State of California

Department of Fish and Wildlife

Memorandum

Date: June 23, 2025

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Department of Fish and Wildlife

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State of California Department of Fish and Wildlife

Merced River Escapement Report 2022

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photo credit: Vanessa Kollmar, CDFW

Note to the readers:

2022 Merced River Fall Chinook Salmon Escapement Survey summarizes our annual Chinook (*Oncorhynchus tshawytscha*) salmon escapement survey and analyzes fishery and environmental data on the Merced River. The report documents salmon migration timing, spawning temporally and spatially and estimates 2022 fall Chinook salmon spawning population in the Merced River. The report discusses challenges faced during our survey.

Information collected is used in the Department's Ocean Salmon Project Coded-Wire Tags recovery report and the California Central Valley Chinook Population Database Report known as GrandTab.

All data is reviewed by Ryan Kok and Christopher Diviney, Central Region, Lower San Joaquin River Research and Restoration, PO Box 10 La Grange, CA 95329.

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Introduction

The Merced River, a 135-mile tributary of the San Joaquin River, begins in the Sierra Nevada Mountain Ranges near Yosemite National Park (NOAA 2022) and ends at its convergence with the San Joaquin River in Neuman, California. Historically, the Merced River supported populations of both spring and fall-run Chinook salmon (*Oncorhynchus tshwaytscha*); however, environmental changes in the twentieth-century lead to the extirpation of spring-run Chinook salmon (Yoshiyama 1996). Fall-run Chinook salmon ("fall-run") populations are on the decline and have recently been listed as a "Species of Special Concern" by the National Marine Fisheries Service (NOAA 2022). Since 1953, the California Department of Fish and Wildlife (CDFW) has monitored the migration of adult fall-run Chinook to the Merced River in an effort to estimate the returning reproductive population (Azat 2025). In 2022 CDFW conducted its annual fall-run Chinook salmon escapement survey ("survey") with the objective to: 1. Collect data and analyze coded-wire tag (CWT) data from hatchery-origin Chinook salmon. 2. Collect sex and fork length data. 3. Collect tissue samples for age and life-history reconstruction analyses. 4. Collect data on redd distributions and redd formation timing. 5. Estimate the reproductive population of adult fall-run in the Merced River.

Study Area

The survey covers 28 miles of the lower Merced River. It begins at the terminus of anadromy and ends downstream in Livingston, California. The survey is sub-divided into four sections (Figure 1). Section 1 begins at Crocker-Huffman Dam (RM52) and ends at the Snelling Road Bridge (RM47). Section 2 begins at Snelling Road Bridge and ends at the Highway 59 Bridge (RM42). Section 3 begins at the Highway 59 Bridge and ends at Shaffer Bridge in Winton, Ca (RM32). Section 4 begins at Shaffer Bridge and ends at Riverdance Farms in Livingston, California (RM24). In 2018, riffles were mapped with a Trimble Nomad® Submeter GPS Unit and drawn in ArcView® (Table 1). Riffles within the study area were labeled using an alphanumeric labeling system that consists of a letter and a number. The letters represent the RM, with "A" representing the first RM of the survey and the numbers representing the sequence of riffles within the mile. In 2022 three new riffles were added to the survey based on observed spawning activity: G4 (RM45), BB1 (RM24), and BB2 (RM24).

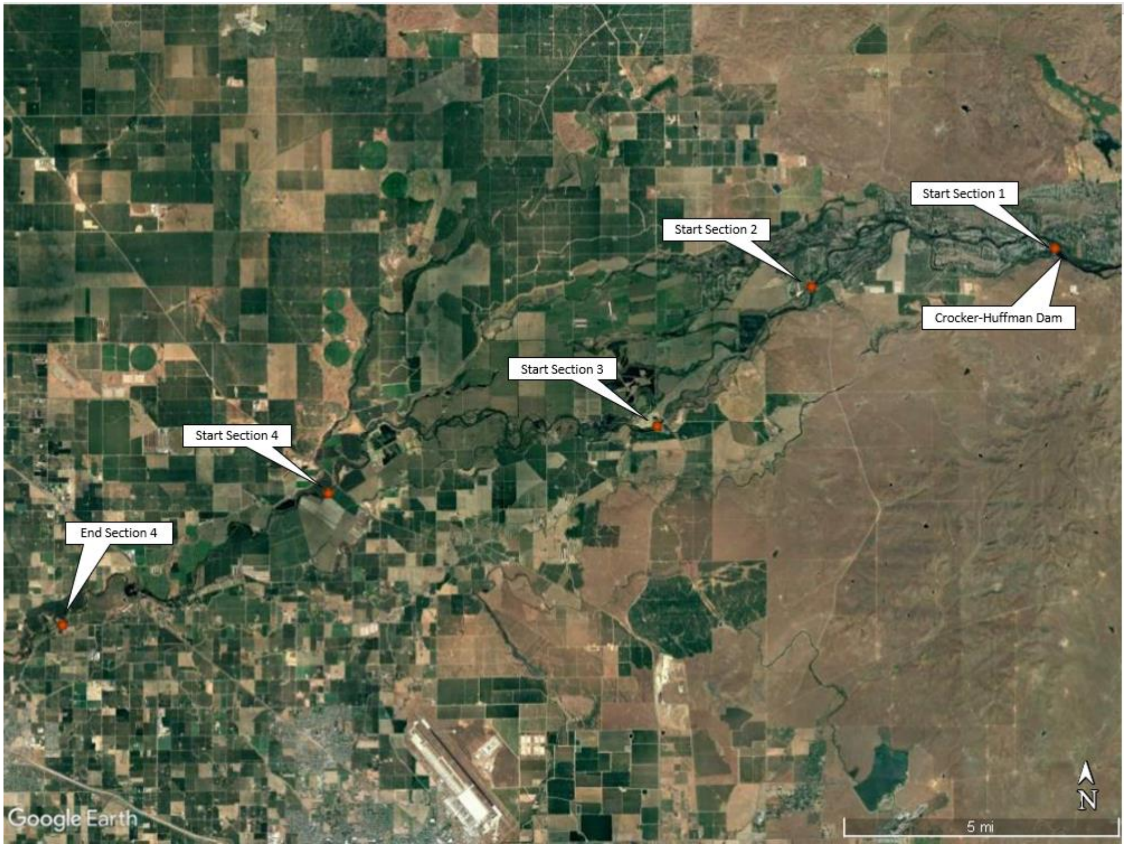

Figure 1. Satellite image of the lower Merced River showing the 28-mile surveyed area. (map data: Google Earth Pro)

Table 1. Riffle name reference table. Riffles are grouped by section and river miles are included in parenthesis.

