Nov 19	Nov 28	Nov 28	Apr 22	Apr 28	May 01
2017	Nov 21	Nov 21	Nov 21	Dec 15	Mar 04	Apr 19
2016	Oct 25	Nov 14	Nov 16	Dec 11	Dec 13	May 08
2015	Nov 03	Nov 11	Nov 14	Dec 12	Dec 16	Apr 28
2014	Nov 17	Nov 18	Nov 21	Dec 09	Dec 10	May 24
2013	Nov 05	Nov 21	Nov 22	Dec 10	Dec 16	Apr 23
2012	Nov 18	Nov 22	Nov 26	Dec 15	Dec 19	Jan 04
2011	Nov 01	Nov 18	Nov 18	Dec 05	Dec 14	Mar 16
Median Month	November	November	November	December	December	April

USFWS = U.S. Fish and Wildlife Service.

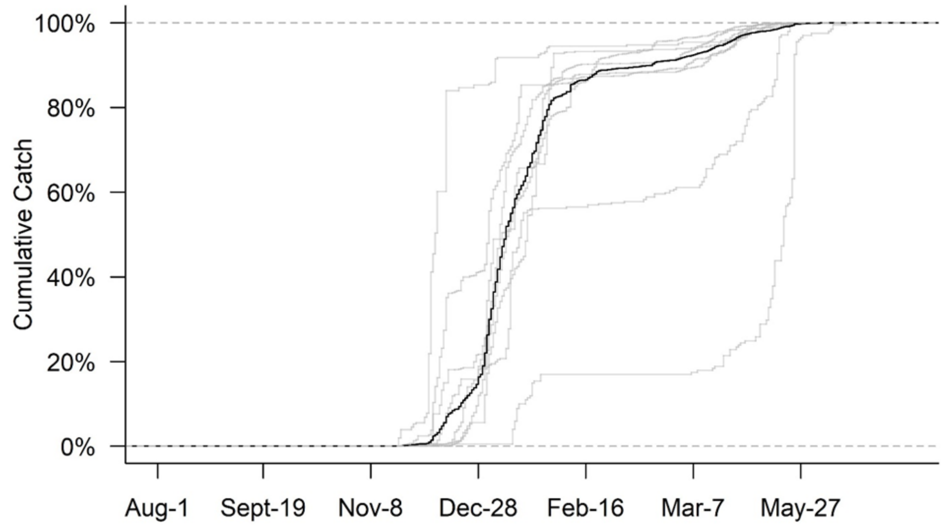


Figure 11. Upper Battle Creek Catch, Life Stage: Yolk-Sac Fry to Smolt.

Table 16. Upper Battle Creek Spring-Run Chinook Salmon Passage Timing, 2011–2018; Life Stage: Yolk-Sac Fry to Smolt

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2018	Nov 28	Dec 07	Dec 11	Feb 01	Apr 19	May 31
2017	Dec 16	Dec 20	Dec 22	May 16	May 17	May 23
2016	Nov 21	Nov 28	Dec 05	Jan 05	Mar 25	May 09
2015	Dec 01	Dec 07	Dec 07	Apr 11	Apr 26	May 28
2014	Nov 25	Jan 14	Jan 19	May 24	May 25	Jun 17
2013	Nov 22	Dec 24	Dec 28	Feb 21	Mar 20	Jun 05
2012	Nov 15	Dec 12	Dec 15	Feb 12	Apr 12	Jun 27
2011	Dec 06	Dec 24	Dec 31	Apr 03	Apr 25	Jun 12
Median Month	November	December	December	March	April	May

USFWS = U.S. Fish and Wildlife Service.

Table 17. Spring-Run Chinook Salmon Migration Timing Passing Red Bluff Diversion Dam

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Nov 18	Jan 08	Mar 12	Apr 09	Apr 17	Jun 09
2019	Nov 19	Nov 27	Dec 03	Mar 19	Mar 21	Mar 23
2018	Nov 19	Mar 19	Mar 20	Apr 20	Apr 20	Jul 17

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2017	Nov 19	Feb 05	Mar 15	May 08	May 13	Jun 07
2016	Oct 17	Nov 02	Mar 14	Apr 28	May 03	Jun 23
2015	Oct 16	Dec 15	Mar 17	Apr 13	Apr 14	Jun 01
2014	Oct 16	Dec 02	Dec 24	Apr 29	May 03	May 30
2013	Oct 18	Nov 02	Dec 06	Apr 17	Apr 24	Jun 17
2012	Oct 16	Oct 19	Oct 22	Apr 23	May 03	Aug 01
2011	Oct 16	Oct 18	Oct 20	Apr 16	Apr 28	Jun 01
2010	Oct 16	Oct 26	Oct 26	Apr 20	May 05	Jun 12
2009	Oct 16	Dec 04	Dec 15	Apr 22	Apr 30	May 27
2008	Oct 16	Nov 11	Nov 21	Apr 17	Apr 24	Jun 07
2007	Oct 16	Nov 23	Dec 01	Dec 26	Mar 26	Jun 20
2006	Oct 16	Oct 20	Oct 23	Apr 18	Apr 21	Jul 05
Median Month	October	October	December	April	May	June

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 18. Spring-Run Chinook Salmon Migration Timing Passing Knights Landing

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Oct 25	Mar 19	Mar 23	Apr 13	Apr 16	May 03
2019	Oct 15	Dec 10	Dec 10	Apr 03	Apr 04	May 06
2018	Dec 03	Jan 13	Mar 23	Apr 16	Apr 21	May 22
2017	Oct 31	Mar 17	Apr 09	Apr 15	Apr 23	May 03
2016	Oct 21	Dec 13	Dec 19	Apr 08	Apr 14	May 09
2015	Dec 14	Dec 14	Dec 19	Dec 28	Dec 28	Dec 30
2014	Oct 23	Dec 08	Dec 08	Feb 18	Apr 09	May 05
2013	Nov 08	Mar 02	Mar 03	Apr 10	Apr 14	Apr 24
2012	Nov 24	Dec 02	Dec 03	Dec 08	Dec 09	Dec 13
2011	Oct 21	Mar 17	Mar 19	Apr 14	Apr 18	May 09
2010	Dec 07	Dec 17	Dec 19	Apr 19	Apr 20	Apr 28
2009	Oct 20	Jan 24	Feb 16	Apr 15	Apr 15	May 09
2008	Oct 24	Feb 23	Feb 25	Apr 16	Apr 22	May 11
2007	Oct 15	Jan 06	Jan 07	Apr 28	Apr 28	May 12
2006	Dec 12	Dec 16	Dec 16	Apr 24	Apr 29	May 13
Median Month	October	December	December	April	April	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

3.4 Delta Juvenile Rearing and Migration

Identification of juvenile spring-run Chinook salmon can be challenging. Unlike winter-run Chinook salmon, the length-at-date approach used in the San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta) to identify run of juvenile fish does not differentiate spring-run Chinook salmon very accurately due to the overlap of emergence with fall-run Chinook salmon.

Spring-run Chinook salmon juveniles show two migration patterns through the Delta: (1) the majority of spring-run Chinook salmon juveniles emigrate through the Sacramento River and the Delta in the spring; and (2) a proportion of juvenile oversummer in natal habitats and exit with the first rainstorms on the fall or winter following their birth. These fish are typically called *older* or *yearling* juveniles.

Delta entry is monitored at the Sacramento beach seines and trawl locations. Delta exit is monitored at the Chipps Island trawl location. Catch data was collected by USFWS and is displayed on the SacPAS database at https://www.cbr.washington.edu/sacramento/data/juv_monitoring.html. Juvenile passage in the Delta starts in November, peaks in the spring months around March, and ends by May (Table 13, Table 21, Table 22, and Table 23). Salvage data from the CVP facilities show a shift in occurrence, with the first spring-run detected in January and last in June, and peaking between April and May (Table 23 and Figure 12).

Table 19. Summary of Juvenile Spring-Run Chinook Passage in the Delta by Median Month from USFWS Raw Catch Data on SacPAS

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
Sacramento Beach Seine	December	December	December	April	April	April
Sacramento Trawl	January	March	March	April	April	May
Chipps Island Trawl	March	April	April	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.
USFWS = U.S. Fish and Wildlife Service.

Table 20. Juvenile Spring-Run Chinook Salmon in Sacramento Beach Seines in Sacramento Beach Seines

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Feb 24	Feb 25	Feb 25	Apr 01	Apr 05	Apr 22
2019	Nov 08	Dec 11	Dec 16	Feb 03	Feb 26	Mar 17
2018	Dec 03	Dec 06	Dec 17	Apr 01	Apr 01	May 09
2017	Dec 06	Dec 29	Jan 22	Apr 05	Apr 05	Apr 05
2016	Nov 08	Nov 25	Dec 05	Apr 04	Apr 12	Apr 13
2015	Dec 24	Jan 13	Feb 11	Mar 29	Mar 29	Apr 13

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2014	Dec 05	Dec 10	Dec 17	Mar 17	Apr 07	Apr 21
2013	Nov 14	Feb 11	Feb 12	Feb 28	Apr 03	Apr 29
2012	Nov 26	Dec 07	Dec 12	Feb 07	Feb 14	Apr 18
2011	Dec 05	Dec 12	Dec 21	Mar 29	Apr 03	Apr 18
2010	Nov 01	Dec 10	Dec 15	Mar 17	Mar 29	Apr 20
2009	Dec 28	Jan 04	Jan 04	Apr 15	Apr 15	Apr 22
2008	Jan 21	Feb 24	Feb 24	Apr 14	May 06	May 06
2007	Dec 28	Dec 28	Dec 28	Apr 08	Apr 17	Apr 24
2006	Dec 18	Dec 22	Dec 26	Feb 26	Feb 26	Mar 27
Median Month	December	December	December	April	April	April
2006	Dec 18	Dec 22	Dec 26	Feb 26	Feb 26	Mar 27
Median Month	December	December	December	April	April	April

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 21. Spring-Run Chinook Salmon Presence In Sacramento Trawl

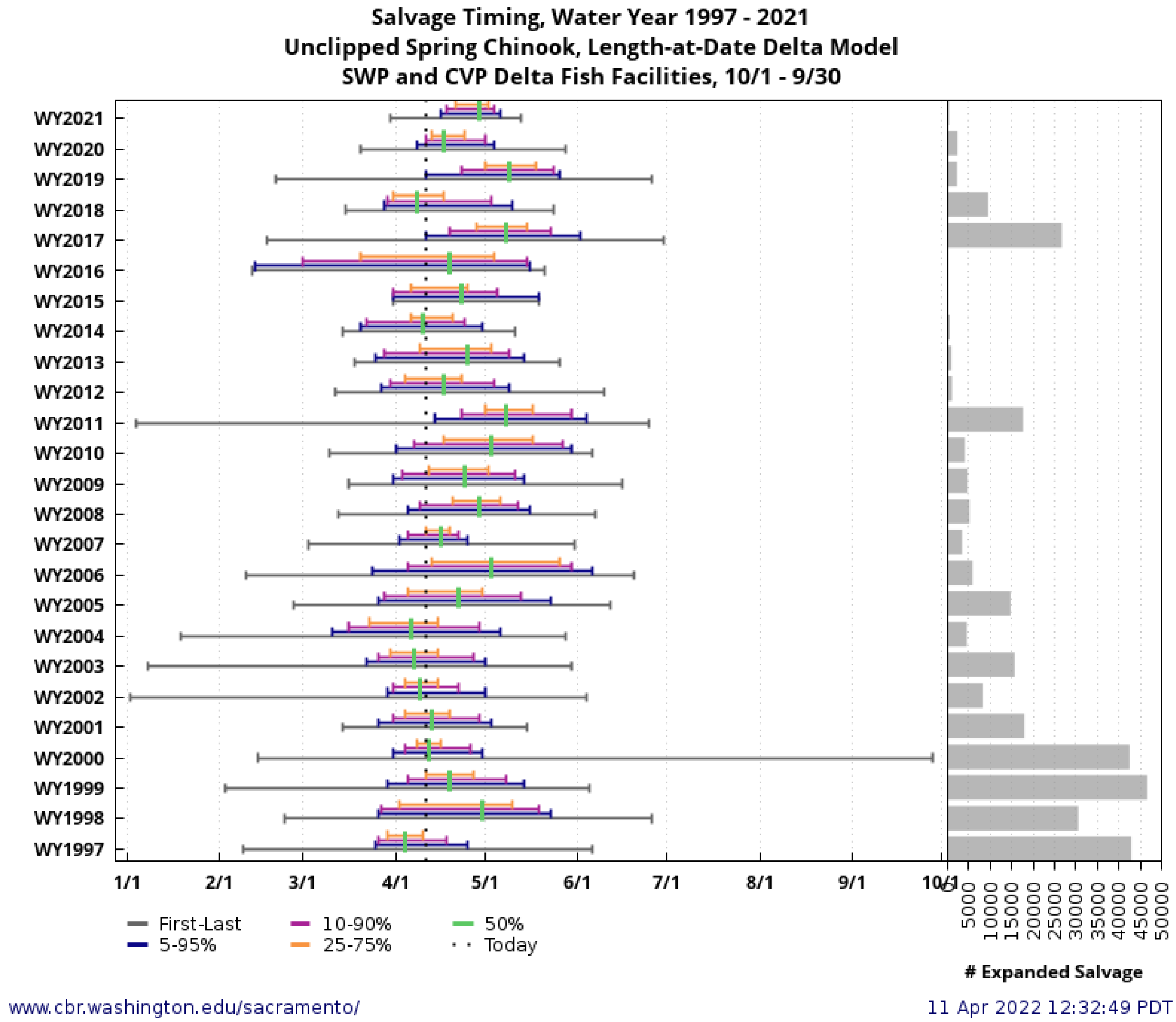
Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Feb 4	Feb 25	Mar 29	Apr 11	Apr 12	Apr 22
2019	Dec 12	Mar 31	Apr 2	Apr 5	Apr 6	Apr 10
2018	Dec 3	Feb 4	Mar 1	Mar 31	Apr 9	Apr 21
2017	Feb 15	Mar 4	Mar 15	Mar 24	Apr 11	Apr 16
2016	Nov 23	Mar 28	Apr 1	Apr 5	Apr 12	May 1
2015	Jan 11	Mar 25	Mar 30	Apr 1	Apr 13	Apr 15
2014	Dec 5	Dec 8	Dec 15	Dec 24	Mar 27	Apr 17
2013	Fe 11b	Feb 15	Feb 22	Mar 7	Apr 7	Apr 11
2012	Dec 3	Apr 1	Apr 1	Apr 10	Apr 17	Apr 19
2011	Jan 25	Mar 16	Mar 19	Mar 30	Mar 30	Apr 18
2010	Dec 8	Dec 20	Jan 3	Apr 13	Apr 20	Apr 22
2009	Feb 3	Mar 1	Apr 9	Apr 16	Apr 16	Apr 23
2008	Feb 23	Apr 2	Apr 10	Apr 15	Apr 16	Apr 24
2007	Jan 7	Jan 7	Jan 11	Feb 27	Apr 14	Apr 25
2006	Feb 7	Feb 14	Feb 14	Apr 9	Apr 17	Apr 17
Median Month	January	March	March	April	April	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 22. Spring-Run Chinook Salmon Presence in Chipps Island Trawl

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Mar 30	Apr 9	Apr 18	May 4	May 10	May 18
2019	Mar 23	Apr 6	Apr 6	May 1	May 8	May 15
2018	Mar 4	Apr 5	Apr 8	May 9	May 10	May 24
2017	Mar 27	Apr 10	Apr 12	Apr 27	Apr 29	May 27
2016	Feb 22	Apr 3	Apr 5	May 8	May 15	Jul 14
2015	Mar 16	Apr 4	Apr 6	Apr 29	May 2	May 31
2014	Feb 17	Mar 30	Apr 1	Apr 24	Apr 27	May 11
2013	Mar 7	Mar 28	Mar 31	May 5	May 8	May 22
2012	Mar 29	Apr 8	Apr 12	May 15	May 17	May 31
2011	Mar 23	Apr 6	Apr 13	May 11	May 14	May 18
2010	Feb 18	Apr 13	Apr 18	May 6	May 11	Jun 6
2009	Mar 29	Apr 9	Apr 16	May 14	May 14	Aug 16
2008	Mar 25	Apr 8	Apr 9	May 9	May 9	May 18
2007	Apr 3	Apr 7	Apr 14	May 5	May 8	May 30
2006	Mar 24	Apr 9	Apr 13	Apr 30	May 1	May 20
Median Month	March	April	April	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

Figure 12. Unclipped Spring Chinook, Length-at-Date Delta Model Salvage Timing at CVP and SWP Fish Facilities

Table 23. Unclipped Spring Chinook, Length-at-Date Delta Model Salvage Timing at CVP and SWP Fish Facilities

Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2021	3/29/2021	4/15/2021	4/17/2021	5/3/2021	5/5/2021	5/12/2021
2020	3/18/2020	4/6/2020	4/9/2020	4/29/2020	5/2/2020	5/26/2020
2019	2/19/2019	4/10/2019	4/22/2019	5/23/2019	5/25/2019	6/25/2019
2018	3/14/2018	3/27/2018	3/28/2018	5/2/2018	5/9/2018	5/23/2018
2017	2/16/2017	4/10/2017	4/18/2017	5/22/2017	6/1/2017	6/29/2017
2016	2/11/2016	2/12/2016	2/28/2016	5/13/2016	5/14/2016	5/19/2016

Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2015	3/30/2015	3/30/2015	3/30/2015	5/4/2015	5/18/2015	5/18/2015
2014	3/13/2014	3/19/2014	3/21/2014	4/23/2014	4/29/2014	5/10/2014
2013	3/17/2013	3/24/2013	3/27/2013	5/8/2013	5/13/2013	5/25/2013
2012	3/10/2012	3/25/2012	3/28/2012	5/2/2012	5/7/2012	6/8/2012
2011	1/3/2011	4/13/2011	4/22/2011	5/29/2011	6/3/2011	6/24/2011
2010	3/9/2010	3/31/2010	4/6/2010	5/26/2010	5/29/2010	6/5/2010
2009	3/15/2009	3/30/2009	4/2/2009	5/10/2009	5/13/2009	6/15/2009
2008	3/11/2008	4/3/2008	4/7/2008	5/10/2008	5/14/2008	6/5/2008
2007	3/2/2007	4/1/2007	4/4/2007	4/21/2007	4/24/2007	5/30/2007
2006	2/9/2006	3/23/2006	4/4/2006	5/29/2006	6/5/2006	6/19/2006
2005	2/25/2005	3/25/2005	3/27/2005	5/12/2005	5/22/2005	6/11/2005
2004	1/18/2004	3/9/2004	3/14/2004	4/27/2004	5/4/2004	5/26/2004
2003	1/7/2003	3/21/2003	3/25/2003	4/26/2003	4/30/2003	5/29/2003
2002	1/1/2002	3/28/2002	3/30/2002	4/21/2002	4/30/2002	6/3/2002
2001	3/13/2001	3/25/2001	3/30/2001	4/28/2001	5/2/2001	5/14/2001
2000	2/13/2000	3/29/2000	4/2/2000	4/24/2000	4/28/2000	9/26/2000
1999	2/2/1999	3/28/1999	4/4/1999	5/7/1999	5/13/1999	6/4/1999
1998	2/22/1998	3/25/1998	3/26/1998	5/18/1998	5/22/1998	6/25/1998
1997	2/8/1997	3/24/1997	3/25/1997	4/17/1997	4/24/1997	6/5/1997
Median	February	March	March	May	May	June

Source: University of Washington, School of Aquatic and Fishery Science 2022.
CVP = Central Valley Project; SWP = State Water Project.

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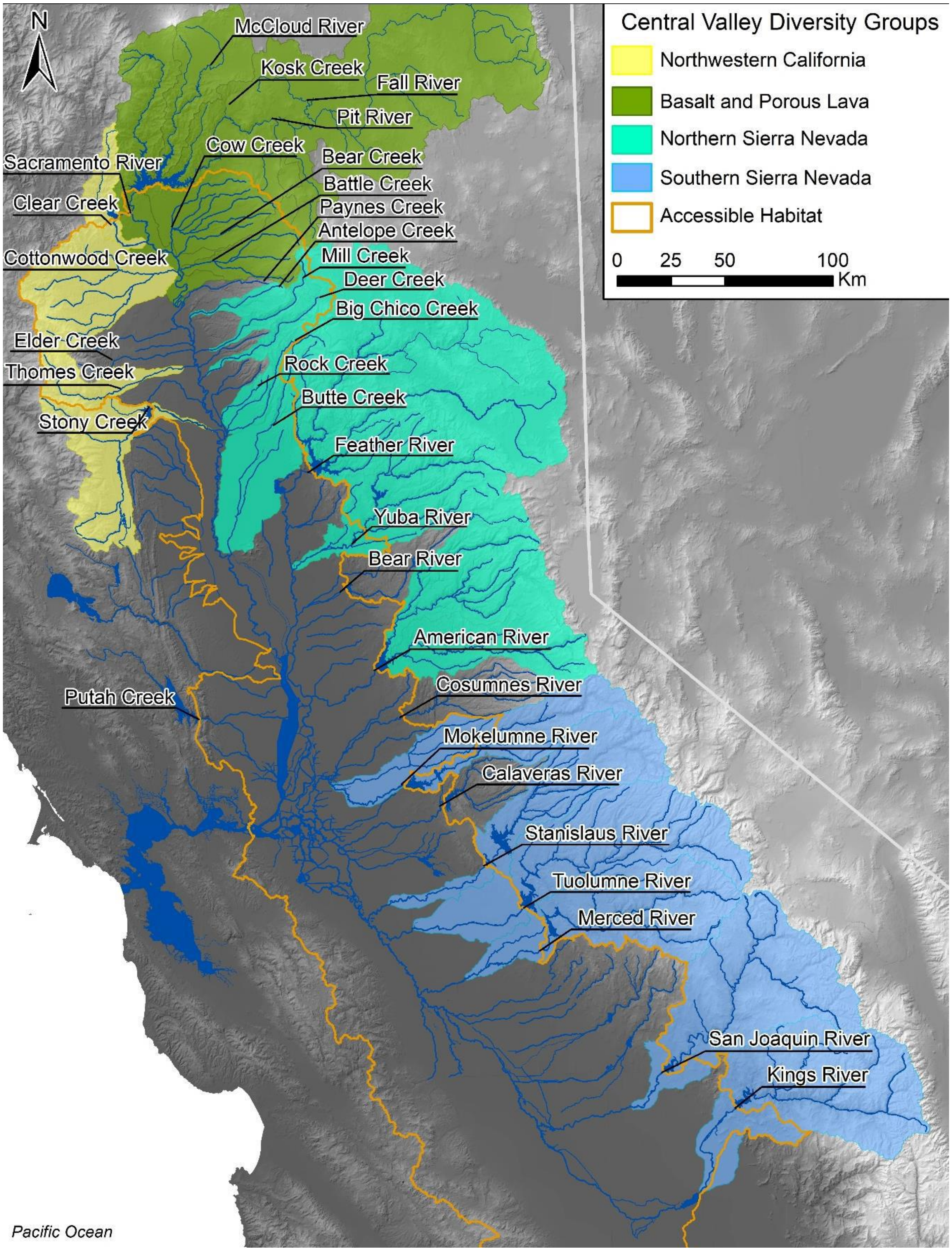
4. Steelhead – Central Valley Distinct Population Segment

Presently, California Central Valley (CCV) steelhead (*Oncorhynchus mykiss [O. mykiss*]) are found in the Sacramento River downstream of Keswick Dam, in major tributary rivers and creeks to the Sacramento River (American River, Feather River, Butte Creek), in major tributaries to the San Joaquin River (Stanislaus, Tuolumne, Merced Rivers), and the Delta (Mokelumne and Calaveras Rivers). A multiagency effort is underway for an improved monitoring plan for CCV steelhead, which involves dividing the Sacramento and San Joaquin basins into four geographically distinct diversity groups (Beakes et al. 2021, Figure 13).



Source: Beakes and Goertler 2021.

Figure 13. Map Illustrating the Location of Target Watersheds within Central Valley Diversity Groups.

The populations in the northern Sierra Nevada (Feather and American Rivers) are supported by the Feather and Nimbus hatcheries, and the populations in the southern Sierra Nevada (lower

Mokelumne River) are supported by the Mokelumne River Fish Hatchery. Other major steelhead populations in the Sacramento River watershed are found in Basalt and Porous Lava diversity group of Battle, Mill, Deer, Clear, and Butte creeks. Steelhead may be present in all rivers and tributaries used in CVP.

Adult steelhead migrate into freshwater systems in the fall and winter and spawn in their natal streams in winter and spring. Juveniles rear in freshwater habitats for 1 to 4 years before emigrating to the ocean. Both spawning areas and migratory corridors are used by juvenile steelhead for rearing prior to outmigration (National Marine Fisheries Service 2009). Adult steelhead are iteroparous, although repeated spawning rates of anadromous individuals are considered low in populations in the Central Valley (Null et al. 2013).

Summaries of the temporal life-history domains for CCV steelhead can be found on Figure 14.

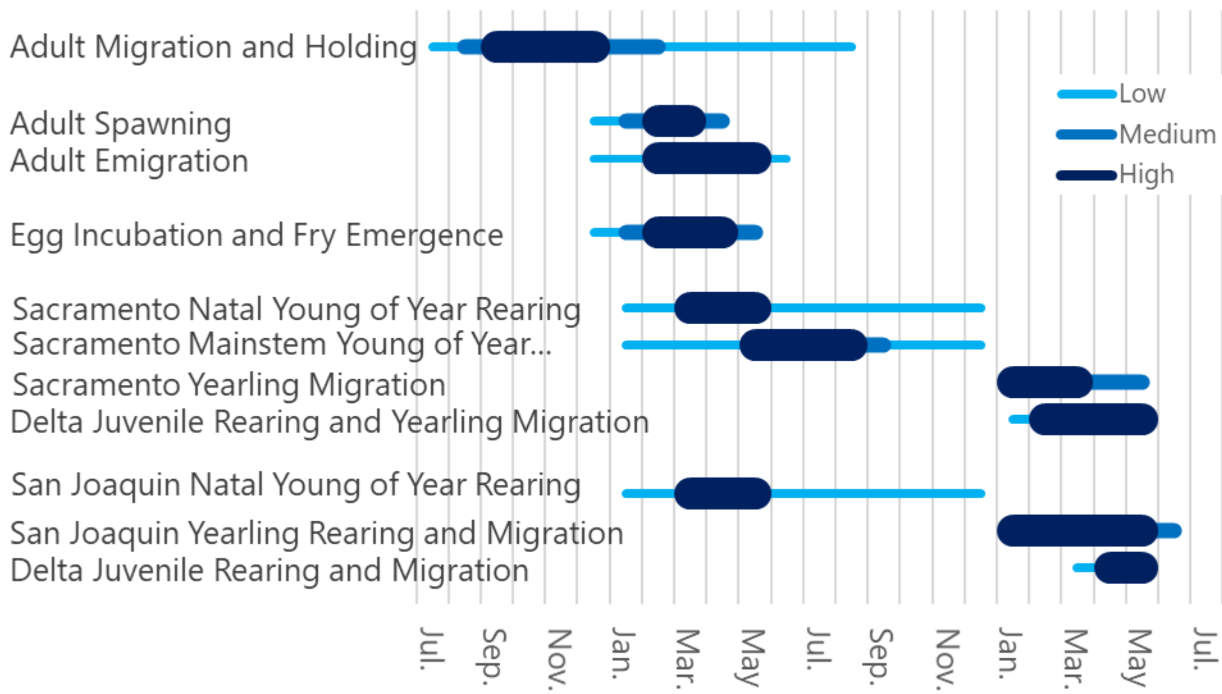


Figure 14. Temporal Life Stage Domains for California Central Valley Steelhead.

