Coho Salmon and Steelhead Monitoring Report

Spring 2021

Prepared by:

Jason Held, Andrew McClary, Mariska Obedzinski, and Laura Slater

California Sea Grant at University of California
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Russian River Salmon & Steelhead Monitoring Program

University of California

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*) 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 (ACOE) currently hosts the Broodstock Program at the Don Clausen Fish Hatchery at Warm Springs Dam. California Sea Grant (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 populations in four Broodstock Program 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 implementation of a statewide salmon and steelhead monitoring program. In 2010, we began documenting relationships between streamflow and juvenile coho 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 new 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 our spring downstream migrant trapping effort, as well as 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 2020 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 releases

Broodstock Program coho salmon were raised by ACOE 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, May- Jun), fall (age-0, Oct-Dec), pre-smolt (age-1, Jan-Feb), and smolt (age-1, Mar-May) (Figure 1). Details pertaining to release groups stocked into Broodstock Program intensive monitoring watersheds are included in this report (Table 1). Fish from the spring release group were stocked as yoy in June, fish from the fall release group were stocked as yoy in November and December 2020, fish from the pre-smolt release group were stocked as age-1 in February, and fish from the smolt release group were stocked as age-1 in April 2021.

All fish were released directly into the streams. During the spring and fall seasons, when streamflows were low and thought to impede natural dispersal of fish, biologists stocked fish into individual pools throughout reaches after ensuring they were characterized by suitable salmonid habitat. For pre-smolt and smolt release groups, which occurred when streamflows were high enough to allow fish to disperse naturally throughout the streams, fish were released at point locations (Figure 1). No coho salmon were released in Mill Creek due to anticipated negative impacts from the Walbridge fire, which burned more than 55,000 acres in August and October, 2020. Fall releases were made in Willow, Dutch Bill, and Green Valley creeks, pre-smolt releases were made in Green Valley Creek, and smolt releases were made in Dutch Bill and Green Valley creeks (Table 1). Due to low streamflow conditions across the Russian River watershed during the spring of 2021, Green Valley Creek was the only Broodstock Program watershed in which smolts were released above our traps.

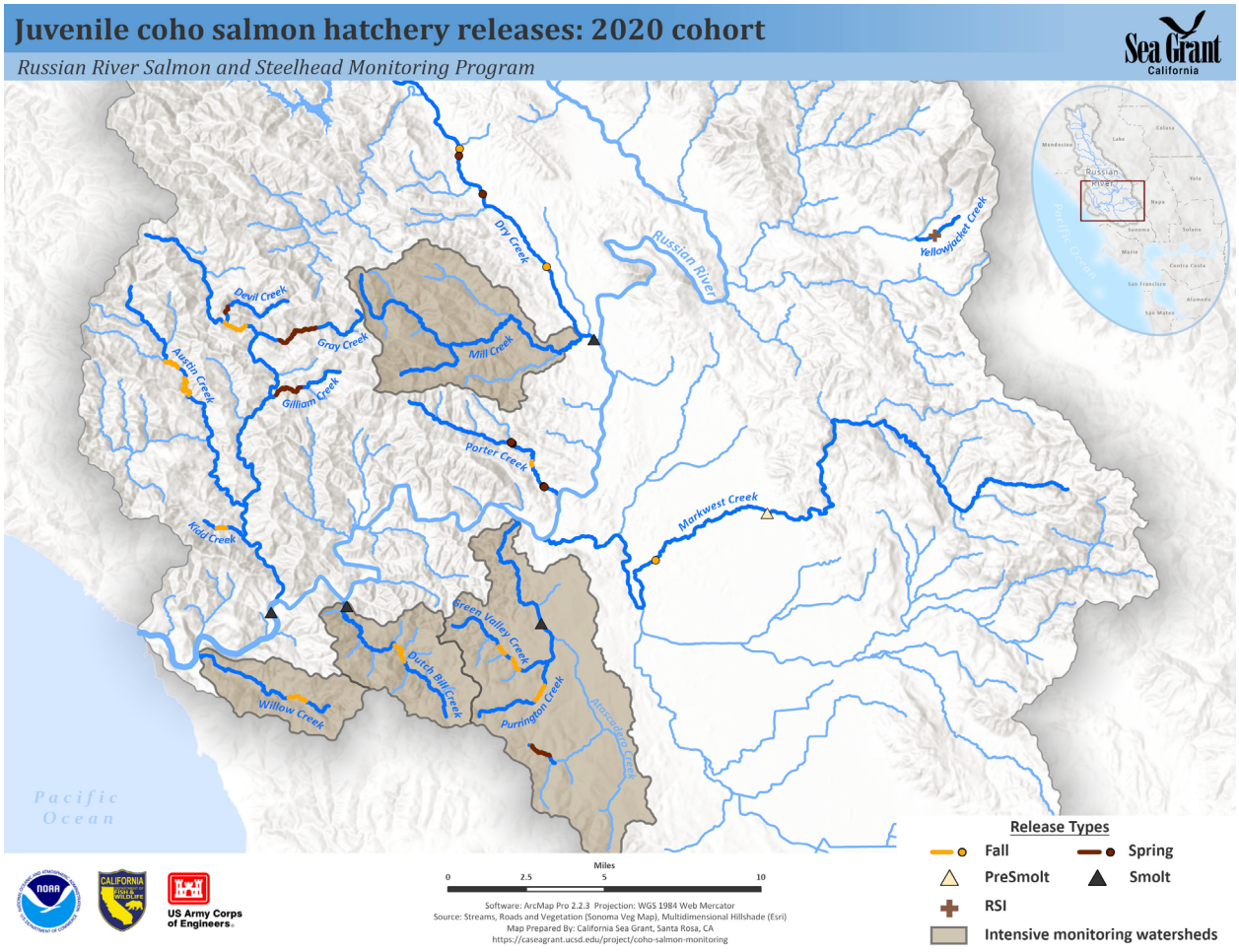

Figure 1. Map of juvenile coho salmon stocking locations for 2020 cohort (hatch year) in the four Broodstock Program intensive monitoring watersheds and additional locations. Note the location indicated for smolt release in Green Valley Creek is also where a pre-smolt release occurred.

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.

In addition to hatchery-released fish, wild coho salmon were PIT tagged in summer 2020 as part of the CMP life-cycle monitoring effort. These numbers were small relative to the number of stocked fish, with 857 tagged in Dutch Bill Creek, 14 tagged in Green Valley Creek, and 98 tagged in Mill Creek.

Table 1. Number of juvenile coho salmon released from the 2020 cohort, by release group and watershed. The percent of fish from each release group that were implanted with a PIT tag is noted in parentheses. Note that totals for the Green Valley Creek watershed included releases into Purrington and Redwood (Atascadero) creeks.

Release group	Release dates	Willow Creek	Dutch Bill Creek	Green Valley Creek	Mill Creek
Spring	June 22, 2021	0	0	2,072 (15%)	0
Fall	Nov 25 - Dec 15, 2020	6,634 (15%)	11,084 (16%)	21,726 (15%)	0
Pre-smolt	Feb 23, 2021	0	0	10,079 (15%)	0
Smolt	April 9, 2021	0	2,543[1] (15%)	3,634 (15%)	0
Total released		**6,634**	**13,627**	**37,511**	**0**

[1] *All fish were released downstream of the trap and therefore were unlikely to be captured.*

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 or solar power. 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 2020 through June 2021, 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. More frequent visits (approximately daily) were made during storm events.

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 2021, 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 data from their effort were provided to CSG 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 (CWT). All PIT-tagged smolts were measured for fork length (mm) and weight (g). Additionally, the first 30 coho salmon smolts with 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 natural-origin coho smolts (no CWT or PIT) were measured and weighed, and a PIT tag was applied to every other fish (50% of natural-origin smolts). A genetics sample was collected for every CWT-only and natural-origin 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). On Mill and Dutch Bill creeks, steelhead parr and smolts were also PIT tagged as part of the Coastal Monitoring Program effort. Steelhead and unidentifiable salmonid yoy ≥ 35 mm that were captured in the traps were tallied and released downstream; additionally, up to 10 per site/day were measured and weighed. 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 for smolts. If disconnections were observed, crews released captured fish downstream of the downstream-most disconnection to ensure coho and steelhead smolts had the opportunity to continue their migration to the Russian River mainstem.

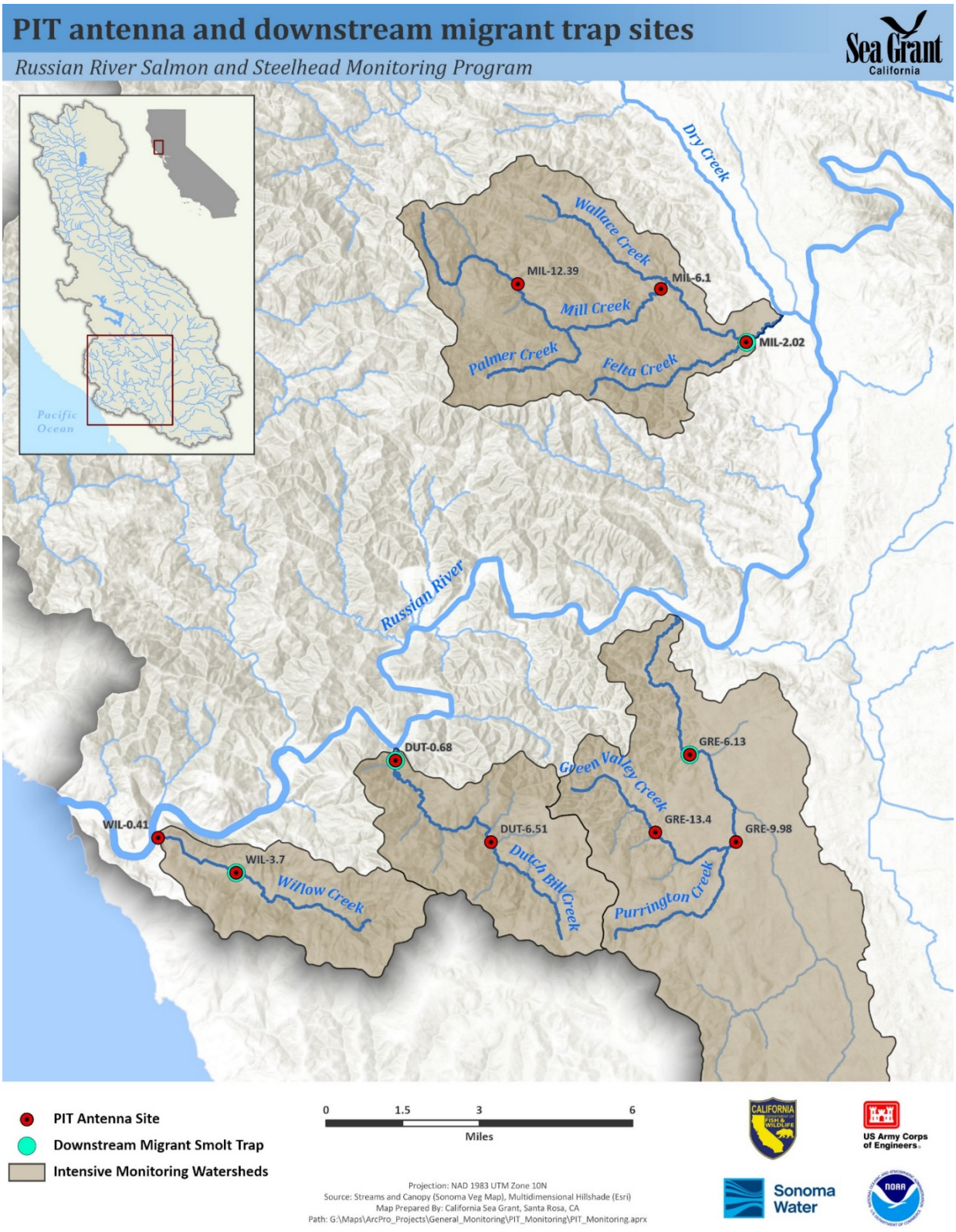

Figure 2. Map showing PIT antenna and smolt trap locations on Broodstock Program intensive monitoring watersheds, with antenna site codes.

