
# JUVENILE SALMONID AND SMOLT MONITORING IN THE LAGUNITAS CREEK WATERSHED – 2023-2024

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Marin Water would like to thank the Gallagher family for granting us access onto their property to conduct downstream migrant monitoring.

Cover image: An unusually large Coho Salmon smolt in 2024

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## EXECUTIVE SUMMARY

This report summarizes two salmonid monitoring efforts conducted by Marin Water in 2023 and 2024. Between September 6 and October 25, 2023, Marin Water staff and Watershed Stewards Program members estimated the abundance of juvenile Coho Salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) in the Lagunitas Creek Study Area, which consists of Lagunitas Creek and two of its main tributaries, San Geronimo Creek and Devil's Gulch. Downstream-migrating salmonid smolts were monitored between March 20 and May 31, 2024 using a rotary screw trap (RST) in lower Lagunitas Creek, near Point Reyes Station. These two surveys were performed in accordance with Marin Water's Lagunitas Creek Stewardship Plan (MMWD 2011) and the data collected are used to estimate survival rates of these species during critical life stages.

In September and October, 2023, survey crews captured 723 juvenile Coho Salmon and 261 juvenile steelhead, and implanted Passive Integrated Transponder (PIT) tags into 684 coho and 38 steelhead. Juvenile coho abundance at three historic index reaches suggested a study area population of approximately 18,000. In the spring of 2024, 46% of tagged coho were detected at the RST or nearby antennas, and the apparent overwinter survival rate was 58%. Using this survival rate to back-calculate from the smolt abundance estimate, juvenile coho abundance in 2023 was 22,000. Coho Salmon tagged in Devil's Gulch appeared to survive at higher rates than coho tagged in the other streams.

The RST captured 4,251 Coho Salmon smolts, 581 Chinook and 450 steelhead smolts. Emigration estimates were as follows: 12,439 Coho Salmon, 1,659 Chinook and 6,370 steelhead. The coho emigration was larger than average and much larger than the emigration three years earlier. The steelhead emigration estimate was one of the highest in 18 years of monitoring, although high flows and poor trapping efficiency resulted in a large confidence interval around that estimate. We can confidently conclude that the 2024 steelhead emigration was larger than the previous three years. The Chinook Salmon emigration was fairly typical, following an average run of adult Chinook.

## INTRODUCTION

Lagunitas Creek is a regionally important coastal stream for Coho Salmon (*Oncorhychus kisutch*) and steelhead (*O. mykiss*), with recent Coho Salmon escapement estimates averaging approximately 500 individuals, while steelhead runs are somewhat smaller. Chinook Salmon (*O. tshawytscha*) also spawn in Lagunitas Creek and smolts have been observed in most years.

Salmonid surveys are conducted cooperatively between Marin Water, the California Department of Fish and Wildlife (CDFW), the National Park Service (NPS), the Marin Resource Conservation District, the Watershed Stewards Program (WSP), and the Salmon Protection and Watershed Network (SPAWN). Summer and fall surveys for juvenile Coho Salmon and steelhead were conducted in Lagunitas Creek starting in 1970 and annually since 1993. This represents one of the longest data records for juvenile salmonids in coastal streams of California. Systematic Coho Salmon adult spawner surveys began in 1982 and have been conducted annually since 1995. Marin Water has conducted annual smolt surveys on Lagunitas Creek since 2006, as well as in 1983, 1984 and 1985. Since 2012, juvenile Coho Salmon have been implanted with passive integrated transponder (PIT) tags. Other data collection activities include stream flow monitoring conducted by the United States Geological Survey at gages in Samuel P. Taylor State Park and Point Reyes Station. Another stream gage is maintained by Marin Water on San Geronimo Creek. Marin Water has also monitored water temperature continuously since the early 1990s. Lagunitas Creek streambed conditions are monitored annually and salmonid habitat is quantified approximately every five years.

Marin Water is primarily responsible for salmonid monitoring in Lagunitas Creek (upstream of tidal influence), in the main stem of San Geronimo Creek, and in Devil's Gulch (Figure 1). These streams are collectively referred to as the Lagunitas Creek Study Area. NPS conducts surveys for salmonid adults, juveniles and smolts in Olema Creek, a major tributary to Lagunitas Creek. NPS has monitored salmonid smolt emigration from Olema Creek since 2004, and smolt monitoring was conducted on a tributary to Olema Creek between 1998 and 2004. SPAWN has conducted adult salmonid monitoring in the tributaries to San Geronimo Creek since 1997 and has operated a smolt trap in lower San Geronimo Creek since 2006.

The primary goals of salmonid monitoring in the Lagunitas Creek Study Area include:

- Measuring Coho Salmon survival rates between life stages for multiple streams within the Lagunitas Creek watershed, and identifying the factors that influence those survival rates.
- Estimating Coho Salmon abundance at each life stage.
- Collecting data on steelhead and other salmonid species, including migration timing and distribution.

# METHODS

## Juvenile Salmonid Survey

Since 1997, Marin Water has estimated the abundance of juvenile Coho Salmon and steelhead in Lagunitas Creek and two tributaries, San Geronimo Creek and Devil's Gulch, using a combination of electrofishing and snorkeling. Densities of fish within specific habitat types (pools, runs, riffles and glides) were estimated at 14 long-term index reaches and these density estimates were used to estimate fish abundance throughout these streams. By maintaining consistent survey methods at the same locations, Marin Water could document trends in juvenile salmonid abundance. However, this methodology has a number of disadvantages, including:

- Accurately estimating the density of fish within a habitat unit generally requires a lengthy process of isolating each unit with block nets and electrofishing the unit three times.
- Intensive, three-pass electrofishing can result in fish injury and mortality.
- Within a monitoring season, only 4-5% of each stream was sampled. Coho Salmon distribution is extremely patchy and sampled habitats are not necessarily representative. Habitat quality within index reaches also changes over time.
- Extrapolating fish densities to similar habitats requires accurate habitat data, which is time consuming to collect and prone to surveyor bias.
- Deep habitats must be snorkeled, which requires extensive training.

In March, 2023, Marin Water Fisheries staff convened an advisory group to recommend improvements to our juvenile salmonid monitoring methods. The advisory group consisted of the following members: Stephanie Carlson (University of California), Jodi Charrier (National Oceanographic and Atmospheric Administration), Leslie Ferguson (San Francisco Bay Regional Water Quality Control Board), Gregg Horton (Sonoma Water), Michael Reichmuth (National Park Service), Seth Ricker (CA Department of Fish and Wildlife), Gabe Rossi (University of California) and Ryan Watanabe (CDFW). Modifying our monitoring methods had three primary goals:

1) Collect data that promote Coho Salmon recovery in the Lagunitas Creek watershed.
2) Meet regulatory monitoring requirements.
3) Maintain adequate consistency with previous methods to allow for the comparison of past and current abundance estimates.

The advisory group recommended that Marin Water measure Coho Salmon survival directly using passive integrated transponder (PIT) tags, instead of using less-precise abundance estimates to calculate survival. Using this technology to measure survival across the watershed has a number of benefits, including:

- Capturing fish where they are most abundant, regardless of where fish were captured in previous years.
- Sampling habitats without needing to isolate them.
- Using the least-injurious methods for capturing fish, including single-pass electrofishing and seining (when substrates and streambanks are suitable).
- Less frequent and less intensive habitat monitoring.

This new methodology also has some costs, including:

- Additional costs for PIT tags, antennas, and associated technology.
- By no longer measuring salmonid densities within different habitat types, we will not be able to estimate salmonid abundance in individual study streams.
- The diverse life histories of steelhead make this methodology unsuitable for estimating juvenile steelhead abundance.

