California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2020

Prepared by:

Andrew McClary and Mariska Obedzinski

California Sea Grant at University of California
November 2020, Windsor, CA.

1. Contents

Suggested reference: California Sea Grant. 2020. California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2020. Windsor, CA.

2. Background

In 2004, the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) began releasing juvenile coho salmon into tributaries of the Russian River with the goal of re-establishing populations that were on the brink of extirpation from the watershed. California Sea Grant at University of California (UC) 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, UC has been closely monitoring smolt abundance, adult returns, survival, and spatial distribution of coho populations in four Broodstock Program release streams: Willow, Dutch Bill, Green Valley, and Mill creeks. Data collected from this effort are provided to the Broodstock Program for use in adaptively managing future releases.

Over the last decade, UC has developed many partnerships in salmon and steelhead 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 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 several 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 update, 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.

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

3.1. 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 2019 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-tag antenna arrays.

3.2. Methods

3.2.1. Coho releases

Broodstock Program coho salmon were raised by US Army Corps of Engineers (ACOE) personnel at the Don Clausen Fish Hatchery at Warm Springs Dam and released as juveniles into selected Broodstock Program streams in three release groups; spring, fall, and smolt. Fish from the spring release group were stocked as young-of-the-year (yoy) in June 2019, fish from the fall release group were stocked as yoy in December 2019, and fish from the smolt release group were stocked at age-1 in March and April 2020. All fish were planted directly into the streams. Due to low streamflow across the watershed during the spring of 2020, Green Valley Creek was the only Broodstock Program monitoring stream in which smolts were released.

During the late spring and fall seasons, when streamflows were low and thought to impede natural dispersal of fish, biologists stocked fish into individual pools throughout reaches characterized by suitable salmonid habitat (Figure 1). For smolt releases, which occurred when streamflows were high enough to allow fish to disperse naturally throughout the streams, fish were released at point locations (Figure 1).

Figure 1. Map of juvenile coho salmon stocking locations for 2019 cohort (hatch year) in the four Broodstock Program monitoring watersheds.

3.2.2. PIT tagging

Prior to release, approximately 20% of all hatchery juvenile coho salmon were implanted with 12.5 mm full duplex (FDX) PIT tags at the Don Clausen Fish Hatchery at Warm Springs Dam. As part of an oversummer survival study, all juveniles released in the spring into a specific reach of Mill Creek were also PIT-tagged. Coho salmon destined for tagging were randomly selected from holding tanks at the hatchery and, for all fish ≥ 56mm and 2g, a small incision was made on the ventral side of the fish using a scalpel, and the tag was then inserted into the body cavity. The number and percent of PIT-tagged coho salmon by stream and release group for Willow, Dutch Bill, Green Valley, and Mill creeks are shown in Table 1. In addition to hatchery-released fish, wild coho salmon were PIT tagged in the summer of 2019 as part of the CMP life-cycle monitoring effort. These numbers were small relative to the number stocked, with 170 tagged in Green Valley Creek, 79 tagged in Willow Creek, 47 tagged in Dutch Bill Creek, and two tagged in Mill Creek.

Table 1. Number and percent of PIT-tagged juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creek watersheds for the 2019 cohort.

		Number released (% PIT-tagged)			
Release season	**Release dates**	**Willow Creek**	**Dutch Bill Creek**	**Green Valley Creek**	**Mill Creek**
Spring	Jun 15, 2019	0	0	0	511 (100%)
Fall	Dec 2-13, 2019	6,015 (33%)	9,081 (15%)	15,676 (15%)	19,605 (15%)
Smolt	Mar 24 - Apr 27, 2020	0	0	5,077 (20%)	0
Total released		**6,015**	**9,081**	**20,753**	**20,116**

3.2.3. Field methods

3.2.3.1. Stationary PIT antennas

As part of the Broodstock Program monitoring effort, UC 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 2019 through June 2020, PIT-tag detection systems were visited at two-week intervals to download data and check antenna status, with the exception of the early summer season if antenna sites became dry. More frequent visits (approximately daily) were made during storm events.

3.2.3.2. Downstream migrant trapping

Downstream migrant (funnel and/or pipe) traps were operated by UC on Willow, Green Valley, and Mill creeks (Figure 2) between March and June 2020, a window of time that coincides with the majority of the coho salmon smolt outmigration and when the flows are conducive to trap operation in flashy streams. Sonoma Water operated a trap on Dutch Bill Creek during the same time period and coho data from this effort were provided to UC 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. In an effort 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, UC 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. Salmonid yoy ≥35 mm that were captured in the traps were measured, weighed, and released downstream (up to 10 per site/day, after which they were tallied). Tallies were made of all other vertebrates and crustaceans captured.

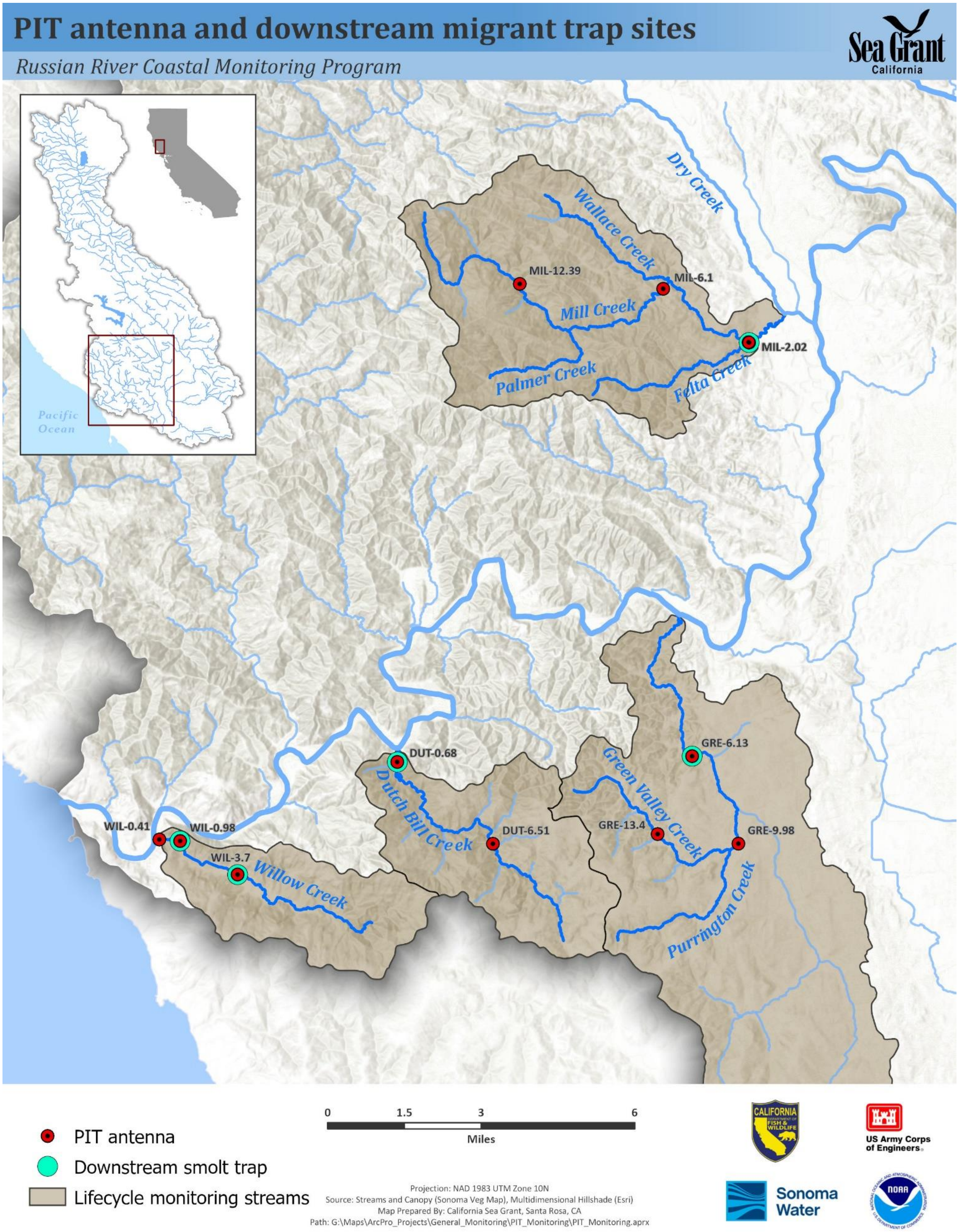


Figure 2. Map showing PIT antenna and smolt trap locations on Broodstock Program monitoring streams, with antenna site codes.

3.2.4. Data analysis

3.2.4.1. 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 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.

3.2.4.2. Smolt abundance

A two-trap mark-recapture design and analytical methodology was used to estimate the total number of coho salmon smolts emigrating from each creek during the trapping season during the time when traps were in (Bjorkstedt 2005; Bjorkstedt 2010). 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.

Because traps were removed for over a month during the 2020 outmigration window due to public health measures implemented in response to Covid-19, trap captures could not be used to calculate outmigration for that period. Instead, antenna detections were used to estimate smolt abundance for that time period. The number of unique PIT tags detected during that time was multiplied by the ratio of untagged to tagged fish observed on each tributary during the period that traps were in operation. This number was then adjusted for the efficiency of each antenna array, as calculated during the survival analysis, in order to estimate smolt abundance over the time period that traps were not in operation. This abundance was then added to the estimated abundance for the period where traps were operating to obtain an estimate for the entire season.

3.2.4.3. 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 6/30/20 and emigration prior to 3/1/20 for multiple release groups (i.e., spring, fall, and smolt) in the four Broodstock Program monitoring streams.

3.2.4.4. 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, 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.

3.2.4.5. Size and growth

All fish PIT-tagged at the hatchery were measured for fork length (mm) and weight (g) within two weeks of 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).

3.3. Results

3.3.1. Trap operation

In 2020, the traps were installed between 3/9 and 3/11 and each trap was operated until the site became disconnected from flow. From 3/18-4/25 trap operation was suspended in order to comply with public health measures implemented in response to Covid-19. Trap operation was resumed once safety protocols were developed and approval for operation was granted by the appropriate authorities. During this time antenna operation continued.

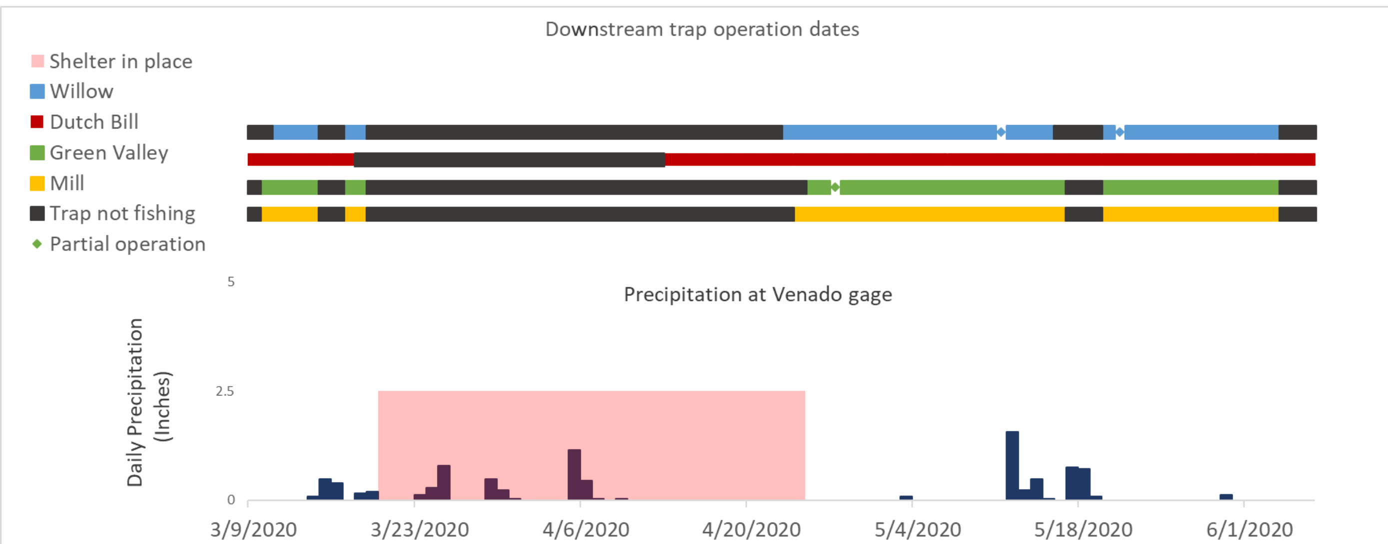


Figure 3. Trap operation dates in relation to precipitation at Venado rain gage in upper Mill Creek watershed. Daily rain totals from raw gage data posted on NOAA's California Nevada River Forecast Center website (http://www.cnrfc.noaa.gov/formPrecipMap.php).