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.

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 = 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 6/30/21 and emigration prior to 3/1/21 for multiple release groups (i.e., fall, pre-smolt, and smolt) 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 (spring, fall, pre-smolt, and smolt) passing the 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. Measurements of PIT-tagged fish captured in the downstream migrant traps were compared 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. Growth rates for length were calculated for individual hatchery fish as (FL2-FL1)/(t2-t1) where FL1= fork length at hatchery prior to release, FL2= fork length at the smolt trap, t1=date measured at hatchery, and t2= date captured in the smolt trap. Individual growth rates 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 2021, the traps were installed between March 8-10, and each trap was operated until the site became disconnected from upstream flow (Figure 3). From April 10-21, trap operation on Green Valley Creek was temporarily suspended following a mortality event due to an unexpectedly rapid emigration rate of hatchery-released smolts. Trap operation resumed once the majority of the smolt-release group emigrated past the trapsite and approval for operation was granted by NMFS and CDFW. During this period, antenna operation continued. Due to early stream drying, traps were removed earliest on Dutch Bill and Mill creeks, followed by Willow and Green Valley creeks (Figure 3).

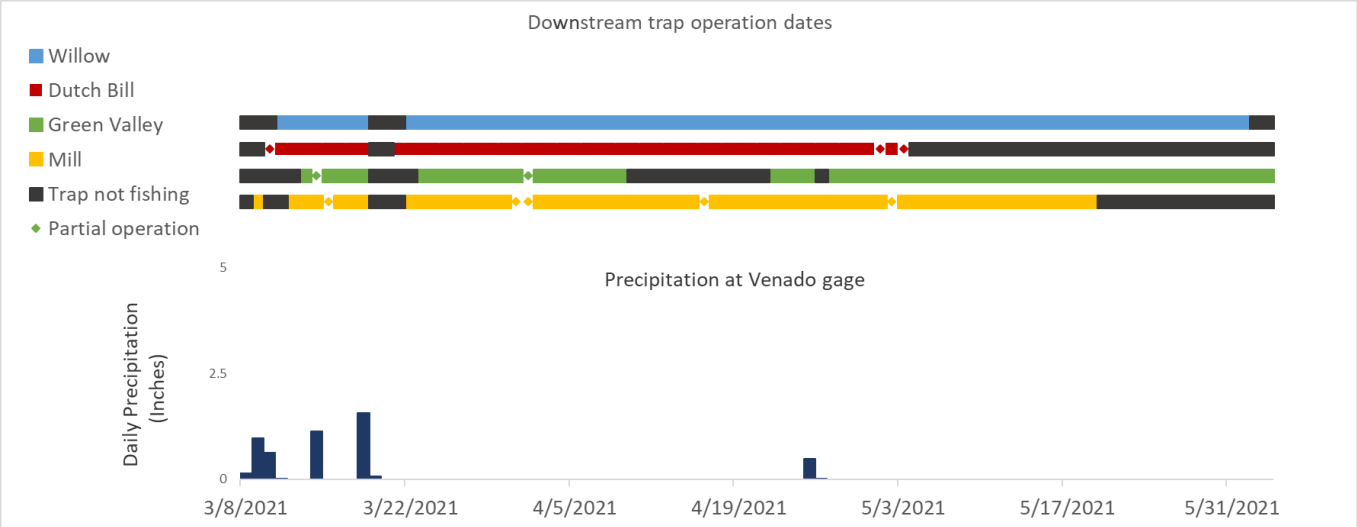

Figure 3. Trap operation dates in relation to precipitation at Venado rain gage in upper Mill Creek watershed. Daily rain totals from raw gage data posted on NOAA's California Nevada River Forecast Center website (http://www.cnrfc.noaa.gov/formPrecipMap.php).

2.3.2. Trap counts

Counts of coho salmon smolts captured in the four downstream migrant traps operated in 2021 ranged from 111 in Dutch Bill Creek to 1,033 in Green Valley Creek, with 201 in Mill Creek and 802 in Willow Creek (Table 2). When compared to previous years, coho salmon smolt counts were low in Willow and Green Valley creeks, and extremely low in Dutch Bill and Mill creeks (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.

Although downstream migrant traps target the capture of coho salmon smolts and were not operated during the full steelhead and Chinook salmon outmigrant seasons, incidental capture of steelhead and Chinook salmon occurred in 2021. The number of steelhead smolts captured in the traps in 2021 was moderate to low, ranging from three in Willow Creek to 86 in Mill Creek (Table 3). Chinook salmon smolts were only observed in Mill Creek (n = 8; 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 three-spined stickleback (n = 225), sculpin (n = 144), and Sacramento pikeminnow (n = 1); in Dutch Bill Creek they were sculpin (n = 48), Sacramento sucker (n = 4), and three-spined stickleback (n = 2); in Green Valley Creek they were three-spined stickleback (n = 2,521), sculpin (n = 528), and Bluegill (n = 198); and in Mill Creek they were California roach (n = 220), sculpin (n = 107), and Fathead minnow (n = 19) (Table 4). 96 freshwater shrimp were captured in Green Valley Creek in 2021, almost three times as many as captured in any of the previous five years (Table 4).

Table 2. Coho salmon smolts captured in traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2021 downstream migrant season, by origin.

Stream	Hatchery	Natural	Unknown origin	Total	Percent natural
Willow Creek	710	91	1	802	11.4
Dutch Bill Creek	69	41	1	111	37.3
Green Valley Creek	986	46	1	1,033	4.5
Mill Creek	6	195	0	201	97.0

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in downstream migrant traps, years 2005-2021. NA indicates that 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
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
		Yoy	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0	27	2	2	0
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	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
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5	3	0	0	2
Dutch Bill Creek	Chinook salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2	8	6	17	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
		Yoy	NA	NA	NA	NA	NA	0	5	0	2	0	0	18	2	3	1	4	1
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0	0	2	0	2
		Parr/yoy	NA	NA	NA	NA	NA	58	31	21	79	1,138	13	74	524	22	140	2,304	159
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6	1	5	11	4
Green Valley Creek	Chinook salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	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
		Yoy	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2	3	2	0	0
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1	1	0	0	0
		Parr/yoy	1,723	NA	36	497	1	5	3	NA	NA	NA	38	356	11	15	46	32	1
		Smolt	49	NA	70	29	43	0	1	NA	NA	NA	3	3	12	17	12	0	5
Mill Creek	Chinook salmon	Smolt	70	128	2	31	1	1	0	11	0	22	0	0	1	1	0	0	8
	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
		Yoy	24	314	58	43	0	4	329	515	530	0	10	10	30	63	8	202	107
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	2	0	2	0	2	0	2
		Parr/yoy	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941	898	75	1,989	887	86
		Smolt	116	49	266	176	118	190	97	41	32	13	17	15	32	22	6	22	32

Table 4. Annual downstream migrant trap counts for common non-salmonid species, years 2011-2021. NA indicates that no trap was in operation.

Origin	Species [1]	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
WILLOW CREEK												
Non-native	Bluegill	NA	0	0	0	0	0	0	0	0	1	0
	Bullfrog	NA	0	1	0	0	0	0	0	0	1	0
	Fathead minnow	NA	0	0	0	0	0	0	0	0	0	0
	Green sunfish	NA	0	0	0	0	0	1	0	0	0	0
Native	California roach	NA	0	1	1	7	0	1	0	0	0	0
	Freshwater shrimp	NA	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	NA	0	219	0	198	8	36	99	0	137	1
	Sacramento sucker	NA	1	24	1	46	2	9	4	0	1	0
	Sculpin sp.	NA	339	4,206	680	2,462	548	2,898	653	1,455	335	144
	Three-spined stickleback	NA	383	268	296	193	71	496	157	69	402	225
	Western brook lamprey	NA	0	0	0	0	0	0	0	0	0	0
DUTCH BILL CREEK												
Non-native	Bluegill	0	0	0	2	0	4	19	1	3	9	0
	Bullfrog	1	0	0	0	0	0	0	0	1	0	0
	Fathead minnow	0	0	0	0	2	98	2	0	0	0	0
	Green sunfish	1	0	0	5	20	8	21	3	4	12	0
Native	California roach	129	59	725	3	252	94	28	14	1	5	0
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	95	1	412	0	27	50	18	156	23	1,235	0
	Sacramento sucker	178	1	307	4	25	106	265	51	7	784	4
	Sculpin sp.	393	437	1,204	136	974	440	323	276	452	384	49
	Three-spined stickleback	7	56	517	2	5	46	4	2	307	91	2
	Western brook lamprey	0	1	0	0	1	1	1	18	16	1	0
GREEN VALLEY CREEK												
Non-native	Bluegill	1	NA	NA	NA	3	137	472	659	551	148	198
	Bullfrog	1	NA	NA	NA	4	11	171	37	8	7	21
	Fathead minnow	54	NA	NA	NA	96	59	65	32	5	0	2
	Green sunfish	0	NA	NA	NA	25	32	133	209	35	5	1
Native	California roach	53	NA	NA	NA	314	54	51	48	92	82	46
	Freshwater shrimp	4	NA	NA	NA	318	33	26	13	30	10	96
	Sacramento pikeminnow	32	NA	NA	NA	70	7	14	6	33	21	2
	Sacramento sucker	3	NA	NA	NA	64	25	36	24	2	17	0
	Sculpin sp.	24	NA	NA	NA	192	62	365	145	368	99	528
	Three-spined stickleback	56	NA	NA	NA	373	167	11,931	2,309	2,191	1,610	2,521
	Western brook lamprey	0	NA	NA	NA	109	160	148	48	52	16	71
MILL CREEK												
Non-native	Bluegill	120	127	3	29	4	56	71	72	17	2	0
	Bullfrog	84	300	65	41	11	12	74	73	11	0	1
	Fathead minnow	25	4	4	0	14	103	68	128	22	1	19
	Green sunfish	5	1	3	5	6	22	16	12	42	5	0
Native	California roach	116	151	363	20	258	114	453	146	149	0	220
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	87	21	7	0	82	9	152	6	40	17	2
	Sacramento sucker	81	33	36	0	68	3	71	6	17	66	24
	Sculpin sp.	398	669	966	60	105	675	719	542	359	193	107
	Three-spined stickleback	7	17	1	1	3	2	6	5	1	0	4
	Western brook lamprey	0	0	0	0	0	1	0	0	0	0	3

[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 four Broodstock Program intensive monitoring watersheds in 2021 (Table 5). The contribution of natural-origin fish to the total number of coho salmon captured ranged from 4.5% in Green Valley Creek to 97.0% in Mill Creek (where no hatchery fish were released in the fall of 2020 (Table 2)). The number of natural-origin smolts in the four streams was low, ranging from 41 in Dutch Bill Creek to 195 in Mill Creek (Table 5).