4.1 Adult Migration and Holding

CCV steelhead exhibit life histories in which they spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Due to their varying life-history strategies and iteroparity, migrating adult steelhead are difficult to monitor using the same strategies employed for Chinook salmon in the California Central Valley. Historical data at the Fremont Weir have shown that adult CCV steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through February or March (Hallock 1989;

McEwan 2001; Hallock et al. 1957). The latest records of adult steelhead migration into the Sacramento River include passage estimates based on observations at RBDD ladders between 1994–2007[1] . These data suggested that the first passage at RBDD occurs in August, and the last passage by September, prior to the dam being decommissioned in 2013.

Adult migration data are limited even further for rivers and tributaries of the Bay-Delta. Estimates of migrating adults in the San Joaquin River are made from CDFW angling report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007). Migration timing in the Delta ranges from July until May, with peaks at both the beginning of the spawning season, as migrants move to their natal streams, and at the end of the season, in May, potentially as post-spawn kelts emigrate back to the ocean (Moyle 2002; Hallock 1961).

4.2 Adult Spawning

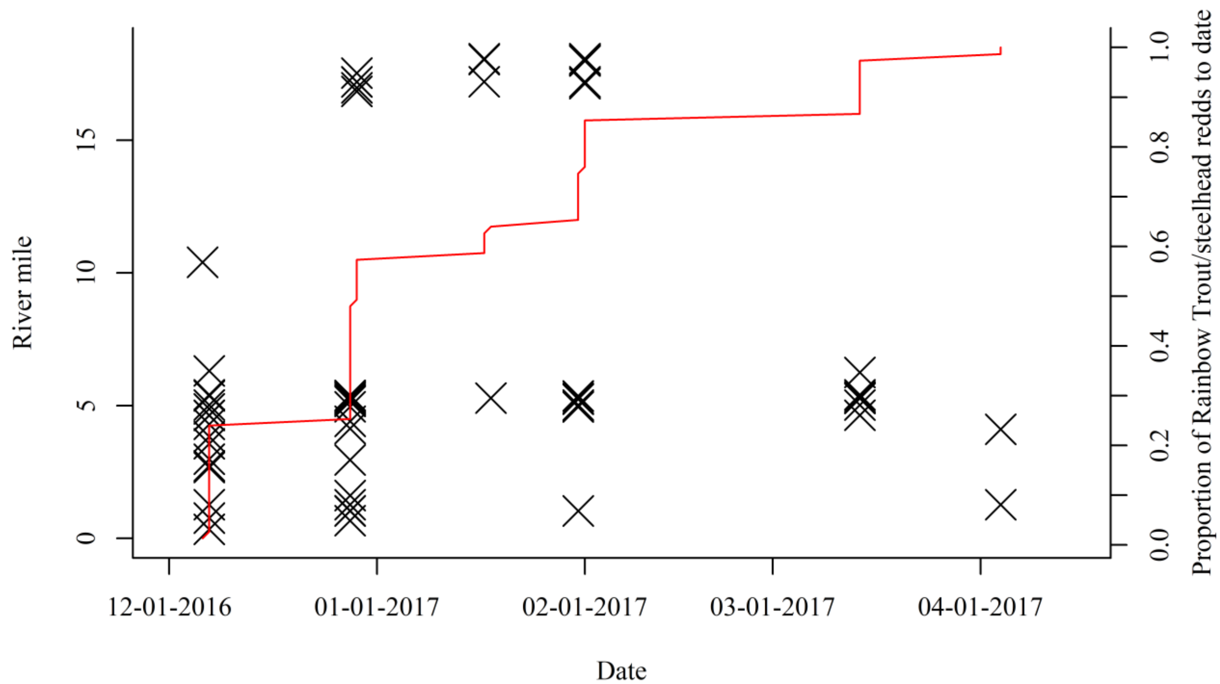
Redd surveys are conducted for CCV steelhead in Clear Creek and the American, Calaveras, Tuolumne, Yuba, lower Mokelumne, and Feather rivers. Redd survey data for rivers and streams within the CVP were available for Clear Creek and the American River. Construction of redds provide observations of spawning, although redd data are not typically linked to life-history type. Spawning for CCV steelhead starts as early as November, peaks December through April, and can last until June (McEwan 2001). Alternative methods for assessing spawning periodicity include video monitoring and adult counts at spawning facilities. The latter two methods are utilized at the Coleman National Fish Hatchery (CNFH) for annual spawner estimates on Battle Creek.

Redd estimates on Clear Creek are observed through annual kayak surveys that start in December and span April and are documented in USFWS reports (Provins and Chamberlain 2019, 2020). Based on the number of redds observed, most spawning appears to occur near to the confluence with the Sacramento River, between river miles 6.5 and 0 (Figure 15 and Figure 16). The temporal distribution of the redd count data shows peak spawning occurring from December–January, with 90% of redds constructed by February. Redd construction tapers off in the month of March, and all redds have been constructed by the end of April (Table 24 and Figure 17). The lack of redds observed in December 2014 may be due to two storm events, given that increases in discharge lead to increased turbidity, redd scour, and reduction in visibility (Provins and Chamberlain 2019a). Estimates of spawners on Battle Creek are made through video monitoring and adult counts at the spawning building in CNFH. In 2001, CNFH initiated a comprehensive (100%) marking program of hatchery-produced CCV steelhead, with adipose fin-clipped fish marked as hatchery produced and unclipped fish labeled as natural origin. Peak spawning at the hatchery occurs in March (Figure 18 and Figure 19); however, unclipped steelhead that arrive at the facility are not spawned and are released above the barrier prior to the

[1] Raw data were only available on hard copies (i.e., datasheets or notebooks) that were moved to electronic ledgers by CDFW staff. Digitizing these data required review and interpretation of procedures for data collection and analysis by CDFW (Killam pers. comm.). When information on these procedures was limited, the raw data were recorded based on what CDFW predecessors had originally reported. CDFW summaries in their Upper Sacramento River annual report supplementation materials include periodicity.

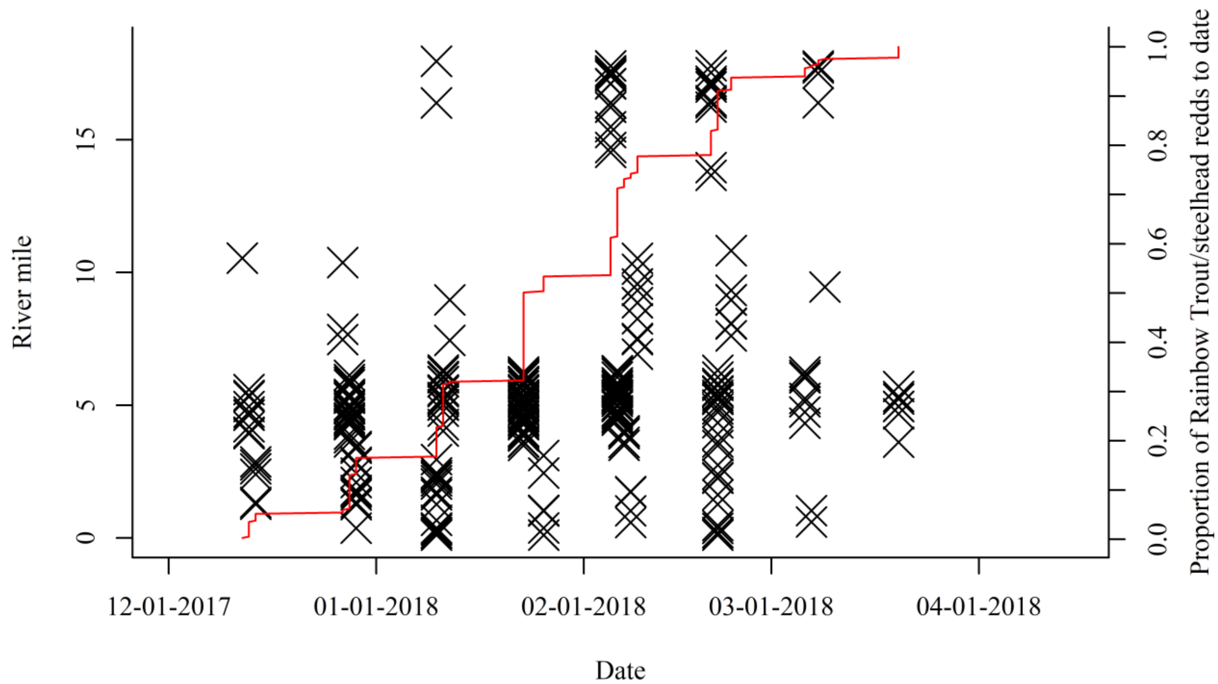
opening of the barrier weir fish ladder on March 1. Unclipped releases prior to opening of the barrier on March 1 are not included in the migration timing figures (Figure 18 and Figure 19).

Redd estimates on the lower American River are observed through redd surveys that start during the first week of August and extend through the end of May. Based on the number of redds observed from 2002–2021, CCV steelhead start spawning in January, continue building redds throughout the month of February, and 90% of the redds have been constructed by March. By mid-April, the last redd has been constructed (Figure 20 and Table 25).



Source: Provins and Chamberlain 2019b.
Note: The X axis indicates the initial survey date at which the redd was first observed. The red line displays the cumulative proportion of redds to date scaled to the right Y axis.

Figure 15. Plot Illustrating the Distribution of *O. Mykiss* Observations by Date and River Mile on Clear Creek for the 2016–2017 Survey Season.



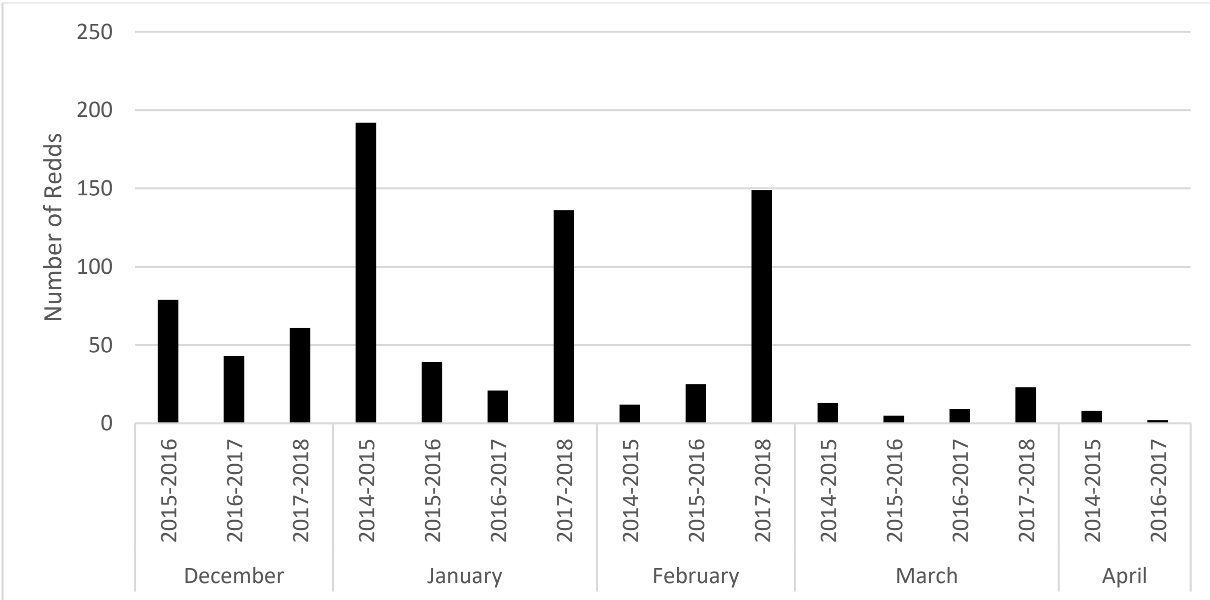
Source: Provins and Chamberlain 2020.
Note: The X axis indicates the initial survey date at which the redd was first observed. The red line displays the cumulative proportion of redds to date scaled to the right Y axis.

Figure 16. Plot Illustrating the Distribution of *O. Mykiss* Observations by Date and River Mile on Clear Creek for the 2017–2018 Survey Season.

Table 24. Redd Construction Timing on Clear Creek, 2014–2018

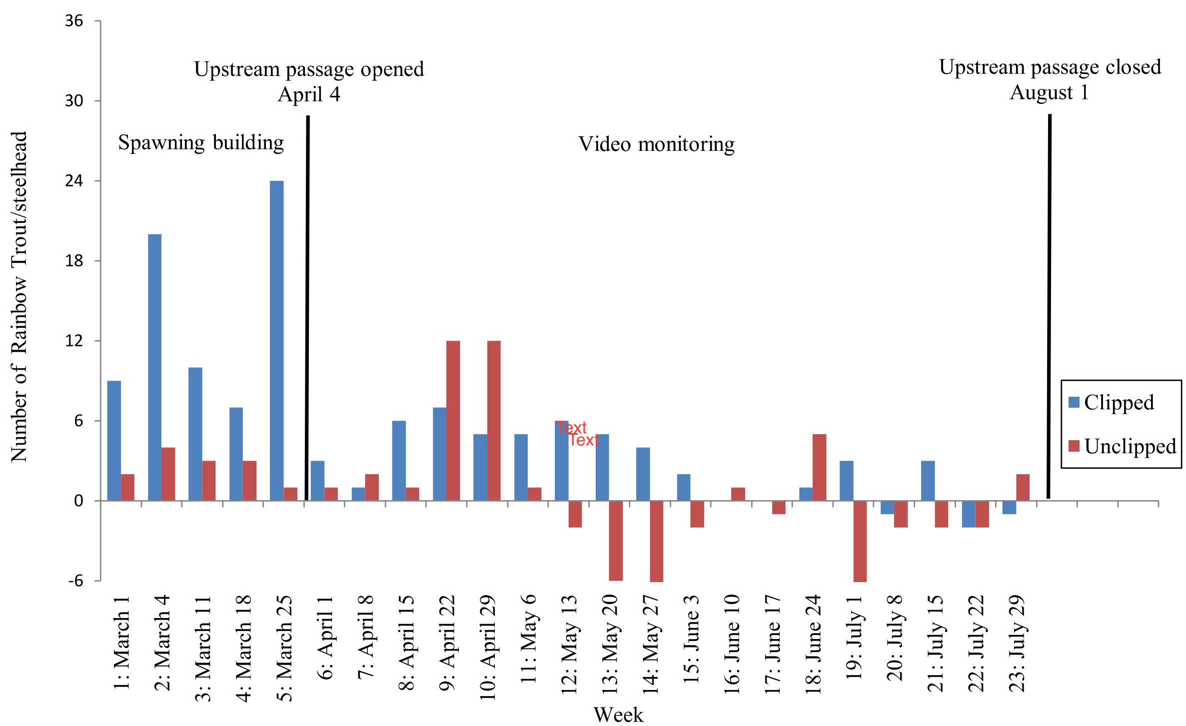
Observation Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2017–2018	Dec 17	Dec 17	Dec 17	Feb 18	Mar 18	Mar 18
2016–2017	Dec 16	Dec 16	Dec 16	Mar 17	Mar 17	Apr 17
2015–2016	Dec 15	Dec 15	Dec 15	Feb 16	Feb 16	Mar 16
2014–2015	Jan 15	Jan 15	Jan 15	Feb 15	Mar 15	Apr 15
Median Month	December	December	December	February	March	March/April

Sources: Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020



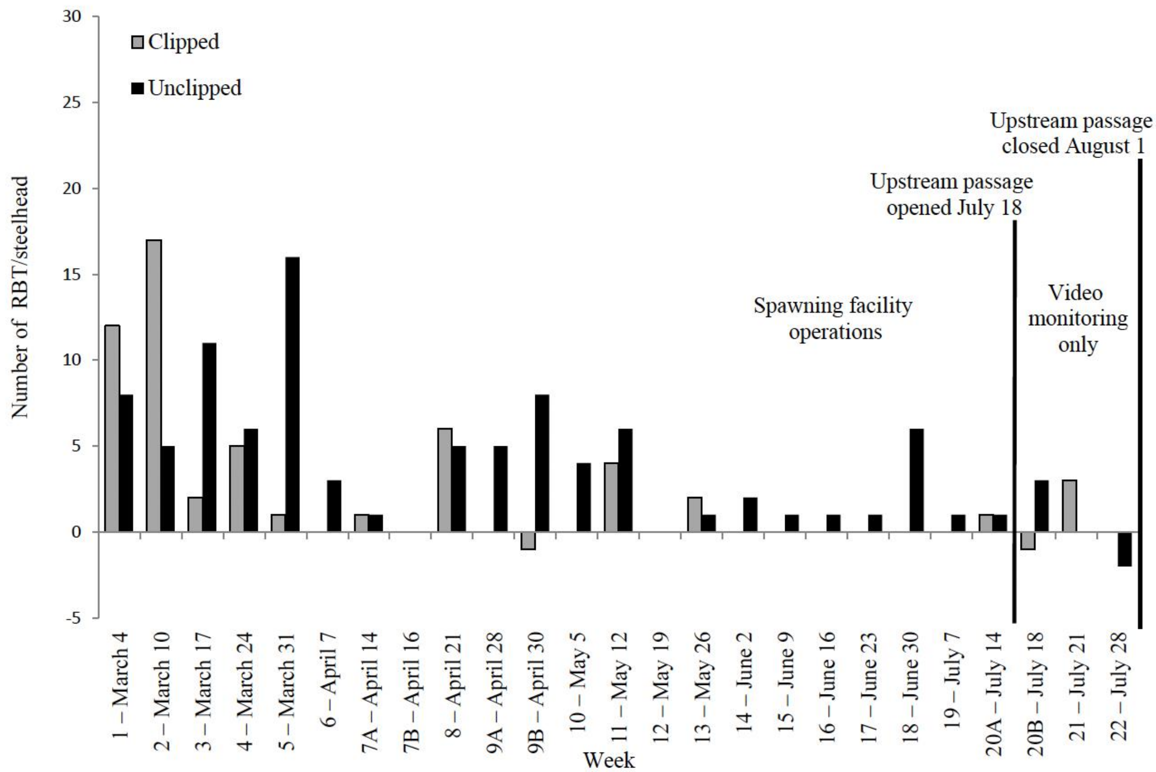
Source: Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020.

Figure 17. Plot of Central California Valley Steelhead/Rainbow Trout Redds Observed on Clear Creek During Annual Kayak Surveys for 2014–2018.



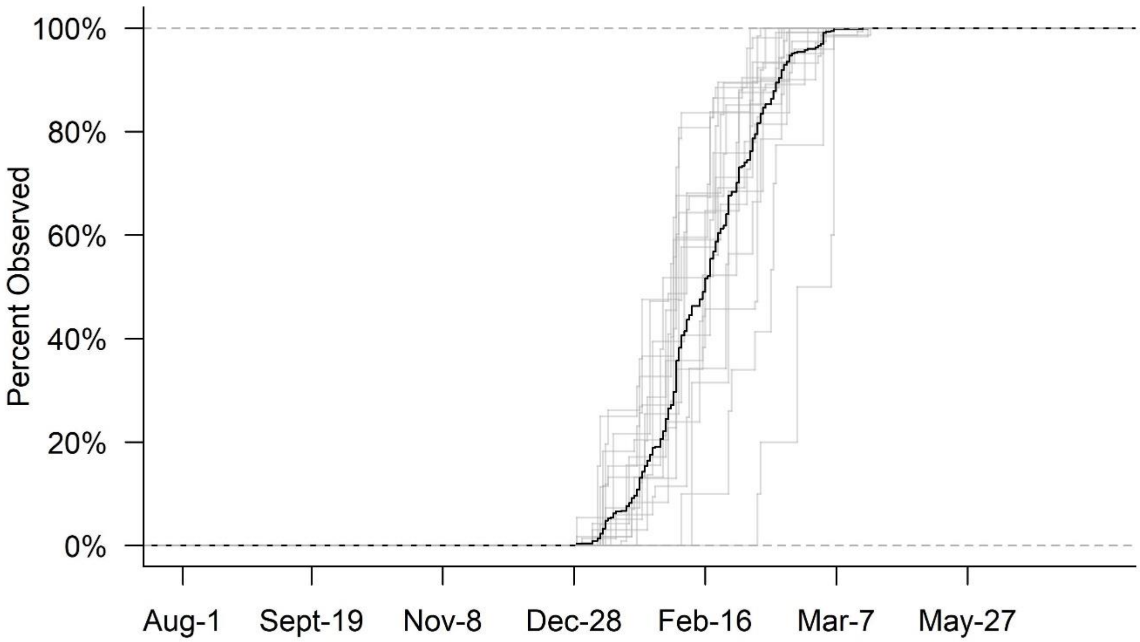
Source: Bottaro and Earley 2020a.
Note: Dates begin the Sunday of each week.

Figure 18. Plot Illustrating the Distribution of *O. Mykiss* Observations at Coleman National Fish Hatchery Fish Ladder (in the Spawning Building and by Video) in 2018, by Week.



Source: Bottaro and Earley 2020b.
Note: Dates begin the Sunday of each week.

Figure 19. Plot Illustrating the Distribution of *O. Mykiss* Observations at Coleman National Fish Hatchery Fish Ladder (in the Spawning Building and by Video) in 2019, by Week.



Source: Cramer Fish Sciences 2021.
Note: Multiple redds at a single observation location are not distinguished due to variability in how the observation was recorded across years.

Figure 20. Lower American River *O. Mykiss* Redd Construction Timing, 2002–2021.

Table 25. Lower American River O. Mykiss Redd Construction Timing, 2002–2021

Observation Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2021	Jan 6	Jan 6	Jan 6	Mar 15	Mar 17	Mar 18
2020	Jan 8	Jan 8	Jan 8	Mar 2	Mar 3	Mar 16
2019	Jan 8	Jan 8	Jan 8	Mar 20	Mar 20	Apr 19
2018	Jan 11	Jan 22	Jan 23	Mar 19	Mar 20	Mar 20
2017	Mar 8	Mar 8	Mar 9	Apr 6	Apr 6	Apr 6
2016	Jan 7	Jan 7	Jan 7	Mar 4	Mar 4	Mar 4
2015	Jan 21	Jan 21	Jan 22	Mar 6	Mar 19	Mar 20
2014	Jan 15	Jan 17	Jan 17	Mar 13	Mar 21	Apr 3
2013	Jan 9	Jan 9	Jan 9	Mar 5	Mar 11	Mar 11
2012	Jan 4	Jan 18	Jan 18	Mar 10	Mar 29	Mar 30
2011	Jan 4	Jan 25	Jan 25	Mar 1	Mar 8	Mar 9
2010	Jan 12	Jan 12	Jan 12	Mar 9	Mar 22	Apr 20
2009	Feb 11	Feb 11	Feb 11	Mar 26	Mar 27	Dec 29
2007	Jan 4	Jan 19	Feb 2	Mar 2	Mar 16	Mar 16

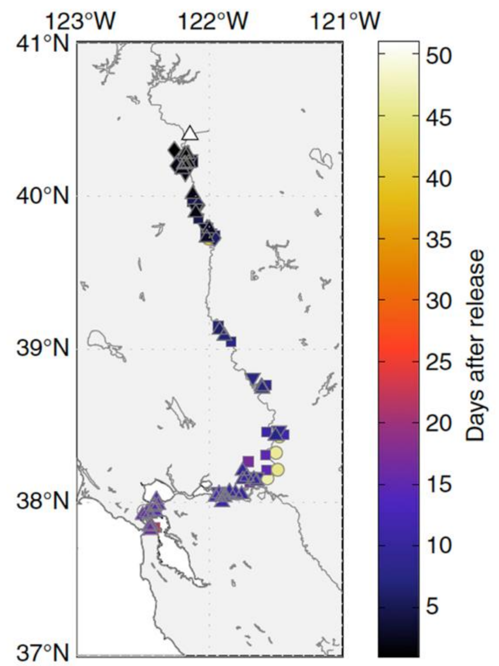
Observation Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2005	Jan 19	Jan 20	Jan 20	Mar 15	Mar 15	Apr 4
2004	Jan 13	Jan 27	Feb 7	Mar 17	Mar 31	Dec 29
2003	Jan 7	Jan 9	Jan 22	Mar 17	Mar 18	Dec 31
2002	Feb 7	Feb 7	Feb 23	Apr 2	Apr 2	Apr 2
Median Month	January	January	January	March	March	March

Source: Cramer Fish Sciences 2021.

4.3 Adult Kelt Emigration

CCV steelhead exhibit some of the most complex life-history strategies of all salmonids, ranging from fully anadromous to completely resident. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et. al 2013). A study by Teo et al. (2011) has shown the spatial distribution for CCV steelhead kelts and the complexity of their migration patterns, as some migrate to San Francisco Bay and back into freshwater several weeks later. In this study, CCV steelhead kelts were implanted with acoustic tags, released in May, and tracked over a 50-day period throughout the Sacramento basin and Bay-Delta region (Figure 21).

