Coho Salmon and Steelhead Monitoring Report

Spring 2022

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Suggested reference: California Sea Grant. 2022. Coho salmon and steelhead monitoring report: Spring 2022. Windsor, CA.

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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*) into tributaries of the Russian River with the goal of re-establishing populations that were on the brink of extirpation from the watershed. The US Army Corps of Engineers (USACE) is the principal federal agency responsible for operating the Broodstock Program at the Don Clausen Fish Hatchery at Warm Springs Dam in Geyserville, CA. 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 intensive monitoring 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 informing future releases.

Over the last decade, CSG has developed many partnerships in salmon and steelhead (*O. mykiss*) recovery, and our program has expanded to include identification of limiting factors to survival, evaluation of habitat enhancement and streamflow improvement projects, and participation in a statewide salmon and steelhead monitoring program. 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 California Coastal Monitoring Program (CMP), a statewide effort to document status and trends of anadromous salmonid populations using standardized methods and a centralized statewide database. These projects have led to the expansion of our program, which now includes over 50 Russian River tributaries.

The intention of our monitoring and research is to provide science-based information to all 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 this seasonal monitoring report, we provide results from spring downstream migrant trapping efforts and operation of 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 2021 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

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 as juveniles in four designated release groups: spring (age-0, Jun-Jul), fall (age-0, Nov-Dec), pre-smolt (age-1, Mar), and smolt (age-1, Apr-May) (Figure 1). Fish from the spring release group were stocked as yoy in June and July 2021, fish from the fall release group were stocked as yoy in November and December 2021, fish from the pre-smolt release group were stocked as age-1 in March 2022, and fish from the smolt release group were stocked as age-1 in April and May 2022. Due to drought conditions, spring releases only occurred in Dry Creek at point locations (Figure 1) where SW acclimated them in net pens for one week. Fall release fish were stocked into individual pools spread throughout multiple stream reaches. For smolt and pre-smolt releases, which occurred in the lower mainstem Russian River only due to drought, fish were released at point locations. Due to low streamflow conditions across the Russian River watershed during the springs of 2021 and 2022, no spring, pre-smolt or smolt releases took place in Broodstock Program watersheds (Table 1).

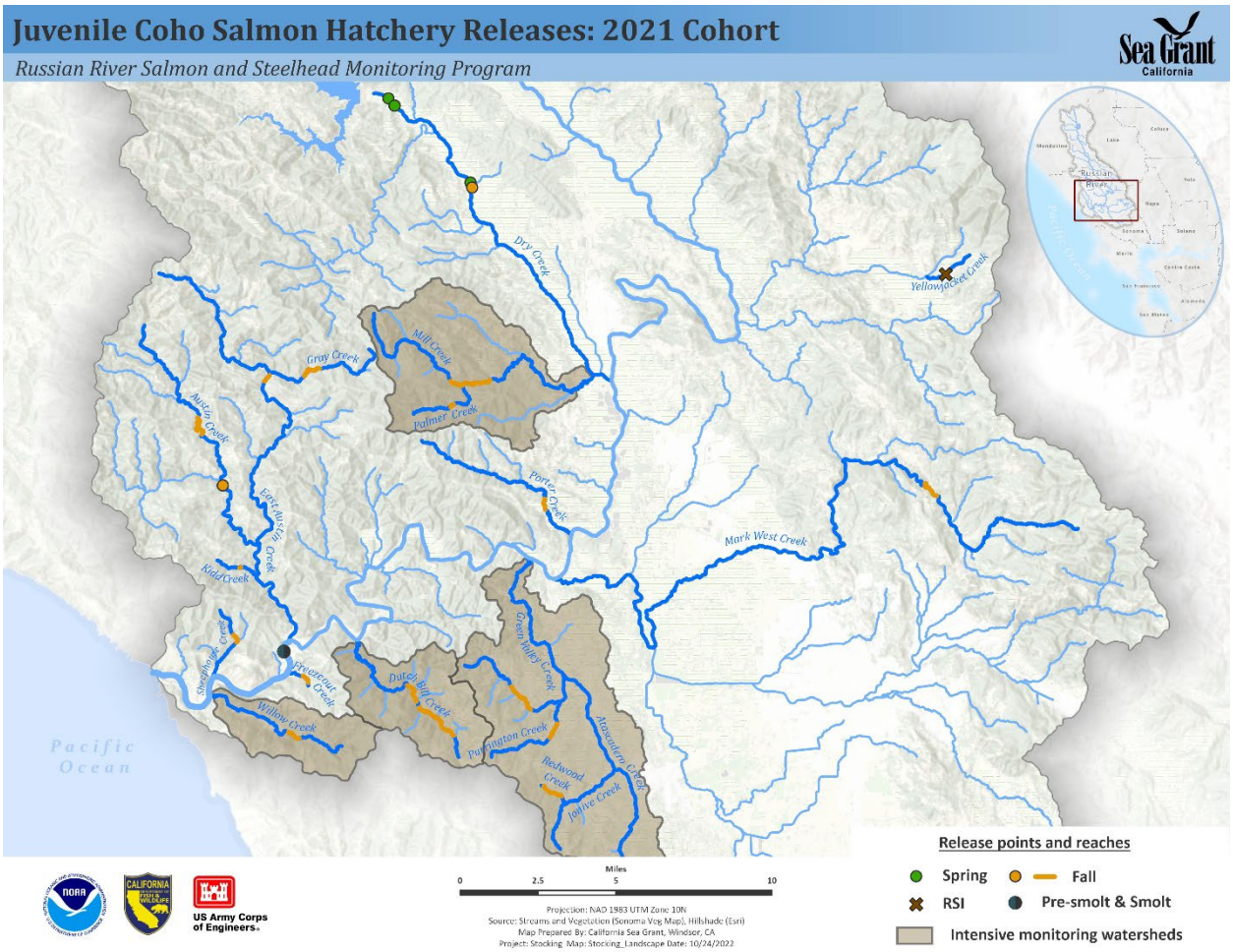


Figure 1. Map of juvenile coho salmon stocking locations for 2021 cohort (hatch year) in the four Broodstock Program intensive monitoring watersheds and additional locations, including the mainstem Russian River and Dry Creek.

2.2.2. PIT tagging

Prior to release, approximately 15% 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.

Table 1. Number of 2021 cohort juvenile coho salmon released into Broodstock Program intensive monitoring watersheds. Note that the total for the Green Valley Creek watershed included releases into Purrington and Redwood (Atascadero) creeks and the total for Mill Creek watershed included releases into Palmer Creek.

			Tributary totals		*Subwatershed totals*	
Subwatershed	**Tributary**	**Release dates**	**Number PIT-tagged**	**Total number released**	**Number PIT-tagged**	**Total number released**
Willow Creek	Willow Creek	11/18/2021	610	4,033	610	4,033
Dutch Bill Creek	Dutch Bill Creek	11/8 - 11/9/21	1,811	11,930	1,811	11,930
Green Valley Creek	Green Valley Creek	12/1/2021	1,722	11,467	2,329	15,508
	Purrington Creek	11/20/2021	302	2,041		
	Redwood Creek (Atascadero)	11/26/2021	305	2,000		
Mill Creek	Mill Creek	11/16/2021	1,827	12,210	2,287	15,260
	Palmer Creek	11/10/2021	460	3,050		

2.2.3. Field methods

2.2.3.1. Stationary PIT antennas

As part of the Broodstock Program monitoring effort, CSG 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 DC conversion systems, solar power, or by swapping batteries every two weeks. Fifteen by two-and-a-half foot antennas, housed in four-inch PVC, were placed flat on top of the streambed and secured with duckbill anchors. Antennas located near the mouths of each creek (as well as the upper Willow Creek site) were placed in paired (upstream and downstream), channel spanning arrays so that detection efficiency could be estimated, and the movement direction of individuals could be determined. Antennas located further up in the watersheds were single, channel-spanning arrays. 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. During significant storm events, stream depths exceeded 24”, such that if PIT-tagged fish were travelling in the water column above that depth, they may not have been detected on the antennas. To account for undetected fish, the paired arrays were used to estimate antenna efficiency. From October 2021 through June 2022, PIT-tag detection systems were visited at two-week intervals to download data and check antenna status, except during the summer season if antenna sites were dry. Surrounding large winter 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 issues if they arose.

2.2.3.2. Downstream migrant trapping

Downstream migrant pipe traps were operated by CSG on Willow, Green Valley, and Mill creeks (Figure 2) between March and June 2022, a window of time that coincides with the majority of the coho salmon smolt outmigration and when streamflow is conducive to trap operation in flashy streams. SW operated a trap on Dutch Bill Creek during this same period, and coho salmon data from their monitoring efforts were provided for this report. 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 0.3 g of tricaine methane-sulphonate (MS-222) per two gallons of water. All fish were counted and scanned for PIT and coded wire tags (CWTs). All PIT-tagged smolts were measured for fork length (mm) and weight (g). Additionally, the first 30 coho salmon smolts with a CWT and first 100 coho salmon smolts 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, CSG biologists waited for fish to recover fully in a separate aerated bucket before releasing them downstream of the trap. Genetics samples were catalogued and prepared for transport to National Marine Fisheries Service Southwest Fisheries Science Center for storage and analysis.

All captured steelhead smolts were scanned for PIT tags and measured for fork length (mm) and weight (g). Steelhead smolts were classified as those > 130mm. On Mill and Dutch Bill creeks, steelhead smolts were also PIT tagged as part of the Coastal Monitoring Program effort. The first 10 steelhead yoy, steelhead parr, and unidentifiable salmonid yoy ≥ 35 mm that were captured in the traps each day were measured for fork length (mm) and weight (g) and released downstream. All other vertebrates and crustaceans captured in the traps were tallied.

Throughout the season, CSG field crews scouted downstream of trap locations on Willow, Green Valley, and Mill creeks to ensure stream connectivity to the confluence and therefore passable conditions for

smolts. During periods when disconnections were observed, crews released captured fish downstream of disconnections to ensure coho salmon and steelhead smolts had the opportunity to continue their migration to the Russian River mainstem.

