Coho Salmon and Steelhead Monitoring Report

Spring 2023

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Sonoma Water

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RUSSIAN RIVER SALMON & STEELHEAD MONITORING PROGRAM

UNIVERSITY OF CALIFORNIA

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Contents

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1. Background

In 2004, the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) began releasing juvenile coho salmon (*Oncorhynchus kisutch*) raised at the US Army Corps of Engineer's (USACE) Don Clausen Fish Hatchery into tributaries of the Russian River with the goal of reestablishing populations that were on the brink of extirpation from the watershed. California Sea Grant at University of California (CSG) worked with local, state, and federal biologists to design and implement a coho salmon monitoring program to track the survival and abundance of hatchery-released fish. Since the first Broodstock Program releases, CSG has been closely monitoring smolt abundance, adult returns, survival, and spatial distribution of coho salmon populations in four life cycle monitoring (LCM) watersheds: Willow, Dutch Bill, Green Valley, and Mill creeks. Data collected from this effort are provided to the Broodstock Program for use in evaluating the success of hatchery releases and adaptively managing future releases.

Over the last decade, CSG has developed many partnerships in coho salmon and steelhead (*O. mykiss)* recovery, and our work has expanded to include identification of limiting factors to survival, evaluation of habitat enhancement and streamflow improvement projects, and implementation of a statewide salmon and steelhead monitoring program California Coastal Monitoring Program (CMP). In 2010, we began documenting relationships between streamflow and juvenile coho salmon survival as part of the Russian River Coho Water Resources Partnership (Coho Partnership), an effort to improve streamflow and water supply reliability to water-users in flow-impaired Russian River tributaries. In 2013, we partnered with Sonoma Water (SW) and California Department of Fish and Wildlife (CDFW) to begin implementation of the CMP, a statewide effort to document status and trends of anadromous salmonid populations using standardized methods and a centralized statewide database.

The intention of our monitoring and research is to provide science-based information to stakeholders involved in salmon and steelhead recovery. Our work would not be possible without the support of our partners, including public resource agencies and non-profit organizations, along with hundreds of private landowners who have granted us access to the streams that flow through their properties.

In 2023, CSG began transitioning away from field data collection and subcontracted with SW to conduct field activities associated with Broodstock Program monitoring. During the winter of 2022/2023, field data was collected by both organizations and beginning in spring 2023, field data collection was conducted entirely by SW.

In this seasonal monitoring report, we provide results from spring downstream migrant trapping efforts and operation of passive integrated transponder (PIT)-tag detection systems located on Willow, Dutch Bill, Green Valley, and Mill creeks. Additional information and previous reports can be found on our website.

2. Downstream migrant trapping and operation of PIT-tag antenna arrays

2.1. Goals and objectives

The primary goals of this study were to estimate smolt abundance, natural production, freshwater survival, migration timing, and freshwater growth of the 2022 cohort (hatch year) of juvenile coho salmon in Willow, Dutch Bill, Green Valley, and Mill creeks using a combination of downstream migrant smolt trapping and operation of PIT antenna arrays.

2.2. Methods

2.2.1. Coho salmon releases into LCM streams

Broodstock Program coho salmon were raised by USACE personnel at the Don Clausen Fish Hatchery at Warm Springs Dam and released at locations across the lower Russian River basin. Generally, four release groups are defined by their age and month of release: spring (age-0, June - July), fall (age-0, October - December), presmolt (age-1, January - February), and smolt (age-1, March - June). For the 2022 hatch year (2021 brood year) in the LCM watersheds, fall releases were stocked in December 2022, presmolt releases were stocked in January 2023, and smolt releases were stocked in March - June 2023 (Table 1). There were no spring releases in 2022. For the fall releases into Dutch Bill and Mill creeks as well as the Willow Creek presmolt release, fish were stocked into individual pools spread throughout multiple stream reaches (Figure 1). For the Purrington Creek presmolt release and Green Valley and Dutch Bill Creek smolt releases, fish were released at point locations. The Dutch Bill Creek smolt release and the Green Valley smolt releases after March 21 were released downstream of our LCM monitoring sites.

Table 1. Number of 2022 cohort (hatch year) juvenile coho salmon released into Broodstock Program LCM watersheds. Note that the total for the Green Valley Creek watershed includes releases into Purrington Creek.

				Tributary totals		*Subwatershed totals*	
Subwatershed	**Tributary**	**Release group**	**Release dates**	**Number PIT-tagged**	**Total number released**	**Number PIT-tagged**	**Total number released**
Willow Creek	Willow Creek	presmolt	1/27/2023	775	3,018	775	3,018
Dutch Bill Creek	Dutch Bill Creek	fall	12/13/2022	1,612	6,192	1,612	6,192
		smolt	5/7/2023	1,045	3,993	1,045	3,993
Green Valley Creek	Green Valley Creek	smolt	3/21/23 - 5/1/23	6,427	24,291	7,212	27,830
	Purrington Creek	presmolt	1/26/2023	785	3,539		
Mill Creek	Mill Creek	fall	12/1/2022	1,454	4,678	1,454	4,678

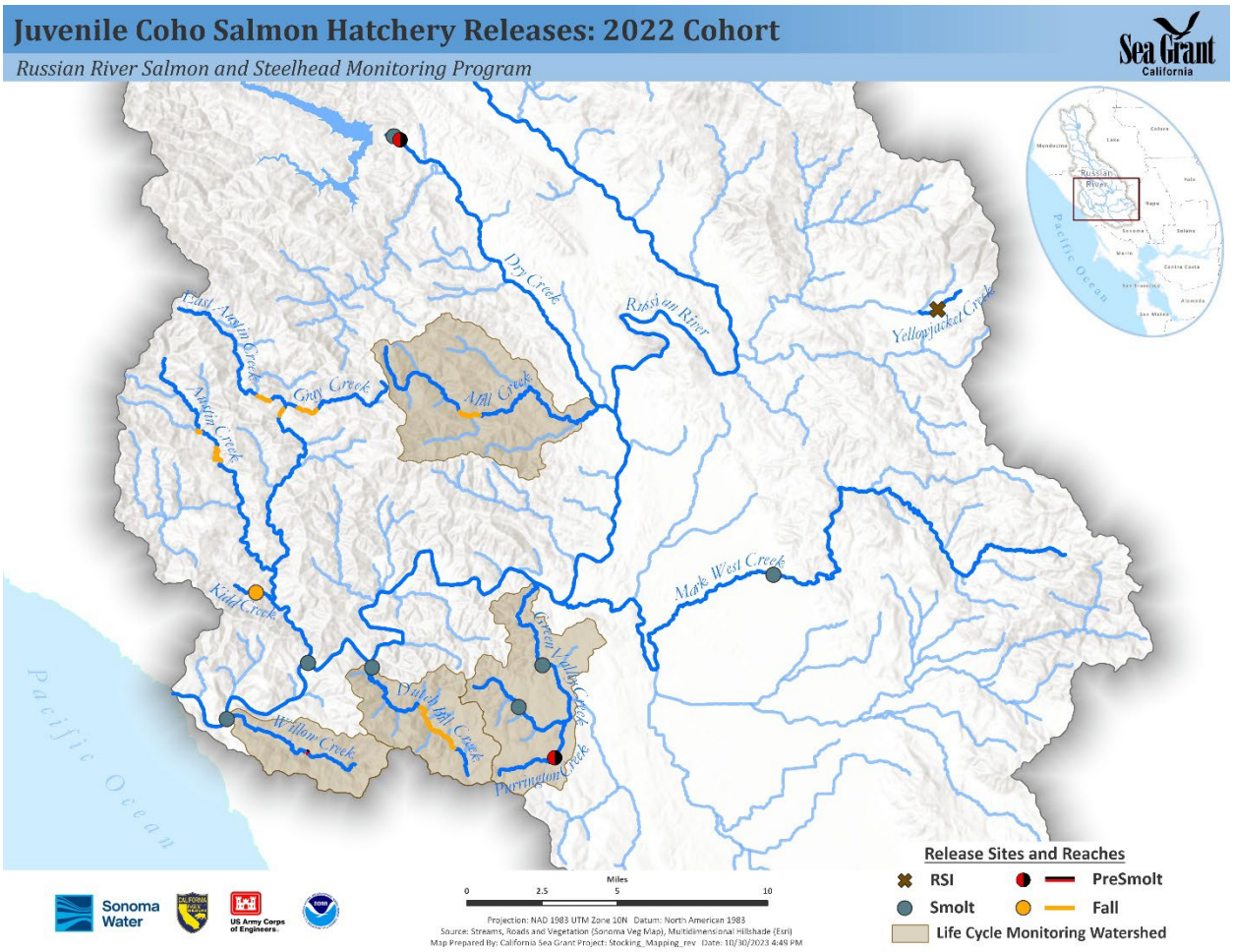

Figure 1. Map of juvenile coho salmon stocking locations for 2022 cohort (hatch year) in the four Broodstock Program LCM watersheds and additional locations, including the mainstem Russian River and Dry Creek.

2.2.2. PIT tagging

Prior to release, approximately 26% of juvenile coho salmon were implanted with 12.5 mm full duplex (FDX) PIT tags at the Don Clausen Fish Hatchery at Warm Springs Dam (Table 1). Coho salmon were randomly selected for tagging from each release group and checked to ensure they met the minimum size for tagging (i.e., 56 mm and 2 g). During tagging, a small incision was made on the ventral side of the fish using a scalpel, and the tag was inserted into the body cavity.

2.2.3. Field methods

2.2.3.1. Stationary PIT antennas

As part of the Broodstock Program monitoring effort, SW operates stationary PIT-tag detection systems year-round in stream channels near the mouths of Willow, Dutch Bill, Green Valley, and Mill creeks, and at one or more sites upstream within each watershed (Figure 2). Biomark multiplexing transceivers or single IS1001 nodes, capable of reading FDX tags, were placed in waterproof boxes on the streambank

and powered using AC power with AC-DC conversion systems, solar power, or by 24 v batteries changed every one to two weeks. Rectangular antennas (approximately 15 feet by 2.5 feet), housed in four-inch PVC, were placed flat on top of the streambed and secured with earth anchors. For estimating early juvenile emigration, smolt survival, and smolt abundance, multiple antennas within an array were placed across the stream channel (i.e., perpendicular to stream flow). Antenna efficiency estimation was facilitated by situating antennas in multiple (two to three) upstream to downstream cross sections near one another (approximately 10 - 20 feet apart). This configuration also allowed determination of movement direction and allowed increased sample size (due to higher detection efficiency) for depicting movement patterns such as migration timing. Antennas located further up in the watersheds were single, channel-spanning arrays that were useful for documenting within-watershed movement patterns. Based on test-tag trials at the time of installation, read-range in the water column above the antennas ranged from 10" to 24" during base flow conditions. From October 2022 through June 2023, PIT-tag detection systems were visited at two-week intervals to download data and check antenna status. Surrounding large storm events, additional site visits were conducted to preemptively remove equipment that is prone to flooding, assess any damage to equipment following a storm, and to troubleshoot any issues that may arise.

2.2.3.2. Downstream migrant trapping

Downstream migrant traps were operated by SW on Willow, Dutch Bill, Green Valley, and Mill creeks (Figure 2 and Figure 3) between April and June 2023, a window of time that coincides with coho salmon smolt outmigration and when streamflow is conducive to trap operation in flashy systems. Traps were tended daily, with additional checks during peak outmigration and high flows. During significant storm events, the traps were opened or removed to prevent injury to fish, avoid loss of equipment, and ensure the safety of personnel.

During each trap tend, captured coho salmon smolts were carefully netted out of the trap box, placed into aerated buckets, and anesthetized using a solution of 1-2 tablets of Alka-Seltzer Gold (aspirin free) brand sodium bicarbonate ($NaHCO_3$) per gallon of water. Each day, all coho salmon regardless of life stage were counted and scanned for PIT and coded wire tags (CWTs). All PIT-tagged coho were measured for fork length (±1 mm) and weight (±0.1 g). Additionally, the first 30 coho smolts with a CWT and first 30 coho without a CWT were measured and weighed, regardless of PIT tag presence. To increase the sample size for estimates of smolt-to-adult return ratios, a PIT tag was applied to every fourth CWT-only smolt that did not already have a PIT tag (25% of all CWT-only fish), and measurements were taken on each of these fish. All presumed natural-origin coho salmon smolts (no CWT or PIT) were measured and weighed, and a PIT tag was applied to every other fish (50% of unmarked smolts). A genetics sample was collected for every CWT-only and unmarked smolt to which a PIT tag was applied, by clipping a small corner of the lower caudal fin (1 mm^2) and placing it in an envelope lined with chromatography paper. After workup, biologists waited for fish to recover fully in a separate aerated bucket before releasing them downstream of the trap. Genetics samples were cataloged and prepared for transport to National Marine Fisheries Service Southwest Fisheries Science Center for storage and analysis.

