



## **SMOLT MONITORING IN THE LAGUNITAS CREEK WATERSHED – 2018**

Eric Ettlinger, Aquatic Ecologist

Marin Municipal Water District  
220 Nellen Avenue, Corte Madera, CA 94925  
(415) 945-1193

In association with the National Park Service

January 2019



## **Acknowledgements**

The Marin Municipal Water District (MMWD) would like to thank the Gallagher family for granting us access onto their property to conduct this monitoring.

Cover image: The Lagunitas Creek smolt trap and fish processing deck.

## Table of Contents

<b>EXECUTIVE SUMMARY .....</b>	<b>1</b>
<b>INTRODUCTION .....</b>	<b>2</b>
<b>METHODS.....</b>	<b>3</b>
Lagunitas Creek Monitoring .....	3
Olema Creek Monitoring.....	4
Data Analysis .....	5
<b>RESULTS .....</b>	<b>5</b>
Lagunitas Creek Rotary Screw Trap.....	5
Lagunitas Creek PIT Tag Antenna .....	8
Olema Creek Monitoring.....	8
<b>DISCUSSION.....</b>	<b>9</b>
Sampling conditions and emigration timing .....	9
Age and size composition of salmonids .....	9
Smolt abundance trends and implications for winter survival .....	10
<b>REFERENCES .....</b>	<b>11</b>

### List of Tables

Table 1. Marking schedule at Lagunitas and San Geronimo Creek smolt traps .....	4
Table 2. Estimated smolt emigration from Lagunitas Creek, 2006-2016 .....	6
Table 3. Salmonids captured in the Lagunitas Creek rotary screw trap by length and week .....	7
Table 4. PIT-tagged coho detections .....	8

### List of Figures

Figure 1. Trap locations.....	12
Figure 2. Lagunitas Creek smolt emigration, lunar cycle, and stream flow. ....	13
Figure 3. Weekly trap efficiency and Lagunitas Creek flow.....	14
Figure 4. Lagunitas Creek smolt estimates .....	15
Figure 5. Juvenile coho abundance and subsequent smolt abundance.....	16

## **EXECUTIVE SUMMARY**

Downstream migrating salmonid smolts were sampled using a rotary screw trap (RST) in lower Lagunitas Creek, near Point Reyes Station (Figure 1). This represents the 13<sup>th</sup> consecutive year of smolt monitoring at that location. From late March through late May the trap was monitored cooperatively by staff and volunteers from the Marin Municipal Water District (MMWD) and the Watershed Stewards Program (WSP). A passive integrated transponder (PIT) tag antenna was also in operation at that location to detect PIT-tagged coho smolts. In addition, a smolt trap was operated on Olema Creek by National Park Service (NPS) staff.

In 2018 the RST was disabled for three days in early April due to high flows, and was not operational for one additional day in mid-April due to a debris jam. For the season, a total of 4,883 coho smolts were captured at the RST and 7,812 ( $\pm 715$ ) coho smolts were estimated to have emigrated past the trap. The previous fall 10,877 coho fry were estimated to reside upstream of the RST, yielding a winter survival rate of 72%. Coho smolt emigration from Olema Creek was estimated at 572 ( $\pm 1,004$ ). The total emigration from the watershed was estimated at 8,384 ( $\pm 1,233$ ) coho smolts.

A total of 536 steelhead smolts were captured at the RST and an estimated 1,879 ( $\pm 576$ ) steelhead smolts emigrated past the trap. Chinook salmon smolts were observed for the fifth year in a row. The RST captured 1,509 Chinook smolts and 4,407 ( $\pm 1,027$ ) were estimated to have migrated past the trap.

## INTRODUCTION

Lagunitas Creek is a regionally important coastal stream for coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*), although run sizes for both species are significantly reduced from historical numbers. Recent coho escapement estimates have averaged approximately 400 individuals, and available data suggest that steelhead runs are similar in size. Chinook salmon (*O. tshawytscha*) also spawn periodically in Lagunitas Creek and smolts have been observed in seven of the last 13 years.

MMWD has conducted annual smolt surveys on Lagunitas Creek since 2006, as well as in 1983, 1984 and 1985. Summer and fall electrofishing surveys for juvenile coho salmon and steelhead trout were conducted in Lagunitas Creek starting in 1970 and annually since 1993. Since 2012 juvenile coho captured during these surveys have been implanted with passive integrated transponder (PIT) tags. This represents one of the longest data records for juvenile salmonids in coastal streams of California. Surveys have been conducted cooperatively between MMWD, the California Department of Fish and Wildlife (CDFW), the National Park Service (NPS), the Marin Resource Conservation District, the Watershed Stewards Program, and the Salmon Protection and Watershed Network (SPAWN). Systematic coho adult spawner surveys began during the 1982-83 and 1983-84 spawning seasons, and have been conducted annually since 1995-96. Since the early 1980s, stream flows in Lagunitas Creek have been monitored daily by United States Geological Survey gages located in Samuel P. Taylor State Park and near Point Reyes Station. A separate gage is maintained by MMWD on San Geronimo Creek. Water temperature monitoring has been performed by MMWD since the early 1990s. Lagunitas Creek streambed conditions are monitored annually and salmonid habitat is quantified approximately every five years.

This project is being conducted in collaboration with NPS, which conducts similar monitoring surveys in Olema 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.

Smolt monitoring in the Lagunitas Creek watershed is intended to answer the following questions:

- What are the trends in coho salmon and steelhead smolt abundance?
- What are salmonid overwinter survival rates, what factors influence those rates, and do those rates differ between subwatersheds?
- What are coho marine survival rates and how do these rates compare to other populations in the region?

## **METHODS**

### **Lagunitas Creek Monitoring**

A rotary screw trap (RST) with a five-foot diameter cone was installed on March 27, 2018 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 trap was operated for 54 days and disabled for three days. The cone rotation speed was outside the target range for three days. Trapping was discontinued on May 25.