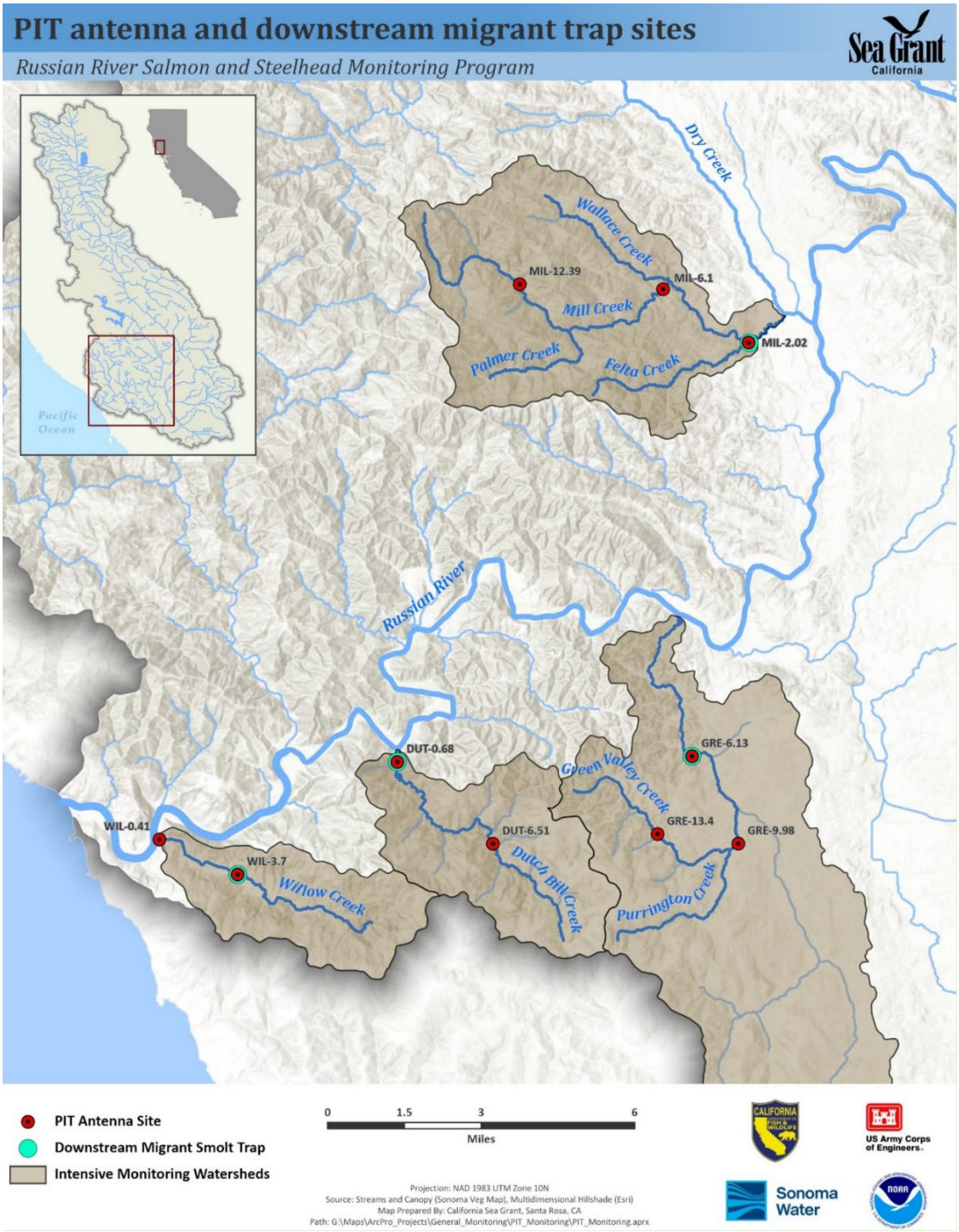


Figure 2. Map showing PIT antenna and smolt trap locations on Broodstock Program intensive monitoring watersheds, with antenna site codes that indicate the river kilometer from the mouth of the stream.

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 fish and any fish without a CWT was recorded as a natural-origin 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 natural- to hatchery-origin smolts for each stream. In Mill Creek, CWT rates were far lower than expected for the group of fish that were PIT tagged at the hatchery (expected rate of 100%). Following consultation with USACE biologists, we suspected this was due to an issue with CWT application at the hatchery and that there was a higher than usual shed tag rate for Mill Creek. We therefore assigned non-PIT-tagged fish in that watershed an "unknown" origin.

2.2.4.2. Smolt abundance

A two-trap mark-recapture model (Bjorkstedt 2005; Bjorkstedt 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 stock-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 6/30/22 and emigration prior to 3/1/22 for fall release groups in the four Broodstock Program intensive monitoring watersheds.

2.2.4.4. Migration timing

The earliest detection date was used to evaluate migration timing for individually PIT-tagged fish at locations of interest. These detections were used to sum the total number of individuals from each

release group (fall only for cohort 2021) passing a given site each week. Total weekly sums were then plotted by week from October 29 (earliest known stream reconnection date) 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 (mm) and weight (g) within a two-week period 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. Coho salmon smolts captured in the downstream migrant traps were measured and data were used to generate average fork lengths and weights of smolts emigrating from each stream. We compared 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 growth rates for individual fish 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. Growth rates for individual fish were then averaged by stream and release group. Note that 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 2022, downstream migrant traps in the four Broodstock Program watersheds were installed between March 9-17, and each trap was operated until the site became disconnected from upstream flow (Figure 3). In response to rain events in mid-April, all traps were temporarily opened. The trap in Green Valley Creek was purposfully opened on May 20 for 24 hours to allow direct passage to smolts that were reluctant to pass through our trap. PIT tag antennas in all four streams ran continously throughout the duration of downstream migrant trapping season, ensuring coverage even during times when traps were temporarily opened. Due to early stream drying, the Dutch Bill Creek trap was removed first on May 30. Traps on Mill, Willow and Green Valley creeks were removed on June 7 (Figure 3).

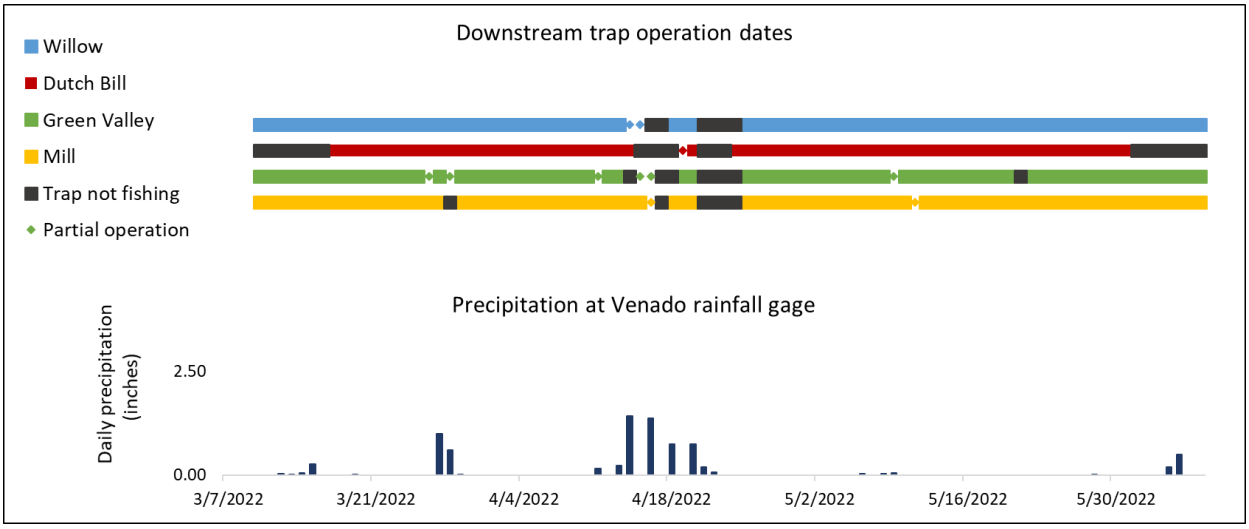


Figure 3. Trap operation dates in relation to precipitation at the Venado rainfall gage in the upper Mill Creek watershed. Daily precipitation data were obtained from the California Data Exchange Center (https://cdec.water.ca.gov/).

2.3.2. Trap counts

Counts of coho salmon smolts captured in the four downstream migrant traps operated in 2022 ranged from 159 in Dutch Bill Creek to 1,649 in Mill Creek, with 1,174 in Willow Creek and 1,369 in Green Valley Creek (Table 2). When compared to previous years, coho salmon smolt counts were moderate in Mill and Willow creeks, low in Green Valley Creek, and extremely low in Dutch Bill Creek (Table 3). The numbers shown in Table 2 and Table 3 are minimum counts and should not be confused with abundance estimates of emigrating coho salmon smolts, which account for differences in trap efficiency and are summarized in the *Smolt abundance* section of this report. A notably high number of coho salmon yoy were captured in the Willow Creek trap as compared to other years and streams (Table 3).

Although downstream migrant traps target the capture of coho salmon smolts and we did not operate them during the entire steelhead and Chinook salmon outmigration seasons, incidental capture of steelhead occurred in 2022. No Chinook salmon were caught in 2022. The number of steelhead smolts captured in the traps in 2022 was low, ranging from zero in Green Valley Creek to 23 in Mill Creek (Table 3). Incidental capture of steelhead yoy also occurred and was likely influenced by proximity of redds to the trap site.

In Willow Creek, the three most abundant non-salmonids were sculpin (n = 1,716), three-spined stickleback (n = 571), and Sacramento pikeminnow (n = 318); in Dutch Bill Creek they were sculpin (n = 474), three-spined stickleback (n = 221), and Sacramento sucker (n = 129); in Green Valley Creek they

were three-spined stickleback (n = 13,105), sculpin (n = 447), and Sacramento pikeminnow (n = 174); and in Mill Creek they were California roach (n = 631), sculpin (n = 241), and Sacramento sucker (n = 235) (Table 4). 103 freshwater shrimp were captured in Green Valley Creek in 2022, which was the highest catch observed since 2015 (Table 4).

Table 2. Coho salmon smolts captured in traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2022 downstream migrant season, by origin.

Stream	Hatchery	Natural	Unknown origin	Total	Percent natural
Willow Creek	1,115	54	5	1,174	4.6
Dutch Bill Creek	121	34	4	159	21.9
Green Valley Creek	1,249	117	3	1,369	8.6
Mill Creek	1,483	0	166[1]	1,649	UNK[1]

[1]. Due an issue with coded wire tag application in the Mill Creek release group, origin of non-tagged fish were considered unknown

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in downstream migrant traps, years 2005-2022. NA indicates no trap was in operation.