Although steelhead were not a target species for the Broodstock Program monitoring, all captured steelhead smolts were scanned for PIT tags and measured for fork length (±1 mm) and weight (±0.1 g). Each day, every other non-adipose-clipped steelhead smolt was also PIT tagged as part of the Coastal Monitoring Program effort. The first 10 steelhead yoy and steelhead parr were measured for fork length (±1 mm) and weight (±0.1 g) and released downstream. The first 10 unidentifiable salmonid yoy ≥ 35 mm that were captured in the traps each day were measured for fork length only. All other vertebrates and crustaceans captured in the traps were tallied and released downstream of the traps.

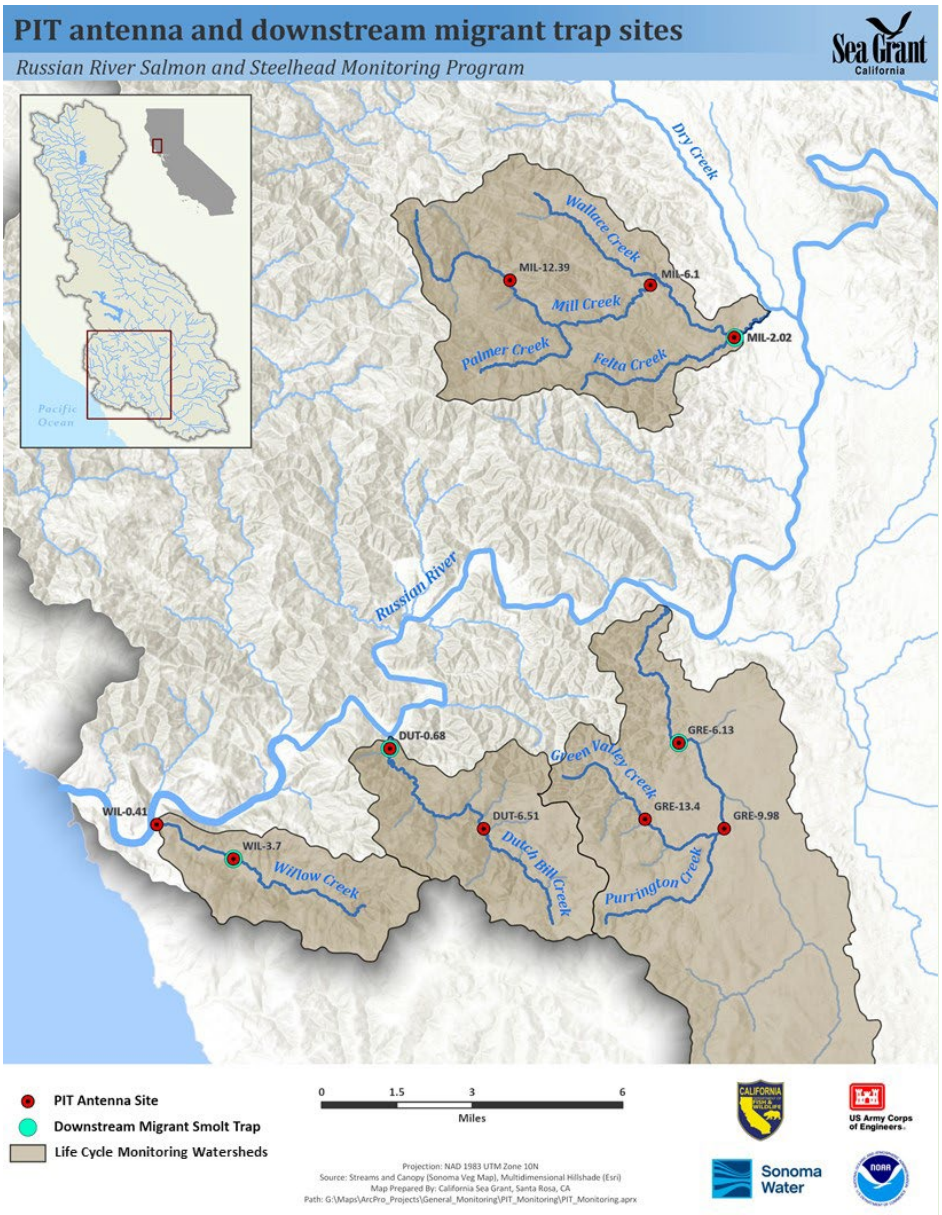

Figure 2. PIT antenna and smolt trap locations on Broodstock Program LCM watersheds, with antenna site codes that indicate the distance in river kilometers along the stream course from the mouth of the stream.

Figure 3. Downstream migrant funnel trap at a new trap site on Green Valley Creek.

2.2.4. Data analysis

2.2.4.1. Natural production

Fish origin (natural or hatchery) for non-PIT-tagged fish was determined for each coho salmon captured in the smolt traps based on the presence of a CWT. Any fish with a CWT present was recorded as a hatchery-origin (HOR) fish and any fish without a CWT was recorded as a natural-origin (NOR) or "wild" fish. Origin of fish with PIT tags was determined by looking up the tag number in our database and assigning the origin recorded at the time of tagging. These data were used to develop ratios of NOR to HOR smolts for each stream.

2.2.4.2. Smolt abundance

A two-trap mark-recapture model (Bjorkstedt 2005, 2010) was used to estimate the total number of coho salmon smolts emigrating from each creek during the time when traps were operated. An antenna array located immediately upstream of each smolt trap acted as an upstream "trap" where fish were "marked" (marked fish refers to all PIT-tag detections on antenna array), and the smolt trap served as a downstream trap where fish were recaptured. PIT-tagged fish detected at both the antenna array and captured in the trap were considered recaptures, and non-PIT-tagged fish and PIT-tagged fish only detected in the trap (but not the antenna) were considered unmarked fish.

2.2.4.3. Probability of survival and early winter emigration

PIT-tag detections at antenna and trap sites were used to estimate release-to-smolt (freshwater) survival and early winter emigration, defined as emigration prior to March 1. A multistate emigration model (Horton et al. 2011), as implemented in Program MARK (White and Burnham 1999), was used to

compare probability of survival from the time of release to 6/30/23. The model was also used to estimate the probability of emigration prior to 3/1/23 for fall and presmolt release groups in the four LCM watersheds. In addition, we estimated survival of one smolt release group that was released upstream of our PIT antennas in Green Valley Creek. All other fish stocked at the smolt stage were released downstream of our PIT antenna arrays; therefore survival could not be estimated for these groups.

2.2.4.4. Migration timing

The earliest date of each PIT-tagged individual detected was used to evaluate migration timing at locations of interest. The total number of individuals from each release group (fall, presmolt, and smolt for cohort 2022) passing a given site each week were then plotted for the period from October 29 through June 30.

2.2.4.5. Size and growth

All fish that were implanted with a PIT tag at the hatchery were measured for fork length (±1 mm) and weight (±0.1 g) prior to being released into the tributaries. These measurements were used to calculate the average length and weight of fish for each release group and stream prior to release. For coho salmon smolts that were captured in the downstream migrant traps and measured, we calculated mean fork length and weight of smolts emigrating from each stream. We aligned measurements of PIT-tagged fish captured in the downstream migrant traps with size data collected in the hatchery at the time of tagging to calculate individual growth rates from the time of tagging to the time of capture in the smolt traps. Daily growth rates for length were calculated for individual hatchery fish as $(FL_2\text{-}FL_1)/(t_2\text{-}t_1)$ where FL_1= fork length at hatchery prior to release, FL_2= fork length at the smolt trap, t_1=date measured at hatchery, and t_2= date captured in the smolt trap. Similar calculations were made for weight and then growth rates for individual fish were averaged by stream and release group. Note that for interannual comparisons, growth rates were calculated in a slightly different manner between 2011 and 2014 (California Sea Grant 2018).

2.3. Results

2.3.1. Trap operation

In 2023, downstream migrant traps in the four LCM watersheds were installed between April 11-14, and each trap was operated until the site became disconnected from upstream flow (Figure 4). The relatively late start dates were because of high stream flows from rain events in March and early April (Figure 5) that precluded installation during early March as is typical. PIT antennas in all four streams ran continously throughout the duration of downstream migrant trapping season, ensuring coverage even prior to trap installation.

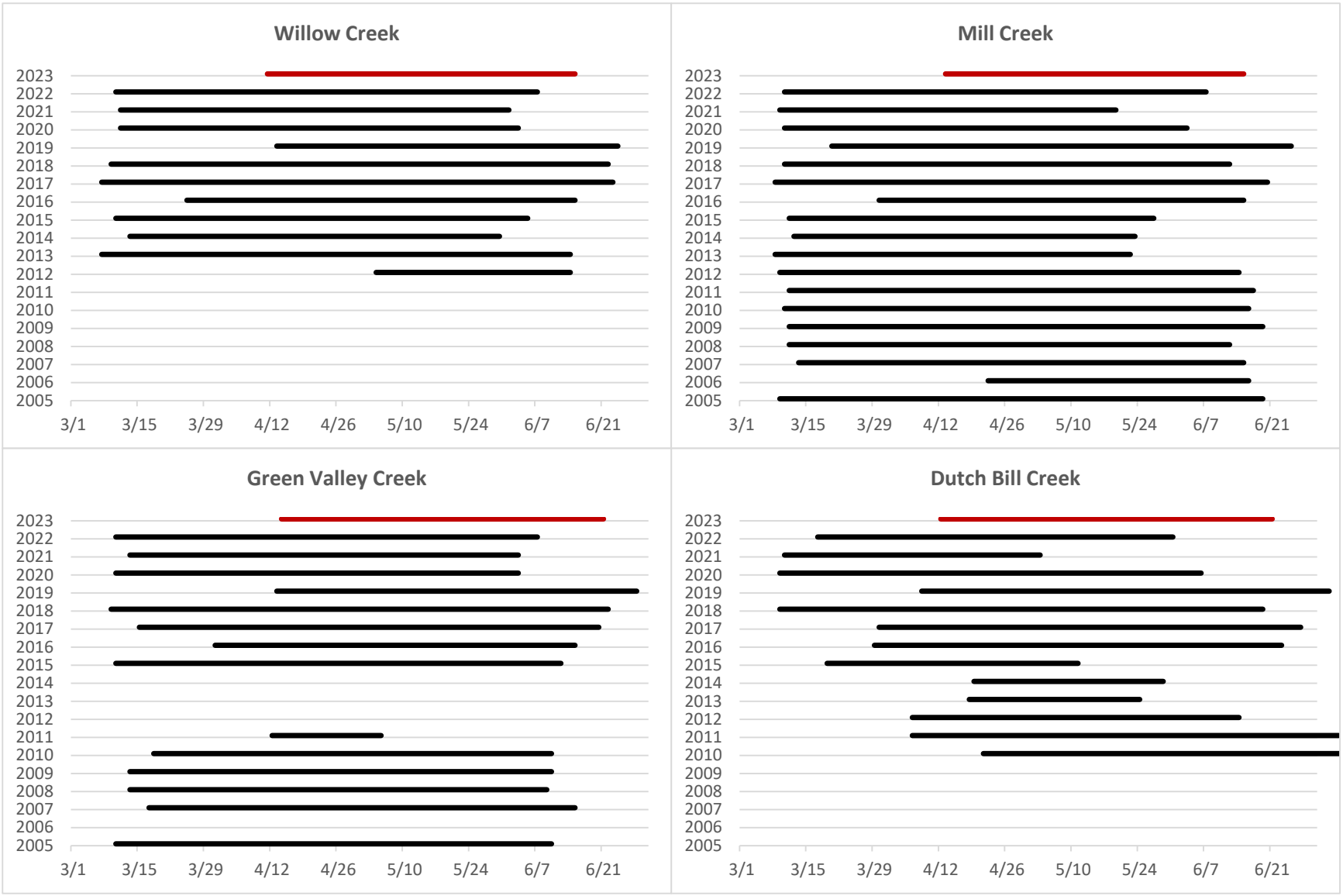

Figure 4. Timing of downstream migrant trap operation, 2005-2023.