3.3.2. Trap counts

Coho salmon smolt counts from downstream migrant traps on all four study streams in 2020 ranged from 361 in Green Valley Creek to 2,546 in Dutch Bill Creek, with 1,554 in Mill Creek and 1,023 in Willow Creek (Table 2). The percentage of coho smolts of natural-origin ranged from 2.3% in Mill Creek to 12.7% in Dutch Bill Creek (Table 2).

When compared to previous years, coho salmon smolt counts were high in Dutch Bill Creek, low in Willow and Mill creeks, and extremely low in Green Valley 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 smolts, which account for differences in trap efficiency and are summarized in the *Smolt abundance* section of this report.

Although downstream migrant smolt traps targeted the capture of coho smolts and were not operated during the full steelhead and Chinook out-migrant seasons, incidental capture of steelhead and Chinook occurred in 2020. The number of steelhead smolts captured in the traps in 2020 was low, ranging from 0 in Green Valley and Willow creeks to 22 in Mill Creek (Table 3). Chinook salmon smolts (17) were only observed in Dutch Bill 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 three-spined stickleback (402), sculpin (335), and Sacramento pikeminnow (137); in Dutch Bill Creek they were Sacramento pikeminnow (1,235), Sacramento sucker (784), and sculpin (384); in Green Valley Creek they were three-spined stickleback (1,610), bluegill (148), and sculpin (99); and in Mill Creek they were sculpin (193), Sacramento sucker (66), and Sacramento pikeminnow (17) (Table 4). Sacramento pikeminnow numbers in Willow and Dutch Bill creeks were unusually high. Ten freshwater shrimp were captured in Green Valley Creek in 2020, lower than the four previous years (Table 4).

Table 2. Coho salmon smolts captured in traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2020 downstream migrant season.

Stream	Hatchery	Natural	Unknown origin	Total	Percent natural
Willow Creek	926	92	5	1,023	9.0
Dutch Bill Creek	1,491	216	485	2,192	12.7
Green Valley Creek	349	10	1	360	2.8
Mill Creek	1,492	35	27	1,554	2.3

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in downstream migrant traps, years 2005-2020. 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
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
		Yoy	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0	27	2	2
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0	0	0	0	0
		Parr/yoy	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603	77	111	238	17
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5	3	0	0
Dutch Bill Creek	Chinook salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2	8	6	17
	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
		Yoy	NA	NA	NA	NA	NA	0	5	0	2	0	0	18	2	3	1	4
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0	0	2	0
		Parr/yoy	NA	NA	NA	NA	NA	58	31	21	79	1,138	13	74	524	22	140	2,304
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6	1	5	11
Green Valley Creek	Chinook salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	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
		Yoy	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2	3	2	0
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1	1	0	0
		Parr/yoy	1,723	NA	36	497	1	5	3	NA	NA	NA	38	356	11	15	46	32
		Smolt	49	NA	70	29	43	0	1	NA	NA	NA	3	3	12	17	12	0
Mill Creek	Chinook salmon	Smolt	70	128	2	31	1	1	0	11	0	22	0	0	1	1	0	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
		Yoy	24	314	58	43	0	4	329	515	530	0	10	10	30	63	8	202
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	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
		Smolt	116	49	266	176	118	190	97	41	32	13	17	15	32	22	6	22

Table 4. Annual downstream migrant trap counts for common non-salmonid species, years 2005-2020. NA indicates that no trap was in operation.

Origin	Species [1]	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
WILLOW CREEK																	
Non-native	Bluegill	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	1
	Bullfrog	NA	NA	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0	1
	Fathead minnow	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0
	Green sunfish	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	1	0	0	0
Native	California roach	NA	NA	NA	NA	NA	NA	NA	0	1	1	7	0	1	0	0	0
	Freshwater shrimp	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	NA	NA	NA	NA	NA	NA	NA	0	219	0	198	8	36	99	0	137
	Sacramento sucker	NA	NA	NA	NA	NA	NA	NA	1	24	1	46	2	9	4	0	1
	Sculpin sp.	NA	NA	NA	NA	NA	NA	NA	339	4,206	680	2,462	548	2,898	653	1,455	335
	Three-spined stickleback	NA	NA	NA	NA	NA	NA	NA	383	268	296	193	71	496	157	69	402
	Western brook lamprey	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0
DUTCH BILL CREEK																	
Non-native	Bluegill	NA	NA	NA	NA	NA	0	0	0	0	2	0	4	19	1	3	9
	Bullfrog	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0	0	1	0
	Fathead minnow	NA	NA	NA	NA	NA	0	0	0	0	0	2	98	2	0	0	0
	Green sunfish	NA	NA	NA	NA	NA	0	1	0	0	5	20	8	21	3	4	12
Native	California roach	NA	NA	NA	NA	NA	130	129	59	725	3	252	94	28	14	1	5
	Freshwater shrimp	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	NA	NA	NA	NA	NA	22	95	1	412	0	27	50	18	156	23	1,235
	Sacramento sucker	NA	NA	NA	NA	NA	8	178	1	307	4	25	106	265	51	7	784
	Sculpin sp.	NA	NA	NA	NA	NA	8	393	437	1,204	136	974	440	323	276	452	384
	Three-spined stickleback	NA	NA	NA	NA	NA	9	7	56	517	2	5	46	4	2	307	91
	Western brook lamprey	NA	NA	NA	NA	NA	0	0	1	0	0	1	1	1	18	16	1
GREEN VALLEY CREEK																	
Non-native	Bluegill	627	NA	68	21	59	155	1	NA	NA	NA	3	137	472	659	551	148
	Bullfrog	10	NA	42	7	5	57	1	NA	NA	NA	4	11	171	37	8	7
	Fathead minnow	15	NA	14	0	22	89	54	NA	NA	NA	96	59	65	32	5	0
	Green sunfish	40	NA	4	0	31	12	0	NA	NA	NA	25	32	133	209	35	5
Native	California roach	211	NA	497	498	298	776	53	NA	NA	NA	314	54	51	48	92	82
	Freshwater shrimp	8	NA	0	1	9	36	4	NA	NA	NA	318	33	26	13	30	10
	Sacramento pikeminnow	62	NA	104	95	93	17	32	NA	NA	NA	70	7	14	6	33	21
	Sacramento sucker	53	NA	79	178	90	3	3	NA	NA	NA	64	25	36	24	2	17
	Sculpin sp.	371	NA	474	370	602	420	24	NA	NA	NA	192	62	365	145	368	99
	Three-spined stickleback	1,699	NA	253	1,497	409	5,606	56	NA	NA	NA	373	167	11,931	2,309	2,191	1,610
	Western brook lamprey	5	NA	69	44	71	105	0	NA	NA	NA	109	160	148	48	52	16
MILL CREEK																	
Non-native	Bluegill	54	11	1	2	7	66	120	127	3	29	4	56	71	72	17	2
	Bullfrog	666	20	27	52	56	462	84	300	65	41	11	12	74	73	11	0
	Fathead minnow	22	13	13	6	109	150	25	4	4	0	14	103	68	128	22	1
	Green sunfish	35	5	1	0	12	6	5	1	3	5	6	22	16	12	42	5
Native	California roach	110	65	84	60	341	198	116	151	363	20	258	114	453	146	149	0
	Freshwater shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sacramento pikeminnow	29	27	12	16	49	99	87	21	7	0	82	9	152	6	40	17
	Sacramento sucker	100	38	38	89	47	99	81	33	36	0	68	3	71	6	17	66
	Sculpin sp.	895	4,066	414	704	431	372	398	669	966	60	105	675	719	542	359	193
	Three-spined stickleback	0	0	0	0	0	1	7	17	1	1	3	2	6	5	1	0
	Western brook lamprey	3	3	9	9	11	8	0	0	0	0	0	1	0	0	0	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.*

3.3.3. Natural production

Natural-origin coho salmon smolts were observed in all four Broodstock Program monitoring streams in low percentages. Dutch Bill Creek had the highest number and percent natural-origin in the past five years while Green Valley Creek had the lowest observed over the last five years. Willow and Mill creeks were slightly below average (Table 5).

Table 5. Number and percent of natural-origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2020. NA indicates that no trap was in operation.

Year	Willow Creek			Dutch Bill Creek			Green Valley Creek			Mill Creek		
	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

3.3.4. Smolt abundance

Smolt abundance estimates indicate that thousands of smolts emigrated from each of the four Broodstock Program monitoring tributaries during the spring of 2020. Smolt abundance was highest in Green Valley Creek; however, Green Valley Creek had the highest number of total fish released and was the only creek in which smolts were released (Table 6). Abundance was lowest in Willow and Dutch Bill creeks; however, this was to be expected as the number of fish released was lower than on Green Valley and Mill creeks. The proportion of fish that were estimated to have out-migrated while traps were out was low for all streams except for Green Valley, where approximately half of the smolts were estimated to leave when traps were out (Figure 4**Error! Reference source not found.**). Abundance estimates were below average compared to the past five years in all four streams in 2020 (Figure 5).

Table 6. Number of cohort 2019 juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creeks and estimated number of coho salmon smolts emigrating from each tributary during spring of 2020. Abundance estimates include both marked and unmarked smolts.