Using an online statistical tool (https://clincalc.com/stats/samplesize.aspx), we conducted a power analysis to determine the number of PIT tags necessary to detect differences in Coho Salmon survival rates between streams. The analysis assumed independent fish populations in each stream and dichotomous endpoints for each fish (i.e., dead/not dead). This analysis determined that 387 fish would need to be tagged in each stream to detect survival differences of at least 10%. As an example, if 50% of juvenile Coho Salmon tagged in Lagunitas Creek survive through the winter, while 40% of fish tagged in San Geronimo Creek survive, the difference in apparent survival would be statistically significant as long as at least 387 fish were tagged in each stream. We set an annual goal of tagging 400 coho in each stream, for a total of 1,200 tags. If that goal could not be achieved in one stream, a significantly larger number of fish would need to be tagged in the other streams. For example, if only 300 fish were tagged in Devil's Gulch, 600 fish would need to be tagged in the two other streams (1,500 tags in total) for the same level of statistical power.

Methods for selecting sampling locations differed by stream. In Devil's Gulch, all suitable habitat within spawning reaches was sampled, moving upstream, until 400 Coho Salmon were tagged. In San Geronimo Creek, suitable habitats were selected largely based on landowner access. In Lagunitas Creek, sampling locations were selected based on habitat suitability, past Coho Salmon densities, and accessibility.

Stream habitat with gently sloping banks, small substrates, and little wood were sampled using a beach seine, which was pulled through the habitat unit (pool, glide, etc.) and onto a bank. Captured salmonids were placed into buckets with fresh, aerated water, while other non-target animals were immediately released. Habitats that were not suitable for seining were electrofished, following National Marine Fisheries Service guidelines (NMFS 2000). ETS Electrofishing Systems ABP-3 backpack electrofishers were used and set to a pulse rate of 60 Hz and a duty cycle of 25%. Voltages ranged from 140 to 200 volts depending on water depth and conductivity, measured prior to electrofishing. One or two electrofishers were used in each habitat (depending on the width of the site) with one to three people using dip-nets to capture immobilized fish. Netted fish were placed into buckets containing fresh stream water and portable aerators, with the exception of sculpin, which were immediately released to avoid predation of salmonids. Habitats were generally sampled once, although habitats with abundant coho were sampled multiple times.

Coho Salmon and steelhead were anesthetized using tricaine methanesulfonate (MS-222) and measured in millimeters (mm). All Coho Salmon were weighed to the nearest tenth of a gram, while at least 20 steelhead were weighed per day. Coho Salmon at least 60 mm in fork length and at least 2.7 grams in weight were implanted with passive integrated transponder (PIT) tags. Approximately 50 steelhead measuring at least 110 mm in length were also tagged in each stream. Tags were inserted into the abdominal cavity just posterior to the pectoral fins, using either a hypodermic injector or a scalpel incision. Fish between 60 and 69 mm fork length received a 9 mm full duplex (FDX) tag and fish ≥ 70 mm received a 12 mm FDX tag, consistent with Vollset et al. (2020). After handling, all fish were placed into a black recovery bucket containing cool, aerated stream water. Once sampling was completed, captured fish were released back into the habitat unit from which they were captured.

To assess long-term juvenile Coho Salmon population trends, three of the 14 historic index reaches were selected for continued monitoring using established methods. Coho observations at these index reaches have been strongly correlated with annual population estimates. Two index reaches in Lagunitas Creek (LG-2 and LG-5) were snorkeled, while one index reach in San Geronimo Creek (SG-4) was sampled using electrofishers. Block nets were used to isolate the pools at index reach SG-4, and multiple electrofishing passes were made through each site until catch numbers showed adequate depletion.

On September 6th and 7th, 2023, Marin Water assisted CDFW personnel with the rescue and relocation of juvenile Coho Salmon from a drying portion of upper San Geronimo Creek. Marin Water staff implanted these fish with PIT tags before CDFW relocated approximately half of the fish a short distance upstream into cool, shaded water. CDFW released the other half of the rescued fish into Lagunitas Creek, just downstream of Peters Dam. Marin Water then investigated overwinter survival of these two groups of fish.

## Smolt Survey

In spring 2024, Marin Water operated a rotary screw trap (RST) with a five-foot diameter cone in lower Lagunitas Creek, approximately 2.1 miles above the Highway 1 Bridge in Point Reyes Station. The trap was situated in a pool directly downstream of a small bedrock cascade, and was in the same location as has been used since 2006. The bedrock cascade concentrates enough flow to operate the RST in the otherwise low gradient reach of the creek.

The RST was generally in operation Monday through Friday, except during peak Coho Salmon migration periods, when the trap was operated seven days per week. Peak migration periods have been previously observed to coincide with the new moon in April. At the start of each day, trap function was visually inspected and the rotation speed of the trap cone was recorded. The trap was occasionally realigned to maintain cone speeds in the target range of three to eight revolutions per minute (RPM). A qualitative description of debris within the live box was recorded daily. Each day, captured fish were removed from the trap and identified to the species level.

Salmonid smolts and parr were checked for marks such as fin clips, visually inspected for signs of smoltification, measured, weighed, allowed to recover, and then released approximately 200 m downstream of the point of capture. Scales were collected from a subsample of fish for later age analysis. Coho Salmon and steelhead smolts were scanned for passive integrated transponder (PIT) tags. Steelhead at least 130 mm in length were generally called smolts, although some fish displaying characteristics intermediate between parr and smolts (e.g., some loss of scales, some silver color, fading parr marks, etc.) were classified as "transitional." These transitional steelhead could not be assumed to be emigrating and were not included in the smolt estimate. Coho Salmon were classified as fry (<40 mm), parr, transitionals, or smolts based on the degree of smoltification. Young-of-the-year Coho Salmon displaying smolt characteristics (e.g., silvery appearance) were classified as smolts. All Chinook Salmon were assumed to be emigrating and classified as smolts. Adult steelhead that appeared unspawned were released upstream of the bedrock cascade. Spawned steelhead (kelts) were immediately released off the trap.

The proportion of downstream migrants captured each week (trap efficiency) was determined by recapturing previously marked fish. Up to 20 Coho Salmon and steelhead smolts per day were implanted with PIT tags, while up to 20 Chinook Salmon were given a fin clip. Marked fish were released approximately 300 m upstream. Some of these fish were subsequently recovered at the trap a second time and served as the basis for calculating trap efficiencies.

Marin Water also operates a PIT tag antenna upstream of the RST, primarily to detect PIT-tagged coho smolts and investigate rates of overwinter survival in different parts of the Lagunitas Creek watershed.

### Data Analysis

The abundance of Coho Salmon, Chinook, and steelhead smolts was calculated using the Darroch Analysis with Rank Reduction (DARR) 2.0.2 algorithm (Bjorkstedt 2005, 2010) in R statistical software. This algorithm uses mark-recapture data to calculate the weekly efficiency of the Lagunitas Creek rotary screw trap and generate emigration estimates and standard errors for each species.

Juvenile coho salmon abundance during the previous year was calculated using estimates of smolt abundance and overwinter survival. Overwinter survival was calculated using detections of tagged Coho Salmon at either the RST or antennas in lower Lagunitas Creek or Olema Creek. The probability of detecting tagged coho at these locations was calculated using detection rates of coho smolts tagged at the RST.

To compare juvenile Coho Salmon abundance with previous years, we generated a separate abundance estimate based on observations at three index reaches. During a 16-year period, juvenile Coho Salmon observation at index reaches LG-2, LG-5, and SG-4 comprised 0.9% of the study area estimates (range 0.6-1.2%). Dividing juvenile coho observations at these three index reaches by 0.009 produced an abundance estimate that can be compared to previous years.

## RESULTS

### Juvenile Salmonid Observations

In 2023 we captured 723 juvenile Coho Salmon and 261 steelhead at 46 locations in Lagunitas Creek, San Geronimo Creek and Devil's Gulch (Table 1).