Section 1	Section 2	Section 3	Section 3 (continued)	Section 4
2022	2022	2022	2022	2022
A1(52.0)	F3(46.3)	K1(42.0)	O1(37.9)	T3(32.3)
A2(51.6)	F4(46.0)	K2(41.8)	O2(37.7)	U1(31.7)
A3(51.4)	G1(45.7)	K3(41.5)	O3(37.6)	U2(31.5)
A4(51.3)	G2(45.5)	K4(41.5)	O4(37.5)	U3(31.2)
A5(51.0)	G3(45.2)	K5(41.3)	O5(37.0)	V1(30.9)
B1(50.9)	G4(45.1)	K6(41.1)	P1(36.8)	V2(30.9)
B2(50.8)	H1(45.0)	L1(40.6)	P2(36.6)	V3(30.7)
B3(50.5)	H2(44.9)	L2(40.4)	P3(36.3)	V4(30.5)

Section 1	Section 2	Section 3	Section 3 (continued)	Section 4
B4(50.3)	H3(44.8)	L3(40.2)	P4(36.2)	W1(30.0)
B5(50.2)	H4(44.7)	L4(40.1)	P5(36.0)	W2(29.9)
B6(50.0)	H5(44.4)	M1(39.9)	Q1(36.0)	W3(29.7)
C1(49.9)	H6(44.2)	M2(39.7)	Q2(35.8)	W4(29.4)
C2(49.8)	I1(43.9)	M3(39.6)	Q3(35.7)	W5(29.4)
C3N(49.4)	I2(43.8)	M4(39.4)	Q4(35.6)	X1(29.0)
C3S(49.4)	I3(43.6)	M5(39.3)	Q5(35.4)	X2(28.8)
C4(49.1)	I4(43.5)	N1(39.0)	Q6(35.2)	X3(28.7)
D1(48.5)	I5(43.5)	N2(38.8)	Q7(35.0)	X4(28.6)
D2(48.3)	I6(43.3)	N3(38.6)	R1(34.9)	X5(28.5)
D3(48.2)	I7(43.3)	N4(38.4)	R2(34.6)	X6(28.4)
E1(47.9)	I8(43.0)	N5(38.1)	R3(34.4)	X7(28.3)
E2(47.3)	J1(42.9)	-	S1(33.9)	X8(28.2)
F1(46.9)	J2(42.7)	-	S2(33.8)	Y1(28.0)
F2(46.8)	J3(42.6)	-	S3(33.4)	Y2(27.9)
-	J4(42.4)	-	S4(33.2)	Y3(26.9)
-	J5(42.3)	-	S5(33.1)	Z1(26.5)
-	J6(42.1)	-	T1(32.6)	Z2(26.2)
-	-	-	T2(32.5)	Z3(26.1)
-	-	-	-	AA1(25.9)
-	-	-	-	AA2(25.8)
-	-	-	-	AA3(25.5)
-	-	-	-	BB1(24.7)
-	-	-	-	BB2 (24.6)

Methods

Carcass Collection

Using traditional mark-recapture methods, weekly surveys were conducted by drift boat with a 2–3-person crew. When possible, areas inaccessible by boat were surveyed on foot. All recoverable carcasses were collected from each riffle complex—which includes a riffle, glide, and pool—tagged, sampled, and released back into the current. Carcasses were categorized based on decomposition as fresh, decayed, or skeleton. Fresh carcasses were identified by one clear eye and firm muscle tissue (Figure 2), while decayed carcasses had cloudy eyes and soft muscle tissue (Figure 3). Fresh and decayed carcasses were fitted with aluminum tags attached to the lower jaw, enabling week-to-week tracking (Figure 3). Skeletons were defined as carcasses in advanced stages of decomposition, with severely fragmented or liquefied muscle tissue, or those heavily predated upon the point that they were no longer viable for recapture (Figure 4). All skeletons were counted and destroyed before being returned to the river.

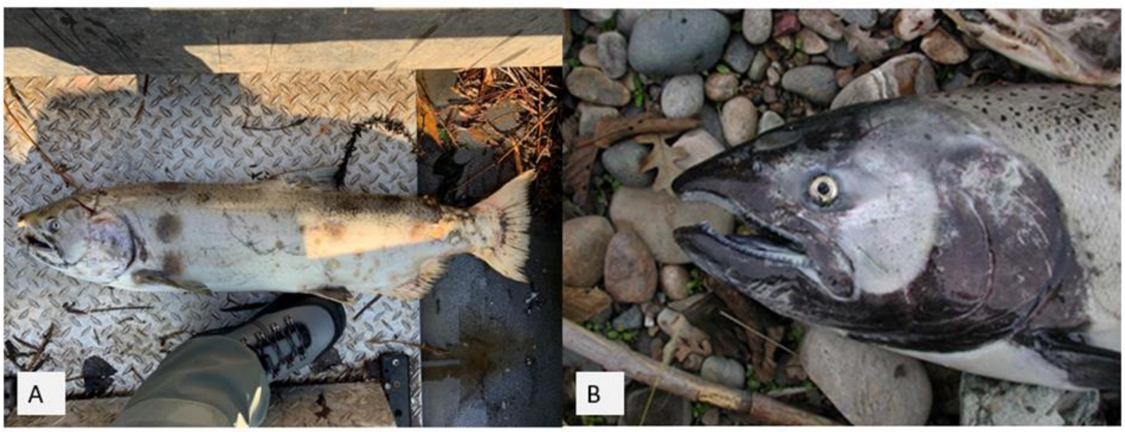

Figure 2. Fresh salmon carcass: A) Full body and B) Example of a clear eye.

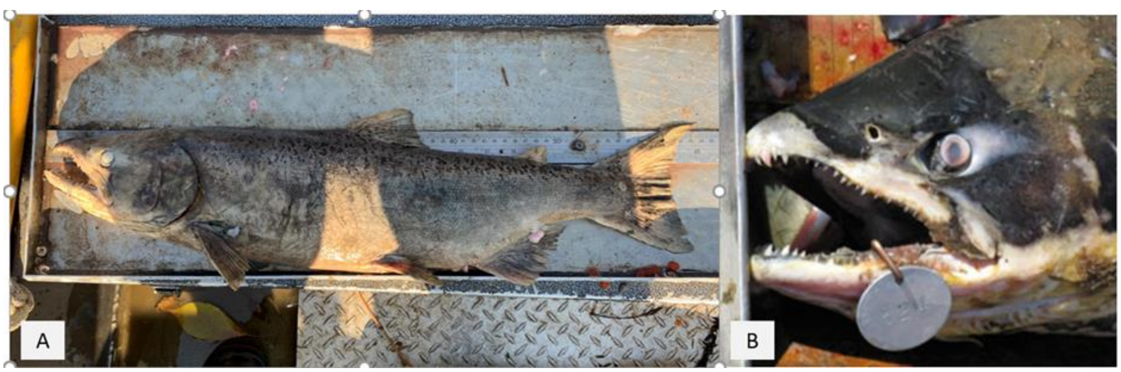

Figure 3. Decayed salmon carcass: A) Full body and B) Example of a clouded eye and positioning of the aluminum tag.