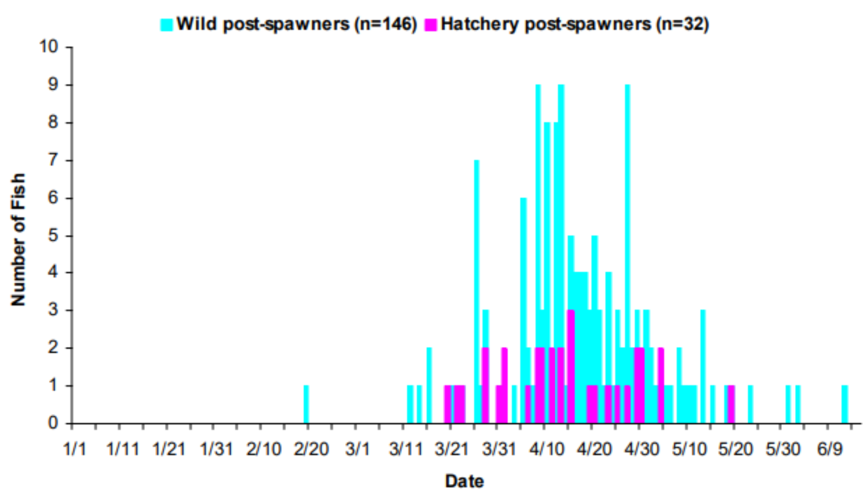
The spatial distribution of kelt emigration is both highly variable, as demonstrated by Teo et al. (2011), and difficult to track on a temporal scale because iteroparity in California steelhead populations is considered relatively rare (Moyle 2002; Null et al. 2013). Much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by June (Mayer et al. 2008; Figure 22).



Release location of steelhead kelts (white Δ) and approximate locations of acoustic tag detections. Five steelhead were detected after release and symbols indicate individual steelhead: A (◊), B (Δ), D (□), E (∇), and I (○). Locations of acoustic tag detections are jittered for clarity

Source: Teo et al. 2011.

Figure 21. Distribution of *O. Mykiss* Kelts in Acoustic Telemetry Study.



Source: Mayer et al. 2008.

Figure 22. Daily Catch of Post-Spawning Steelhead by Origin at the Asotin Creek, Washington, Weir in 2007.

4.4 Egg Incubation

CCV steelhead eggs start incubating when redd construction occurs. Spawning success is associated with water flow and water temperature. Studies on incubation temperature by the Washington State Department of Ecology have found that water temperatures between 40 degrees Fahrenheit (°F) and 55°F (4.4 degrees Celsius [°C] and 12.8°C) are suitable for successful spawning, egg incubation, and fry development for steelhead (Washington State Department of Ecology 2002). Steelhead egg incubation to post-hatch varies with temperature and requires approximately 490 accumulated temperature units. For example, in 50°F (10°C) water, incubation would end approximately 50 days after incubation starts. On the American River, egg incubation starts in December and ends in May, with peak incubation between March and May (Hannon pers. comm., Table 26).

Table 26. Steelhead Egg Incubation

Life stage	First	5% Fertilized	10% Fertilized	90% Fertilized	95% Fertilized	Last
Steelhead Egg Incubation	December	January	January	May	May	May

Source: Hannon pers. comm..

4.5 Young-of-the-Year Fry Migration

Once CCV steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Specific data on the young-of-the-year life stage is available from the lower Battle Creek rotary screw trap, which suggests migration occurs from February through June on Battle Creek (Figure 23; Schraml and Earley 2019).

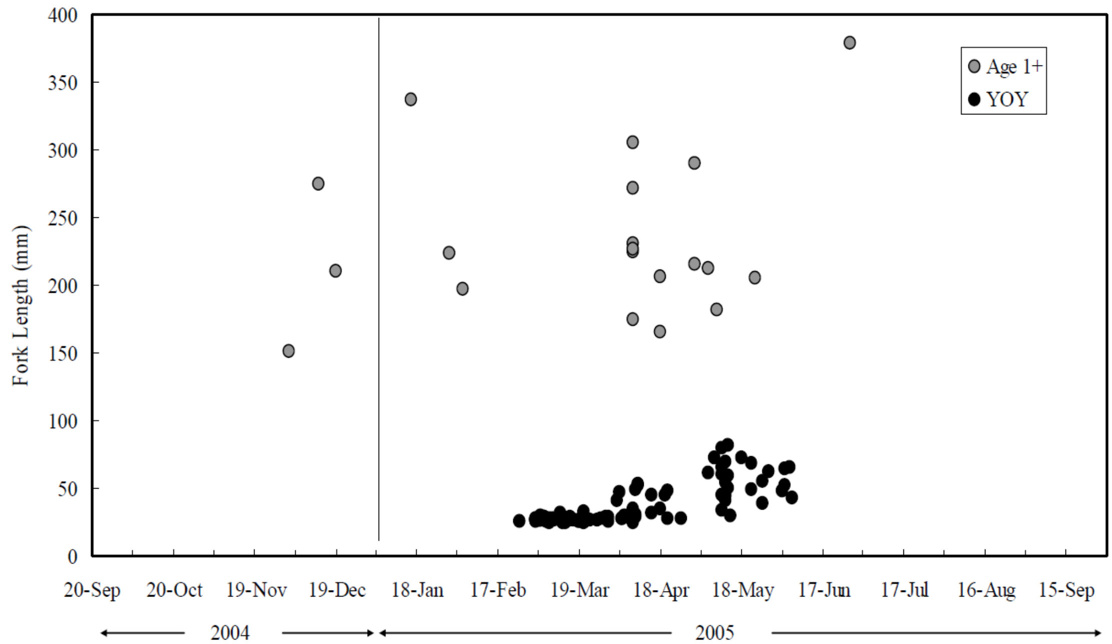


Figure 9. Fork length (mm) distribution for age 1+ and young-of-the-year (YOY) rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2004 through September 30, 2005. Age 1+ fish may include individuals from more than one year class.

Source: Schraml and Earley 2019.

Figure 23. Representative Year of Rotary Screw Trap *O. Mykiss* Catch in Battle Creek Showing Two Cohorts of *O. Mykiss* Rearing and Migrating.

4.6 Juvenile and Yearling Natal River Rearing and Migration

The timing of yearling and juvenile migration depends on the watershed and water year. Upper reaches of the Sacramento River basin appear to have the longest migration period detected for yearlings and juveniles, including detection of juveniles year-round at the mainstem at RBDD (Table 28 and Table 33). In Battle Creek and Clear Creek, occurrence of yearlings and juveniles at the monitoring traps starts in November, and the last yearlings and juveniles are detected in June (Table 27, Table 30, and Table 31).

USFWS also estimates juvenile passage for the mainstem Sacramento River at the Knights Landing rotary screw trap, where juveniles are first detected later in the season, in January; 90% median passage occurs in May, and the last detection occurs by June (Tables 30 and 31). A lower tributary in the Sacramento River, the American River exhibits a similar timing as the mainstem near Knights Landing, with the first occurrence in January, 90% median passage occurring in May, and the last occurrence in June (Table 27 and Table 32).

CDFW estimates the presence of steelhead juveniles from the San Joaquin River Basin annually, based on the Mossdale Trawl and by PSMFC at the Stanislaus River Caswell screw trap. The Mossdale Trawl captures steelhead juveniles, although usually in small numbers (i.e., under 25 juveniles each year according to SacPAS from 2007–2020). These limited datasets give misleading median month timing, but still start in January, with 90% median passage occurring in May, and end in June (Table 29 and Table 36). The Stanislaus River screw trap detects juvenile median monthly passage from January to June, with 90% passing by May, and may see year-round presence in select years (see Brood Years 2000, 2002, and 2011 in Table 29 and Table 35).

Table 27. Summary of Sacramento River Basin Natal River Yearling and Juvenile Rearing for O. Mykiss (from Table 30, Table 31, and Table 32)

Tributary	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
Clear Creek	November	February	March	May	June	June
Battle Creek	November	April	April	June	June	June
American River	January	March	March	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 28. Summary of Sacramento River Mainstem Yearling and Juvenile Migration for O. Mykiss (Table 33 and Table 34)

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
RBDD	January	May	May	August	September	December
KNL	January	January	January	April	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 29. Summary of San Joaquin River Basin Natal River Yearling and Juvenile Emigration for O. Mykiss (from Table 35 and Table 36)

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
Stanislaus	January	January	January	May	June	June
Mossdale Trawl	March	April	April	May	May	May
San Joaquin River Juvenile	January	January	January	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

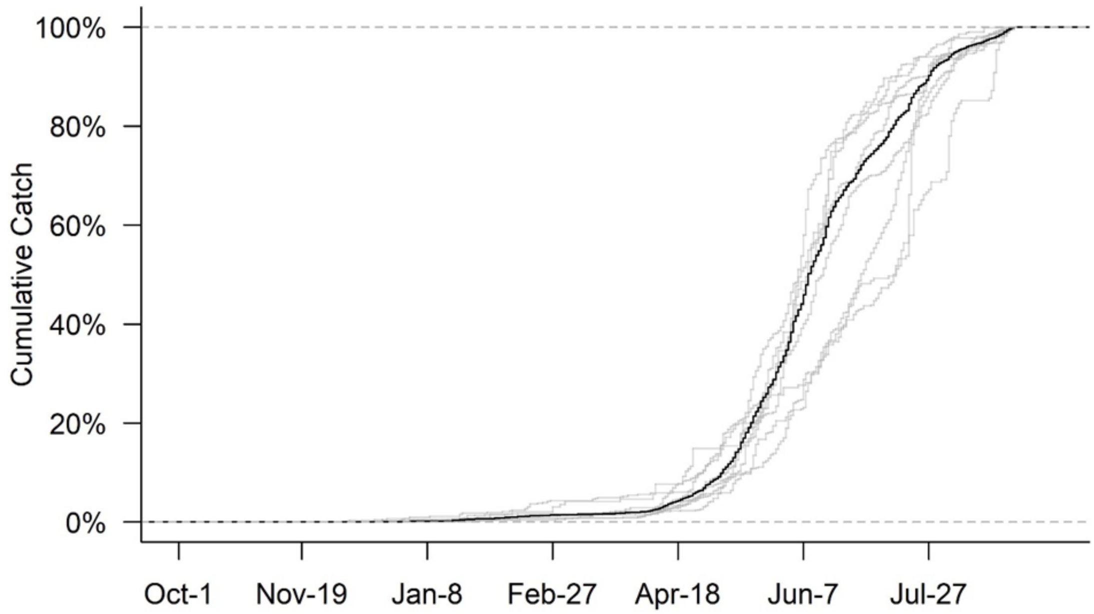
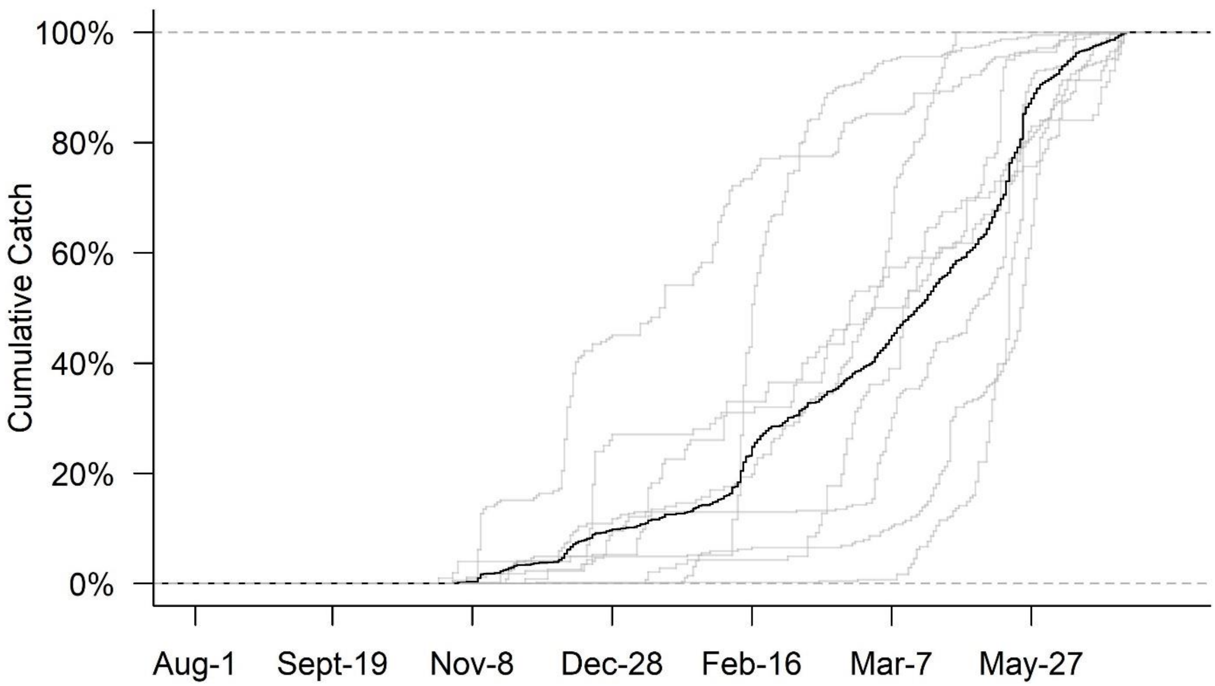


Figure 24. Lower Clear Creek Rotary Screw Trap, *O. Mykiss* Catch, all Yearling and Juvenile Age Classes, 2011–2018.

Table 30. Lower Clear Creek Rotary Screw Trap, *O. Mykiss* Catch, all Yearling and Juvenile Age Classes, 2011–2018

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2018	Nov 27	Feb 6	Feb 19	Jun 22	Jun 23	Jun 30
2017	Oct 6	Feb 18	Feb 26	May 14	Jun 4	Jun 25
2016	Oct 19	Jan 25	Mar 15	Jun 4	Jun 15	Jun 30
2015	Nov 7	Feb 11	Feb 26	May 26	Jun 7	Jun 29
2014	Nov 18	Feb 25	Mar 17	May 27	Jun 11	Jun 30
2013	Nov 5	Feb 24	Mar 8	May 12	May 27	Jun 30
2012	Nov 15	Feb 26	Mar 10	May 25	Jun 7	Jun 30
2011	Nov 1	Mar 3	Mar 11	May 31	Jun 10	Jun 29
Median Month	November	February	March	May	June	June



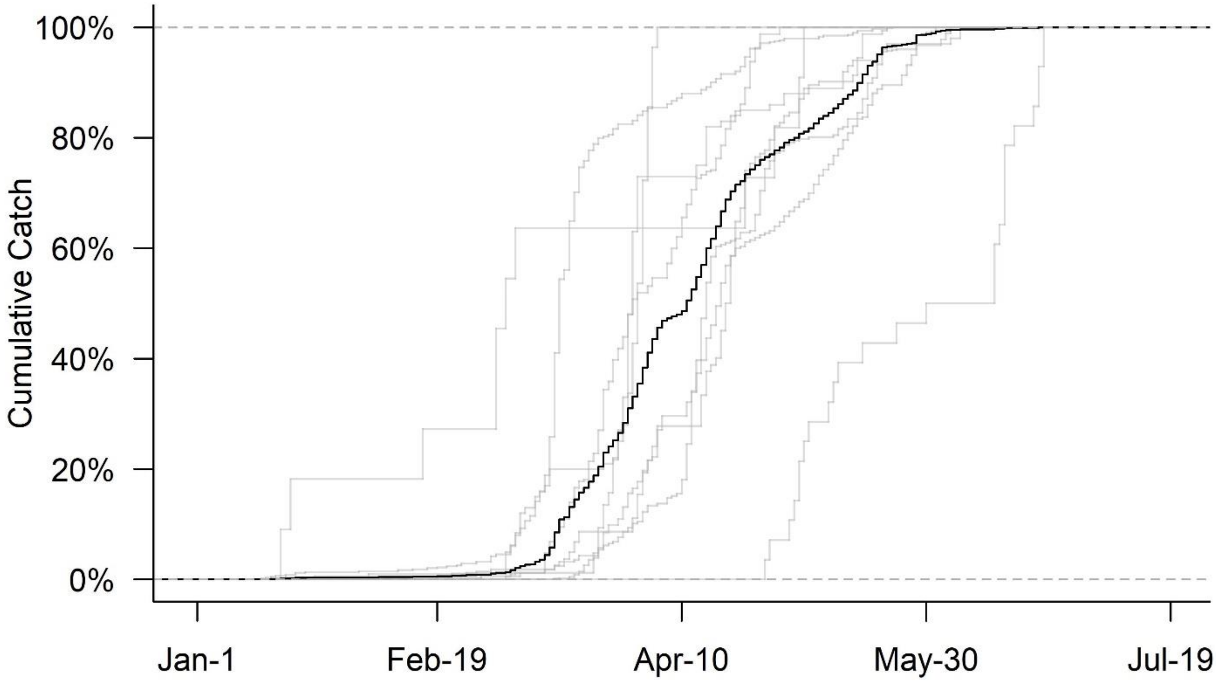
Source: Bottaro and Earley 2020.

Figure 25. Upper Battle Creek, Coleman Hatchery Barrier Weir Trap, *O. Mykiss* Catch, all Yearling and Juvenile Age Classes, 2010–2018.

Table 31. Upper Battle Creek, Coleman Hatchery Barrier Weir Trap, *O. Mykiss* Catch, all Yearling and Juvenile Age Classes, 2010–2018

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2018	Nov 27	Dec 24	Jan 1	Jun 6	Jun 23	Jun 29
2017	Jan 9	Mar 8	Mar 12	May 17	May 18	Jun 12
2016	Oct 27	Dec 19	Dec 21	Jun 21	Jun 26	Jun 29
2015	Nov 5	Nov 10	Nov 11	Apr 28	May 12	Jun 19
2014	Dec 1	Apr 16	Apr 23	May 26	Jun 9	Jun 30
2013	Nov 20	Jan 29	Feb 9	Mar 18	Apr 6	Jun 6
2012	Nov 9	Dec 9	Dec 16	Jun 9	Jun 23	Jun 29
2011	Jan 22	Jan 28	Apr 6	Jun 11	Jun 16	Jun 29
2010	Jan 1	Mar 2	Mar 11	Jun 23	Jun 26	Jun 30
Median Month	November	April	April	June	June	June

Source: Bottaro and Earley 2020.



Source: Bottaro and Chamberlain 2019.
Note: Data include brood years 2013–2021. Function is plotted for individual years (gray lines) and the across all years (black line)

Figure 26. Plotted Empirical Cumulative Distribution of Juvenile Steelhead Rotary Screw Trap Catch as a Function of Julian Day.

Table 32. Summary of Juvenile *O. Mykiss* Catch, Passage in the Lower American River Screw Trap, 2013–2021

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2021	Feb 7	Mar 23	Mar 31	May 25	May 31	Jun 3
2020	Feb 5	Mar 5	Mar 7	May 12	May 19	Jun 5
2019	Jan 20	Mar 13	Mar 16	Apr 23	Apr 24	Apr 29
2018	Mar 4	Mar 18	Mar 30	May 7	May 16	May 21
2017	Apr 26	Apr 28	May 2	Jun 21	Jun 22	Jun 22
2016	Jan 19	Mar 23	Mar 24	Apr 3	Apr 3	Apr 4
2015	Jan 18	Jan 19	Jan 20	May 3	May 3	May 4
2014	Jan 14	Mar 5	Mar 8	Apr 15	Apr 23	May 22
2013	Mar 14	Mar 24	Mar 28	May 27	May 29	May 31
Median Month	January	March	March	May	May	May

Source: CalFish 2022.

Table 33. Summary of Juvenile O. Mykiss Catch, Passage at Red Bluff Diversion Dam, 2006–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Jan 01	Jul 03	Jul 08	Sep 11	Sep 28	Dec 30
2019	Jan 12	May 09	May 15	Dec 17	Dec 21	Dec 28
2018	Jan 03	Apr 11	Apr 27	Sep 09	Sep 27	Dec 29
2017	Mar 09	Mar 19	Apr 28	Oct 03	Oct 31	Dec 31
2016	Jan 10	Jan 11	Apr 13	Sep 26	Oct 18	Dec 19
2015	Jan 23	Apr 16	Apr 19	Sep 20	Oct 19	Dec 29
2014	Jan 03	Feb 28	Feb 28	Aug 19	Sep 05	Dec 10
2013	Jan 11	Apr 22	May 04	Aug 23	Sep 04	Dec 31
2012	Jan 12	May 27	Jun 14	Sep 14	Oct 02	Dec 19
2011	Jan 01	Apr 28	May 09	Sep 21	Oct 07	Dec 30
2010	Jan 13	May 07	May 17	Sep 28	Oct 10	Dec 13
2009	Jan 12	May 22	Jun 25	Aug 28	Sep 13	Dec 25
2008	Jan 08	May 30	Jun 05	Sep 06	Sep 25	Dec 29
2007	Jan 08	Jul 14	Aug 02	Aug 19	Sep 04	Dec 31
2006	Jan 22	Apr 23	Apr 27	Sep 12	Oct 06	Dec 31
Median Month	January	May	May	August	September	December

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 34. Summary of Juvenile Unclipped O. Mykiss Catch in the Knights Landing Screw Trap, 2006–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Jan 27	Jan 27	Jan 27	Apr 30	Apr 30	Apr 30
2019	Jan 14	Jan 14	Jan 14	May 30	May 30	May 30
2018	Jan 12	Jan 12	Jan 12	Apr 27	Apr 27	Apr 27
2017	Feb 10	Feb 10	Feb 10	May 10	May 19	May 19
2016	Jan 17	Jan 17	Jan 17	Mar 29	Mar 29	Mar 29
2015	Feb 10	Feb 10	Feb 10	May 25	May 25	May 25
2014	Feb 13	Mar 2	Mar 2	Apr 1	Apr 5	Jun 2
2013	–	–	–	–	–	–
2012	Jan 27	Jan 27	Mar 18	Apr 5	Apr 5	Apr 5
2011	Feb 18	Feb 18	Feb 18	Feb 18	Feb 18	Feb 18
2010	Jan 19	Jan 19	Jan 27	Apr 28	May 3	May 3
2009	Jan 28	Jan 28	Feb 22	May 11	May 20	May 20
2008	Jan 19	Jan 19	Jan 19	May 22	May 22	May 22

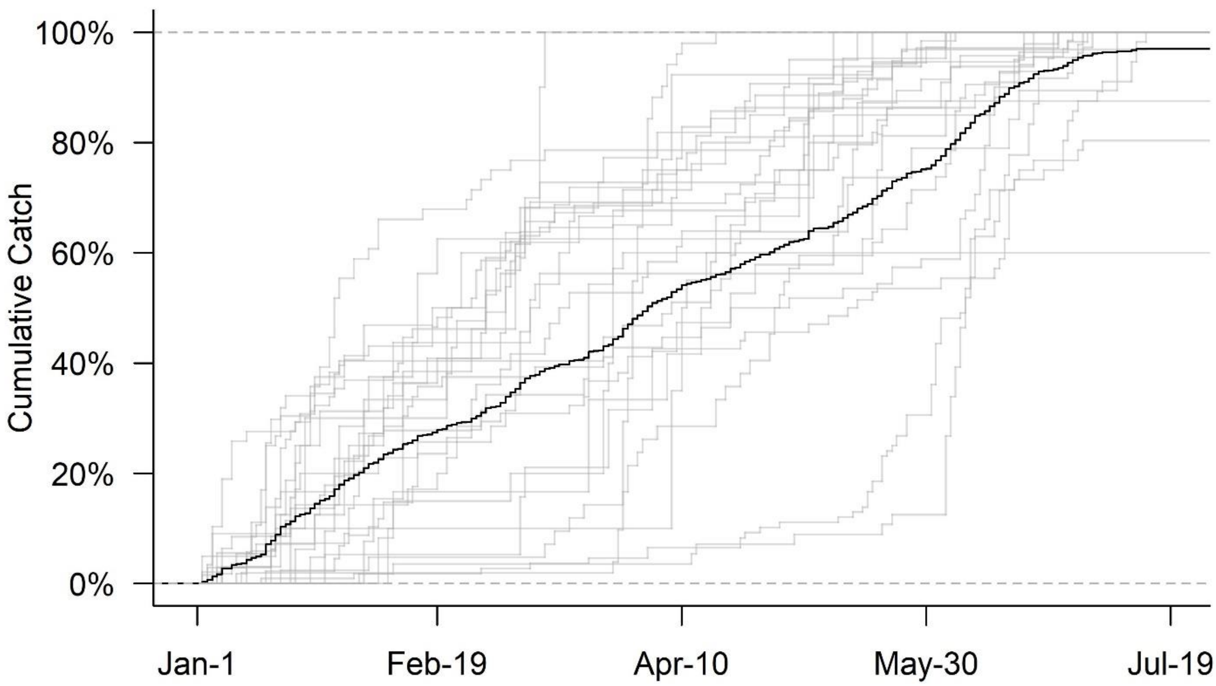
Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2007	Feb 13	Feb 13	Feb 13	Jun 1	Jun 1	Jun 1
2006	Jan 21	Jan 21	Jan 23	Apr 15	Apr 20	Apr 20
Median Month	January	January	January	April	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 35. Summary of Juvenile Unclipped *O. Mykiss* Catch in the Stanislaus River Caswell Screw Trap, 2013–2021

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2021	Jan 24	Jan 27	Jan 29	May 6	May 12	Jun 2
2020	Jan 2	Jan 29	Apr 7	Jun 2	Jun 15	Jun 18
2019	Jan 16	Jan 17	Jan 18	May 25	Jun 7	Jun 20
2018	Feb 7	Feb 9	Feb 14	May 5	May 7	May 10
2017	Jan 20	Jan 21	Jan 23	Mar 11	Mar 12	Mar 12
2016	Jan 10	Mar 27	Mar 28	Apr 3	Apr 6	Apr 16
2015	Feb 9	Feb 9	Feb 10	Apr 30	May 2	May 15
2014	Jan 6	Jan 16	Jan 20	May 5	May 20	Jun 25
2013	Jan 2	Jan 7	Jan 14	May 25	Jun 4	Jun 25
2012	Jan 14	Apr 7	May 13	Jun 21	Jun 28	Jul 2
2011	Jan 3	Jan 16	Jan 21	Dec 3	Dec 8	Dec 13
2010	Jan 21	Jan 24	Jan 28	Aug 9	Oct 16	Oct 18
2009	Jan 15	Jan 30	Feb 1	Jun 10	Jun 17	Jun 30
2008	Jan 9	Jan 15	Jan 15	May 10	May 18	Jul 1
2007	Jan 5	Jan 15	Feb 7	Jun 13	Jun 23	Jun 28
2006	Feb 3	Apr 12	Apr 12	Jul 1	Jul 10	Jul 13
2005	Jan 4	Jan 6	Jan 22	May 24	Jun 3	Jun 3
2004	Jan 3	Jan 4	Jan 6	May 20	May 22	May 25
2003	Jan 5	Jan 10	Jan 14	May 9	May 24	Jun 2
2002	Jan 11	Jan 18	Jan 18	Apr 23	May 18	Dec 19
2001	Jan 2	Jan 16	Jan 17	May 22	May 23	Jun 4
2000	Jan 6	Jan 12	Jan 25	Dec 14	Dec 19	Dec 28
1999	Jan 18	Mar 12	Mar 17	Jun 6	Jun 22	Jun 24
1998	Jan 27	Mar 5	Mar 7	Jun 19	Jul 7	Jul 7
1996	Feb 4	Feb 6	Feb 11	Apr 7	Apr 11	May 18
Median Month	January	January	January	May	June	June

Source: CalFish 2022; Pacific States Marine Fisheries Commission Caswell screw trap.