Trap function was visually inspected each day to ensure proper operation. The rotation speed of the trap cone was recorded daily. The trap was occasionally moved either toward or away from the cascade to maintain cone speeds of between three and eight revolutions per minute (RPM). Debris was removed daily from the live box and only interfered with trap operation on one occasion, when a small log prevented the cone from spinning. Plywood baffles were installed in front of the cone on April 30 to increase the cone rotation speed and improve trap efficiency.

Each day, captured fish were removed from the trap and identified by species. 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 downstream of the point of capture. Coho smolts were scanned for passive integrated transponder (PIT) tags, implanted the previous fall. Steelhead displaying characteristics intermediate between fry/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 were classified as fry, transitionals, or smolts based on the degree of smolt characteristic development. Young-of-the-year coho displaying smolt characteristics (e.g., silvery appearance) were classified as smolts. All Chinook were assumed to be emigrating and classified as smolts. Downstream migrating fry of all species that were less than 70 mm long were tallied into five-millimeter length bins and not weighed. Adult steelhead that appeared unspawned were released upstream of the bedrock cascade. Spawned steelhead (kelts) were immediately released off the trap.

The proportion of migrating fish captured each week (trap efficiency) was determined by recapturing previously marked fish. Up to ten smolts per species per day were given a fin clip unique to the week (Table 1) and released approximately 500 m upstream. Some of these fish were subsequently recovered at the trap a second time and served as the basis for calculating trap efficiencies. Smolts smaller than 60 mm were not fin-clipped.

**Table 1.** Marking schedule at the Lagunitas Creek smolt trap, 2018

Week	Date	Mark Applied
1	March 26 to April 1	lower caudal clip (LC)
2	April 2 to April 8	dorsal & lower caudal clip (DLC)
3	April 9 to April 15	lower caudal and anal fin clip (LCAC)
4	April 16 to April 22	lower and upper caudal clip (LUC)
5	April 23 to April 29	lower caudal clip (LC)
6	April 30 to May 6	dorsal & lower caudal clip (DLC)
7	May 7 to May 13	lower caudal and anal fin clip (LCAC)
8	May 14 to May 20	lower and upper caudal clip (LUC)
9	May 21 to May 27	lower caudal clip (LC)

In addition to monitoring smolts with the RST, MMWD operated a PIT tag antenna upstream of the RST through the winter and spring of 2017-18. PIT tag monitoring was intended to estimate overwinter survival rates and the factors influencing survival. In 2017 coho between 61 and 69 mm were implanted with 8 mm full duplex tags (FDX) and fish  $\geq 70$  mm were implanted with 12 mm half duplex tags (HDX). Fish with HDX tags could be detected at the antenna as well as at the screw trap where all captured fish were scanned with a handheld PIT tag detector. The antenna cannot detect FDX tags, therefore FDX tags could only be detected at the screw trap.

### Olema Creek Monitoring

A fyke/pipe trap was installed by NPS staff on March 27 and was in operation for 59 days. The trap design was based on traps used by CDFW on the Noyo River (Gallagher 2000). The trap was checked daily, and no more than 30 coho smolts (or up to 50% of the catch that day) were anesthetized with carbon dioxide and marked with PIT tags. Marked smolts were released immediately after recovering from anesthetization at a predetermined site approximately 100 m or at least three habitat units above the trap site. After being measured, all recaptured smolts and unmarked smolts were released immediately in low velocity areas below the trap. Studies using similar methods of marking and tagging have demonstrated little marking mortality (Greis and Letcher 2002) and a study using the same trapping methodology on five northwestern California streams revealed that trap mortality was less than one percent for smolts and less than three percent for fry (Manning 2001).

Salmonids were identified to species and life stage (fry, parr, smolt, or adult) prior to being measured. Fry are less than one year old and can be identified by the presence of distinct parr marks and small body size. Age 1+ steelhead and coho were separated into the following morphological categories: parr (smaller size, parr marks present) or smolt (faint or absent parr marks, silver body, deciduous scales, black fin margins). A random sub-sample of up to ten coho smolts and steelhead parr and smolts were measured to the nearest millimeter (fork length),

and weighed to the nearest 0.01 g using an electronic scale. All fish that were anesthetized and marked were also measured and weighed. Any adult steelhead encountered in the trap were released downstream immediately without being measured. Random sub-samples of ten coho fry and ten steelhead fry were measured daily and individuals greater than 40 mm were weighed to the nearest 0.01 g using an electronic scale. Ten individuals of each non-salmonid species were also randomly selected, measured, and weighed. Sub-samples were obtained by taking blind scoops out of the holding bucket with a small aquarium dip net. After processing, each fish is placed in an aerated recovery bucket, keeping larger sculpin in separate buckets to avoid predation on smaller fish. Fish in the recovery bucket were monitored to ensure sedated fish recover fully before being released.

In addition to smolt trapping, a PIT tag antenna array was installed upstream of the Olema Creek smolt trap (Figure 1). For more detailed descriptions of smolt trapping methods, please refer to SOP (standard operating procedure) 3, SOP 4, SOP 6, SOP 9, and SOP 11 of the San Francisco Bay Area Network Salmonid Monitoring Protocol version 4.0 (Reichmuth et al. 2010).

### **Data Analysis**

The efficiency of the Lagunitas Creek rotary screw trap and populations of coho and steelhead smolts were estimated using Darroch Analysis with Rank Reduction (DARR) 2.0.2 software (Bjorkstedt 2005, 2010) from mark-recapture data. The DARR 2.0.2 software was developed to allow populations of downstream migrants to be estimated using mark-recapture data, particularly in small watersheds. This program applies a set of algorithms to stratified mark-recapture data to produce an abundance estimate while defining the variability in capture probability and the distribution of recaptured individuals within the strata.