Tributary	Species	Life stage	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Willow Creek	Coho salmon	Smolt	NA	NA	NA	NA	NA	NA	NA	864	3,405	916	707	2,028	1,729	3,486	457	1,023	802	1,174
		Yoy	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0	27	2	2	0	2,965
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0	0	0	0	0	0	0
		Parr/yoy	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603	77	111	238	17	3	1
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5	3	0	0	2	8
Dutch Bill Creek	Chinook salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2	8	6	17	0	0
	Coho salmon	Smolt	NA	NA	NA	NA	NA	185	2,908	1,987	823	1,939	201	2,681	3,678	1,276	368	2,546	111	159
		Yoy	NA	NA	NA	NA	NA	0	5	0	2	0	0	18	2	3	1	4	1	3
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0	0	2	0	2	0
		Parr/yoy	NA	NA	NA	NA	NA	58	31	21	79	1,138	13	74	524	22	140	2,304	159	30
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6	1	5	11	4	7
Green Valley Creek	Chinook salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	0	0	0	0	0	0	0	0
	Coho salmon	Smolt	16	NA	625	309	608	348	231	NA	NA	NA	6,810	3,573	4,880	5,840	4,887	361	1,033	1,369
		Yoy	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2	3	2	0	0	29
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1	1	0	0	0	0
		Parr/yoy	1,723	NA	36	497	1	5	3	NA	NA	NA	38	356	11	15	46	32	1	575
		Smolt	49	NA	70	29	43	0	1	NA	NA	NA	3	3	12	17	12	0	5	0
Mill Creek	Chinook salmon	Smolt	70	128	2	31	1	1	0	11	0	22	0	0	1	1	0	0	8	0
	Coho salmon	Smolt	800	892	2,963	5,425	14,756	5,061	7,256	4,801	2,019	1,448	5,715	2,428	2,559	1,271	230	1,554	201	1,649
		Yoy	24	314	58	43	0	4	329	515	530	0	10	10	30	63	8	202	107	224
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	2	0	2	0	2	0	2	0
		Parr/yoy	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941	898	75	1,989	887	86	531
		Smolt	116	49	266	176	118	190	97	41	32	13	17	15	32	22	6	22	32	23

Table 4. Annual downstream migrant trap counts for common non-salmonid species over the past decade, years 2013-2022. NA indicates that no trap was in operation.

Origin	Species [1]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
WILLOW CREEK											
Non-native	Bluegill	0	0	0	0	0	0	0	1	0	7
	Bullfrog	1	0	0	0	0	0	0	1	0	0
	Fathead minnow	0	0	0	0	0	0	0	0	0	0
	Green sunfish	0	0	0	0	1	0	0	0	0	0
Native	California roach	1	1	7	0	1	0	0	0	0	3
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	219	0	198	8	36	99	0	137	1	318
	Sacramento sucker	24	1	46	2	9	4	0	1	0	28
	Sculpin sp.	4,206	680	2,462	548	2,898	653	1,455	335	144	1,716
	Three-spined stickleback	268	296	193	71	496	157	69	402	225	571
	Western brook lamprey	0	0	0	0	0	0	0	0	0	0
DUTCH BILL CREEK											
Non-native	Bluegill	0	2	0	4	19	1	3	9	0	13
	Bullfrog	0	0	0	0	0	0	1	0	0	0
	Fathead minnow	0	0	2	98	2	0	0	0	0	0
	Green sunfish	0	5	20	8	21	3	4	12	0	26
Native	California roach	725	3	252	94	28	14	1	5	0	6
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	412	0	27	50	18	156	23	1,235	0	40
	Sacramento sucker	307	4	25	106	265	51	7	784	4	129
	Sculpin sp.	1,204	136	974	440	323	276	452	384	49	474
	Three-spined stickleback	517	2	5	46	4	2	307	91	2	221
	Western brook lamprey	0	0	1	1	1	18	16	1	0	0
GREEN VALLEY CREEK											
Non-native	Bluegill	NA	NA	3	137	472	659	551	148	198	91
	Bullfrog	NA	NA	4	11	171	37	8	7	21	2
	Fathead minnow	NA	NA	96	59	65	32	5	0	2	4
	Green sunfish	NA	NA	25	32	133	209	35	5	1	27
Native	California roach	NA	NA	314	54	51	48	92	82	46	91
	Freshwater shrimp	NA	NA	318	33	26	13	30	10	96	103
	Sacramento pikeminnow	NA	NA	70	7	14	6	33	21	2	174
	Sacramento sucker	NA	NA	64	25	36	24	2	17	0	82
	Sculpin sp.	NA	NA	192	62	365	145	368	99	528	447
	Three-spined stickleback	NA	NA	373	167	11,931	2,309	2,191	1,610	2,521	13,105
	Western brook lamprey	NA	NA	109	160	148	48	52	16	71	28
MILL CREEK											
Non-native	Bluegill	3	29	4	56	71	72	17	2	0	4
	Bullfrog	65	41	11	12	74	73	11	0	1	0
	Fathead minnow	4	0	14	103	68	128	22	1	19	9
	Green sunfish	3	5	6	22	16	12	42	5	0	48
Native	California roach	363	20	258	114	453	146	149	0	220	631
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	7	0	82	9	152	6	40	17	2	0
	Sacramento sucker	36	0	68	3	71	6	17	66	24	235
	Sculpin sp.	966	60	105	675	719	542	359	193	107	241
	Three-spined stickleback	1	1	3	2	6	5	1	0	4	2
	Western brook lamprey	0	0	0	1	0	0	0	0	3	0

[1] *Other species captured but not listed in the table include: alligator lizard, black bullhead, black crappie, California giant salamander, California slender salamander, common merganser, foothill yellow-legged frog, golden shiner, hardhead, hitch, largemouth bass, mallard duck, mole, mosquitofish, mouse, muskrat, Oregon ensatina, Pacific lamprey, Pacific treefrog, red-bellied newt, red-eared slider, red swamp crayfish, rough skinned newt, Sacramento blackfish, shiner surfperch, shrew, signal crayfish, smallmouth bass, snake, speckled black salamander, tule perch, vole, western fence lizard, western pond turtle, western skink, western toad, white crappie, wood duck, and yellow-eyed ensatina.*

2.3.3. Natural production

Natural-origin coho salmon smolts were captured in traps in all three Broodstock Program intensive monitoring watersheds where origin could be determined in 2022 (Table 5). The contribution of natural-origin fish to the total number of coho salmon captured ranged from 4.6% in Willow Creek to 21.9% in Dutch Bill Creek and was unknown for Mill Creek. The number of natural-origin smolts in the four watersheds was low, ranging from 34 in Dutch Bill Creek to 117 in Green Valley Creek (Table 5). Due to an issue with CWT application at the hatchery for the Mill Creek release group, the CWT shed rate was much higher than typically observed so we were unable to distinguish wild-origin smolts from hatchery-origin smolts that had shed CWTs.

Table 5. Number and percent of natural-origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2022. NA indicates that no trap was in operation.

	Willow Creek			Dutch Bill Creek			Green Valley Creek			Mill Creek		
Year	Number natural origin	Total captured (known origin)	Percent natural origin	Number natural origin	Total captured (known origin)	Percent natural origin	Number natural origin	Total captured (known origin)	Percent natural origin	Number natural origin	Total captured (known origin)	Percent natural origin
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	245	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	1,440	11.7
2015	20	700	2.9	8	200	4.0	827	6,764	12.2	155	5,673	2.7
2016	430	2,020	21.3	85	2,666	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	4,877	5.8	3	227	1.3
2020	92	1,018	9.0	216	1,707	12.7	10	359	2.8	35	1,527	2.3
2021	91	710	12.8	41	69	59.4	46	986	4.7	195	201	96.9
2022	54	1,169	4.6	34	155	21.9	117	1,366	8.6	UNK[1]	1,648	UNK[1]

1. Due to technical issues coded wire tags in the Mill Creek release group were shed at a high rate so origin of non tagged fish was considered unknown

2.3.4. Smolt abundance

Smolt abundance estimates indicate that nearly 16,000 smolts emigrated from Willow, Dutch Bill, and Green Valley creeks combined during the spring of 2022 (Table 6, Figure 4). Smolt abundance was highest in Mill Creek and lowest in Willow Creek. Abundance estimates were below average compared to the past five years in all four streams in 2022; however, no smolt releases took place in 2022 so interannual comparisons could be misleading (Figure 4).

Table 6. Number of cohort 2021 juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creeks, and estimated number of coho salmon smolts that emigrated from each tributary during spring 2022. Abundance estimates include both marked and unmarked smolts.

	Number released						
Tributary	Spring	Fall	Pre-smolt	Smolt	Total	Total released upstream of trap	Estimated smolt abundance (95% CI)
Willow Creek	0	4,033	0	0	4,033	4,033	2,219 (412)
Dutch Bill Creek	0	11,930	0	0	11,930	11,930	2,257 (1,039)
Green Valley Creek	0	15,508	0	0	15,508	15,508	5,457 (1,072)
Mill Creek	0	15,260	0	0	15,260	15,260	5,996 (2,238)

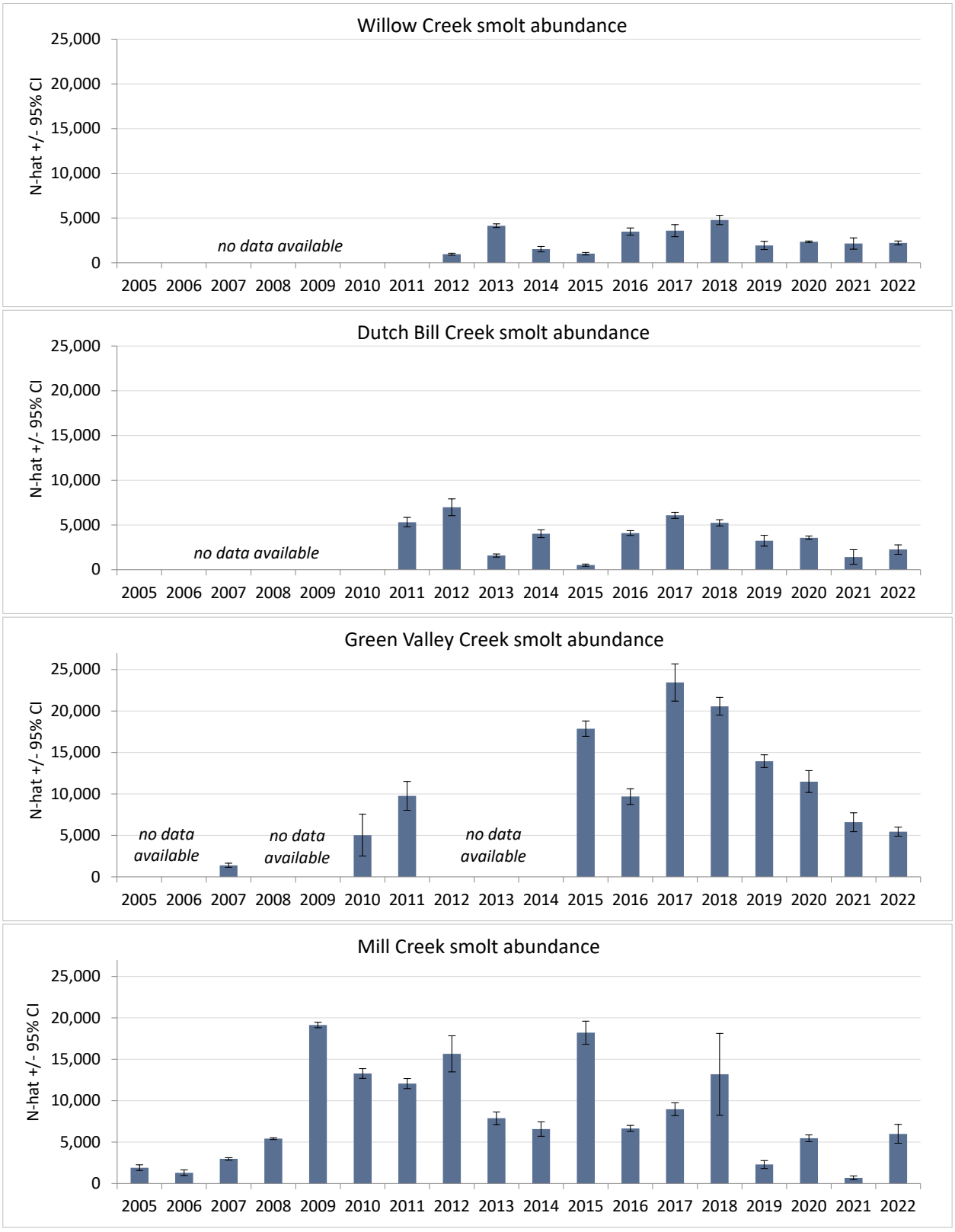


Figure 4. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2022.

