



— BUREAU OF —
RECLAMATION

Weekly Assessment of CVP and SWP Delta Operations on ESA-listed Species

March 19, 2024

Executive Summary

Operational Conditions

See Weekly Fish and Water Operation Outlook document for March 19 – March 25.

Winter-run Chinook Salmon

Loss of natural winter-run Chinook Salmon (by length at date, LAD) has occurred in the past week at the State and Federal fish salvage facilities. Loss of genetically confirmed winter-run Chinook Salmon in WY 2024 occurred at both facilities between 1/16/2024 and 3/13/2024. Loss of natural winter-run Chinook Salmon at the Central Valley Project (CVP) and State Water Project (SWP) fish collection facilities is likely to occur over the next week. 65-79 of juvenile natural winter-run Chinook Salmon from brood year (BY) 2023 are estimated to be present in the Delta. The 50% single year loss threshold for LAD winter-run Chinook Salmon period was exceeded on 2/25/2024. The 75% single year loss threshold for LAD winter-run Chinook Salmon period was exceeded on 3/7/2024. The 100% single year loss threshold for LAD winter-run Chinook Salmon may be exceeded during the upcoming week if salvage trends continue.

Spring-run Chinook Salmon

Loss of natural YOY spring-run Chinook Salmon LAD has occurred in the past week at the State or Federal fish salvage facilities. 55-70% of juvenile natural YOY spring-run Chinook Salmon was estimated in the Delta. CV spring-run Chinook Salmon fry are rearing and migrating downstream. Loss of natural spring-run Chinook Salmon at the CVP and SWP fish collection facilities is likely to occur over the next week.

Central Valley Steelhead

Loss of natural CCV steelhead has occurred in the past week at the State and Federal fish salvage facilities. Loss of CCV steelhead at the CVP and SWP fish collection facilities is likely to occur over the next week. 25-50% of CCV steelhead were estimated in the Delta. The 50% single year loss threshold for the Dec 1 to March 31 period was exceeded on 2/11/2024 the 75% single year loss threshold was exceeded on 2/22/2024, and the 100% single year loss threshold was exceeded on 2/23/2024. The CVP and SWP will operate to -500 OMRI in order to reduce steelhead loss in response to the 100% exceedance and encroachment of the incidental take limit. As of 3/18/2024 total loss is 2733.15 and the incidental take statement threshold is 2,760.

DCC gates recommendation

The DCC gates were closed for the OMR Season on 11/27/2023.

Delta Smelt

Based on recent detection data and distribution patterns over the past decade, Delta Smelt have likely completed their population-level spawning migration and are distributed throughout the Delta, and temperatures are suitable for spawning. Three marked Delta Smelt have been detected by surveys in Suisun Marsh, the lower Sacramento River, and the Sacramento Deep Water Shipping Channel since 3/5/2024. Risk of entrainment in the OMR corridor remains low for adults, based on low turbidity, and lack of detections in salvage and the central and south Delta. Risk of entrainment of fish in the OMR corridor has decreased to low for larvae, based on a South and Central Secchi depth > 1m. COA 8.5.2 is no longer triggered as of 3/18/24. Implementation of steelhead protections may reduce the chance of entraining Delta Smelt as reduced OMRI tend to entrain less fish.

Monitoring Teams summary

There were no non-consensus issues to report from the Smelt Monitoring Team.

Reclamation is elevating a proposal to operate to an OMRI no more negative than -1500 cfs to WOMT.

Operational and Regulatory Conditions

See current Weekly Fish and Water Operation Outlook document.

Biology, Distribution, and Evaluation Winter-run Chinook salmon, Spring-run Chinook salmon, Central Valley Steelhead

Population Status

Winter-run Chinook Salmon

- Delta Life Stages:
 - Juveniles, Adults
- Brood Year 2023 Productivity:
 - Natural winter-run Chinook salmon: The Final WR JPE for BY 2023 is 234,896.
 - Mean cumulative weekly passage of winter-run Chinook salmon through January 14th at Red Bluff Diversion Dam (RBDD) for the last 21 years of passage data is 99.3% (one SD of 1.1%). By 3/10/2024, 1,107,209 winter-run Chinook salmon

were estimated to have passed RBDD compared to the total cumulative passage for WY 2023 of 240,059 winter-run Chinook salmon.

- Hatchery winter-run Chinook salmon:
 - One release of Livingston Stone National Fish Hatchery CWT tagged winter-run Chinook salmon occurred on 12/28/23
 - The second release of LSNFH CWT tagged winter-run Chinook salmon occurred on 1/19/24.
 - A third release of LSNFH CWT tagged winter-run Chinook salmon occurred on 2/16/24. A subset of these fish were acoustically tagged and will be tracked through CalFish
 - 47,937 Coleman NFH Complex brood year 2023 winter Chinook Salmon on March 4, 2024. The release will take place on the North Fork Battle Creek at Wilson Hill Bridge near Manton, CA. 100% marked (with an adipose-fin and a left pelvic-fin clip and CWT) and has an overall estimated average fork length of 85 mm.
 - 84,994 Coleman NFH Complex brood year 2023 winter Chinook Salmon on March 11, 2024. The release took place on the North Fork Battle Creek at Wilson Hill Bridge near Manton, CA. 100% marked (with an adipose-fin and a left pelvic-fin clip and CWT) and has an overall estimated average fork length of 85 mm.

Spring-run Chinook Salmon

- Delta Life Stages:
 - Young-of-year (YOY) and Yearlings
- Brood Year 2023 Productivity:
 - Natural spring-run Chinook salmon: No JPE has been established for spring-run Chinook salmon.
 - Hatchery spring-run Chinook salmon surrogates associated with the Proposed Action (PA 4.10.5.10.2 Additional Real-Time OMR Restrictions and Performance Objectives):
 - Approximately 60,764 brood year 2023 late-fall Chinook salmon were released on December 22, 2023 into Battle Creek at the Coleman NFH. This group is 100% marked with an adipose-fin clip and coded-wire tagged.
 - Approximately 71,049 Coleman NFH brood year 2023 late-fall Chinook Salmon were released on December 29, 2023 into Battle Creek at Coleman

NFH. This group is 100% marked (with an adipose-fin clip and CWT) and has an overall estimated average fork length of 145 mm.

- Approximately 67,018 Coleman NFH brood year 2023 late-fall Chinook Salmon were released on January 11, 2024 into Battle Creek at Coleman NFH. This group is 100% marked (with an adipose-fin clip and CWT) and has an overall estimated average fork length of 145 mm.
- Loss has occurred for release group 1, release group 2, and release group 3 of the hatchery spring-run surrogates.
- A release of 699,854 of spring-run Chinook salmon from the Feather River hatchery at Gridley Boat Launch and Boyd's Pump Boat Launch occurred on March 15, 2024. This group was 100% marked (with an adipose fin clip and CWT) and had an overall estimated average fork length of 74 mm.

Central Valley Steelhead

- Delta Life Stages:
 - Spawning Adults, Kelts, Juveniles
- Brood Year 2023 Productivity:
 - Spawner abundance: There is limited information about the adult steelhead population. It is estimated to be small, contributing to the limited productivity of the population.
 - Natural steelhead: No JPE has been established for steelhead. Data are limited.
 - Hatchery steelhead: Reclamation's Proposed Action has no hatchery steelhead triggers.
 - A release of 240 hatchery steelhead occurred on 3/15/24 at Lighthouse Marina from the Mokelumne hatchery. These fish will be acoustically tagged and tracked through CalFishTrack. The goal of the release is to evaluate the effect of steelhead movement through the Delta at -500 cfs OMR.
 - 6-year Steelhead study hatchery fish will be released on 3/20/24 into the Lower San Joaquin River.

Distribution

Winter-run Chinook Salmon

Current Distribution:

- For winter-run Chinook Salmon observations reported to SaMT since previous meeting, see Table 1.