Table 5. Number and percent of natural origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2021. 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	801	11.4	41	110	37.3	46	1,032	4.5	195	201	97.0

2.3.4. Smolt abundance

Smolt abundance estimates indicate that over 10,000 smolts emigrated from Willow, Dutch Bill, and Green Valley creeks combined during the spring of 2021 (Table 6). Smolt abundance was highest in Green Valley Creek; however, Green Valley Creek had the highest number of fish released, was the only creek in which pre-smolts were released, and was the only creek in which smolts were released above the trap site. Abundance was lowest in Mill Creek; however, this was to be expected as no cohort 2020 hatchery fish were released in the Mill Creek watershed. Abundance estimates were below average compared to the past five years in all four streams in 2021 (Figure 4).

Table 6. Number of cohort 2020 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 2021. Abundance estimates include both marked and unmarked smolts.

Tributary	Number released						Estimated smolt abundance (95% CI)
	Spring	Fall	Pre-smolt	Smolt	Total	Total released upstream of trap	
Willow Creek	0	6,634	0	0	6,634	6,634	2,161 (629)
Dutch Bill Creek	0	11,084	0	2,543	13,627	11,084[1]	1,418 (815)
Green Valley Creek	0	18,687	3,634	10,079	32,400	32,400	6,586 (1,141)
Mill Creek	0	0	0	0	0	0	692 (221)

[1] *The smolt release on Dutch Bill Creek took place downstream of the trap site so those fish were unlikely to be detected at the trapsite*

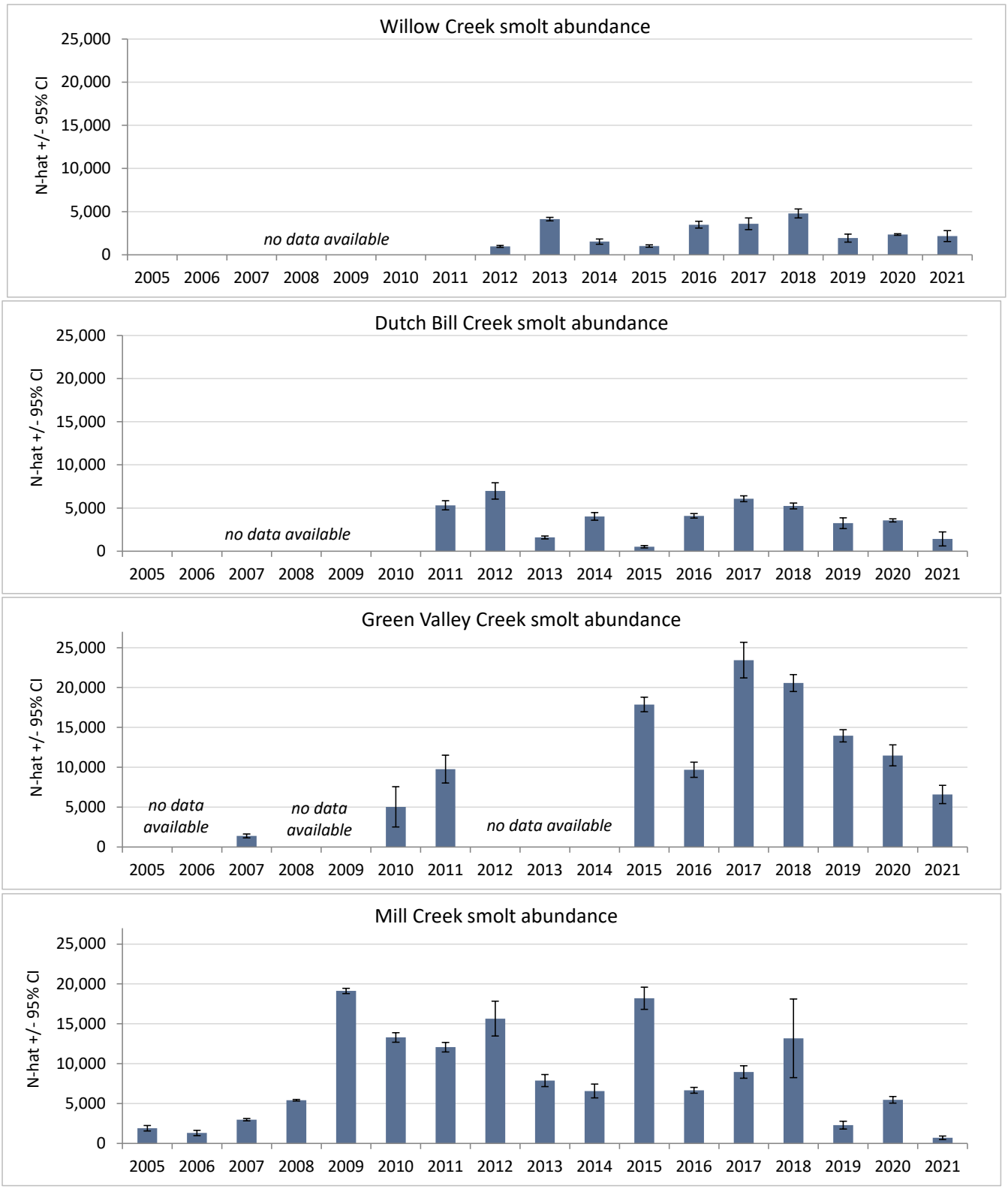

Figure 4. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2021.

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 late November/early December 2020 through June 30, 2021 ranged from 0.04 on Willow Creek to 0.06 on Dutch Bill Creek (Table 7). When compared to previous years' estimates, survival over the winter of 2020/21 was much lower than in previous years (Figure 5). Since no cohort 2020 coho salmon were released into Mill Creek, we were not able to generate an estimate of overwinter survival for that stream.

Due to poor streamflow conditions, pre-smolts and smolts were released only into Green Valley; one pre-smolt release on 2/23/21 and one smolt release on 4/9/21. Survival for each group to the Green Valley antennas at river km 6.13 was 0.62 and 0.91, respectively (Table 8).

The estimated probability of fall-release juvenile coho salmon emigrating prior to March 1 was minimal during the winter of 2020/21, ranging from 0.00 in Willow Creek to 0.02 in Dutch Bill and Green Valley creeks (Table 7). 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 winter 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 close to zero (0.01) in 2020/21, unlike in the previous five winters when we observed an early emigration probability of 0.18 – 0.30 past the upper antennas and close to zero past the lower antennas (Figure 6). Estimated probabilities for pre-March 1 emigration were lower than previous years in Dutch Bill Creek, and similar in Green Valley Creek.

Table 7. Estimated probability of juvenile coho salmon survival and early emigration (prior to 3/1) from the date of release in 2020 through 6/30/21 for the fall release group. NA indicates that no fish were released.

Tributary	Release date	Interval (days)	Probability of survival (95%CI)	Probability of emigration prior to 3/1 (95% CI)
Willow Creek	12/4/2020	208	0.04 (0.03-0.06)	0.00 (0.00-0.01) [1]
Dutch Bill Creek	11/30/2020	212	0.06 (0.05-0.08)	0.02 (0.01-0.03)
Green Valley Creek	12/14/2020	198	0.05 (0.04-0.06)	0.02 (0.01-0.02)
Mill Creek	NA	NA	NA	NA

[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 0.17 (0.15-0.20), and emigration downstream of 3rd bridge prior to 3/1 was 0.01 (0.00-0.02).*

Table 8. Estimated probability of juvenile coho salmon survival released directly into Green Valley Creek at Iron Horse Bridge (river km 7.8) from the date of release through 6/30/21.

Release group	Release date	Days imprinted	Survival interval	Probability of survival (95%CI)
pre-smolt	2/23/2021	0	127	0.62 (0.60 - 0.65)
smolt	4/9/2021	0	82	0.91 (0.88 - 0.93)

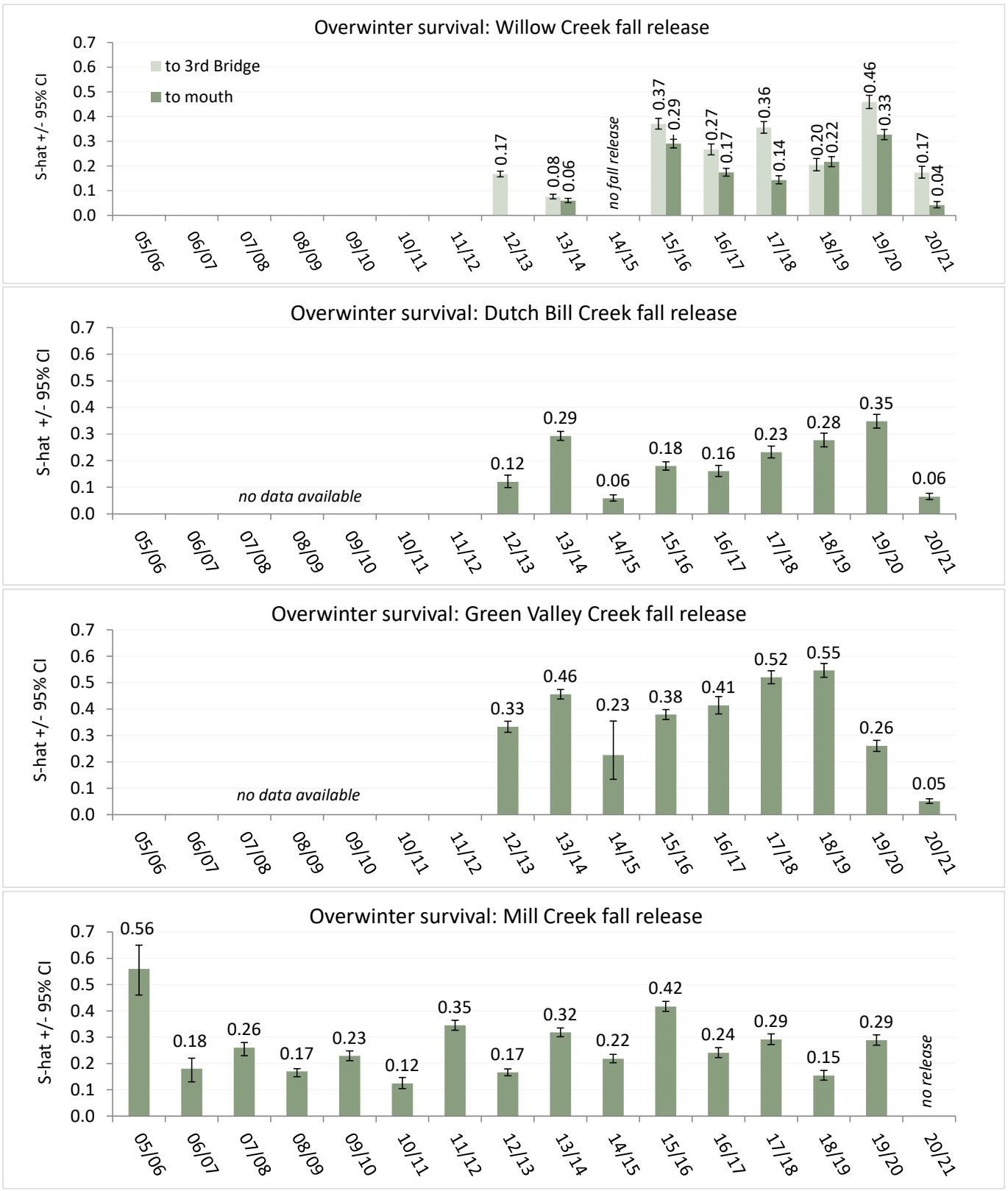

Figure 5. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.