Source: CalFish 2022.
Note: Data include brood years 1996–2021 (less 1997). Function is plotted for individual years (gray lines) and the across all years (black line). Data available on Calfish Stanislaus River – RST Monitoring.

Figure 27. Plotted Empirical Cumulative Distribution of Stanislaus River Caswell Juvenile Steelhead Rotary Screw Trap Catch as a Function of Julian Day.

Table 36. Summary of Juvenile Unclipped O. Mykiss Catch, Passage from the Mossdale Trawls by USWFS, 2006–2020.

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	–	–	–	–	–	–
2019	–	–	–	–	–	–
2018	May 06	May 06	May 06	May 06	May 06	May 06
2017	Apr 10	Apr 10	Apr 10	May 08	May 08	May 08
2016	–	–	–	–	–	–
2015	Apr 07	Apr 07	Apr 07	Apr 30	Apr 30	Apr 30
2014	Mar 31	Apr 09	Apr 13	May 21	May 28	May 28
2013	Mar 05	Mar 05	Apr 04	May 31	Jun 02	Jun 02
2012	Jan 07	Apr 02	Apr 04	May 17	May 18	May 18
2011	Apr 05	Apr 05	Apr 06	May 22	May 24	May 24
2010	Mar 30	Mar 30	Mar 30	May 24	May 24	May 24
2009	Apr 22	Apr 22	Apr 22	May 14	May 14	May 14

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2008	Apr 08	Apr 08	Apr 08	Apr 08	Apr 08	Apr 08
2007	May 08	May 08	May 08	May 29	May 29	May 29
2006	Feb 28	Apr 02	Apr 06	May 14	May 19	May 29
Median Month	March	April	April	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.
USWFS = U.S. Fish and Wildlife Service.

4.7 Delta Juvenile and Yearling Migration

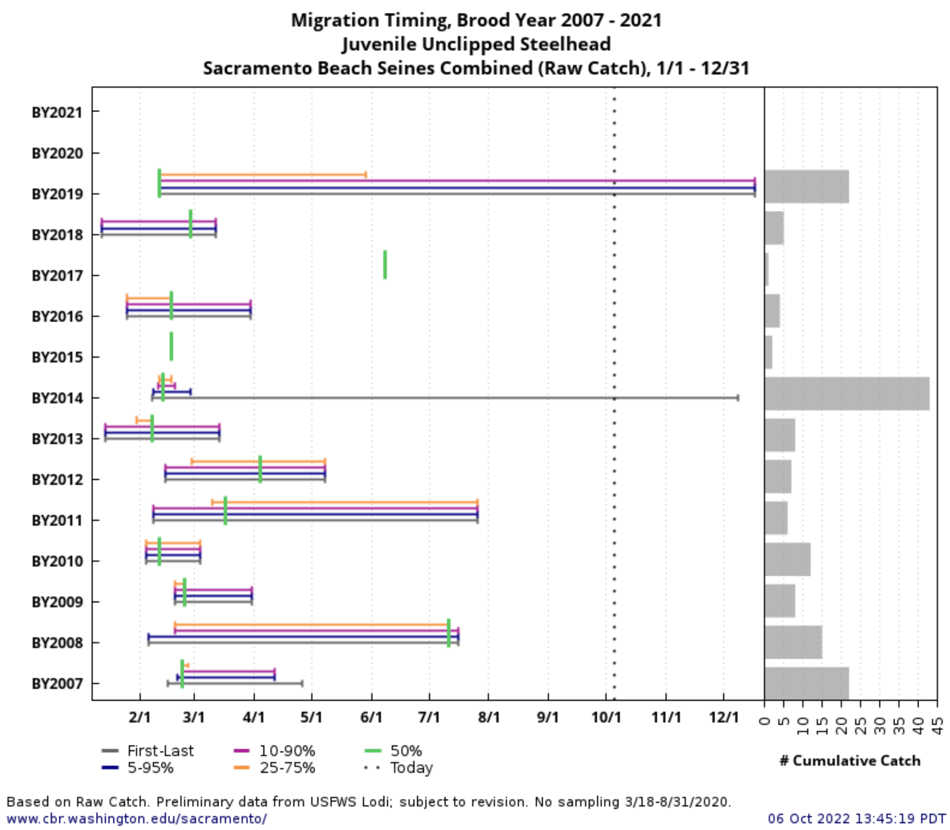
Juvenile steelhead can be found in all waterways of the Delta, but particularly in the main channels leading from their natal river systems (National Marine Fisheries Service 2009). Delta entry is monitored at the Sacramento beach seines and trawl locations. Delta exit is monitored at the Chipps Island trawl location. Juvenile steelhead are recovered in trawls from February through May at Chipps Island and Sacramento and through combined catch data from Sacramento beach seines in the Delta January through March. Chipps Island catch data indicate a difference in the emigration timing between natural origin (i.e., unclipped) and hatchery-reared (i.e., clipped) steelhead smolts from the Sacramento River and eastside tributaries. Hatchery fish are typically recovered at Chipps Island from January through March, with a peak in February and March corresponding to the schedule of hatchery releases of steelhead smolts from the Central Valley hatcheries (Nobriga and Cadrett 2001; U.S. Bureau of Reclamation 2008:3–11). The timing of unclipped steelhead emigration is more protracted and, based on salvage records at the CVP and SWP fish-collection facilities, emigration occurs over approximately 6 months, with the highest levels of recovery in February through June (Figure 30 and Figure 31; Aasen 2011, 2012). Median timing of juveniles captured in the Sacramento beach seines is January through March, but with potential for year-round presence of juveniles (see Brood Year 2018–2019: Figure 28, Table 37, and Table 38). Trawl data at Sherwood Harbor, south of Sacramento, shows juvenile migration is first detected in January, with 90% median passage occurring by May, and the last passage occurring in June (Table 37 and Table 39).

Emigrating steelhead smolts enter the Delta primarily from the Sacramento and San Joaquin rivers. Mokelumne River steelhead smolts can follow either the north or south branches of the Mokelumne River, through the central Delta, before entering the San Joaquin River, although some fish may enter farther upstream if they diverge from the south branch of the Mokelumne River into Little Potato Slough. Calaveras River steelhead smolts enter the San Joaquin River downstream of the Port of Stockton. Although CDFW has routinely documented steelhead in trawls at Mossdale since 1988 (San Joaquin River Group Authority 2011), it is unknown whether successful emigration occurs outside the historical-seasonal installation of the barrier at the Head of Old River (between April 15 and May 15 in most years). Prior to the installation of the Head of Old River fish-control gate, steelhead smolts exiting the San Joaquin River Basin could follow one of two routes to the ocean, either staying in the mainstem San Joaquin River, through the central Delta, or entering the Head of Old River and migrating through the south Delta and its associated network of channels and waterways.

Table 37. Summary of Juvenile *O. Mykiss* Passage in the Delta by Median Month from USFWS Raw Catch Data on SacPAS

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
Sacramento Seines	January	February	February	March	March	March
Sacramento Trawl	February	February	February	May	May	May
Chipps Island	February	February	February	May	May	May
Delta Juvenile	January	February	February	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.
Note: Delta juvenile timing is based on the earliest or latest observation of that percentile.
USFWS = U.S. Fish and Wildlife Service.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

Figure 28. Unclipped *O. Mykiss* Juvenile Migration Timing, Sacramento Beach Seines 2007–2020.

Table 38. Unclipped *O. Mykiss* Juvenile Migrating Timing, Sacramento Beach Seines, 2006–2019

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2019	Feb 11	Feb 11	Feb 11	Dec 17	Dec 17	Dec 17
2018	Jan 12	Jan 12	Jan 12	Mar 12	Mar 12	Mar 12
2017	Jun 08	Jun 08	Jun 08	Jun 08	Jun 08	Jun 08
2016	Jan 25	Jan 25	Jan 25	Mar 29	Mar 29	Mar 29
2015	Feb 17	Feb 17	Feb 17	Feb 17	Feb 17	Feb 17
2014	Feb 07	Feb 08	Feb 10	Feb 19	Feb 27	Dec 08
2013	Jan 14	Jan 14	Jan 14	Mar 14	Mar 14	Mar 14
2012	Jan 15	Feb 14	Feb 14	May 07	May 07	May 07
2011	Jan 16	Feb 08	Feb 08	Jul 26	Jul 26	Jul 26
2010	Jan 17	Feb 04	Feb 04	Mar 04	Mar 04	Mar 04
2009	Jan 18	Feb 19	Feb 19	Mar 31	Mar 31	Mar 31
2008	Jan 19	Feb 05	Feb 19	Jul 15	Jul 15	Jul 15
2007	Jan 20	Feb 20	Feb 23	Apr 12	Apr 12	Apr 26
2006	Jan 21	Feb 23	Feb 23	Feb 28	May 23	May 23
Monthly Median	January	February	February	March	March	March

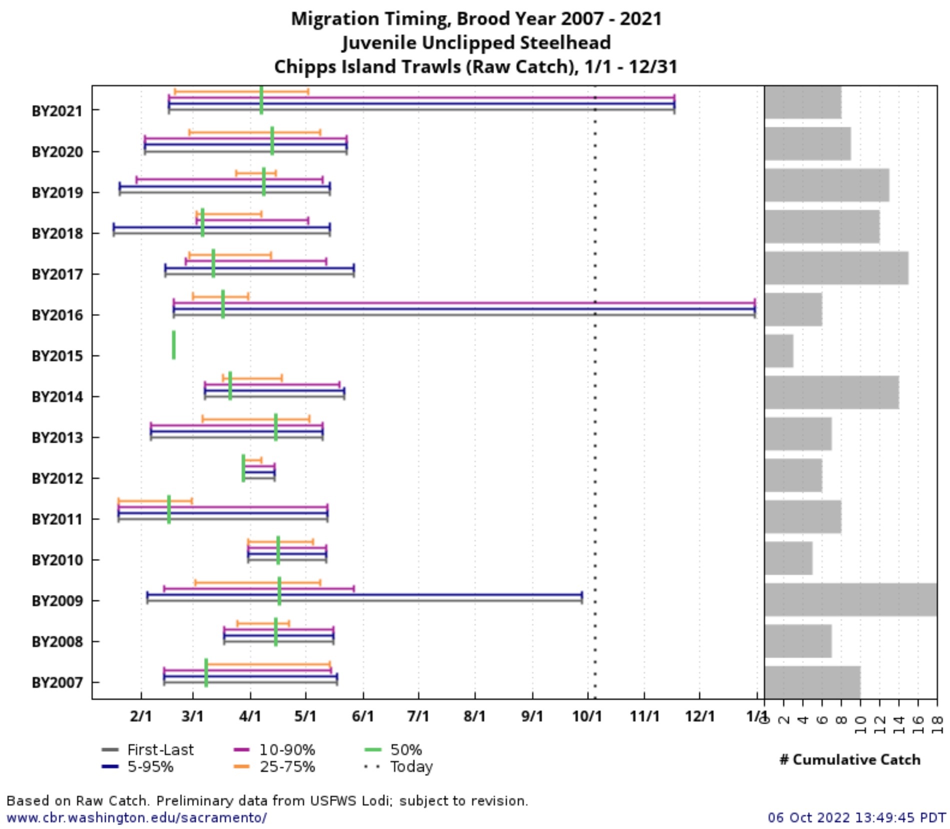
Source: University of Washington, School of Aquatic and Fishery Science 2022.

Table 39. Unclipped *O. Mykiss* Juvenile Migrating Timing, Sacramento Trawl at Sherwood Harbor, 2006–2020

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2020	Jan 13	Jan 13	Jan 13	May 22	May 22	May 22
2019	Jan 25	Jan 25	Feb 10	Apr 21	May 28	May 28
2018	Feb 27	Feb 27	Feb 27	May 14	May 14	May 14
2017	Feb 23	Feb 23	Feb 23	May 25	Jun 02	Jun 02
2016	–	–	–	–	–	–
2015	Apr 20	Apr 20	Apr 20	Apr 20	Apr 20	Apr 20
2014	Feb 11	Feb 11	Feb 11	Apr 07	Apr 07	Apr 07
2013	Apr 12	Apr 12	Apr 12	May 31	May 31	May 31
2012	Jan 27	Jan 27	Jan 27	May 01	May 01	May 01
2011	May 10	May 10	May 10	Jun 21	Jun 21	Jun 21
2010	Feb 08	Feb 08	Feb 08	Jun 10	Jun 10	Jun 10
2009	May 02	May 02	May 02	May 07	May 07	May 07
2008	Jan 11	Jan 11	Jan 11	Jan 11	Jan 11	Jan 11
2007	Feb 12	Feb 12	Feb 12	Jun 12	Jun 12	Jun 12

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2006	Feb 15	Feb 15	Feb 15	Jun 14	Jun 14	Jun 14
Median Month	February	February	February	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022

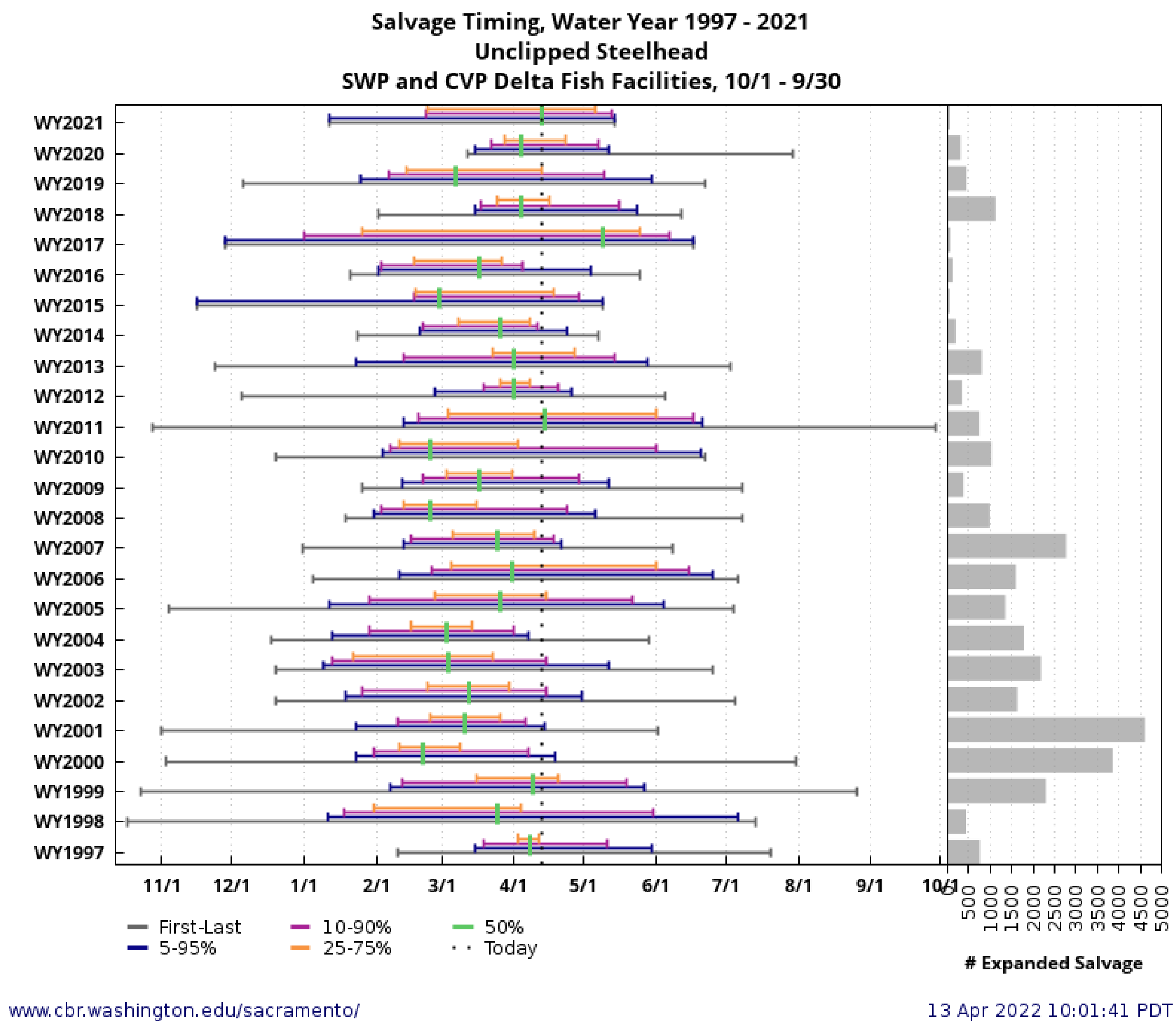
Figure 29. Unclipped *O. Mykiss* Juvenile Migration Timing, Chipps Island Migration Timing, 2006–2021.

Table 40. Unclipped O. Mykiss Juvenile Migration Timing, Chipps Island Migration Timing, 2006–2021

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Final
2021	Feb 16	Feb 16	Feb 16	Nov 17	Nov 17	Nov 17
2020	Feb 03	Feb 03	Feb 03	May 11	May 22	May 22
2019	Jan 29	Jan 29	Jan 29	May 10	May 14	May 14
2018	Jan 17	Jan 17	Mar 03	May 02	May 14	May 14
2017	Feb 14	Feb 14	Feb 25	May 12	May 27	May 27
2016	Feb 18	Feb 18	Feb 18	Dec 30	Dec 30	Dec 30
2015	Feb 18	Feb 18	Feb 18	Feb 18	Feb 18	Feb 18

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Final
2014	Mar 07	Mar 07	Mar 07	May 19	May 22	May 22
2013	Feb 06	Feb 06	Feb 06	May 10	May 10	May 10
2012	Mar 27	Mar 27	Mar 27	Apr 13	Apr 13	Apr 13
2011	Jan 19	Jan 19	Jan 19	May 13	May 13	May 13
2010	Mar 31	Mar 31	Mar 31	May 12	May 12	May 12
2009	Feb 04	Feb 04	Feb 13	May 27	Sep 28	Sep 28
2008	Mar 17	Mar 17	Mar 17	May 15	May 15	May 15
2007	Feb 13	Feb 13	Feb 13	May 15	May 18	May 18
2006	Feb 09	Feb 13	Mar 03	Jun 09	Jun 14	Jun 26
Median Month	February	February	February	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

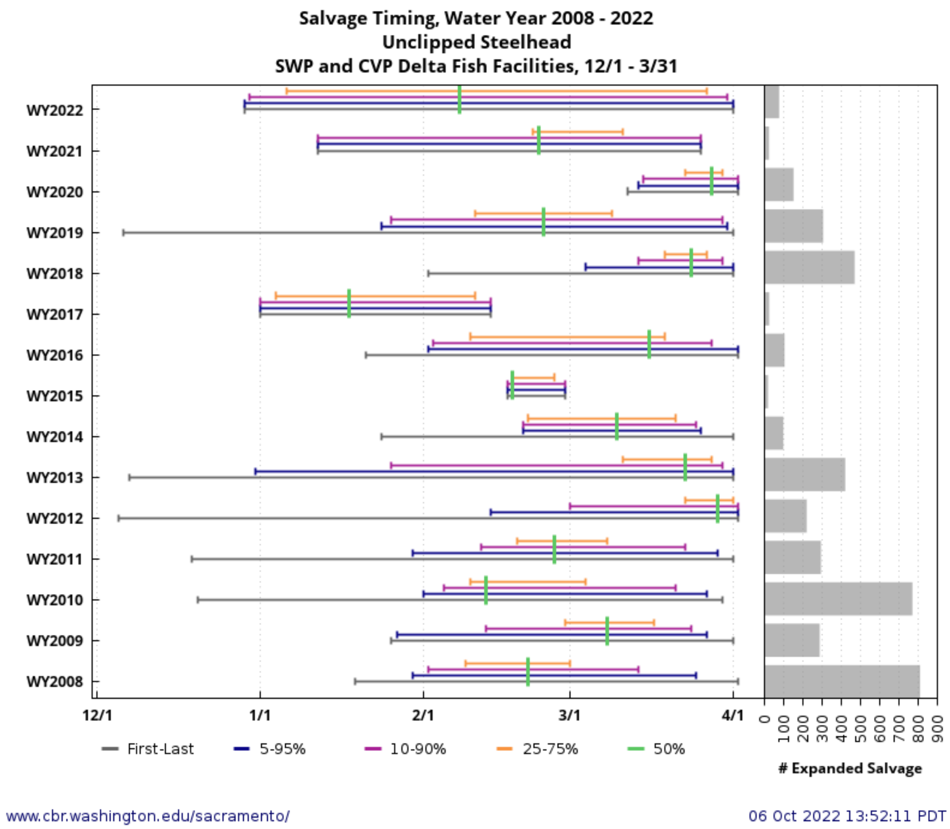
Figure 30. Unclipped *O. Mykiss* Juvenile Migration Timing, Salvage at CVP and SWP Fish Facilities, 2006–2021.

Table 41. Unclipped *O. Mykiss* Juvenile Migration Timing, Salvage at CVP and SWP Fish Facilities, 2006–2021

Water Year	First	5%	10%	90%	95%	Last
2021	1/11/2021	1/11/2021	2/21/2021	5/12/2021	5/13/2021	5/13/2021
2020	3/10/2020	3/13/2020	3/20/2020	5/5/2020	5/10/2020	7/28/2020
2019	12/6/2018	1/24/2019	2/5/2019	5/9/2019	5/29/2019	6/21/2019
2018	2/1/2018	3/14/2018	3/17/2018	5/15/2018	5/23/2018	6/11/2018
2017	11/27/2016	11/27/2016	12/31/2016	6/6/2017	6/16/2017	6/16/2017
2016	1/20/2016	2/1/2016	2/2/2016	4/3/2016	5/2/2016	5/23/2016

Water Year	First	5%	10%	90%	95%	Last
2015	11/16/2014	11/16/2014	2/16/2015	4/28/2015	5/8/2015	5/8/2015
2014	1/23/2014	2/19/2014	2/20/2014	4/10/2014	4/23/2014	5/6/2014
2013	11/23/2012	1/22/2013	2/12/2013	5/13/2013	5/27/2013	7/2/2013
2012	12/5/2011	2/25/2012	3/17/2012	4/18/2012	4/24/2012	6/3/2012
2011	10/28/2010	2/12/2011	2/18/2011	6/16/2011	6/20/2011	9/28/2011
2010	12/20/2009	2/3/2010	2/6/2010	5/31/2010	6/19/2010	6/21/2010
2009	1/25/2009	2/11/2009	2/20/2009	4/28/2009	5/11/2009	7/7/2009
2008	1/18/2008	1/30/2008	2/2/2008	4/22/2008	5/4/2008	7/6/2008
2007	12/31/2006	2/12/2007	2/15/2007	4/17/2007	4/20/2007	6/7/2007
2006	1/4/2006	2/10/2006	2/24/2006	6/14/2006	6/24/2006	7/5/2006
2005	11/3/2004	1/11/2005	1/28/2005	5/21/2005	6/3/2005	7/3/2005
2004	12/18/2003	1/12/2004	1/28/2004	3/30/2004	4/5/2004	5/27/2004
2003	12/20/2002	1/8/2003	1/12/2003	4/14/2003	5/11/2003	6/24/2003
2002	12/20/2001	1/18/2002	1/25/2002	4/14/2002	4/29/2002	7/4/2002
2001	10/31/2000	1/22/2001	2/9/2001	4/5/2001	4/13/2001	6/1/2001
2000	11/3/1999	1/22/2000	1/30/2000	4/5/2000	4/17/2000	7/29/2000
1999	10/23/1998	2/6/1999	2/11/1999	5/18/1999	5/26/1999	8/25/1999
1998	10/17/1997	1/10/1998	1/17/1998	5/30/1998	7/5/1998	7/13/1998
1997	2/9/1997	3/14/1997	3/18/1997	5/10/1997	5/29/1997	7/19/1997
Median Month	December	January	February	May	May	June

Source: University of Washington, School of Aquatic and Fishery Science 2022.



Source: University of Washington, School of Aquatic and Fishery Science 2022.

Figure 31. Clipped *O. Mykiss* Juvenile Migration Timing, Salvage at SWP and CVP Fish Facilities, 1997–2021.

Table 42. Clipped O. Mykiss Juvenile Migration Timing, Salvage at SWP and CVP Fish Facilities, 1997–2021

Water Year	First	5%	10%	90%	95%	Last
2021	1/20/2021	2/6/2021	2/12/2021	4/28/2021	5/5/2021	5/11/2021
2020	10/17/2019	3/5/2020	3/9/2020	4/19/2020	4/23/2020	5/6/2020
2019	12/6/2018	1/24/2019	2/3/2019	3/23/2019	4/5/2019	6/7/2019
2018	1/21/2018	3/2/2018	3/3/2018	4/9/2018	4/14/2018	5/27/2018
2017	1/31/2017	2/6/2017	2/6/2017	5/10/2017	6/3/2017	6/3/2017
2016	1/19/2016	1/25/2016	2/1/2016	3/22/2016	3/28/2016	6/3/2016
2015	1/23/2015	1/30/2015	2/16/2015	3/11/2015	3/18/2015	4/23/2015
2014	2/18/2014	2/18/2014	2/18/2014	4/15/2014	4/24/2014	6/17/2014
2013	1/26/2013	1/30/2013	2/7/2013	4/22/2013	5/4/2013	7/4/2013
2012	1/25/2012	2/5/2012	2/16/2012	4/17/2012	4/23/2012	7/7/2012
2011	1/19/2011	1/24/2011	1/29/2011	6/12/2011	6/20/2011	6/29/2011

Water Year	First	5%	10%	90%	95%	Last
2010	1/19/2010	1/27/2010	2/3/2010	3/8/2010	3/21/2010	6/24/2010
2009	1/18/2009	2/16/2009	2/18/2009	3/30/2009	4/8/2009	5/23/2009
2008	1/20/2008	1/28/2008	1/31/2008	3/4/2008	3/23/2008	7/8/2008
2007	1/25/2007	2/14/2007	2/22/2007	4/10/2007	4/16/2007	5/31/2007
2006	2/2/2006	2/22/2006	2/27/2006	3/19/2006	3/21/2006	6/4/2006
2005	1/22/2005	1/28/2005	1/29/2005	4/4/2005	4/24/2005	5/31/2005
2004	1/19/2004	2/8/2004	2/14/2004	3/7/2004	3/12/2004	4/12/2004
2003	12/21/2002	1/10/2003	1/13/2003	2/26/2003	3/23/2003	6/9/2003
2002	1/14/2002	1/21/2002	1/25/2002	3/23/2002	3/30/2002	5/8/2002
2001	12/14/2000	2/1/2001	2/8/2001	3/17/2001	3/22/2001	5/5/2001
2000	1/1/2000	1/20/2000	1/28/2000	2/29/2000	3/10/2000	5/28/2000
1999	1/16/1999	1/16/1999	1/21/1999	4/23/1999	4/30/1999	6/9/1999
1998	12/16/1997	12/18/1997	1/5/1998	2/4/1998	2/10/1998	2/21/1998
1997	3/24/1997	3/24/1997	3/24/1997	3/24/1997	3/24/1997	3/24/1997
Median	January	January	February	March	April	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.