## **RESULTS**

### **Lagunitas Creek Rotary Screw Trap**

The Lagunitas Creek RST captured 4,883 coho smolts, 536 steelhead smolts, and 1,509 Chinook smolts in 2018. 11 adult steelhead were captured. An estimated 7,812 coho smolts emigrated from Lagunitas Creek during the monitoring period (Table 2). Additionally, 108 young-of-the-year coho were captured, along with eight age 2+ coho smolts. The remaining coho catch was comprised of 1+ fish (1-2 years old) (Table 3). The highest estimated passage occurred during the week of April 16, with 1,993 coho smolts passing through and around the RST (Figure 2). The highest catch for a single day occurred on April 21 when 401 coho smolts were captured. The weekly trap efficiency for coho smolts varied from 18% to 87% (mean 57%) (Figure 3). Coho smolts averaged 106 mm fork length (FL) and weighed an average of 11.9 g.



**Table 2.** Estimated smolt emigration from Lagunitas Creek, 2006-2018.

Year	Survey start date	Survey end date	Coho		Steelhead		Chinook	
			Observed	Estimated	Observed	Estimated	Observed	Estimated
2006	21 March	9 June	1,342	5,946 ( $\pm 1,570$ )	308	6,949 ( $\pm 6,133$ )	237	504
2007	15 March	30 May	611	2,776 ( $\pm 692$ )	475	3,632 ( $\pm 2,066$ )	775	2,445
2008	18 March	5 June	2,532	6,101 ( $\pm 780$ )	449	1,134 ( $\pm 259$ )	0	0
2009	10 March	5 June	3,150	5,711 ( $\pm 461$ )	646	2,041 ( $\pm 537$ )	0	0
2010	17 March	27 May	631	2,129 ( $\pm 480$ )	651	3,867 ( $\pm 1,419$ )	0	0
2011	1 April	20 May	1,684	3,300 ( $\pm 470$ )	829	3,753 ( $\pm 941$ )	0	0
2012	26 March	31 May	4,339	8,315 ( $\pm 1,372$ )	251	1,991 ( $\pm 1,252$ )	0	0
2013	19 March	7 June	4,942	7,479 ( $\pm 504$ )	684	1,876 ( $\pm 380$ )	0	0
2014	11 March	4 June	8,415	15,055 ( $\pm 1,974$ )	448	1,720 ( $\pm 478$ )	1,229	2,011 ( $\pm 241$ )
2015	19 March	9 June	7,373	10,643 ( $\pm 596$ )	814	2,699 ( $\pm 594$ )	2,005	3,376 ( $\pm 382$ )
2016	16 March	24 May	3,428	9,719 ( $\pm 2,225$ )	371	4,396 ( $\pm 3,099$ )	191	833 ( $\pm 370$ )
2017	14 March	26 May	5,550	29,306 ( $\pm 11,286$ )	524	3,164 ( $\pm 1,313$ )	925	2,224 ( $\pm 425$ )
2018	30 March	25 May	4,883	7,812 ( $\pm 715$ )	536	1,879 ( $\pm 576$ )	1,509	4,407 ( $\pm 1,027$ )

During the monitoring period, an estimated 1,879 steelhead smolts emigrated from Lagunitas Creek (Table 2). The peak of emigration occurred during the week of April 9, with an estimated 621 steelhead smolts (Figure 2). The highest catch for a single day occurred on April 3, when 50 steelhead smolts were captured. The weekly trap efficiency for steelhead smolts ranged from 10% to 70% (mean 38%) (Figure 3).

For the season the steelhead catch was comprised of 35% fry, 21% age 1+ and 44% age 2+ and older steelhead (Table 3). Age 1+ steelhead were easily distinguished from YOY, but overlapped in size with Age 2+ steelhead. An indistinct break in the size distribution between 170 and 185 mm appeared to differentiate Age 3+ steelhead from younger fish. We classified 536 steelhead as fully-smolted, while 169 steelhead, ranging between 75 and 180 mm, were classified as “transitional” due to their mix of juvenile and smolt characteristics. Transitional steelhead were not included in the emigration estimate, since some of these fish may not have emigrated. Steelhead smolts averaged 158 mm FL and weighed 42.4 g on average. We captured between six and ten heavily spotted *O. mykiss* ranging from 229-290 mm that appeared to be resident

Table 3. Salmonids captured in the Lagunitas Creek rotary screw trap by length and week, 2018.

Coho										
Week:	1	2	3	4	5	6	7	8	9	
Dates	3/26 4/1	4/2 4/8	4/9 4/15	4/16 4/22	4/23 4/29	4/30 5/6	5/7 5/13	5/14 5/20	5/21 5/27	
Length (mm)	Age 0+									
20-24										
25-29		1								
30-34		4		2						
35-39		2	2	2						
40-44				4						
45-49	2	2	6	1						
50-54		1	7	2	1		1	2		
55-59		1	2	3		1		3	3	
60-64					1	2	1	5	4	
65-69	Age 1+			1			1	9	4	
70-74								6	7	
75-79							2	4	3	
80-84			2	2				1	3	
85-89		2	2	1	1		1	3	1	
90-94		5	8	5	1	2	7	9	12	9
95-99		2	3	4	4	11	17	19	27	25
100-104		2	8	9	12	16	47	48	31	25
105-109		5	14	8	17	41	40	48	28	13
110-114		2	4	4	33	39	25	23	19	12
115-119		1	5	2	32	23	4	3	8	2
120-124				5	19	11	2			
125-129		1			8		2			
130-134		1	1	1						
135-139		1	1	1						
140-144	Age 2+			1						
145-149										
150-154		1								
155-159										
160-164										
165-169										
170-174										
175-179										
180-184										
185-189										
190-194										
195-199										
200+										
Totals										
Age 0	2	11	17	15	2	3	5	30	25	11%
Age 1+	17	46	41	128	144	144	151	128	86	88%
Age 2+	0	4	2	2	0	0	0	0	0	1%