Figure 4. Various forms of skeleton carcasses. Both A) and B) show the two more common skeleton stages observed during the survey. Seen here are fish in extreme stages of decay. The bodies are extremely soft and covered with fungus. C) Is an example of a predated carcass that will not be viable for recapture.

Sample Collection

Tissue samples collected from carcasses included scales, otoliths, and heads from hatchery-origin fish. Biometric data collected included fork length (cm) and sex. Scales were taken from above the lateral line, between the dorsal and adipose fins, and stored on wax paper inside sample envelopes. At the end of each day, envelopes were laid out on drying racks to air-dry fully before storage. Otoliths were extracted from the brain cavity, placed in Eppendorf tubes, and labeled with Shamrock® waterproof stickers. Heads from adipose-clipped fish (an indicator of hatchery origin) were preserved by freezing and sent out for post-season processing at CDFW's Tissue Archive Lab in West Sacramento. Biometric and biological data were used to assess the size and age composition of the annual spawning population. Scales and fork lengths were used to estimate fish age, otoliths are analyzed to reconstruct juvenile life history (from conception to ocean entry), and coded wire tags (CWTs) were used to determine hatchery origin and brood year.

Environmental Data Collection

Flow and dam release data were obtained from the California Data Exchange Center, operated by the California Department of Water Resources. Flow gauges used were the "Merced River at Exchequer Dam" (EXC) and the "Merced River Below Crocker-Huffman Dam" (MBH). Water temperature data were collected using four HOBO temperature loggers maintained by CDFW, each programmed to record hourly readings year-round. Weather conditions were recorded in the field and categorized by survey staff. Water visibility was measured using a Secchi disc attached to a 17-foot line, with readings taken in the deepest pool of each survey section.

Weekly Fish Distribution and Redd Counts

Using a single-pass method, weekly live fish and redd counts were conducted over the 11-week survey period. Surveys covered a total of 130 riffle matrices. At each riffle complex, staff used handheld tally counters to record the number of fresh (active) redds and live fish observed. Fresh Chinook redds were identified based on several key characteristics: (1) a pot-like depression with a "V"-shaped gravel tailspill that appeared cleaner and lighter in color than the surrounding substrate, and (2) the presence of a female holding over the cleaned gravel bed. Redds were considered fresh as long as a female was actively guarding them. Once the female died and the redd showed signs of aging—such as algal growth or debris accumulation—it was no longer counted.

Quality Control and Analysis

Information recorded on all samples was compared against field datasheets and then entered into a Microsoft Access database. Contents of the database were subsequently exported to R, where a series of quality control checks identified less obvious errors—such as multiple recaptures of the same tag within a week, tag duplication, transcription errors, and suspicious tag movements. After these checks, the data were aggregated into three tables: a covariates table, a live/redd/skeleton table, and a mark-recapture table. These tables were then used in the Cormack-Jolly-Seber (CJS) statistical model v2.1 that generates an escapement estimate.

Results

Survey

The survey was conducted for 11 weeks beginning October 6, 2022, and ending December 15, 2022. All sections were surveyed, except for section four in Week 2 due to staffing limitations associated with Covid-19 restrictions. This year the survey was also cut short due to staffing limitations and Covid 19 restrictions.

Environmental Conditions

Weather conditions were favorable this season, with clear skies on two-thirds of the survey days. Water clarity was generally good, with a median visibility depth of 11 ft (range: 2.5 ft to 16 ft). However, visibility decreased significantly—by 54%—during the peak of attraction flow releases (1,377 cfs; EXC) on October 17 (CDEC 2024). Between October 16 and 21, the Merced Irrigation District released a block of water to attract migrating Chinook to the Merced River (Figure 5). Outside this attraction flow event, mean river flow was 177 cfs (range: 149 to 248 cfs). Significant dam releases and rainfall events can reduce water clarity by mobilizing sediment. For example, a storm in Week 11 dropped three to six inches of precipitation in the Sierras (NWS 2023), reducing visibility to 3.9 ft (range: 2.5 ft to 6 ft). Water temperatures averaged 19.4°C across the study area at the start of the season, dropping to an average of 8.6°C by the end (Figure 6). Ideal temperatures for spawning and embryo development range from 5.0 to 13°C (CDFW 2015). Average water temperatures fell below 13°C in Week 7 of the survey. Notably, the first redd was observed two weeks earlier, on November 2, 2022 (Week 5; RM 36), when the average water temperature was 14.6°C.