Table 1. Salmonid observations and tagging

| Stream | Sample Sites | Coho Observed | Coho Tagged | Coho Released* | Steelhead Observed | Steelhead Tagged |
|---|---|---|---|---|---|---|
| Lagunitas Creek | 10 | 124 | 118 | 262 | 62 | 9 |
| San Geronimo Creek | 6 | 489 | 460 | 316 | 47 | 1 |
| Devil's Gulch | 31 | 110 | 106 | 106 | 152 | 28 |
| Study Area Total | 46 | 723 | 684 | 684 | 261 | 38 |

* CDFW rescued and relocated 144 tagged coho from San Geronimo Creek to Lagunitas Creek

At the three historic index reaches we observed 160 juvenile Coho Salmon. Applying a proportion of 0.9% to that observation, the corresponding abundance estimate was approximately 18,000 (Table 2) in the study area.

Table 2. Juvenile Coho Population, Extrapolated from Three Index Reaches

| Index Reach Observations | | | | Population |
|---|---|---|---|---|
| LG-2 | LG-5 | SG-4 | Total | Estimate |
| 53 | 54 | 53 | 160 | 18,000 |

Incidental mortalities from our sampling effort consisted of nine Coho Salmon (1.2% of captured fish) and seven steelhead (2.7% of captured fish). Mean size and condition are presented in Table 3.

Table 3. Juvenile Salmonid Lengths and Condition

| | Mean Length (mm) | | Condition (Fulton's K) | |
|---|---|---|---|---|
| Stream | Coho | YOY SH | Coho | YOY SH |
| Lagunitas | 80.0 | 85.2 | 1.15 | 1.14 |
| San Geronimo | 75.2 | 69.3 | 1.14 | 1.16 |
| Devil's Gulch | 79.4 | 64.6 | 1.17 | 1.17 |
| Study Area Total | 76.7 | 82.5 | 1.15 | 1.16 |

K = (weight in grams) / (length in cm)$^3$ *100

## Other Species Encountered During Juvenile Monitoring

In addition to Coho Salmon and steelhead, four other native fish species were observed: Southern Coastal Roach (*Hesperoleucus venustus subditus*), Threespine Stickleback (*Gasterosteus aculeatus*), Pacific Lamprey (*Lampetra tridentata*), and sculpin (*Cottus* spp). The sculpin were not identified to species but were most likely Prickly Sculpin (*Cottus asper*). Other, less common sculpin species may include Coast Range Sculpin (*C. aleuticus*) and Riffle Sculpin (*C. gulosus*) (Page and Burr 1991). California Freshwater Shrimp were also observed in Lagunitas Creek.

## Lagunitas Creek Rotary Screw Trap

The RST was operated for 45 days between March 19 and May 31, 2024. During that period flows at the Point Reyes Station stream gauge ranged between 15 and 824 cfs at the USGS gauge at Point Reyes Station. The highest daily catch of 576 Coho Salmon smolts occurred on April 19. Weekly smolt passage peaked at 3,499 for the week of April 15. Coho Salmon emigration for the season was estimated at 12,439 (Table 4). During the monitoring period we measured 932 Coho Salmon, 538 steelhead, and 431 Chinook Salmon (Table 5).

Table 4. Salmonid Smolt Captures, Emigration Estimates, Lengths and Weights

| Species | Smolts | Non-Smolts | Emigration Estimate | Confidence Interval Low | Confidence Interval High | Mean Length (mm) | Mean Weight (mm) |
|---|---|---|---|---|---|---|---|
| Coho Salmon | 4,251 | 27 | 12,439 | 10,987 | 13,891 | 113.7 | 16.2 |
| Chinook Salmon | 581 | 0 | 1,659 | 1,441 | 1,877 | 83.3 | 6.7 |
| Steelhead | 450 | 154 | 6,370 | 2,247 | 10,493 | 171.3 | 51.6 |

The highest daily catch of Chinook Salmon was 60 smolts on May 2. Peak weekly Chinook passage was 364 for the week of May 13. For the season, an estimated 1,659 Chinook Salmon emigrated past the RST. Steelhead emigration peaked during the week of April 8, with 2,336 smolts. The peak catch of 30 steelhead smolts occurred on April 10. An estimated 6,370 steelhead emigrated past the RST.

Table 5. Salmonids Captured in the Lagunitas Creek Rotary Screw Trap by Length and Week, 2024.

Coho Salmon

| Week: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 3/18 3/24 | 3/25 3/31 | 4/1 4/7 | 4/8 4/14 | 4/15 4/21 | 4/22 4/28 | 4/29 5/5 | 5/6 5/12 | 5/13 5/19 | 5/20 5/26 | 5/27 6/2 | |
| Length (mm) | Age 0+ | | | | | | | | | | | |
| < 40 | | | | | | | 1 | | | | | |
| 40-44 | | 1 | | | | | | | | | | |
| 45-49 | | | | | | | | | | | | |
| 50-54 | | | | | | | | | | | | |
| 55-59 | | | | | 1 | | | | | | | |
| 60-64 | | | | | | | 1 | | | | | |
| 65-69 | Age 1+ | | | | | | 1 | | | 1 | | |
| 70-74 | | | | | | | 1 | | | 3 | | |
| 75-79 | | | | | | | | | 2 | | 3 | |
| 80-84 | | | | | | | 1 | | 8 | 5 | 11 | |
| 85-89 | | | | | | | **3** | 1 | 1 | 7 | 14 | |
| 90-94 | | | | | | 1 | 3 | 2 | 6 | 13 | 15 | |
| 95-99 | | | | | | 4 | 16 | 6 | 11 | 9 | 10 | |
| 100-104 | | | | | 4 | 4 | 13 | 17 | 22 | 15 | 7 | |
| 105-109 | 2 | 5 | 1 | 2 | 10 | 9 | 40 | 15 | 19 | 17 | 2 | |
| 110-114 | 4 | 4 | 4 | 5 | 17 | 22 | 17 | 18 | 17 | 7 | 1 | |
| 115-119 | 4 | 6 | 1 | 9 | 29 | 25 | 24 | 21 | 5 | 7 | 1 | |
| 120-124 | 4 | 2 | 3 | 13 | 39 | 30 | 15 | 6 | 5 | 1 | | |
| 125-129 | | 4 | | 23 | 30 | 12 | 14 | 5 | | | | |
| 130-134 | | 3 | 2 | 8 | 18 | 5 | 2 | 1 | 1 | | | |
| 135-139 | | 6 | 1 | 11 | 11 | 8 | | | | | | |
| 140-144 | | 1 | | 7 | 6 | | | | | | | |
| 145-149 | 2 | | | 1 | 3 | | 1 | | | | | |
| 150-154 | | 1 | | 2 | 4 | 1 | | | | | | |
| 155-159 | Age 2+ | | | | 1 | | | | | | | |
| 160-164 | 1 | 1 | | 1 | | 1 | | | | | | |
| 165-169 | | | | 1 | | | | | | | | |
| 170-174 | | | | 1 | | | | | | | | |
| 175-179 | | | | | | | | | | | | |
| 180+ | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | |
| Age 0+ | 0 | 1 | 0 | 0 | 1 | 0 | 4 | 0 | 11 | 29 | 53 | 11% |
| Age 1+ | 16 | 32 | 12 | 81 | 172 | 121 | 149 | 92 | 86 | 56 | 11 | 89% |
| Age 2+ | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1% |

Chinook Salmon

| Week: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (mm) | | | | | | | | | | | | |
| < 40 | | | | | | | | | | | | |
| 45-49 | | | | | | | | | | | | |
| 50-54 | | | | | | | | | | | | |
| 55-59 | | 2 | | | | | | | | | | |
| 60-64 | | 1 | | | | | | | | | | |
| 65-69 | | | | 1 | 1 | | | | | | | |
| 70-74 | | | | | | | | | | 1 | 1 | |
| 75-79 | | | | 1 | | 1 | | | 4 | 4 | | |
| 80-84 | | | | | 1 | | 8 | 4 | 15 | 20 | 16 | |
| 85-89 | | | | | 2 | 17 | 57 | 28 | 25 | 34 | 18 | |
| 90-94 | | | | | 7 | 18 | 38 | 19 | 25 | 15 | 15 | |
| 95-99 | | | | | 4 | 6 | 6 | 9 | 7 | 3 | 2 | |
| 100-104 | | | | | | 1 | | 1 | 3 | | 1 | |
| 105+ | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | |
| Age 0+ | 0 | 3 | 0 | 2 | 11 | 36 | 109 | 61 | 79 | 77 | 53 | 100% |
| Age 1+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

Note: Age classifications are based on this year's length histograms as well as historical size distributions. Shaded cells indicate scale age analysis.