- For SaMT distribution estimates, see Table 2.
- As of 3/13/2024, 13 genetic natural winter-run Chinook Salmon has been identified at the SWP facility. As of 3/13/2024, 6 genetic natural winter-run Chinook Salmon have been identified at the CVP facility.
- Under the 2023 IOP Reclamation will be operating to the COA 8.6.3 Mid- and Late-season Natural Winter-run Chinook Salmon Daily Loss Threshold:
 - January 1 – January 31: $0.0000635 * 234,896 = 14.92$
 - February 1 – February 28: $0.0000991 * 234,896 = 23.28$
 - March 1 – March 31: $0.000146 * 234,896 = 34.29$
 - April 1 – April 30: $0.0000507 * 234,896 = 11.91$
 - May 1 – May 31: $0.000077 * 234,896 = 18.09$
- Daily loss threshold under the 2023 IOP COA 8.6.3 of LAD winter run was triggered 5 times in the previous week (3/10/2024-3/16/2024).

Historical Trends

- For historical winter-run Chinook salmon trends in salvage, see Table 3.
- Loss of natural winter-run Chinook salmon at the CVP and SWP fish collection facilities is likely to occur over the next week based on hydrology. Based on historic trends in salvage winter-run Chinook salmon loss may increase over the next week.

Forecasted Distribution within Central Valley and Delta regions

- The STARS model projects route-specific proportion of entrainment, survival, and travel times (Table 5). This model does not estimate entrainment into the lower Sacramento River sloughs (i.e., Three-Mile Slough).

Spring-run Chinook salmon

Current Distribution

- For spring-run Chinook salmon observations reported to SaMT since previous meeting, see Table 1.
- For SaMT distribution estimates, see Table 2.

Historical Trends

- For historical spring-run Chinook salmon trends in salvage, see Table 3. Based on historic trends in salvage YOY spring-run Chinook salmon loss may increase over the next week.

Forecasted Distribution within Central Valley and Delta regions

- YOY spring-run Chinook are migrating into the Delta.

Central Valley Steelhead

Current Distribution

- For CCV Steelhead observations reported to SaMT since previous meeting, see Table 1.
- For SaMT distribution estimates, see Table 2.
- As of 3/10/2024, 345 unclipped CCV steelhead have been observed at the CVP or SWP facilities.
- Loss of CCV Steelhead exceeded the 50% of the annual loss threshold for the Dec. 1 to March 31 period on 2/11/2024.
- Loss of CCV Steelhead exceeded the 75% of the annual loss threshold for the Dec. 1 to March 31 period on 2/22/2024.
- Loss of CCV Steelhead exceeded the 100% of the annual loss threshold for the Dec. 1 to March 31 period on 2/23/2024.
- Steelhead have been observed within the Delta and at the salvage facilities in the last 7 days.
- Steelhead have also been observed in the Chipps Island Trawl which supports out-migrating is occurring.
- Acoustically tagged wild steelhead from the Stanislaus were observed passing receivers at Benicia Bridge.

Historical Trends

- At Red Bluff Diversion Dam, the estimated passage of BY23 steelhead is 57,255, third highest in the last 10 brood years (https://www.cbr.washington.edu/sacramento/tmp/hrt_1710862871_863.html).
- For historical CCV steelhead trends in salvage, see Table 3. The number of steelhead salvaged for water year 2024 is currently 1,114 and the highest in the last 10 water years. Based on historic trends in salvage, juvenile CCV steelhead loss may occur over the next week.
- Based on historical trends in steelhead observations, salvage is expected to increase and observations of out-migrating steelhead should increase as the season progresses.

Forecasted Distribution within Central Valley and Delta regions

- The entrainment tool estimates CCV steelhead loss to be increasing (Table 6, Fig. 1).

Table 1. Fish observation reported since the previous SaMT meeting. NAs represent no data reported. See Operations Outlook for notes on interruptions in any surveys.

Locations	Reporting Period	SR Chinook	WR Chinook	LFR Chinook	Steelhead (Wild)	Green Sturgeon
Butte Creek RST	3/4-3/11	7	0	0	4	0
Tisdale RST	3/11-3/18	5	1	0	0	0
Knights Landing RST	3/11-3/17	6	0	0	2	0
Lower Sacramento RST	2/18-2/24	15	7	0	0	0
Beach Seines	3/10-3/16	6	0	0	0	0
Sac. Trawl	3/10-3/16	2	1	0	0	0
Chippis Island Midwater Trawl	3/10-3/16	1	2	0	1	0
Mossdale Kodiak Trawl	3/10-3/16	1	1	0	0	0
EDSM	3/10-3/16	0	2	0	1	0
Feather River Herring RST	3/6-3/17	2	0	0	0	0
Feather River Eye Side RST	3/10-3/17	0	0	0	94	0
Lower Feather River	2/26-3/3	5	0	0	1	0

Table 2. Salmonid distribution estimates

Location	Yet to Enter Delta (%)	In the Delta (%)	Exited Delta past Chipps Island (%)
Young-of-year (YOY) winter-run Chinook salmon	Current: 1-5% Last Week: 1-5%	Current: 65-79% Last Week: 70-84 %	Current: 20-30% Last Week: 15-25%
YOY spring-run Chinook salmon	Current: 29- 40% Last Week: 33-49%	Current: 55-70% Last Week: 50-65%	Current: 1-5% Last Week: 1-2%
YOY hatchery winter-run Chinook salmon	Current: 79-85% Last Week: 90-95%	Current: 10-20% Last Week: 5-10%	Current: 1-5% Last Week: 0%
Natural origin steelhead	Current: 25-40% Last Week: 25-40%	Current: 25-50% Last Week: 30-55%	Current: 25-35% Last Week: 20-30%

Table 3. Historic migration and salvage patterns. Last updated 03/18/2023.

Species	Red Bluff Diversion Dam	Tisdale Rst	Knights Landing Rst	SacTrawl Sherwood Catch Index	Chippis Island Trawl Catch Index	Salvage
Chinook, Winter- run, Unclipped	99.5%(99.3 %,99.8%) BY: 2014 - 2022	98.4%(97.4%, 99.4%) BY: 2014 - 2022	98.5%(97.1%,9 9.8%) BY: 2014 - 2022	66.2%(45.8%,86. 7%) BY: 2014 - 2022	31.3%(12.6%,5 0.1%) BY: 2014 - 2022	68.0%(50.2%,85. 8%) WY: 2014 - 2023
Chinook, Spring- run, Unclipped	29.3%(8.9%, 49.7%) BY: 2014 - 2022	27.9%(6.1%,4 9.7%) BY: 2014 - 2022	37.7%(12.6%,6 2.8%) BY: 2014 - 2022	12.7%(1.5%,23.9 %) BY: 2014 - 2022	0.2%(0.0%,0.3 %) BY: 2014 - 2022	2.3%(- 1.7%,6.3%) WY: 2014 - 2023
Steelhead, Unclipped (January- December)	3.7%(0.5%,6 .9%) BY: 2014 - 2023	50.5%(30.7%, 70.3%) BY: 2014 - 2023	46.5%(26.8%,6 6.2%) BY: 2014 - 2023	62.6%(36.2%,88. 9%) BY: 2014 - 2023	49.2%(34.1%,6 4.4%) BY: 2014 - 2023	N/A
Steelhead, Unclipped (December -March)	N/A	N/A	N/A	N/A	N/A	71.2%(50.3%,92. 1%) WY: 2014 - 2023
Steelhead, Unclipped (April- June)	N/A	N/A	N/A	N/A	N/A	N/A

Table 4. Mean daily flow and percent change (Wilkins Slough, Deer Creek, Mill Creek; cfs from CDEC) and temperature and percent change (Knights Landing; °F from RST).