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5. Delta Smelt

Delta smelt are a small, euryhaline, pelagic fish species endemic to the San Francisco Estuary San Francisco Estuary in Northern California. Delta smelt are listed as threatened at the federal level and endangered at the state level. Primarily an annual species, their life cycle follows the seasons, hatching in spring in freshwater, mostly migrating to the low-salinity zone (i.e., less than 6 parts per thousand salinity) to rear in summer and fall and returning to freshwater in the winter to spawn (Bennett 2005; Interagency Ecological Program 2015). Most individuals within the population follow this semi-anadromous life history, but smaller portions of the population may remain resident completely in freshwater or completely in brackish water for the full life cycle (Hobbs et al. 2019). Delta smelt have a reproductive strategy that is more closely aligned with perennial species, characterized by low fecundity, low spawning frequency, and an extended spawning period. Each life stage of Delta smelt has specific environmental requirements (Bennett 2005). Delta smelt are generally found in the tidal freshwater and brackish portions of the San Francisco Estuary, from Suisun Marsh and Grizzly Bay to the Cache Slough Complex on the Sacramento River, although the location within the San Francisco Estuary varies with life stage (Bennett 2005; Merz et al. 2011). Their overall geographic distribution spans from the northern San Francisco Bay in the west to the confluence of the Sacramento and Feather Rivers in the northeast (individuals have been collected as far upstream as Knights Landing on the Sacramento River; Vincik and Julienne 2012) and the divergence of Old and San Joaquin Rivers in the south Delta (Merz et al. 2011).

Survey sampling captures life stage to characterize the timing of that life stage in the upper San Francisco Estuary. Overall, adult and subadult/juvenile delta smelt may be present year-round in the upper San Francisco Estuary, whereas larval delta smelt are generally present in the system between March and July.

Patterns of occurrence discussed further below are based on historical data because delta smelt today are close to extinction, with fewer than 50 total fish caught during monitoring during the calendar year of 2021. For the summary herein, three size classes were identified for delta smelt, defined by fork length (FL, in millimeters [mm]): larvae (<20-mm FL), juvenile (20-mm to 58-mm FL), and adult (>58-mm FL) life stages. For the online version of the tables, please see: https://bmahardja. github.io/spatiotemporal-domain/DeltaSmelt.html.

The following surveys were used to evaluate the occurrence of Delta smelt in the Bay-Delta:

1. San Francisco Bay Study (1994–2020)
2. Suisun Marsh Study (1994–2021)
3. Fall Midwater Trawl (1994–2020)
4. Spring Kodiak Trawl (2002–2021)
5. Delta Juvenile Fish Monitoring Program (1994–2020)

6. Enhanced Delta Smelt Monitoring (2016–2021)
7. 20-mm Survey (1995–2021)
8. Smelt Larval Survey (2009–2021)
9. Summer Townet Survey (1994–2021)

5.1 Adult Delta Smelt

Adult spawning migration generally occurs during the first flush of turbid freshwater following precipitation events in winter (Grimaldo et al. 2009; Sommer et al. 2011). Adults generally migrate from brackish waters in the low-salinity zone to freshwater spawning habitat in Suisun Marsh, the lower Sacramento River, the Cache Slough Complex, and the Napa River (Moyle et al. 1992; Merz et al. 2011). Delta smelt exhibit pre-spawning holding behavior similar to other migratory species. They hold for long periods of time, estimated to be at least a month, before spawning (Sommer et al. 2011). Hobbs et al. (2019) found that there was life-history diversity within the species surrounding all life stages, including spawning. The majority of fish studied were semianadromous; however, a small percentage resided either in freshwater or brackish water year-round. The study also found evidence of spawning occurring in fresh and brackish waters, further confirming residency. This confirms that Delta smelt have resident and migratory contingents within a year-class, also known as *partial migration* (Hobbs et al. 2019).

The 2022 Phase 1 of the USFWS Enhanced Delta Smelt Monitoring (EDSM) program focused on adult Delta smelt throughout eight regions of the San Francisco Estuary following the release of 55,733 captively produced fish between December 2021 and February 2022. Results show that all the fish captured were marked with either an adipose fin clip or a visible tag, signifying a recapture of a captively released fish. The fish were released in the Sacramento River at Rio Vista, in the Sacramento Deepwater Shipping Channel, and in Suisun Marsh. A total of 55 fish were recaptured, primarily in the three regions where they were released, with the exception of two adult fish recaptured in the lower San Joaquin region and one in the Cache Slough Complex. Fish were caught between mid-December and late March (USFWS EDSM Phase 1 2022).

Most adult delta smelt die after spawning, but a small proportion of adult delta smelt can reside for over a year in the upper San Francisco Estuary and spawn at age 2. Table 43 summarizes the occurrence of adult (i.e., >58 mm) Delta smelt as the cumulative percentage of fish from June 1 of the first year to May 31 of the following year. In general, a small percentage of >58-mm fish occur during June/July, reflecting fish entering their second year, with most occurring between November/ December and May, largely reflecting the prevailing one-year life-history pattern. The phenomenon of 1+-year-old adult delta smelt was more common in the 1990s, when the species was more abundant. The considerably higher fecundity of these older and larger fish (Damon et al. 2016) may be evidence of a survival tactic to ensure population persistence (Bennett 2005). Examples of overlapping cohorts of adult Delta smelt are shown on Figure 32 and Figure 33.

As shown on Figure 32 and Figure 33, adult Delta smelt are present in the San Francisco Estuary year-round. They are detected from the Napa River through to the east and south Delta and up through Cache Slough and the Sacramento Deepwater Shipping Channel from January to April, with the greatest densities detected in the Suisun Marsh and Bay and the confluence of the Sacramento and San Joaquin Rivers (Confluence). Adults also appear to be abundant in the Cache Slough Complex and San Joaquin River during February. In May, the detection of adults begins to decrease, with no adults detected in the Napa River. From June to August, the frequency of detection significantly decreases. In general, a small percentage of >58-mm fish occurs during June to August, reflecting fish entering their second year, with most occurring between November/December and May, largely reflecting the prevailing one-year life-history pattern. From September to December, the frequency of detection significantly increases in the regions of the Suisun Bay and Marsh, the Confluence, lower Sacramento River, Cache Slough, and the Sacramento Deepwater Shipping Channel. In November and December, Delta smelt are frequently detected in the lower San Joaquin River, in addition to the aforementioned regions.

Table 43. Adult (>58-mm) Delta Smelt Occurrence in the Bay-Delta

Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	6/1/1994	6/20/1994	11/23/1994	4/22/1995	5/6/1995	5/31/1995	2,017
1995	6/1/1995	9/25/1995	10/25/1995	5/10/1996	5/16/1996	5/31/1996	14,341
1996	6/3/1996	6/3/1996	6/8/1996	5/18/1997	5/27/1997	5/31/1997	951
1997	6/1/1997	6/8/1997	6/20/1997	5/1/1998	5/11/1998	5/30/1998	1,694
1998	6/1/1998	11/28/1998	12/15/1998	5/2/1999	5/11/1999	5/29/1999	4,773
1999	6/1/1999	10/7/1999	11/8/1999	3/07/2000	4/3/2000	5/31/2000	5,673
2000	6/7/2000	10/5/2000	11/8/2000	3/19/2001	4/27/2001	5/31/2001	1,686
2001	6/1/2001	7/3/2001	8/30/2001	3/06/2002	3/18/2002	5/25/2002	1,589
2002	6/4/2002	10/16/2002	12/7/2002	4/28/2003	5/2/2003	5/31/2003	2,436
2003	6/1/2003	10/9/2003	1/12/2004	4/19/2004	4/29/2004	5/20/2004	2,046
2004	6/2/2004	10/12/2004	11/23/2004	5/4/2005	5/16/2005	5/31/2005	2,103
2005	6/1/2005	6/24/2005	7/8/2005	4/17/2006	5/10/2006	5/31/2006	1,427
2006	6/1/2006	6/6/2006	6/21/2006	4/5/2007	4/5/2007	5/22/2007	1,091
2007	6/6/2007	10/3/2007	12/12/2007	4/22/2008	4/29/2008	5/30/2008	434
2008	6/6/2008	9/3/2008	12/16/2008	3/18/2009	4/15/2009	5/27/2009	766
2009	6/1/2009	8/4/2009	10/26/2009	4/22/2010	4/22/2010	5/26/2010	971
2010	6/7/2010	7/19/2010	8/16/2010	4/6/2011	4/11/2011	5/25/2011	904
2011	6/1/2011	9/7/2011	10/7/2011	4/17/2012	5/2/2012	5/25/2012	2,112
2012	6/1/2012	6/29/2012	7/13/2012	3/07/2013	4/4/2013	5/24/2013	870
2013	6/7/2013	7/24/2013	11/13/2013	4/8/2014	4/10/2014	5/8/2014	602
2014	6/2/2014	7/16/2014	9/11/2014	2/12/2015	3/11/2015	5/6/2015	190
2015	7/1/2015	8/3/2015	9/1/2015	4/4/2016	4/4/2016	5/23/2016	58
2016	6/7/2016	12/8/2016	12/8/2016	3/01/2017	3/08/2017	5/31/2017	465
2017	6/7/2017	7/20/2017	8/9/2017	2/14/2018	3/07/2018	3/22/2018	84
2018	7/9/2018	9/17/2018	9/24/2018	2/11/2019	2/12/2019	3/03/2019	45

Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
2019	11/29/2019	11/29/2019	12/4/2019	3/05/2020	3/16/2020	3/16/2020	18
Median Month	June	June	December	April	April	May	–

The summary is of the cumulative percentage of catch during the period June 1–May 31. Note that this generally spans two adult cohorts of delta smelt.

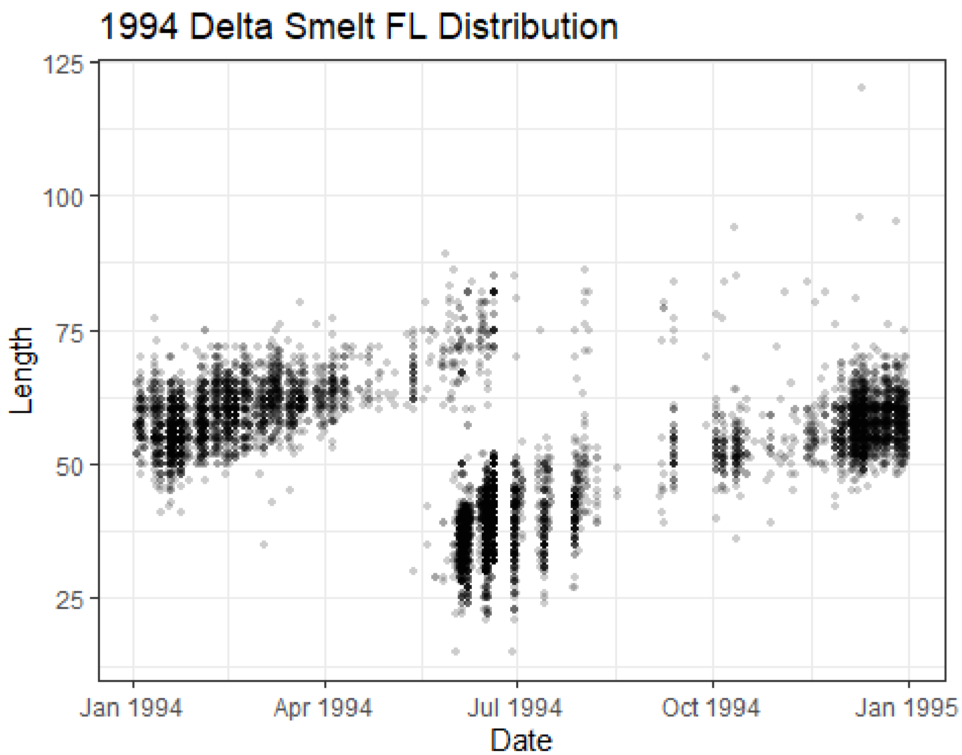


Figure 32. Distribution of Delta Smelt in 1994 Showing Overlapping 1- and 2-Year-Old Adult Delta Smelt.

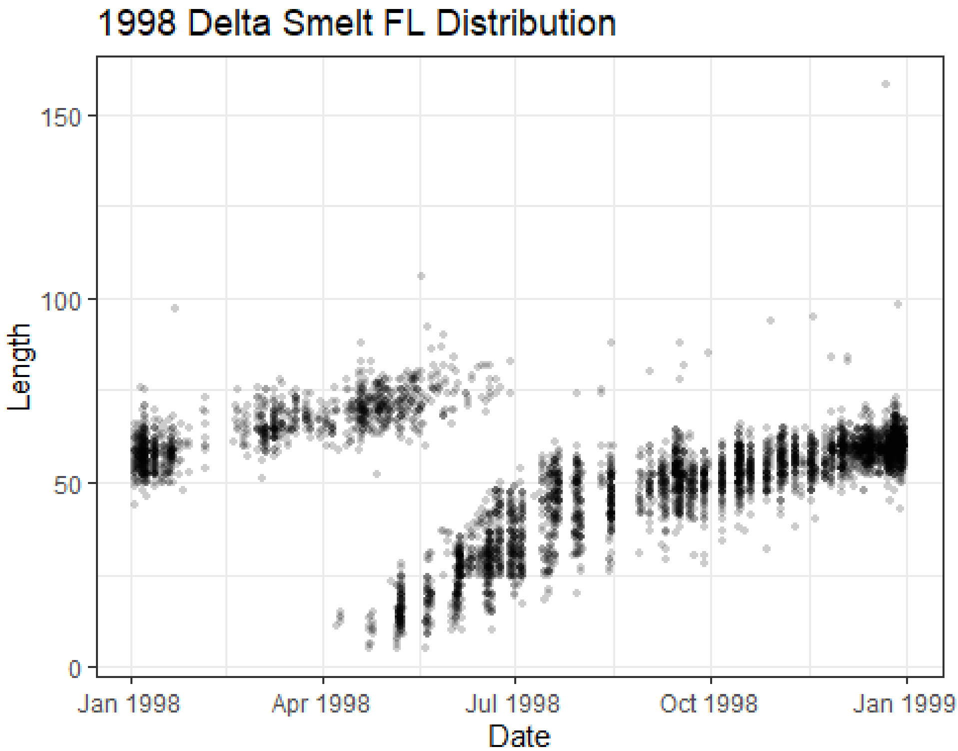


Figure 33. Distribution of Delta Smelt in 1998 Showing Overlapping 1- and 2-Year-Old Adult Delta Smelt.

5.2 Larval Delta Smelt

Larval Delta smelt are found in the San Francisco Estuary from March to July (Merz et al. 2011; Figure 32 and Figure 33). After hatching in spring, most larvae generally migrate downstream, toward the brackish portion of the San Francisco Estuary (Dege and Brown 2004). They are predominantly found in the upper Napa River, Suisun Marsh, Suisun Bay, the Confluence, lower San Joaquin River, lower Sacramento River, and the Cache Slough Complex; however, larvae were also observed more frequently than other life stages in the south and east Delta. Larvae are observed in the greatest densities in the Confluence (Merz et al. 2011). Optimal temperatures for larval survival are between 59°F–63°F (15°C and 17°C; Bennett 2005). Larval Delta smelt generally occur in low-salinity habitats (Sommer et al. 2011), with their habitat shifting upstream of Suisun Bay in drier years (Sommer and Mejia 2013).

The current abundance of larval and early juvenile Delta smelt appears to be very low, based on available monitoring. The 2022 Phase 2 of the EDSM program focused on postlarval and early juvenile Delta smelt throughout six regions of the San Francisco Estuary in April to July 2022. A total of 18 postlarval and juvenile fish were caught between April and early June 2022. All fish were caught in the Sacramento Deepwater Shipping Channel, except for 2 that were caught in Suisun Bay. No adults from the earlier releases (see discussion above for *Adult Delta Smelt*) were recaptured during Phase 2 (USFWS EDSM Phase 2 2022).

Table 44. Larval Delta Smelt (<20-mm) Occurrence in the Bay-Delta

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	6/2/1994	6/2/1994	6/2/1994	6/29/1994	6/29/1994	6/29/1994	2
1995	4/27/1995	5/10/1995	5/12/1995	7/19/1995	7/20/1995	8/7/1995	228
1996	4/10/1996	4/25/1996	4/29/1996	6/14/1996	6/26/1996	7/25/1996	2,007
1997	3/31/1997	4/28/1997	4/29/1997	6/11/1997	6/11/1997	7/24/1997	1,148
1998	4/8/1998	4/24/1998	5/6/1998	6/18/1998	6/20/1998	7/30/1998	229
1999	4/12/1999	4/16/1999	4/28/1999	7/8/1999	7/8/1999	8/3/1999	1,380
2000	3/20/2000	4/7/2000	5/1/2000	6/14/2000	6/14/2000	7/11/2000	2,007
2001	3/21/2001	4/7/2001	4/7/2001	5/5/2001	5/15/2001	6/30/2001	4,193
2002	4/2/2002	4/2/2002	4/15/2002	6/11/2002	6/14/2002	6/29/2002	300
2003	3/24/2003	3/26/2003	4/7/2003	6/18/2003	6/30/2003	7/3/2003	362
2004	3/29/2004	4/14/2004	4/26/2004	5/27/2004	6/8/2004	6/22/2004	309
2005	3/15/2005	4/27/2005	4/28/2005	6/6/2005	6/9/2005	7/8/2005	394
2006	4/21/2006	4/22/2006	5/5/2006	6/16/2006	6/29/2006	7/18/2006	587
2007	3/14/2007	3/16/2007	3/16/2007	6/5/2007	6/20/2007	6/20/2007	31
2008	4/14/2008	4/14/2008	4/14/2008	6/9/2008	6/9/2008	6/12/2008	62
2009	4/6/2009	4/6/2009	4/22/2009	6/15/2009	6/15/2009	7/1/2009	196
2010	3/17/2010	4/12/2010	4/26/2010	6/25/2010	7/8/2010	7/8/2010	430
2011	3/15/2011	4/26/2011	4/26/2011	6/21/2011	7/5/2011	7/7/2011	666
2012	3/19/2012	3/19/2012	3/20/2012	6/5/2012	6/6/2012	7/12/2012	948
2013	3/18/2013	3/18/2013	3/19/2013	5/20/2013	5/21/2013	7/3/2013	655
2014	3/3/2014	3/4/2014	3/18/2014	5/12/2014	5/13/2014	5/27/2014	132
2015	3/3/2015	3/24/2015	3/24/2015	5/13/2015	5/13/2015	6/23/2015	42
2016	3/14/2016	3/15/2016	3/15/2016	5/12/2016	5/25/2016	6/22/2016	67
2017	3/13/2017	3/15/2017	3/15/2017	5/24/2017	6/5/2017	7/5/2017	116
2018	3/12/2018	3/12/2018	3/12/2018	3/29/2018	4/11/2018	6/12/2018	33
2019	3/11/2019	3/11/2019	3/12/2019	5/21/2019	6/5/2019	6/5/2019	13
2020	3/17/2020	3/17/2020	3/17/2020	5/11/2020	5/19/2020	5/20/2020	38
Median Month	March	April	April	June	June	July	

Note: Cohort year set to calendar year.

5.3 Juvenile Delta Smelt

Juvenile Delta smelt generally are found in the San Francisco Estuary from June/July–December, although, based on a size range of 20–58 mm for juveniles, smaller numbers of juveniles occur before and after this general time period (Figure 32). Data from the monitoring programs suggest that an important rearing area for juveniles from June to December is in the North Delta Arc (Moyle et al. 2018), from Suisun Bay/Suisun Marsh, through the lower Sacramento River and up into the Cache Slough Complex/Sacramento Deep Water Shipping Channel area (Merz et al. 2011; Sommer et al. 2011).

The current abundance of juvenile Delta smelt appears to be very low based on available monitoring. The 2022 Phase 3 of the EDSM program began in July and, up to week 12 (September 19–22, 2022), had caught a total of six Delta smelt (three in the lower Sacramento River, two in the Sacramento Deepwater Shipping Channel, and one in Suisun Marsh), with extrapolated population abundance of 2,500 fish or less (USFWS EDSM Phase 3 2022).

Table 45. Juvenile (20–58-mm FL) Delta Smelt Occurrence in the Bay-Delta

Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	3/2/1994	6/5/1994	6/7/1994	12/15/1994	1/4/1995	2/24/1995	8,178
1995	3/3/1995	6/21/1995	7/6/1995	1/13/1996	1/16/1996	2/8/1996	8,143
1996	3/1/1996	5/24/1996	5/29/1996	12/7/1996	12/10/1996	2/5/1997	5,410
1997	3/4/1997	5/31/1997	6/9/1997	12/30/1997	1/9/1998	2/25/1998	3,028
1998	3/4/1998	6/5/1998	6/18/1998	12/30/1998	1/8/1999	2/23/1999	3,060
1999	3/8/1999	5/28/1999	6/9/1999	12/20/1999	1/5/2000	2/22/2000	5,048
2000	3/7/2000	5/31/2000	6/12/2000	12/15/2000	1/30/2001	2/26/2001	5,425
2001	3/2/2001	5/5/2001	5/5/2001	10/10/2001	10/10/2001	2/5/2002	2,490
2002	3/6/2002	5/14/2002	5/20/2002	10/8/2002	11/5/2002	1/24/2003	987
2003	5/6/2003	6/5/2003	6/12/2003	1/27/2004	1/27/2004	2/24/2004	1,324
2004	3/9/2004	5/20/2004	5/20/2004	10/4/2004	11/8/2004	2/24/2005	984
2005	3/2/2005	5/12/2005	5/16/2005	12/5/2005	1/18/2006	2/27/2006	895
2006	5/5/2006	5/20/2006	6/2/2006	1/10/2007	1/22/2007	2/22/2007	1,109
2007	3/6/2007	5/3/2007	6/6/2007	8/21/2007	12/12/2007	2/4/2008	188
2008	4/29/2008	5/20/2008	5/28/2008	1/14/2009	1/14/2009	2/13/2009	493
2009	3/18/2009	5/6/2009	5/20/2009	9/14/2009	1/14/2010	1/28/2010	557
2010	3/10/2010	5/10/2010	5/10/2010	8/11/2010	10/4/2010	2/10/2011	764
2011	4/1/2011	5/25/2011	6/7/2011	12/7/2011	1/19/2012	2/22/2012	2,213
2012	3/5/2012	5/21/2012	5/23/2012	7/26/2012	9/4/2012	2/6/2013	736
2013	4/8/2013	5/6/2013	5/6/2013	9/3/2013	9/16/2013	2/12/2014	1114
2014	3/12/2014	4/28/2014	5/12/2014	8/14/2014	12/8/2014	1/15/2015	307
2015	4/16/2015	4/27/2015	5/8/2015	9/1/2015	9/1/2015	12/1/2015	164
2016	3/9/2016	4/13/2016	4/27/2016	12/22/2016	12/28/2016	2/8/2017	132
2017	3/8/2017	5/9/2017	5/24/2017	9/18/2017	10/10/2017	1/10/2018	527
2018	5/2/2018	7/5/2018	7/17/2018	11/7/2018	12/28/2018	2/25/2019	160

Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
2019	4/29/2019	6/18/2019	7/3/2019	9/17/2019	10/22/2019	1/15/2020	153
2020	5/5/2020	5/11/2020	5/19/2020	9/23/2020	1/6/2021	1/26/2021	35
2021	5/6/2021	5/6/2021	5/6/2021	5/6/2021	5/6/2021	5/6/2021	1
Median Month	March	May	June	December	January	February	–

Note: The summary is of the cumulative percentage of catch during the period March 1 of the first year to the last day of February of the following year. Note that this may span two separate cohorts of delta smelt.

6. Longfin Smelt – Bay-Delta Distinct Population Segment

Longfin smelt are a small, euryhaline, anadromous, pelagic fish species that typically reach maturity at the end of their second year (Dryfoos 1965; Merz et al. 2013). Longfin smelt are found throughout the coastal Pacific Ocean from southern Alaska to central California (Moyle 2002) and in some Northern California watersheds (Garwood 2017), with the San Francisco Estuary population being the southernmost self-sustaining population along the Pacific Coast, and comprising the Bay-Delta DPS (Moyle 2002; Merz et al. 2013). Longfin smelt are listed as threatened under the California Endangered Species Act and designated as warranted, but precluded, under the federal Endangered Species Act.

Data from the status and trend fish monitoring surveys and Delta Regional Monitoring Program were used to characterize the distribution and timing of specific life stages of longfin smelt in the San Francisco Estuary by Merz et al. (2013). Overall, longfin smelt were observed from Tiburon in the central San Francisco Bay in the west to Colusa on the Sacramento River in the north, to Lathrop on the San Joaquin River to the east, and to Dumbarton Bridge in south San Francisco Bay to the south. Longfin smelt were frequently observed throughout a large portion of their range, including east San Pablo Bay, Suisun Marsh, Grizzly Bay, Suisun Bay, the Confluence, and the lower Sacramento River. Based on life-stage distribution, adult longfin smelt appear to have a larger upstream and downstream range than rearing juvenile longfin smelt (Merz et al. 2013).

The longfin smelt life cycle typically spans 2 to 3 years (Rosenfield 2010; Merz et al. 2013). Mature adult longfin smelt likely spawn near the low-salinity zone, where brackish and freshwater meet, during January to April (Grimaldo et al. 2017). Spawning habitat could also include freshwater locations in the lower Sacramento River, Cache Slough, eastern Suisun Bay, Suisun Marsh, Napa River, San Joaquin River, and tributaries to San Francisco Bay (Rosenfield 2010; Lewis et al. 2020). Recently, larval longfin smelt have been most prevalent in the Suisun, Confluence, and northern Delta regions and less common in the south Delta and Napa River regions. Larval fish densities in the San Francisco Estuary have substantially declined since 2009 (Eakin 2021). Juvenile fish rear in the upper San Francisco Estuary in brackish waters before migrating downstream to more saline waters, where they remain until adulthood (Hobbs et al. 2006; Rosenfield and Baxter 2007). Juveniles and subadults have been observed to migrate seasonally within the San Francisco Estuary, downstream during summer months, and upstream in the late fall and winter. It is possible that adult longfin smelt mature sexually as they migrate back toward spawning locations in freshwater. A shift in longfin smelt distribution toward freshwater was detected in late fall, continuing into the spring (Rosenfield 2010).