Steelhead

| Week: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 3/18 3/24 | 3/25 3/31 | 4/1 4/7 | 4/8 4/14 | 4/15 4/21 | 4/22 4/28 | 4/29 5/5 | 5/6 5/12 | 5/13 5/19 | 5/20 5/26 | 5/27 6/2 | |
| Length (mm) | Age 0+ | | | | | | | | | | | |
| < 40 | | | | | | | | | | | | |
| 40-44 | | | | | | | | | | | | |
| 45-49 | | | | | | | | | | | | |
| 50-54 | | | | | | | | | | | | |
| 55-59 | | | | | | | | | | | | |
| 60-64 | | | | | | | | | | | | |
| 65-69 | Age 1+ | | | | | | | | 2 | | 1 | |
| 70-74 | | | | | | | | | | | | |
| 75-79 | | | | | | | | | | | 1 | |
| 80-84 | | | | | | | | | | | 1 | |
| 85-89 | | | | | 1 | | | 1 | | | | |
| 90-94 | | | | 1 | 1 | | | | | | | |
| 95-99 | 1 | | | | | 1 | 3 | | | | 1 | |
| 100-104 | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| 105-109 | | | 1 | | 2 | | | | 2 | | 1 | |
| 110-114 | 1 | 1 | | 1 | 3 | | 2 | 2 | 2 | 1 | | |
| 115-119 | | | 1 | 3 | 1 | | | 2 | 1 | | | |
| 120-124 | | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | | |
| 125-129 | | | | 3 | 1 | 2 | 1 | 1 | | | | |
| 130-134 | 1 | | | | 1 | 1 | 3 | | 2 | | | |
| 135-139 | 1 | 1 | | 1 | | 3 | 3 | 3 | | | | |
| 140-144 | 2 | 1 | | 1 | 3 | 1 | 3 | 1 | | Age 2+ | | |
| 145-149 | 3 | 1 | | 3 | 7 | 2 | 9 | 2 | 1 | | | |
| 150-154 | 3 | 1 | 1 | 3 | 9 | 4 | 4 | 1 | 1 | | | |
| 155-159 | 1 | 4 | 2 | 11 | 21 | 13 | 8 | 1 | | 1 | 1 | |
| 160-164 | 8 | 1 | 4 | 13 | 12 | 14 | 10 | | | 1 | 1 | |
| 165-169 | 4 | 3 | 4 | 11 | 19 | 12 | 5 | | 1 | | | |
| 170-174 | 7 | 5 | 3 | 7 | 15 | 11 | 5 | 1 | | | | |
| 175-179 | 5 | 1 | | 8 | 13 | 8 | | | | 1 | | |
| 180-184 | 5 | | 3 | 2 | 5 | 5 | 1 | | | | 1 | |
| 185-189 | 6 | 3 | | 5 | 3 | 2 | 2 | 1 | | 1 | | |
| 190-194 | 4 | 1 | 2 | 3 | 5 | | 1 | | | 1 | | |
| 195-199 | 3 | Age 3+ | | 2 | 2 | 2 | 1 | | 1 | | | |
| 200-204 | 2 | | | 1 | 2 | 1 | | | | | | |
| 205-209 | 4 | 1 | | | 2 | 2 | 1 | | | | | |
| 210-214 | 1 | | | | | 1 | | | | | | |
| 215-219 | 1 | 1 | | | | | | | | | 1 | |
| 220-224 | 2 | | | | 1 | | | | | | | |
| 225-229 | | | | | | | | | | | | |
| 230-234 | | 1 | | 1 | | | | | | | | |
| 235-239 | | | | | | | | | | | | |
| 240-244 | | | | | | | | | | | | |
| 245-249 | | | | | | | | | | | | |
| 250-254 | 2 | | | | | | | | | | | |
| 255-259 | 1 | | | | | | 1 | | | | | |
| 260-264 | | | | | | | | | | | | |
| 265-269 | | | | | | | | | | | | |
| 270-274 | | | | | | | | | | | | |
| 275-279 | | | | | | | | | | | | |
| 280-284 | | | | | | | | | | | | |
| 285-289 | | | | | | | | | | | | |
| 290-294 | | | | | | | | | | | | |
| 295-299 | | | | | | | | | | | | |
| 300+ | 1 | | | | | | | | | | | |
| Totals | | | | | | | | | | | | |
| Age 0+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1% |
| Age 1+ | 2 | 2 | 5 | 11 | 13 | 6 | 12 | 9 | 8 | 3 | 2 | 14% |
| Age 2+ | 11 | 9 | 14 | 60 | 107 | 75 | 52 | 10 | 4 | 5 | 3 | 65% |
| Age 3+ | 56 | 16 | 5 | 12 | 12 | 6 | 2 | 0 | 0 | 0 | 1 | 20% |

Weekly trap efficiency for Coho Salmon smolts varied from 7% to 44% (mean 27%). Trap efficiency for Chinook Salmon ranged from 24% to 50% (mean 33%). Trap efficiency for steelhead ranged from 4% to 30%, with a mean of 12% (Figure 2).

Based on size breaks (Table 5), 89% percent of captured Coho Salmon appeared to be one year old and five individuals were two years old. Scale analysis confirmed the gap in sizes between one-year-old and older coho. All Chinook Salmon smolts appeared to be less than one year old.

Non-salmonid fish species included the following native and non-native species, in order of abundance: Southern Coastal Roach, sculpin spp., Golden Shiner (*Notemigonus crysoleucas*), crappie (*Pomoxis spp.*), Bluegill (*Lepomis macrochirus*), Threespine Stickleback, catfish (likely *Ameiurus catus*), Goldfish (*Carassius auratus*), Pacific Lamprey and Largemouth Bass (*Micropterus salmoides*). Non-fish captures included California Freshwater Shrimp (*Syncaris pacifica*), Signal Crayfish (*Pacifastacus leniusculus*), Red Swamp Crayfish (*Procambarus clarkii*), Rough-skinned Newt (*Taricha granulosa*), Bullfrog (*Lithobates catesbeianus*), Northwestern Pond Turtle (*Actinemys marmorata*) and Aquatic Garter Snake (*Thamnophis atratus*).

## Juvenile Coho Salmon Abundance and Overwinter Survival

Juvenile coho salmon tagged in 2023 could be detected in the lower watershed at three locations: the Lower Lagunitas Creek antenna, the Olema Creek antenna, or the rotary screw trap (RST). Detections at these locations and the probability of detecting tags (i.e., detection efficiency) are shown in Table 6. Of the 684 juvenile coho tagged, 313 were subsequently detected in the lower watershed (Table 7). We estimated that 81 tagged coho were not detected, and 58% of tagged coho survived to emigrate from Lagunitas Creek. Based on this apparent survival rate, approximately 22,000 juvenile coho were present in the study area in the late summer of 2023.