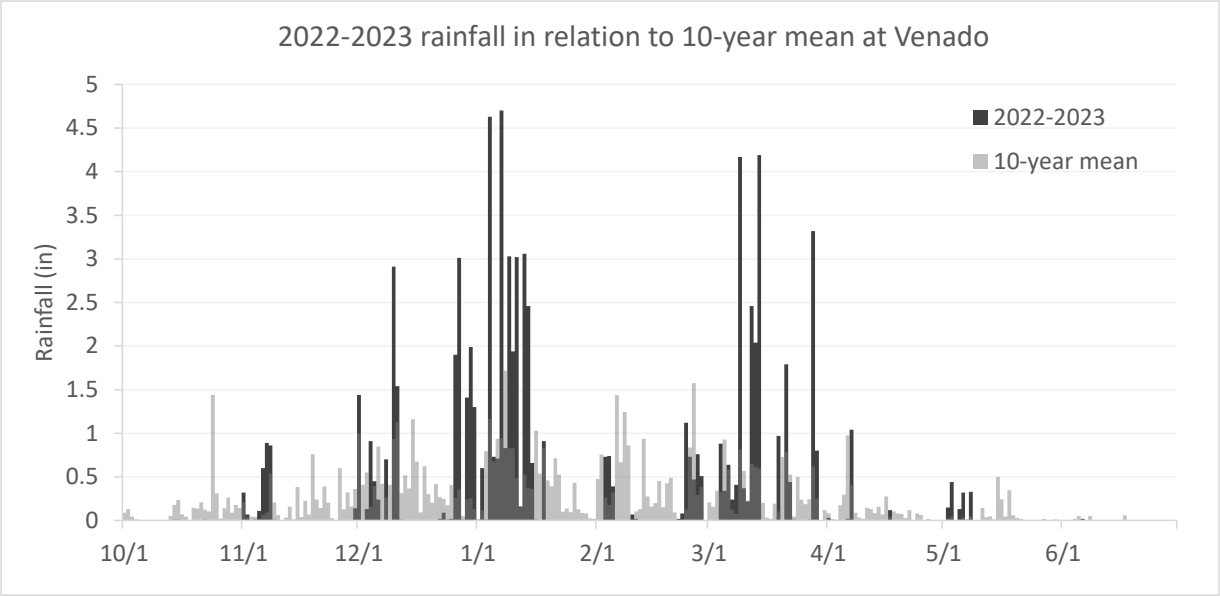

Figure 5. Comparison of daily precipitation at NOAA's Venado gage between 2022-2023 and the 10-year mean.

2.3.2. Trap counts

Counts of coho salmon smolts captured in the four downstream migrant traps operated in 2023 ranged from 371 in Mill Creek to 2,080 in Green Valley Creek, with 1,253 in Dutch Bill Creek and 1,332 in Willow Creek (Figure 6**,** Table 2). When compared to previous years, coho salmon smolt counts were moderate in Willow, Dutch Bill, and Green Valley creeks, and extremely low in Mill Creek. Only five coho salmon yoy were captured in the traps in 2023 (all on Mill Creek).

Downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks target the capture of coho salmon smolts. These tributaries generally do not provide habitat for Chinook salmon and the period of operation does not encompass the entirety of the steelhead smolt migration period. However, in most years we do capture some juvenile steelhead, a few steelhead smolts and in some years we capture a few Chinook salmon smolts (Table 2). In 2023, no Chinook smolts or juvenile steelhead were captured and only one steelhead smolt was captured (Mill Creek).

The three most abundant non-salmonids captured in the traps were sculpin (n = 5,339), three-spined stickleback (n = 2,320), and bluegill (n = 733) (Table 3). Notably, we also captured 406 Sacramento blackfish with the majority captured in Green Valley Creek (387).

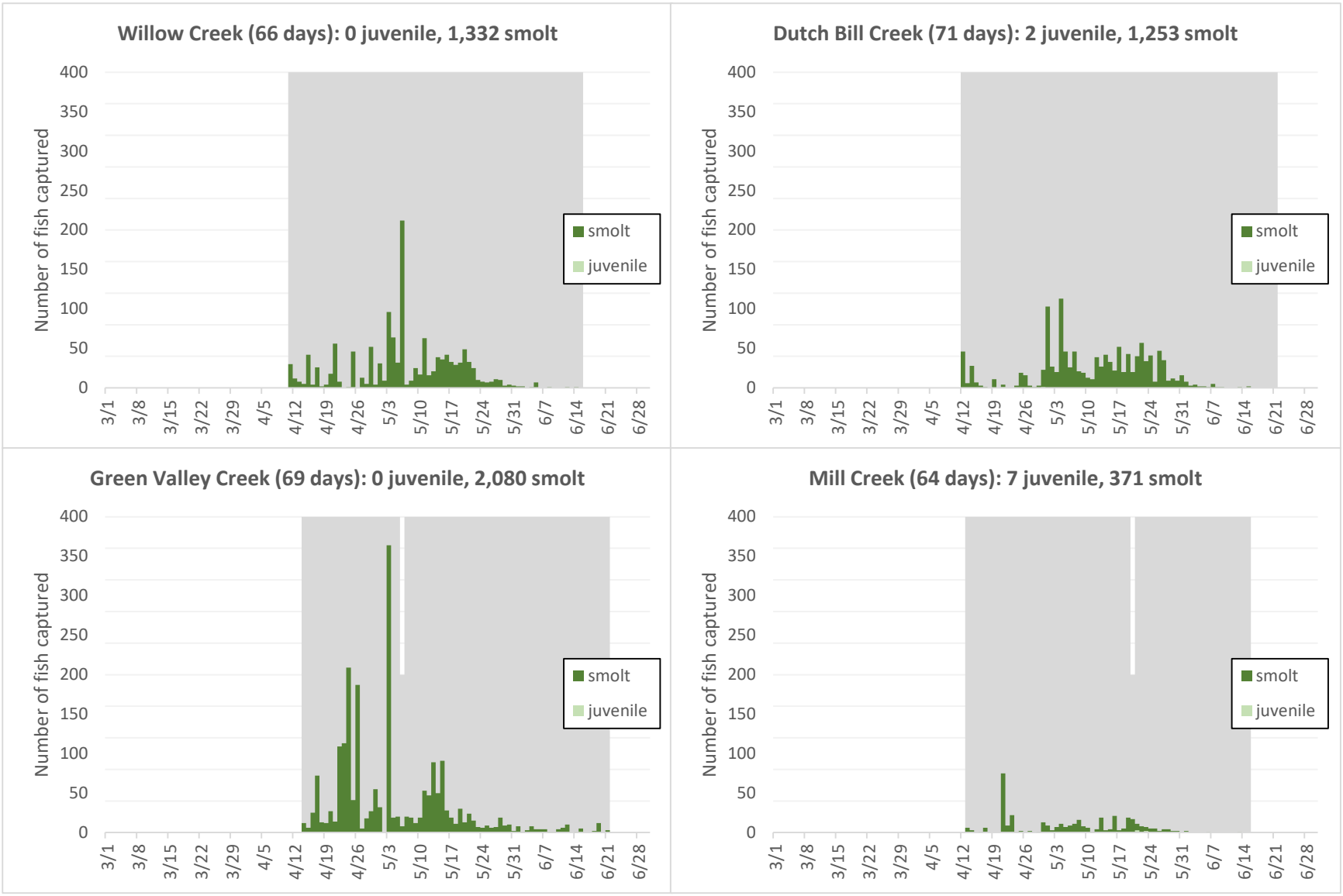

Figure 6. Downstream migrant trap catch of coho salmon juveniles and smolts, 2023. Shaded background indicates that the trap was fishing.

Table 2. Total number of coho salmon, steelhead, and Chinook salmon captured in downstream migrant traps, 2005-2023. "na" indicates that the trap was not operated. Note: these values are minimum counts and not abundance estimates.

Tributary	Species	Life stage	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Willow Creek	coho salmon	juvenile	na	na	na	na	na	na	na	0	0	0	7	0	0	27	2	2	0	2,965	0
		smolt	na	na	na	na	na	na	na	864	3,405	916	707	2,028	1,729	3,486	457	1,165	723	1,174	1,332
	steelhead	juvenile	na	na	na	na	na	na	na	26	142	866	462	603	77	111	238	29	3	1	2
		smolt	na	na	na	na	na	na	na	5	25	11	22	8	5	3	0	1	2	8	1
		adult	na	na	na	na	na	na	na	0	1	0	1	0	0	0	0	1	0	0	0
Dutch Bill Creek	Chinook salmon	smolt	na	na	na	na	na	4	34	13	0	10	0	15	2	8	6	0	0	0	4
	coho salmon	juvenile	na	na	na	na	na	39	5	0	2	0	0	18	2	3	1	4	0	3	2
		smolt	na	na	na	na	na	185	2,908	1,987	823	1,939	201	2,681	3,678	1,276	368	2,192	93	159	1,253
	steelhead	juvenile	na	na	na	na	na	58	31	21	79	1,138	13	74	524	22	138	2,295	159	30	0
		smolt	na	na	na	na	na	5	47	11	18	0	3	8	6	1	5	11	2	7	2
		adult	na	na	na	na	na	0	2	0	0	0	0	0	0	0	2	0	2	0	0
Green Valley Creek	Chinook salmon	smolt	925	na	226	40	0	14	16	na	na	na	0	0	0	0	0	0	0	0	0
	coho salmon	juvenile	0	na	0	0	0	1	1	na	na	na	2	0	2	3	2	0	0	29	0
		smolt	15	na	509	299	608	2,418	231	na	na	na	6,810	3,573	4,880	5,840	4,887	360	897	1,369	2,080
	steelhead	juvenile	1,723	na	36	497	1	67	3	na	na	na	38	356	11	15	46	32	1	575	76
		smolt	49	na	69	29	43	29	1	na	na	na	3	3	12	17	12	0	4	33	3
		adult	1	na	8	1	0	2	0	na	na	na	2	1	0	1	0	0	0	0	0
Mill Creek	Chinook salmon	smolt	70	128	2	31	1	1	0	11	0	18	0	0	1	1	0	0	8	0	0
	coho salmon	juvenile	24	314	58	43	0	4	329	515	530	0	10	10	30	63	8	202	107	224	7
		smolt	636	648	2,408	4,760	14,754	5,060	7,256	4,801	2,019	1,448	5,715	2,428	2,559	1,271	229	1,554	178	1,649	371
	steelhead	juvenile	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941	898	75	1,989	886	86	531	1,504
		smolt	106	43	228	158	118	190	97	41	32	8	17	15	32	22	6	22	31	23	32
		adult	11	5	31	15	2	1	0	1	5	1	2	0	2	0	2	0	2	0	1

Table 3. Annual downstream migrant trap counts for common non-salmonid species, 2013-2023. "na" indicates that the trap was not operated.