Date	Mill Creek (MLM) : mean daily flow (cfs)	Mill Creek (MLM): flow percent change	Mill Creek (MLM): Alert	Deer Creek (DCV): mean daily flow (cfs)	Deer Creek (DCV): flow percent change	Deer Creek (DCV): Alert	Wilkins Slough (WLK): mean daily flow (cfs)	Knights Landing RST: water temp- erature (f)	Alert Triggered
3/17/2024	327.4	0.2%	Flow>95cfs	455.1	-1.9%	Flow>95cfs	22,247.2	N/A	N/A
3/16/2024	326.6	-2.7%	Flow>95cfs	464.0	-2.6%	Flow>95cfs	22,896.5	N/A	N/A
3/15/2024	335.8	-6.2%	Flow>95cfs	476.6	-6.1%	Flow>95cfs	23,516.4	N/A	N/A
3/14/2024	358.0	-9.3%	Flow>95cfs	507.3	-8.7%	Flow>95cfs	23,827.7	N/A	N/A

Date	Mill Creek (MLM): mean daily flow (cfs)	Mill Creek (MLM): flow percent change	Mill Creek (MLM): Alert	Deer Creek (DCV): mean daily flow (cfs)	Deer Creek (DCV): flow percent change	Deer Creek (DCV): Alert	Wilkins Slough (WLK): mean daily flow (cfs)	Knights Landing RST: water temperature (f)	Alert Triggered
3/13/2024	394.8	1.6%	Flow>95cfs	555.9	3.7%	Flow>95cfs	23,687.6	N/A	N/A
3/12/2024	388.7	4.0%	Flow>95cfs	536.0	2.6%	Flow>95cfs	23,528.9	N/A	N/A
3/11/2024	373.8	-5.2%	Flow>95cfs	522.7	-6.1%	Flow>95cfs	23,681.6	N/A	N/A

Table 5. STARS model simulations for route-specific entrainment, travel times, and survival. Travel time is calculated in days.

Stock	Date	Route	Median Travel Time	Survival	Routing Probability
Winter Chinook	2024-03-16	Overall	4.55	0.71	N/A
Winter Chinook	2024-03-16	Sacramento River	4.11	0.76	0.65
Winter Chinook	2024-03-16	Yolo Bypass	9.76	0.65	0.00
Winter Chinook	2024-03-16	Sutter Slough	4.84	0.63	0.13
Winter Chinook	2024-03-16	Steamboat Slough	4.09	0.76	0.11
Winter Chinook	2024-03-16	Interior Delta	7.19	0.50	0.11
Late-fall Chinook	2024-03-16	Overall	4.60	0.64	N/A
Late-fall Chinook	2024-03-16	Delta Cross Channel	N/A	N/A	0.00
Late-fall Chinook	2024-03-16	Georgiana Slough	7.29	0.36	0.18
Late-fall Chinook	2024-03-16	Sacramento River	3.87	0.71	0.47
Late-fall Chinook	2024-03-16	Sutter and Steamboat Slough	4.62	0.69	0.34

The entrainment tool estimates a median and maximum loss of winter-run Chinook Salmon and juvenile CCV Steelhead each week (Table 6a).

Table 6a-c. WY 2024 loss and salvage predictor data: Environmental details, current and forecast. Unless values (i.e. OMR and export) are explicitly stated in Table 6c, covariate values are the same as values listed in 6b. Model results from 3/11/2024.

- a) WY 2024 loss and salvage predictor data: Predicted weekly loss of winter-run Chinook salmon and steelhead at CVP and SWP facilities estimated from model developed in Tillotson et al. (2022).

Parameter	Modeled Current Week	Modeled Next Week
Predicted Steelhead, Median %	201	91
Predicted Steelhead, High %	527	284
Predicted Chinook Winter Run, Median %	297	243
Predicted Chinook Winter Run, High %	729	729

- b) Environmental details, current and forecast

Parameter	Data	Forecast
Temperature (Mallard Island, C)	12.4	12.4
Precipitation (5-d running sum, inches)	0.06	0.06
Old and Middle River Flows (cfs)	-827	-827
Sacramento River Flow (Freeport, cfs)	55659	55659
DCC Gates	closed	closed
San Joaquin River Flow (Vernalis, cfs)	5781	5781
Export	3826	3826

- c) Salvage predictor estimates for natural origin Central Valley Steelhead from model developed in Tillotson et al. (2022)¹ across multiple OMR flow scenarios represented within a range of percentiles. The model with expected discharge values (Discharge Range) in the Sacramento and San Joaquin Rivers through 3/15.

OMR	Exports	San Joaquin Flow	Sacramento Flow	25th Percentile Weekly Loss	Median Weekly Loss	75th Percentile Weekly Loss	Median Daily Loss
900	1500	5357	37794	25.98	57.4	116.7225	8.2
0	2500	5357	37794	30.31	60.62	131.12	8.66
-500	3000	5357	37794	30.31	65.28	141.765	9.33
-1000	3600	5357	37794	30.31	67.145	143.22	9.59

¹ Tillotson, M.D., J. Hassrick, A.L. Collins, & C. Phillis. 2022. Machine Learning Forecasts to Reduce Risk of Entrainment Loss of Endangered Salmonids at Large-Scale Water Diversions in the Sacramento-San Joaquin Delta, California. San Francisco Estuary & Watershed Science 20(2):1-21

OMR	Exports	San Joaquin Flow	Sacramento Flow	25th Percentile Weekly Loss	Median Weekly Loss	75th Percentile Weekly Loss	Median Daily Loss
-1500	4150	5357	37794	33.765	77.44	143.8575	11.06
-2000	4700	5357	37794	33.765	80.88	161.385	11.55
-2500	5200	5357	37794	34.64	83.1	171.59	11.87
-3000	5800	5357	37794	33.335	80.16	176.03	11.45
-3500	6300	5357	37794	30.31	86.6	219.66	12.37
-4000	6900	5357	37794	25.98	122.44	235.44	17.49
-4500	7400	5357	37794	25.98	148.94	337.07	21.28
-5000	8000	5357	37794	52.47	161	354.06	23

Table 7. Annual loss of clipped juvenile steelhead at the salvage facilities and total hatchery juvenile steelhead release numbers for brood years 2016 to 2023*. From 2016 to 2024, average annual % lost to the facilities was 0.153%. Note that release locations and dates, which vary by year, were not considered for this calculation. Hatchery release numbers were acquired from: CDFW hatchery releases- Calfish.org and USFWS hatchery releases data provided by Kevin Offill, 3/13/2024. Water facility loss data acquired from: SacPAS and reflects Water Year 2017 - 3/12/2024. * BY23 includes all fish released prior to 3/14/2024 (data is preliminary)

Brood Year	Total Hatchery Steelhead Release Number (BY)	Loss of clipped steelhead at the facilities (WY)	% Total Hatchery Number Lost to the Facilities	Water Year
2016	1,019,501	164.29	0.016	2017
2017	811,379	2,462.90	0.304	2018
2018	1,264,939	5,777.70	0.457	2019
2019	1,084,899	659.44	0.061	2020
2020	1,853,751	341.69	0.018	2021
2021	1,676,701	639.79	0.038	2022
2022	1,623,483	3,650.30	0.225	2023
2023*	1,517,998	1,581.93	0.104	2024

“Today, the Central Valley O. mykiss population complex is dominated by hatchery-origin fish” (NMFS 2003; Lindley et al. 2007). Best available information indicates that natural-origin O. mykiss comprise only 6% to 16% of the O. mykiss in the northern Sacramento-San Joaquin Delta and San Francisco Estuary. While diversifying the portfolio of release practices is expected to

benefit stock complex resiliency and stability, it is also important to consider the potential genetic and ecological impacts of releasing hatchery-origin pre-smolts on natural-origin *O. mykiss* and other life stages of hatchery-origin *O. mykiss*." See Eric R. Huber, Rachael E. Ryan, Rachel C. Johnson, Anna M. Sturrock, Robert A. Lusardi, and Stephanie M. Carlson. Seventy years of diminishing biocomplexity of California Central Valley hatchery steelhead, *Oncorhynchus mykiss*. Canadian Journal of Fisheries and Aquatic Sciences.