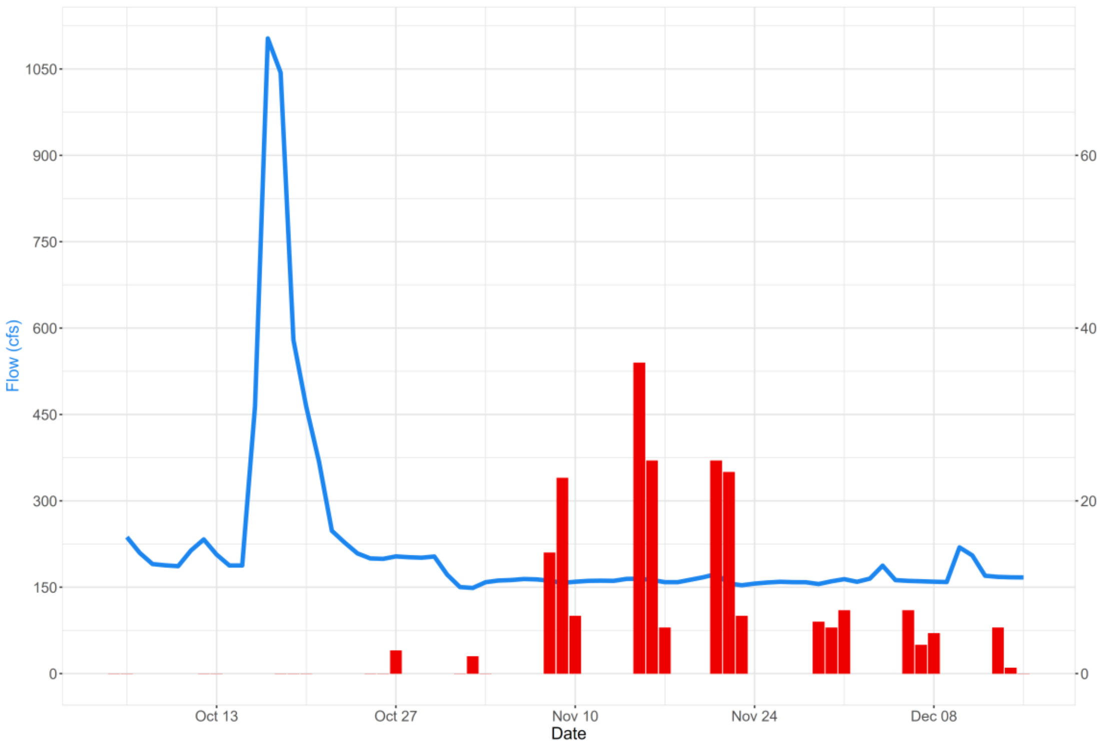

Figure 5. Flow overlaid with Chinook salmon observations on the Merced River October to December 2022.

Figure 6. Daily average water temperature on the Merced River by section October to December 2022. The trend line is shown in black.

Live, Redd, Skeleton and Carcass Distribution

The first live fish was observed on October 27, 2022 (Week 4) at RM 25. Weekly live fish counts steadily increased until Week 7, peaking at 99 individuals (Table 2 & Figure 7). The last live fish observation occurred on December 14, 2022. In the last week of the survey, a total of nine fish were observed in the first three sections of the study area. The first redd was observed on November 2, 2022 (Week 6) at RM 36. Redd counts steadily increased throughout the study area, peaking at 75 during Week 8 (Table 2 & Figure 7). Historically, RM 51 has been the most productive spawning site; however, this season most spawning occurred near RM 36, with a maximum redd count of 17 (Figure 8). The reasons behind this shift in spawning location compared to previous years remain unclear. In total, 20 carcasses were tagged in 2022 (Table 2). The first carcass was collected on November 16, 2022 (Week 7) and the last was collected on December 07, 2022 (Week 10). Nine carcasses were classified as “decayed” and 11 were classified as “fresh”. Tissue samples were collected from all 20 carcasses. Three heads from hatchery-origin fish were retained and sent to the Tissue Archive Lab for extraction. A total of eight skeletons were recovered in Weeks 8 and 9 of the survey (Table 2). Due to the low number of observed live fish and available carcasses, tissue samples were taken from skeletons when possible. Of the eight carcasses encountered, scale and otolith samples were collected from three, and one head was retained from a hatchery-origin fish.

Table 2. Live, Redd, Skeleton and Carcass Recoveries by Week

Week	Live	Redds	Skeletons	Carcass
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	4	0	0	0
5	3	1	0	0
6	65	29	0	0
7	99	61	0	2
8	82	75	4	10
9	28	69	4	6
10	23	41	0	2
11	9	4	0	0