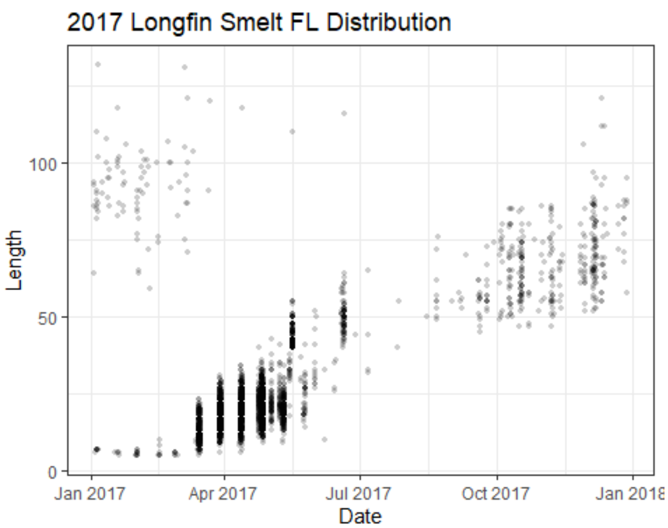
Some longfin smelt may reach sexual maturity in one year (Reclamation 2007). Most individuals die after spawning, but a few females may survive to spawn a second time (Moyle 1976). Older smelt spawn earlier in the season than younger ones, which may explain the extended spawning season. Longfin smelt smaller than the current approximate size for maturity ($\geq$ 85-mm FL; i.e., juvenile fish, Figure 3) are found within the Delta upstream of X2 during winter. Larval growth is slow, requiring almost 3 months to achieve 20-mm total length (c.f., months of first sizable abundance of yolk-sac larvae and 20-mm juveniles, Figure 5; Lewis et al. 2017).

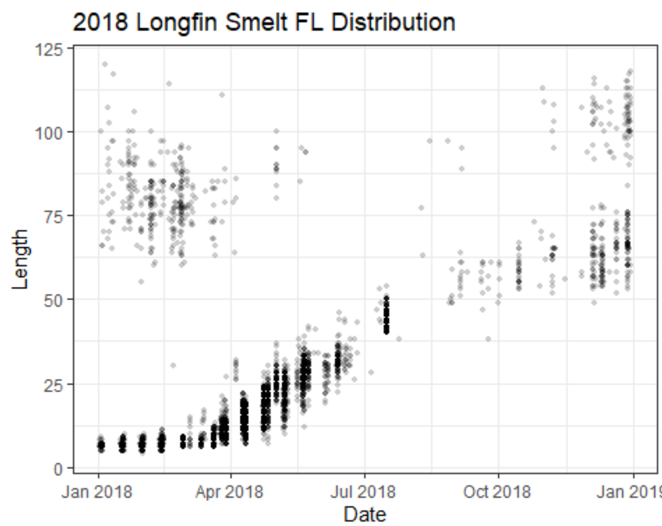
For the summary herein, three size classes were identified for longfin smelt, defined by FL (mm): larvae (<20-mm FL), juvenile (20-mm to 84-mm FL), and adult (>84-mm FL)

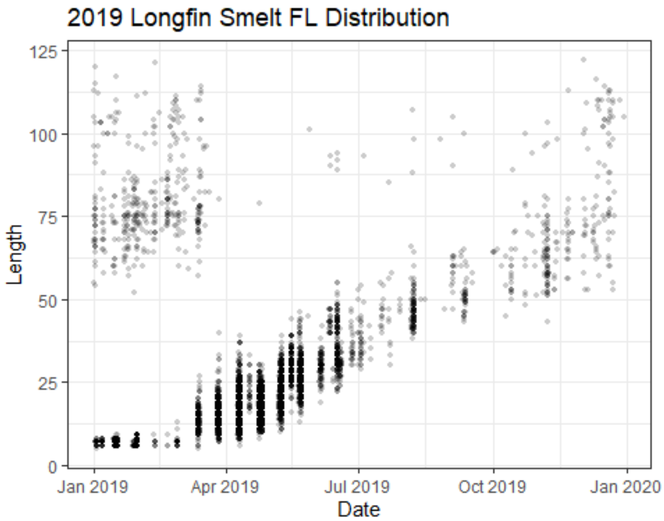
6.1 Brood Year Cutoff for the Life Stages

- Larvae: brood year = calendar year
- Juvenile: brood year = calendar year
- Adult: brood year starts on July 1 of current year to June 30 of the following year

Subadult and adult longfin smelt typically are present and caught from January to July, and then again starting October to November.







Source: Mahardja 2021.

Figure 34. Distribution of Longfin Smelt by Fork Length and Date in Sample Years 2017, 2018, and 2019.

The Bay-Delta can be split into three regions to better describe the spatial and temporal patterns of longfin smelt presence within the estuary (Figure 35).

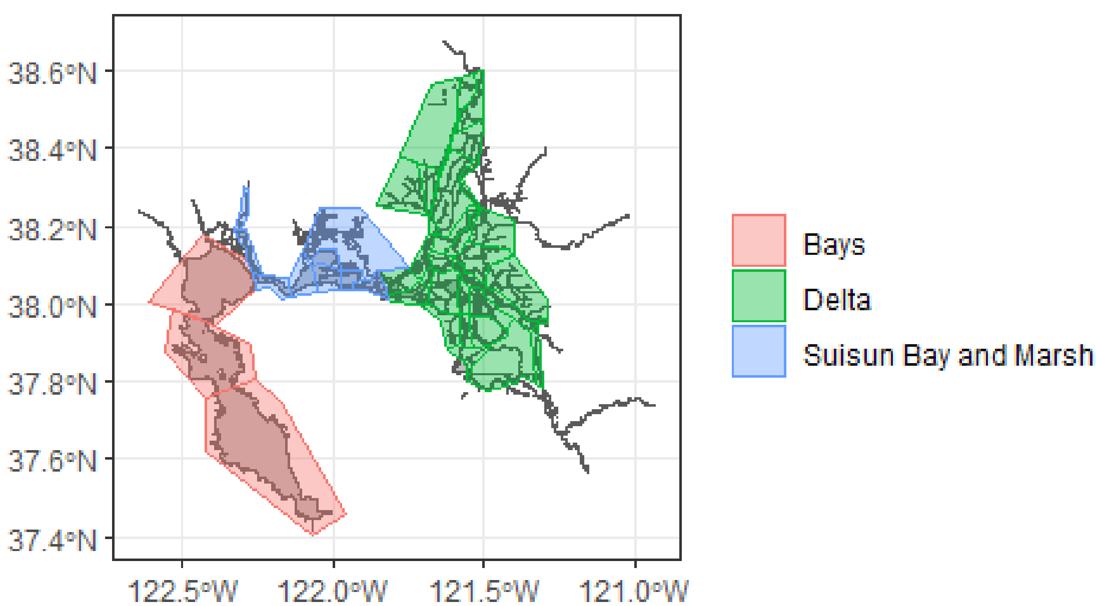


Figure 35. Regions Used to Summarize Longfin Smelt Occurrence in the San Francisco Estuary.

6.2 Bays (South Bay, San Francisco Bay, and San Pablo Bay)

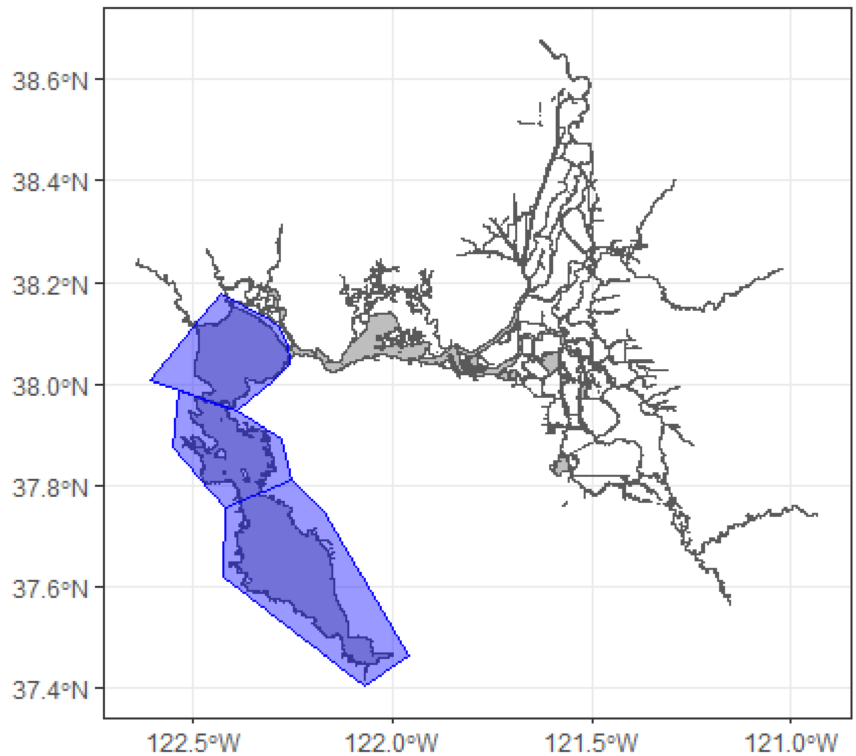


Figure 36. The Extent of the Defined Bay Region of South Bay, San Francisco Bay, and San Pablo Bay.

6.2.1 Adult Longfin Smelt

Adult longfin smelt generally are found in the Bay region from July through June of the following year; however, since 2014, the temporal distribution of adults has been more variable, and the sample size has shrunk to <20 individuals (Table 46). Adult longfin smelt were detected in south San Francisco Bay, suggesting that spawning may occur in the South Bay tributaries (Merz et al. 2013).

From 2011–2019, during October–April, Lewis et al. (2019) observed consistent populations of sexually mature adult longfin smelt in marshes and sloughs of the Coyote Creek watershed in the south San Francisco Bay. Larvae were also observed in April and May in the same area, during the wet years of 2017 and 2019. This finding corroborates Merz et al. (2013) and suggests that spawning in this region is likely during all years, with recruitment success being limited by freshwater outflow. High densities of adult longfin smelt were often detected in restored tidal marshes and their adjacent sloughs, areas where other studies did not sample (Lewis et al. 2019). This is consistent with the hypothesis that shallow tidal wetlands of the many small watersheds throughout San Francisco and San Pablo Bays are used for spawning, rearing, and feeding habitat (Lewis et al. 2019).

Table 46. Adult Longfin Smelt Presence in Bay Region

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	7/6/1994	9/12/1994	11/7/1994	5/3/1995	5/4/1995	5/9/1995	80
1995	6/10/1995	6/10/1995	1/8/1996	6/6/1996	6/10/1996	6/10/1996	203
1996	7/3/1996	8/12/1996	11/6/1996	4/14/1997	5/12/1997	6/10/1997	439
1997	7/9/1997	9/8/1997	11/5/1997	5/11/1998	5/11/1998	6/8/1998	181
1998	11/2/1998	12/3/1998	12/7/1998	5/27/1999	6/9/1999	6/15/1999	173
1999	7/8/1999	6/12/1999	6/12/1999	4/5/2000	5/10/2000	6/13/2000	119
2000	7/7/2000	8/24/2000	12/12/2000	4/16/2001	5/10/2001	6/7/2001	196
2001	6/17/2001	10/25/2001	11/14/2001	4/4/2002	4/4/2002	5/14/2002	154
2002	9/9/2002	12/4/2002	1/8/2003	6/2/2003	6/25/2003	6/25/2003	114
2003	6/17/2003	8/7/2003	10/14/2003	4/15/2004	5/5/2004	5/11/2004	67
2004	9/9/2004	9/9/2004	12/6/2004	6/9/2005	6/9/2005	6/13/2005	62
2005	6/11/2005	10/5/2005	11/8/2005	5/6/2006	5/18/2006	6/14/2006	95
2006	6/19/2006	9/7/2006	11/8/2006	5/14/2007	5/14/2007	6/5/2007	65
2007	6/11/2007	6/11/2007	8/8/2007	3/5/2008	6/5/2008	6/5/2008	15
2008	8/7/2008	11/5/2008	12/2/2008	4/13/2009	5/6/2009	6/3/2009	62
2009	6/13/2009	6/13/2009	6/13/2009	3/8/2010	3/10/2010	5/12/2010	41
2010	7/8/2010	12/6/2010	1/13/2011	5/4/2011	5/4/2011	6/8/2011	39
2011	7/7/2011	10/10/2011	12/7/2011	4/9/2012	5/10/2012	6/7/2012	77
2012	7/5/2012	6/10/2012	9/6/2012	3/11/2013	6/11/2013	6/11/2013	46
2013	7/3/2013	7/3/2013	7/9/2013	2/11/2014	5/19/2014	5/19/2014	19
2014	12/3/2014	12/3/2014	12/3/2014	5/12/2015	5/12/2015	5/12/2015	7
2016	12/12/2016	12/12/2016	12/12/2016	6/21/2017	6/21/2017	6/21/2017	8
2017	10/31/2017	10/31/2017	11/29/2017	2/27/2018	2/28/2018	2/28/2018	16
2018	12/6/2018	12/6/2018	12/6/2018	6/12/2019	6/17/2019	6/17/2019	10
2019	6/22/2019	6/22/2019	8/7/2019	2/3/2020	2/3/2020	2/3/2020	17
2020	9/23/2020	9/23/2020	9/23/2020	11/12/2020	11/12/2020	11/12/2020	5
Median Month	July	July	November	April	May	June	–

Note: The summary is of the cumulative percentage of catch during the period July 1–June 31. Note that this generally spans multiple adult cohorts of longfin smelt.

6.2.2 Larval Longfin Smelt

Larval longfin smelt are generally found in the Bay region from March–May (Table 47). Larvae were observed frequently in east San Pablo Bay and Grizzly Bay (Merz et al. 2013). Larvae were also observed in the marshes and sloughs of the Coyote Creek watershed in the south San Francisco Bay in April and May of wet years 2017 and 2019, after adults were observed in the same locations annually. This suggests that recruitment success is limited by freshwater outflow because high frequencies of larvae were not detected in nonwet years. The highest densities of larvae were within shallow, recently restored tidal marshes and their adjacent sloughs, which have not been sampled in other studies (Lewis et al. 2019). Larvae were predominantly found in Suisun Bay during low-flow years, and in the San Pablo and South Bays during high-flow years, reflecting the fluctuation in the low-salinity zone from freshwater outflow (Grimaldo et al. 2020).

The Napa River is also thought to be important spawning habitat; however, Eakin (2021) found that the Napa River had low densities of larvae, compared to Suisun Bay and Marsh and the Delta.

Table 47. Larval Longfin Smelt Presence in Bay

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1995	4/28/1995	4/28/1995	4/28/1995	5/26/1995	5/26/1995	6/09/1995	146
1996	4/14/1996	4/14/1996	4/14/1996	4/17/1996	4/17/1996	5/29/1996	2,759
1997	4/18/1997	4/18/1997	4/18/1997	4/18/1997	4/18/1997	4/18/1997	14
1998	4/10/1998	4/10/1998	4/10/1998	5/08/1998	5/08/1998	6/05/1998	398
1999	4/15/1999	4/15/1999	4/15/1999	5/13/1999	5/13/1999	6/25/1999	43
2000	3/24/2000	3/24/2000	3/24/2000	5/04/2000	5/04/2000	9/11/2000	298
2001	3/23/2001	3/23/2001	3/23/2001	4/06/2001	4/06/2001	4/20/2001	26
2002	3/22/2002	3/22/2002	3/22/2002	3/22/2002	6/01/2002	6/01/2002	13
2004	4/15/2004	4/15/2004	4/15/2004	4/15/2004	4/15/2004	4/15/2004	1
2005	4/02/2005	4/02/2005	4/02/2005	4/29/2005	4/29/2005	4/29/2005	8
2006	3/24/2006	4/22/2006	4/22/2006	5/06/2006	5/19/2006	5/19/2006	7,006
2007	3/30/2007	3/30/2007	3/30/2007	4/13/2007	4/13/2007	4/13/2007	6
2008	3/20/2008	3/20/2008	3/20/2008	3/20/2008	3/20/2008	3/20/2008	3
2009	3/13/2009	3/13/2009	3/13/2009	3/26/2009	4/24/2009	5/08/2009	31
2010	3/17/2010	3/17/2010	3/17/2010	4/14/2010	4/14/2010	5/26/2010	37
2011	3/17/2011	4/25/2011	4/25/2011	4/25/2011	4/25/2011	5/10/2011	2,972
2012	3/14/2012	3/14/2012	3/14/2012	5/23/2012	5/23/2012	5/23/2012	7
2013	4/10/2013	4/10/2013	4/10/2013	4/24/2013	4/24/2013	4/24/2013	8
2017	3/15/2017	3/15/2017	3/15/2017	4/26/2017	4/26/2017	5/10/2017	1,530
2018	3/28/2018	3/28/2018	3/28/2018	3/28/2018	3/28/2018	3/28/2018	1
2019	3/13/2019	3/13/2019	3/27/2019	4/24/2019	4/24/2019	5/22/2019	1,784
Median Month	March	March	April	April	April	May	–

6.2.3 Juvenile Longfin Smelt

Juvenile longfin smelt are generally found in the Bay-Delta region year-round (January–December); however, during the sampling season of 2021, just one juvenile longfin smelt was captured (Table 48). Prior to 2014, juveniles were frequently caught in San Pablo Bay, central San Francisco Bay, and subadults (described by Merz et al. 2013 as 41-100mm FL) in the south San Francisco Bay (Merz et al. 2013).

Table 48. Juvenile Longfin Smelt Presence in Bay

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	2/4/1994	2/4/1994	2/4/1994	1/25/1994	12/5/1994	12/5/1994	288
1995	1/5/1995	5/4/1995	5/9/1995	9/11/1995	11/14/1995	12/13/1995	14,009
1996	1/8/1996	1/8/1996	2/14/1996	12/9/1996	12/11/1996	12/12/1996	1,390
1997	1/7/1997	2/4/1997	3/4/1997	12/1/1997	12/1/1997	12/9/1997	969
1998	1/6/1998	2/11/1998	5/8/1998	11/2/1998	12/2/1998	12/8/1998	3927
1999	1/13/1999	2/8/1999	4/21/1999	9/7/1999	9/30/1999	11/29/1999	6,184
2000	1/24/2000	2/9/2000	3/24/2000	11/17/2000	12/12/2000	12/15/2000	2,352
2001	1/10/2001	1/10/2001	1/10/2001	9/10/2001	10/31/2001	12/11/2001	425
2002	2/14/2002	3/14/2002	4/6/2002	11/6/2002	12/4/2002	12/9/2002	638
2003	1/8/2003	1/9/2003	1/9/2003	12/1/2003	12/3/2003	12/18/2003	428
2004	1/7/2004	1/7/2004	1/13/2004	12/6/2004	12/7/2004	12/14/2004	432
2005	1/5/2005	1/5/2005	1/11/2005	10/11/2005	12/13/2005	12/20/2005	402
2006	1/9/2006	4/22/2006	4/22/2006	95/2006	10/4/2006	12/11/2006	7,929
2007	1/8/2007	1/8/2007	1/8/2007	9/13/2007	10/10/2007	12/5/2007	308
2008	1/28/2008	6/5/2008	6/10/2008	12/2/2008	12/4/2008	12/4/2008	237
2009	1/7/2009	1/12/2009	1/13/2009	6/13/2009	10/12/2009	12/9/2009	243
2010	1/6/2010	1/19/2010	2/9/2010	12/6/2010	12/6/2010	12/9/2010	151
2011	1/12/2011	2/10/2011	3/14/2011	12/5/2011	12/7/2011	12/12/2011	1,386
2012	1/5/2012	1/5/2012	15/2012	11/6/2012	11/6/2012	12/10/2012	328
2013	1/9/2013	1/9/2013	26/2013	12/4/2013	12/9/2013	12/10/2013	334
2014	1/13/2014	1/13/2014	1/13/2014	11/12/2014	12/4/2014	12/9/2014	66
2015	1/7/2015	1/7/2015	1/7/2015	6/9/2015	10/12/2015	10/12/2015	31
2016	5/4/2016	5/4/2016	5/4/2016	9/7/2016	11/29/2016	12/13/2016	32
2017	29/2017	3/29/2017	3/29/2017	67/2017	10/17/2017	12/13/2017	1,083
2018	2/26/2018	2/27/2018	5/29/2018	12/10/2018	12/11/2018	12/11/2018	406
2019	1/14/2019	3/13/2019	3/27/2019	9/12/2019	11/7/2019	12/11/2019	945
2020	1/28/2020	6/23/2020	6/27/2020	11/5/2020	11/5/2020	12/1/2020	321
2021	2/22/2021	2/22/2021	2/22/2021	2/22/2021	2/22/2021	2/22/2021	1
Median Month	January	January	January	December	December	December	–

6.3 Suisun Bay and Suisun Marsh

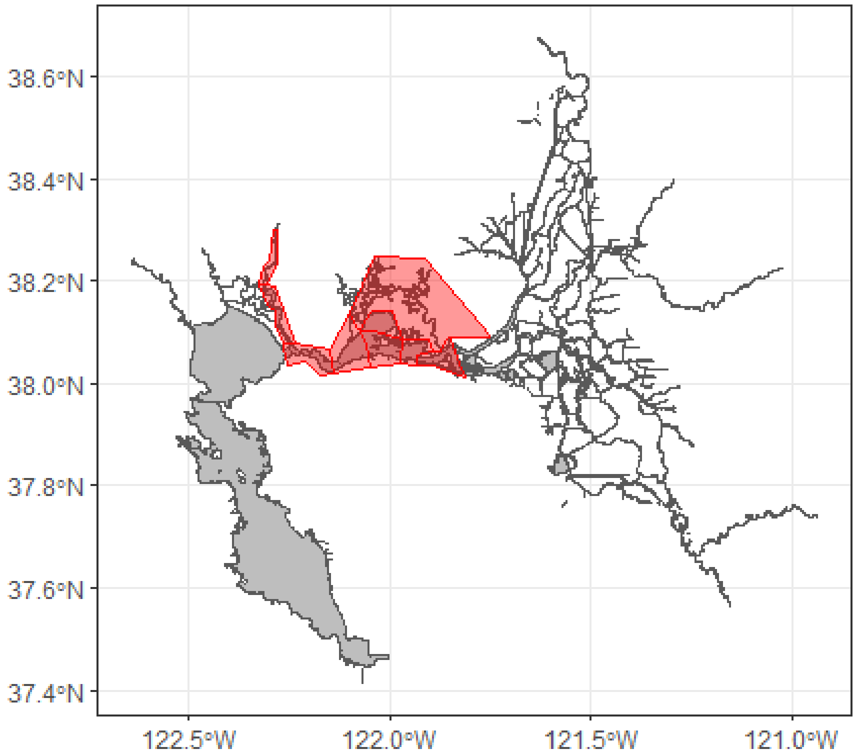


Figure 37. The Extent of the Defined Suisun Bay and Suisun Marsh Region.

6.3.1 Adult Longfin Smelt

Adult longfin smelt are generally found in the Suisun Bay and Marsh region from July through June of the following year. In recent years, occurrence has become more variable, but generally remained within this range (Table 49).

Table 49. Adult Longfin Smelt Presence in Suisun Marsh and Bay

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	7/3/1994	11/30/1994	12/7/1994	2/10/1995	3/6/1995	6/12/1995	1,929
1995	8/9/1995	1/3/1996	1/4/1996	5/13/1996	5/13/1996	6/27/1996	2,003
1996	7/10/1996	12/8/1996	12/17/1996	1/23/1997	3/3/1997	6/30/1997	11,703
1997	7/15/1997	12/6/1997	12/9/1997	1/12/1998	1/26/1998	6/3/1998	1,879
1998	9/16/1998	12/7/1998	12/9/1998	5/19/1999	6/8/1999	6/16/1999	1,421
1999	7/7/1999	12/4/1999	12/16/1999	3/6/2000	5/9/2000	6/14/2000	2,826
2000	7/11/2000	12/8/2000	12/20/2000	3/19/2001	4/12/2001	6/13/2001	1,761
2001	7/3/2001	12/12/2001	12/19/2001	1/22/2002	2/27/2002	6/18/2002	6,671
2002	7/10/2002	12/17/2002	12/24/2002	1/22/2003	1/31/2003	6/24/2003	1,913

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
2003	7/14/2003	12/14/2003	12/17/2003	1/12/2004	3/2/2004	6/30/2004	4,916
2004	7/7/2004	12/7/2004	12/16/2004	1/24/2005	2/14/2005	6/23/2005	1,438
2005	7/25/2005	12/7/2005	12/10/2005	2//9/2006	2/22/2006	4/21/2006	725
2006	7/17/2006	11/11/2006	12/17/2006	4/20/2007	5/6/2007	6/13/2007	211
2007	8/13/2007	12/1/2007	12/11/2007	2/12/2008	2/26/2008	4/2/2008	722
2008	10/22/2008	11/24/2008	12/9/2008	3/18/2009	4/15/2009	6/25/2009	376
2009	7/7/2009	12/9/2009	12/16/2009	3/10/2010	3/15/2010	5/27/2010	586
2010	10/7/2010	12/17/2010	12/17/2010	1/11/2011	2/25/2011	6/7/2011	238
2011	8/2/2011	10/26/2011	11/14/2011	3/6/2012	3/20/2012	6/5/2012	200
2012	9/10/2012	12/10/2012	12/17/2012	1/11/2013	2/15/2013	5/13/2013	1,038
2013	9//9/2013	11/12/2013	11/25/2013	2/26/2014	3/19/2014	5/15/2014	116
2014	9/3/2014	12/10/2014	12/19/2014	3/2/2015	4/7/2015	6/8/2015	113
2015	7/10/2015	7/10/2015	9/17/2015	2/12/2016	2/22/2016	2/24/2016	20
2016	11/8/2016	12/9/2016	12/19/2016	3/1/2017	3/6/2017	3/22/2017	77
2017	10/10/2017	11/7/2017	12/5/2017	5/3/2018	5/3/2018	5/23/2018	112
2018	8/15/2018	11/8/2018	12/4/2018	3/6/2019	3/15/2019	6/17/2019	173
2019	7/5/2019	10/23/2019	12/3/2019	2/28/2020	3/12/2020	6/11/2020	98
2020	7/7/2020	9/15/2020	10/15/2020	2/12/2021	2/12/2021	4/29/2021	32
Median Month	July	December	December	January	March	June	–

Source: Mahardja 2021.
Note: The summary is of the cumulative percentage of catch during the period July 1–June 31. Note that this generally spans multiple adult cohorts of longfin smelt.