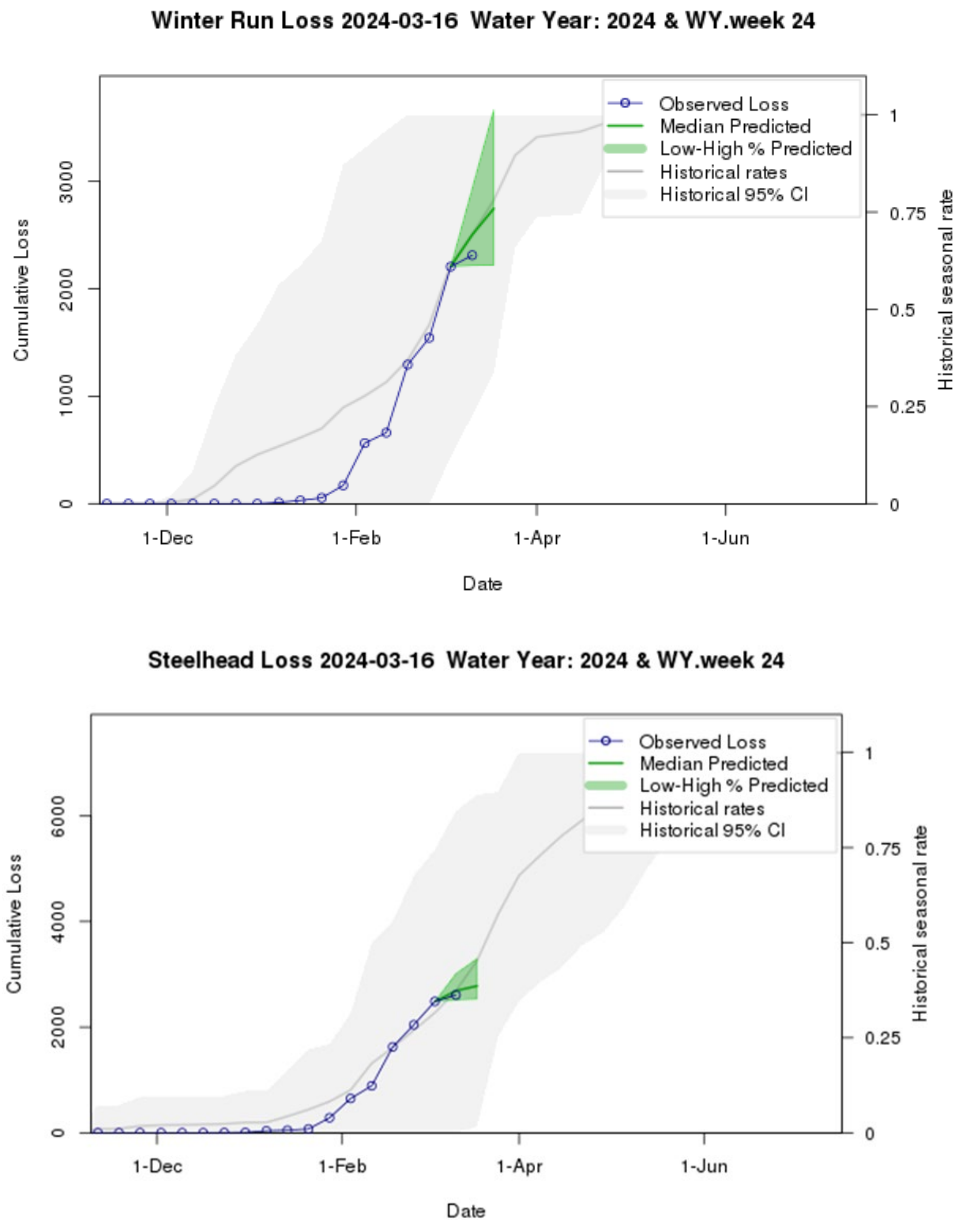


Figure 1. Predicted weekly loss of steelhead and winter-run Chinook salmon at the CVP and SWP facilities

Figure 1 is two-line graphs of the predicted weekly loss of steelhead and winter-run Chinook salmon for water year 2024 beginning on December 1, 2023. The first line graph shows the cumulative loss of winter-run Chinook salmon comparing the predicted loss of 2700 and the observed loss of 2400. The second line graph shows the cumulative loss

of Steelhead salmon comparing the median predicted loss of about 3000 and the observed loss of about 2900.

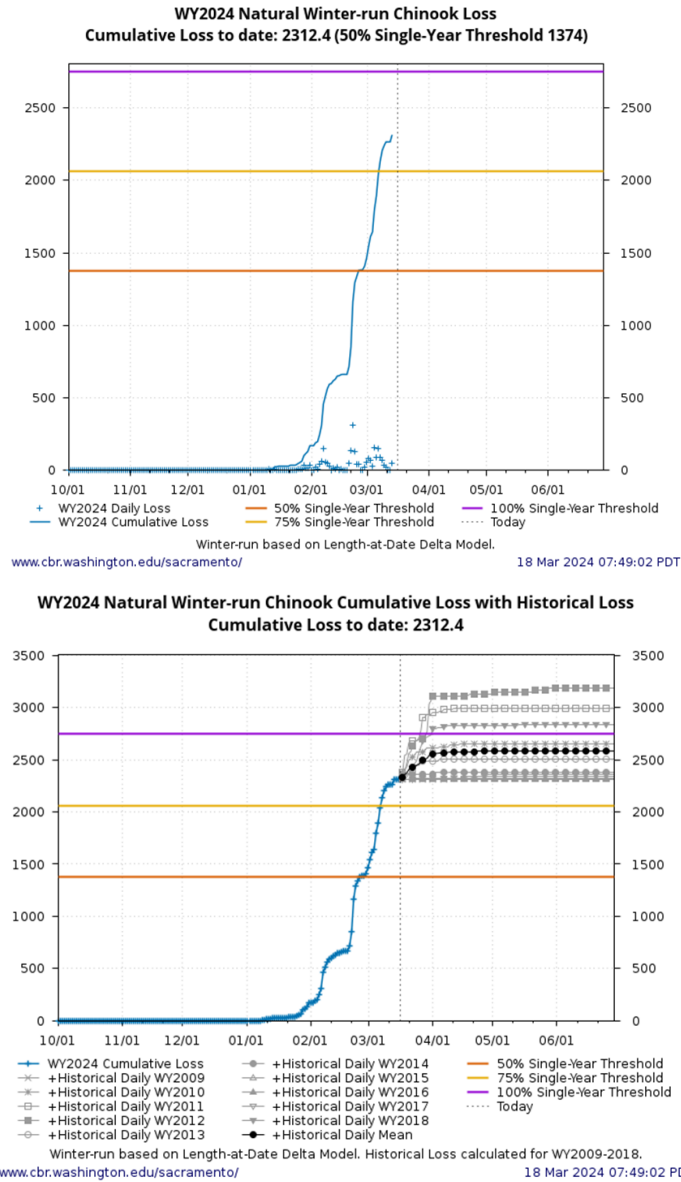


Figure 2. Cumulative natural winter-run Chinook salmon loss for the year (blue) and 2009 – 2018 historic cumulative loss (gray, different symbols). Historic daily mean plotted in black circles.

Figure 2 is two line graphs showing the natural winter-run Chinook salmon cumulative loss for water year 2024 beginning on October 1, 2023, and ending on June 30, 2024.

The first line graph shows the water year 2024 cumulative loss to date. The water year 2024 cumulative loss passes the the 50 percent single-year threshold on February 21, 2024, and the 75 percent single-year threshold on March 10, 2024.

The second line graph shows the water year 2024 cumulative loss combined with historical daily water years from 2009 – 2018. Water year 2024 cumulative loss combined with historical daily water year loss exceeds the 75 percent single-year threshold for water years 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, and 2018.