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 November or December 2021 through June 30, 2022 ranged from 0.13 on Green Valley Creek to 0.30 on Mill Bill Creek (Table 7). When compared to previous years' estimates, survival over the winter of 2021/22 was generally lower than in most previous years of monitoring except in Mill Creek (Figure 5).

The estimated probability of fall release juvenile coho salmon emigrating prior to March 1 was variable during the winter of 2021/22 and depended on stream (Table 7). In Dutch Bill and Mill Creeks, we observed higher early emigration than in any previous year, whereas in Green Valley and Willow creeks, early emigration was near zero or zero, respectively (Figure 6).

In Willow Creek, where paired antennas were operated year-round at the trap site (upstream of 3rd Bridge) and at the mouth (Figure 2), we had the ability to estimate early emigration from the release reach (upstream of Third Bridge) to both the trap site and to the mouth. The probability of early winter emigration past the antennas at the trap site was lower than most years (0.05) in 2021/22 suggesting that fewer fish overwintered in the lower gradient reach between the two antenna sites as compared to the winters of 2015/16 through 2019/20 (Figure 6).

Table 7. Estimated probability of juvenile coho salmon survival and early emigration (prior to 3/1) from the date of release in 2021 through 6/30/22 for the fall release group.

Tributary	Release date	Interval (days)	Probability of survival (95%CI)	Probability of emigration prior to 3/1 (95% CI)
Willow Creek	11/18/2021	224	0.15 (0.12-0.18)	0.00 (0.00-0.00) [1]
Dutch Bill Creek	11/8/2021	234	0.19 (0.17-0.21)	0.20 (0.17-0.23)
Green Valley Creek	12/1/2021	211	0.13 (0.11-0.15)	0.01 (0.01-0.02)
Mill Creek	11/16/2021	226	0.30 (0.27 - 0.32)	0.37 (0.35 - 0.39)

[1] *For comparison with other streams, probabilities to the mouth of Willow Creek were included in the table; probability of survival of fish that overwintered only upstream of 3rd Bridge was 0.26 (0.22-0.30), and emigration downstream of 3rd bridge prior to 3/1 was 0.05 (0.04-0.07).*

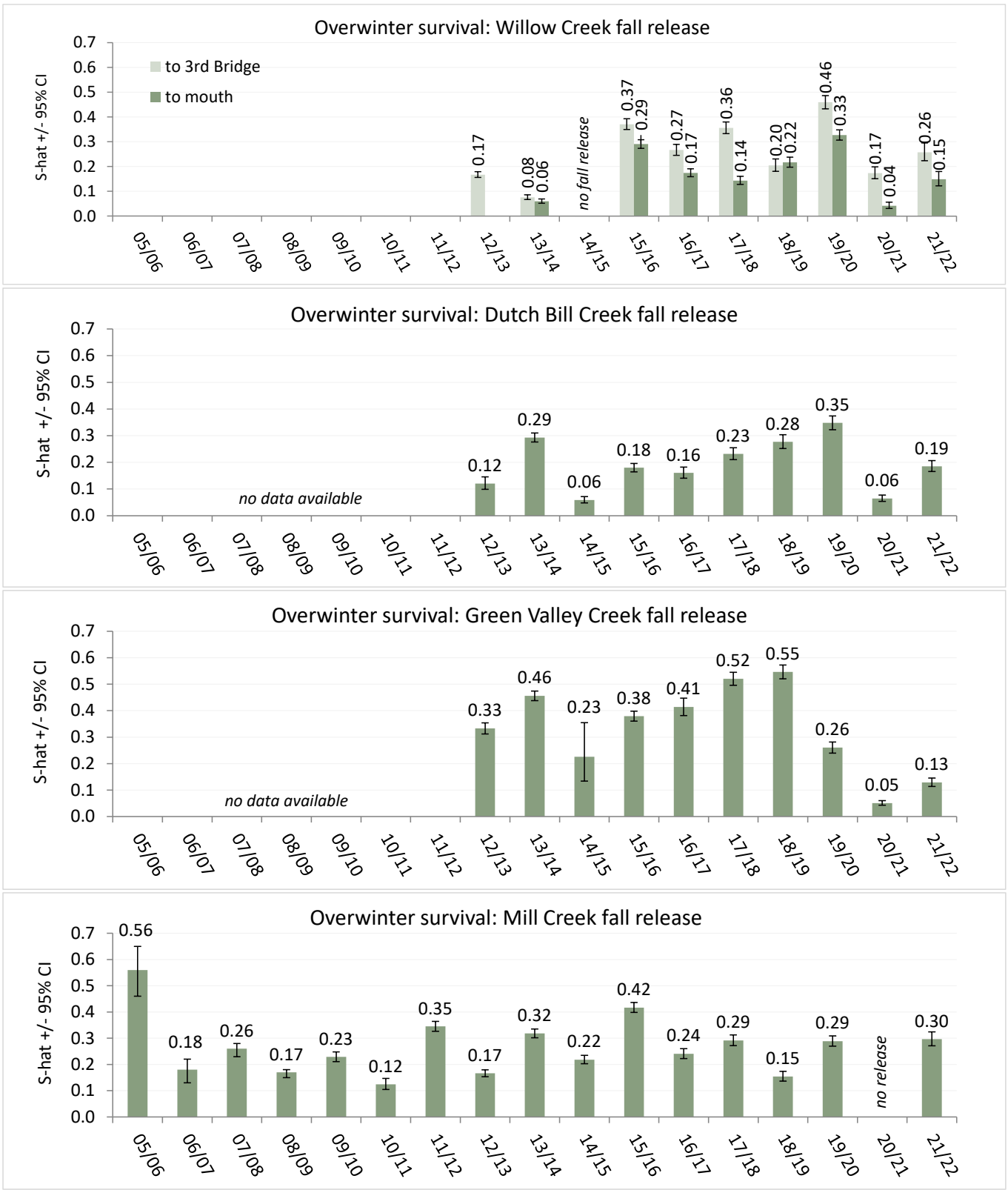
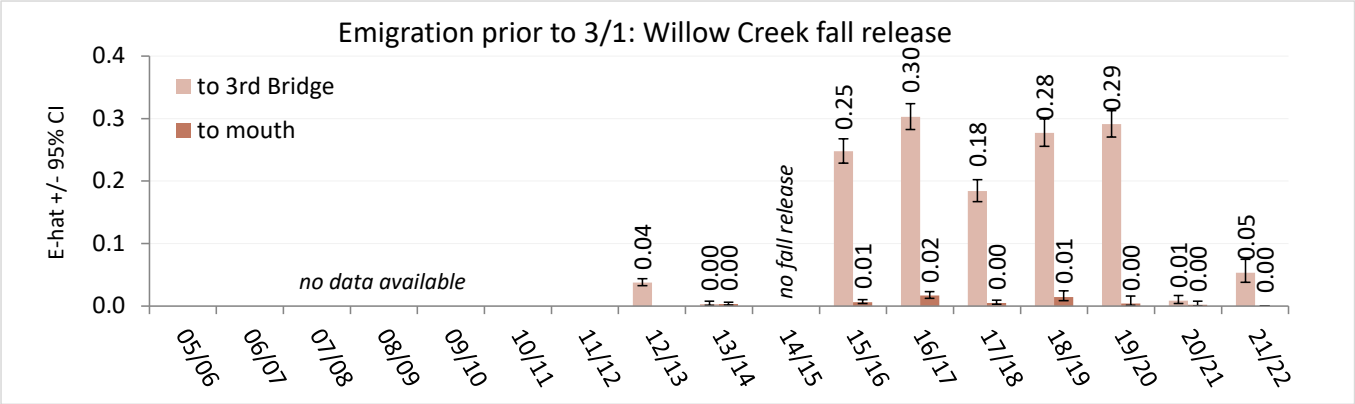
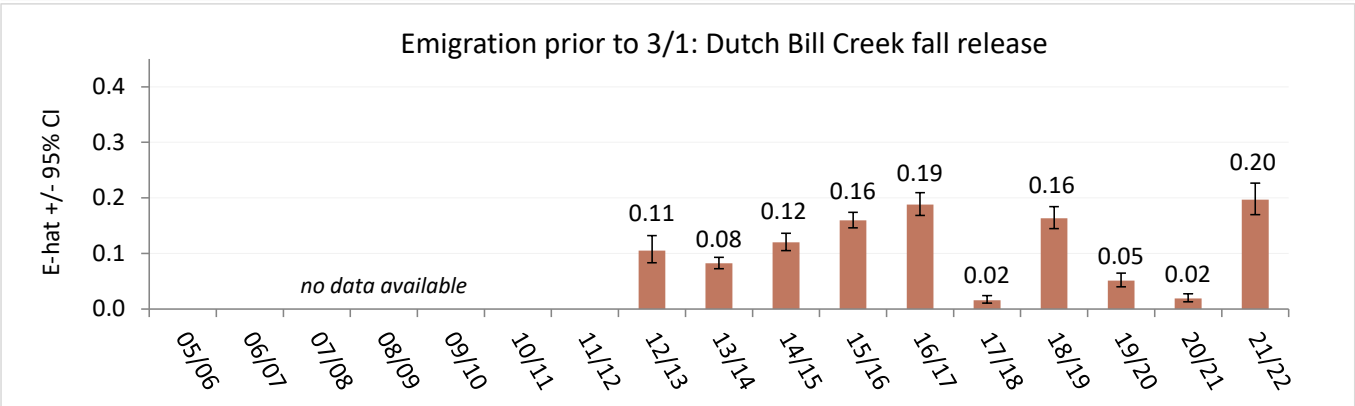
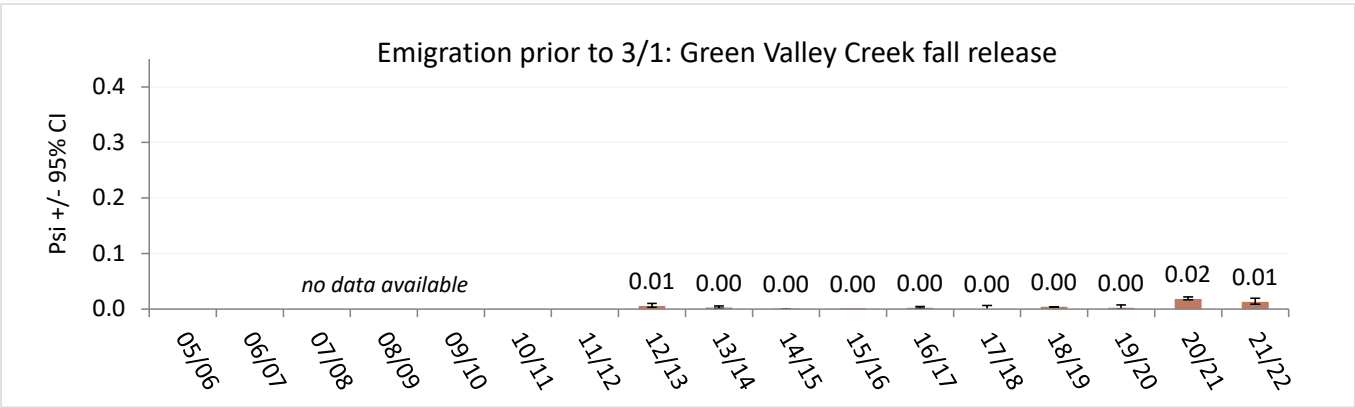


Figure 5. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.