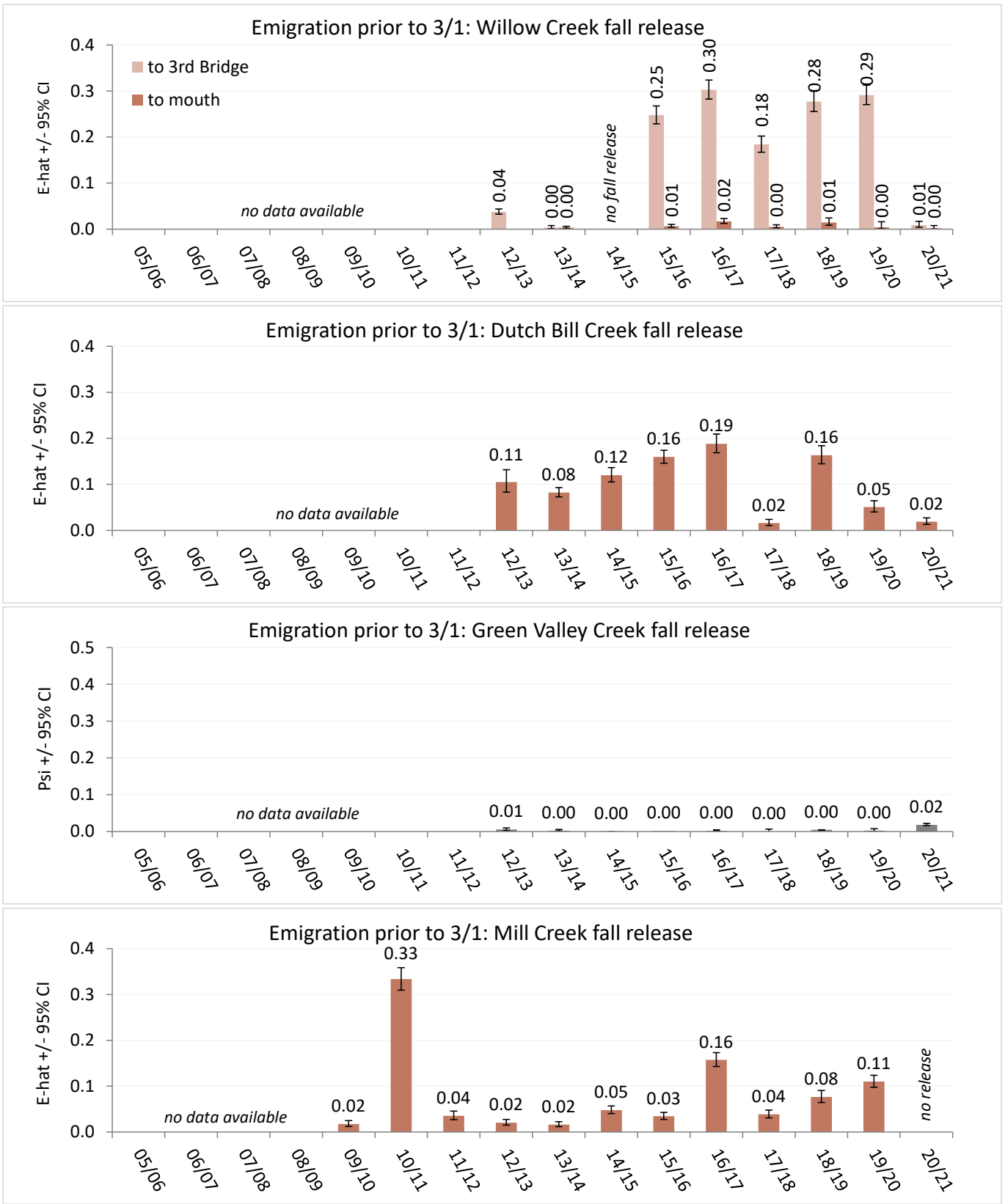

Figure 6. Probability of emigration (E-hat) past antenna sites prior to 3/1 in Willow, Dutch Bill, Green Valley, and Mill creeks.

2.3.6. Migration timing

2.3.6.1. Overview

Weekly totals of out-migrating smolts were plotted by release group and antenna site within the watershed for the period of October 29, 2020 to June 30, 2021 and compared with stream depth (stage height) data from each creek (Figure 7-Figure 14; 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, 0.41 river 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. No timing graphs are shown for Mill Creek because no fish were released in that stream in 2020/21.

2.3.6.2. Fall release group

In Willow, Dutch Bill, and Green Valley 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 8, Figure 10, and Figure 12). 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 Green Valley creeks and lower emigration from Willow Creek. In Dutch Bill Creek, the majority of the winter emigrants left the creek during a storm event in late January/early February (Figure 9, Figure 10), whereas in Green Valley Creek, the largest pulse of early emigrants left during a storm event in the middle of December (Figure 11, Figure 12).

Winter detections on antenna arrays located higher up in each watershed occurred in Dutch Bill and Green Valley creeks, but not in Willow Creek (Figure 7-Figure 14).

2.3.6.3. Pre-smolt and smolt release groups

Immediately following both the pre-smolt and smolt release groups on Green Valley Creek at river km 7.80, we observed an immediate pulse of fish moving downstream past the lower antenna array at river km 6.13 (Figure 13, Figure 14). There were few detections following these initial downstream pulses, indicating that almost all the fish from each of these release groups moved downstream immediately following release.

Of interest, a few fish moved upstream after the pre-smolt release, as detected on the middle antenna array at river km 9.98 (Figure 13). No fish were detected on the upper antenna array at river km 13.40, indicating the fish did not move that far upstream. No smolts were detected on the middle or upper antenna sites.

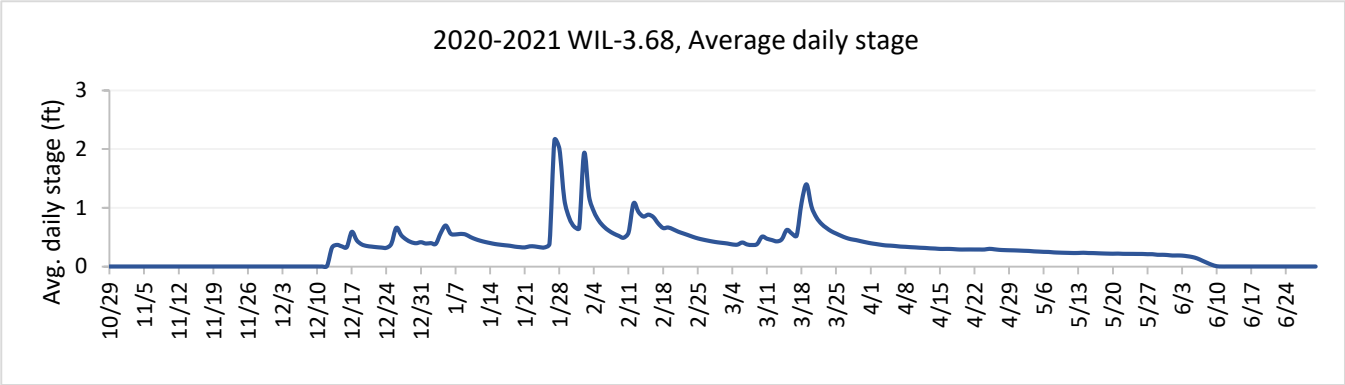

Figure 7. Average daily stage height at the Willow Creek smolt trap site (river km 3.68) between October 29, 2020 and June 30, 2021.

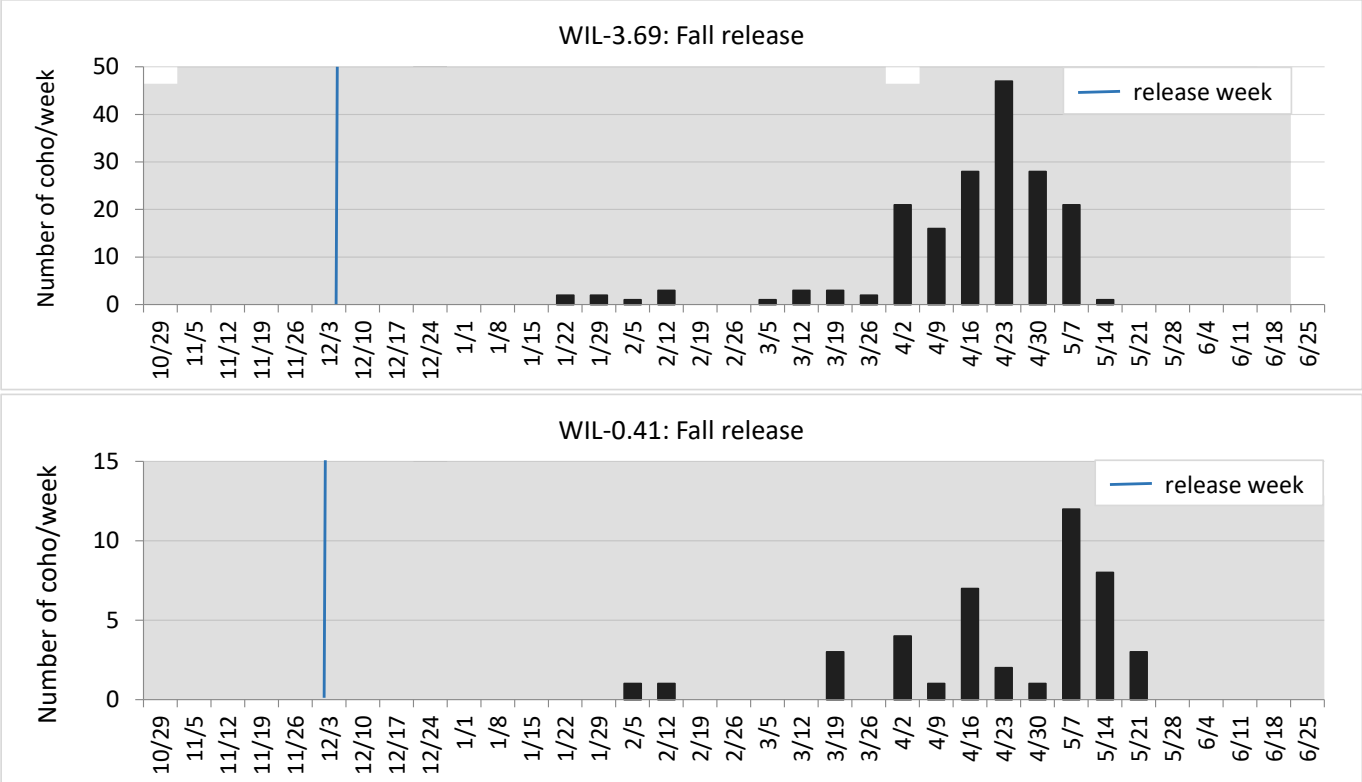

Figure 8. Number of fall-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2020 and June 30, 2021. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released between river km 5.48 and 6.39.