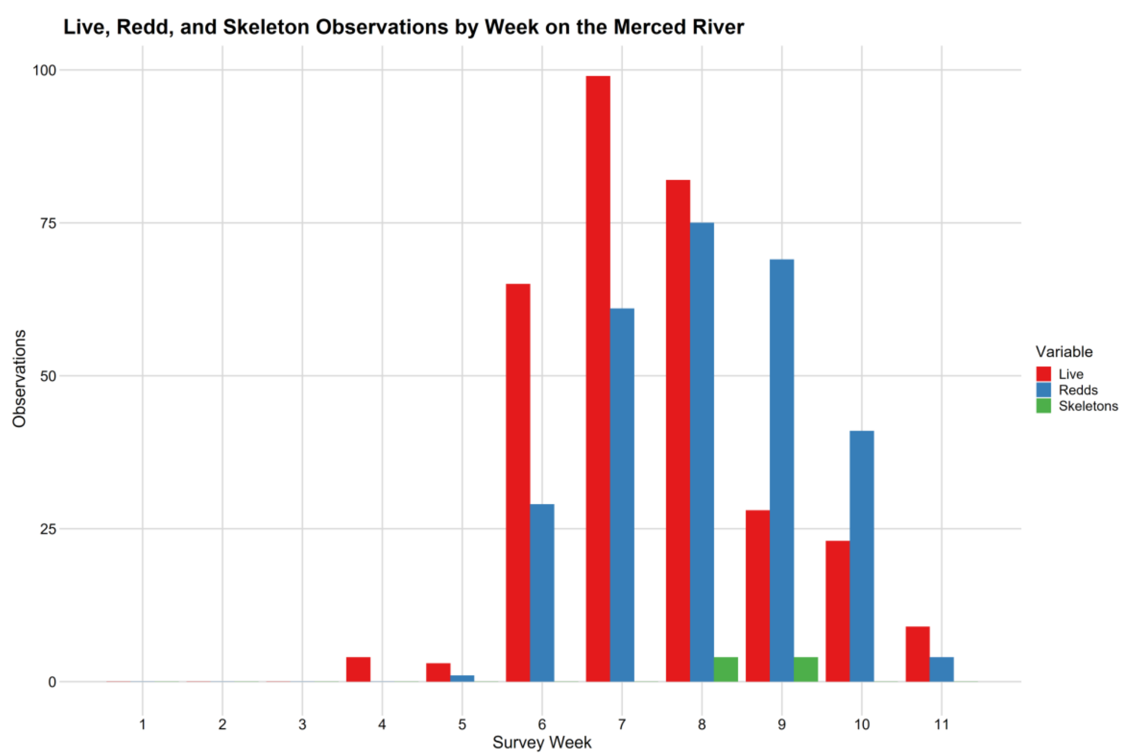

Figure 7. Live, Redd, Skeleton Observations by Week

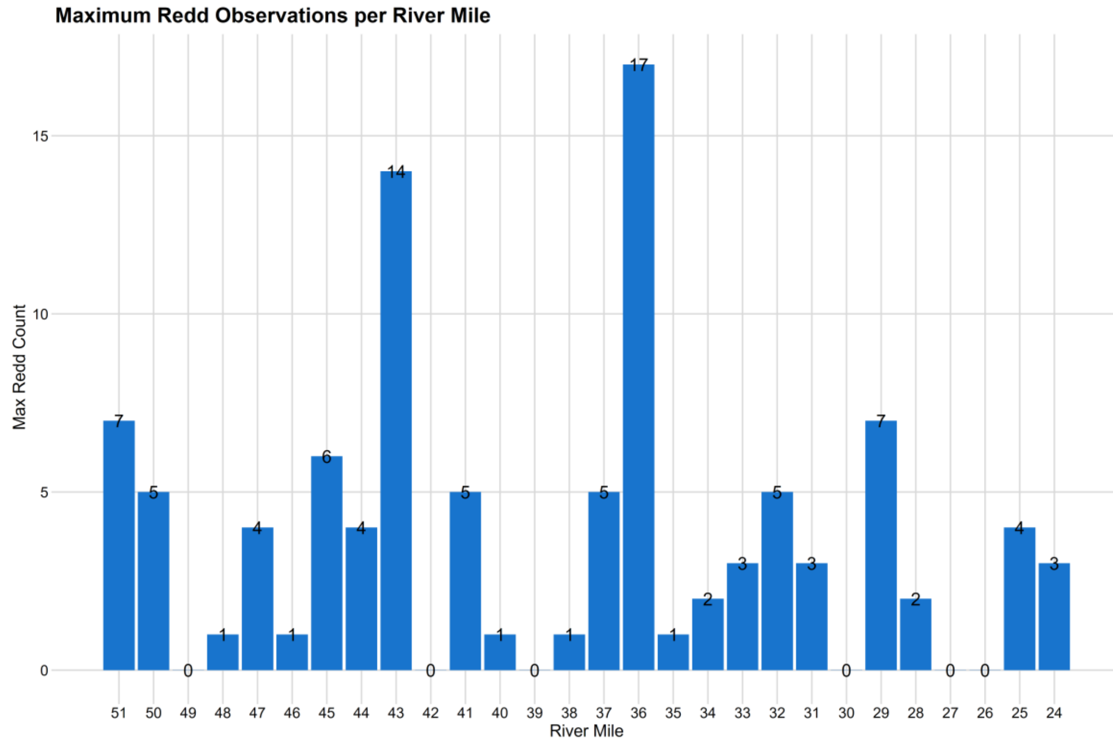

Figure 8. Maximum redd observations by river mile. This chart represents the largest number of redds observed at each riffle, over the course of the survey.

Hatchery-origin Salmon

Four CWTs were recovered this season. Information from the codes revealed that three hatchery-origin fish were age-3 females from the Mokelumne River Fish Hatchery, and the fourth was an age-3 male from the Feather River Fish Hatchery (Table 3). All four fish were fall-run that were released in 2020 as juveniles in the Sacramento-San Joaquin Delta.

Table 3. CWT Summary Data

Tag	CWT	Brood Year	Hatchery of Origin	Release Location
926	062066	2019	MOK R FISH INS	SAN JOAQ SHRM ISL NET PEN
2,002	062066	2019	MOK R FISH INS	SAN JOAQ SHRM ISL NET PEN
919	062062	2019	MOK R FISH INS	SAN JOAQ SHRM ISL NET PEN
916	061594	2019	FEATHER R HATCHERY	MARE ISLAND NET PEN

Sex and Fork Length

The ratio of male to female carcasses was 1:1 (n=10 male, n=10 female). Female fork lengths ranged from 65 cm to 74 cm (P50 = 70.5 cm) with an average length of 69.5 cm. Male fork lengths ranged from 59 cm to 94 cm (P50 = 73.5 cm) with an average length of 76.5 cm (Figure 9). The grilse (sub-adult) break point this year was 61 cm for females and

70 cm for males. All the females sampled were classified as adult, while 40% of the males were classified as grilse (Table 4 & Figure 10).

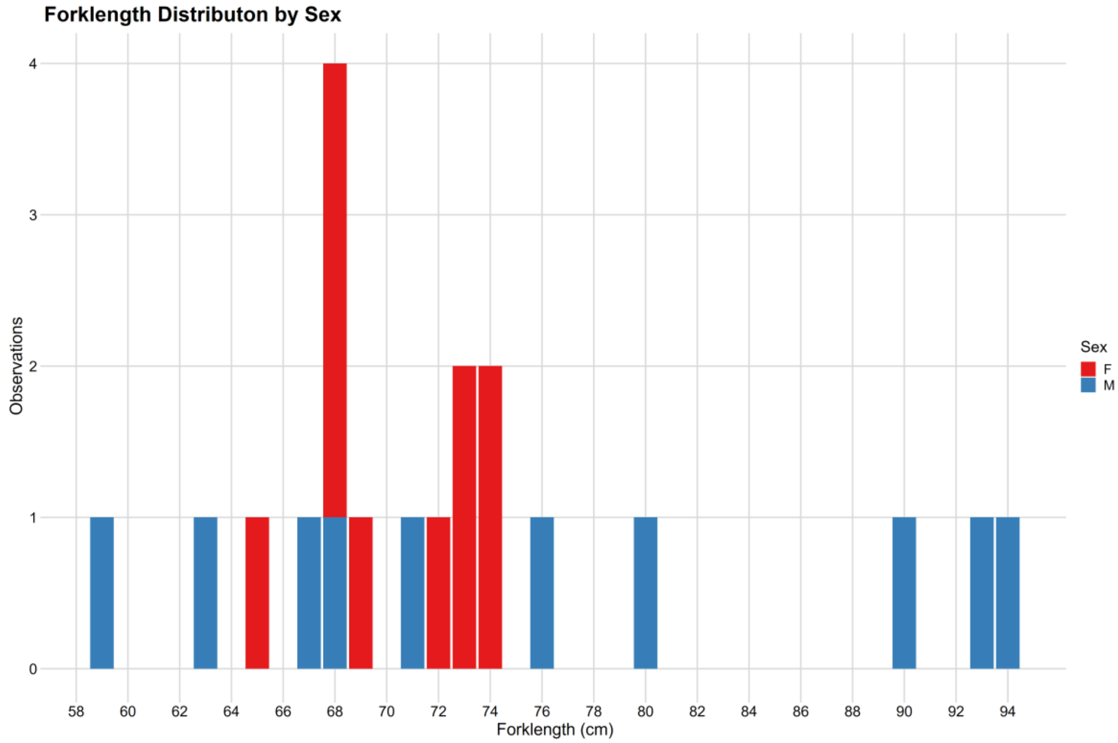

Figure 9. Fork length Distribution by Sex

Table 4. Grilse breakdown expanded to population level

Category	Value
Adult Female	10
Adult Male	6
Grilse Male	4
Total Adults	16
Total Grilse	4
Total Tagged	20
Population Expansion- Grilse	15
Population Expansion- Adult	60
Grilse (%)	20