Tributary	Origin	Species *	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Willow Creek	non-native	Bluegill	0	0	0	0	0	0	0	2	0	7	0
		Bullfrog	1	0	0	0	0	0	0	1	0	0	0
		Fathead minnow	0	0	0	0	0	0	0	0	0	0	0
		Green sunfish	0	0	2	4	1	0	0	0	0	2	0
	native	California roach	1	1	7	0	1	0	0	0	0	3	0
		California freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0
		Sacramento pikeminnow	219	0	198	8	36	99	0	145	1	318	0
		Sacramento sucker	24	1	46	2	9	4	0	1	0	28	0
		Sculpin sp	4,206	680	2,462	548	2,898	653	1,455	821	144	1,716	2,834
		Threespine stickleback	268	296	193	71	427	157	69	1,098	225	571	555
		Western brook lamprey	0	0	0	0	0	0	0	0	0	0	0
Dutch Bill Creek	non-native	Bluegill	0	2	0	4	22	1	3	9	0	13	7
		Bullfrog	0	0	0	0	0	0	1	0	0	0	0
		Fathead minnow	0	0	2	98	2	0	0	0	0	0	0
		Green sunfish	12	5	20	8	34	3	4	12	0	26	39
	native	California roach	845	3	252	94	30	14	1	5	0	6	4
		California freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0
		Sacramento pikeminnow	516	0	27	50	19	156	23	1,235	0	40	7
		Sacramento sucker	425	4	25	106	290	51	7	784	4	129	144
		Sculpin sp	1,530	136	974	440	371	276	452	384	49	474	1,715
		Three-spined stickleback	679	2	5	46	5	2	307	91	2	221	35
		Western brook lamprey	1	0	1	1	1	18	16	1	0	0	36
Green Valley Creek	non-native	Bluegill	na	na	3	137	472	659	551	148	198	91	711
		Bullfrog	na	na	4	11	171	37	8	7	21	2	44
		Fathead minnow	na	na	96	59	65	32	5	0	2	4	3
		Green sunfish	na	na	25	32	133	209	35	5	1	27	191
	native	California roach	na	na	314	54	51	48	92	82	46	91	51
		California freshwater shrimp	na	na	318	33	26	13	30	10	96	103	59
		Sacramento pikeminnow	na	na	70	7	14	6	33	21	2	174	0
		Sacramento sucker	na	na	64	25	36	24	2	17	0	82	36
		Sculpin sp	na	na	192	62	365	145	368	99	528	447	208
		Three-spined stickleback	na	na	373	167	11,931	2,309	2,191	1,610	2,521	13,105	1,696
		Western brook lamprey	na	na	109	160	148	48	52	16	71	28	168
Mill Creek	non-native	Bluegill	2	29	4	56	71	72	17	2	0	4	15
		Bullfrog	62	41	11	12	74	73	11	0	1	0	10
		Fathead minnow	3	0	14	103	68	128	22	1	19	9	43
		Green sunfish	1	5	6	22	16	12	42	5	0	48	24
	native	California roach	94	20	258	114	453	146	149	42	220	631	325
		California freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0
		Sacramento pikeminnow	7	0	82	9	152	6	40	17	2	93	16
		Sacramento sucker	36	0	68	3	71	6	17	66	24	235	32
		Sculpin sp	19	60	105	675	719	542	359	193	107	241	582
		Three-spined stickleback	1	1	3	2	6	5	1	0	4	2	34
		Western brook lamprey	0	0	0	1	0	0	0	0	3	0	85

** Other species captured but not listed in the table include: , Alligator Lizard, Belted Kingfisher, Black Bullhead, Black Crappie, Black Salamander, Bluegill, Brown Bullhead, Bullfrog, California Freshwater Shrimp, California Giant Salamander, California Newt, California Red-Legged Frog, California Roach, California Slender Salamander, Coast Range Newt, Common Merganser, Fathead Minnow, Foothill Yellow-Legged Frog, Golden Shiner, Green Sunfish, Hardhead, Hitch, Largemouth Bass, Mallard, Mole, Mosquitofish, Mouse, Muskrat, Pacific Brook Lamprey, Pacific Lamprey, Pacific Treefrog, Prickly Sculpin, Red Swamp Crayfish, Red-Bellied Newt, Redear Sunfish, Red-Eared Slider, Riffle Sculpin, Rough Skinned Newt, Russian River Tule Perch, Sacramento Blackfish, Sacramento Pikeminnow, Sacramento Sucker, Shiner Surfperch, Shrew, Signal Crayfish, Smallmouth Bass, Three-Spined Stickleback, Vole, Western Brook Lamprey, Western Fence Lizard, Western Pond Turtle, Western Skink, Western Toad, White Crappie, Yellow-Eyed (Ensatina) Salamander*

2.3.3. Natural production

In 2023, the overall proportion of NOR coho salmon smolts captured in the four LCM watersheds was 53.5%. This was the highest proportion ever recorded since downstream migrant trapping began on Mill and Green Valley creeks in 2005 (Table 4, Figure 7). The contribution of natural-origin fish to the total number of coho salmon captured ranged from nearly 70% in Willow Creek to 23% in Mill Creek.

Table 4. Number and percent of natural-origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2023. "na" indicates that no trap was in operation.

	Willow Creek			Dutch Bill Creek			Green Valley Creek			Mill Creek		
Year	Number NOR	Total captured	Percent NOR	Number NOR	Total captured	Percent NOR	Number NOR	Total captured	Percent NOR	Number NOR	Total captured	Percent NOR
2005	na	na	na	na	na	na	9	15	60.0%	2	635	0.3%
2006	na	na	na	na	na	na	na	na	na	1	648	0.2%
2007	na	na	na	na	na	na	1	509	0.2%	1	2,408	0.0%
2008	na	na	na	na	na	na	0	299	0.0%	1	4,760	0.0%
2009	na	na	na	na	na	na	1	607	0.2%	65	14,730	0.4%
2010	na	na	na	1	185	0.5%	0	2,407	0.0%	9	5,051	0.2%
2011	na	na	na	0	2,904	0.0%	2	231	0.9%	22	7,240	0.3%
2012	0	863	0.0%	35	1,987	1.8%	na	na	na	154	4,781	3.2%
2013	12	3,397	0.4%	106	823	12.9%	na	na	na	3	2,014	0.1%
2014	331	914	36.2%	262	1,930	13.6%	na	na	na	168	1,441	11.7%
2015	20	704	2.8%	8	200	4.0%	827	6,803	12.2%	155	5,712	2.7%
2016	430	2,020	21.3%	85	2,676	3.2%	231	3,570	6.5%	24	2,425	1.0%
2017	43	1,727	2.5%	151	3,667	4.1%	396	4,865	8.1%	159	2,553	6.2%
2018	663	3,484	19.0%	40	1,260	3.2%	529	5,831	9.1%	39	1,270	3.1%
2019	52	453	11.5%	12	364	3.3%	282	4,879	5.8%	3	227	1.3%
2020	117	1,159	10.1%	216	1,707	12.7%	10	359	2.8%	35	1,527	2.3%
2021	91	722	12.6%	34	92	37.0%	46	897	5.1%	172	178	96.6%
2022	54	1,169	4.6%	34	155	21.9%	117	1,365	8.6%	0	1,483	0.0%
2023	923	1,324	69.7%	670	1,240	54.0%	996	2,061	48.3%	85	369	23.0%

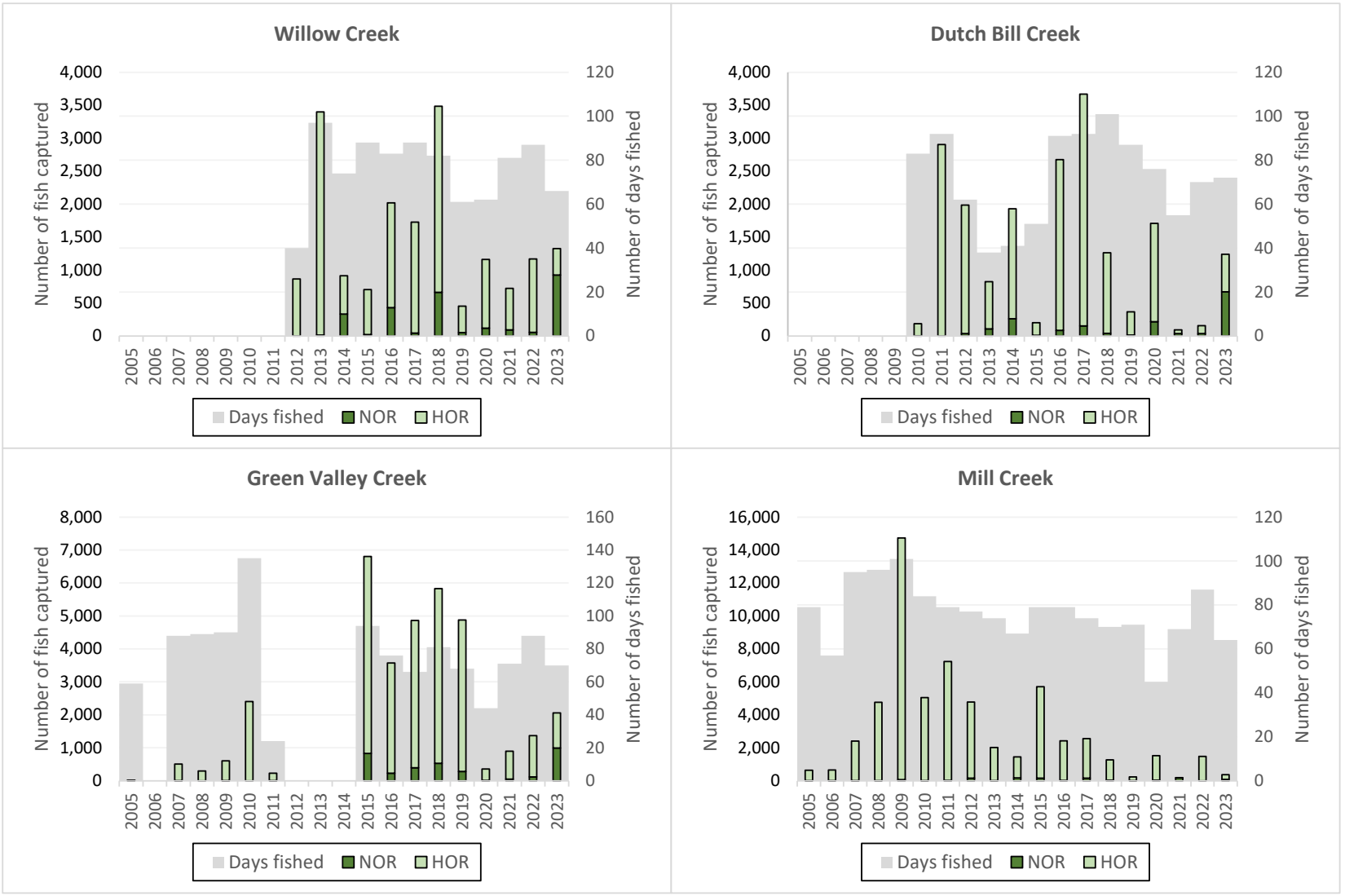

Figure 7. Downstream migrant trap catch of coho salmon smolts and number of days fished in the trapping season, 2005-2023.

2.3.4. Smolt abundance

Smolt abundance estimates indicate that over 9,000 smolts emigrated from Willow, Dutch Bill, and Green Valley creeks combined during the spring of 2023 (Table 5, Figure 8). Smolt abundance was highest in Green Valley Creek and lowest in Mill Creek. Abundance estimates were below average in all four streams in 2023; however, only one smolt release took place upstream of our trap sites in 2023 so interannual comparisons could be misleading.

Table 5. Number of 2022 cohort (hatch year) of juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill Creek watersheds, and estimated number of coho salmon smolts that emigrated from each tributary during spring 2023. Abundance estimates include both marked and unmarked smolts.

	Number released						
Tributary	Spring	Fall	Presmolt	Smolt	Total	Total released upstream of trap	Estimated smolt abundance (±95% CI)
Willow Creek	0	0	3,018	0	3,018	3,018	1,902 (306)
Dutch Bill Creek	0	6,192	0	3,993	10,185	6,192	1,534 (134)
Green Valley Creek	0	0	3,539	24,291	27,830	11,199	4,900 (1,253)
Mill Creek	0	4,678	0	0	4,678	4,678	957 (188)