Tributary	Number released				Estimated smolt abundance (95% CI)
	Spring	Fall	Smolt	Total	
Willow Creek	0	6,015	0	6,015	2,348 (93)
Dutch Bill Creek	0	9,081	0	9,081	3,576 (181)
Green Valley Creek	0	15,676	5,077	20,753	12,113 (1,567)
Mill Creek	511	19,605	0	20,116	5,460 (460)

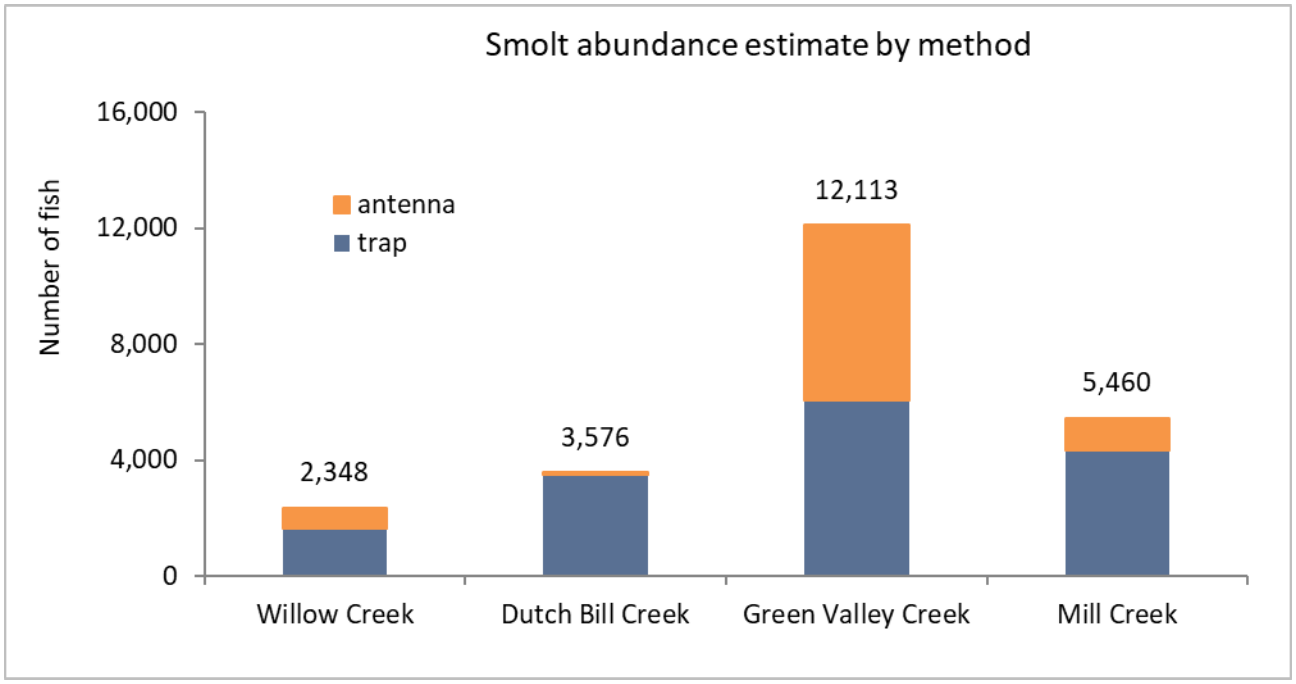


Figure 4. Estimated abundance of coho salmon smolts emigrating from Broodstock Program monitoring streams during the spring of 2020. Antenna counts were used to generate abundance estimates for the period of time that traps were removed due to Covid-19 restrictions.

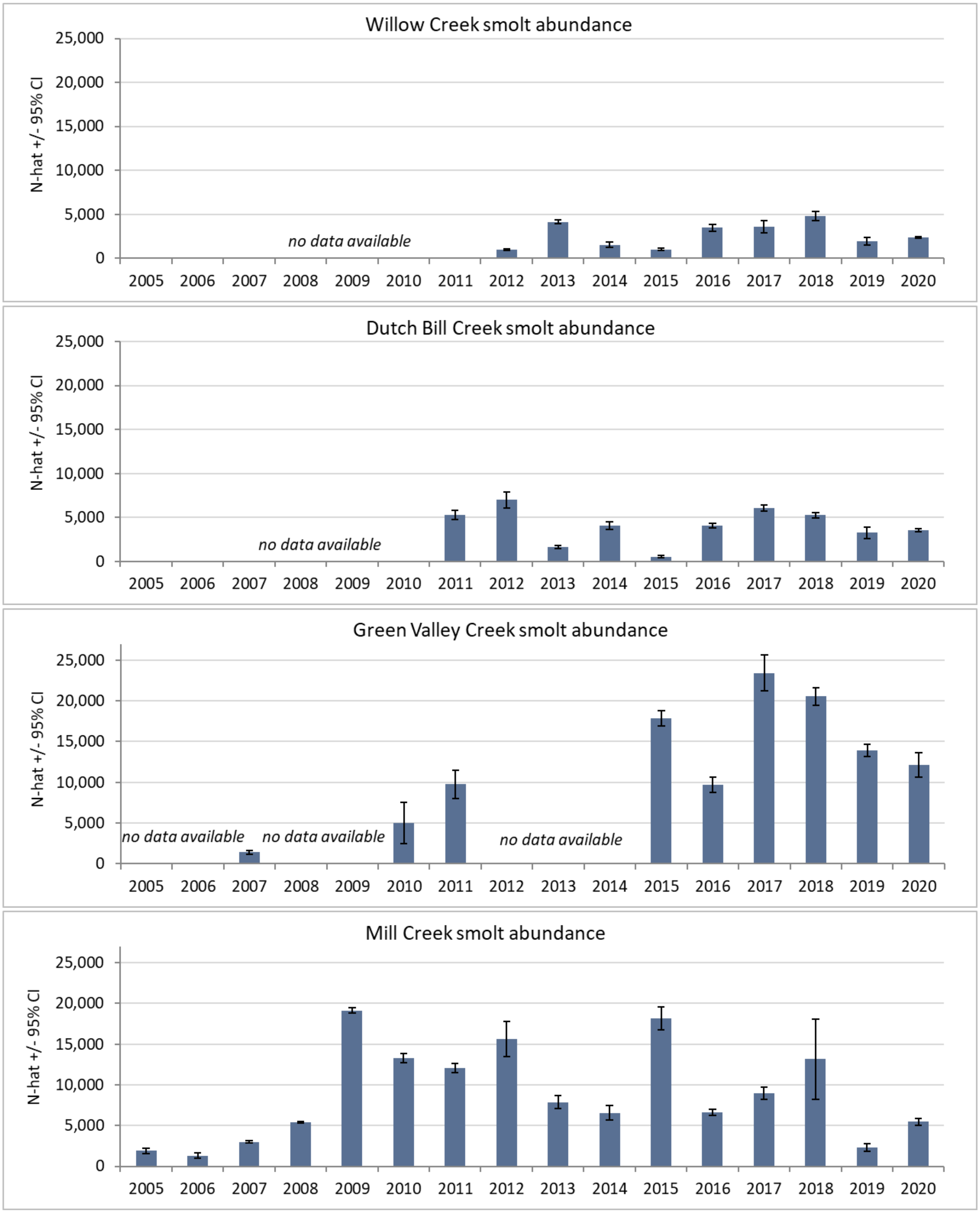


Figure 5. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2020.

3.3.5. Probability of survival and early winter emigration

In 2019, the Broodstock Program released only 511 fish in the spring in Mill Creek for the purpose of continuing a summer survival dataset. These fish were released into one 250 m-long, long-term study reach in upper Mill Creek rather than distributed evenly throughout the watershed. The estimated probability of survival of this group of juvenile coho salmon from the time of release on 6/15/19 through 6/30/20 (approximately one year later) was 0.12 (Table 7), which was equal to the 12-year average (CA Sea Grant unpublished data). It is important to recognize that the spring-release survival estimates presented in Table 7 only represent survival of fish stocked into this one reach and therefore inferences cannot be made about survival in the entire stream.

The estimated probability of survival of fall-release juvenile coho in all streams, from the time of release in December 2019 through 6/30/19 was higher than for the spring release, ranging from 0.26 on Green Valley Creek to 0.35 on Dutch Bill Creek (Table 7). When comparing fall-release survival estimates with previous years' estimates, survival over the winter of 2019/20 was lower than average for Green Valley Creek and higher than average for Mill Creek, and the highest observed on Willow and Dutch Bill creeks (Figure 6).

The estimated probability of survival for the smolt-release group on Green Valley Creek varied by time of release (Table 8). The group released on 3/24/20 had a significantly higher survival probability than the group released on 4/27/20 (0.85 and 0.13, respectively).

The estimated probability of spring-release juvenile coho salmon emigrating from Mill Creek prior to March 1 was 0.01 (Table 9). For the fall release group, estimates of early emigration ranged from 0.00 in Willow and Green Valley creeks to 0.11 in Mill Creek. 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. Early winter emigration probability past the antennas at the trap site was 0.29, but past the antennas at the mouth was zero, suggesting that fish that moved downstream below the trap site prior to 3/1/20 did not immediately emigrate out of Willow Creek and into the Russian River (Table 9, see footnote).

Compared with previous years, estimated probabilities for pre-March 1 emigration for the fall release groups were similar to previous years in Willow, Green Valley, and Mill creeks, and lower than average from Dutch Bill Creek (Figure 7).

Table 7.Estimated probability of juvenile coho salmon survival from the date of release in 2019 through 6/30/20 for spring and fall release groups 2019. NA=not applicable (no fish were released).

Tributary	Spring release			Fall release		
	Release date	Interval (days)	Probability of survival (95%CI)	Release date	Interval (days)	Probability of survival (95%CI)
Willow Creek	NA	NA	NA	12/13/2019	200	0.33 (0.31-0.35)
Dutch Bill Creek	NA	NA	NA	12/12/2019	201	0.35 (0.32-0.37)
Green Valley Creek	NA	NA	NA	12/10/2019	203	0.26 (0.24-0.28)
Mill Creek	6/15/2019	381	0.12 (0.09-0.15)	12/3/2019	210	0.29 (0.27-0.31)

[1] *For comparison with other streams, probability of survival to the mouth of Willow Creek was included in the table; probability of survival of fish that overwintered only upstream of 3rd Bridge was 0.46 (0.43-0.49).*

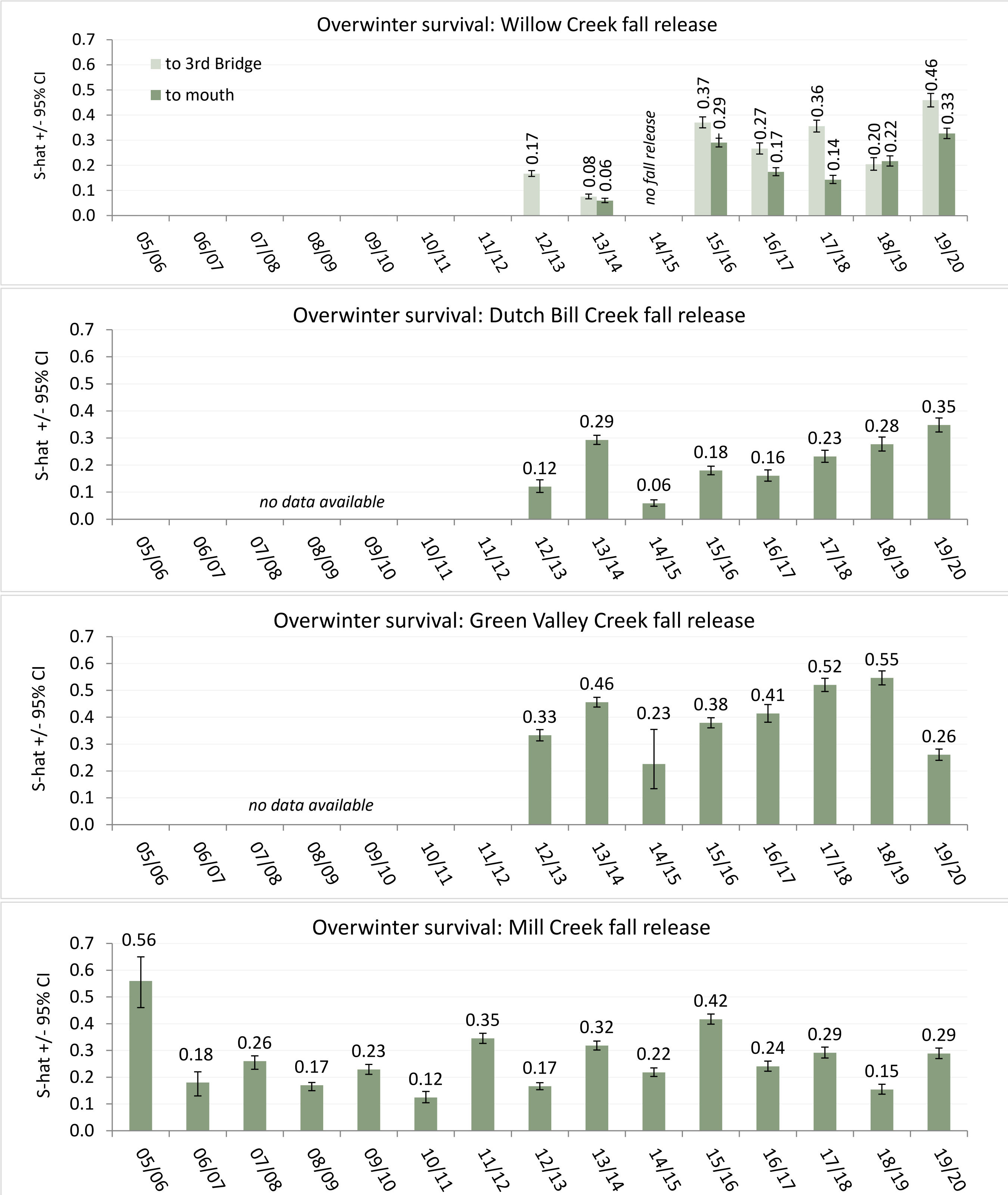


Figure 6. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.