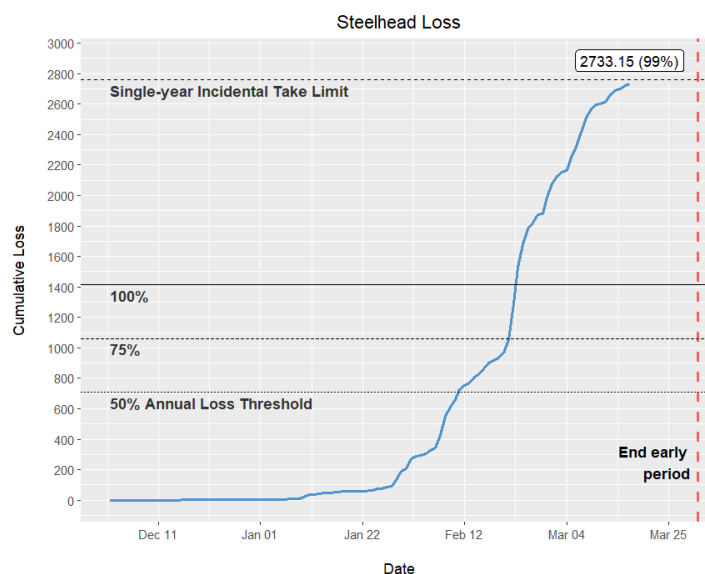
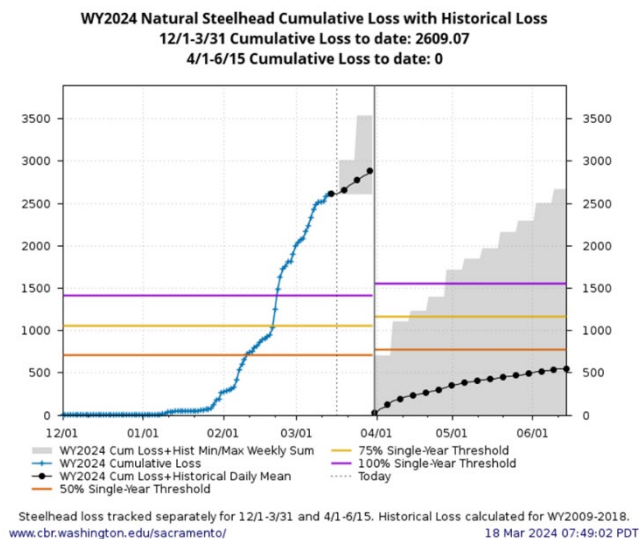


Figure 3. Top Graph: Cumulative natural steelhead loss overlaid with mean, minimum, and maximum historic salvage rates. Bottom Graph: Cumulative natural steelhead loss in WY2024 representing the most current steelhead loss numbers.

Figure 3 is two line graphs, the first of which shows the cumulative natural steelhead loss of WY2024 compared with the 2009-2018 historic cumulative natural steelhead loss beginning on December 1, 2023, and finishing on June 15, 2023, and the second of which shows the most current steelhead loss numbers in 2024.

The first line graph shows the WY2024 cumulative loss and historical daily mean pass the 100% single-year threshold on February 21, 2024 and reach 2600 on March 15, 2024. The WY2024 cumulative loss and historical daily mean begins to approach the 50% single-year threshold at the start of April 2023 and reached just above 500 on June 15, 2024.

The second line graph shows the WY2024 cumulative loss at 2733.15 or 99 percent of the single-year incidental take limit.

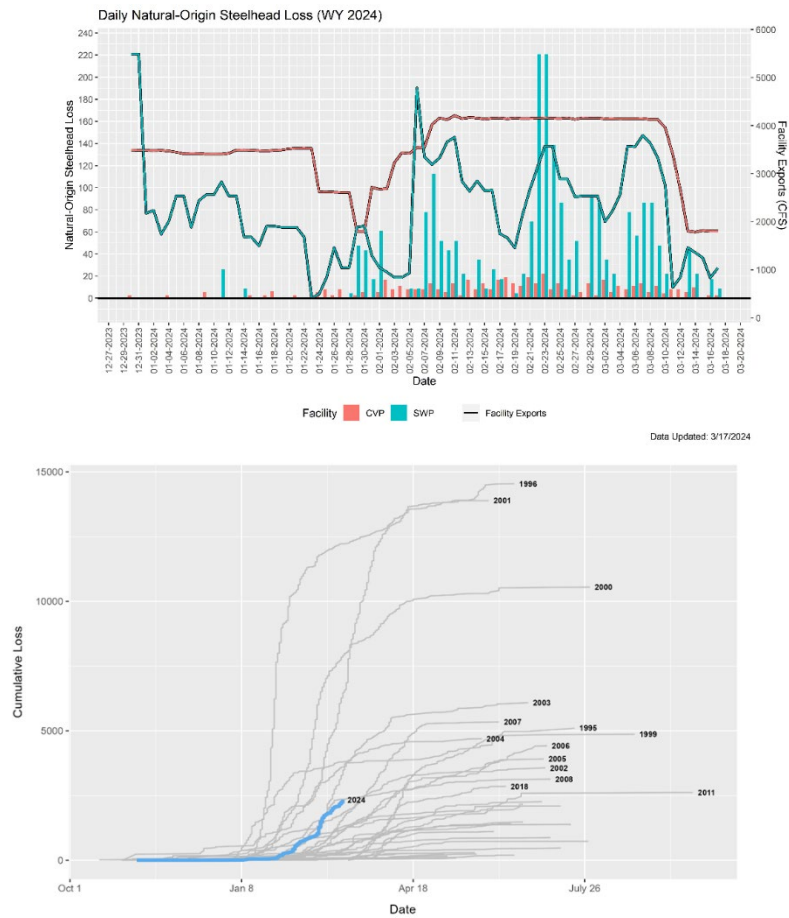


Figure 4. (Top) Daily steelhead loss as it relates to exports at CVP and SWP facilities. (Bottom) Central Valley Steelhead historic cumulative loss from salvage facilities from water year (WY) 1994-2024. The solid blue line represents 2024 and to ensure readability, only cumulative loss curves that have exceeded current 2024 cumulative loss were labeled by WY (updated through 3/12).

Figure 4 is two line graphs, the first of which shows daily steelhead loss as it relates to exports at CVP and SWP facilities, and the second shows Central Valley Steelhead historic cumulative loss from salvage facilities from the years 1999-2023 compared with cumulative loss in WY 2024.

The first graph compares Natural Origin Steelhead Loss with Facility Exports from December 27, 2023, until March 20, 2024.

The second graph shows cumulative loss from salvage facilities for WY 2024 at around 2500, and highlights years that have exceeded this number which include 1995, 1996, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2011, 2018, and 2024.

Evaluation

1. After January 1, are more than 5% of juveniles from one or more salmonid species present in the Delta?

Greater than 5% of all salmonid species are estimated to be present in the Delta.

2. Does the operational outlook's ranges impact fish movement and change the potential distribution of fish?

Potential effects within the 7 days (near-term) in the operations outlook.

OMR flow is expected to be more positive than -5,000 cfs this upcoming week. OMR flows more positive than -5,000 cfs are hypothesized to have a less negative impact on movement and distribution of salmonids in the South Delta (NMFS 2009, SST 2017, Perry et al. 2016).

Potential effects longer than the 7 days (longer-term) in the operations outlook.

Not applicable, see response above to (2) (i).

3. What is the likelihood of increased loss exceeding the next annual loss threshold (50%, 75% or 90% of threshold) resulting in OMR management actions based on population distribution, abundance, and behavior of fish in the Delta?

Winter-run Chinook salmon

Total juvenile natural winter-run Chinook salmon (LAD) loss is 2633.66 fish (as of 03/17/2024). Loss of juvenile winter-run Chinook salmon (LAD) has occurred in the past week at the CVP and SWP fish salvage facilities. The 50% single-year loss threshold was exceeded on 2/25/2024 and the 75% single-year loss threshold was exceeded on 3/7/2024. The agencies in the SaMT assessed the likelihood of exceeding the annual loss threshold and believe the loss occurring in the next week may lead to exceedance of the 100% single-year loss threshold. It is possible annual loss threshold (2,748) and incidental take limit (4,698) will be exceeded this year, based on length at date.