Steelhead										
Week:	1	2	3	4	5	6	7	8	9	
Dates	3/26 4/1	4/2 4/8	4/9 4/15	4/16 4/22	4/23 4/29	4/30 5/6	5/7 5/13	5/14 5/20	5/21 5/27	
Length (mm)	Age 0+									
20-24			8	5	1	2	9	35	17	
25-29			21	15		4	6	34	13	
30-34			8	6		2	3	3	3	
35-39			5	6	1		4	3		
40-44			3	8	1	4	9	5	2	
45-49			1		1	5	10	12	8	
50-54						6	11	25	7	
55-59						1	7	15	13	
60-64	1							13	15	
65-69	Age 1+						1	2	2	
70-74		1	1	1	1			1		
75-79		1	4	3	1		1		1	
80-84		1	6		2		1	1	1	
85-89		10	7	1	3	1	1		1	
90-94		7	8	4	3	2	1	2		
95-99		5	7	5	4	3	1	4	2	
100-104		5	4	1	7	7	1	1	1	
105-109		9	5	6	5	6		1	2	1
110-114		4	1	2	2	8		2	3	2
115-119			3	4	4	7	3	2	1	1
120-124	1		2	3	1	5	3	2		2
125-129	3	2	2	2	4	2	5	1	1	
130-134	Age 2+	3	6	6	9	4	1	3		
135-139		6	4	2	15	8	3	6	1	
140-144		4	3	4	8	14	4	1	6	
145-149		1	7	6	6	18	4		2	1
150-154		5	7	6	19	17	6	3		
155-159		2	4	3	19	20	7	3	2	
160-164		4	6	7	10	10	6	1	2	1
165-169		6	8	9	13				1	1
170-174		6	7	5	11	2	3			1
175-179	3	7	3	5	5	2	1			
180-184	1	2	7	2				2		
185-189		6	3							
190-194	Age 3+	1								
195-199		4								
200+	2	6	1	3	2	2	1	2	1	
Totals										
Age 0	0	0	46	40	4	25	61	148	81	35%
Age 1+	43	48	30	33	44	11	23	27	13	24%
Age 2+	46	77	64	119	105	41	9	9	4	41%

Chinook										
Week:	1	2	3	4	5	6	7	8	9	
Length (mm)										
35-39			3							
40-44			6							
45-49		3	4							
50-54		8	17		1	4				
55-59	8	19	24	9	12	4	2			
60-64	11	34	30	22	15	19	6	1	2	
65-69	1	15	25	34	13	24	26	16	13	
70-74		1	3	8	12	38	47	39	18	
75-79				12	9	19	27	41	17	
80-84				2	1	2	9	22	13	
85-89				1	1	2	3		10	
Totals	20	80	112	88	64	112	120	119	73	

rainbow trout. A few of these fish may have been recaptured, resulting in the uncertainty in abundance.

An estimated 4,407 Chinook smolts emigrated from Lagunitas Creek, with a peak emigration of 1,085 during the week of April 2. The weekly trap efficiency for Chinook ranged from 17% to 67% (mean 43%) (Figure 3). Chinook smolts were 68 mm in length and weighed 3.6 g on average.

Non-salmonid fish species included the following native and non-native species, in order of abundance: Tomales roach (*Hesperoleucus symmetricus symmetricus*), sculpin spp. (*Cottidae*), goldfish (*Carassius auratus*), bluegill (*Lepomis macrochirus*), threespine stickleback (*Gasterosteus aculeatus*), black crappie (*Pomoxis nigromaculatus*), Pacific lamprey (*Lampetra tridentata*), golden shiner (*Notemigonus crysoleucas*), Sacramento sucker (*Catostomus occidentalis*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), and largemouth bass (*Micropterus salmoides*). A record number of adult Pacific lamprey were observed this year, with 50 captures at the RST.

#### Lagunitas Creek PIT Tag Antenna

During the summer and early fall of 2017 PIT tags were implanted into 249 coho fry. The PIT tag antenna detected only nine of the 151 HDX-tagged coho (6%). The RST captured 26 HDX-tagged coho (17%) and 26 FDX-tagged coho (26%). Detection rates for fish tagged in Lagunitas Creek were notably lower than for fish tagged elsewhere (Table 4).

**Table 4.** PIT-tagged coho detections

Tag Type	Tagging Location	Fish Tagged in 2017	2018 Antenna Detections	Antenna Detection Rate	2018 RST Detections	Total Detections	Total Detection Rate
HDX	Lagunitas Creek	84	4	5%	11	11	13%
	San Geronimo Cr.	40	4	10%	9	9	23%
	Devil's Gulch	27	1	4%	6	6	22%
	All	151	9	6%	26	26	17%
FDX	Lagunitas Creek	7	NA	NA	0	0	0%
	San Geronimo Cr.	43	NA	NA	12	12	28%
	Devil's Gulch	50	NA	NA	14	14	28%
	All	100	NA	NA	26	26	26%
All	All	249	9	6%	50	50	20%

#### Olema Creek Monitoring

The Olema Creek smolt trap captured only 40 coho smolts and an estimated 572 ( $\pm 1,004$ ) coho emigrated from the creek. This was the second-lowest estimate for the period of smolt monitoring, which began in 2004. In addition, 34 steelhead smolts were captured, but an emigration estimate was not calculated.

## **DISCUSSION**

### **Sampling conditions and emigration timing**

The smolt trap was installed on March 29, after flows receded following a large storm on March 22. Another storm on April 6 required the trap to be disabled for three days, but conditions were favorable for the rest of the monitoring period. During the first few days of trap operation an estimated 58 coho emigrated from Lagunitas Creek, representing less than 1% of the total migration and suggesting that few coho smolts had yet emigrated. Estimated emigration remained below 100 per day until the new moon on April 15 (Figure 2), when captures started to increase dramatically. The peak of the season occurred on April 21 when 393 coho smolts were captured.

The steelhead migration appeared to be well on its way during the first few days of monitoring. The peak steelhead catch occurred on the fifth day of monitoring, and a quarter of all steelhead smolts were captured during those first five days. An unknown but possibly significant number of steelhead outmigrated prior to trap installation. Estimated emigration peaked during the third week of monitoring, roughly coinciding with the new moon.

The peak in Chinook captures also peaked on the fifth day of monitoring, but unlike steelhead, these early catches comprised a small part of the observed emigration. The peak in emigration occurred during Week 2, and coincided with elevated stream flows. Interestingly, Chinook catches dropped to single digits as the full moon approached in late April, and then reached a third peak just before the new moon in mid-May (Figure 2).