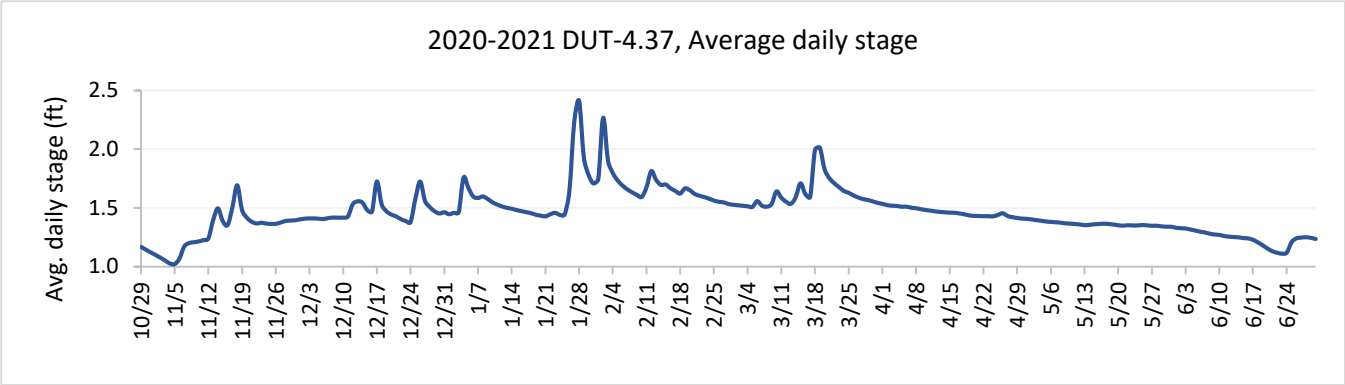

Figure 9. Average daily stage height at Dutch Bill Creek (river km 4.37) between October 29, 2020 and June 30, 2021. Data were provided by Trout Unlimited.

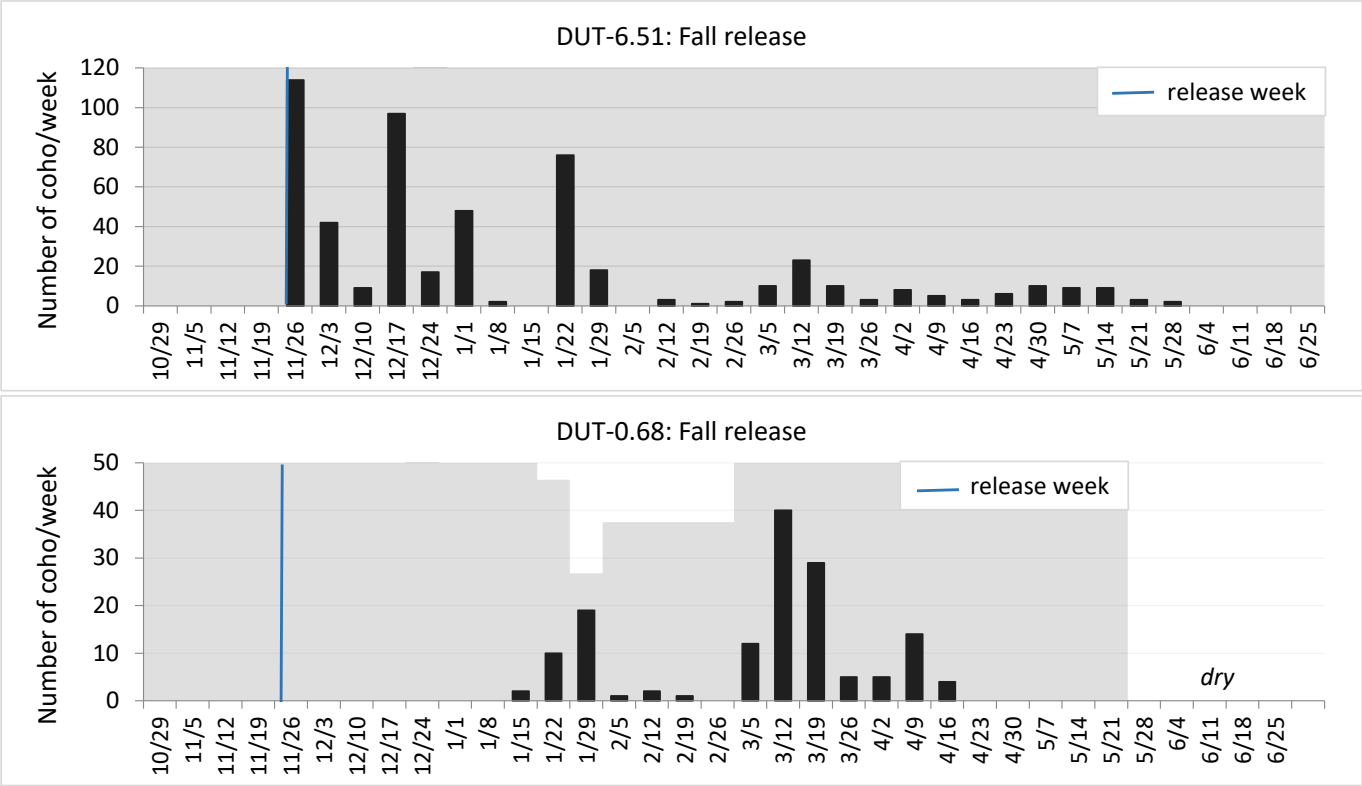

Figure 10. Number of fall-release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and the smolt trap site (DUT-0.68) each week between October 29, 2020 and June 30, 2021. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released between river km 6.04 and 9.57.

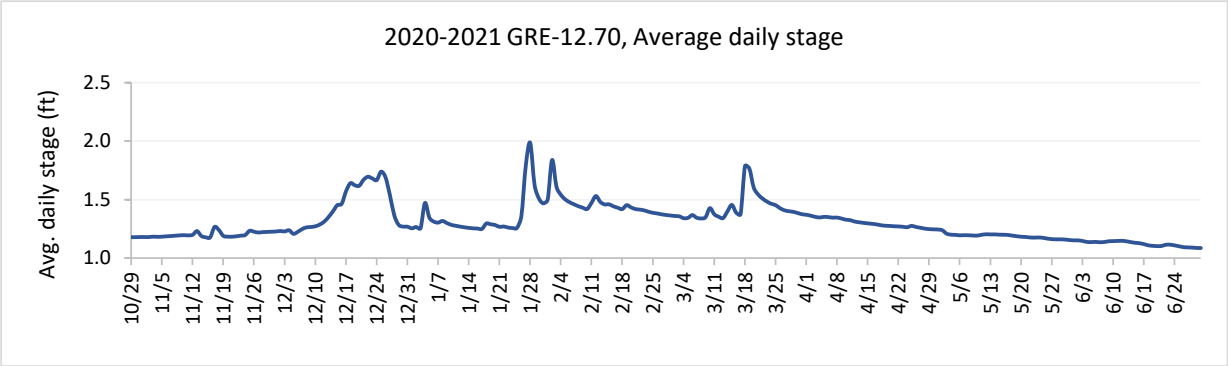

Figure 11. Average daily stage height on Green Valley Creek (river km 12.70) between October 29, 2020 and June 30, 2021. Data were provided by Trout Unlimited.

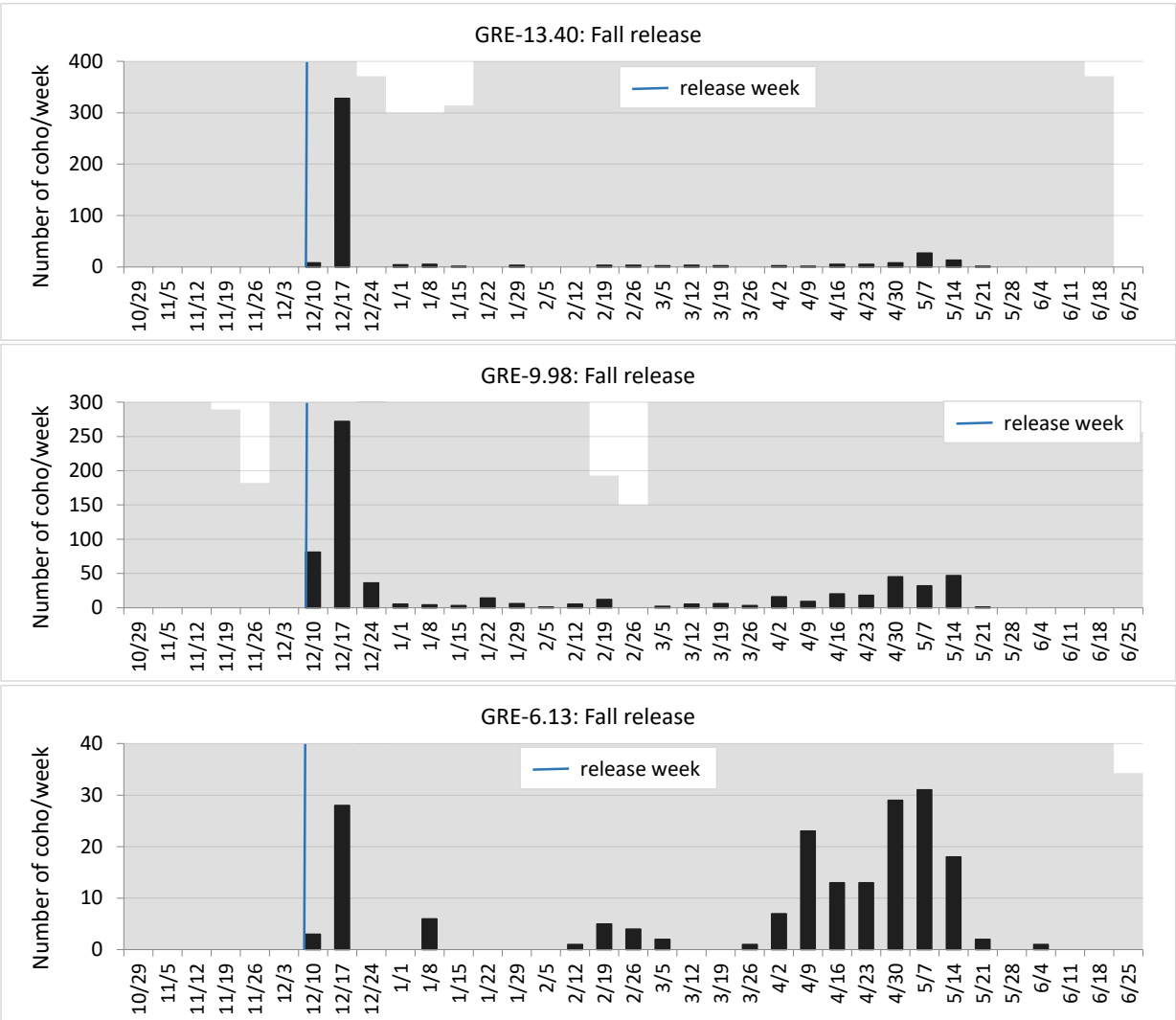

Figure 12. Number of fall-release coho salmon that moved past the upper (GRE-13.40) and middle (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2020 and June 30, 2021. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released between river km 12.57 and 14.39.