The length-at-date model is used for tracking exceedance of these thresholds; however, only a small fraction of the winter-run LAD salmon observed at the salvage facilities have been genetically identified as winter-run to date. Figures 1 and 2 also provide a forecast of winter-run loss for the year and indicate possible

exceedance of these salvage based winter-run triggers. It is uncertain how well the historical data described in Figure 2 may be relevant this year. Genetic methods provide a more accurate measure of identifying winter-run Chinook salmon than length-at-date. DNA results through 3/13/2024 indicate a loss of 114.46 winter-run Chinook salmon so far this year.

Central Valley Steelhead

Total natural juvenile steelhead loss is 2733.15 fish (as of 03/17/2024). Loss of natural juvenile steelhead has occurred in the past week at the CVP and SWP fish salvage facilities. The 50% single year loss threshold for the Dec 1 to March 31 period was exceeded on 2/11/2024, the 75% loss threshold was exceeded on 2/22/2024, and the 100% loss threshold was exceeded on 2/23/2024.

A means of calculating a juvenile production estimate currently does not exist for steelhead, limiting the ability of SaMT to assess the impact of loss on the basin-wide or genetically distinct populations of *Oncorhynchus mykiss*. Information on steelhead abundance and distribution in the Delta is also limited, as the existing fish surveys do not target steelhead and may be ineffective at catching these larger-sized fish (yearling or older). Although the proportion of wild steelhead population lost at the salvage facilities is unknown due to lack of WY 2024 population size, the proportion of hatchery or tagged steelhead observed at the facilities relative to release or tagged fish numbers can potentially offer insight into the proportional entrainment of wild steelhead. Annual loss of clipped steelhead at the salvage facilities represent between 0.02 to 0.46% of total hatchery release numbers between water year 2017 and 2024 (Table 7). Meanwhile, acoustic tag study of wild steelhead from the Stanislaus River indicate that 9 out of 197 (~4.6%) tagged fish arrived nearby or at the facilities ([CalFish Track](#)).

Salmonid species are expected to have increased survival when flows are high (Michel et al. 2021) and acoustic telemetry studies indicated that survival is correlated with increased flows at Vernalis for San-Joaquin origin Steelhead (Buchanan et al. 2021), potentially influencing the number of fish observed at the salvage facilities.

However, SaMT recognizes that reduction of export or a more positive OMR should generally lead to a reduction in salvage and loss of steelhead (Table 6c, Figure 5). The agencies in the SaMT assessed the likelihood of exceeding the incidental take limit and believe that loss occurring in the next week can exceed this threshold (see Figures 2 and 4).

The CVP and SWP have been operating to OMRI of no more negative than –500 cfs beginning on 3/11/2024. Weekly loss of natural-origin steelhead has decreased significantly. Since 3/11/24, loss of natural-origin steelhead totaled 139.03 (salvage data through 3/17/24), which is a decrease from the past 3 weeks:

- 2/19/24-2/25/24: 1650.16
- 2/26/24-3/3/24: 530.81
- 3/4/24-3/10/24: 723.80
- 3/11/24-3/17/24: 139.03

Continued OMRI of -500 cfs is likely to continue to show lower steelhead loss in the upcoming week.

4. If an annual loss threshold has been exceeded, do continued OMR restrictions benefit fish movement and survival based on real-time information?

Winter-run Chinook salmon

The 100% annual loss threshold for winter-run Chinook salmon has not been exceeded in WY 2024. However, the 50% and 75% single year loss thresholds have been exceeded and export facilities will operate such that the fourteen-day average OMRI flow is no more negative than -2,500 cfs through the end of OMR management season or until the risk is no longer present based on a risk assessment.

Central Valley Steelhead

The 100% annual loss threshold for steelhead (December 1 – March 31) has been exceeded for WY 2024.

It is uncertain if additional OMR restrictions benefit fish movement and survival. Buchanan et al.'s (2021) study indicated that high flows increase through-Delta survival of steelhead, with little to no association between Delta export and survival. However, this study was conducted in 2011-2016 when OMR was restricted to be no more negative than -5,000 cfs, and therefore does not necessarily suggest that higher Delta export cannot be associated with lower survival.

STARS model output indicates higher survival for Sacramento River-origin salmon in the Delta relative to the past several years due to hydrological conditions ([STARS Predicted Survival, Travel-Time and Routing for Winter Run](#)). Steelhead appear to be outmigrating at a larger sizes than Chinook salmon based on salvage data (~200-300 mm fork length) and therefore may have even higher survival than Chinook salmon. Although the December-March period is expected to reflect the

Delta outmigration timing of Sacramento-basin steelhead, real-time data from [CalFish Track](#) indicate that some steelhead from the Stanislaus River (San Joaquin basin) have been entrained at the salvage facilities and some have even migrated past Benicia.

Mokelumne hatchery steelhead were released on 3/15/2024 at the Lighthouse Resort in the Delta to evaluate the effects of export on steelhead. To date, 5 fish have been detected upstream of the release site.

The current average loss of CCV Steelhead is 15.33 per day over the last week while targeting an OMRI no more negative than -500 cfs with a total loss of 2733.15 for the Dec-Mar. period. At this rate the NMFS Incidental Take Limit (ITL) of 2,760 for the December to March period will likely be exceeded before March 31. A mean daily loss less than 1.92 would be required to not exceed the ITL before March 31st. According to the Tillotson Model runs, a more positive OMR flow would decrease loss of steelhead.

The Tillotson Model results at OMRI of -500 cfs predicted a median daily loss of 23.43 per day last week, which is higher than what was observed over the previous week when a no more negative than -500 cfs OMRI was targeted. At -1500 cfs OMRI the latest range of model runs (Table 7) predicts a median daily loss of 11.06 and at -500 cfs OMRI the prediction for the median daily loss is 9.33. CVP and SWP may target an OMRI no more negative than -1,500 cfs. SaMT acknowledges that this would likely result in an increase in loss per day based on the Tillotson Model which would not be beneficial to the steelhead population, increasing the likelihood of exceeding the ITL sooner. Since the 100% threshold is exceeded and the ITL is likely to be exceeded this month, any decrease in loss of steelhead would benefit the species.

5. If OMR is more negative than -5,000 cfs, are there changes in spawning, rearing, foraging, sheltering, or migration behavior beyond those anticipated to occur under OMR management at -5,000 cfs?

Expected OMR flows are targeting -1500 cfs for the next week. Under OMR flows more negative than -5,000 cfs the SaMT expects impacts to rearing, foraging, sheltering, or migration of salmonids present in the south Delta. Salmonid presence in the south Delta is difficult to assess because of limited observations and there is uncertainty in how much of the population might be impacted.

Salmonid References

Buchanan RA, Buttermore E, Israel J. 2021. Outmigration survival of a threatened steelhead population through a tidal estuary. *Can J Fish Aquat Sci.* 78(12):1869–1886.
<https://doi.org/10.1139/cjfas-2020-0467>

Michel CJ, Notch JJ, Cordoleani F, Ammann AJ, Danner EM. 2021. Nonlinear survival of imperiled fish informs managed flows in a highly modified river. *Ecosphere*. 12(5). <https://doi.org/10.1002/ecs2.3498>

Tillotson M, Hassrick J, Collins A, Phillis C. 2022. Machine Learning Forecasts to Reduce Risk of Entrainment Loss of Endangered Salmonids at Large-Scale Water Diversions in the Sacramento–San Joaquin Delta, California. *San Fr Estuary Watershed Sci*. 20(2):0–21. <https://doi.org/10.15447/sfew.2022v20iss2art3>

Biology Distribution and Evaluation of Green Sturgeon

Population Status

- Delta Life Stages:
 - Adults and Juveniles

Distribution

Current Distribution

- Adults: Most abundant during spring spawning migration period of March through May, and post spawning out-migration periods May through June; October through January depending on first winter storm event resulting in significant Sacramento River flow increases. Adult presence year-round to a lesser extent mainly in San Pablo Bay.
- Juveniles: Age-1 through Age-3 juveniles present year-round and widely distributed. Juveniles tagged with acoustic tags in the main channel Sacramento River near Sherman Island detected in the Sacramento River as far upstream as the Cache Slough complex, in the San Joaquin River at the Antioch Bridge, in Threemile, Horseshoe Bend, and Montezuma Sloughs. Seasonal abundance at the primary sampling site (near Sherman Island) appears to be highest during summer in based on capture and telemetry data. Residence time at the primary sampling site for individual fish ranges from one day to over one year but telemetry data show outmigration from the primary sampling site to the Pacific Ocean ranges from 27 to 552 days. Recent capture data shows diurnal depth preference in the main channel of the Sacramento River. No recent documentation of shallow water habitat presence or foraging.