Table 8. Estimated probability of juvenile coho salmon survival from the date of release through 6/30/20 for each smolt release group.

Tributary	Release group	Release type	Release site	River km	Release date	Days imprinted	Survival interval	Probability of survival (95%CI)
Green Valley Creek	smolt	stream	GRE Iron Horse Bridge	7.8	3/24/2020	0	98	0.85 (0.83-0.87)
Green Valley Creek	smolt	stream	GRE Iron Horse Bridge	7.8	4/27/2020	0	64	0.13 (0.10-0.15)

Table 9. Estimated probability of juvenile coho salmon emigrating from each tributary prior to 3/1/20. NA indicates that no fish were released.

Tributary	Probability of emigration prior to 3/1 (95% CI)	
	Spring release	Fall release
Willow Creek	NA	0.00 (0.00-0.02) [1]
Dutch Bill Creek	NA	0.05 (0.04-0.06)
Green Valley Creek	NA	0.00 (0.00-0.01)
Mill Creek	0.01 (0.00-0.02)	0.11 (0.10-0.12)

[1] *For comparison with other streams, probability of emigration from the mouth of Willow Creek was included in the table; probability of emigrating downstream of 3rd Bridge prior to 3/1/20 was 0.29 (0.27-0.31).*

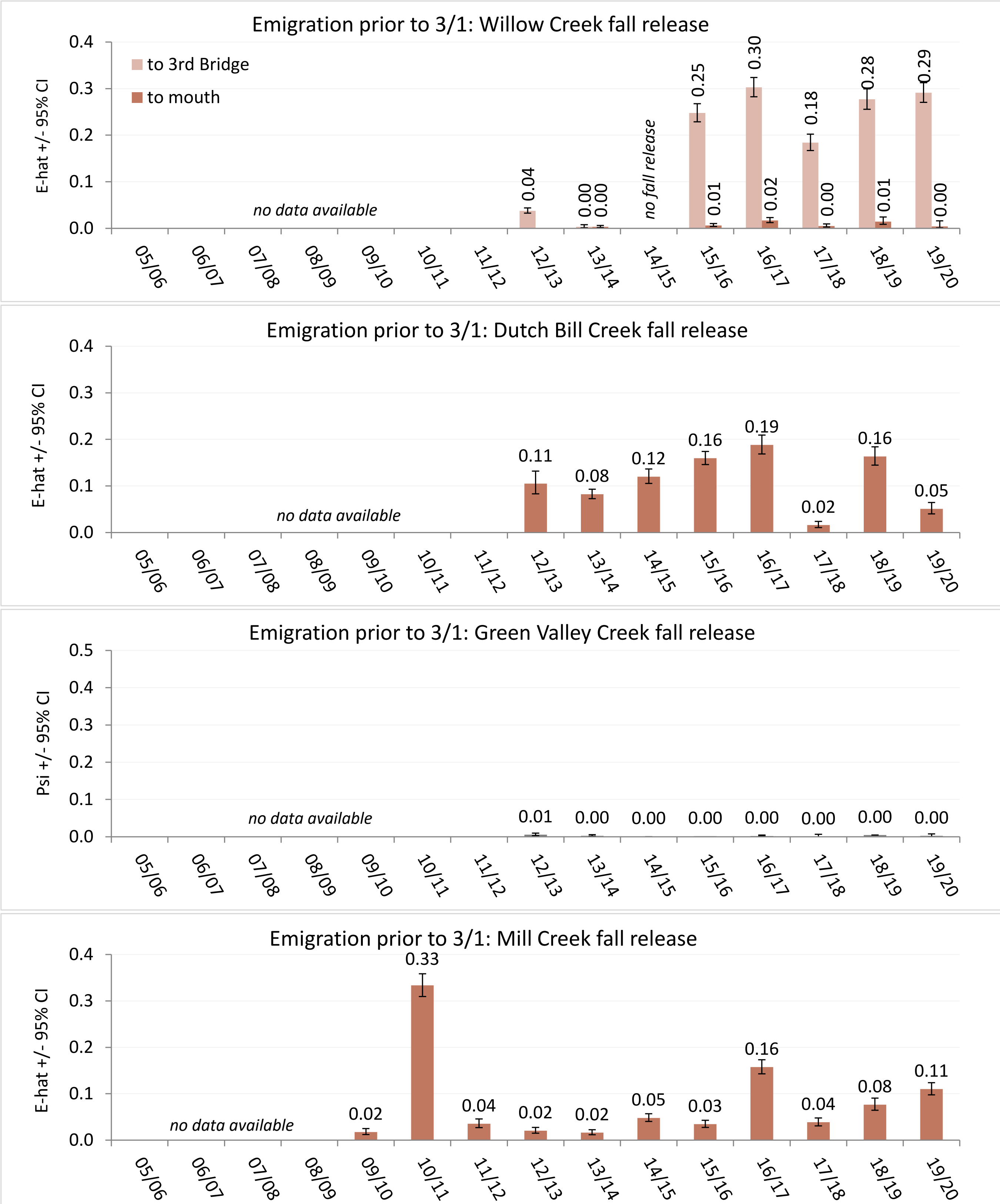


Figure 7. Probability of emigration (E-hat) past antenna sites prior to 3/1. Willow, Dutch Bill, Green Valley, and Mill creeks.

3.3.6. Migration timing

3.3.6.1. Overview

Weekly totals of out-migrating smolts were plotted by release group and antenna site within the watershed for the period of October 29, 2019 to June 30, 2020 and compared with stream depth (stage) data from each creek (Figure 8-Figure 17); note the difference in the y-axes scales). 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 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.

3.3.6.2. Spring and fall release groups

In all four Broodstock Program monitoring streams, we observed winter movement of spring- and/or fall-release juvenile coho salmon, as well as migration during the typical coho salmon smolt migration period of March 1 through June 30 (Figure 9, Figure 11, Figure 13, Figure 16-Figure 17). 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 Mill and Dutch Bill creeks and lower emigration in Willow and Green Valley creeks. In Mill Creek, a large pulse of fall-release fish emigrated during the first week of December immediately following the release (Figure 17) and corresponding to a storm event (Figure 15). A smaller pulse occurred in Dutch Bill Creek in mid-December after multiple storm events had already occurred (Figure 10, Figure 11).

Winter migration past antenna arrays located higher up in each watershed occurred in all creeks, which provides some insight as to where juveniles are overwintering in each system. In Willow Creek, we observed more fish moving downstream during the winter season past the antenna located at river km 3.69 than past the one located at river km 0.41, suggesting that some fish likely overwintered in the lower gradient habitat between the two antenna sites (Figure 9). In Dutch Bill Creek, we observed a large pulse of fish moving past the upper antenna site (river km 6.51) and a smaller pulse moving past the lower site (river km 0.68) in December (Figure 11). In Green Valley Creek, we observed fish moving downstream past the two upstream antenna arrays (river km 13.40 and 9.98) during the early winter season, but not past the lowest antenna array (river km 6.13), suggesting that a portion of the fall release group overwintered lower in the watershed (both upstream and downstream of GRE-9.98) (Figure 13). In Mill Creek, we observed spring-release fish moving past the upper two arrays (river km 12.39 and 6.10) in late-November through mid-December but almost no spring-released fish were detected at the lower array (river km 2.01) until March (Figure 16). In contrast, a large proportion of the fall-release group was detected on all three Mill Creek arrays immediately following release in early December (Figure 17).

3.3.6.3. Smolt release groups

Immediately following the two smolt releases on Green Valley Creek at river km 7.80, we observed pulses of fish moving downstream past the antenna array at river km 6.13 (Figure 14). However, we continued to detect fish until mid-May, suggesting that at least a portion of the smolt-release fish remained in Green Valley Creek for multiple weeks before out-migrating.

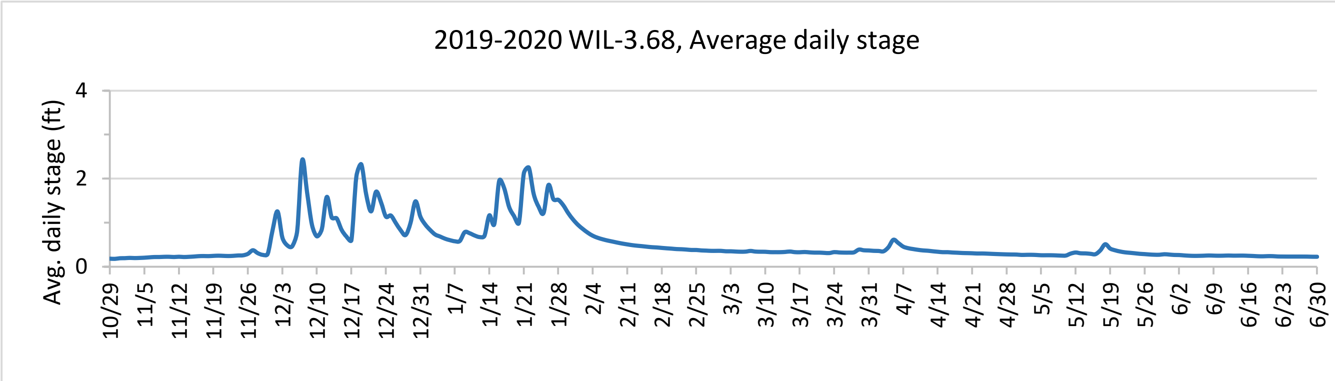
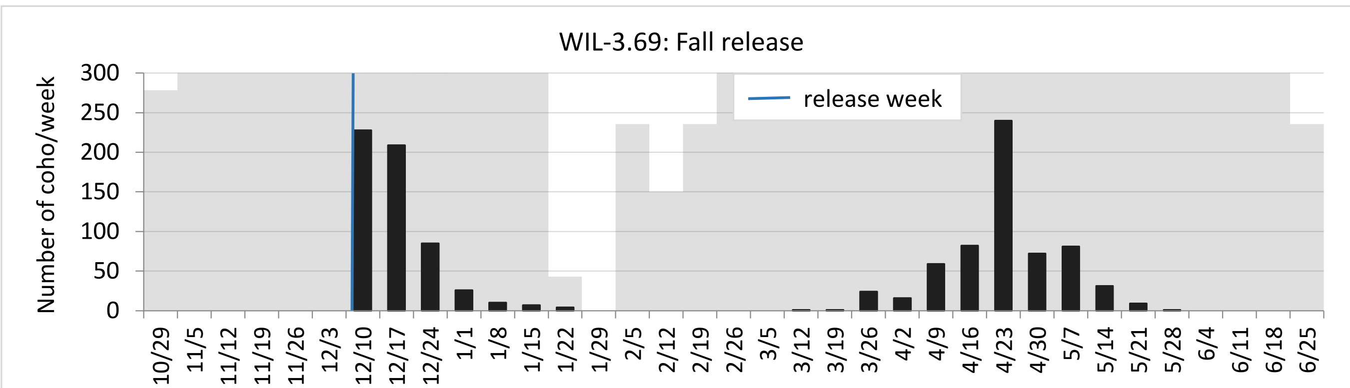


Figure 8. Average daily stage height at the Willow Creek smolt trap site (river km 3.68) between October 29, 2019 and June 30, 2020.