In past years a number of hypotheses have been proposed to explain the timing of salmonid smolt migration including water temperatures and stream flows. In 2018 there was no evidence that elevated water temperatures prompted migration for any species, while the storm in early April may have influenced the migratory behavior of steelhead and Chinook. The lunar cycle may have played the largest role in influencing migration timing, with the emigration peaks of all three species falling between full moons. In future years the lunar cycle should be considered when planning trap installation dates and staffing levels.

### **Age and size composition of salmonids**

In 2018 age 1+ coho smolts were easily distinguishable by size from nearly all of the young-of-the-year (YOY) coho captured. Only two YOY coho were described as “transitional” and another two as smolts, indicating that very few YOY coho were smolting and emigrating from Lagunitas Creek.

Age 1+ and older steelhead overlapped significantly in size and size breaks were not readily apparent during most of the monitoring period. Fish ages were deduced from size distributions (Table 3), but in future years more scales should be collected and analyzed to differentiate age classes.

### **Smolt abundance trends and implications for winter survival**

The 2018 coho emigration from the Lagunitas Creek watershed was somewhat below-average in size and a decline of 27% from three years earlier (Figure 4). Of the 10,877 juvenile coho estimated to reside upstream of the Lagunitas smolt trap in 2017, 72% survived through the winter. This was the highest survival rate since 2011.

Coho smolt abundance is negatively correlated with the number storms producing stream flows between 60 and 500 cfs. These flows are to a large degree contained within the stream channel, and may require coho to expend significant energy to maintain their positions without delivering many terrestrial invertebrates from the floodplain. Each flow in this range may therefore reduce coho energy reserves and increase mortality. In 2017-18 four storms produced runoff between approximately 100 and 300 cfs. This is a typical number of storms of this magnitude and predicted an average coho smolt emigration.

An alternative explanation for this year's coho numbers is that winter survival rates have been increasing, possibly as a result of habitat enhancement efforts. Figure 5 shows the relationship between juvenile coho abundance and smolt abundance the following year for four time periods. That relationship has changed from one resembling a carrying capacity prior to 2012 to a density-dependent or constant-survival relationship in recent years. More years of monitoring will be necessary to determine if coho winter survival is more strongly influenced by the frequency of moderate flows or by habitat enhancement efforts.

## REFERENCES

- Bjorkstedt, E. P. 2005. DARR 2.0: updated software for estimating abundance from stratified mark-recapture data. NOAA Technical Memorandum NMFS-SWFSC-368.
- Bjorkstedt, E. P. 2010. DARR 2.0.2: DARR for R.  
<http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346>
- Brown, P. (SPAWN). Personal Communication, November 8, 2016.
- Ettlinger, E., P. Doughty, V. Rogers and G. Andrew. 2016. Smolt monitoring in the Lagunitas Creek watershed 2015. Marin Municipal Water District.
- Gallagher, S. P. 2000. Results of the 2000 Steelhead (*Oncorhynchus mykiss*) Fyke Trapping and Stream Resident Population Estimations and Predictions for the Noyo River, California with Comparison to Some Historic Information. California State Department of Fish and Game, Steelhead Research and Monitoring Program, Fort Bragg, CA. Report FB-03-Draft, September 2000. 75pp.
- Greis, G., and B. H. Letcher. 2002. Tag retention and survival of age-0 Atlantic salmon following surgical implantation with passive integrated transponder tags. North American Journal of Fisheries Management 22: 219-222.
- Manning, D.J. 2001. Carrying capacity and limiting habitat analysis for coho salmon (*Oncorhynchus kisutch*) in streams of northwestern California. Humboldt State University: Masters Thesis, Arcata, California.
- Reichmuth, M., B.J. Ketcham, D. Fong, S. Carlisle, E. Brown, and M. Koenen. 2010. Salmonid Monitoring Protocol for the San Francisco Bay Area Network: narrative and appendices – version 4.0. Natural Resource Report NPS/SFAN/NRR—2010/202. National Park Service, Fort Collins, Colorado.
- Stillwater Sciences. 2008. Lagunitas limiting factors analysis; limiting factors for coho salmon and steelhead. Final Report. Prepared by Stillwater Sciences, Berkeley, California for Marin Resource Conservation District, Point Reyes Station, California.