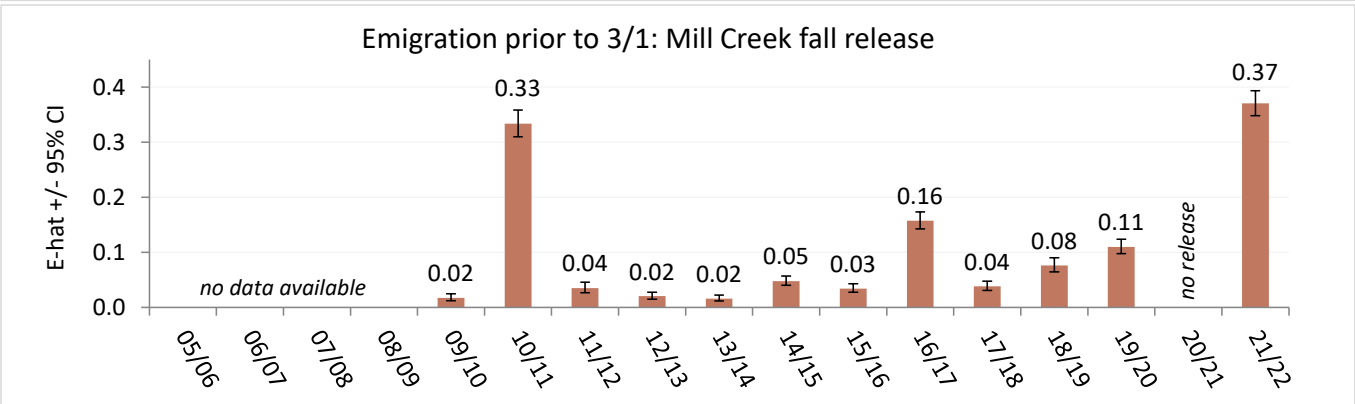


Figure 6. Probability of emigration (E-hat) past antenna sites prior to 3/1 in Willow, Dutch Bill, Green Valley, and Mill creeks.

2.3.6. Migration timing

2.3.6.1. Overview

Weekly totals of out-migrating smolts were plotted by antenna site for the fall release group within each watershed for the period of October 29, 2021 to June 30, 2022 and compared with stream depth (stage height) data from each creek (Figure 7-Figure 13; note the differences in the y-axes scales across figures). No stage data were available for Willow Creek due to an equipment failure. 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 0.41 river kilometer (km) 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 of fall release fish

In Willow, Dutch Bill, Green Valley, and Mill creeks, we observed winter movement of fall release juvenile coho salmon, as well as migration during the typical coho salmon smolt migration period of March 1 through June 30 (Figure 7, Figure 9, Figure 11, and Figure 13). The proportion of juvenile coho salmon migrating out of each creek during the winter (i.e., past the downstream-most antenna array) varied by stream, with higher winter emigration occurring in Dutch Bill and Mill creeks and lower emigration from Green Valley Creek. In all of the creeks, there was a pulse of fish that moved immediately following the fall release; however, in Green Valley and Willow creeks, movement was only observed on the upstream antennas and the fish did not appear to emigrate from the streams altogether. Additional early emigration occurred in all streams except Willow Creek between December and the end of February, and was most pronounced in Dutch Bill Creek.

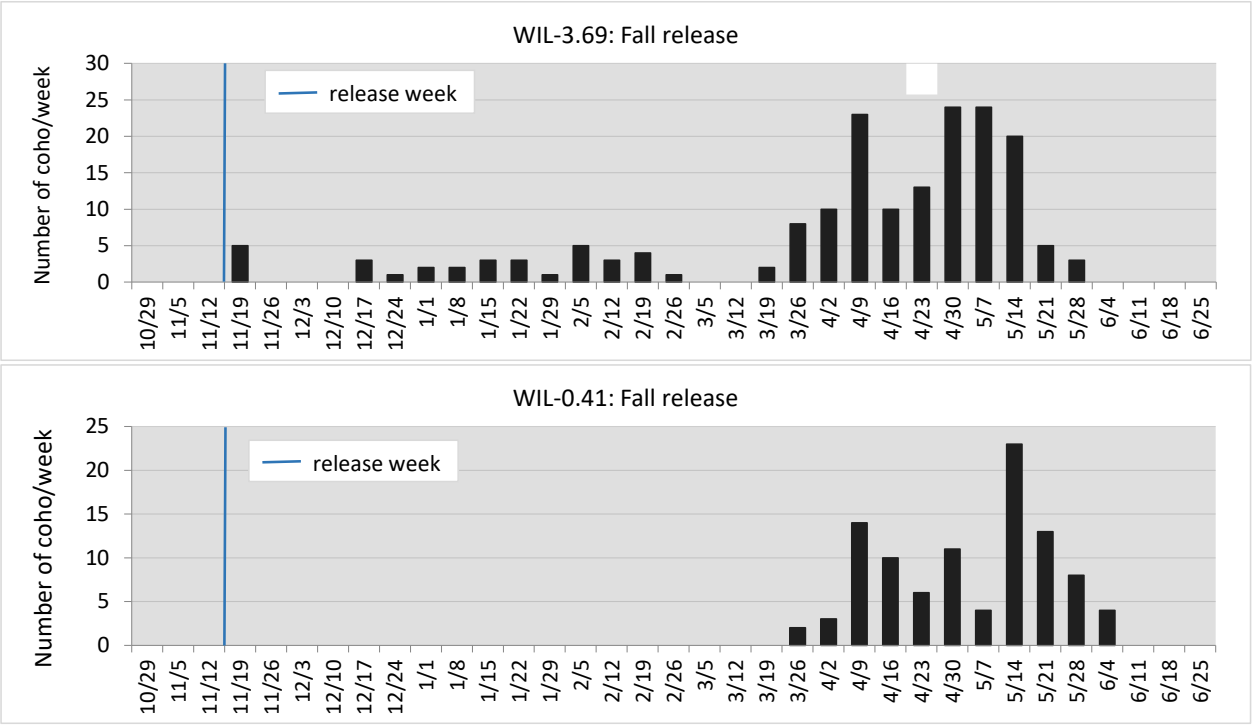


Figure 7. Number of fall release coho salmon that moved past the Willow Creek antenna and smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2021 and June 30, 2022. The total number of fish/week was assigned to the first day of each 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 5.64 and 6.43.

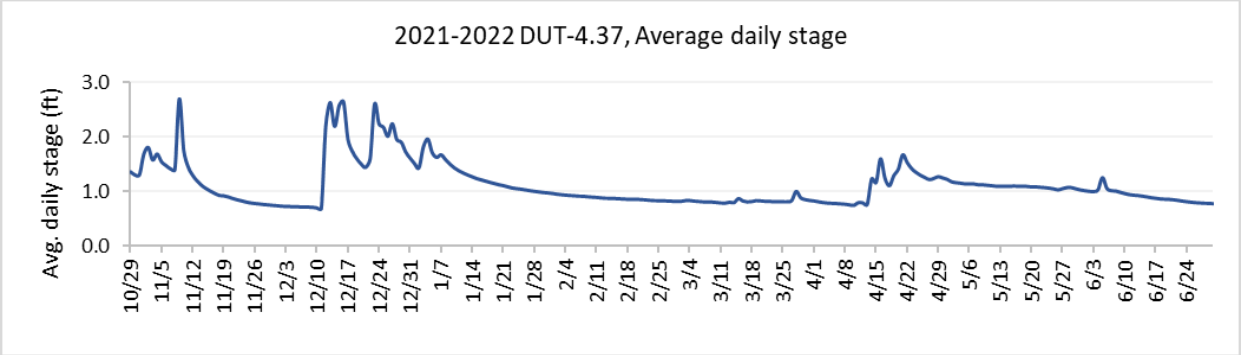


Figure 8. Average daily stage height at Dutch Bill Creek (river km 4.37) between October 29, 2021 and June 30, 2022. Data were provided by Trout Unlimited.

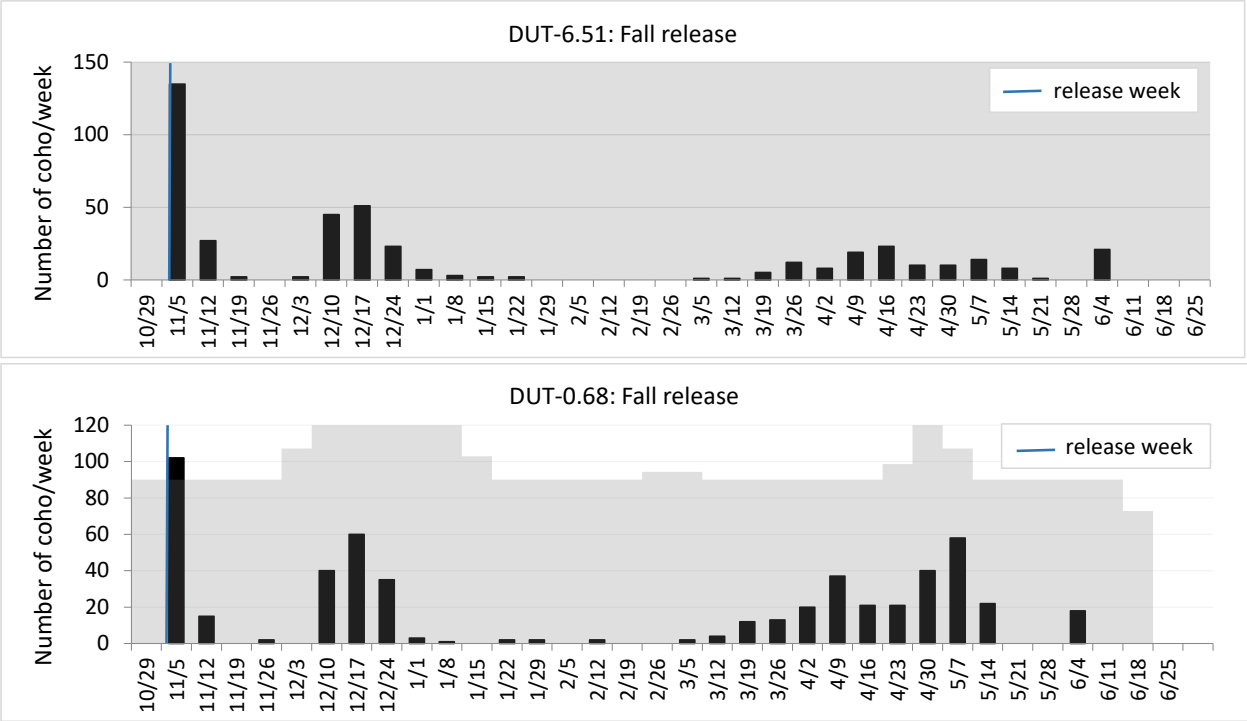


Figure 9. Number of fall release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and antenna site (DUT-0.68) each week between October 29, 2021 and June 30, 2022. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Dutch Bill Creek between river km 5.96 and 10.29.