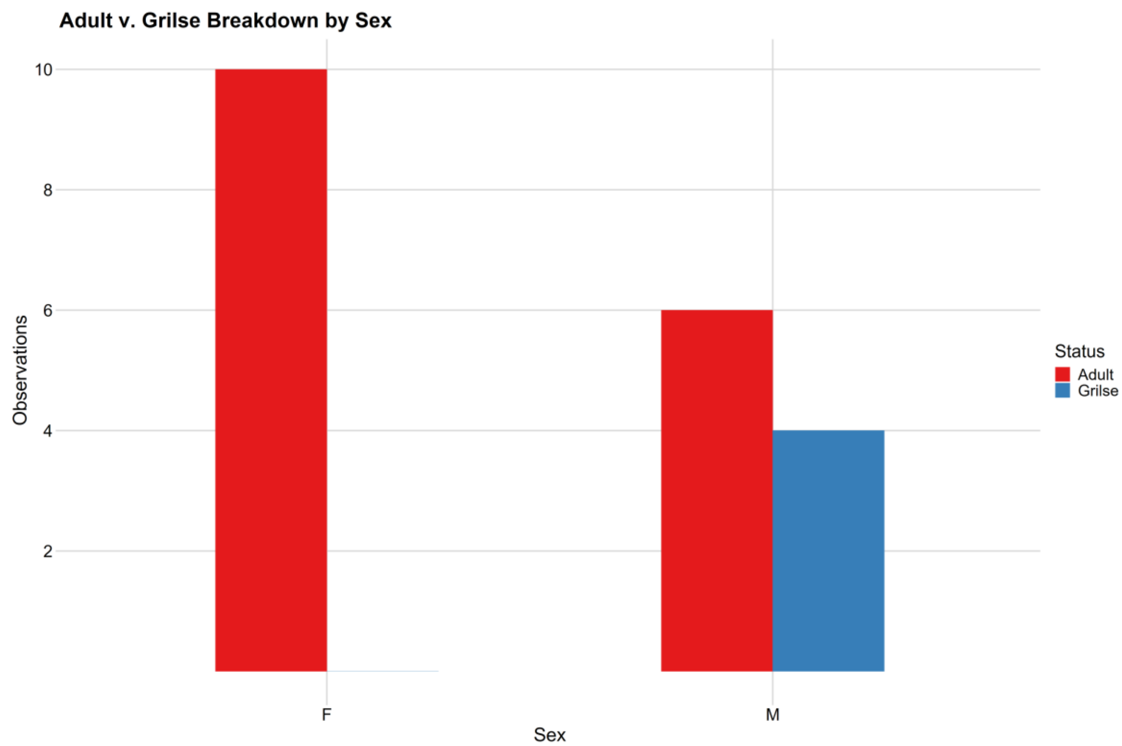

Figure 10. Adult v Grilse Breakdown by Sex

Scale Read Age Determination

One method for aging Chinook salmon is through "scale reading." Similar to counting tree rings, growth patterns on a salmon's scale can be analyzed to estimate its age. Scale-based aging is generally reliable, though not without limitations. During migration, salmon reabsorb bodily tissues—including parts of the scales—which can erode the outer edges. This process shortens the scale and may lead to underestimating the fish's true age. For example, we know fish #2002 was an age-3 female because the information associated with CWT recovered (Table 3). The age estimation from the scale read gave an age estimate of 2 (Table 5). Aside from this one datapoint, the age assignment for the other three hatchery-origin fish were accurate. Of all 23 scales samples collected and read in 2022, 78.3% were estimated to be age-3 adults, 17.4% were estimated to be age-2 adults and 4.3 % estimated to be age-4 adults (Table 5).

Table 5. Age Estimation from Scale Reads.

Tag Number	Sex	Fork Length (cm)	Estimated Age
926	F	73	3
925	M	67	3
924	M	63	2

Tag Number	Sex	Fork Length (cm)	Estimated Age
923	M	59	2
2,002	F	67	3
919	F	68	3
920	F	74	3
2,001	F	76	3
922	F	73	3
921	F	65	3
918	F	68	3
914	F	74	3
915	M	90	3
913	F	72	3
2,000	M	60	2
917	F	68	3
916	M	94	3
99	F	69	3
98	M	68	2
100	M	76	3
97	M	93	4
95	M	80	3
96	M	71	3

Escapement Estimate

Although, sex and fork length data were collected on three skeletons, this information was not incorporated into the covariates table and used in the CJS model run. The CJS model identified three top-performing models for estimating the escapement population (Figure 11). The three models had equivalent QAICc scores therefore one model was selected at random —Models 3. This model estimated an escapement of 75 fish with a confidence interval of (57, 1,121) (Figure 12). The CJS model estimates population size more confidently when supported by a large number of capture and recapture events. However, due to the limited number of carcass recoveries and even fewer recaptures during this year's Merced River survey, the model's estimate was highly uncertain, as reflected in the wide confidence interval. In 2022 the Merced River Fish Facility (MRFF), trapped and spawned 67 salmon during the season. Since these fish are not included in the study but were Merced River returns, they were included in the final escapement estimate. This year's total escapement estimate was 142 fish.