6.3.2 Larval Longfin Smelt

Larval longfin smelt are generally found in the Suisun Bay and Marsh region from January–June (Table 50). According to the Smelt Larval Survey, larvae remain prevalent in the Suisun region (Eakin 2021). The low-salinity zone occurs within the Suisun Bay, making it an important nursery habitat for several native fish species, including longfin smelt (Meng and Matern 2001; Hobbs et al. 2006; Eakin 2021). Larval detection in the Suisun Bay and Marsh region was consistently high before 2014, becoming more variable after 2014 (Eakin 2021). Larvae were predominantly found in Suisun Bay during low-flow years and in San Pablo and South Bays during high-flow years, reflecting the fluctuation in the low-salinity zone from freshwater outflow (Grimaldo et al. 2020).

Table 50. Larval Longfin Smelt Presence in Suisun Marsh and Bay

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	3/18/1994	3/18/1994	3/18/1994	4/24/1994	4/24/1994	4/24/1994	4
1995	4/27/1995	4/27/1995	4/27/1995	5/12/1995	5/25/1995	6/27/1995	386
1996	4/12/1996	4/13/1996	4/16/1996	5/13/1996	5/14/1996	6/29/1996	9,816
1997	4/4/1997	4/4/1997	4/4/1997	4/19/1997	4/30/1997	6/1/1997	6,650
1998	4/10/1998	4/10/1998	4/10/1998	4/10/1998	4/10/1998	6/19/1998	10,706
1999	4/14/1999	4/15/1999	4/15/1999	4/30/1999	5/14/1999	7/23/1999	28,194
2000	3/23/2000	3/24/2000	4/6/2000	4/21/2000	4/22/2000	6/17/2000	100,249
2001	3/21/2001	3/22/2001	3/23/2001	4/20/2001	4/20/2001	7/12/2001	49,415
2002	3/20/2002	3/20/2002	3/21/2002	4/17/2002	4/18/2002	7/31/2002	24,859
2003	3/26/2003	3/26/2003	3/26/2003	4/11/2003	4/25/2003	6/7/2003	13,196
2004	4/1/2004	4/1/2004	4/1/2004	4/16/2004	4/28/2004	5/28/2004	7,392
2005	3/17/2005	3/17/2005	3/18/2005	4/27/2005	4/29/2005	6/15/2005	5,572
2006	3/23/2006	3/24/2006	3/24/2006	6/2/2006	6/3/2006	7/13/2006	709
2007	3/16/2007	3/17/2007	3/17/2007	4/13/2007	4/25/2007	5/12/2007	2,085
2008	3/6/2008	3/18/2008	3/19/2008	4/30/2008	4/30/2008	6/12/2008	10,952
2009	1/7/2009	2/4/2009	2/18/2009	4/8/2009	4/21/2009	6/11/2009	15,885
2010	1/4/2010	1/19/2010	2/1/2010	4/14/2010	4/28/2010	5/26/2010	24,279
2011	1/18/2011	1/31/2011	1/31/2011	5/11/2011	5/11/2011	6/30/2011	15,228
2012	1/9/2012	1/9/2012	1/23/2012	4/11/2012	5/8/2012	6/6/2012	13,242
2013	1/2/2013	2/11/2013	2/11/2013	4/10/2013	4/23/2013	7/3/2013	37,186
2014	1/6/2014	1/6/2014	1/21/2014	4/2/2014	4/15/2014	4/30/2014	2,996
2015	1/8/2015	1/8/2015	1/22/2015	3/20/2015	4/3/2015	4/28/2015	774
2016	1/4/2016	1/20/2016	2/3/2016	4/26/2016	4/26/2016	5/23/2016	1,149
2017	1/5/2017	3/16/2017	3/16/2017	5/10/2017	5/11/2017	5/25/2017	1,297
2018	1/3/2018	1/18/2018	1/31/2018	4/24/2018	4/25/2018	6/5/2018	4,270
2019	1/3/2019	1/17/2019	1/30/2019	5/10/2019	5/10/2019	6/5/2019	4,182
2020	1/8/2020	1/21/2020	1/21/2020	4/22/2020	4/28/2020	5/20/2020	2,753
2021	1/12/2021	1/13/2021	2/10/2021	4/7/2021	4/21/2021	5/19/2021	1,570
Median Month	January	January	January	April	April	June	–

Source: Mahardja 2021.

6.3.3 Juvenile Longfin Smelt

Juvenile longfin smelt are generally found in the Suisun Bay and Marsh region year-round from January to December (Table 51). Juvenile locations fluctuate between the bays and Suisun Marsh in relation to the low-salinity zone (Merz et al. 2013). The distribution of juveniles tends to follow the low-salinity zone (Dege and Brown 2004), which shifts downstream during wet years and upstream during dry years (Grimaldo et al. 2020). Suisun Bay has been identified as a critical nursery habitat for longfin smelt, providing ideal rearing conditions (Merz et al. 2013).

Table 51. Juvenile Longfin Smelt Presence in Suisun Marsh and Bay

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	1/3/1994	1/11/1994	3/8/1994	6/14/1994	6/17/1994	12/31/1994	10,221
1995	1/3/1995	4/28/1995	5/12/1995	12/6/1995	12/20/1995	12/28/1995	8,856
1996	1/3/1996	1/4/1996	1/11/1996	6/29/1996	7/29/1996	12/30/1996	15,855
1997	1/17/1997	4/4/1997	4/5/1997	12/15/1997	12/23/1997	12/31/1997	7,724
1998	1/3/1998	4/10/1998	4/10/1998	11/27/1998	12/15/1998	12/31/1998	24,064
1999	1/1/1999	4/15/1999	4/16/1999	8/16/1999	10/5/1999	12/31/1999	41,573
2000	1/2/2000	4/6/2000	4/7/2000	6/9/2000	9/1/2000	12/20/2000	63,160
2001	1/3/2001	2/6/2001	3/24/2001	5/30/2001	6/3/2001	12/31/2001	24,142
2002	1/2/2002	3/21/2002	3/22/2002	6/14/2002	10/18/2002	12/31/2002	18,238
2003	1/2/2003	3/26/2003	3/28/2003	5/22/2003	10/8/2003	12/31/2003	8,288
2004	1/2/2004	1/27/2004	2/2/2004	9/8/2004	12/9/2004	12/31/2004	4,078
2005	1/2/2005	1/5/2005	1/24/2005	6/9/2005	9/7/2005	12/28/2005	2,387
2006	1/10/2006	3/24/2006	3/24/2006	10/3/2006	11/7/2006	12/31/2006	1,324
2007	1/4/2007	1/10/2007	1/22/2007	5/26/2007	6/7/2007	12/30/2007	1,081
2008	1/2/2008	3/19/2008	3/19/2008	6/4/2008	6/18/2008	12/24/2008	10,528
2009	1/2/2009	3/12/2009	3/25/2009	6/11/2009	6/17/2009	12/23/2009	2,295
2010	1/5/2010	3/16/2010	3/17/2010	5/13/2010	5/25/2010	12/6/2010	4,829
2011	1/5/2011	3/16/2011	4/13/2011	6/17/2011	11/14/2011	12/30/2011	4,451
2012	1/4/2012	2/24/2012	3/28/2012	6/13/2012	6/27/2012	12/21/2012	1,470
2013	1/4/2013	4/9/2013	4/9/2013	6/6/2013	6/12/2013	12/11/2013	11,590
2014	1/7/2014	3/19/2014	3/20/2014	5/15/2014	6/18/2014	12/31/2014	1,081
2015	1/2/2015	1/6/2015	1/6/2015	5/12/2015	5/27/2015	6/9/2015	315
2016	2/3/2016	3/10/2016	3/29/2016	5/11/2016	5/24/2016	12/27/2016	739
2017	1/3/2017	3/30/2017	3/30/2017	10/18/2017	11/30/2017	12/28/2017	1,272
2018	1/4/2018	2/8/2018	3/28/2018	8/29/2018	12/20/2018	12/30/2018	1,672
2019	1/1/2019	3/28/2019	4/11/2019	6/6/2019	6/26/2019	12/23/2019	4,317
2020	1/3/2020	4/6/2020	4/22/2020	6/18/2020	6/22/2020	12/28/2020	1,538
2021	1/4/2021	4/7/2021	4/7/2021	5/19/2021	6/4/2021	8/11/2021	2,206
Medina Month	January	March	March	June	June	December	–

Sacramento and San Joaquin Delta

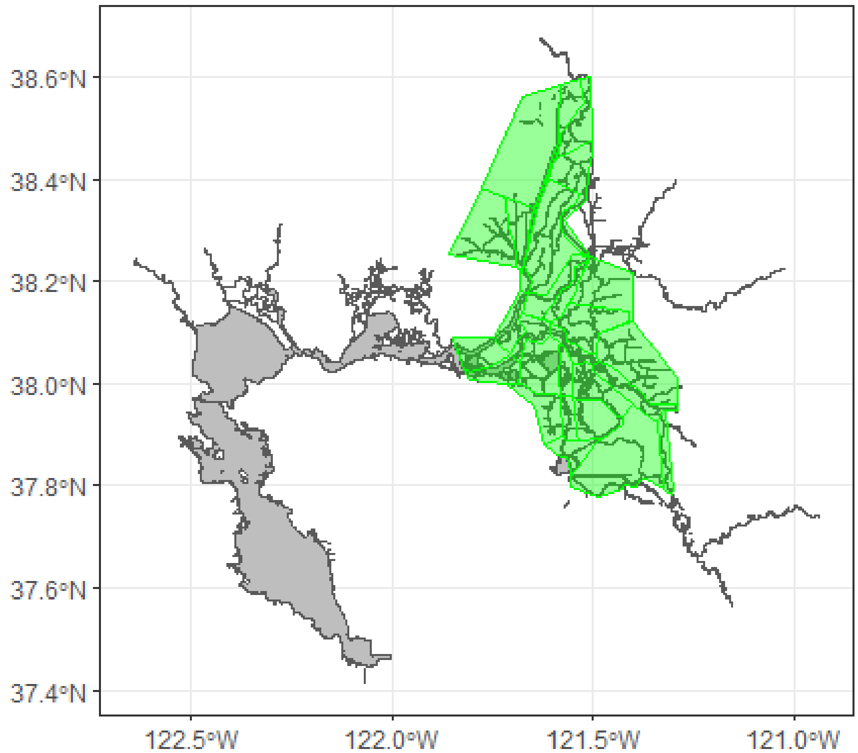


Figure 38. The Extent of the Defined Sacramento and San Joaquin Delta Region.

6.3.4 Adult Longfin Smelt

Adult longfin smelt are generally found in the Delta region from November to March (Table 52). Most longfin smelt become anadromous typically during their second year of life, evidenced by low abundance of adults in the San Francisco Estuary in spring and summer months. Once mature, adults migrate back upstream in fall and winter. Adults were detected upstream of the Confluence, in the upper Sacramento River, Cache Slough, and Sacramento Deep Water Shipping Channel. Adults migrate into the upper Delta regions to spawn (Merz et al. 2013).

Table 52. Adult Longfin Smelt Presence in Delta

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	10/11/1994	10/11/1994	12/12/1994	2/9/1995	2/9/1995	2/9/1995	52
1995	10/17/1995	10/17/1995	10/17/1995	1/9/1996	1/9/1996	1/9/1996	23
1996	11/4/1996	12/2/1996	12/12/1996	3/6/1997	3/6/1997	3/6/1997	51
1997	11/3/1997	11/12/1997	11/12/1997	3/9/1998	3/9/1998	3/9/1998	25
1998	11/2/1998	11/2/1998	11/2/1998	2/1/1999	3/15/1999	3/15/1999	10
1999	9/28/1999	11/2/1999	12/2/1999	1/20/2000	3/6/2000	4/3/2000	37
2000	10/5/2000	11/14/2000	12/5/2000	2/8/2001	2/20/2001	2/20/2001	146
2001	10/10/2001	10/24/2001	11/8/2001	3/6/2002	3/12/2002	4/15/2002	97

Cohort Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
2002	10/10/2002	10/10/2002	10/10/2002	2/3/2003	2/3/2003	2/3/2003	8
2003	9/15/2003	11/6/2003	12/1/2003	1/5/2004	1/13/2004	2/2/2004	56
2004	1/3/2005	1/3/2005	1/3/2005	3/7/2005	3/7/2005	3/7/2005	11
2005	9/12/2005	9/12/2005	9/12/2005	3/8/2006	3/8/2006	3/8/2006	9
2006	11/15/2006	11/15/2006	11/15/2006	3/5/2007	3/5/2007	3/5/2007	7
2007	11/15/2007	12/3/2007	12/3/2007	3/3/2008	3/3/2008	3/10/2008	22
2008	10/16/2008	10/16/2008	12/9/2008	2/3/2009	2/3/2009	3/2/2009	20
2009	11/30/2009	11/30/2009	11/30/2009	3/10/2010	3/10/2010	3/10/2010	16
2010	12/21/2010	12/21/2010	1/10/2011	1/12/2011	1/12/2011	1/12/2011	13
2011	11/15/2011	12/5/2011	12/5/2011	2/6/2012	3/5/2012	4/2/2012	54
2012	12/3/2012	12/12/2012	12/12/2012	3/4/2013	3/4/2013	3/4/2013	55
2013	10/9/2013	10/9/2013	11/13/2013	12/10/2013	1/6/2014	1/6/2014	12
2014	1/5/2015	1/5/2015	1/5/2015	5/4/2015	5/4/2015	5/4/2015	8
2016	12/6/2016	12/6/2016	12/6/2016	3/21/2017	3/21/2017	3/21/2017	6
2017	12/5/2017	12/5/2017	12/5/2017	3/27/2018	3/27/2018	3/27/2018	6
2018	12/10/2018	12/10/2018	12/10/2018	2/5/2019	2/5/2019	2/5/2019	9
2019	12/2/2019	12/2/2019	12/2/2019	3/12/2020	3/12/2020	3/12/2020	6
2020	12/8/2020	12/8/2020	12/8/2020	3/3/2021	3/3/2021	3/3/2021	7
Median Month	November	December	December	March	March	March	

6.3.5 Larval Longfin Smelt

Larval longfin smelt are generally found in the Delta region from January–June (Table 53; Merz et al. 2013). Larvae were frequently detected upstream of the Confluence, in the lower Sacramento River, upper Sacramento River, Cache Slough, Sacramento Deep Water Shipping Channel, and lower San Joaquin River. Larvae were caught less frequently in the east and south Delta regions (Merz et al. 2013).

Detection of larval longfin smelt in the south Delta, a region that includes the San Joaquin River and its distributaries, has been relatively low since 2009, and sampling from the Fall Midwater Trawl Survey and Smelt Larval Survey has shown density declines in the years since (Eakin 2021). Historically, increases in larval densities have been positively correlated with freshwater outflows from the Delta (Kimmerer et al. 2009); however, the moderate increases in larval densities observed in the wet years of 2017 and 2019 remained lower than larval densities observed before the observed larval decline in 2014. Specifically, larval densities in the northern Delta region decreased significantly. The increase of potential spawning stock that was seen in 2017 was not reflected in a significant increase in larval density in 2019 (Eakin 2021).

Table 53. Larval Longfin Smelt Presence in Delta

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1996	4/24/1996	4/30/1996	4/30/1996	4/30/1996	4/30/1996	4/30/1996	69
1997	3/31/1997	4/15/1997	4/15/1997	4/30/1997	5/14/1997	5/15/1997	1,790
1999	4/12/1999	4/14/1999	4/14/1999	5/13/1999	5/15/1999	5/23/1999	130
2000	3/22/2000	4/5/2000	4/5/2000	5/8/2000	5/8/2000	6/14/2000	989
2001	3/19/2001	3/21/2001	3/21/2001	5/1/2001	5/15/2001	5/29/2001	962
2002	3/18/2002	3/19/2002	3/20/2002	5/1/2002	5/13/2002	6/14/2002	3,244
2003	3/24/2003	3/24/2003	3/25/2003	4/23/2003	4/23/2003	5/6/2003	356
2004	3/29/2004	3/30/2004	4/1/2004	5/11/2004	5/12/2004	6/10/2004	100
2005	3/14/2005	3/14/2005	3/14/2005	4/26/2005	4/27/2005	6/21/2005	134
2006	4/18/2006	4/18/2006	5/1/2006	8/16/2006	8/16/2006	8/16/2006	11
2007	3/14/2007	3/27/2007	3/28/2007	5/9/2007	5/9/2007	5/11/2007	83
2008	3/5/2008	3/18/2008	4/1/2008	5/15/2008	5/16/2008	6/12/2008	1,453
2009	1/5/2009	1/20/2009	1/21/2009	4/7/2009	4/21/2009	6/3/2009	3,598
2010	1/4/2010	1/5/2010	1/5/2010	3/24/2010	4/14/2010	5/26/2010	3,268
2011	1/18/2011	1/18/2011	1/31/2011	2/15/2011	3/14/2011	4/26/2011	3,001
2012	1/9/2012	1/10/2012	1/10/2012	3/6/2012	3/14/2012	5/23/2012	4,178
2013	1/2/2013	1/29/2013	2/11/2013	4/24/2013	5/7/2013	6/3/2013	11,822
2014	1/6/2014	1/21/2014	1/22/2014	3/4/2014	3/19/2014	5/13/2014	3,502
2015	1/5/2015	1/22/2015	2/2/2015	4/13/2015	4/27/2015	5/11/2015	434
2016	1/4/2016	1/4/2016	1/5/2016	3/16/2016	4/12/2016	5/23/2016	166
2017	1/4/2017	1/4/2017	1/17/2017	4/12/2017	6/7/2017	6/7/2017	13
2018	1/2/2018	1/3/2018	1/3/2018	2/28/2018	2/28/2018	5/21/2018	178
2019	1/2/2019	1/3/2019	1/3/2019	1/29/2019	1/29/2019	2/26/2019	82
2020	1/6/2020	1/8/2020	1/22/2020	3/17/2020	3/31/2020	12/28/2020	899
2021	1/11/2021	1/26/2021	2/25/2021	4/21/2021	5/5/2021	6/3/2021	3,727
Median Month	January	January	January	April	May	May	–

6.3.6 Juvenile Longfin Smelt

Juvenile longfin smelt are generally found in the Delta region year-round, from January to December; however, in 2020 and 2021 juveniles were only detected until June (Table 54). The location of longfin smelt when they become juveniles is dependent on spawning location, outflow from the Delta, and spring tides. Juveniles migrate seasonally, downstream during the summer and upstream during the late fall and winter (Rosenfield et al. 2010).

Table 54. Juvenile Longfin Smelt Presence in Delta

Calendar Year	0.0%	5.0%	10.0%	90.0%	95.0%	100.0%	Sample Size
1994	1/7/1994	1/14/1994	1/14/1994	6/16/1994	6/14/1994	11/15/1994	43
1995	1/5/1995	10/17/1995	11/6/1995	12/11/1995	12/11/1995	12/11/1995	373
1996	1/3/1996	1/4/1996	1/4/1996	12/2/1996	12/2/1996	12/2/1996	55
1997	4/14/1997	4/15/1997	4/16/1997	5/14/1997	5/14/1997	12/4/1997	3/492
1998	1/13/1998	10/20/1998	10/20/1998	11/4/1998	11/4/1998	11/4/1998	358
1999	1/4/1999	4/14/1999	4/27/1999	9/28/1999	11/4/1999	11/4/1999	146
2000	1/10/2000	5/2/2000	5/8/2000	12/7/2000	12/7/2000	12/11/2000	840
2001	1/3/2001	1/5/2001	1/8/2001	5/30/2001	5/31/2001	12/3/2001	940
2002	3/18/2002	4/15/2002	4/15/2002	6/14/2002	6/17/2002	12/10/2002	3/000
2003	3/24/2003	4/7/2003	4/7/2003	12/1/2003	12/4/2003	12/4/2003	167
2004	1/5/2004	5/10/2004	5/11/2004	6/23/2004	7/8/2004	12/13/2004	365
2005	3/14/2005	3/14/2005	3/14/2005	11/7/2005	12/8/2005	12/8/2005	32
2006	1/20/2006	5/1/2006	9/14/2006	11/15/2006	12/4/2006	12/4/2006	40
2007	1/3/2007	1/3/2007	1/3/2007	5/23/2007	6/6/2007	11/15/2007	81
2008	3/17/2008	4/15/2008	4/30/2008	6/3/2008	6/24/2008	12/16/2008	951
2009	1/6/2009	4/6/2009	4/20/2009	6/3/2009	6/10/2009	12/10/2009	373
2010	3/29/2010	4/1/2010	4/14/2010	5/26/2010	5/26/2010	12/6/2010	146
2011	4/6/2011	6/14/2011	6/28/2011	12/12/2011	12/12/2011	12/12/2011	79
2012	1/3/2012	1/3/2012	3/5/2012	6/4/2012	6/11/2012	6/26/2012	123
2013	3/12/2013	4/10/2013	4/23/2013	5/8/2013	5/8/2013	12/10/2013	8/565
2014	1/6/2014	3/18/2014	3/21/2014	5/14/2014	6/3/2014	12/9/2014	257
2015	1/5/2015	3/30/2015	4/2/2015	5/11/2015	5/12/2015	6/8/2015	128
2016	5/4/2016	5/4/2016	5/4/2016	5/23/2016	5/25/2016	6/8/2016	21
2017	2/10/2017	2/10/2017	2/15/2017	12/5/2017	12/5/2017	12/5/2017	11
2018	1/18/2018	1/18/2018	1/18/2018	12/10/2018	12/10/2018	12/10/2018	6
2019	1/16/2019	1/16/2019	1/24/2019	12/3/2019	12/4/2019	12/4/2019	16
2020	3/16/2020	4/27/2020	5/12/2020	5/12/2020	5/12/2020	6/12/2020	132
2021	1/20/2021	4/6/2021	4/7/2021	5/5/2021	5/19/2021	6/19/2021	3/794
Median Month	January	April	April	May	December	December	–

6.4 Green Sturgeon – Southern Distinct Population Segment

Green sturgeon spend most of their life in the Pacific Ocean, along the western coast of North America, returning to the Sacramento River watershed to spawn every 4 years, on average

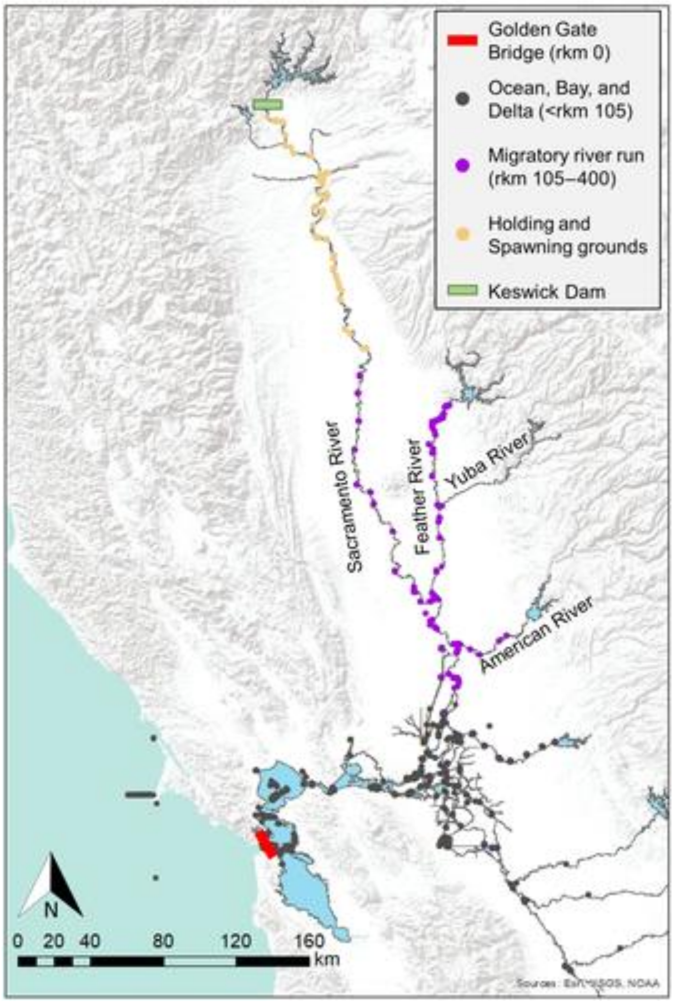
(Miller et al. 2020; Colborne et al. 2022). Two distinct population segments of North American green sturgeon are recognized, the federally threatened southern Distinct Population Segment (sDPS) and the northern Distinct Population Segment (nDPS), a Species of Special Concern. The two DPSs are differentiated by genetics and spawning-site fidelity, with the sDPS spawning in the Sacramento River basin, and the nDPS spawning in the Rogue River, in Oregon, Klamath River in Northern California, and additional evidence of nDPS spawning in the Eel River in Norther California (Benson et al. 2007; Stillwater Sciences and Wiyot Tribe Natural Resources Department 2017; National Marine Fishery Service 2018). Nonspawning green sturgeon adults of the sDPS generally occur in marine waters from Graves Harbor, Alaska, to Monterey Bay, California; however, adult green sturgeon are detected in the San Francisco Estuary and Delta year round (Moser and Lindley 2007; Lindley et al. 2008, 2011; Schreier et al. 2016; Miller et al. 2020). Presently, the only known recurring spawning population of the sDPS green sturgeon occurs in the Sacramento River in Northern California, part of the San Francisco Estuary watershed; however, during the 2011 high-spring outflow and wet water year, green sturgeon were documented to have spawned in the Feather River (Seesholtz et al. 2015) and possibly the Yuba River (Poytress et al. 2015). Seesholtz et al. (2015) found that an area near the Thermalito Afterbay Outlet may be important green sturgeon spawning habitat and that the Feather River has potential to provide a second production area for the sDPS green sturgeon population. Green sturgeon in the San Francisco Estuary watershed represent the most southerly spawning population of the species (Heublein et al. 2017a).

The majority of green sturgeon spawning occurs in the upper mainstem of the lower Sacramento River. Inmigration takes place during spring, peaking in March (Colborne et al. 2022). Spawning occurs from April–June, but can extend into summer months with periodic late-summer and fall spawning (Heublein et al. 2017b). Many adult green sturgeon spend the summer months in the river near the spawning grounds, with outmigration to the Pacific Ocean occurring bimodally, either in the late spring months or late summer through fall months. Green sturgeon typically remain in the Pacific Ocean between spawning migration events (Erickson and Webb 2007); however, adult green sturgeon (and white sturgeon) are present in the system year-round (Miller et al. 2020).