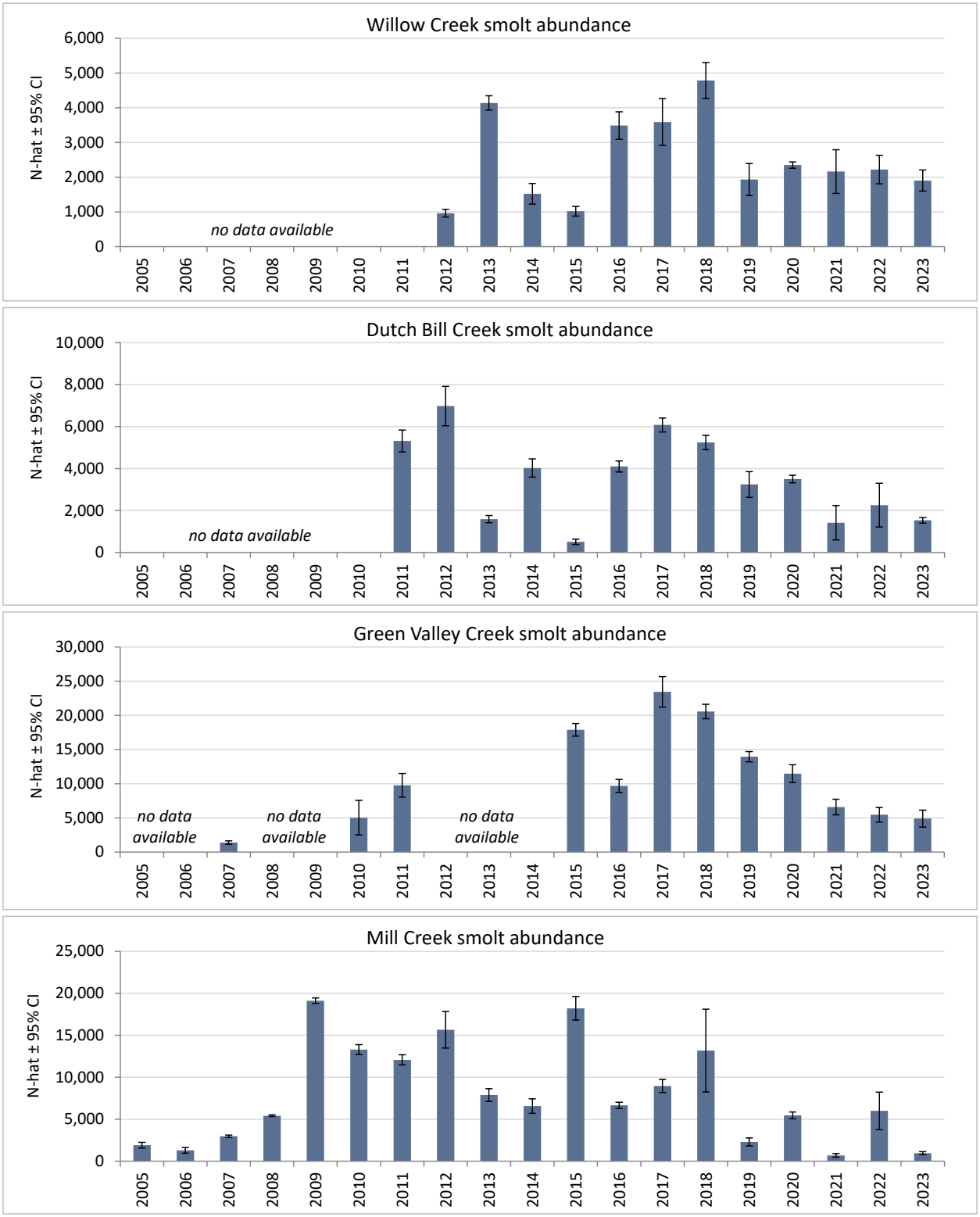

Figure 8. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2023.

2.3.5. Probability of survival and early winter emigration

The estimated probability of survival of fall-release juvenile coho salmon from the time of release in December 2022 through June 30, 2023 was 0.22 on Dutch Bill Creek and 0.17 on Mill Bill Creek (Table 6). When compared to previous years' estimates, survival over the winter of 2022/23 was similar in Dutch Bill Creek and slightly below average in Mill Creek (Figure 9).

The estimated probability of fall release juvenile coho salmon emigrating prior to March 1 was 0.11 on Dutch Bill Creek and 0.05 on Mill Creek during the winter of 2022/23 (Table 6). Compared to previous years, these rates were average for Dutch Bill Creek and lower than average for Mill Creek (Figure 10).

The estimated probability of survival of presmolt release juvenile coho salmon from the time of release in late-January 2023 through June 30, 2023 was 0.55 in Willow Creek and 0.27 in Purrington Creek (Table 6). Estimated survival probability for the one group of smolts released upstream of our PIT antennas in Green Valley Creek on March 31, 2023 was 0.32.

Table 6. Estimated probability of juvenile coho salmon survival and early emigration (prior to 3/1) from the date of release in 2022 through 6/30/23.

Tributary	Release group	Release site	River km	Release date	Survival interval (days)	Probability of survival (95%CI)	Probability of emigration prior to 3/1 (95% CI)
Dutch Bill Creek	fall	upper half of stream	6.10 - 9.62	12/13/2022	199	0.22 (0.20-0.24)	0.11 (0.09-0.12)
Mill Creek	fall	middle reach near Palmer confluence	10.13 - 11.38	12/1/2022	211	0.17 (0.15-0.19)	0.05 (0.04-0.06)
Willow Creek	presmolt	Hunter's camp	5.85 - 6.02	1/27/2023	154	0.55 (0.51 - 0.59)	na
Purrington Creek	presmolt	upper Graton Road crossing	2.25	1/26/2023	155	0.27 (0.23 - 0.31)	na
Green Valley Creek	smolt	Pool below upper Green Valley Road crossing	14.37	3/21/2023	101	0.32 (0.29 - 0.34)	na

Figure 9. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.

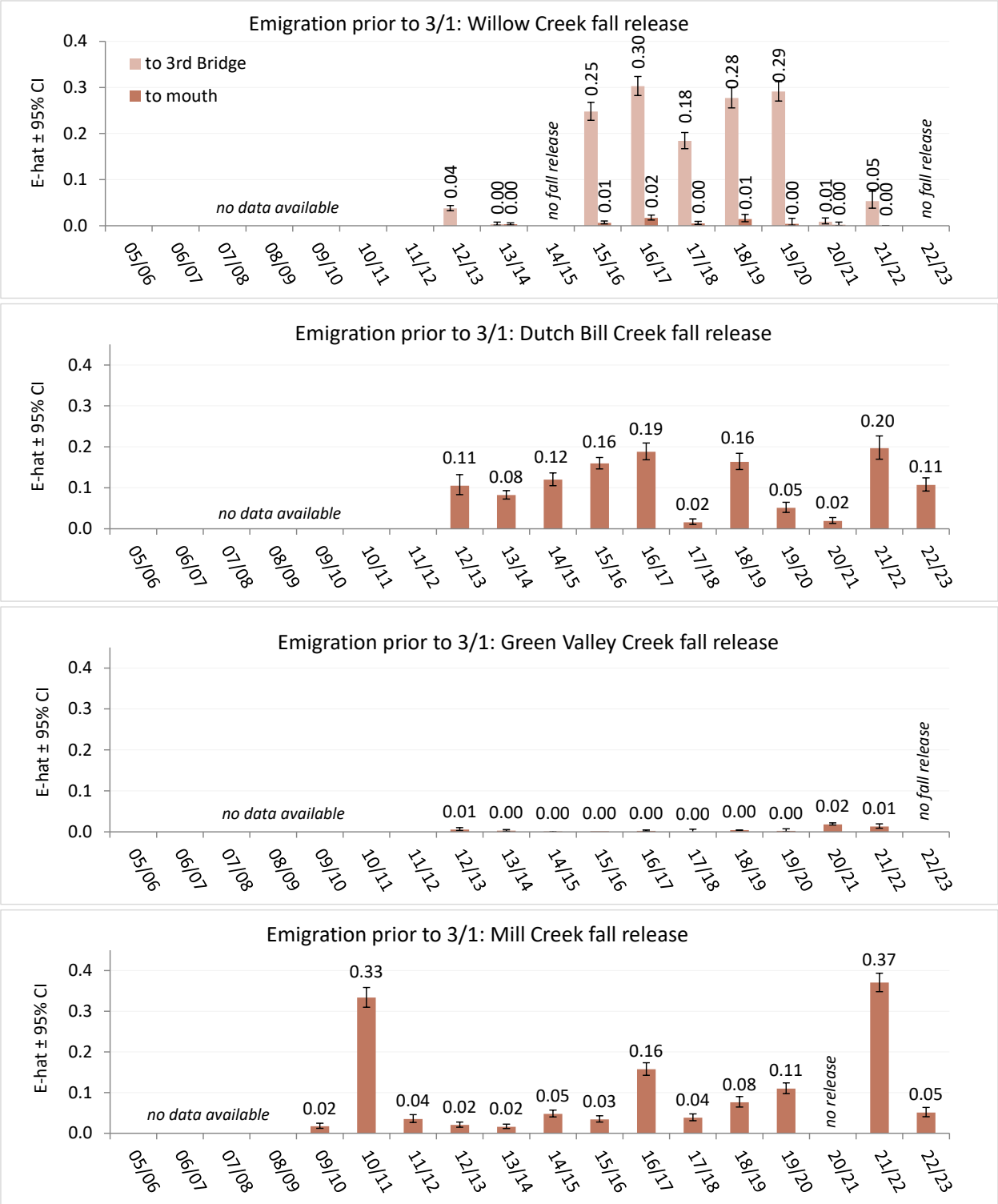

Figure 10. Probability of emigration (E-hat) past antenna sites prior to 3/1 in Willow, Dutch Bill, Green Valley, and Mill creeks.

2.3.6. Migration timing

2.3.6.1. Overview

Weekly totals of out-migrating smolts were plotted by antenna site for the fall, presmolt and smolt release groups within each watershed for the period of October 29, 2022 to June 30, 2023 and compared with stream depth (stage height) data from each creek when available (Figure 11 - Figure 18; note the differences in the y-axes scales across figures). Antennas at multiple locations within each stream (Figure 2) allowed us to document movement patterns from upstream to downstream in each watershed. The distance of each stationary antenna or stage logger from the mouth of the stream is indicated by a site code at the top of each plot (e.g., antenna site WIL-0.41 is located on Willow Creek at river kilometer (river km) 0.41 upstream of the mouth of Willow Creek). Winter movement, for the purposes of this report, is defined as downstream migration past an antenna site during the winter season, prior to March 1.

2.3.6.2. Movement timing

In Dutch Bill and Mill creeks, where fall releases of juvenile coho occurred, we observed winter movement, as well as migration during the typical coho salmon smolt migration period of March 1 through June 30 (Figure 11 - Figure 14). In both streams, we observed a pulse of movement at the antenna arrays immediately downstream of the release locations (DUT-6.51 and MIL-6.10) during the week after stocking, and additional detections occurred throughout the winter in conjunction with flow events. Large pulses of fish on the lower-most PIT antenna arrays (DUT-0.68 and MIL-2.00) during the typical spring smolt emigration period in April and May suggest that many of the fish detected on the upper arrays during the winter months did not leave the streams altogether in the winter. In Mill Creek, a small number of fish were detected on the upper-most PIT antenna array (MIL-12.39), upstream of the release site, between December and May.

Presmolt movement patterns were different in Willow and Purrington creeks (Figure 15, Figure 16). In Willow Creek, a high proportion of fish were detected on the upper antenna array (WIL-3.69) immediately following release in late-January; however, very few fish were detected at the lower Willow Creek site (WIL-0.41) at that time, suggesting that fish that moved downstream early remained in the lower reaches of Willow Creek during the winter before emigrating from the stream altogether in spring. In contrast, the majority of the presmolts released into Purrington Creek moved past all three antenna sites immediately following release with a lower proportion remaining in lower Green Valley Creek until the spring season.

Smolts released into upper Green Valley Creek on March 21, 2023 moved rapidly downstream past the antenna sites at river km 13.40 and 9.98, but the majority of the fish remained in lower Green Valley Creek until mid- to late-April (Figure 18).

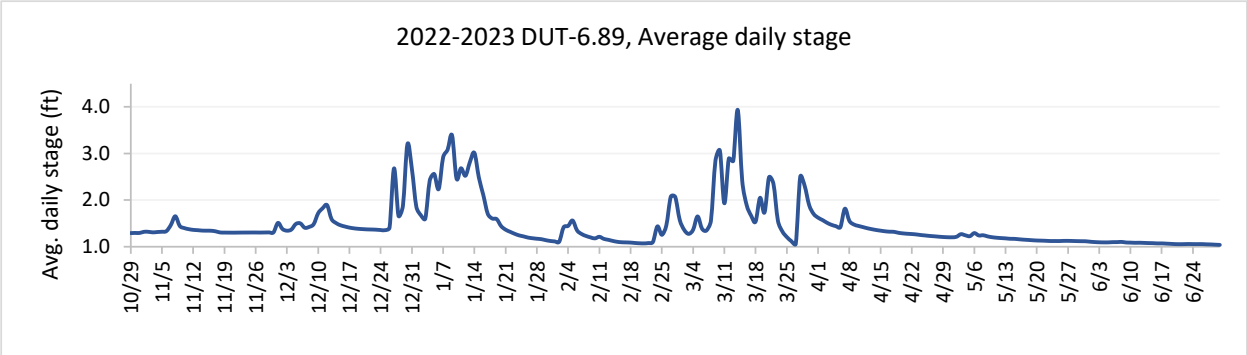

Figure 11. Average daily stage height at Dutch Bill Creek (river km 6.89) between October 29, 2022 and June 30, 2023. Data were provided by Trout Unlimited.