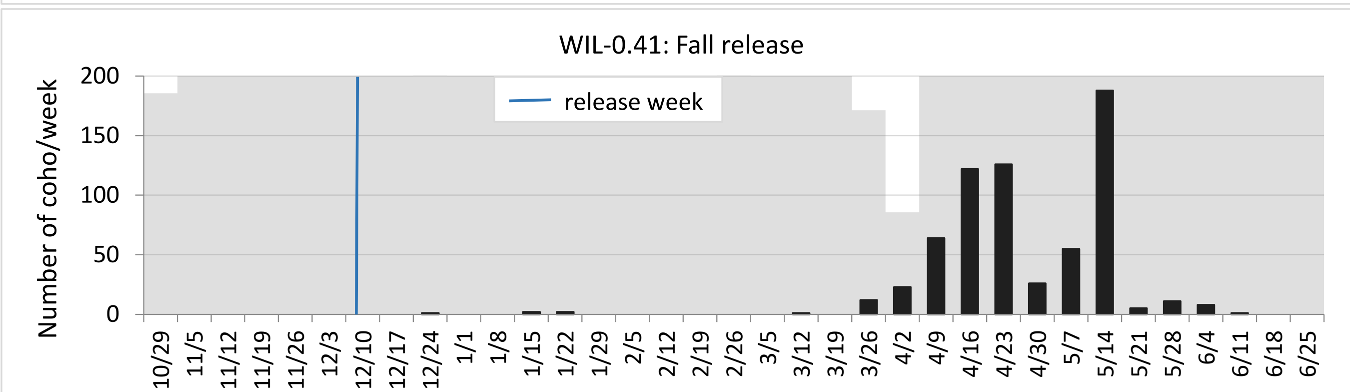


Figure 9. Number of fall-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2019 and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 5.48 to 6.39.

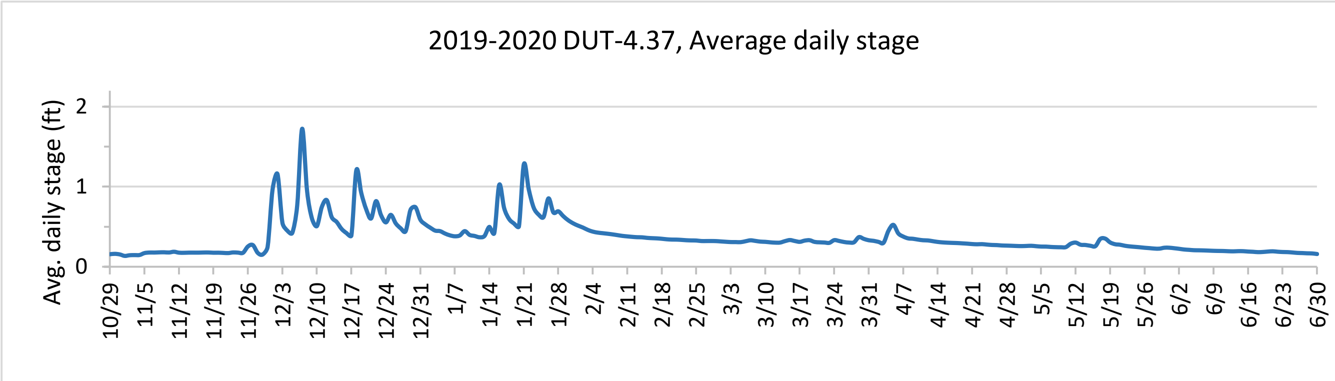


Figure 10. Average daily stage height at Dutch Bill Creek river km 4.37 between October 29, 2019 and June 30, 2020. Data was provided by Trout Unlimited.

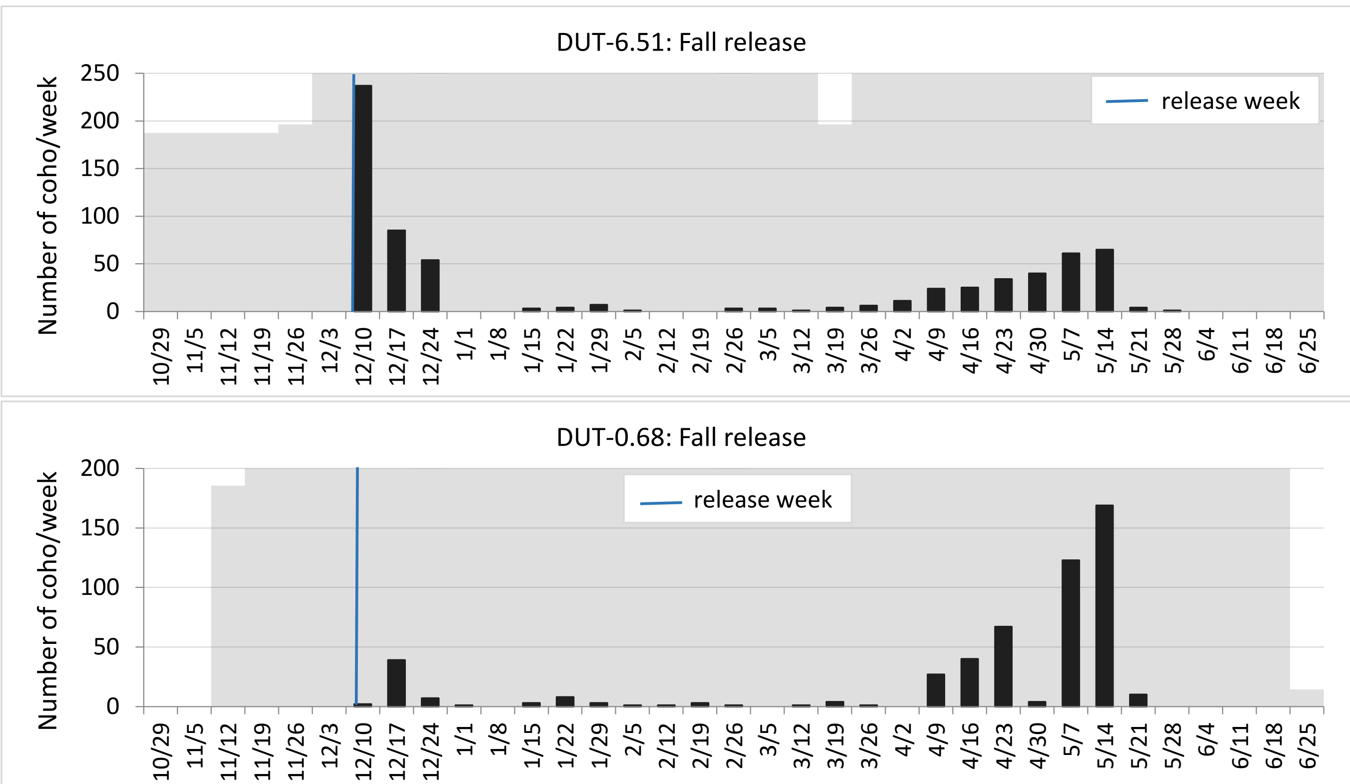


Figure 11. Number of fall-release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and the smolt trap site (DUT-0.68) each week between October 29, 2019 and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 6.04 to 9.57.

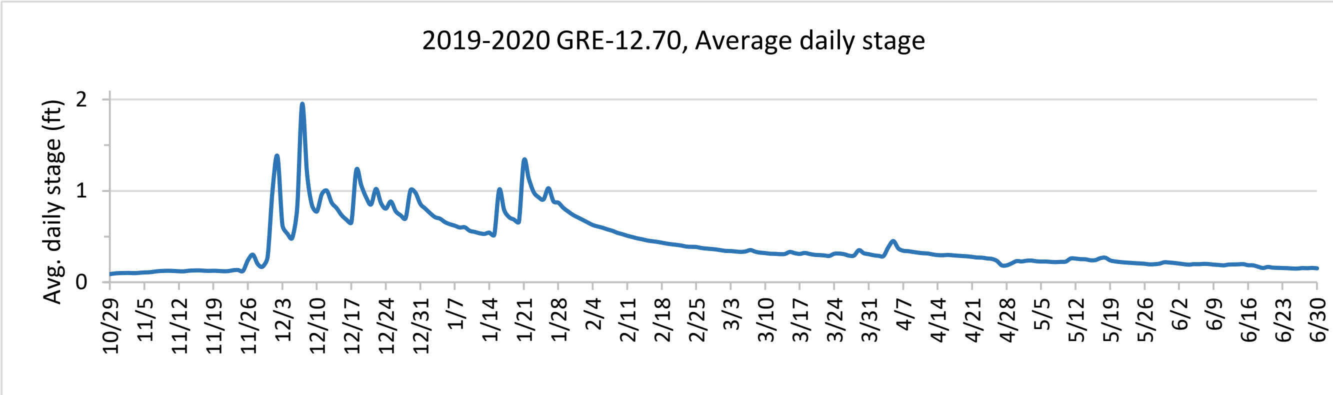


Figure 12. Average daily stage on Green Valley Creek (river km 12.70) between October 29, 2018 and June 30, 2019. Data was provided by Trout Unlimited.

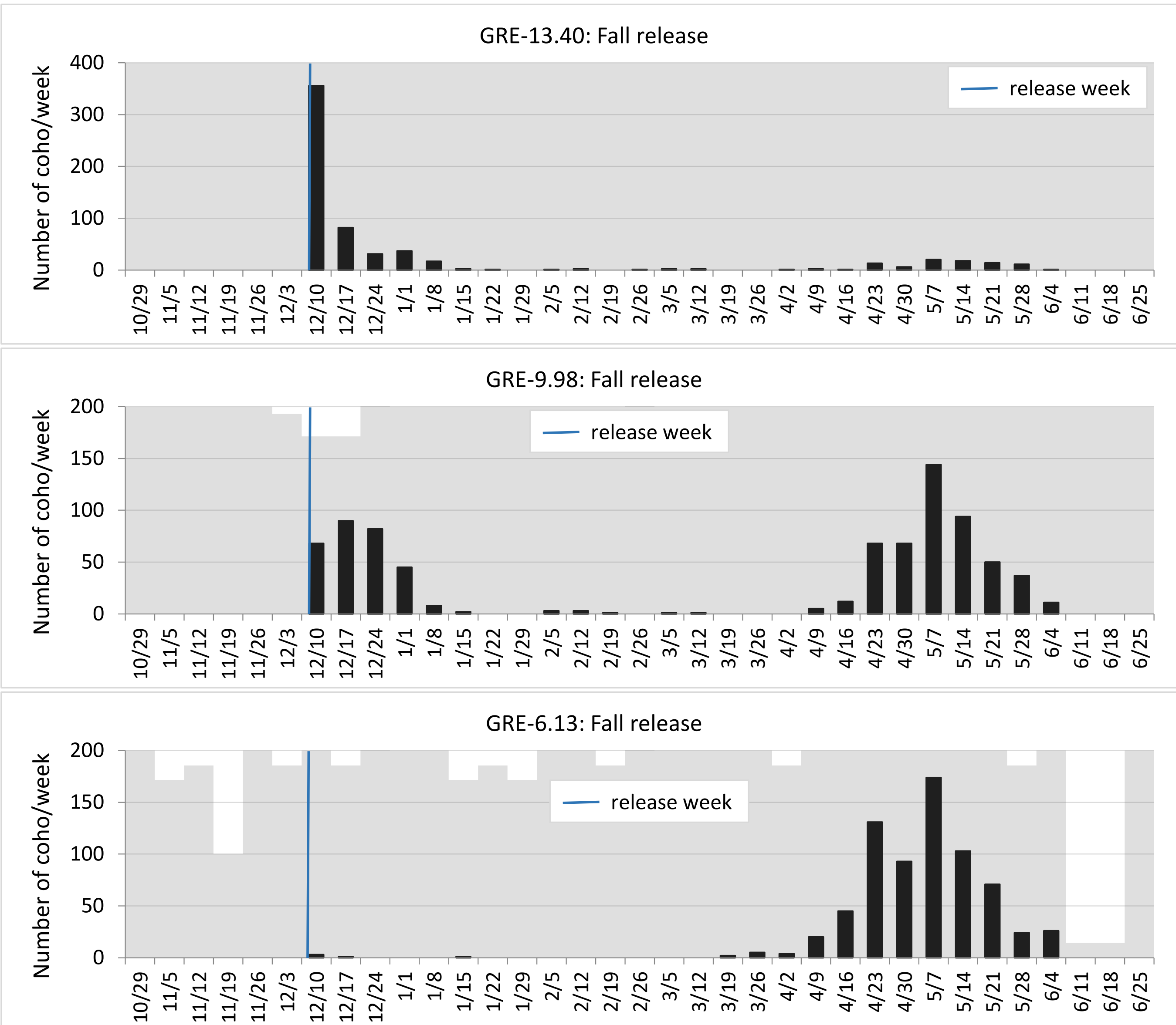


Figure 13. Number of fall-release coho salmon that moved past the upper (GRE-13.40) and mid (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2019 and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 12.60 to 14.37.