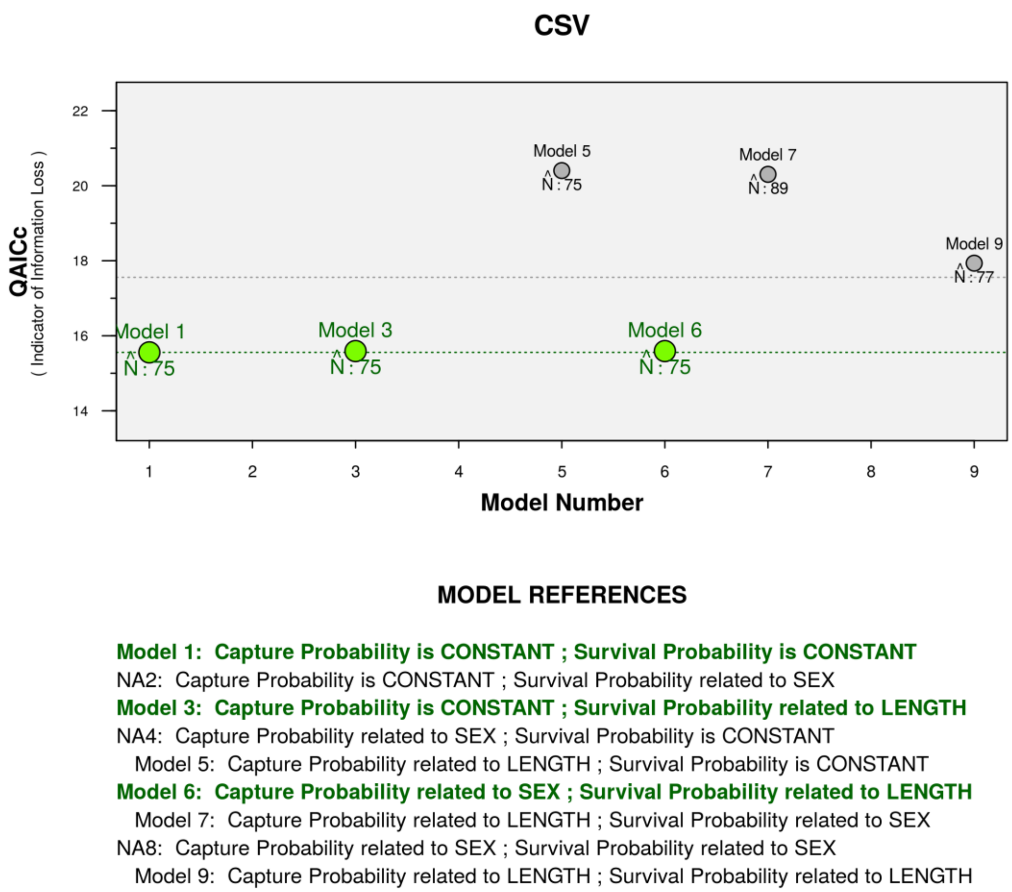

Figure 11. CJS Model Comparison

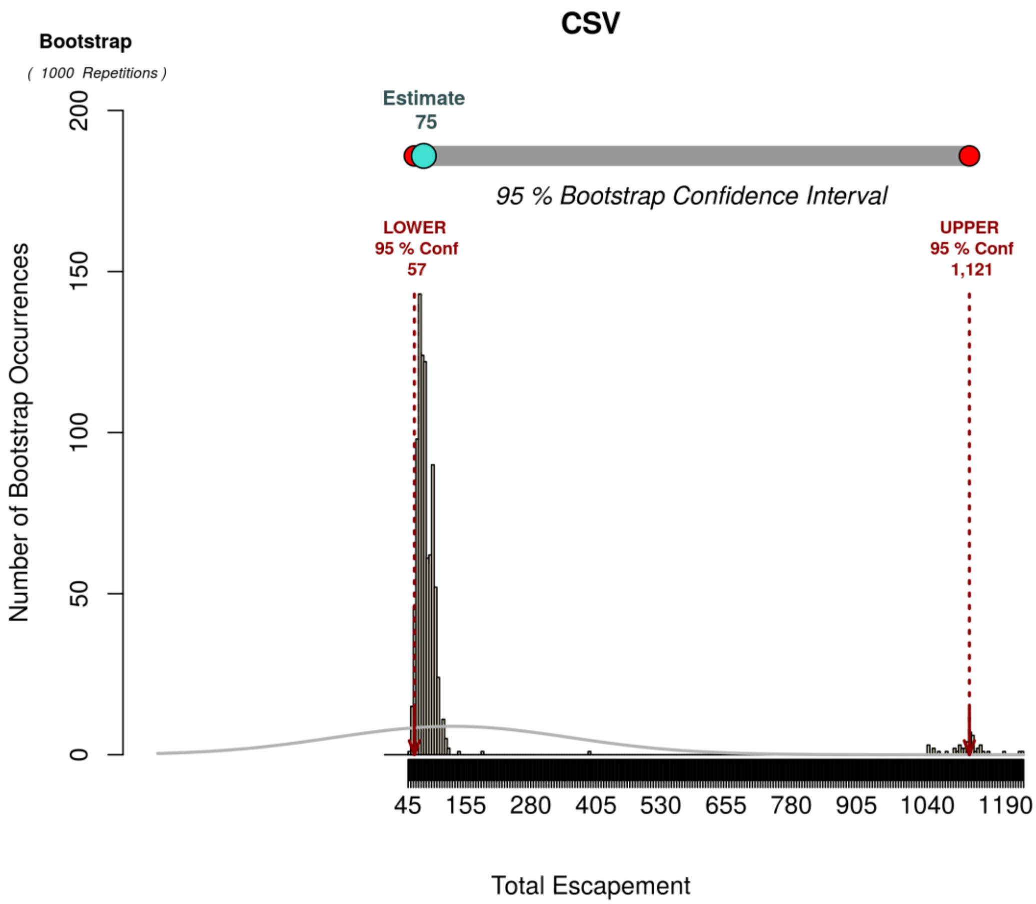

Figure 12. 2022 Escapement Estimate

Discussion

Environmental Conditions

Water year 2022 was classified as "critically dry" (DWR 2024). With minimal snowpack and precipitation, McClure and McSwain Reservoirs were not adequately replenished, making water a scarce resource. The Merced Irrigation District (MID), which holds senior water rights in the state and operates the dams at both reservoirs, is responsible for delivering water to approximately 2,200 growers (MID 2025). Due to the shortage, water availability for fish and wildlife was severely limited. Although MID operated within the terms of its license issued by the Federal Energy and Regulation Commission, the river ran dry in the summer of 2022. Between July and October, the Merced River was completely disconnected from the San Joaquin River (Dahl 2023) creating a passage barrier for returning adult salmon. Fall-run migration can begin as early as July with the bulk of the run arriving in mid-October (CDFW2015). However, the river did not reconnect until October 7, 2022 (Vance 2022), effectively shortening the migration window by up to three months. The first live wasn't observed until three weeks after the river was reconnected and six days after the onset of the attraction flows (Figure 5). In the months following, flows ranged from 37cfs to 986 cfs at the confluence with the median flow at 175 cfs (CDEC 2024).

Live, Redd, Skeleton and Carcass Distribution

As discussed above, this season had seen a shift in the arrival times of adult Chinook salmon. In 2022, the live fish were first observed in the fourth week of the survey, whereas in the previous four years live fish were observed in the first week. This can be attributed to the poor flow conditions early in the season which lead to a truncated migration window and a weakened olfactory signal downstream in the San Joaquin River. There was also a shift in spawning preference. Historically, the first river mile of the survey (RM 51) has then the most popular location for spawning. This season we observed that the greatest density of redds was located at RM 36. It is unclear what factors influenced the shift in spawning preference and why so few fish spawned within RM 51. Carcass recoveries were notably low this year, with only 28 fish handled. Of these, just 20 were in suitable condition to be included in the mark-recapture study; the remaining eight were classified as skeletons and destroyed. Of the 20 fish tagged and released, only 10% (n=2) were ever recaptured.