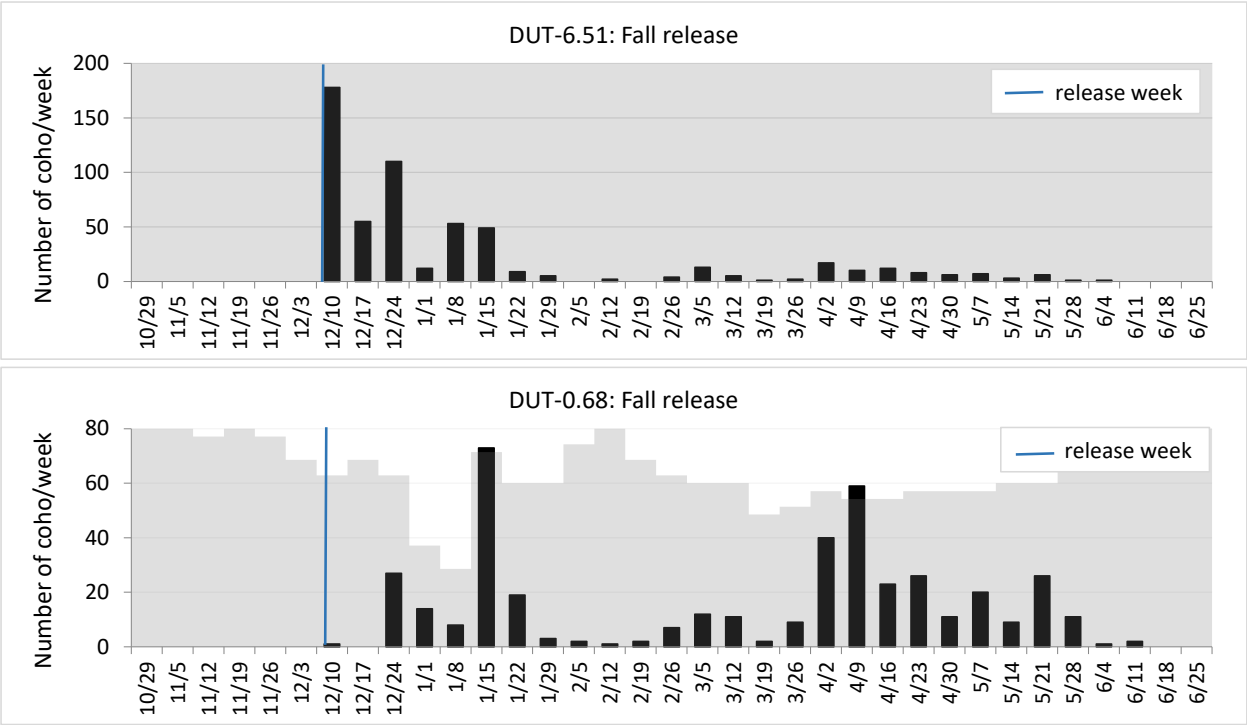

Figure 12. Number of fall release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and lower antenna site (DUT-0.68) each week between October 29, 2022 and June 30, 2023. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Dutch Bill Creek between river km 7.01 and 9.62.

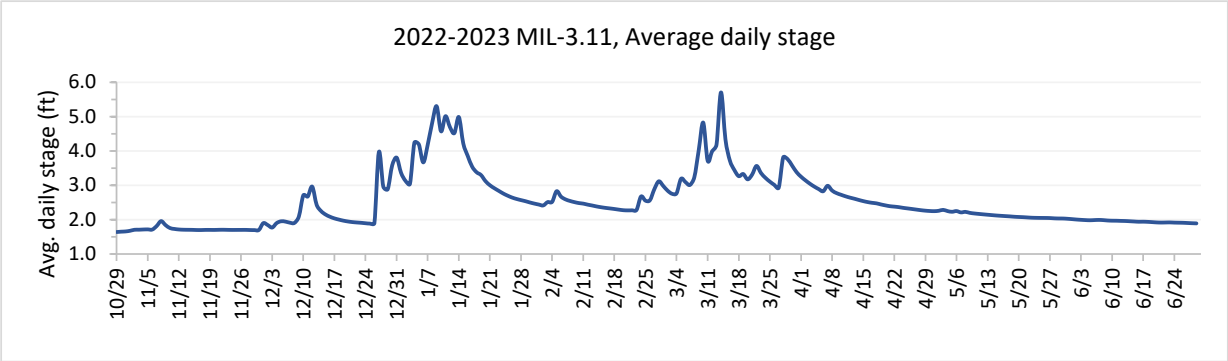

Figure 13. Average daily stage height on Mill Creek (river km 3.11) between October 29, 2022 and June 30, 2023. Data were provided by Trout Unlimited.

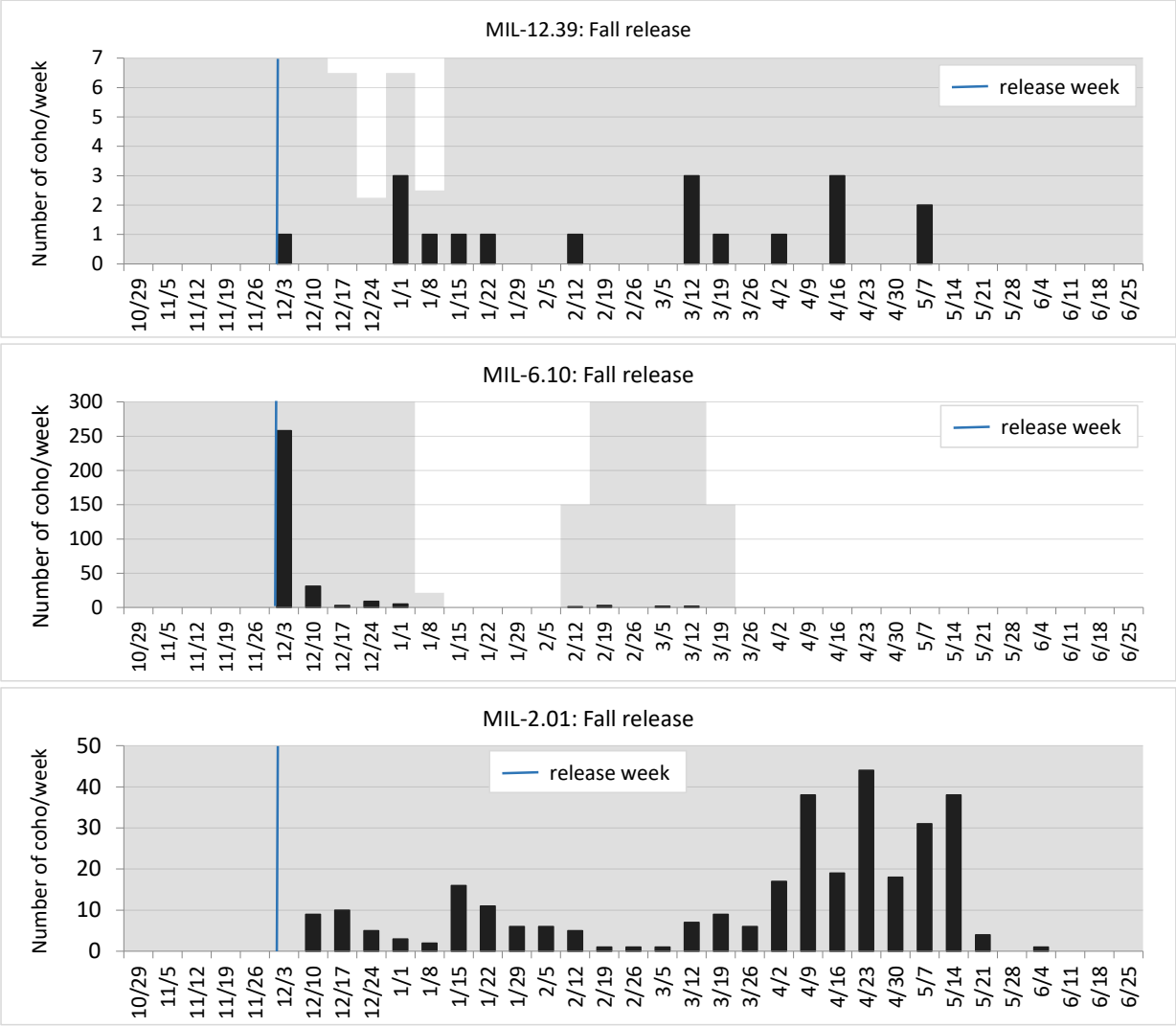

Figure 14. Number of fall release coho salmon detected on the upper (MIL-12.39), middle (MIL-6.10), and lower (MIL-2.01) Mill Creek antenna sites each week between October 29, 2022 and June 30, 2023. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Mill Creek between river km 10.13 and 11.38 (Figure 1).

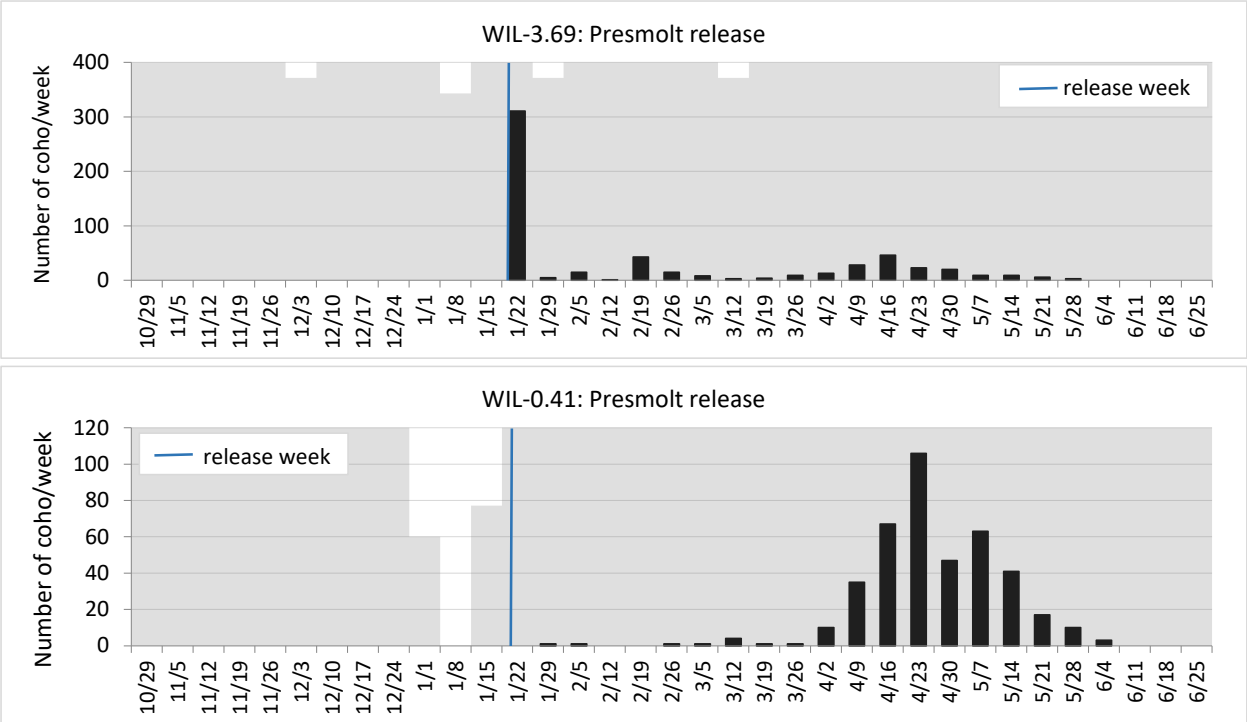

Figure 15. Number of presmolt release coho salmon that moved past the Willow Creek antenna and smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2022 and June 30, 2023. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Willow Creek between river km 5.85 and 6.02.