Table 6 Tagged coho salmon detection efficiency

| | |
|---|---|
| Coho tagged at RST in 2024 | 783 |
| Coho recaptured at RST | 259 |
| **Rotary Screw Trap (RST) efficiency** | **33%** |
| Coho detected at Lower Lagunitas or Olema Creek antennas | 563 |
| **Antenna efficiency** | **72%** |
| Coho detected at RST or antennas | 622 |
| **Combined detection efficiency** | **79%** |

Table 7. Back-calculated juvenile abundance

| | |
|---|---|
| Juvenile coho tagged in 2023 | 684 |
| Coho detected at RST, Lower Lagunitas or Olema Creek antennas | 313 |
| Tag detection rate | 46% |
| Detection efficiency (Table 6) | 79% |
| Estimated undetected tags | 81 |
| Estimated emigration of tagged coho | 394 |
| **Apparent coho survival rate** | **58%** |
| Smolt estimate (Table 4) | 12,439 |
| **2023 Juvenile Population** | **22,000** |

Juvenile Coho Salmon typically spend approximately 18 months in freshwater (including incubation) and 18 months in the ocean, returning to spawn in their natal stream in their third year (Shapovalov and Taft 1954). Therefore, Coho Salmon can be grouped into year classes of three-year increments. The parent generation of the 2023 juvenile Coho Salmon was estimated to number 21,041 in 2020 (Figure 2). The Coho Salmon smolt estimate in 2021 was 7,684 (Figure 3).

Detection rates varied among Coho Salmon tagged in the three study streams (Figure 4), as did the corresponding apparent survival rates (Table 8). Overwinter survival rates for Lagunitas and San Geronimo Creek coho were similar, while Devil's Gulch coho appeared to survive at a significantly higher rate.

Table 8. Coho Salmon overwinter survival by stream

| Tagging Location | Coho Tagged in 2023 | Coho Detected in 2024 | Detection Rate | Detection Efficiency* | Apparent Survival |
|---|---|---|---|---|---|
| Lagunitas Creek | 262 | 119 | 45% | 79% | 57% |
| San Geronimo Creek | 316 | 131 | 41% | 79% | 52% |
| Devil's Gulch | 106 | 63 | 59% | 79% | 75% |
| All | 684 | 313 | 46% | 79% | 58% |

* From Table 6

## DISCUSSION

In the first year of the new juvenile salmonid monitoring methodology, tagging 400 juvenile Coho Salmon in each study stream proved to be challenging. Low abundance of coho in Devil's Gulch meant that only 106 fish were tagged, despite six days spent electrofishing 31 habitats. A mid-season assessment determined that tagging more coho in the other two streams would not significantly improve the statistical power to detect differences in overwinter survival. In Lagunitas Creek, coho appeared to be distributed very patchily, and achieving our tagging target in this stream proved to be difficult as well. In future years, we plan to snorkel Lagunitas Creek to locate schools of coho before attempting to capture them.

### Juvenile Coho Salmon Abundance

Based on over two decades of salmonid monitoring in the Lagunitas Creek Study Area, the primary factors driving juvenile Coho Salmon abundance appear to be adult abundance, winter stream flows that scour or entomb redds, and spring flows that displace newly-emerged fry. Adult abundance in 2022-23 was low, with only 105 redds documented in the study area. The peak stream flow during egg incubation was above average, while flows during fry emergence were typical. Despite some adverse conditions, egg-to-juvenile survival was well above average, at 9.1%. Two-thirds of coho redds were constructed in tributary streams, where flows were lower, which likely contributed to the unexpectedly high egg-to-juvenile survival rate.

### Smolt Monitoring Conditions and Emigration Timing

The RST was installed on March 19, 2024, which is a typical installation date. Fluctuating stream flows necessitated frequent adjustments of the RST position and trap efficiency was poor until the second week of April (Figure 5). Nearly half of steelhead smolts appeared to emigrate during the first three weeks of trap operation (Figure 6). Catches of both Coho Salmon and steelhead smolts increased during the week of April 8, coinciding with a new moon. The following week, coho numbers rose sharply despite a waxing moon, likely in response to unseasonably warm weather. The peak catch occurred on April 19, with 576 coho smolts. As catches of both Coho Salmon and steelhead declined, catches of Chinook Salmon increased, peaking on May 2, just ahead of another new moon. During the last week of monitoring, the smolt emigration estimate consisted of 342 Coho Salmon (3% of the coho emigration), 169 Chinook Salmon (12% of the Chinook emigration), and no steelhead.

### Age and Salmonid Migration Status

A clear size break was evident between young-of-the-year (YOY) Coho Salmon and smolts through April, but we began to observe large YOY and small age 1+ coho beginning in May (Table 5). Some individual coho as small as 76 mm appeared to be smolting, while some as large as 96 mm did not. Scale age analysis determined that one 85 mm Coho Salmon displaying smolt characteristics was a YOY. Scale age analysis also determined that five Coho Salmon larger than 160 mm were older than two years.

Steelhead displayed a clear size break between YOY and age 1+ age classes, some overlap between age 1+ and age 2+, and significant overlap among older age classes (Table 5). One of the largest steelhead smolts of the year was determined to be three years old through scale age analysis. We defined steelhead smolts as being at least 130 mm in length, which was supported by a clear size break between age 1+ and age 2+ steelhead at that length. Of 670 steelhead captured, 51 could not be classified as either parr or smolts and were classified as "transitionals."

### Smolt Abundance Trends and Implications for Winter Survival

The 2024 Coho Salmon emigration from Lagunitas Creek was above average and significantly larger than the parent generation three years prior (Figure 3). Overwinter survival was somewhat above average, at 58%, which fits well with our understanding of the potential drivers of overwinter survival. The winter of 2023-24 was wetter than average, with frequent storms. When streams remain turbid between storm events, birds such as mergansers likely have fewer opportunities to prey on juvenile salmonids.

The steelhead emigration estimate of 6,370 was one of the highest since smolt monitoring began in 2006. The 450 steelhead smolts captured, however, was below average, and low trap efficiency resulted in a very wide confidence interval around the emigration estimate (Table 4). The lower limit of the emigration estimate places this cohort ahead of steelhead emigrations in five previous years, including the emigrations in 2021 through 2023. The Chinook Salmon emigration was somewhat larger than average, and ranks as the ninth-largest cohort in 18 years of monitoring. The adult Chinook run in 2022 was average in size, with 11 redds observed, and produced approximately 151 Chinook smolts per redd, which was also average.

PIT tag detections revealed that coho tagged in Devil's Gulch appeared to survive at a significantly higher rate than coho tagged elsewhere. While our sample size was small, this is the first time we have observed a higher overwinter survival rate for Devil's Gulch coho. In 2020-21, Lagunitas Creek coho appeared to have the highest survival rates and in 2021-22, San Geronimo Creek coho survived at the highest rates. Whether these differences are statistically significant, and what factors may be driving these differences, warrant further investigation.

## CONCLUSIONS

Juvenile salmonid monitoring in 2023 marked a significant change in how Marin Water estimates salmonid abundance and survival. This monitoring demonstrated that juvenile Coho Salmon abundance can be estimated using PIT tags to measure overwinter survival. We plan to continue investigating to what extent Coho Salmon overwinter survival varies across our three study streams, and why.