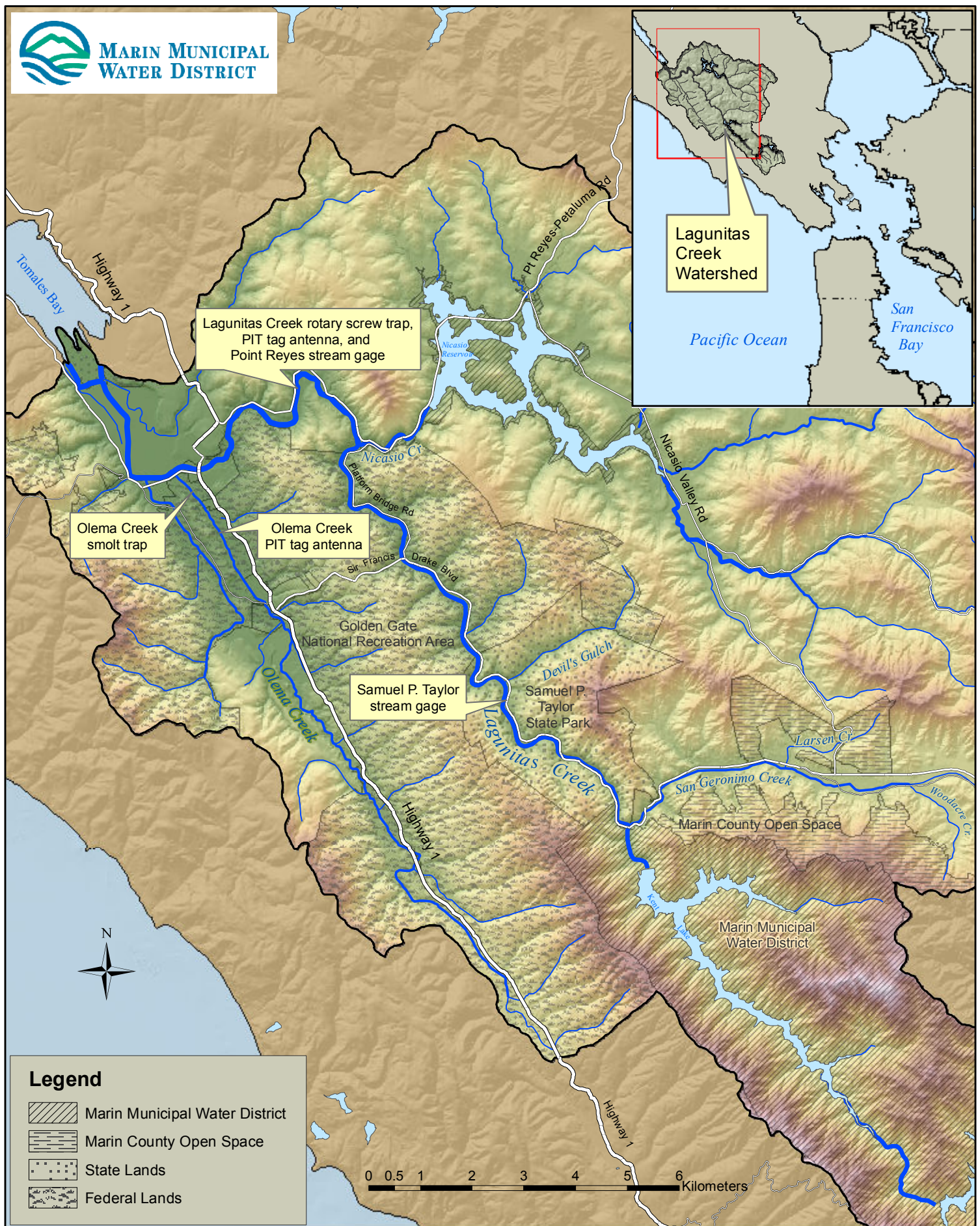


Figure 1. Smolt monitoring locations in the Lagunitas Creek watershed.

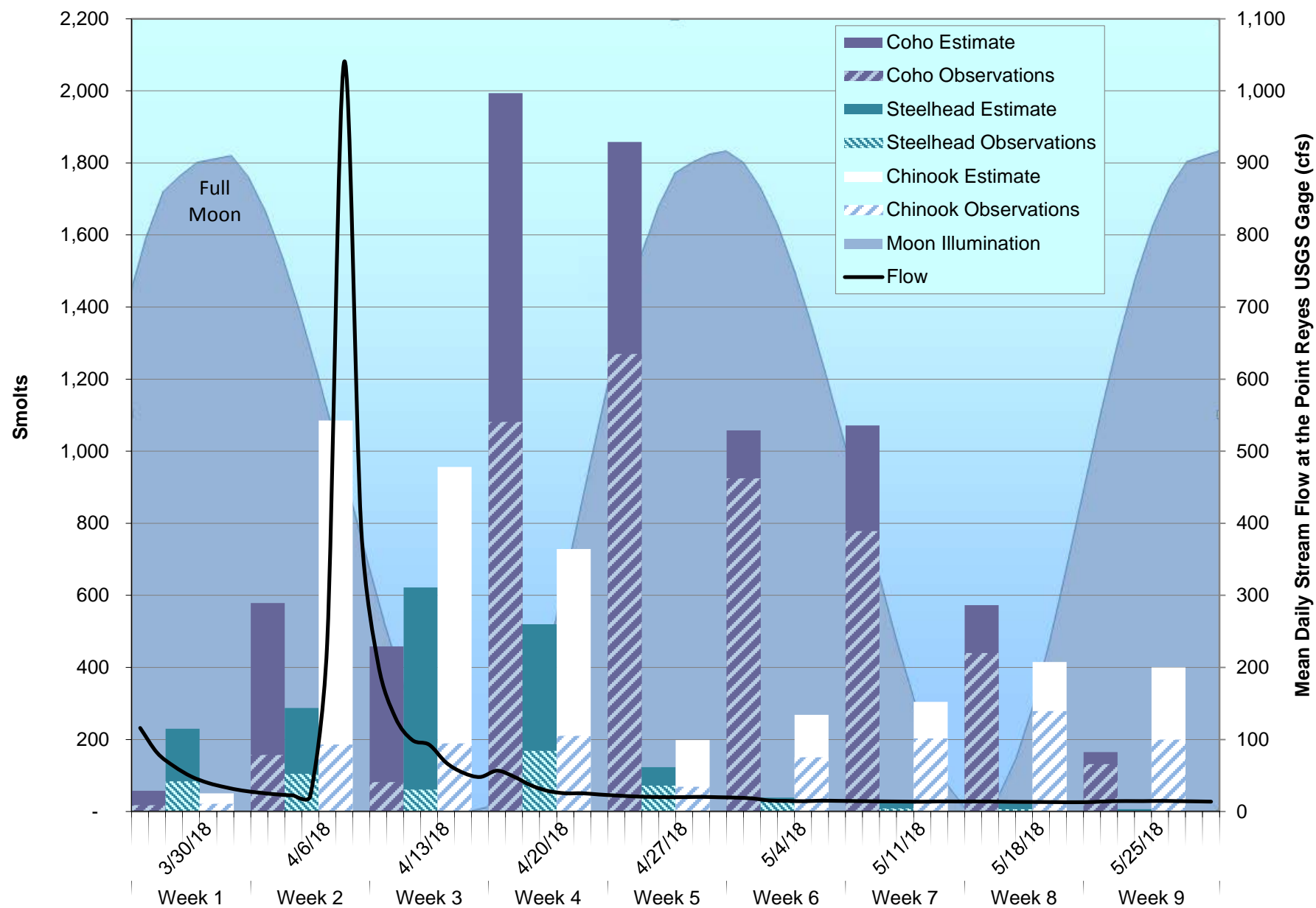


Figure 2. Lagunitas Creek smolt emigration, lunar cycle, and stream flow.