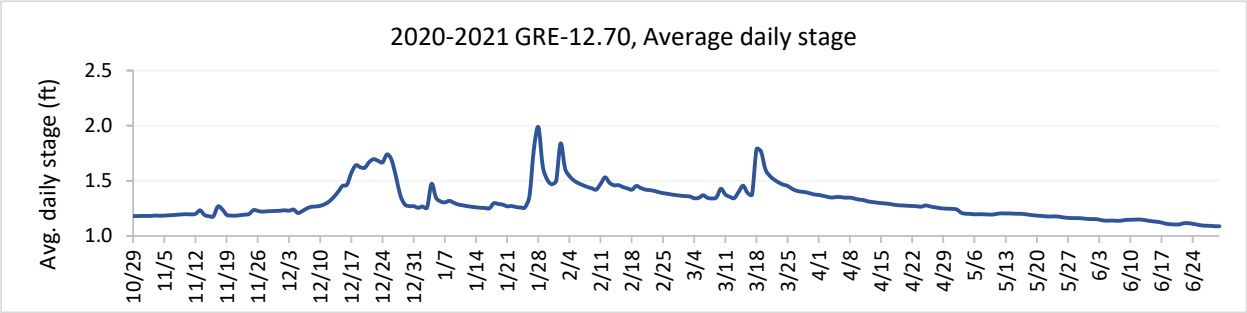


Figure 10. Average daily stage height on Green Valley Creek (river km 12.70) between October 29, 2021 and June 30, 2022. Data were provided by Trout Unlimited.

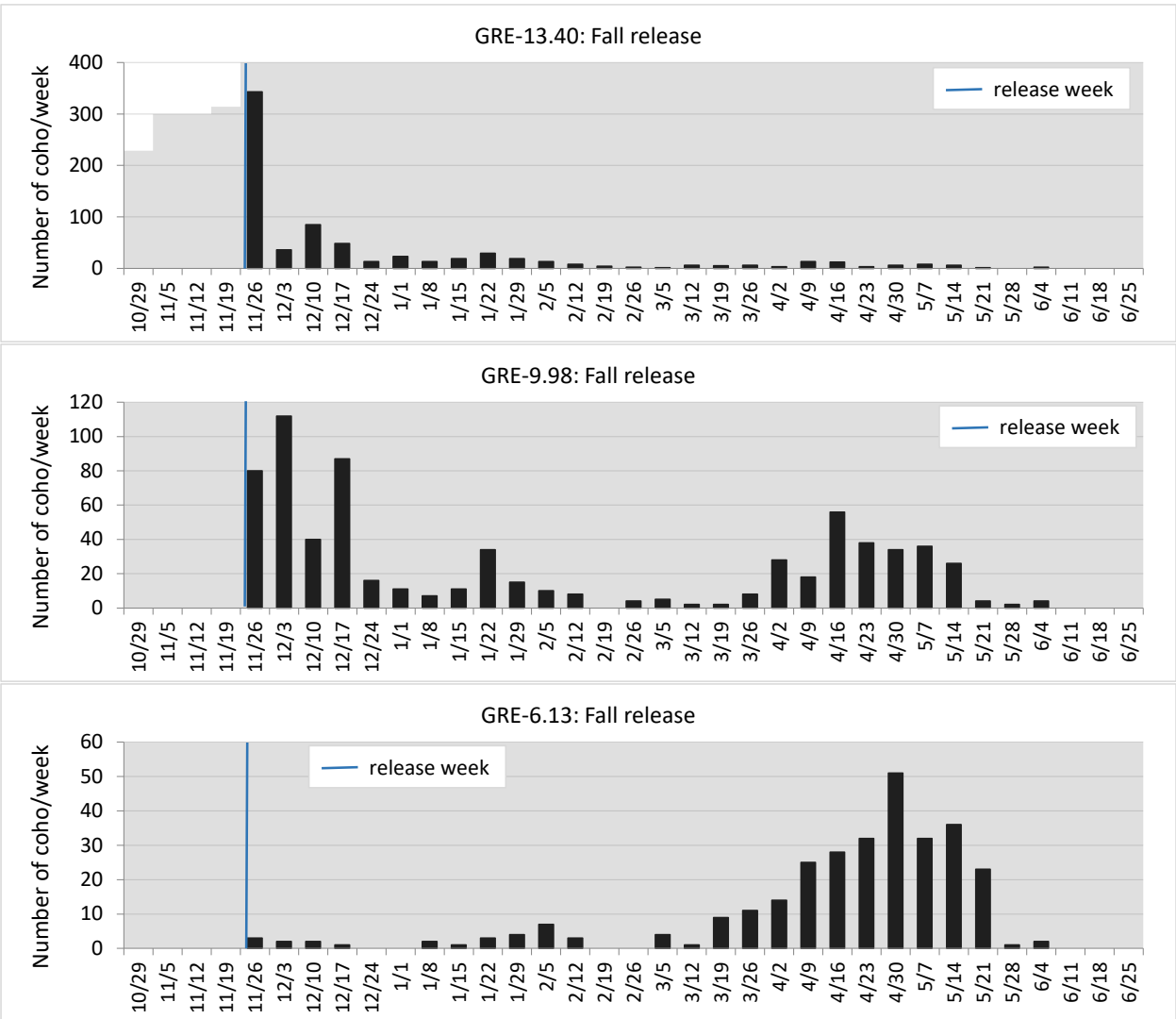


Figure 11. Number of fall release coho salmon that moved past the upper (GRE-13.40), middle (GRE-9.98), and lower (GRE-6.13) Green Valley Creek antenna sites each week between October 29, 2021 and June 30, 2022. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Green Valley Creek between river km 12.65 and 14.37. Additional fish were released in Purrington Creek, which joins Green Valley Creek at river km 10.77 and Redwood Creek, a tributary of Atascadero Creek, which joins Green Valley Creek at river km 9.05 (Figure 1).

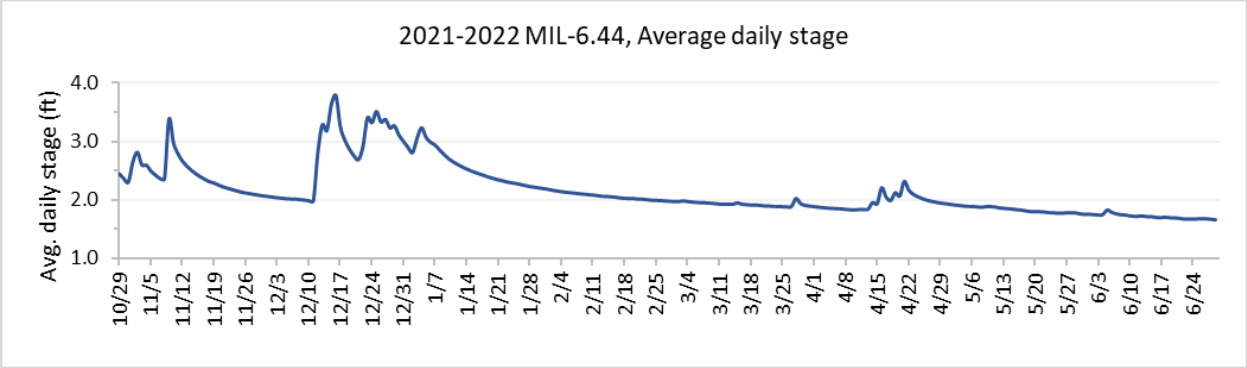


Figure 12. Average daily stage height on Mill Creek (river km 6.44) between October 29, 2021 and June 30, 2022. Data were provided by Trout Unlimited.