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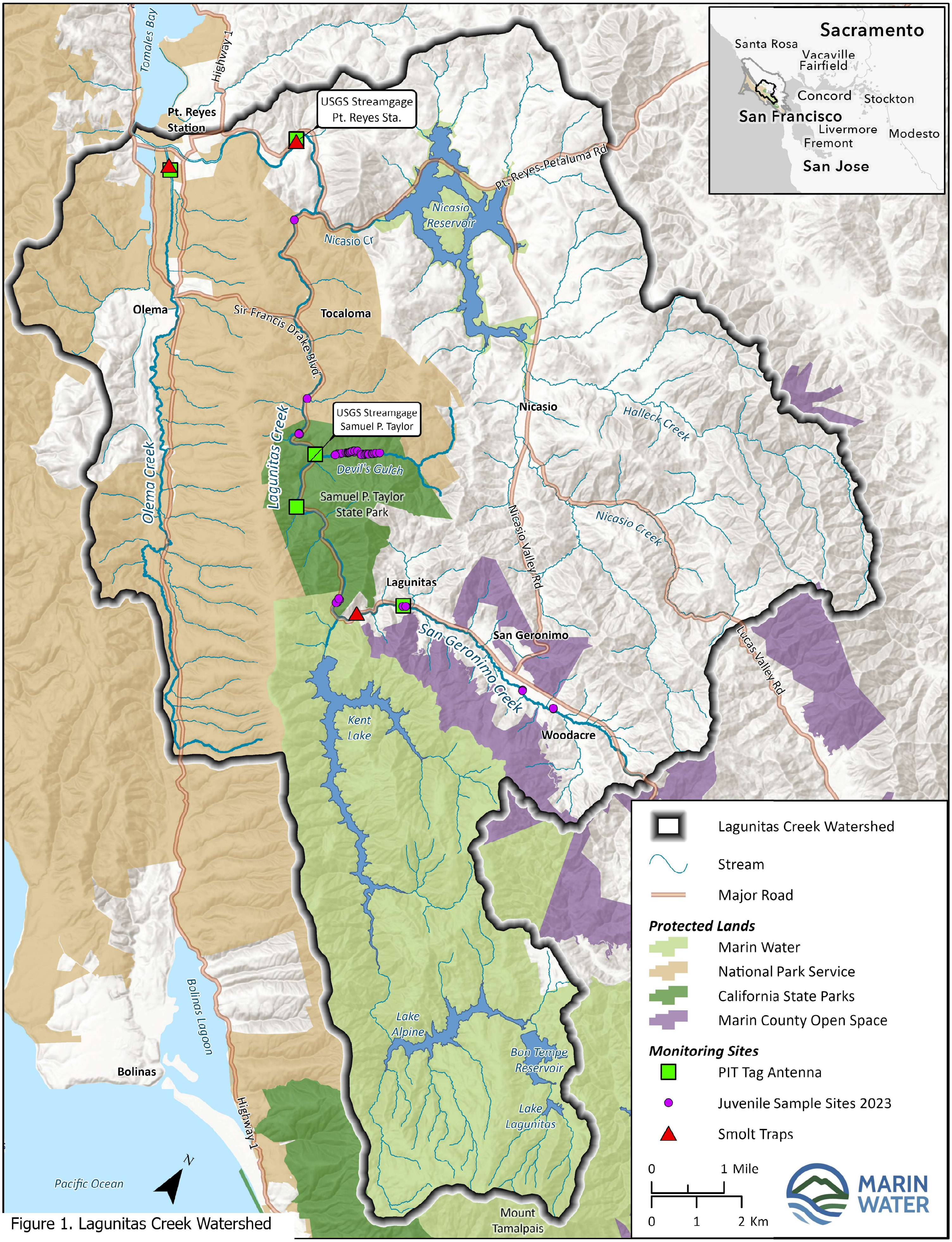