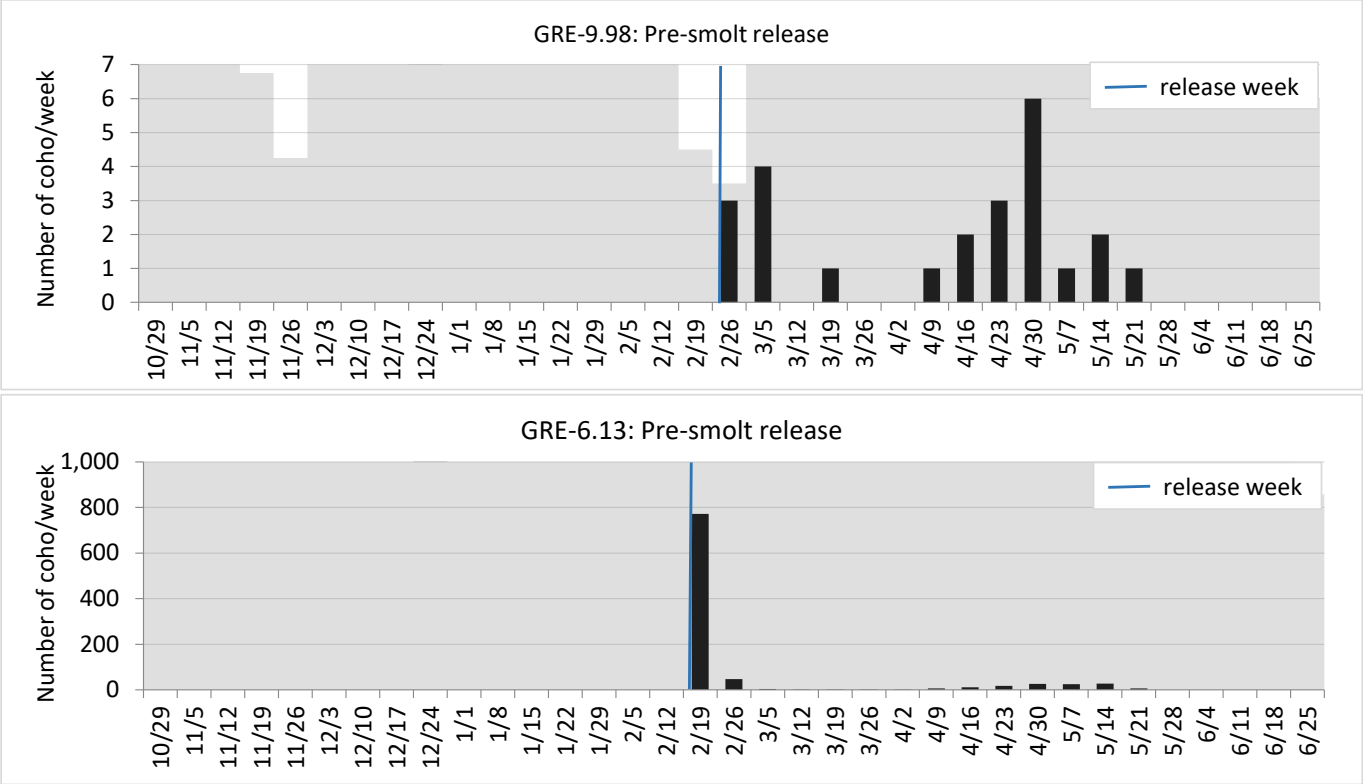

Figure 13. Number of pre-smolt-release coho salmon that moved past the middle (GRE-9.98) Green Valley Creek antenna site and the smolt trap site (GRE-6.13) each week between October 29, 2020 and June 30, 2021. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 7.80.

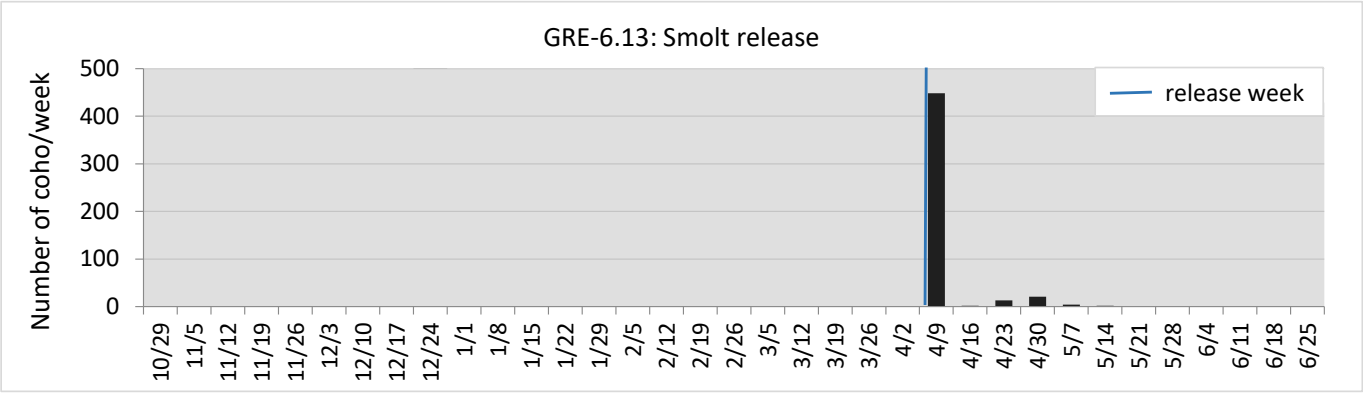

Figure 14. Number of smolt-release coho salmon that moved past the Green Valley Creek smolt trap site (GRE-6.13) each week between April 6, 2021 (when they were released) and June 30, 2021. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 7.80.

2.3.7. Size

In all Broodstock Program intensive monitoring watersheds, the average size at release increased progressively with the age of the fish (fall < pre-smolt < smolt), and within release groups only slight differences were observed among streams. Average sizes across all 2020 cohort Broodstock Program release groups were 90.4 mm and 9.3 g (fall), 103.4 mm and 13.7 g (pre-smolt), and 116.5 mm and 19.0 g (smolt) (Table 9).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 109.2 mm and 13.8 g in Dutch Bill Creek to 119.9 mm and 19.1 g in Green Valley Creek (Table 10). Average fork length and weight of smolts captured in Willow Creek (110.6 mm and 14.9 g) and Mill Creek (111.3 mm and 15.5 g) were intermediate.

Natural-origin coho salmon smolts were larger than their hatchery-origin counterparts in all streams except Dutch Bill Creek, but these differences were generally minimal. Green Valley Creek natural-origin smolts were the largest among all groups, averaging 120.7 mm and 19.4 g (Table 10).

Table 9. Average fork length (mm) and weight (g) of cohort 2020 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	86.2 (±12.2)	8.5 (±3.6)	1,000
Dutch Bill Creek	Fall	93.6 (±9)	10 (±3.1)	1,731
	Smolt	113.7 (±9.8)	17.6 (±4.6)	385
Green Valley Creek	Fall	89.9 (±11.3)	9.1 (±3.6)	2,426
	Pre-smolt	103.4 (±11.2)	13.7 (±4.4)	1,521
	Smolt	119.1 (±12.4)	20.4 (±6.4)	549

Table 10. 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 2021 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	110.3 (±9.8)	14.8 (±3.7)	593
Natural	112.6 (±8)	15.7 (±3.3)	91
All smolts	110.6 (±9.6)	14.9 (±3.6)	684
Dutch Bill Creek			
Hatchery	110.2 (±9)	14.2 (±3.2)	58
Natural	107.4 (±11)	13.1 (±4.2)	34
All smolts	109.2 (±9.8)	13.8 (±3.6)	92
Green Valley Creek			
Hatchery	119.9 (±9.7)	19.1 (±4.7)	415
Natural	120.7 (±8.2)	19.4 (±3.8)	35
All smolts	119.9 (±9.6)	19.1 (±4.6)	450
Mill Creek			
Hatchery	110.8 (±7.1)	15.8 (±3.9)	6
Natural	111.3 (±7.4)	15.5 (±3.3)	172
All smolts	111.3 (±7.4)	15.5 (±3.3)	178

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 and release groups (Table 11, Figure 15). Average growth generally increased with length of time in the stream, although in Green Valley Creek pre-smolt release fish grew more than fall release fish despite having been in the stream for an average of 55 fewer days (Table 11). In the fall release group, PIT-tagged smolts recaptured in Green Valley Creek grew more than those from Willow and Dutch Bill creeks in both absolute size since release and average daily growth rate.

Growth rates for fall-release fish captured in the downstream migrant traps in 2021 were higher than rates observed in 2020 but comparable to rates observed in 2019 across the three streams stocked in 2021 (Figure 16). Except for 2020, Green Valley Creek has consistently shown the highest growth rates of the four Broodstock Program watersheds, and this pattern held in 2021 (Figure 16). Because Green Valley Creek smolt and pre-smolt releases have taken place at different times over the past four years, it is possible to examine growth rates relative to release date for these fish. Green Valley Creek release groups have shown a decrease in growth rate with later release dates; however, in 2021 growth rates were slightly higher for the later release (Figure 17).

Table 11. Average growth in fork length (mm) and weight (g) of recaptured PIT-tagged coho salmon smolts during the 2021 downstream migrant trapping season, by release group and stream.