6.5 Adult Delta Migration, River Spawning, and Holding

Since 2004, more than 300 acoustic receivers have been deployed throughout the Sacramento River, Bay-Delta, San Francisco Estuary, and nearshore Pacific Coast to monitor movements of acoustic-tagged fish, including salmonids and sturgeon (Figure 39). Once entering the San Francisco Estuary at Golden Gate Bridge, green sturgeon travel more than 400 river kilometers (RKM) through the Delta and Sacramento River to the spawning grounds (Figure 3; Colborne et al. 2022). Colborne et al. (2022) synthesized telemetry detection records between 2006–2018 for 117 paired (i.e., each individual fish detected during up-river and down-river movement) migration events. From 2006–2018, 151 tagged green sturgeon were detected on receivers in the San Francisco Estuary watershed. The mean date of immigration events was March 22, the mean date of outmigration was October 16, and individuals were present in the Sacramento River for an average of 204 days.

Based on adult and egg presence, spawning occurs in water depths of about 8–9 meters (Wyman et al. 2018) from the Glen Colusa Irrigation District Diversion, near Hamilton City, California, up to Keswick Dam in Redding, California (Thomas et al. 2014; Klimley et al. 2015; Poytress et al. 2015).



Source: Colborne et al. 2022.

Figure 39. Locations of Acoustic Receives Throughout the California Central Valley, San Francisco Estuary, and Nearby Pacific Ocean.

After spawning in the spring–early summer, green sturgeon may immediately outmigrate, primarily in June, or after September in the late fall–early winter months. Outmigration may be linked to flow rates based on the observed early and late outmigration groups. It is theorized that when spring flows are suboptimal, many green sturgeon are likely to hold in the river for several months (Colborne et al. 2022). As drought conditions continue, the number of late outmigrations may increase (Colborne et al. 2022). Miller et al. (2020) observed green sturgeon in the Sacramento River during all months of the year, potentially due to late outmigrants overlapping with the earliest inmigrants (Colborne et al. 2022).

Table 55. Summary of (a) Upstream and (b) Downstream Adult Green Sturgeon Passage at Benicia, 2007–2018

Calendar Year	Total count	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
(a) Upstream							
2007	4	Mar 21	–	–	–	–	May 17
2008	0	–	–	–	–	–	–
2009	3	Mar 12	–	–	–	–	Apr 23
2010	3	Mar 2	–	–	–	–	Apr 25
2011	2	Feb 23	–	–	–	–	Mar 8
2012	17	Mar 6	Mar 6	Mar 9	Apr 29	May 5	May 5
2013	13	Feb 18	Feb 18	Feb 18	Apr 16	May 6	May 6
2014	13	Feb 15	Feb 15	Feb 15	Apr 9	May 5	May 5
2015	20	Feb 18	Feb 18	Mar 12	May 3	May 29	Jun 14
2016	26	Feb 10	Feb 14	Feb 28	Apr 7	Apr 9	Apr 14
2017	16	Feb 24	Feb 24	Feb 25	Apr 12	May 4	May 4
Median Month		February	February	February	April	May	May
(b) Downstream							
2007	4	Aug 17	–	–	–	–	Jan 6
2008	0	–	–	–	–	–	–
2009	3	Oct 14	–	–	–	–	Jan 14
2010	3	Dec 7	–	–	–	–	Dec 11
2011	2	Jun 28	–	–	–	–	Jan 23
2012	17	May 24	May 24	May 25	Dec 1	Dec 2	Dec 2
2013	13	Jul 1	Jul 1	Jul 8	Feb 12	Feb 14	Feb 14
2014	13	May 11	May 11	May 27	Dec 5	Dec 6	Dec 6
2015	20	May 20	May 20	Jun 23	Dec 21	Dec 24	Jan 9
2016	26	Apr 15	Apr 23	May 6	Dec 12	Dec 12	Dec 12
2017	16	May 18	May 18	May 28	Mar 18	Mar 24	Mar 24
Median Month	–	May	May	May	December	December	January

Source: Colborne pers. comm.
Note: Dates are based on acoustic detection records, where both upriver and downriver migrations were captured in the detection records. *Upstream migration* was defined as upstream movement starting at Benicia and continuing past RKM 105 to approximately RKM 400. *Downstream migration* was defined as downstream movement from approximately RKM 400 past RKM 105. RKM is measured as a distance from the entrance to the Pacific Ocean marked by Golden Gate Bridge in San Francisco Bay (Colborne et al. 2022). Note: Percentages passing only calculated for years with >10 fish detected migrating.

Table 56. Downriver Migration Timing Based on Early and Late Groups Identified in Telemetry Analysis

Year	Early Downriver				Late Downriver			
	Count	First Date	Mean Date	Last Date	Count	First Date	Mean Date	Last Date
2007	1	Aug 17	–	–	3	Dec 7	Dec 18	Jan 6
2008	0	–	–	–	–	–	–	–
2009	0	–	–	–	3	Oct 14	Nov 16	Jan 14
2010	0	–	–	–	3	Dec 7	Dec 9	Dec 11
2011	1	Jun 28	–	–	1	Jan 23	–	–
2012	10	May 24	Jun 14	Jul 24	7	Nov 21	Nov 25	Dec 2
2013	3	Jul 1	Jul 7	Jul 12	10	Dec 15	Feb 5	Feb 14
2014	3	May 22	Jun 11	Jul 26	10	Dec 1	Dec 4	Dec 6
2015	4	May 20	Jun 23	Jul 26	16	Oct 15	Dec 14	Jan 9
2016	9	Apr 15	May 21	Jul 7	17	Sep 22	Nov 13	Dec 12
2017	6	May 18	Jun 9	Jul 7	10	Nov 22	Jan 14	Mar 24

Source: Colborne pers. comm.

Unpublished, anecdotal information suggests that green sturgeon are present in the Feather River year round. Seesholtz et al. (2015) found that green sturgeon used the Feather River near the Thermalito Afterbay as spawning grounds in 2011, a wet water year, and the eggs were collected between June 14 and June 22, when the water temperatures were 61°F–63°F (16°C –17°C). This supports the laboratory findings from Van Eenennaam et al. (2005), showing that 61°F (16°C) was the optimal temperature for hatching success and a low chance of embryo deformities.

6.6 Sacramento Egg Incubation

Poytress et al. (2015) conducted an egg-mat study between 2008–2012 in a reach of the Sacramento River from the Glenn-Colusa Irrigation District Diversion to Cow Creek in Anderson, California. A total of 268 eggs and five post-hatch larvae were collected at seven sites between April 2 and July 7 of each year (Figure 40b) from medium-gravel substrates. This study verified a known spawning site 0.5 kilometer above the Glenn-Colusa Irrigation District Diversion, which is believed to be the lower river limit of green sturgeon spawning. The uppermost site where eggs were collected was ~25 kilometers below Cow Creek. Table 57 presents physical habitat data for all years of the study. The temperature range that eggs were sampled at was 53°F–59°F (11.8°C–14.8°C).

Table 57. Site-Specific Physical Habitat Data for all Years Sampled

Site	Eggs or larvae (*n*)	Depth (m)	Temperature (°C)	Discharge (m^3/s)	Turbidity (NTU)	Column Velocity (m/s)	Substrate class
Rkm 426	26	10.1±1.8	12.9±0.8	396±115	4.3±1.5	0.8±0.4	Gravel/ cobble
Rkm 424.5	154	6.8±1.8	12.9±1.0	275±52	4.7±5.2	0.6±0.1	Medium gravel
rkm 407.5	3	6.5±2.9	13.9±0.7	269±10	3.8±0.6	0.8±0.2	Small gravel
rkm 391	4	1.2±0.7	14.8±0.9	323±17	3.4±0.8	NA[a]	Small gravel[b]
rkm 377	81	4.6±1.2	14.1±1.2	311±58	3.8±2.4	1.0±0.1	Medium gravel
rkm 366.5	1	6.2±0.0	11.8±0.5	290±0	4.9±0.0	0.3±0.0	Medium/ large gravel
rkm 332.5	4	7.3±0.2	14.0±1.8	331±87	9.7±11.0	1.2±0.5	Small gravel

[a] Tailrace of RBDD; no velocity measurements were taken during years of dam operation.
[b] Tailrace of RBDD; substrate class was assessed by direct observation.
Source: Potress et al. 2015

The optimal incubation temperature range for green sturgeon eggs is between 14°C–17°C; acceptable temperatures are between 52°F–70°F (11°C–21°C; Figure 40a). Deformed hatched embryos increased at incubation temperatures between 63°F–68°F (17°C–20°C) and hatched embryo length was shorter at 52°F (11°C). Temperatures of 74°F (23°C) and above resulted in total mortality before hatch, and temperatures below 52°F (11°C) were not studied. Suboptimal temperatures are between 63°F–68°F (17°C–20°C), resulting in increased embryo deformities that could affect future survival (Van Eenennaam et al. 2005). Optimal temperatures for sturgeon spawning (below 63°F [17°C]) extend from Keswick Dam to below the RBDD in most years. During years of low reservoir storage and outflow, temperatures at the downstream extent of green sturgeon spawning habitat near RBDD may be suboptimal (above 64°F [17.5°C]) in the late spring (Heublein et al., 2017b).

temperature °C	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
temperature °F	46.4	48.2	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4
egg				b	b	b	b	b	b	b	b	b	b	b	b,f	b,f	b,f	b,f	b,f	b	b
larvae							e	e	e	c	f	dd,f	dd,f	dd,f	dd,f	dd,f	dd,f	dd,c,f	f	f	f
juvenile				a	a	a	a	a	a	a	a	a	a	a	a	a	a,d	a	a	a	a
spawning adult			g	g	g	g	g	g	g,h	g,h											

(green)	optimal temperature
(yellow)	acceptable temperature
(orange)	impaired fitness; avoid prolonged exposure; increasing chance of lethal effects
(red)	likely lethal
(black)	lethal
(light blue)	unknown effect upon survival and fitness

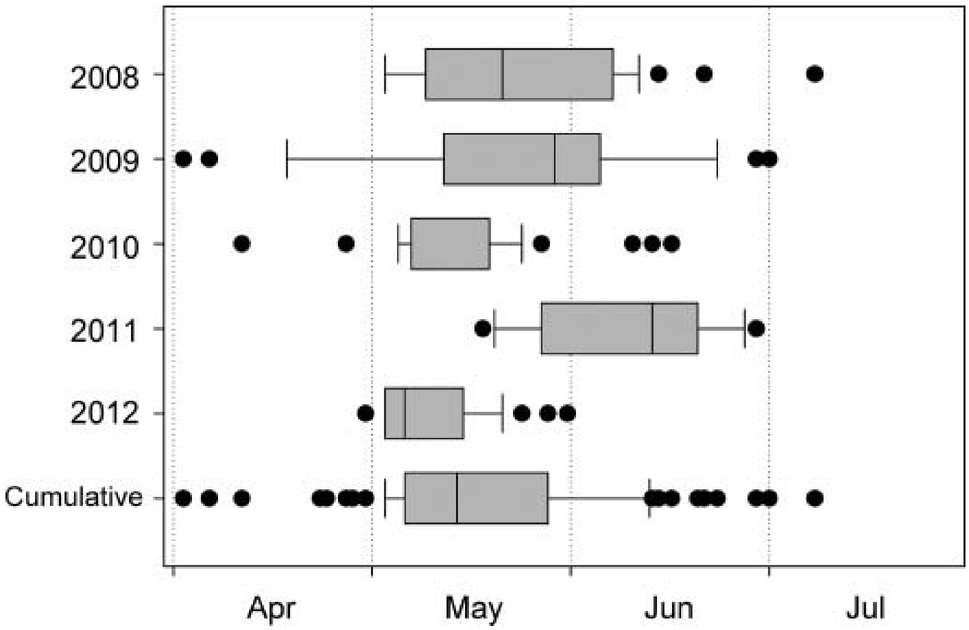
Source: Heublein et al. 2017b.

Figure 41a. Temperature Ranges for Green Sturgeon Life Stages Including Optimal, Lethal, and Unknown

Table 58. Green Sturgeon Eggs from Upper Sacramento River Egg Mat Surveys

Brood Year	First	5%	10%	90%	95%	Last
2008	May 2	May 2	May 2	Jun 10	Jun 13	Jul 7
2009	Apr 2	Apr 23	Apr 23	Jun 23	Jun 23	Jul 1
2010	Apr 11	May 5	May 5	May 24	Jun 13	Jun 16
2011	May 18	May 18	May 27	Jun 20	Jun 29	Jun 29
2012	Apr 29	Apr 29	May 2	May 20	May 23	May 30
Median Month	April	May	May	June	June	June

Source: Poytress pers. comm.



Source: Poytress et al. 2015.

Figure 42b. Box Plots Displaying the Median and 10th, 25th, 75th, and 90th Percentiles with Outliers (Black Dots) of Annual Green Sturgeon Spawning Events (n = Egg Counts) on the Sacramento River for 2008 (n=42), 2009 (n=56), 2010 (n=105), 2011 (n=11), 2012 (n=59), and Cumulatively (n=273).

Larval green sturgeon are suspected to remain near their spawning grounds for about 16 days post hatch, when they begin a first nocturnal migration to disperse from their hatching site (Kynard et al. 2005; Poytress et al. 2012). It is hypothesized that larval green sturgeon spend a period of time foraging in the upper river and may move upstream during the late summer and fall, rather than moving downstream to feed (Poytress et al. 2012). A secondary nocturnal downstream winter migration is thought to occur at 110–181 days post hatch, until water temperatures drop to about 46˚F (8˚C), indicating that juveniles migrate downstream to overwinter (Kynard et al. 2005).

6.7 Juveniles

Green sturgeon are typically defined as juveniles from when they are able to feed exogenously (Klimley et al. 2015) up to when they are capable of entering estuarine and marine waters at about 90 centimeters in length (Miller et al. 2020). Not much is known about juvenile green sturgeon movements, and it is not clear when juvenile green sturgeon leave their birthplace upriver and migrate downstream to rearing habitats in the Delta. Gruber et al. (2022) recently estimated that juveniles would reach the migrant readiness stage at 180 days post hatch, based on research by Kynard et al. (2005). Based on larval presence at the RBDD rotary screw trap, juveniles would be ready to migrate 164 days later. The timing of juvenile outmigration is reliant on their hatch date and can vary from early- to mid-October to January (Gruber et al. 2022). Juveniles were detected making continuous and stepped migrations from the upper Sacramento River in Red Bluff, California, to the Delta. New research suggests that increases in reach discharge, paired with co-occurring turbidity and individual migrant readiness, may influence the initiation of juvenile downstream migration (Gruber et al. 2022). Juveniles likely spend the next 2–4 years rearing in the Delta and San Francisco Estuary (Thomas et al. 2019; Moyle 2002).

During spring 2008 and 2010, Klimley et al. (2015) released six green sturgeon juveniles that were roughly 30 centimeters long at Santa Clara shoals in the Bay-Delta and tracked them by boat for 5 days. The fish were observed moving within the area local to where they were released. Their movements did not appear to be tidally influenced and occurred both day and night. In 2013, an additional 31 tagged individuals, ranging in FL from 30–53 centimeters, were released at Santa Clara shoals (Thomas et al. 2022). They exhibited a diversity of movements, including moving around the Delta, moving into the saltier waters of the Carquinez Straits and San Pablo Bay, moving into San Pablo Bay, and then returning to the Delta, exiting the San Francisco Estuary after migrating through, and moving back and forth between the San Francisco Estuary and the Pacific Ocean. It was found that all 31 tagged fish spent the most amount of time, an average of 87.7 of 290 days in the central Delta, where they were released (Thomas et al. 2022). This is consistent with Miller et al. (2020), who found that large juveniles were generally detected throughout the San Francisco Estuary and Delta, with some individuals detected close to Golden Gate Bridge. Juveniles were detected most frequently in the Delta, peaking in the late winter and early spring. Some individuals were also detected in the central San Francisco Bay, San Pablo Bay, and Suisun Bay, especially in spring and summer (Miller et al. 2020). This is consistent with findings that juvenile green sturgeon are able to detect and seek out saline waters as early as 6 months post hatch (Poletto et al. 2013). The findings by Thomas et al. (2022) suggest that juvenile green sturgeon are flexible in their movements in a highly variable environment.

Table 59. Red Bluff Diversion Dam Juvenile Green Sturgeon Presence

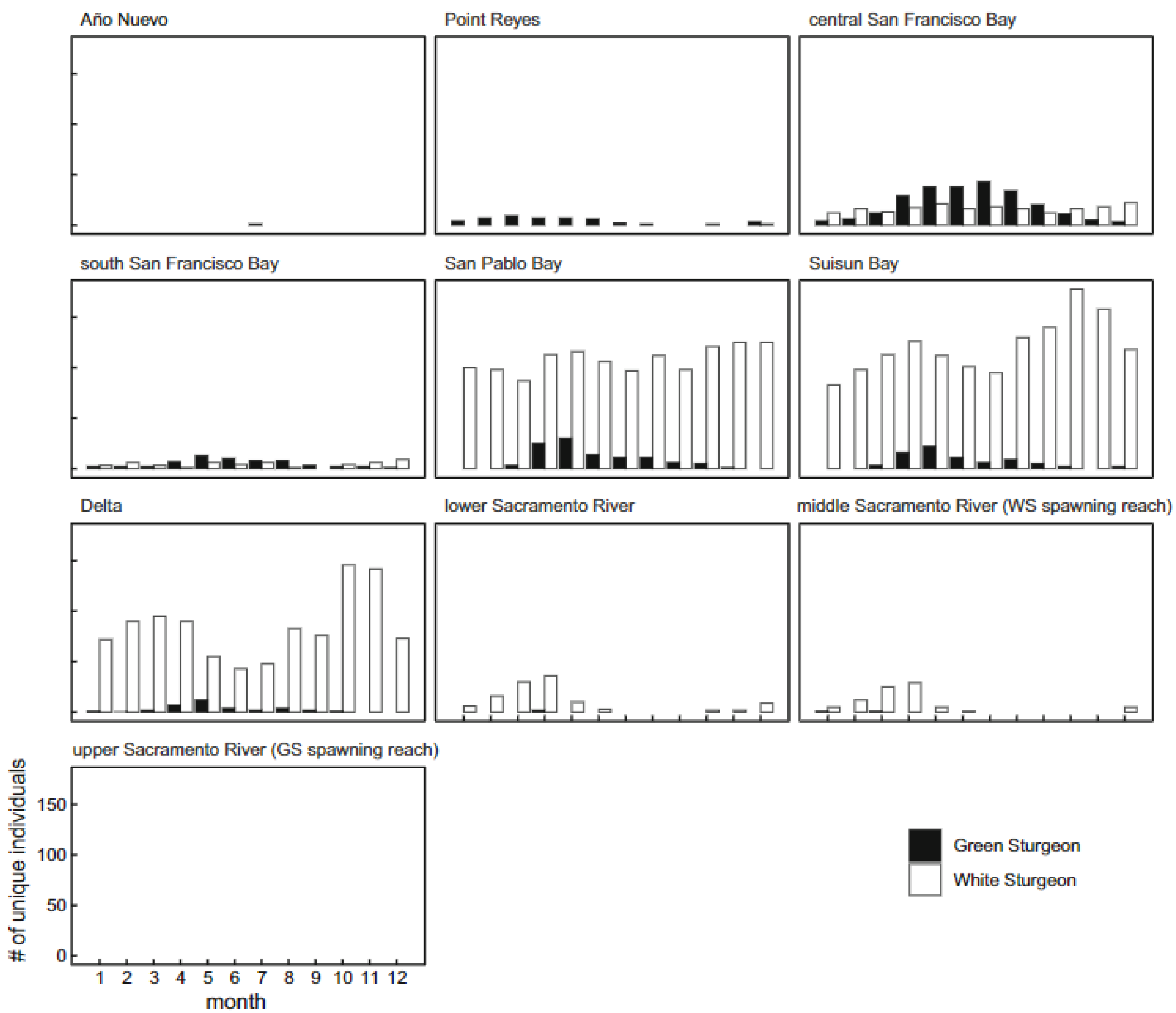
Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2002	May 7	May 7	May 7	Jul 15	Jul 16	Jul 16
2003	Jun 13	Jun 17	Jun 18	Jul 10	Jul 15	Nov 11
2004	May 4	May 17	May 19	Jul 1	Jul 8	Jul 29
2005	May 7	Jun 28	Jun 29	Jul 20	Jul 29	Aug 13
2006	Jun 10	Jun 22	Jun 23	Jul 27	Jul 28	Aug 25
2007	May 11	May 11	Jun 9	Jul 15	Jul 24	Jul 24
2008	–	–	–	–	–	–
2009	May 11	Jun 11	Jun 11	Jul 7	Jul 10	Jul 16
2010	May 26	Jun 2	Jun 12	Jul 29	Jul 31	Aug 29
2011	May 16	May 23	May 24	Jul 21	Jul 25	Aug 27
2012	May 1	May 9	May 10	May 30	May 31	Jun 26
2013	May 2	May 9	May 13	Jul 9	Jul 29	Aug 20
2014	May 3	May 5	May 6	May 24	Jun 6	Aug 4
2015	Apr 14	Apr 22	Apr 23	Jun 11	Jun 21	Jul 6

Brood Year	First	5% Passing	10% Passing	90% Passing	95% Passing	Last
2016	Apr 28	May 5	May 5	Jun 2	Jun 22	Sep 21
2017	May 27	Jun 1	Jun 4	Jul 14	Jul 21	Sep 9
2018	May 10	May 12	May 12	Jun 1	Jun 7	Jun 22
2019	May 13	May 21	May 23	Jun 23	Jul 6	Sep 12
Median Month	May	May	May	July	July	August

Source: Poytress pers. comm.
Note: No fish were caught in 2008; COVID-19 disrupted sampling from March 28–July 1. The majority of the fish in the data set were larvae (99.6%); some juveniles appeared during the October and November sampling period in a few years.

6.8 Bay Subadult and Adult Residence

Subadult and adult green sturgeon are characterized by total lengths of over 90 centimeters (Miller et al. 2020). The San Francisco Estuary provides foraging habitat for subadults and non-spawning adults in the summer months (National Marine Fisheries Service 2018). Subadult green sturgeon have been detected from the Delta to Point Reyes, suggesting that subadult initial migration preference is northward up the Pacific Coast (Miller et al. 2020). Subadult green sturgeon were detected most often in the San Francisco, San Pablo, and Suisun Bays (Figure 41), with peaks in spring and summer months. Occasionally, subadults were detected in the central and lower Sacramento River, but not in the upper Sacramento River. Detections of individual subadult green sturgeon in coastal waters and San Francisco Bay waters suggest that subadults are going in and out of the San Francisco Estuary before making their adult migration into coastal waters (Miller et al. 2020). Pre-spawning adult green sturgeon return to migrated through the San Francisco Estuary to spawning grounds in late winter and early spring, moving through the Bay and Delta quickly to reach their spawning grounds (Israel and Klimley 2008). Post-spawning green sturgeon spent an average of 7 days in the San Francisco Bay before returning to the ocean (Miller et al. 2020).



Source: Miller et al. 2020.
Note: Most subadults were detected in the central San Francisco Bay.

Figure 43. Subadult Green Sturgeon Presence Across all Months by River Reach.

The University of California, Davis, reviewed telemetry data between 2010–2018, looking at tagged green sturgeon. Fish were considered Bay residents if they entered the Bay through the Golden Gate, but did not pass the Benicia Bridge.

Table 60. Cumulative Proportion of Occupancy by Resident Bay Subadult Green Sturgeon

Month	Total count	Cumulative Proportion
Jan	9	0.02
Feb	10	0.05
Mar	18	0.09
Apr	42	0.19

Month	Total count	Cumulative Proportion
May	59	0.33
Jun	62	0.48
Jul	64	0.64
Aug	59	0.78
Sep	38	0.87
Oct	27	0.94
Nov	18	0.98
Dec	7	1.00

Source: Colborne pers. comm.

6.9 Delta Subadult and Adult Residence

Subadult green sturgeon were more frequently detected in the San Francisco Estuary than Delta waters, although they were occasionally detected in the Delta, primarily in the spring months (Figure 41) (Miller et al. 2020). It is assumed adult green sturgeon migrate directly to their spawning grounds, spending an average of 3 days in the Delta during the upstream migration (Miller et al. 2020). Post spawning, the adult green sturgeon appear to hold in the rivers near the spawning sites until fall or winter. It is assumed they use cues of increasing flow rates and decreasing temperatures to begin their outmigration (Israel and Klimley 2008). There is no evidence of tagged adult green sturgeon exhibiting permanent residency in the Delta (Colborne et al. 2022).

The University of California, Davis, reviewed telemetry data between 2010–2018, looking at tagged green sturgeon. Fish were considered Bay residents if they entered the Delta by passing under the Benicia Bridge, but did not pass upstream of RKM 105.

Table 61. Cumulative Proportion of Occupancy by Resident Bay Subadult Green Sturgeon

Month	Total Count	Cumulative Proportion
Jan	3	0.02
Feb	17	0.10
Mar	17	0.19
Apr	21	0.29
May	27	0.43
Jun	21	0.54
Jul	18	0.63
Aug	25	0.75
Sep	20	0.85

Month	Total Count	Cumulative Proportion
Oct	17	0.94
Nov	7	0.97
Dec	5	1.00

Source: Colborne pers. comm.

6.10 Adult Post-Spawn Delta Residence

Post-spawning adults were observed to prefer the mainstem of the Sacramento River for outmigration (Miller et al. 2020). Studies have found that post-spawning adult green sturgeon reside in the river near their spawning grounds for several months, with variations in outmigration from early summer through December (Heublein et al. 2009; Miller et al. 2020). Two distinct outmigration groups have been observed, one in early summer and one in winter (Colborne et al. 2022). Miller et al. (2020) observed an adult green sturgeon remaining in the spawning grounds for nearly a year before outmigrating, a behavior previously unseen. It is speculated that longer holding in the spawning grounds could be a response to environmental conditions that change from year to year. It could also be a feature of the sDPS, individual variation, driven by food requirements before their long journey back to sea, or a response to drought conditions that delayed the flow conditions that trigger outmigration (Miller et al. 2020).

The University of California, Davis, reviewed telemetry data between 2012–2017, looking at tagged green sturgeon. Fish were considered post-spawn Delta residents if they entered the Delta by passing downstream of RKM 105, but did not pass downstream of Benicia Bridge.

Table 62. Cumulative Proportion of Occupancy By Resident Bay Subadult Green sturgeon

Year	Count	Mean Duration (days)	Shortest Period (days)	Longest Period (days)	Mean Arrival Date	Mean Departure Date
2012	15	18	0	86	Sep 12	Sep 30
2013	12	6	1	13	Jan 16	Jan 22
2014	13	20	2	176	Oct 28	Oct 17
2015	20	50	3	248	Oct 14	Dec 3
2016	23	18	2	153	Sept 11	Sept 28
2017	15	12	0	62	Oct 16	Oct 28

Source: Colborne pers. comm.
Note: Considered the same group of fish as green sturgeon with both upriver and downriver migrations (above) defined as when green sturgeon were below RKM 105 and above the Benicia Bridge (38.03994, -122.123) row of receivers.

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