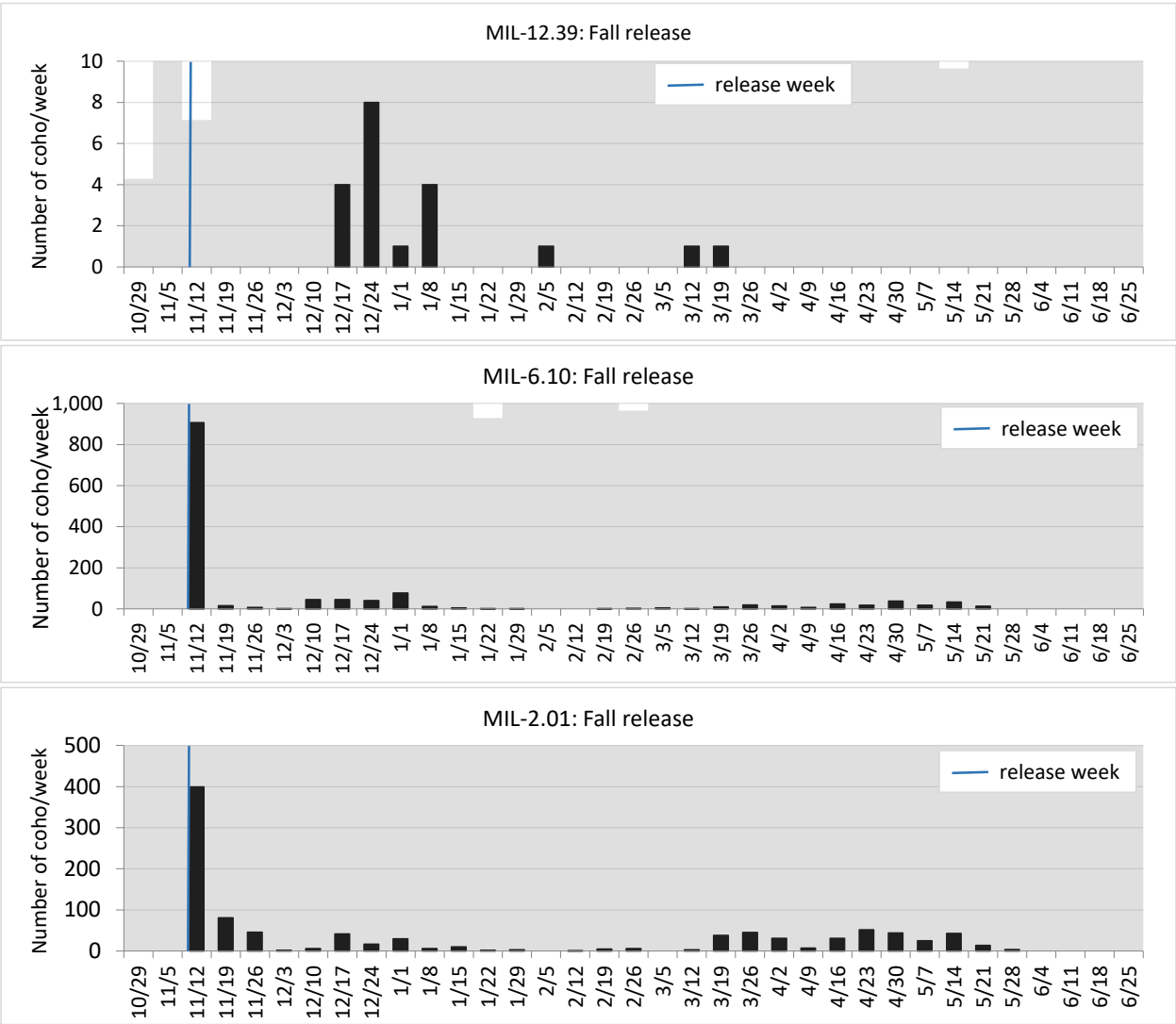


Figure 13. Number of fall release coho salmon detected on the upper (MIL-12.39), middle (MIL-6.10), and lower (MIL-2.01) Mill Creek antenna sites each week between October 29, 2021 and June 30, 2022. The total number of fish/week was assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas were in operation. Fish were released in Mill Creek between river km 8.92 and 11.35. Additional fish were released in Palmer Creek, which joins Mill Creek at river km 10.67 (Figure 1).

2.3.7. Size

Only slight differences were observed in size at release among streams in Broodstock Program intensive monitoring watersheds. Average sizes across all 2021 cohort Broodstock Program fall release groups were 85.4 mm and 7.3 g (Table 8).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 106.6 mm and 13.1 g in Willow Creek to 118.7 mm and 18.5 g in Green Valley Creek. Average fork length and weight of smolts captured in Dutch Bill Creek (108.3 mm and 13.6 g) and Mill Creek (106.7 mm and 13.5 g) were intermediate but more similar to Willow Creek than Green Valley Creek (Table 9).

Natural-origin coho salmon smolts were larger than their hatchery-origin counterparts in Green Valley Creek and smaller in Dutch Bill and Willow creeks, but these differences were generally minimal. Green Valley Creek natural-origin smolts were the largest among all groups, averaging 120.1 mm and 19.0 g (Table 9).

Table 8. Average fork length (mm) and weight (g) of cohort 2021 PIT-tagged coho salmon upon release into program streams.

Tributary	Release group	Avg fork length (SD)	Average weight (SD)	Number of fish
Willow Creek	Fall	86.9 (±7.6)	7.5 (±2)	610
Dutch Bill Creek	Fall	83.2 (±7.6)	6.7 (±1.9)	1,811
Green Valley Creek	Fall	87.6 (±8.5)	8.0 (±2.4)	2,023
Mill Creek	Fall	84.5 (±8)	7.0 (±1.9)	1,827

Table 9. Average lengths and weights of natural- and hatchery-origin coho salmon smolts captured at downstream migrant traps in Willow, Dutch Bill, Green Valley, and Mill creeks during the 2022 season. Origin was determined based on the presence of a CWT (hatchery) or lack of a CWT (natural).

Origin	Average fork length (SD)	Average weight (SD)	Number of fish
Willow Creek			
Hatchery	106.6 (±9.4)	13.1 (±3.5)	1,016
Natural	106.4 (±9.6)	13.4 (±3.9)	54
All smolts	106.6 (±9.4)	13.1 (±3.5)	1,070
Dutch Bill Creek			
Hatchery	109.2 (±11.1)	13.9 (±4.1)	125
Natural	105.1 (±13.4)	12.7 (±4.7)	34
All smolts	108.3 (±11.7)	13.6 (±4.3)	159
Green Valley Creek			
Hatchery	118.5 (±12.4)	18.5 (±6.1)	975
Natural	120.1 (±12.9)	19.0 (±6.4)	115
All smolts	118.7 (±12.4)	18.5 (±6.1)	1,090
Mill Creek			
Hatchery	106.7 (±8.9)	13.5 (±3.6)	1,297
Natural	NA	NA	NA
All smolts	106.7 (±8.9)	13.5 (±3.6)	1,297

2.3.8. Growth

Average growth (mm fork length and g weight gained) and average daily growth rates (mm/day) from the time of release to capture in the downstream migrant trap varied among streams (Table 10, Figure 14). In the fall release group, PIT-tagged smolts recaptured in Green Valley Creek grew more than those from other Broodstock Program streams in both absolute size since release and average daily growth rate.

Growth rates for fall release fish captured in the downstream migrant traps in 2022 were higher than rates observed since 2017 for all creeks except for Willow Creek (Figure 14). Except for 2015 and 2020, Green Valley Creek has consistently shown the highest growth rates of the four Broodstock Program watersheds, and this pattern held in 2022.

Table 10. Average growth in fork length (mm) and weight (g) of recaptured PIT-tagged coho salmon smolts during the 2022 downstream migrant trapping season, by stream.

Release season	Average growth length (SD)	Average growth weight (SD)	Number of recaptures	Average days since release (SD)
Willow Creek downstream migrant trap				
Fall	20.3 (±9.2)	5.8 (±3.1)	90	176 (±17)
Dutch Bill Creek downstream migrant trap				
Fall	23 (±11)	6.9 (±4.3)	18	174 (±27)
Green Valley Creek downstream migrant trap				
Fall	30 (±12.4)	10.7 (±6.4)	66	162 (±21)
Mill Creek downstream migrant trap				
Fall	21 (±10)	5.9 (±3.6)	158	190 (±12)

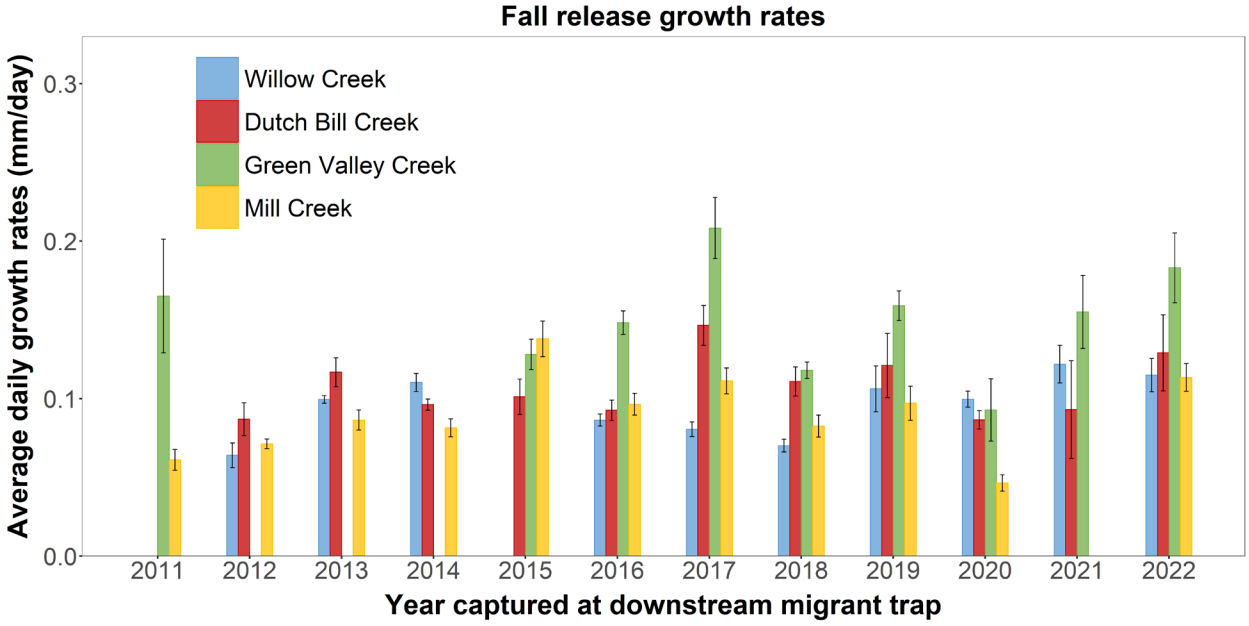


Figure 14. Average daily growth rates in fork length (mm) of fall release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2022.

3. Discussion and Recommendations

Overall, during the spring of 2022, the numbers of emigrating coho salmon smolts captured from each of the four Broodstock Program monitoring watersheds were comparable to previous years and appeared to correspond to the timing of precipitation. Precipitation totals in the 2021/22 water year (October-September) were 81% of the historical average in the Russian River basin (according to California Water Watch, https://cww.water.ca.gov/info?address=Healdsburg). However, the timing of the precipitation was unusual and appeared to influence both early emigration and the timing of smolt

migration. Much of the rainfall during fall 2021 occurred during an atmospheric river event in October (18" at the Venado rainfall gage; California Data Exchange Center, https://cdec.water.ca.gov/queryTools.html). This storm event contributed 38% of the water year's total precipitation of 47" at the Venado rainfall gage. Rainfall was steady during the month of December (totaling 12") and low during the late winter months of January through March (totaling 4") (Figure 15). The lack of late winter rains and the ongoing impact of dry conditions over multiple preceding drought years (see www.drought.gov/states/california for more information) resulted in low water levels in the late winter and early spring months.

Although precipitation in the 2021/22 water year was below average, several spring rain events beginning in mid-April, coincident with coho salmon smolt emigration from Russian River tributaries, had a positive impact on instream conditions and improved smolt emigration success. Prior to these rain events, flow conditions at our traps were similar to those in 2021, a year when many smolts became trapped in streams due to extreme low flows and disconnections (California Sea Grant 2021). In early April of 2022, we observed disconnections in Mill and Willow creeks downstream of the trap sites, but spring rains reconnected both streams, and these streams remained connected into June. Additionally, an early summer rain event in the first week of June elevated streamflows, which resulted in an atypical spike in flow and coho salmon smolt captures for that time of year. This late spike in captures accounted for >15% of total coho salmon smolts captures in the Green Valley Creek trap in 2022. During summer 2022 snorkel surveys, we observed low numbers of coho salmon parr (age 0+) in tributaries (CSG unpublished data), and we interpret this as an indication that streamflows were high enough for smolts to successfully emigrate (i.e., fewer smolts remained within tributaries and less residualization occurred relative to summer 2021). Successful smolt migration in 2022 despite below average annual rainfall suggests that the timing of spring rain events can be especially critical in years of severe drought.