Release season	Average growth length (SD)	Average growth weight (SD)	Number of recaptures	Average days since release (SD)
Willow downstream migrant trap				
Fall	18.6 (±8.5)	4.6 (±2.9)	79	151 (±12)
Dutch Bill downstream migrant trap				
Fall	12.8 (±8)	3.7 (±3.7)	12	133 (±17)
Green Valley downstream migrant trap				
Fall	22.0 (±6.7)	7.5 (±4.4)	28	146 (±18)
Pre-smolt	25.1 (±8.8)	8.7 (±4)	19	91 (±13)
Smolt	11.3 (±3.6)	2.0 (±1.2)	9	38 (±10)

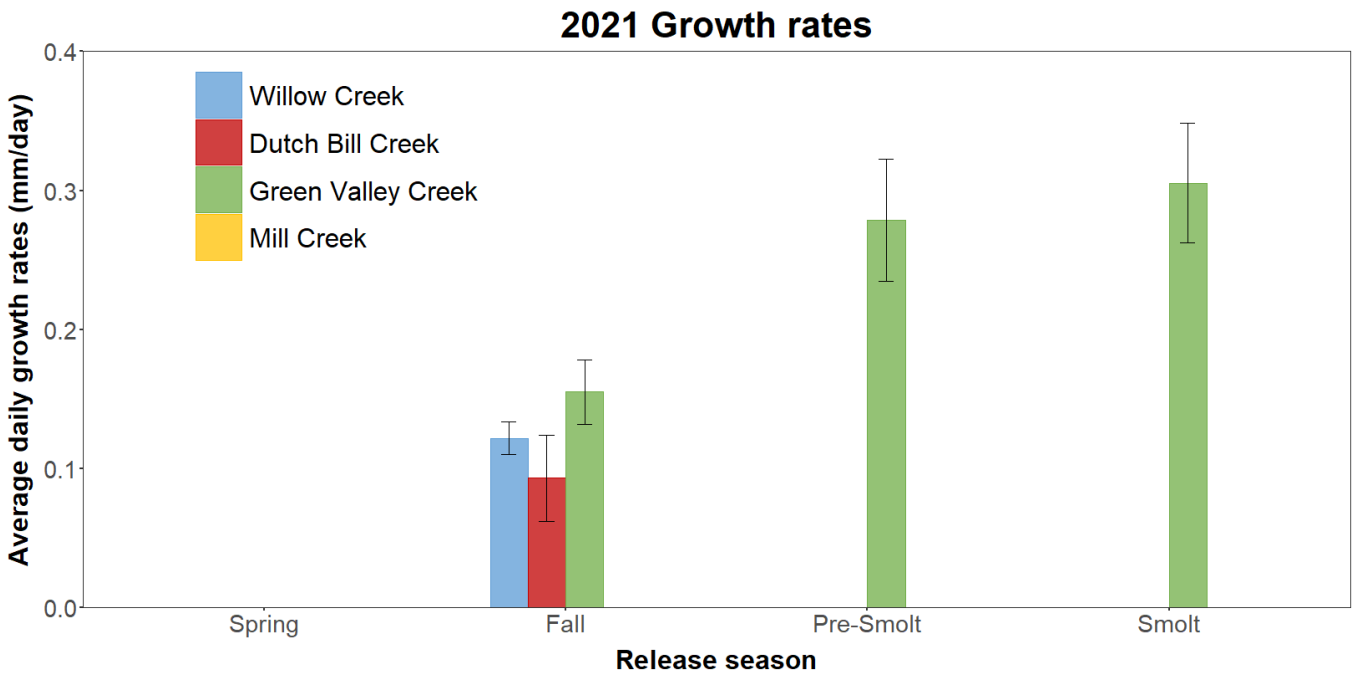

Figure 15. Average daily growth rates in fork length (mm) of PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2021 season, by stream and release group.

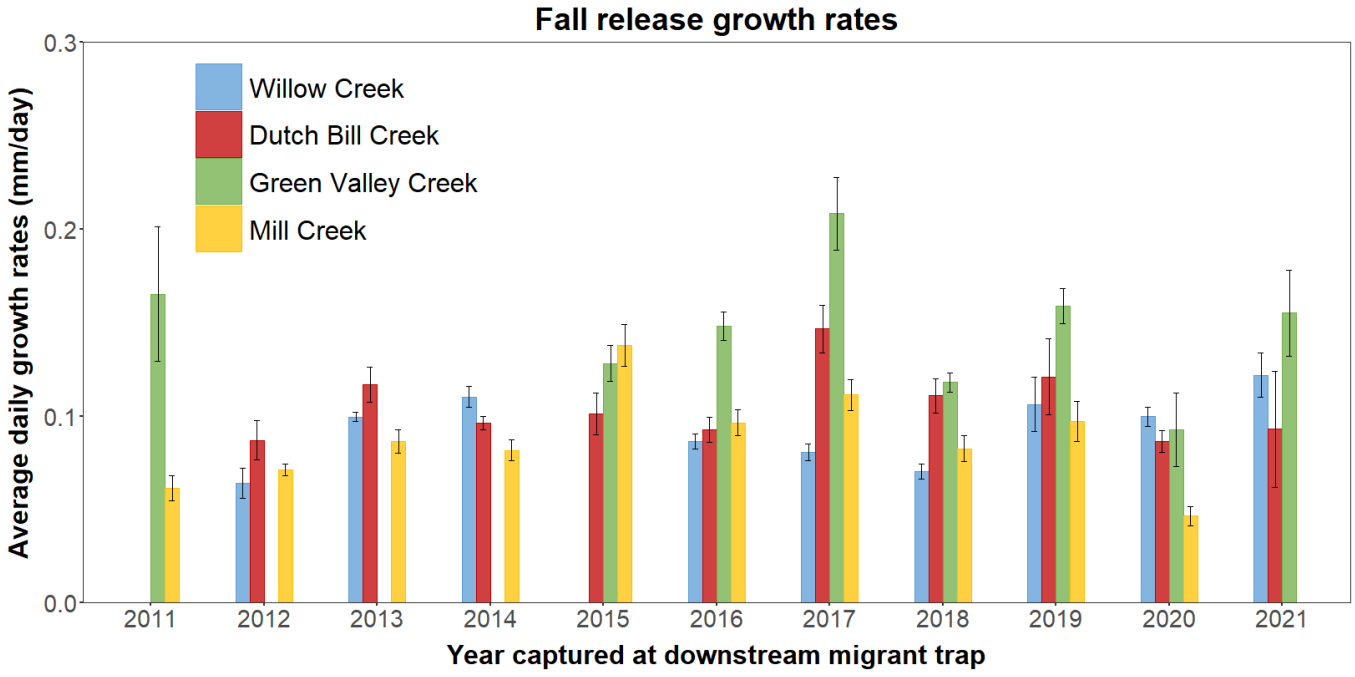

Figure 16. Average daily growth rates in fork length (mm) of fall-release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2021.

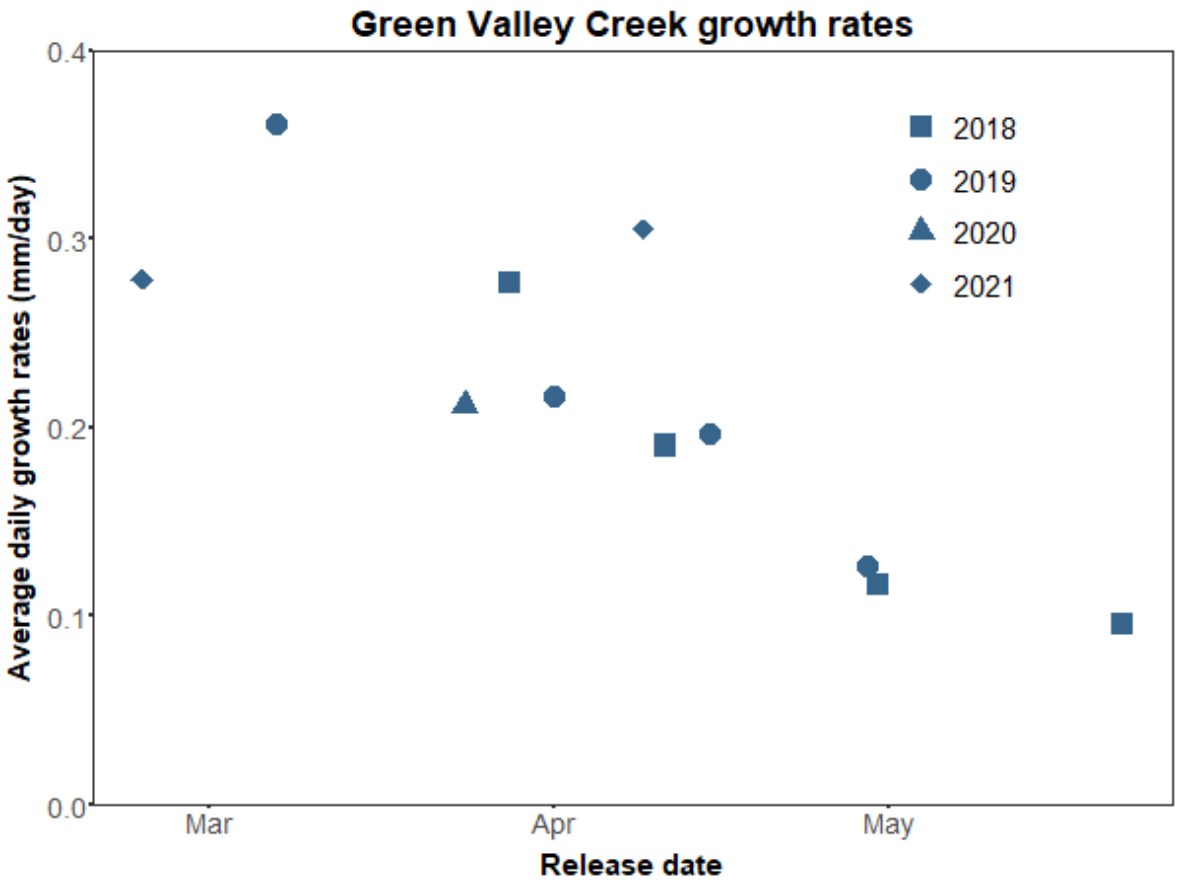

Figure 17. Average growth rates for pre-smolt and smolt release groups in Green Valley Creek over the past four years, by release date.

3. Discussion and Recommendations

Rainfall during the winter of 2020/21 was well below average, with October to June precipitation at the Venado gage in the headwaters of Mill Creek totaling 28.3 inches, which was 24.8 inches lower than the 10-year average (according to raw gage data from NOAA's California Nevada River Forecast Center). As a result of low precipitation through the winter and the culmination of dry conditions over multiple preceding drought years (see www.drought.gov/states/california for more information), streamflow levels for much of the winter and spring were extremely low. Furthermore, in all four streams, we observed streamflow disconnection earlier than in preceding years, and prior to the end of the typical smolt migration window (March – June). These early disconnections undoubtedly inhibited fish passage and are a likely cause for lower than average trap counts and lower than average survival estimates (Table 3, Figure 5).

Streamflow disconnections were documented on all four Broodstock Program intensive monitoring watersheds during the March – June trapping season, and the location of disconnections relative to our trap and antenna sites (upstream or downstream), made it difficult to assess the number of fish that successfully outmigrated from each stream. In Mill Creek, disconnection was first observed on April 15, downstream of our trapsite. From that date forward we continued to operate the trap, but released the fish downstream of the disconnection point. In Willow Creek, it was challenging to evaluate flow conditions downstream of our trap due to the highly braided

and thickly vegetated nature of the stream. However, since we operated additional antennas at the mouth of the creek, we were able to evaluate whether coho smolts were successful in navigating the lower segment between the trap and the stream mouth. Beginning in early April, we observed a dramatic reduction in the proportion of tagged fish released after capture in the Willow Creek trap that were detected at the mouth of the stream, and by late April, that proportion had dropped to zero (Figure 18). At that point, we presumed that passage was blocked between the two antenna sites and on May 7, we began releasing smolts downstream of our lowest antenna site so that fish could access the Russian River. In both Mill and Willow creeks, we captured the majority of the fish after the streams were disconnected from the Russian River (Figure 19). Had we not release these fish downstream of the trap, very few smolts would have had access to the mainstem of the Russian River.