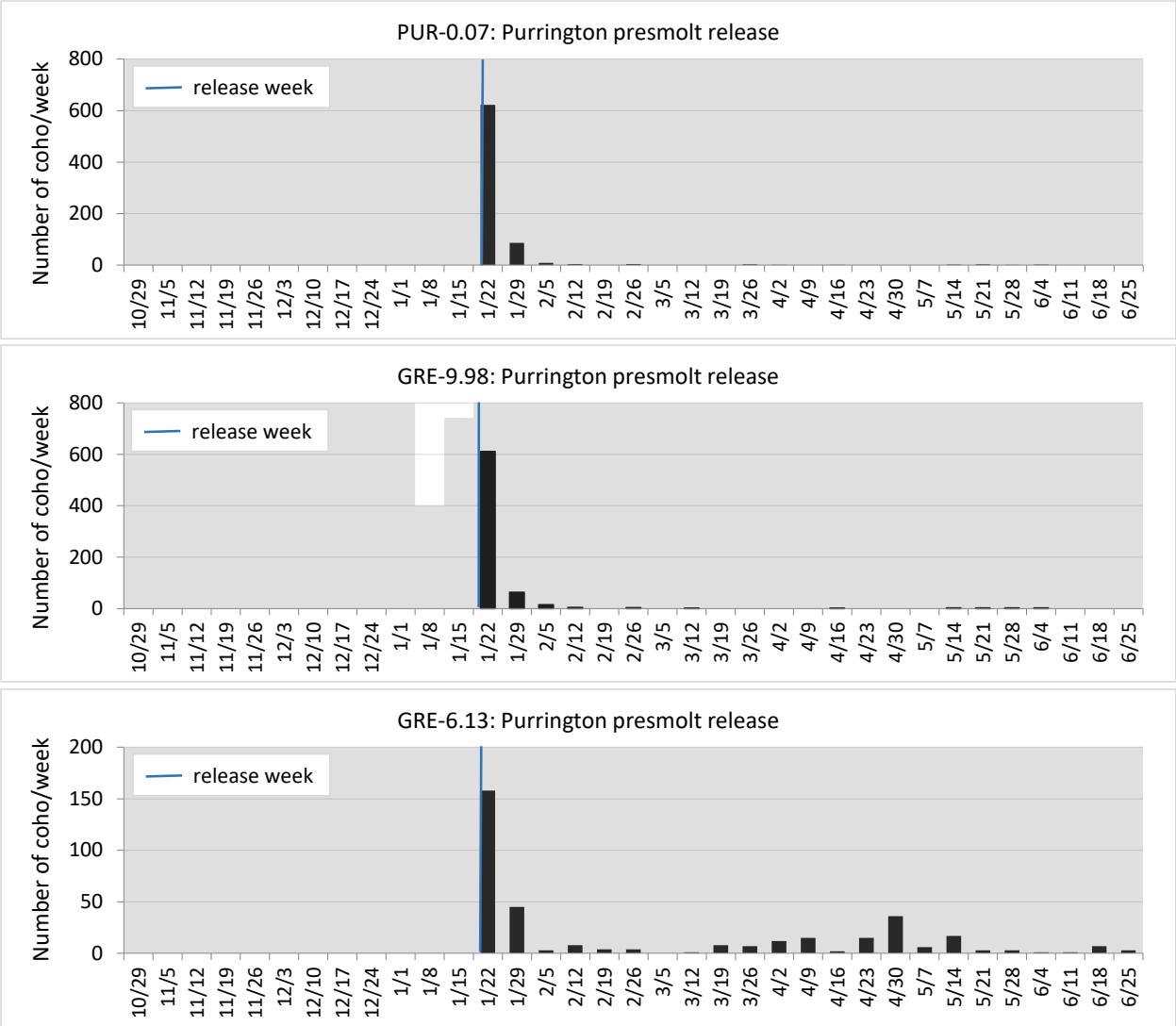

Figure 16. Number of presmolt release coho salmon that moved past the Purrington Creek antenna (PUR-0.07) and two Green Valley antenna sites (GRE-9.98 and GRE-6.13) between October 29, 2022 and June 30, 2023. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Purrington Creek at river km 2.25.

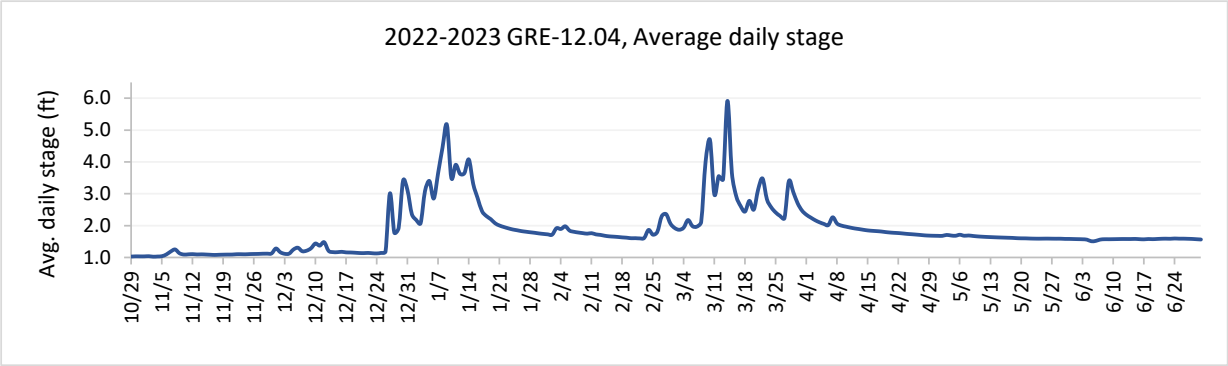

Figure 17. Average daily stage height on Green Valley Creek (river km 12.04) between October 29, 2022 and June 30, 2023. Data were provided by Trout Unlimited.

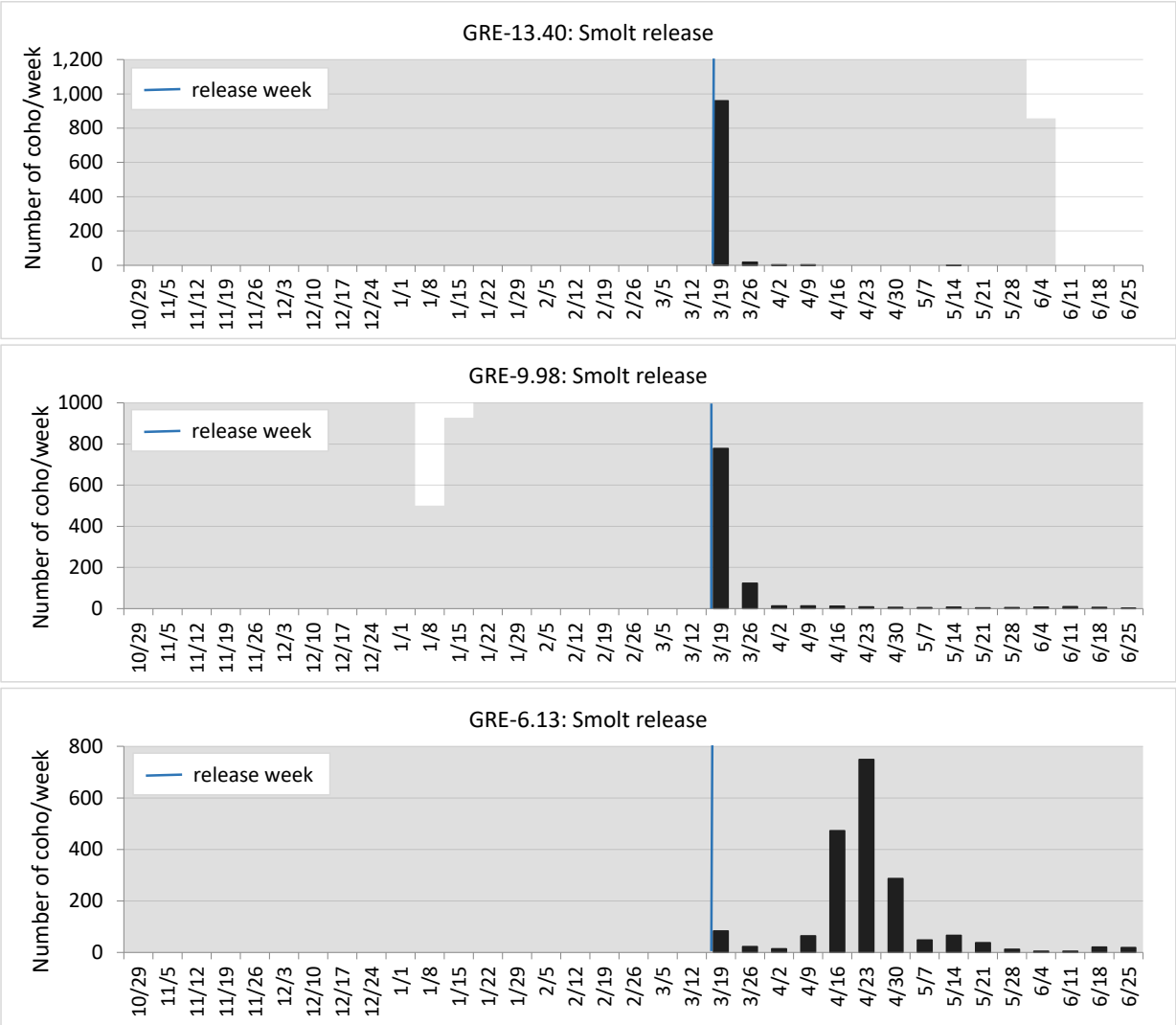

Figure 18. Number of smolt release coho salmon that moved past the upper (GRE-13.40), middle (GRE-9.98), and lower (GRE-6.13) Green Valley Creek antenna sites each week between October 29, 2022 and June 30, 2023. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Green Valley Creek at river km 14.37.

2.3.7. Size

Size of juvenile hatchery coho at the time of tagging was progressively larger the later the fish were released, and within release groups, size was similar among release streams (Table 7). Average size was 93.3 mm and 9.5 g for the fall release groups, 101.9 mm and 12.2 g for the presmolt groups, and 111.7 mm and 14.4 g for the smolt release groups.

Mean lengths and weights of coho smolts captured in the downstream migrant traps ranged from 105.3 mm and 12.8 g in Dutch Bill Creek to 132.5 mm and 24.5 g in Green Valley Creek (Table 8). Overall, smolts were largest in Green Valley Creek, smallest in Willow and Dutch Bill creeks, and intermediate in Mill Creek. In all but Mill Creek, hatchery-origin coho smolts were larger than natural-origin smolts.

Table 7. Mean fork length (mm) and weight (g) of 2022 cohort (hatch year) of PIT-tagged coho salmon at time of tagging in the hatchery.

Tributary	Release group	Mean tag date	Release date	Mean fork length (SD)	Mean weight (SD)	Number of fish
Willow Creek	presmolt	1/10/2023	1/27/2023	101.9 (±8.4)	12.1 (±3.3)	776
Dutch Bill Creek	fall	12/10/2022	12/13/2022	94.4 (±9.1)	10.0 (±3.0)	1,603
Green Valley Creek	smolt	3/2/2023	3/21/2023	111.7 (±12.6)	14.4 (±4.8)	2,072
Purrington Creek	presmolt	1/16/2023	1/26/2023	102.0 (±10.8)	12.3 (±3.9)	783
Mill Creek	fall	11/28/2022	12/1/2022	92.2 (±9.2)	9.1 (±2.7)	1,451

Table 8. Mean fork length (mm) and weight (g) of natural- and hatchery-origin coho salmon smolts captured at downstream migrant traps in Willow, Dutch Bill, Green Valley, and Mill creeks during the 2023 season. Origin was determined based on PIT tag information or the presence of a CWT (hatchery) or lack of a CWT (natural).

LCM watershed	Origin	Mean fork length (SD)	Mean weight (SD)	Number of fish
Willow Creek	hatchery	113.6 (±7.8)	14.6 (±3.0)	389
	natural	105.9 (±9.4)	12.5 (±3.1)	829
	all smolts	108.3 (±9.6)	13.1 (±3.2)	1,218
Dutch Bill Creek	hatchery	114.8 (±8.4)	15.4 (±3.4)	548
	natural	105.3 (±9.6)	12.8 (±3.5)	619
	all smolts	109.8 (±10.3)	14.0 (±3.7)	1,167
Green Valley Creek	hatchery	132.5 (±11.3)	24.5 (±6.9)	870
	natural	126.0 (±12.9)	21.8 (±7.0)	687
	all smolts	129.6 (±12.5)	23.3 (±7.0)	1,557
Mill Creek	hatchery	116.3 (±10.7)	17.1 (±5.0)	269
	natural	117.9 (±16.0)	18.4 (±7.5)	79
	all smolts	116.6 (±12.1)	17.4 (±5.6)	348

2.3.8. Growth

Average growth (mm fork length and g weight gained) and average daily growth rates (mm/day and g/d) from the time of release to capture in the downstream migrant trap varied among streams and release groups (Table 9). Growth and growth rates were lowest for the presmolt release group into Willow Creek, and slightly higher for the Dutch Bill and Mill Creek fall release groups. The Purrington presmolt

release group had the highest growth rates and increased the most in size. The Green Valley smolt release group also had high growth rates, but did not increase as much in size (i.e., fork length growth was lower), likely due to the shorter period of time in the stream environment.

Growth rates in length for fall release fish captured in the downstream migrant traps in 2023 were similar between Dutch Bill and Mill creeks and higher than the average of previous years (Figure 19). The growth rate in Mill Creek was one of the highest documented in 15 years of data collection at the Mill Creek trap.