Figure 1. Lagunitas Creek Watershed

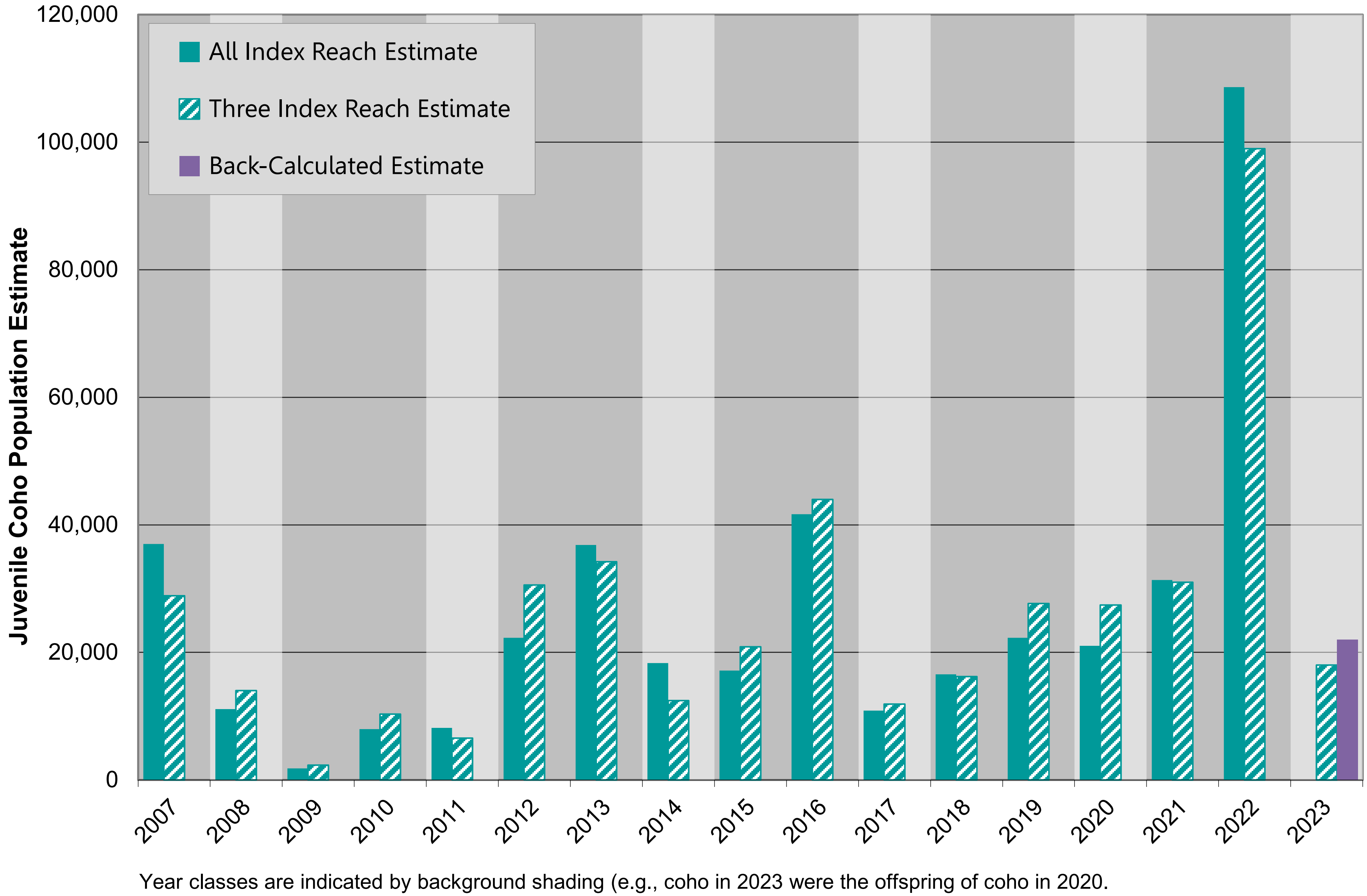


**Figure 2. Juvenile Coho Population Estimates.**

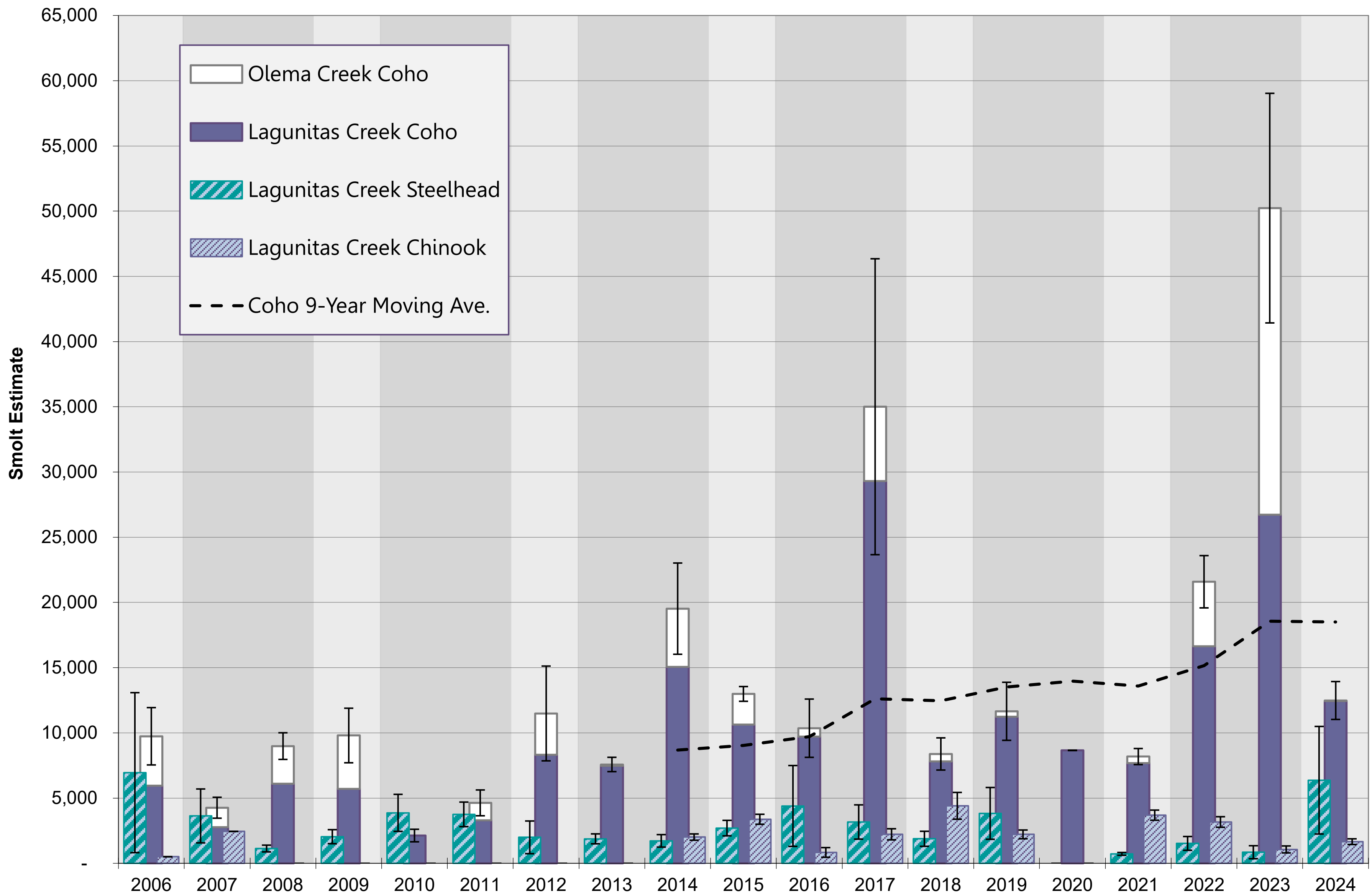


Figure 3. Lagunitas Creek smolt emigration estimates.

Coho year classes are represented by background shading.
(e.g., 2024 smolts are offspring of the 2021 cohort.)

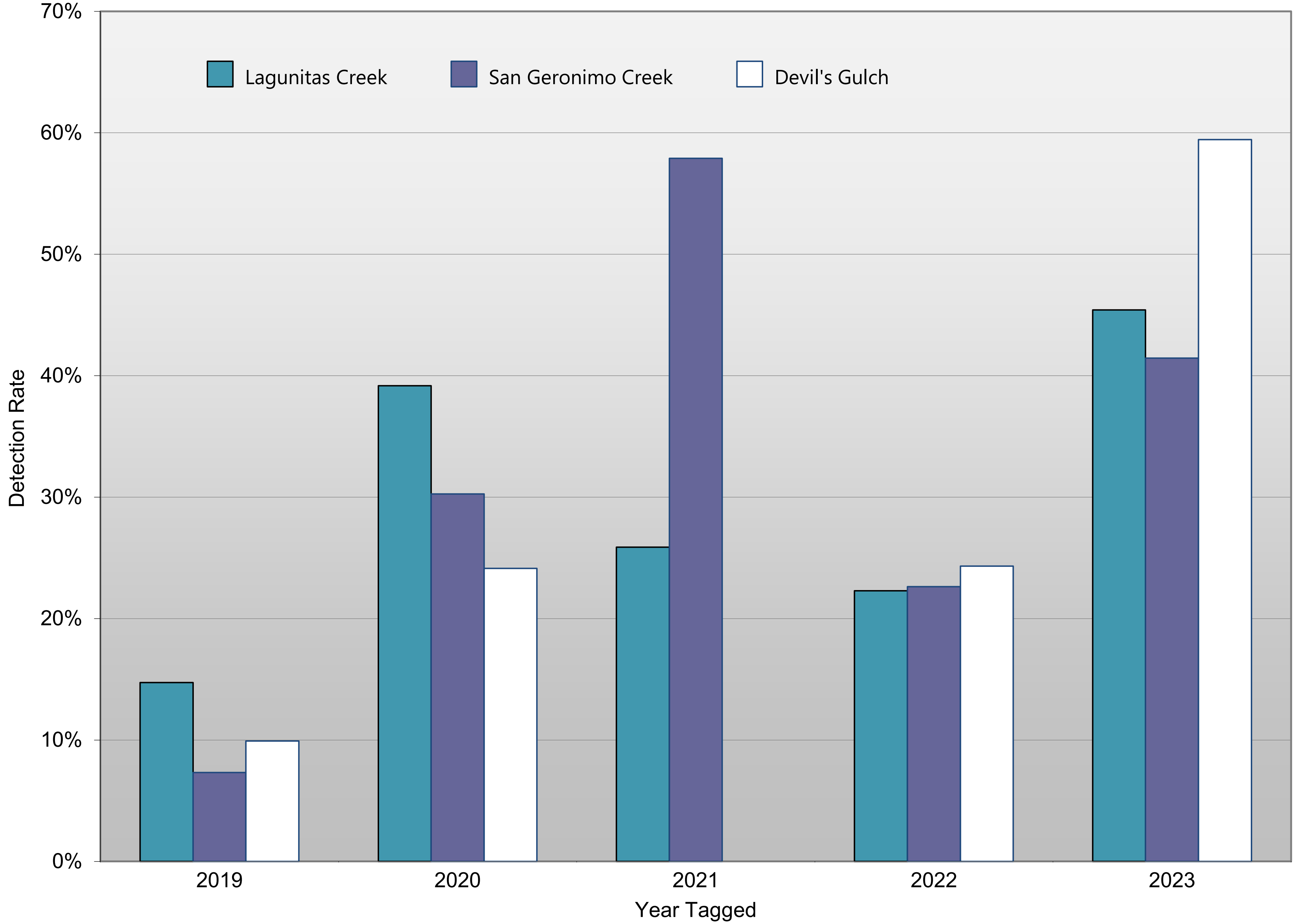


Figure 4. Juvenile Coho Salmon Detected at the RST, Lagunitas Antenna, or Olema Creek Antenna, by Stream Origin