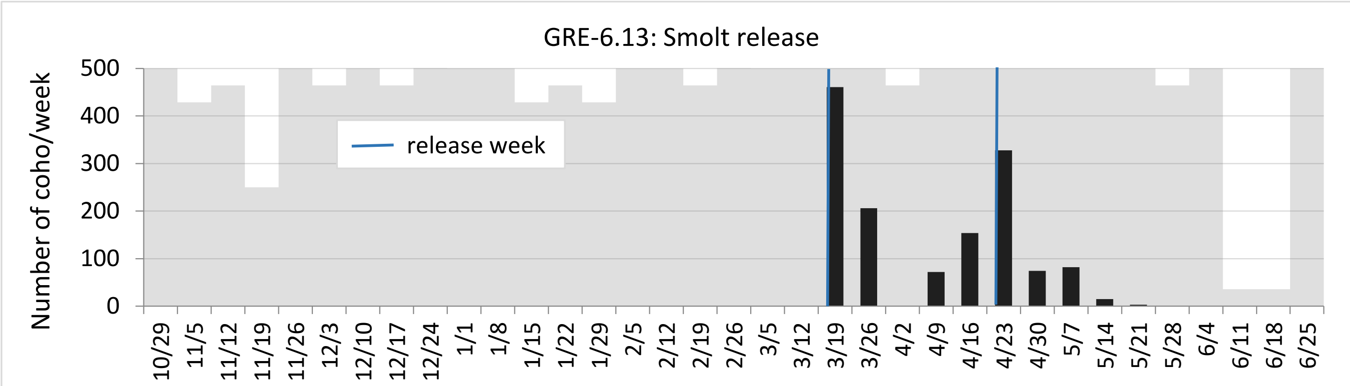


Figure 14. Number of smolt-release coho salmon that moved past the Green Valley Creek smolt trap site (GRE-6.13) each week between March 24, 2020 (when they were first released) and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 7.80.

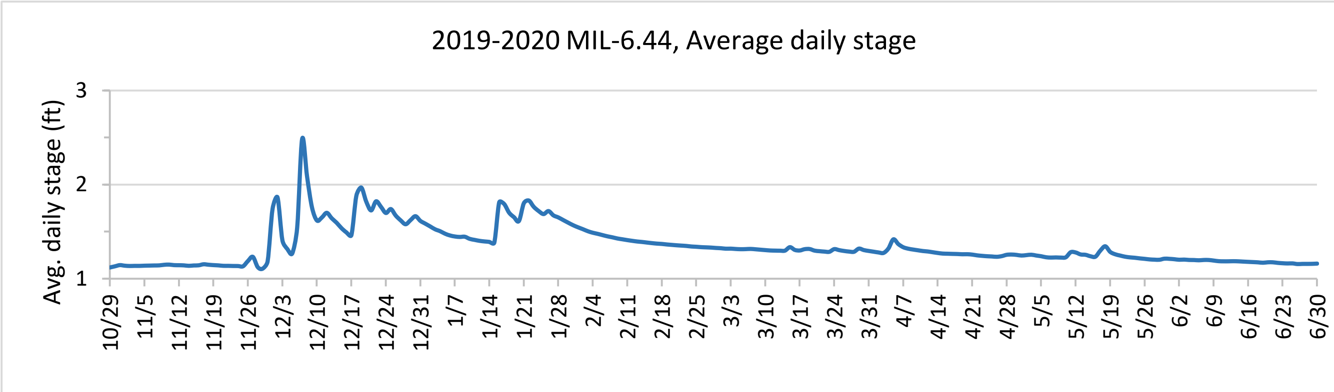


Figure 15. Average daily stage on Mill Creek (river km 6.44) between October 29, 2019 and June 30, 2020. Data was provided by Trout Unlimited.

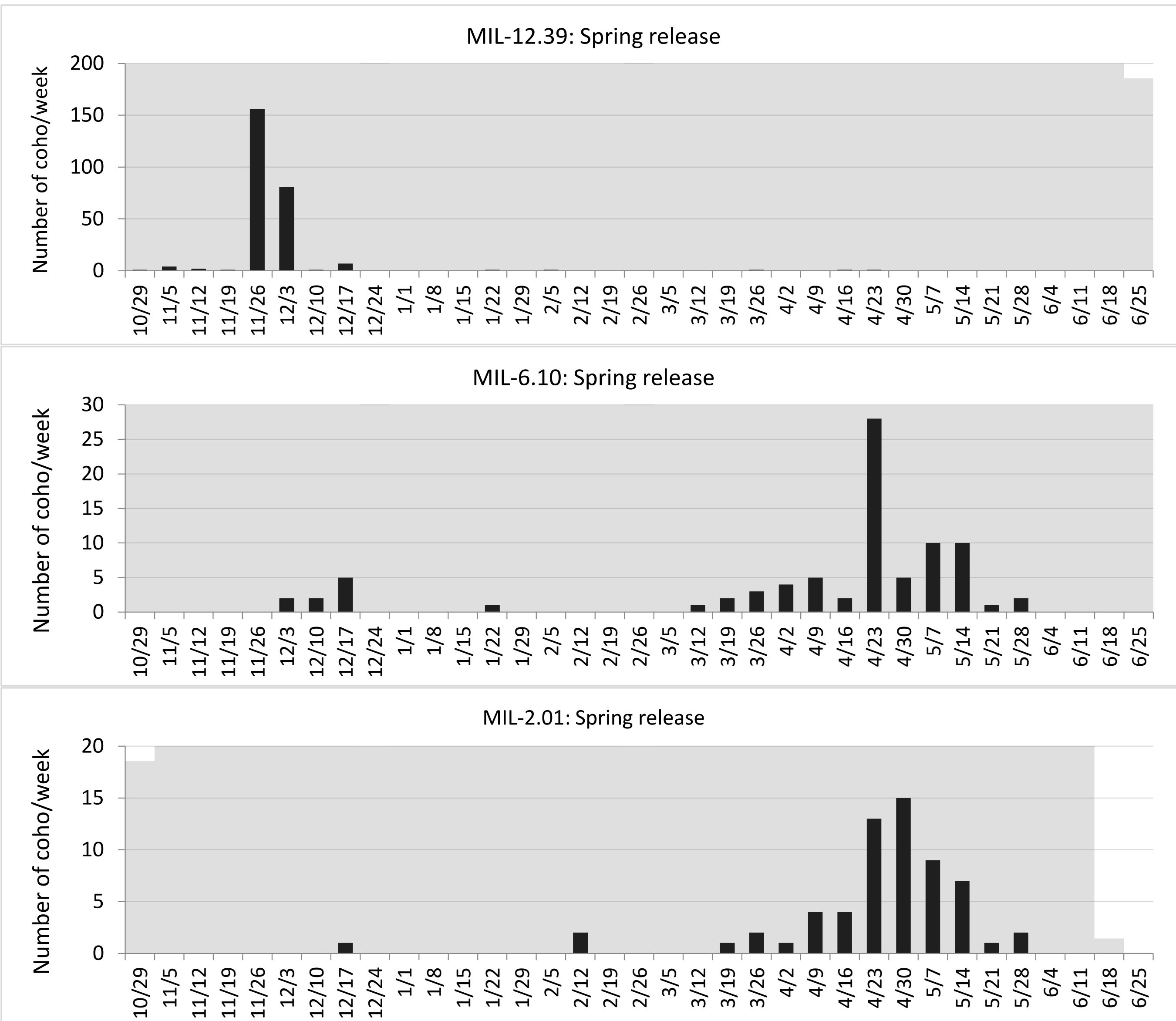


Figure 16. Number of spring-release coho smolts that moved past the upper- (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2019 and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 12.39 to 12.63.

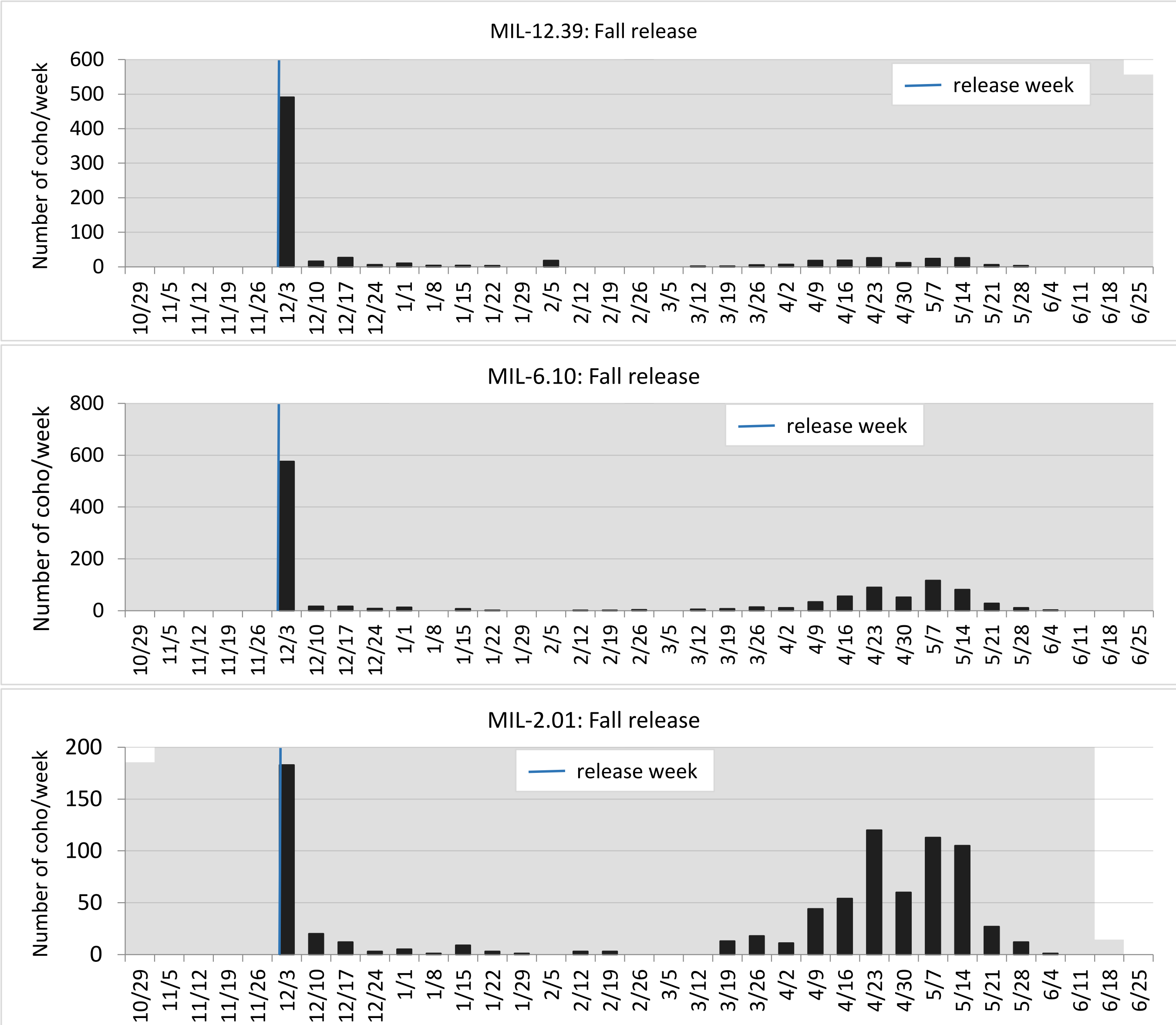


Figure 17. Number of fall-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2019 and June 30, 2020. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 8.92 to 14.44.