The point of disconnection in Dutch Bill Creek occurred upstream of the smolt trap and Sonoma Water operated the trap until disconnection occurred in early May. We can therefore presume that all fish captured in the Dutch Bill trap were able to access the Russian River. In Green Valley, we suspected that the point of disconnection occurred downstream of our trapsite; however, we did not have access to the channel downstream of our trapsite to identify the location of disconnection, and we did not have an antenna near the mouth to determine whether fish were reaching the mouth. We are therefore uncertain what proportion of the fish we captured in the Green Valley trap actually reached the mainstem of the Russian River. In future years, it would be beneficial to operate an antenna at the mouth of Green Valley Creek. Limitations on landowner access has prevented that in the past, but it is worth revisiting in case that is an option.

Overwinter survival of fall-release fish across the three stocked and monitored Broodstock Program watersheds was the lowest our program has ever recorded (Figure 5). Given the low flow conditions we observed in 2021, it is likely fish were stranded upstream of our trap and lower antenna sites. This theory is supported by the large number of coho salmon parr observed during the summer 2021 snorkel surveys, which follows the trapping season. A fourfold increase in the number of coho parr were observed relative to the five-year average across the four Broodstock Program intensive monitoring watersheds (Zac Reinstein, CSG, personal communication). In Dutch Bill Creek, we observed 393 parr compared to a five-year average of 16, in Willow Creek we observed 129 compared to the five-year average of 38, and in Green Valley Creek we observed 417 compared to the five-year average of 85. Of interest, these parr were distributed across multiple pools in each stream indicating little movement (or aggregation) over the spring or subsequent movement back upstream following attempts to emigrate. We observed these fish during early summer snorkeling surveys; however, their probability of survival to the fall is low given the extreme stream drying that occurred during the 2021 dry season.

Although the average proportion of natural-origin smolts captured across the four Broodstock Program intensive monitoring watersheds was higher than in previous years (19%) in the 2021 trap year, the total number captured (373) was still very low, and this total has been less than a thousand since 2019 (Table 5). We had high hopes that the large number of coho yoy observed during snorkel surveys in 2020 (California Sea Grant 2020b), especially in the Broodstock Program watersheds, would result in high counts of natural-origin smolts during the 2021 downstream migrant season. However, dry conditions over 2020 and 2021 have been unfavorable for coho survival and we did not observe the anticipated pulse of natural-origin spring migrants. The low numbers of natural-origin smolts observed during the past three years is a concerning trend and could be an indication of poor recruitment during drought conditions.

For all release groups in Green Valley this year, we observed immediate emigration of at least some proportion of the fish past our downstream-most antenna array (Figure 12-Figure 14). This is noteworthy for the fall release group given that in previous years we did not detect fall release fish at the lower (GRE-6.13) antenna until spring.

We suspect that the immediate emigration of the fall-release fish could be related to a high flow event in mid-December (Figure 11), though this tendency to emigrate is not something we have observed in previous winters with larger storms. For the pre-smolt and smolt release groups, we were left speculating as to why nearly all of the fish emigrated past the GRE-6.13 antenna site so quickly compared to previous years when they left over a period of weeks to months (California Sea Grant 2019; California Sea Grant 2020a). Unlike the fall-release fish, the movement of these two groups was not tied to high flow conditions. It is possible that the fish cued into unfavorable conditions in Green Valley Creek or that they were at a more advanced state of development than fish released in previous years, either of which could have prompted earlier emigration.

Overall, the unprecedented low flow conditions during the spring of 2021 appeared to have a strong negative impact on both hatchery- and natural-origin coho salmon smolts by disrupting their migratory pathway to the ocean. While in previous years, we have occasionally observed certain streams disconnecting during the smolt migration window, in 2021 early spring disconnections occurred in most Russian River coho salmon streams. While releasing fish downstream of disconnection points on Willow and Mill creeks increased the number of smolts that made it to the mainstem of the river, this could not be achieved on other Broodstock Program stocking streams that are not intensively monitored. For many of these streams, CDFW conducted fish rescues to relocate trapped coho smolts to the mainstem of the river. While such emergency measures to transport fish around points of disconnection may help a specific cohort, longer-term solutions are necessary for achieving long-term population viability.

For natural-origin fish, the compounded impacts of extensive stream drying during their first summer of life in 2020 along with early disconnections blocking passage during their smolt migration, left them little probability of survival. Furthermore, a recent study conducted by SW in partnership with ACOE, indicated that survival of coho smolts through the Russian River mainstem and estuary was extremely low during spring 2021 (0.16 from Dry Creek to the estuary, Gregg Horton, SW, personal communication). This suggests that even if fish successfully outmigrated from the tributaries, very few of them likely made it to the ocean. Given these impediments to survival during drought in both the tributaries and mainstem Russian River, in future drought years, we recommend releasing pre-smolts and smolts at the head of the estuary rather than in the tributaries to give them the highest chance of survival. We also recommend releasing fish earlier in the spring (before May) in drought years to avoid entrapment in the estuary caused by early bar closures.

To promote the re-establishment of self-sustaining coho populations, it is critical that we address the limiting factor of low streamflow in the Russian River watershed, not only during the summer dry season, but also in the spring when coho smolts are attempting to migrate to the ocean. Support for streamflow enhancement work is needed on a watershed scale and the focus should be extended from the summer dry season to include the spring smolt migration period beginning in March. We also encourage habitat enhancement efforts that promote fish passage during low streamflow conditions. For multiple years, we have observed a reduction in fish passage in the lower reaches of Willow Creek during low flow conditions, so habitat enhancement efforts to improve passage could greatly increase smolt production in that watershed. Similarly, if there are physical enhancements that could extend the window of connectivity in the alluvial reaches of Mill, Dutch Bill and Green Valley creeks, we recommend support for that work.

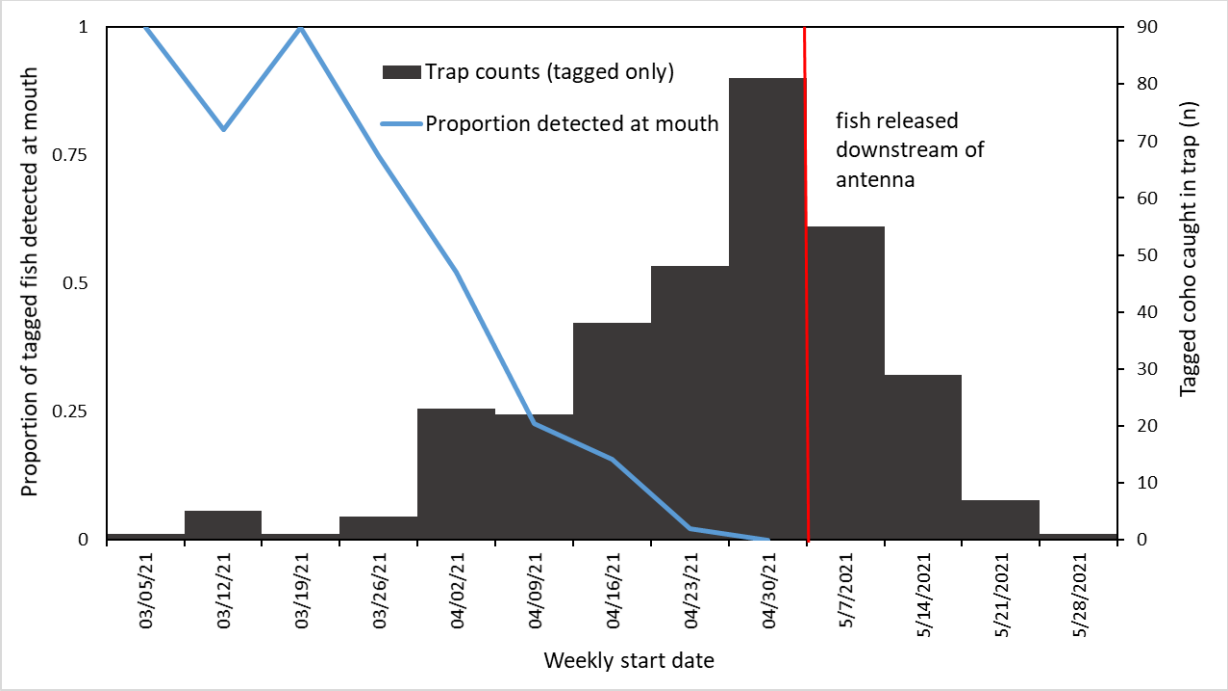

Figure 18. Weekly proportion of PIT tagged coho salmon caught and released at the trap site on Willow Creek that passed the downstream antenna array near the confluence entering the mainstem of the Russian River in 2021 (blue line) and weekly number of PIT tagged coho salmon caught in the trap. Starting May 7, fish were released downstream of the antenna array (red line). Weekly values were assigned to the first day of each seven-day period.

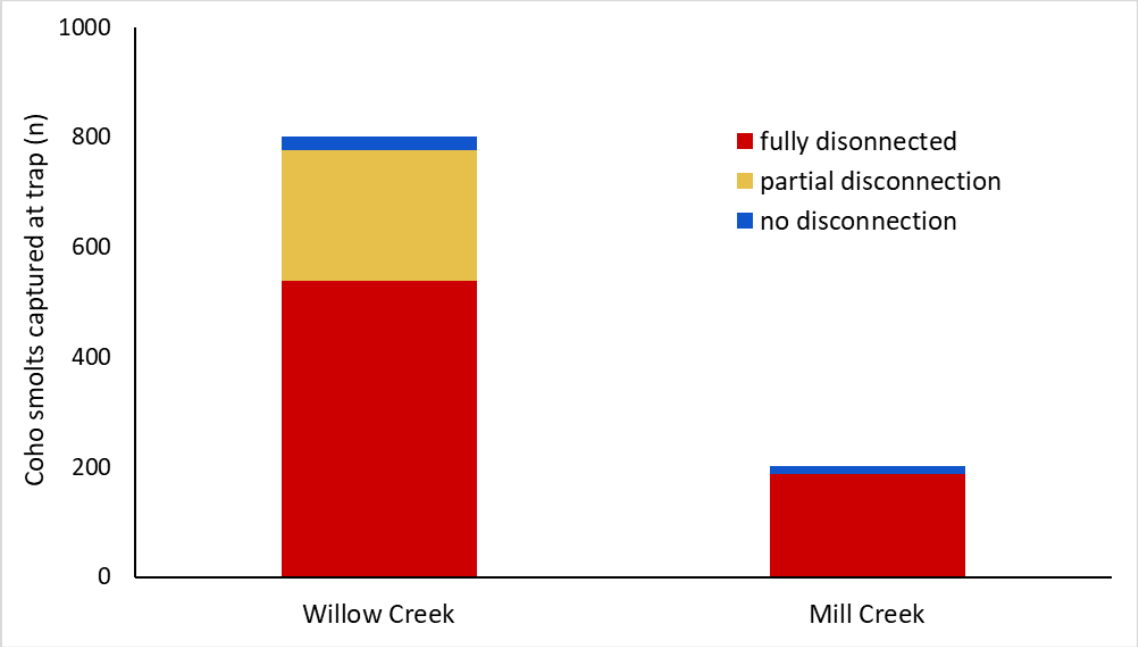

Figure 19. Number of coho smolt captured in traps in Willow and Mill creeks in 2021, with colors indicating whether the stream mouth was connected to the mainstem of the Russian River at the time of capture.

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