Historical Trends

- Juvenile and adult green sturgeon are historically present in the San Joaquin and Sacramento rivers and Delta.

Forecasted Distribution within Central Valley and Delta regions

- Juvenile and adult green sturgeon are likely present in the San Joaquin and Sacramento rivers and Delta during the next week.

Evaluation

1. Is there likely to be salvage that may exceed the annual loss limit?

Green sturgeon salvage is 0 fish (as of 3/17/2024). The agencies in the SaMT assessed the likelihood of salvage occurring in the next week is unlikely to occur.

Biology, Distribution, and Evaluation of Delta Smelt

Population Status

- Delta Smelt Life Stages:
 - Adults, Larvae
- Brood Year 2023:
- Abundance estimate:
 - The most recent non-zero abundance estimate for Delta Smelt is from the week of March 11, 2024 and is 5,150 (95% CI: 1,426 to 13,412).
- Biological Conditions:
 - Adult Delta Smelt are expected to be present in Suisun Marsh, the lower Sacramento River, and the Deep Water Shipping Channel. Delta Smelt have likely completed their population-level, upstream spawning migration in response to increases in turbidity and flow (i.e., “first flush”) conditions, which were met on 1/21/2024 (Grimaldo, et al. 2009; Sommer et al. 2011). Water temperatures became suitable for spawning on 1/31/2024 (based on temperatures from Damon et al. 2016). The Smelt Monitoring Team discussed the most recent monitoring data (TABLE 7) and considered published literature and professional judgement on the historical trends in regional distribution.

Distribution

Current Distribution

- Real time detection data are currently limited to EDSM, Chipps Island Trawl, SLS, and 20 mm Survey. Bay Study provides data as available.
- Forty-eight Delta Smelt have been detected this water year (surveys and salvage). Forty-three of these have been from experimental releases.
- Three marked adult Delta Smelt have been detected by surveys (excluding salvage) in Suisun Marsh, the lower Sacramento River, and the Sacramento Deep Water Shipping Channel since 3/5/2024.

- No Delta Smelt have been salvaged after 2/23/2024. Cumulative seasonal salvage is 56.
- Qualitative Larval sampling began on 2/20/2024 at 0400 at the Tracy Fish Collection Facility (TFCF) and began at 1100 on 3/11/2024 at the Skinner Fish Facility (SFF).
- COA 8.5.2: Triggered 2/5/2024 by SLS survey 3 and implemented starting 2/7/2024; it was retriggered on 2/21/2024 by SLS survey 4, and on 3/4/2024 by SLS survey 5, however it was not triggered by SLS survey 6 on 3/18/2024.

Table 7. Summary of newly reported detections of Delta Smelt by Region and Salvage Facilities since the last assessment. Regions are those defined by EDSM sampling. Delta Smelt >58mm FL are considered adults. Subadult fish are considered by the SMT to be fish from the previous year's cohort based on size and timing of collection. Young of year are considered juveniles and larvae. Salvage values reflect pre-expansion salvage.

Life Stage	North	South	West	Far West	Salvage
Adult	0	0	1	0	0
Subadult	0	0	0	0	0
Larvae/Juvenile	0	0	0	0	0

Table 8. Summary of recent Delta Smelt detections reported since last assessment and the total detections for the current water year. Notes reflect latest information on reported detections or completion of survey for the water year and include both larval and adult detections. Total Fish counts do not distinguish between hatchery origin and wild Delta Smelt. Table indicates new detections and previously reported detections that have undergone preliminary ID, QA/QC, and genetic confirmation. Numbers are updated as QA/QC and genetic confirmation become available. Tracy and Skinner facility counts reflect pre-expansion salvage.

Sampling Method	Frequency	New Detections	Preliminary Detections	QA/QC Detections	Genetically Confirmed to Date	Total WY2024	Notes
0	Weekly	1	N/A	33	N/A	33	Phase 1 began 12/4/2023
SKT	Monthly	0	N/A	N/A	N/A	0	not occurring this year
SLS	Biweekly	0	N/A	N/A	N/A	0	Began 12/11/2023
20-mm	Biweekly	0	N/A	/A	N/A	0	Ongoing

Sampling Method	Frequency	New Detections	Preliminary Detections	QA/QC Detections	Genetically Confirmed to Date	Total WY2024	Notes
Summer Townet	Biweekly	0	N/A	N/A	N/A	0	Begins:
Bay Study	Monthly	0	N/A	N/A	N/A	0	Ongoing
FMWT	Monthly	0	N/A	N/A	N/A	0	Complete
Chippis Island Trawl	Weekly	0	N/A	N/A	N/A	0	Ongoing
DJFMP Electrofishing survey	Monthly	0	N/A	1	N/A	1	Ongoing
FCCL Brood Stock Collections	Weekly	0	N/A	N/A	N/A	0	Complete
LEPS	As available	0	N/A	N/A	N/A	0	Began 1/2/2024
FRP	Daily	0	N/A	N/A	N/A	0	Ongoing
Tracy Fish Collection Facility (CVP)	Daily	0	N/A	14	N/A	14	Ongoing
Skinner Fish Facility (SWP)	Daily	0	N/A	N/A	N/A	0	Ongoing
Total	N/A	N/A	N/A	N/A	N/A	48	Sum of all Delta Smelt observed during the water year

Cultured Delta Smelt Experimental Releases

- Experimental releases completed in Water Year 2024 include:
 - Release 1: 14,104 fish released at Sacramento River at Rio Vista (truck release)
 - Release 2: 13,089 fish released at Sacramento River at Rio Vista (hard and soft releases)
 - Release 3: 12,691 fish released at Sacramento River at Rio Vista (hard carboy and trailer release)
 - Release 4: 25,649 fish released at Sacramento River at Rio Vista (truck release)

- Release 5: 12,778 fish released at Sacramento River at Rio Vista (hard and soft releases)
- Release 6: 13,157 fish released at Sacramento River at Rio Vista (hard trailer and soft release)
- See additional details at: [SacPAS: Central Valley Prediction & Assessment of Salmon](#)

Table 9. Weekly summary of the origin of Delta Smelt. These identifications are considered tentative and additional genetic testing will confirm the identity of individuals. Individuals with no tags are provided alive to the FCCL as potential additions to the FCCL Broodstock.

Date	Survey	Stratum/Station	Total Caught	Ad. Clipped	VIE	No Tag
3/13/2024	EDSM	Lower Sacramento River	1	N/A	X	N/A

Historical Trends

- Upstream migration for Delta Smelt occurs between September and December and in response to “first flush” conditions (Sommer et al. 2011, Grimaldo et al. 2009). Migration typically ranges one to four weeks after flow and turbidity increases, based on salvage data (Sommer et al. 2011).
- Historically, detections of ripe Delta Smelt began in January and peaked in February and March and the majority of Delta Smelt spawning occurs within a temperature range of 9-18°C (Damon et al. 2016).
- Based on historical monitoring data from the past few years (<https://github.com/Delta-Stewardship-Council/deltafish>), first detection of larvae in the Central and South Delta has typically occurred by mid to late March. (https://www.cbr.washington.edu/sacramento/data/query_salvage_hrt.html).
- Salvage data as presented on SacPas indicates that adult Delta Smelt salvage in recent years has reached the 50th percentile at the end of February – beginning of March.
- Historically, the highest peak in salvage is in May and the second highest is in June (Grimaldo et al 2009).