3.3.7. Size

In all Broodstock Program monitoring streams, the average size *at release* increased progressively with the age of the fish (spring < fall < smolt), and within release groups only slight differences were observed among streams. Release group average sizes for all 2019 cohort Broodstock Program release streams combined were 71.7 mm and 4.6 g (spring), 95.6 mm and 10.9 g (fall), and 112.8 mm and 16.7 g (smolt) (Table 10).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 100.3 mm and 10.7 g in Mill Creek to 113.2 mm and 15.9 g in Green Valley Creek (Table 11). Average fork length and weight of smolts captured in Willow Creek (110.2 mm and 14.4 g) and Dutch Bill Creek (111.2 mm and 14.3 g) were intermediate.

Natural-origin coho salmon smolts were larger than their hatchery-origin counterparts in all streams except Green Valley Creek but these differences were generally minimal. Willow Creek natural-origin smolts were the largest among all groups, averaging 113.7 mm and 15.6 g (Table 11). Unlike previous years, Green Valley Creek smolts were not significantly larger than those in other streams.

Table 10. Average fork length (mm) and weight (g) of cohort 2019 PIT-tagged coho salmon upon release into program streams.

Tributary	Release season	Avg fork length (SD)	Average weight (SD)	Number of fish
Willow Creek	Fall	96.6 (±7.3)	11.4 (±2.7)	1,985
Dutch Bill Creek	Fall	95.7 (±7.2)	10.7 (±2.5)	1,359
Green Valley Creek	Fall	95.9 (±9.2)	11.0 (±3.3)	1,734
	Smolt	112.8 (±9.9)	16.7 (±4.5)	2,333
Mill Creek	Spring	71.7 (±3.6)	4.6 (±0.7)	511
	Fall	94.5 (±9.5)	10.6 (±3.3)	2,259

Table 11. 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 2020 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	109.7 (±8.1)	14.2 (±3.1)	747
Natural	113.7 (±8.8)	15.6 (±3.4)	92
All smolts	110.2 (±8.3)	14.4 (±3.1)	839
Dutch Bill Creek			
Hatchery	110.6 (±9.3)	14.1 (±3.7)	714
Natural	113.4 (±9.1)	15.0 (±3.9)	216
All smolts	111.2 (±9.3)	14.3 (±3.8)	930
Green Valley Creek			
Hatchery	113.3 (±9.4)	15.9 (±3.8)	335
Natural	110.9 (±6.4)	14.7 (±2.9)	10
All smolts	113.2 (±9.3)	15.9 (±3.8)	345
Mill Creek			
Hatchery	100.1 (±9.3)	10.6 (±3.1)	960
Natural	104.8 (±11.4)	12.2 (±4.0)	35
All smolts	100.3 (±9.4)	10.7 (±3.1)	995

3.3.8. 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. Average growth generally increased with length of time in the stream, with spring-release fish from Mill Creek showing the greatest increase in length and weight of any release group (Table 12). In the fall release group, PIT-tagged smolts recaptured in Green Valley Creek grew more than those from Willow, Dutch Bill, and Mill creeks in absolute size since release but did not have a greater average daily growth rate (Table 12, Figure 18).

Growth rates for fall-release fish captured in the downstream migrant traps in 2020 were lower than in 2019 across all streams, and generally lower than average relative to previous years (Figure 19). Growth rates were particularly low relative to average in Green Valley and Mill creeks. Green Valley Creek had consistently shown the highest growth rates over the past five years; however, in 2020 growth rates in Green Valley were similar to the other creeks. Because Green Valley Creek smolt and pre-smolt releases have taken place at different times over the past three years it is possible to examine growth rates relative to release date for these fish. Green Valley Creek release groups have shown a steady decrease in growth rate with later release dates and results in 2020 were consistent with this trend (Figure 20).

Table 12. Average growth in fork length (mm) and weight (g) of recaptured PIT-tagged coho salmon smolts during the 2020 downstream migrant trapping season.

Release season	Average growth length (SD)	Average growth weight (SD)	Number of recaptures	Average days since release (SD)
Willow downstream migrant trap				
Fall	14.4 (±6.5)	3.5 (±2.7)	356	143 (±7)
Dutch Bill downstream migrant trap				
Fall	13.2 (±7.4)	2.9 (±3.1)	277	145 (±12)
Green Valley downstream migrant trap				
Fall	15.7 (±8.6)	4.4 (±3.3)	33	160 (±8)
Smolt	11.6 (±7.1)	3.1 (±3.2)	28	51 (±12)
Mill downstream migrant trap				
Spring	24.8 (±6.3)	5.7 (±2.1)	12	343 (±6)
Fall	7.8 (±5.8)	0.9 (±2.2)	214	163 (±12)

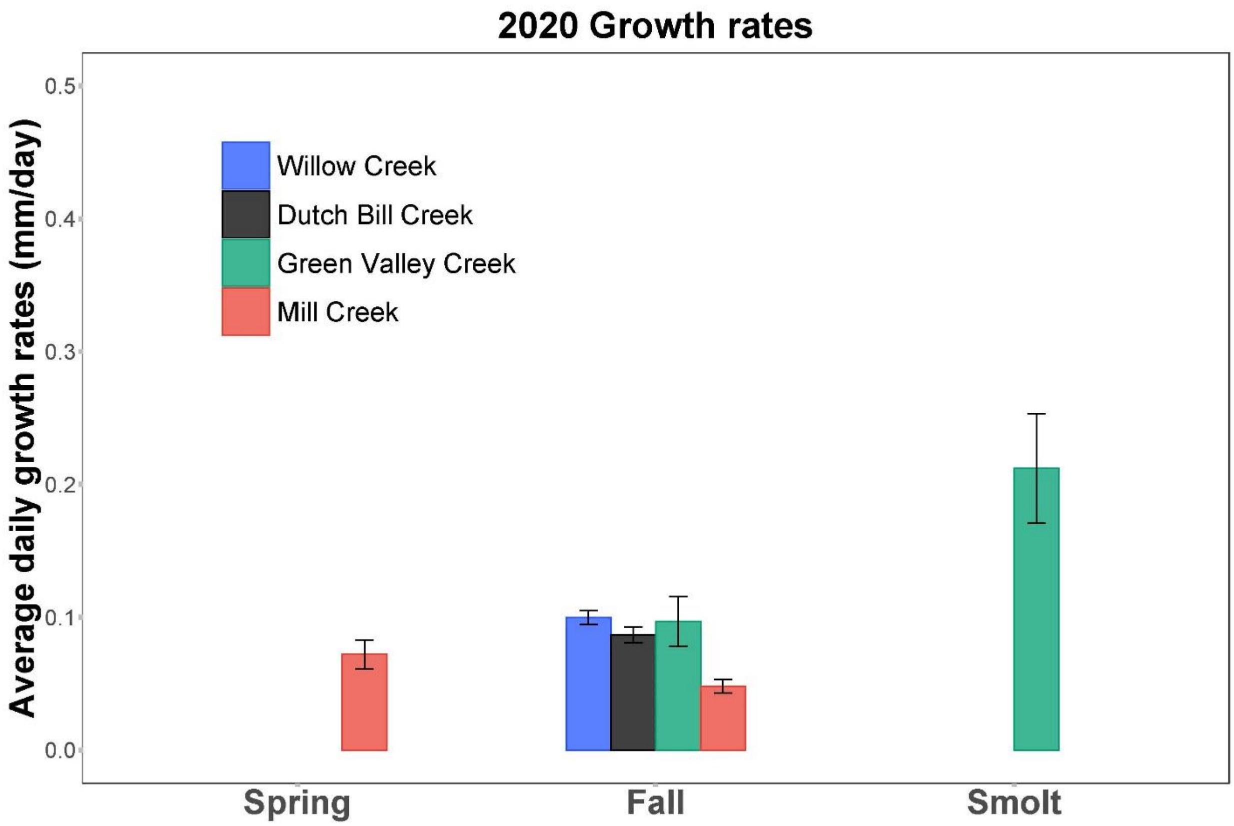


Figure 18. Average daily growth rates in fork length (mm) of PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2020 season, by stream and release season.

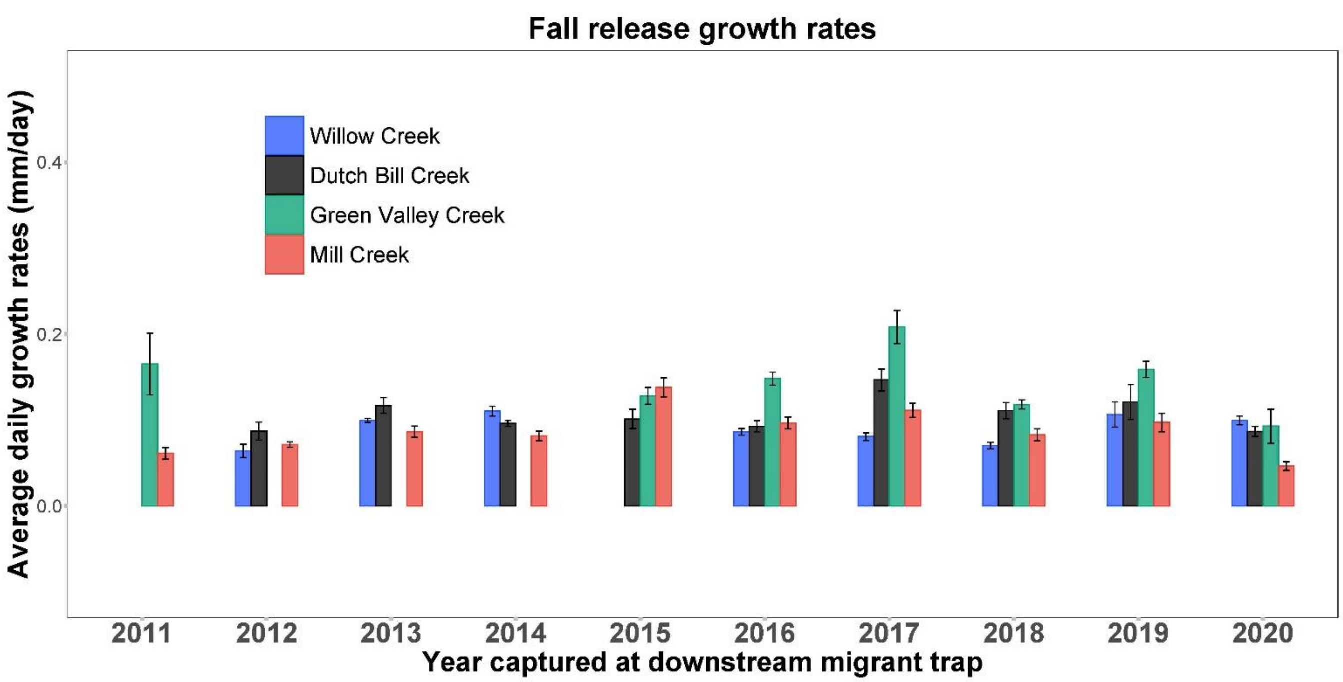


Figure 19. Average daily growth rates in fork length (mm) of fall-release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2019.