Table 9. Mean length and weight growth and daily growth rates for cohort 2022 PIT-tagged hatchery coho salmon recaptured in the downstream migrant traps during spring 2023.

Tributary	Release tributary	Release group	Mean days between tagging and recapture	Mean days in hatchery prior to release	Mean fork length growth (mm)	Mean fork length growth rate (mm/d)	Mean weight growth (g)	Mean weight growth rate (g/d)	Number of fish
Willow Creek	Willow Creek	presmolt	115 (±11)	17 (±1)	13.6 (±5.2)	0.12 (±0.05)	3.1 (±2.1)	0.03 (±0.02)	101
Dutch Bill Creek	Dutch Bill Creek	fall	153 (±13)	2(±3)	20.4 (±8.3)	0.13 (±0.05)	5.7 (±3.8)	0.04 (±0.02)	163
Green Valley Creek	Green Valley Creek	smolt	61 (±14)	18 (±3)	21.4 (±7.8)	0.36 (±0.11)	9.8 (±4.1)	0.16 (±0.06)	316
	Purrington Creek	presmolt	112 (±13)	9 (±2)	44.5 (±10.2)	0.40 (±0.11)	22.0 (±8.8)	0.20 (±0.09)	53
Mill Creek	Mill Creek	fall	161 (±12)	2 (±1)	22.1 (±10.5)	0.14 (±0.07)	7.7 (±5.4)	0.05 (±0.04)	58

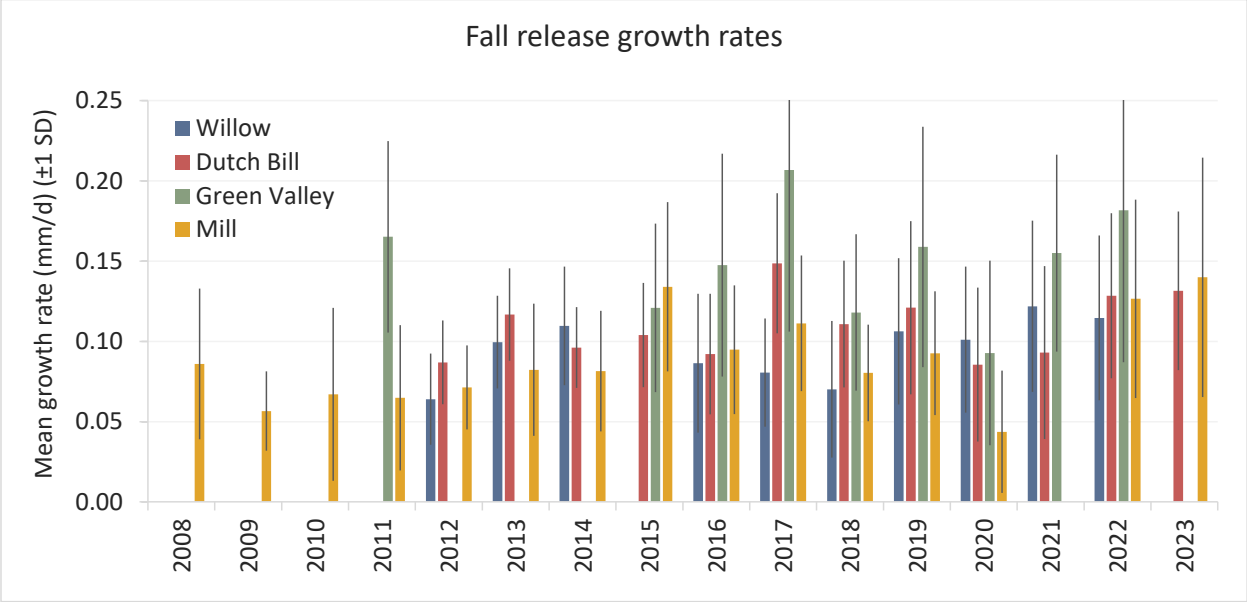

Figure 19. Average daily growth rates in fork length (mm) of fall release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2008-2023.

3. Discussion and Recommendations

Spring rainfall in 2023 was high relative to previous years (Figure 5) and streamflow did not drop to levels at which traps could be safely operated until mid-April, more than one month later than our target installation time of early-March (Figure 4). While not ideal for early spring trapping, the higher flows led to higher surface flow connectivity through the end of June, something that has not occurred often over the last 10 years and was likely beneficial for emigrating smolts. Although we did not operate traps in March and early April, we were able to operate PIT antennas continuously during this time. PIT tag detections on antenna arrays indicate that smolts began emigrating in March and timing was beginning to peak at the time of trap installation (Figure 12, Figure 14, Figure 15, Figure 18) so it is likely that trap catch and abundance estimates would have been higher had we been able to install traps earlier.

A total of 5,036 coho smolts were captured in the four LCM streams combined and smolt abundance was estimated at 9,293 in the four streams combined. Compared to previous years, smolt abundance was generally lower, except in Willow Creek where estimated abundance was average (Figure 8). However, it is important to consider that estimates may have been biased low due to the late trap installation. When comparing across years, it is also important to consider the fact that in earlier years of the Broodstock Program (through 2019), a higher proportion of smolts were released directly into the LCM streams which can greatly increase abundance estimates. In recent drought years, a greater proportion of smolts have been released into the mainstem of the Russian River or in the lower reaches of the tributaries, downstream of our trap sites and therefore unavailable for capture, thus reducing estimates of smolt abundance. In part because of these reasons, the overall number of smolts estimated emigrating from Dutch Bill, Green Valley and Mill creeks has generally declined since 2017. In Willow Creek, smolt abundance estimates have remained similar over the last five years.

The most notable result from monitoring the 2022 cohort is the high number and proportion of NOR coho smolts captured in all four traps relative to previous years (Table 4, Figure 7). In all four streams combined, the percentage of NOR captured was 54%, six times higher than the average of the previous 10 years (9%; 2013-2022) and a significant improvement from the previous decade (1%; 2005-2008) (Figure 20). The relatively larger number of NOR smolts captured in the traps in 2023 tracks the high number of redds observed in the tributaries during the winter of 2021-2022 (California Sea Grant 2022) and a high number of NOR young-of-year observed during snorkeling surveys during summer of 2022 (California Sea Grant 2023). Although we were not able to generate estimates of oversummer and overwinter survival for this cohort, it is likely that the relatively wet conditions in 2022 and 2023 provided a survival advantage for these NOR fish.

Although abundance was generally low in 2023, overwinter survival estimates for the fall release groups stocked in Dutch Bill and Mill creeks were comparable to previous years (Figure 9). Estimates of presmolt survival differed between the two LCM watersheds in which they were released, with an estimate of 0.55 (0.51 – 0.59) for fish released on 1/27/23 into upper Willow Creek and an estimate of 0.27 (0.23 – 0.31) for fish released on 1/26/23 into the upper reaches of Purrington Creek (Table 6).

Migration timing was also different between these two groups (Figure 15, Figure 16). In Willow Creek, a high proportion of the presmolt fish immediately moved downstream past our upper antenna array at river km 3.69 but were not detected at the lower array at river km 0.41 until later in the spring. In contrast, the majority of the presmolt fish released into Purrington Creek immediately moved downstream, leaving Purrington and emigrating past our lower Green Valley antenna array at river km 6.13 with only a small proportion remaining until spring. This was uncharacteristic behavior for fish released into the Green Valley Creek watershed and we are unsure why this occurred. One possible explanation is the manner in which the two groups were released; the Willow Creek fish were stocked throughout a reach into multiple pools, while the Purrington fish were stocked into a single pool. As a precaution, we suggest dispersing fish into multiple pools for future releases of presmolts into Purrington Creek.

We also observed notable differences in growth between the two presmolt release groups, with extremely high growth for Purrington presmolts that remained in the Green Valley watershed and were captured in our downstream migrant trap (Table 9). In contrast, the Willow Creek presmolts had extremely low growth rates, which were even lower than fall release growth rates in Dutch Bill and Mill creeks. We suspect that the high growth rates observed for Purrington Creek presmolts were a result of high growth opportunity in lower Green Valley Creek, where these fish were documented residing (i.e., in the mainstem of Green Valley between river km 9.98 and 6.13). Over the years, body size and growth have been consistently high in Green Valley Creek (Figure 19) so it is not surprising that Purrington Creek presmolts residing in this reach would have extremely high growth. The low growth observed for Willow Creek presmolts may be indicative of low food availability in the upper reaches of Willow Creek (i.e., upstream of river km 3.69). We have observed high quantities of fine sediment in upper Willow Creek with high substrate turnover even in moderate flows. It is possible that this limits production of aquatic invertebrate prey that support rearing salmonids. The lower reaches of Willow Creek between river km 3.69 (just upstream of Third Bridge) and the confluence with the Russian River are thought to have high quality overwinter rearing habitat with refuge from high flows and potentially high food availability. Because our trap was operated upstream of this reach, we were unable to estimate growth of fish that resided in this lower reach. We recommend a companion study to evaluate growth opportunity in the lower reaches of Willow Creek and this could be completed by capturing and measuring smolts near the mouth of the creek or through a combination of invertebrate sampling and bioenergetics modeling. This would help evaluate the value of releasing presmolts into Willow Creek.

Estimated survival of the Green Valley Creek smolt release (March 21) was surprising low at 0.32 (0.29 – 0.34), especially since it was early in the spring. In previous years, smolt release survival in Green Valley Creek has averaged 0.83 (12 years of data collection) and ranged from 0.63 – 0.96. While growth was high for both the Purrington presmolt release group and the Green Valley smolt release group, survival was unusually low. Gold Ridge Resource Conservation District has been coordinating efforts to study and address habitat and water quality impairment that may be negatively impacting fish in lower Green Valley Creek and in the Atascadero watershed (GRRCD and OEI 2021). They have identified that Atascadero Creek has low dissolved oxygen concentrations which may negatively impact fish both in Atascadero and lower Green Valley. Although we cannot be certain, it is possible that low water quality

contributed to the low estimates of survival observed in this watershed. We recommend supporting efforts to improve habitat and water quality in the Green Valley watershed where growth opportunity is higher than in any other stream we have monitored.

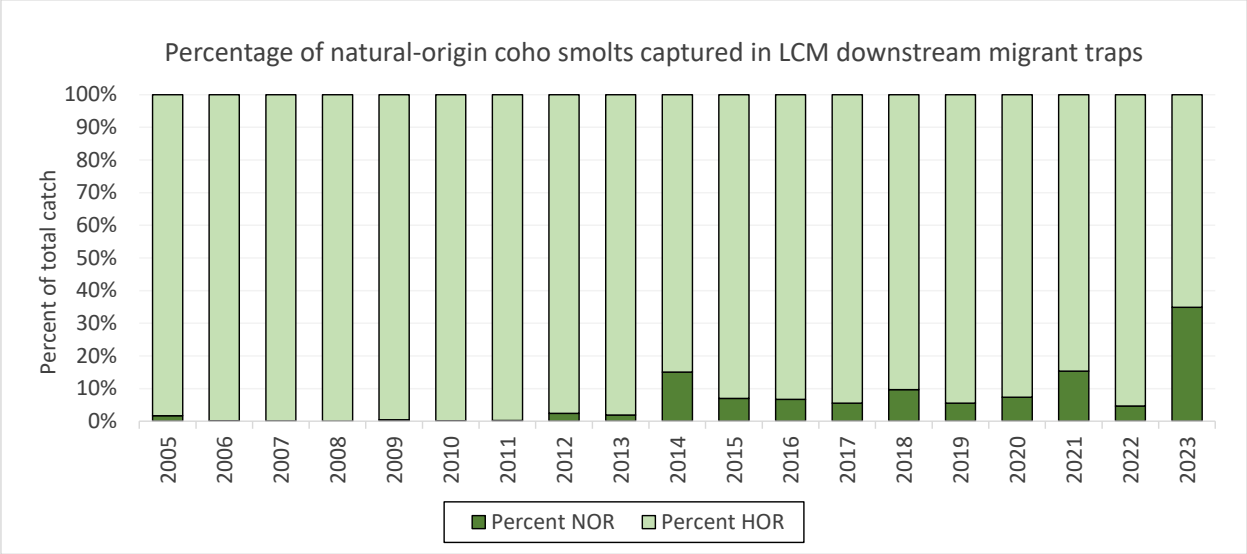

Figure 20. Ratio of natural- to hatchery-origin coho smolts captured in four LCM watersheds each spring, 2005 – 2023. Note that traps were not operated on all four streams every year.

4. References

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