Hatchery-origin Salmon

The Central Valley Constant Fractional Marking and Recovery Program (CFM) is a program that aims to evaluate hatchery contributions to the fishery harvest and escapement. With the information collected during fish releases and tag recoveries, the program can also evaluate stray rates associated with various release strategies. The Merced River Fish Facility can raise up to one million juvenile salmon annually, and despite releasing them at Sherman Island—where juvenile survival is highest—none of their tagged fish returned to the Merced River in 2022. Instead, 25% were out-of-basin strays from the Sacramento River, and 75% were in-basin strays from the Mokelumne River Hatchery. Altogether, strays accounted for 100% of the hatchery-origin salmon recovered in the Merced River.

Age and Sex Breakdown

There is typically a sampling bias with respect to sex. Because females guard their redds until death, their bodies are more likely to settle on the riffle or drift downstream into the slow-moving glide—areas that offer greater visibility and are more accessible. Males, on the other hand, tend to die in backwaters, along channel margins (which may be shelved), or in deep, heavily vegetated pools. These locations make detecting and recovering male carcasses more difficult (Murdoch 2010). While there is an attempt to survey all backwater areas for males, not all are accessible by foot or boat. This year we recovered an equal number of males and females. This difference was not statistically significant and did not influence model selection for the escapement estimate. Size variation was greater in males than in females, with male fork lengths spanning nearly four times the range observed in females. Based on this, we expected a broader age distribution among males. As anticipated, age determination analyses—including fork length, scale reads, and CWT information—indicated that males ranged from age-2 subadults to age-4 adults, while all females were estimated to be age-3 adults.

The Escapement Estimate

The 2022 escapement estimate is the lowest recorded in 30 years (Figure 13 & Table 6). Several factors likely contributed to the decline and low estimate. First, COVID-19 restrictions disrupted field operations, resulting in a shortened survey season. Second, seasonal environmental conditions (i.e., below average snowpack contributing to diminished water storage and reduced flows) impacted salmon recruitment and contributed to a passage barrier that persisted in the summer and early fall. Lastly, there has been a long-term decline in salmon populations across the Central Valley due to habitat loss and water management practices (NMFS 2019). Without better water management practices in the Merced River, it will be difficult to regrow the salmon population.

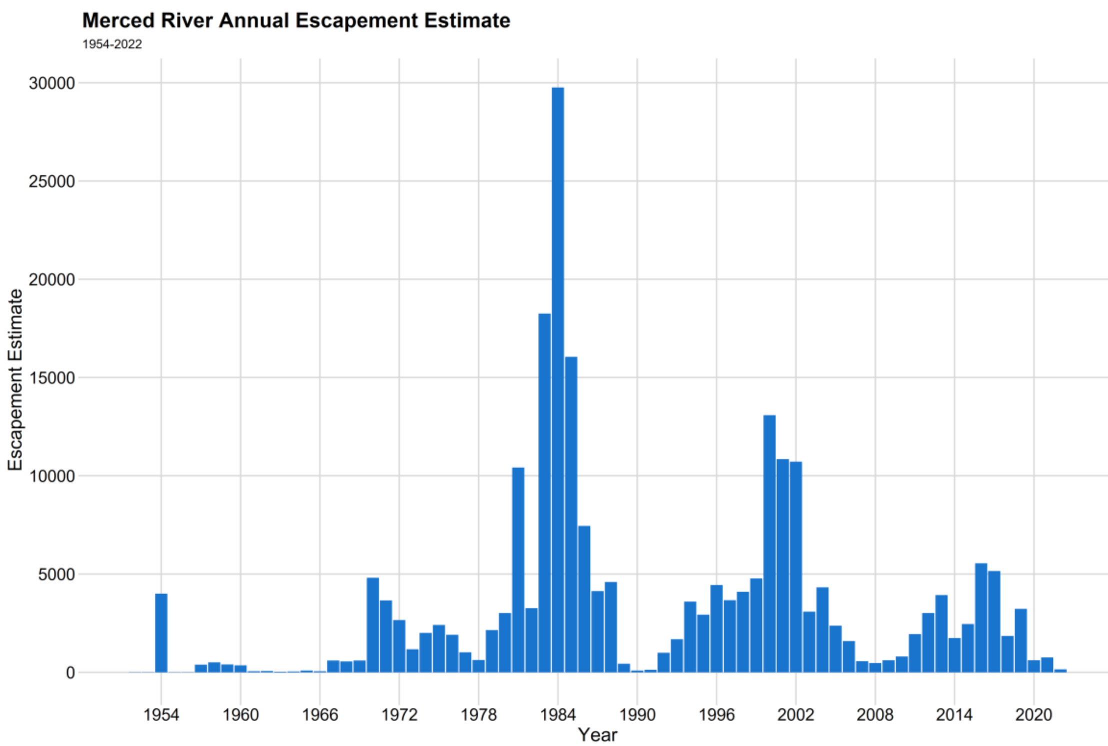

Figure 13. Historical Escapement Estimates 1952-2022

Year	Escapement	Year	Escapement	Year	Escapement	Year	Escapement
1952	0	1972	2648	1992	986	2012	3011
1953	0	1973	1172	1993	1678	2013	3924
1954	4000	1974	2000	1994	3589	2014	1733
1955	0	1975	2400	1995	2922	2015	2453
1956	0	1976	1900	1996	4432	2016	5537
1957	380	1977	1011	1997	3660	2017	5152
1958	500	1978	625	1998	4091	2018	1850
1959	400	1979	2147	1999	4766	2019	3225
1960	350	1980	3006	2000	13076	2020	611
1961	50	1981	10415	2001	10844	2021	754
1962	60	1982	3263	2002	10706	2022	142
1963	20	1983	18248	2003	3079		
1964	35	1984	29749	2004	4320		
1965	90	1985	16052	2005	2363		
1966	45	1986	7439	2006	1579		
1967	600	1987	4126	2007	564		
1968	550	1988	4592	2008	465		
1969	600	1989	427	2009	604		
1970	4800	1990	82	2010	797		
1971	3651	1991	119	2011	1942		

Table 6. Historical Escapement Estimates 1952-2022

Citations

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