The atmospheric river event in late October of 2021 brought elevated streamflows at a time when streams would typically have had low flow conditions. These high flows persisted into November when fall hatchery releases took place and was a likely cause for early emigration behavior in Dutch Bill and Mill creeks, where we observed earlier and higher levels of early emigration than observed in previous years (Figure 9, Figure 13). Early emigration in higher gradient streams such as Dutch Bill and Mill creeks is common in water years when streamflow is high; however, the timing and magnitude of the atmospheric river appeared to enhance this response. Early emigration in lower gradient streams such as Willow and Green Valley creeks was minimal (Figure 7, Figure 11), which was consistent with

observations in previous years. Upstream dispersal was also documented in Mill Creek, as fish released between river km 8.92 and 11.35 were later detected at the upstream PIT tag antenna site at river km 12.39 (Figure 13).

In previous years of low winter flow, we observed relatively higher overwinter survival probabilities; however in winter 2021/22 survival probabilities were unexpectedly average (i.e., in Mill Creek) to somewhat lower than average (i.e., in Willow, Dutch Bill and Green Valley creeks) (Figure 5). This may be explained by accumulated stress that the fall-release group experienced due to severe drought conditions during the summer and fall of 2021. Unprecedented drought contributed to high and variable water temperatures at the hatchery, which resulted in increased levels of disease in 2021 (Ben White, US Army Corps of Engineers, personal communication). While this did not result in high fish mortality while rearing in the hatchery, there may have been latent effects that had a negative effect on overwinter survival. On multiple occasions during winter 2021/22 redd surveys, juvenile coho salmon mortalities were observed, something that was only rarely observed in previous years (CSG unpublished data). We also observed more stressed fish (darker coloration and pop-eyed) and mortalities in our traps than in most years. We encourage USACE biologists to continue their efforts to ensure temperatures remain consistently cool at the hatchery. Additionally, we recommend development of a back-up marking plan for hatchery fish during years of extreme environmental stress, since fish may have a lower tolerance for recovering from PIT tagging in high stress conditions.

The proportion of natural-origin coho salmon smolt captures across Dutch Bill, Green Valley, and Willow creeks was 7.6% in the 2022 trap year (205 natural-origin smolts/2,690 total known-origin smolts captured; no data for Mill Creek in 2022). Although the percentage of natural-origin smolts in Dutch Bill Creek was high at 21.9%, total captures at the trap were low (n = 155) so that percentage may be an artifact of small sample size (Table 5). The natural-origin smolts emigrating in the spring of 2022 endured some of the driest over-summer stream conditions the prior year. Of the 45 streams where CSG conducted wetted habitat mapping in the lower Russian River basin in 2021, only 50% of the 118 miles sampled remained wet and connected through the dry season (CSG unpublished data). Poor over-summer conditions in 2021 likely hindered the chances of natural-origin fish to survive until the spring of 2022.

A record number of coho salmon yoy were captured in the Willow Creek trap (n = 2,965), which exceeds the annual catch not only in Willow Creek but in any of the intensive monitoring watersheds over the history of the monitoring efforts (Table 3). In previous years when coho salmon yoy were captured in

smolt traps, it was only a few fish over short periods of time, which we presumed indicated close proximity of redds to the trap sites. However, in 2022, coho salmon yoy captures in Willow Creek occurred throughout the trapping season, which is not what we would expect if the fish all emerged from a single nearby redd. Daily captures also did not appear entirely correlated with precipitation events, indicating that the migration was due to other factors. Although daily captures increased slightly after mid-April rains, coho salmon yoy caught in April only accounted for 7% of the total catch. In May, only 0.15" of rain was recorded at the Venado rainfall gage, but daily captures steadily increased throughout the month as streamflows decreased (Figure 16). Movement of coho salmon yoy to non-natal habitat is something that has been documented in other watersheds, particularly downstream migration to estuarine habitat (Koski 2009), but such movement has rarely been observed in meaningful numbers in the Russian River during our years of monitoring. Over 6,000 coho salmon yoy were observed during 2022 summer snorkel surveys in upper Willow Creek (CSG unpublished data), which is considerably more than previous observations and indicates a substantial number of yoy remained in the upper watershed despite the large number observed leaving the upstream habitat during the spring trapping season. The downstream migration of yoy in Willow Creek could be a result of high yoy densities, which may indicate that Willow Creek approached its juvenile carrying capacity in 2022. It should be noted that we observed record numbers of coho salmon yoy in Dutch Bill and Green Valley creeks in 2022 summer snorkeling surveys as well; however, we did not catch record numbers of coho salmon yoy at those trap sites. Based on differences in growth rates among watersheds, Green Valley Creek may have more productive habitat relative to Willow Creek and may therefore be able to support higher densities of juvenile salmonids. The downstream migration of yoy in Willow Creek provides an indication that the Russian River coho salmon population has the ability to express different life history strategies as a response to varying environmental conditions.

Growth rates of fall release fish over the winter of 2021/22 were above average in Mill, Dutch Bill, Green Valley and Willow creeks (Figure 14). Fish released into Green Valley Creek experienced the highest growth rates of any of the Broodstock Program streams, which is consistent with what we observed in most years of monitoring (Figure 14). The factors that contribute to fluctuations in growth rate observed among years and watersheds remains unknown. During the winter of 2019/20, a sharp decline in growth rates among all Broodstock Program watersheds coincided with severe drought conditions. At that time, we presumed that winter drought conditions restricted access to flood plain habitat that would otherwise have provided productive foraging opportunities and promoted growth, especially in Green Valley Creek. However, persistent drought conditions over the subsequent two winters were associated

with average growth rates in 2020/21 and near record growth rates for Green Valley Creek in 2021/22, suggesting that the relationship between streamflow and growth rate is more complex than expected. We continue to recommend further study to identify what aspects of Green Valley Creek are driving these high growth rates as well as further study on the relationship between growth and overwinter streamflows.

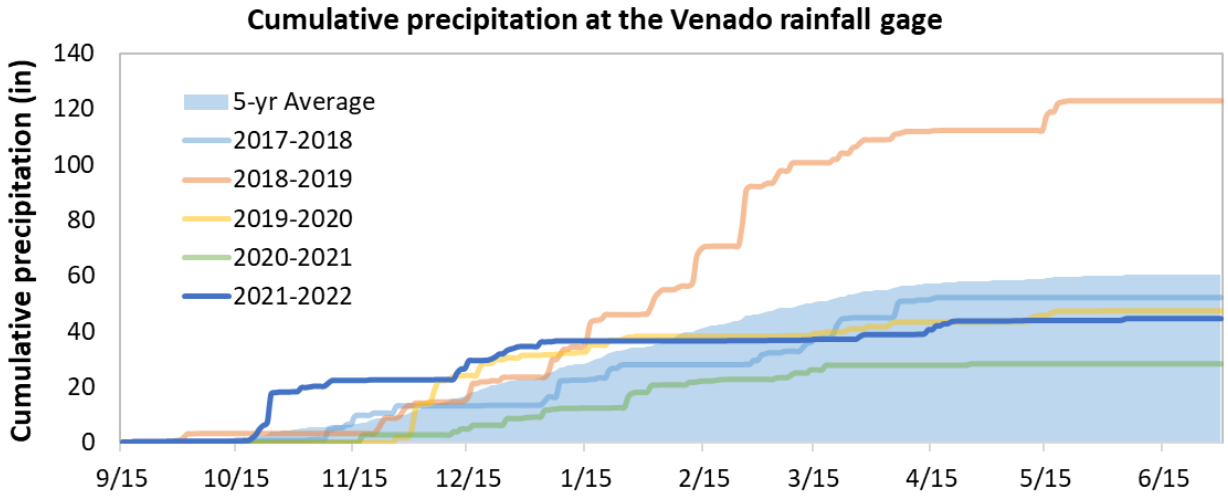


Figure 15. Cumulative precipitation at the Venado rainfall gage by water year over the past five years. The average annual accumulated precipitation over these five years is shown in shaded blue. Data obtained from the California Data Exchange Center (https://cdec.water.ca.gov).

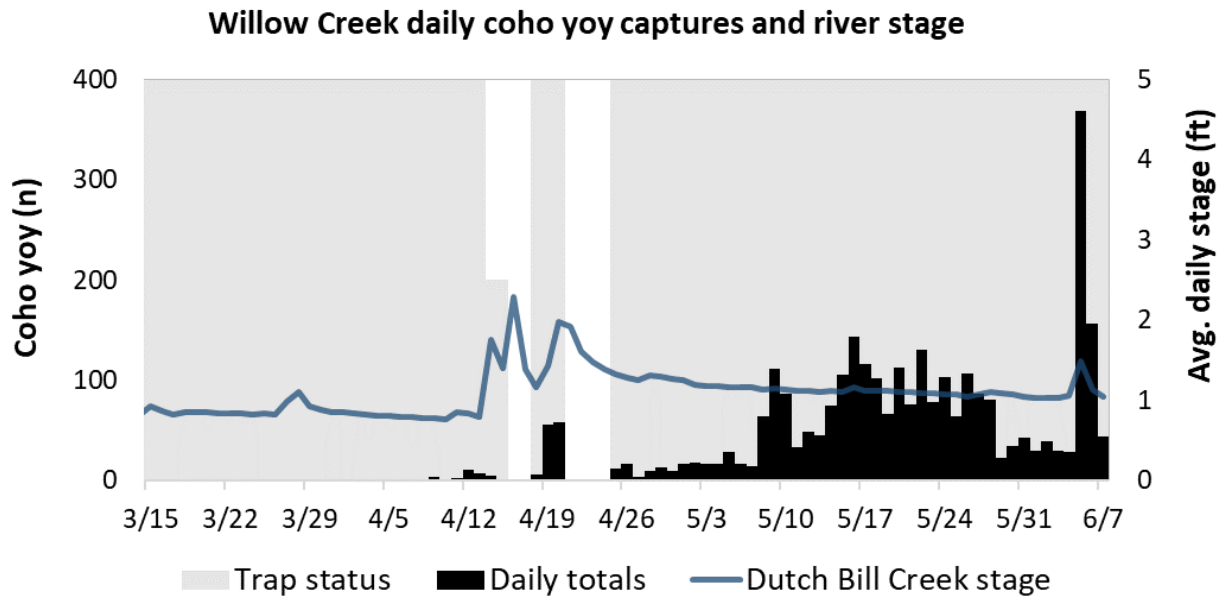


Figure 16. Daily coho salmon yoy captures at Willow Creek downstream migrant trap with the average daily stage height measurements from Dutch Bill Creek (the nearest watershed with available stage data). Stage data were provided by Trout Unlimited. Shaded background indicates proportion of the week that the smolt trap was in operation.

4. References

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