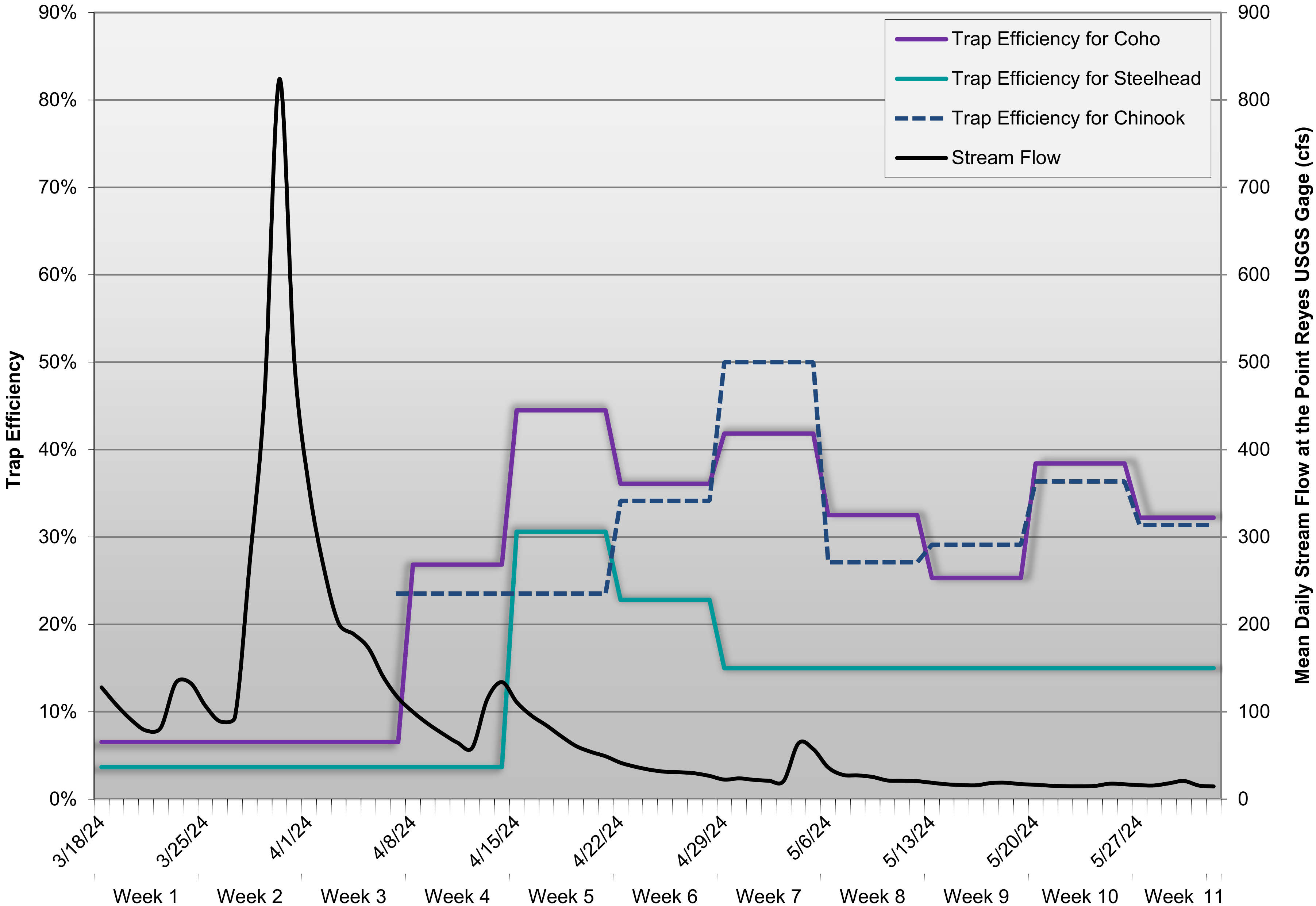


Figure 5. Weekly trap efficiency and Lagunitas Creek stream flow.

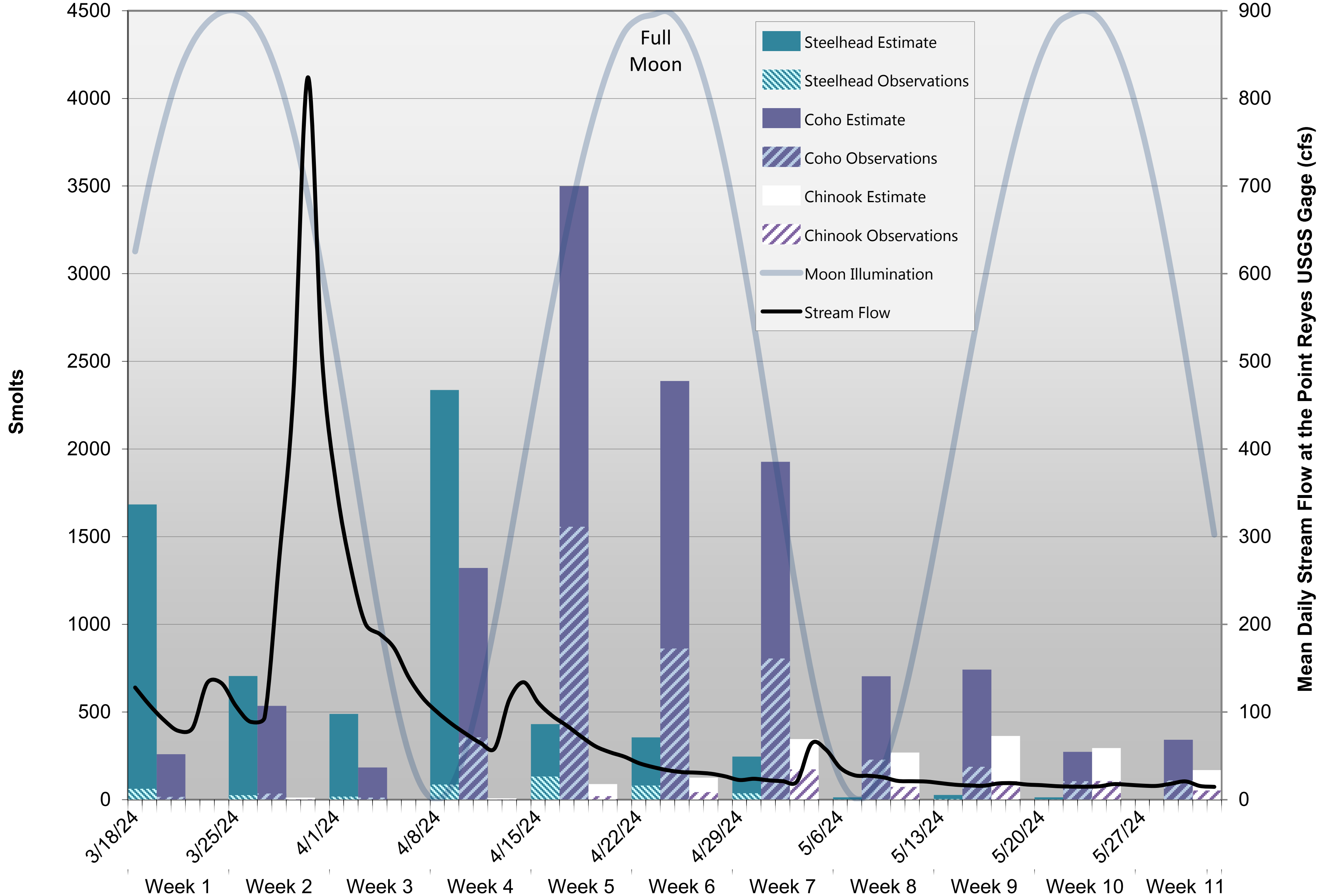


Figure 6. Lagunitas Creek smolt emigration, lunar cycle, and stream flow.