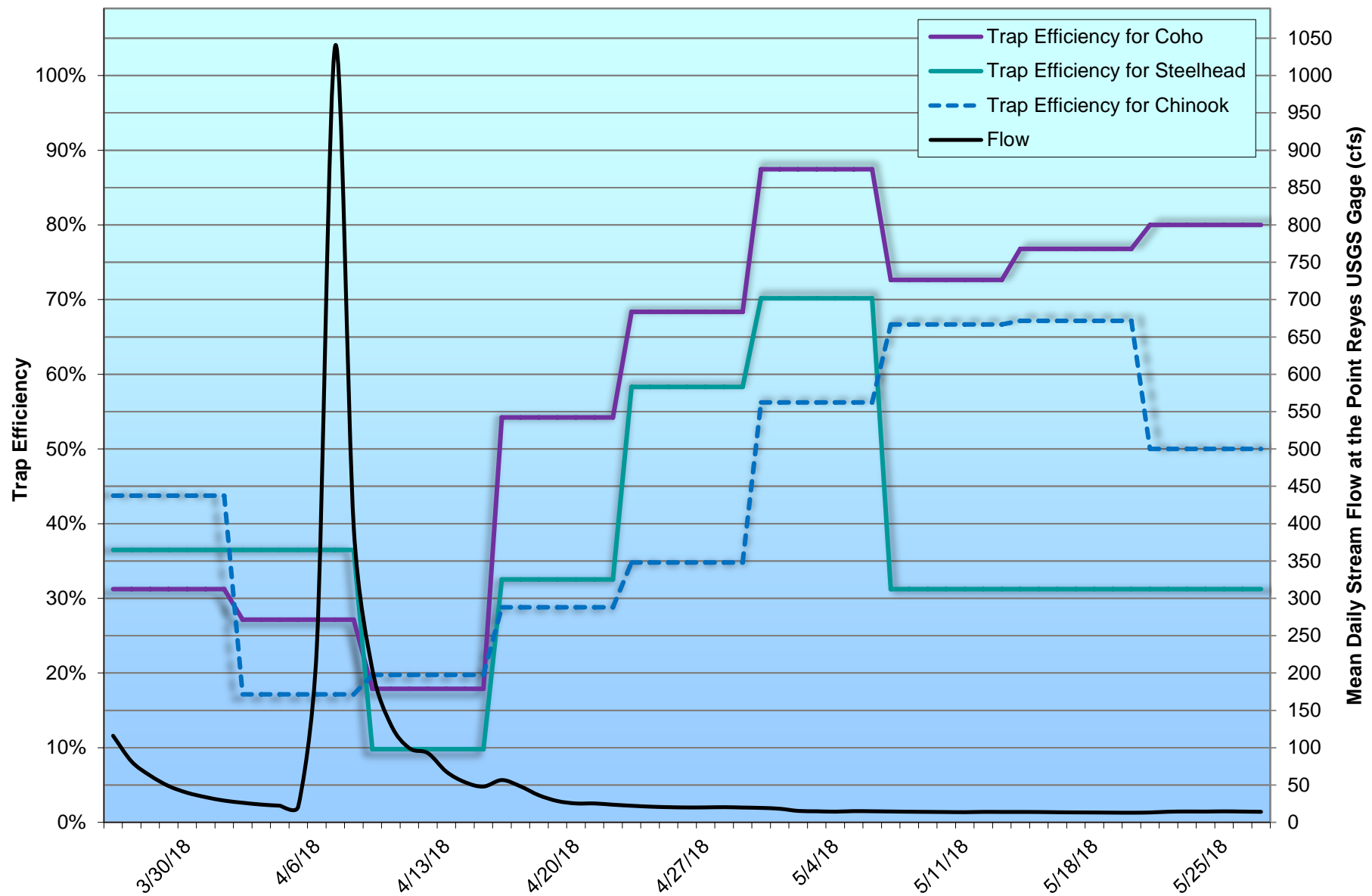


Figure 3. Weekly trap efficiency and Lagunitas Creek stream flow.