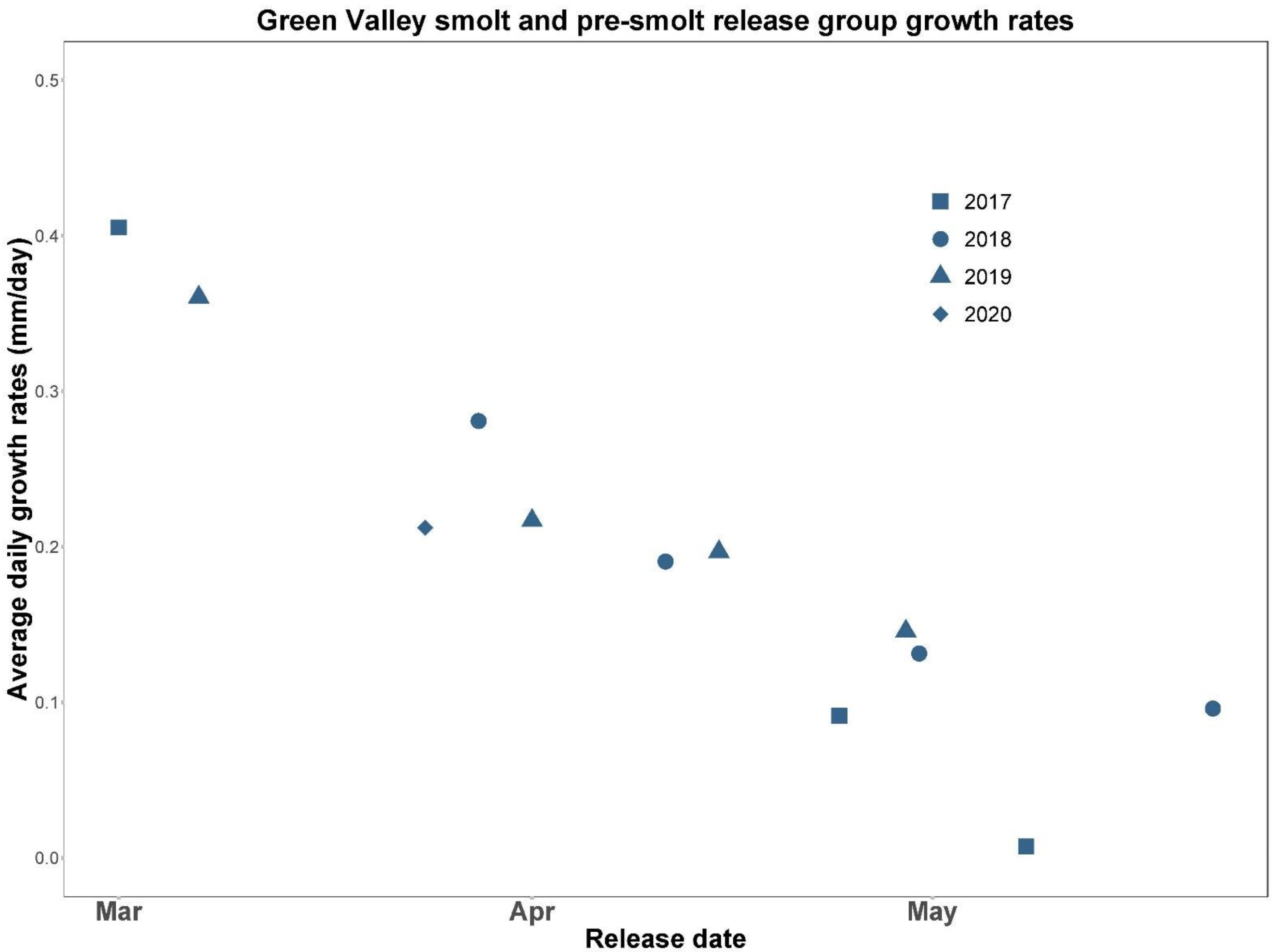


Figure 20. Average growth rates for pre-smolt and smolt release groups in Green Valley Creek over the past four years, by release date.

4. Discussion and Recommendations

Public health measures implemented in response to the Covid-19 pandemic disrupted the early part of our downstream trap operations in 2020. The traps were removed for more than a month while protocols were developed to resume operation safely and once traps were re-installed, field crews had additional safety measures to manage for the remainder of the season. Nonetheless, we were able to fully implement our trapping protocol for the second half of the season to sample the majority of out-migrating coho and obtain a reliable abundance estimate. Fortunately, there was no interruption to the operation of PIT antennas and we were able to use the antenna data to fill in information gaps for the time that the traps were not in operation.

In order to estimate the number of out-migrating smolts during the period where we had removed our traps, we relied on antenna detections as well as the ratios of tagged to untagged fish during the time that the traps were in operation. Estimated antenna efficiency during the downstream migrant season was very high (96-99%) so we are confident that the majority of tagged out-migrating fish were detected (CA Sea Grant unpublished data). However, expanding the number of antenna detections to an overall abundance estimate required making the assumption that the proportion of tagged to untagged fish was consistent throughout the season. It is possible that natural-origin fish in some streams may have had different migration timing to that of tagged hatchery fish. In all creeks except for Green Valley Creek, the antenna-generated estimate was a very small portion of the estimate so even some deviation from this assumption would not significantly impact our final abundance estimate. This concern highlights the continued importance of operating traps throughout as much of the smolt outmigration season as possible, despite the efficiency and convenience of PIT-tag antenna arrays.

Rainfall during the winter of 2019/20 was slightly below average compared to recent years, with October to June precipitation at the Venado gage in the headwaters of Mill Creek totaling 52.6 inches, 0.5 inches lower than the 10-year average (according to raw gage data from NOAA's California Nevada River Forecast Center). Stream flow levels for much of the winter were lower than the precipitation total would indicate, possibly due to the lingering effects of preceding drought years. Due to low water levels in spring and the associated concern about early closure of tributary mouths during the smolt out-migration period, Green Valley Creek was the only broodstock stream where a smolt release took place. Although logistical considerations prevented a pre-smolt release, we were able to conduct staggered smolt releases and we observed similar trends to previous years, with the earlier release having higher survival. Survival for the second release in April (0.13) was dramatically lower than that of the release in March (0.85) (Table 8). No fish from the second release were captured at our trap so growth rates are unavailable, but given the poor survival and rapid downstream movement of that release, growth was also likely low. This information validates the strategy of conducting smolt releases as early as possible and, whenever possible, releasing fish at the pre-smolt stage in January and February.

Overwinter survival of fall-release fish was high compared to previous years of data collection in Willow and Dutch Bill creeks, average in Mill Creek and very low in Green Valley Creek (Figure 8, Table 7). Dutch Bill Creek had the highest overwinter survival we have observed in that creek, a positive indication that a series of recently-constructed large wood habitat enhancement projects may be providing necessary habitat to help improve overwinter survival. Although overwinter survival was fairly similar in the Broodstock Program monitoring streams, the variation in trends across watersheds suggests that winter flow regimes can have very different, sometimes even antithetical, impacts on overwinter survival depending on the individual characteristics of a stream (Table 7). Because of this variability, we recommend continuing the strategy of stocking multiple streams to allow for the best chances of survival regardless of variability in environmental conditions.

Spring releases only took place in Mill Creek and those fish had very low (albeit average as compared to previous years) stock-to-smolt survival. To promote improvements in oversummer survival, we recommend increased support of efforts to enhance streamflow during the dry season. We also recommend continued support of habitat enhancement projects that increase overwintering habitat; the increasing trend in overwinter survival on Dutch Bill Creek, suggest that these types of projects may have an immediate benefit to fish.

In previous years, Green Valley Creek was consistently the most productive of the Broodstock Program monitoring streams for overwintering juveniles. We have observed significantly higher growth, abundance, survival, and average size for fall-release fish in Green Valley Creek than in the other streams. Natural-origin fish captured in the Green Valley Creek trap in past years have also been larger than those captured at other traps. This season, however, this pattern did not continue. In 2020, Willow, Dutch Bill and Mill creeks exhibited average to above-average values across all metrics assessed, while growth, abundance, survival, and average size of Green Valley Creek was poor relative to prior years. One possible explanation is that high productivity in Green Valley Creek is driven by the availability of flood plain habitat and the low flows in the winter of 2019/2020 did not allow juveniles to access this habitat. This possibility is particularly compelling, since very little precipitation fell in February and March; a period when pre-smolts released in Green Valley Creek have historically exhibited rapid growth rates. Increased predation during low flows, particularly from otters, is another possible explanation for the low survival and abundance, but the reduction in growth and size indicates that environmental factors are a more likely cause. Further research on both water quality and variation in rearing location between seasons could provide additional insight into which factors drive productivity in Green Valley Creek and how those factors differed in 2019/2020.

The proportion of natural-origin smolts captured across all streams was 7.7% in the 2020 trap year (353 natural-origin smolts/5,129 total known-origin smolts captured). This proportion was slightly higher than the average proportion over the previous five years. However, the 353 natural-origin smolts captured was the second lowest number captured since 2013 and less than half the number captured in any year except for 2019. The low number of natural-origin fish captured may have been influenced by the traps not being fished for about a month; however, antenna detections indicate that most smolts moved during the period when we were operating the traps so it is likely not the only explanation. Summer 2019 coho yoy counts in the broodstock streams were low (California Sea Grant 2020) so we anticipated that natural-origin smolt counts might be low during the 2020 downstream migrant season. The distribution of natural-origin fish across the monitoring streams was unexpected, however, with Dutch Bill Creek having one of the highest numbers of natural-origin fish despite low summer yoy counts. Green Valley Creek trap counts of natural-origin fish were extremely low relative to previous years, which is likely due to a combination of migration timing (a much higher proportion of fish on Green Valley Creek appear to have moved while traps were out), poor trap efficiency (CA Sea Grant unpublished data), and lower than usual overwinter survival. The low numbers of natural-origin smolts observed during the past two years is a concerning trend and merits continued investigation.

In summary, during the spring of 2020, we observed coho salmon smolts emigrating from each of the four Broodstock Program monitoring streams, indicating successful production to the smolt stage. The total natural-origin smolt count was lower than in previous years, which may reflect gaps in trap operation due to Covid restrictions and/or poor survival at earlier life stages. In general, we recommend that the Broodstock Program continue its bet-hedging strategy of stocking fish in spring, fall, pre-smolt, and smolt release groups to accommodate variable weather and climate patterns and associated variation in survival among years and streams. We encourage a stronger focus on pre-smolt and early-season smolt releases in which fish have demonstrated high growth rates and longer retention within the streams as compared to later releases. Finally, we recommend ongoing support of summer streamflow and winter habitat restoration efforts.

5. References

Bjorkstedt, E. P. 2005. DARR 2.0: updated software for estimating abundance from stratified mark-recapture data. National Marine Fisheries Service, Santa Cruz, CA.

Bjorkstedt, E. P. 2010. DARR 2.02: DARR for R. Addendum to NOAA-TM-NMFS-SWFSC-368. National Marine Fisheries Service, Santa Cruz, CA.

California Sea Grant. 2018. California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2018. University of California, Windsor, CA.

California Sea Grant. 2020. UC coho salmon and steelhead monitoring report: Summer 2019. University of California, Santa Rosa, CA.

Horton, G. E., B. H. Letcher, and W. L. Kendall. 2011. A multistate capture-recapture modeling strategy to separate true survival from permanent emigration for a passive integrated transponder tagged population of stream fish. Transactions of the American Fisheries Society 140(2):320-333.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120-139.