Forecasted Distribution within Central Valley and Delta regions

- Predicting the distribution of Delta Smelt is currently difficult because detection data is limited to a few wild individuals and historic patterns may not be representative of the low population levels.

- The SMT uses turbidity as a surrogate for Delta Smelt presence and in making assessments of the likelihood of entrainment for larval Delta Smelt after spawning begins.
- The potential of experimentally released Delta Smelt to distribute from their release site is unknown at this time and SMT cannot predict their distribution beyond the original release site and subsequent recaptures. There is a high degree of uncertainty regarding the response of cultured fish to environmental cues typically applied to wild Delta Smelt.

Abiotic Conditions

Turbidity

- Clear and sunny today with chance of showers Friday through the rest of the week. In Stockton, light W to WNW winds today through Thursday. In Antioch, light W winds today through Thursday.
- Turbidity is below 12 FNU at OBI and at other stations in the central and south Delta. Turbidity will likely remain stable or decrease this week. The SLS survey 6 mean Secchi depth for 11 of the 12 South Delta stations was 1.11 m as of 3/18/2024.

Table 10. Relevant Environmental Factors to the current management actions for Delta Smelt.

Date Reported	OBI Daily Average Turbidity (FNU)	SJJ 3-day Average Water temperature (°C/°F)	SLS 6 (3/18/2024) 12-station average Secchi Depth (m)
3/18/2024	6.1	13.4/56.2	1.11 (11 of 12 stations measured)

X2 Conditions

- As of 3/18/2024, X2 was estimated to be < 56 km.

Other Environmental Conditions

- The Fish and Water Operation Outlook OMR Index values are expected to range between -400 to -1600 cfs this week.
- QWEST was +11,500 cfs as of 3/18/2024 and is estimated to range between +8,000 to +12,000 cfs. Real time tracking of environmental conditions, relevant thresholds and Delta Smelt catch data are updated daily at: [SacPAS: Central Valley Prediction & Assessment of Salmon](#).
- Water temperature was 13.4°C at Rio Vista and 13.7°C at Antioch as of 3/18/2024.
- Anticipated Vernalis Flows: 4,000 to 6,000 cfs

Evaluation

USBR and DWR Proposed Operations:

- Effective March: X2 at Port Chicago for 27 days in March; $E/I \leq 0.35$.
- Effective 3/8, CVP and SWP project operations will be limited to a 14-day average OMRI flow no more negative than -2,500 cfs per the Proposed Action and ITP COA 8.6.1 with 75% of the annual loss threshold of natural-origin LAD winter-run exceeded on 3/7.
- Effective 2/29, CVP and SWP project operations will be limited to a 14-day average OMRI flow no more negative than -2,500 cfs to continue evaluating steelhead conditions and risks per WOMT decision of 2/28.
- Effective 3/11, CVP and SWP project operations will be limited to an OMRI of no more negative than -500 cfs beginning Monday 3/11, to protect steelhead based on the Proposed Action: Director's decision of 3/7.
- Reclamation and DWR propose to operate to -1,500 cfs OMRI following the conclusion of the SaMT, WOMT, and Director process this week.

1. Between December 1 and January 31, has any first flush condition been exceeded?

First flush conditions were exceeded on 1/21/2024. Integrated Early Winter Pulse Protection (IEWPP) was implemented from 01/23/2024 through 2/5/2024.

2. Do DSM have a high risk of migration and dispersal into areas at high risk of future entrainment? (December 1- January 31)

No longer relevant.

3. Has a spent female been collected?

Neither a ripe nor spent female has been collected.

4. If OMR of -2000 cfs does not reduce OBI turbidity below 12NTU/FNU, what OMR target is deemed protective between -2000 and -5000 cfs?

One-day average turbidity at OBI is < 12 FNU.

5. If OBI is 12 NTU/FNU, what do other station locations show?

OBI, Holland Cut, Victoria Canal and Clifton Court Forebay turbidities are all < 12 NTU/FNU as of 3/18/2024. The SLS survey 6 mean Secchi depth for 11 of the 12 South Delta stations was 1.11 m as of 3/18/2024.

6. If OBI is 12 NTU/FNU, is a turbidity bridge avoidance action not warranted? What is the supporting information?

Turbidity bridge action is not warranted at this time based on OBI turbidity < 12 FNU.

Given current distribution of detected adult DS and low turbidities in the OMR corridor, entrainment risk is low for adult DS.

7. After March 15 and if QWEST is negative, are larval or juvenile DSM within the entrainment zone of the CVP and SWP pumps based on surveys?

Due to following the IOP 2023, we are not considering the March 15 date; instead, we are following COA 8.5.2. QWEST is highly positive and expected to remain positive throughout the week.

Temperature became suitable for spawning on 1/31/2024 (> 12°C three-day average at SJJ; Damon et al. 2016), but no ripe or spent adult female or larval DS have been detected. Mean Secchi depth for 11 of the 12 South Delta stations is > 1 m as of 3/18/2024. Implementation of steelhead protections is expected to reduce the chance of entraining Delta Smelt.

8. Based on real-time spatial distribution of Delta Smelt and currently available turbidity information, should OMR be managed to no more negative than -3,500?

No. Water temperatures became suitable for spawning on 1/31/2024, however mean Secchi depth for 11 of the 12 South Delta stations was >1 m as of 3/18/2024 and no larval or juvenile Delta Smelt have been detected in the Central or South Delta, thus risk is low for larval DS. COA 8.5.2 was not triggered by the most recent SLS survey (SLS 6). Implementation of steelhead protections is expected to reduce the chance of entraining Delta Smelt.

9. What do hydrodynamic models, informed by EDSM or other relevant data, suggest the estimated percentage of larval and juvenile DSM that could be entrained may be?

No larval DS have been detected, and no PTM runs were requested by the SMT in advance of the SMT meeting. Flows at Vernalis and QWEST are and will remain positive throughout the week.

Delta Smelt References

- Damon, L. J., S. B. Slater, R. D. Baxter, and R. W. Fujimura. 2016. Fecundity and reproductive potential of wild female Delta smelt in the upper San Francisco Estuary, California. *California Fish and Game* 102(4):188–210.
- Hobbs, J. A., Lewis, L. S., Willmes, M., Denney, C., & Bush, E. (2019). Complex life histories discovered in a critically endangered fish. *Scientific Reports*, 9(1).
<https://doi.org/10.1038/s41598-019-52273-8>
- Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, B. Herbold & P. Smith (2009) Factors Affecting Fish Entrainment into Massive Water Diversions in a Tidal Freshwater Estuary: Can Fish Losses be Managed? *North American Journal of Fisheries Management*, 29:5, 1253-1270, DOI: 10.1577/M08-062.1
- Gross, E. S. (2021). Modeling Delta Smelt Distribution for Hypothesized Swimming Behaviors. *San Francisco Estuary and Watershed Science*, 19(1).
- Kimmerer, W. J. (2008). Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science*, 6(2).
- Polansky, L., Newman, K.B., Nobriga, M.L. et al. Spatiotemporal Models of an Estuarine Fish Species to Identify Patterns and Factors Impacting Their Distribution and Abundance. *Estuaries and Coasts* 41, 572–581 (2018). <https://doi.org/10.1007/s12237-017-0277-3>
- Smith, W. E., Polansky, L., and M. L Nobriga. 2021. Disentangling risks to an endangered fish: using a state-space life cycle model to separate natural mortality from anthropogenic losses. *Canadian Journal of Fisheries and Aquatic Sciences*, 78: 1008-1029.
- Sommer, T., F. Mejia, M. Nobriga, and L. Grimaldo. 2011. The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 9(2).