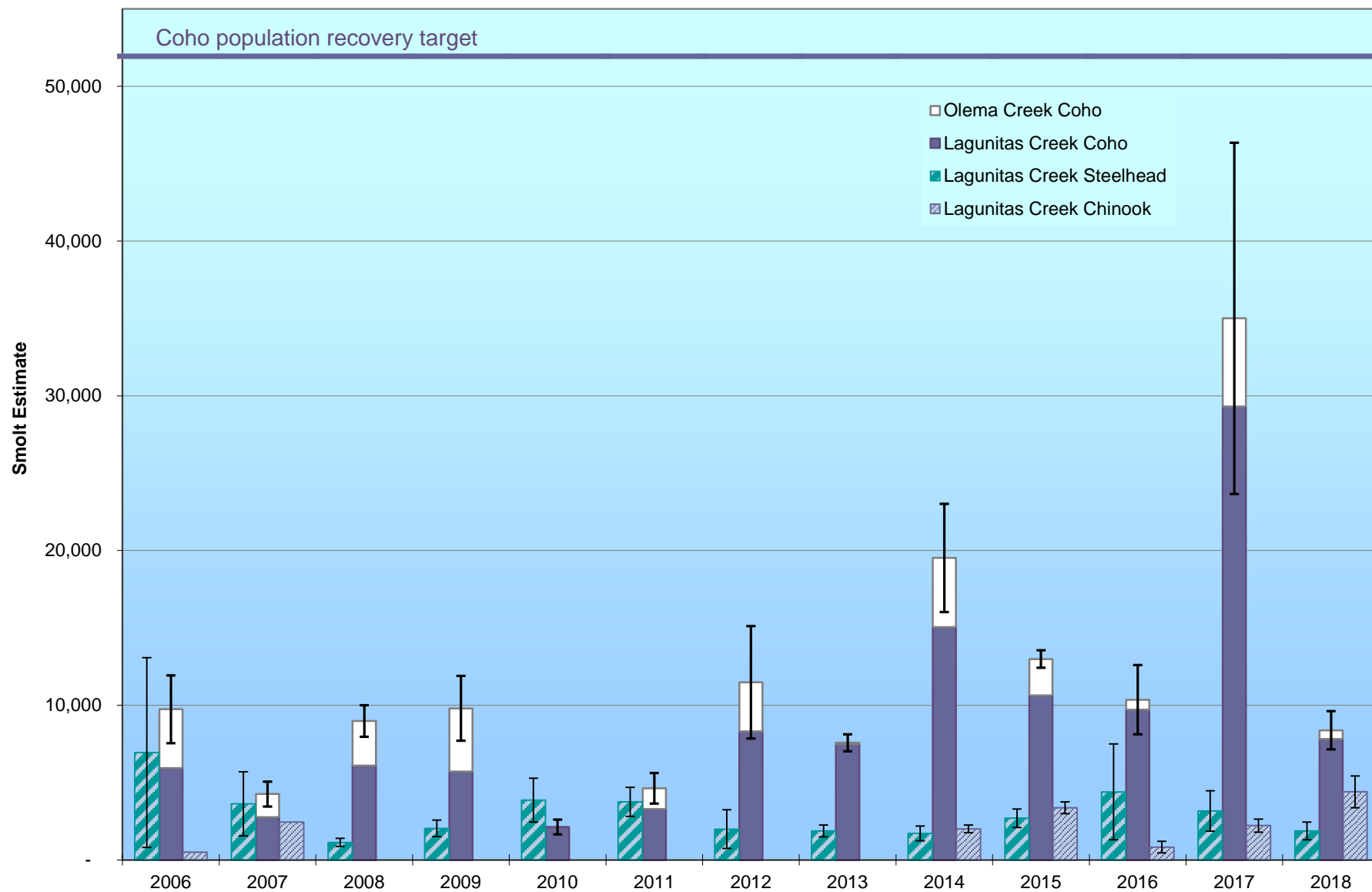


Figure 4. Lagunitas Creek smolt emigration estimates.

Note: The coho recovery target assumes an ocean survival rate of at least 5%, resulting in 2,600 adult returns.

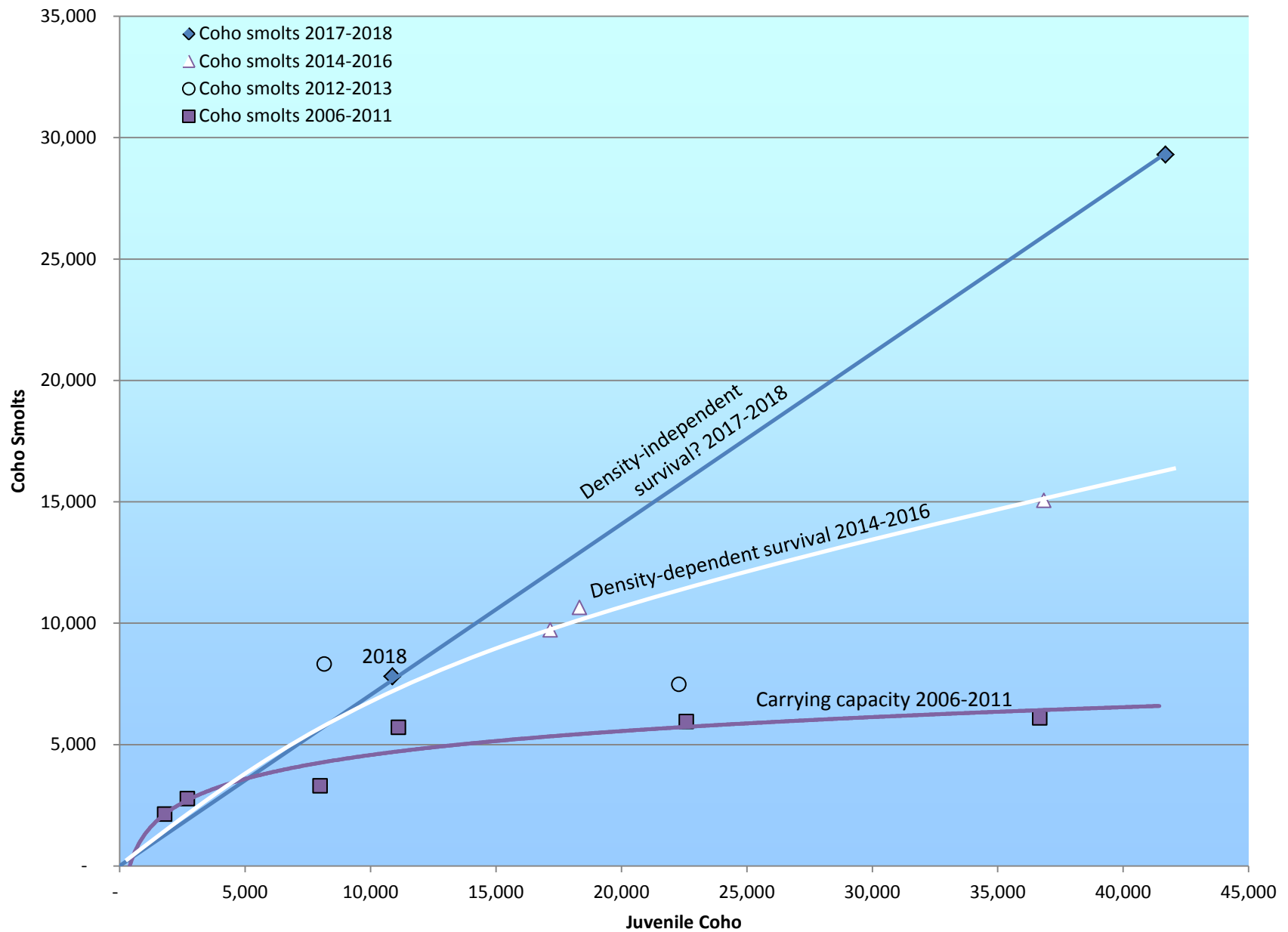


Figure 5. Juvenile coho abundance and subsequent smolt abundance (smolt year shown).

Olema Creek data not included.