California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2019

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Sea Grant California

Russian River Salmon & Steelhead Monitoring Program

University of California

Contents

I. 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 reestablishing 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.

II. Downstream Migrant Trapping and Operation of PIT-Tag Antenna Arrays

Goals

The primary goals of this study were to estimate smolt abundance, natural production, freshwater survival, migration timing, and freshwater growth of the 2018 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.

Methods

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 four release groups; spring, fall, pre-smolt, and smolt. Fish in the spring release group were stocked as young-of-the-year (yoy) in June 2018, fish from the fall release group were stocked as yoy in November and December 2018, fish from the pre-smolt release were stocked at age-1 in early March 2019, and fish from the smolt release group were stocked at age-1 in April 2019. All fish in the spring, fall, and pre-smolt release groups were planted directly into the streams. In Green Valley and Mill creeks, smolts were also stocked directly into the streams, and in Dutch Bill Creek smolts were held in a stream-side acclimation tank for 12 to 17 days prior to release into the stream.

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, Figure 2). For pre-smolt and 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 2).

Figure 1. Juvenile coho salmon are released into the stream environment.

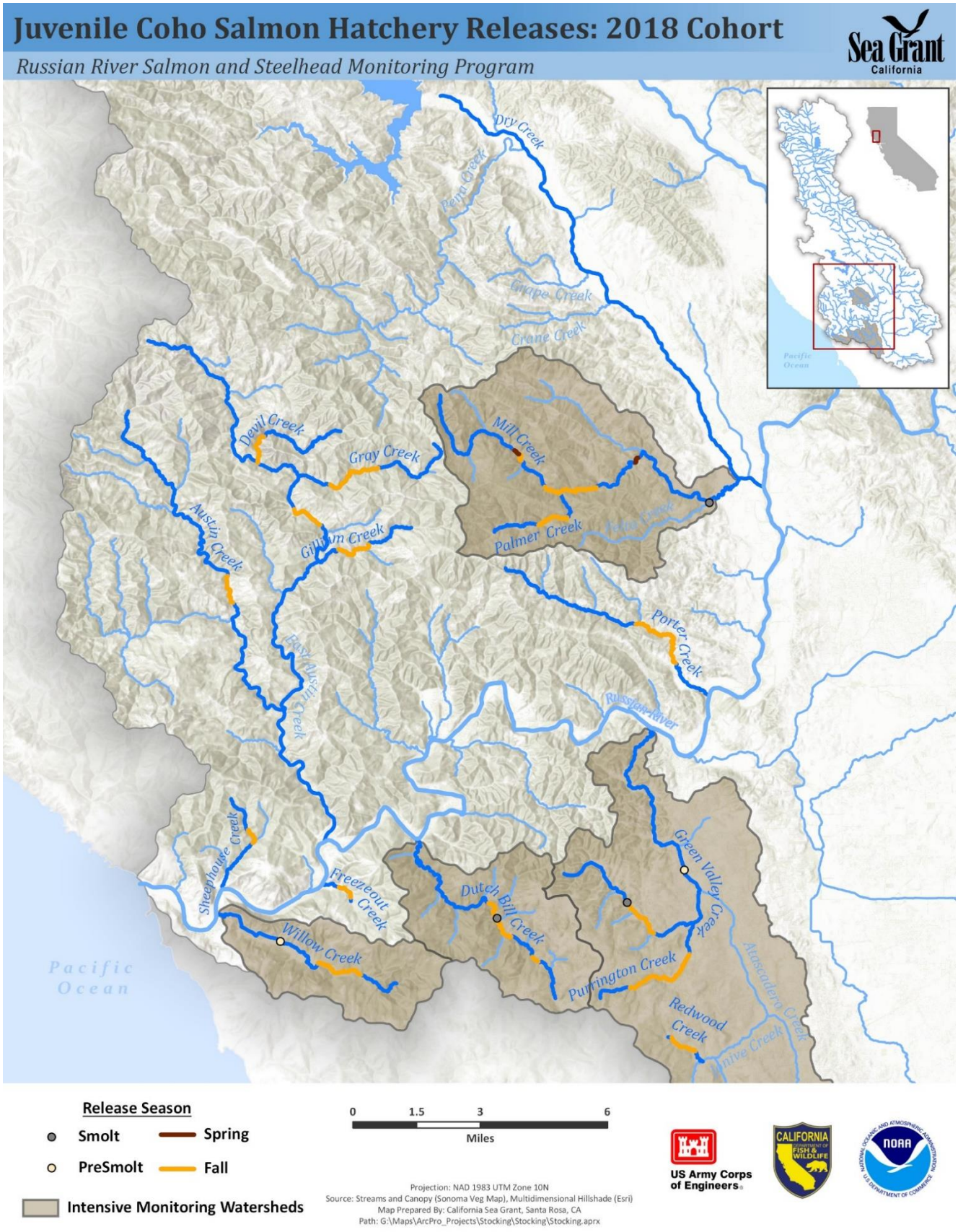


Figure 2. Map of juvenile coho salmon stocking locations for 2018 cohort (hatch year) in the four Broodstock Program monitoring watersheds.

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 specific reaches 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, 51 wild coho were PIT tagged in the Mill Creek system in the summer of 2018 as part of the CMP life-cycle monitoring effort.

Table 1. Number and percent of PIT-tagged juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Milcreek watersheds for the 2018 cohort.

		Number Released (% PIT-tagged)			
Release Season	**Release Dates**	**Willow Creek**	**Dutch Bill Creek**	**Green Valley Creek**	**Mill Creek**
Spring	**Jun 15, 2018**	0	0	0	1,010 (100%)
Fall	**Nov 13 - Dec 7, 2018**	8,194 (20%)	7,062 (20%)	10,079 (20%)	13,237 (20%)
Pre-Smolt	**Mar 5-7, 2019**	7,111 (19%)	0	8,054 (20%)	0
Smolt	**Apr 1-29, 2019**	0	5,047 (20%)	5,077 (20%)	5,087 (20%)
Total Released		15,305	12,109	23,210	19,334

Field Methods

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 3). 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 (Figure 4) 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 2018 through June 2019, PIT-tag detection systems were visited every other week 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.

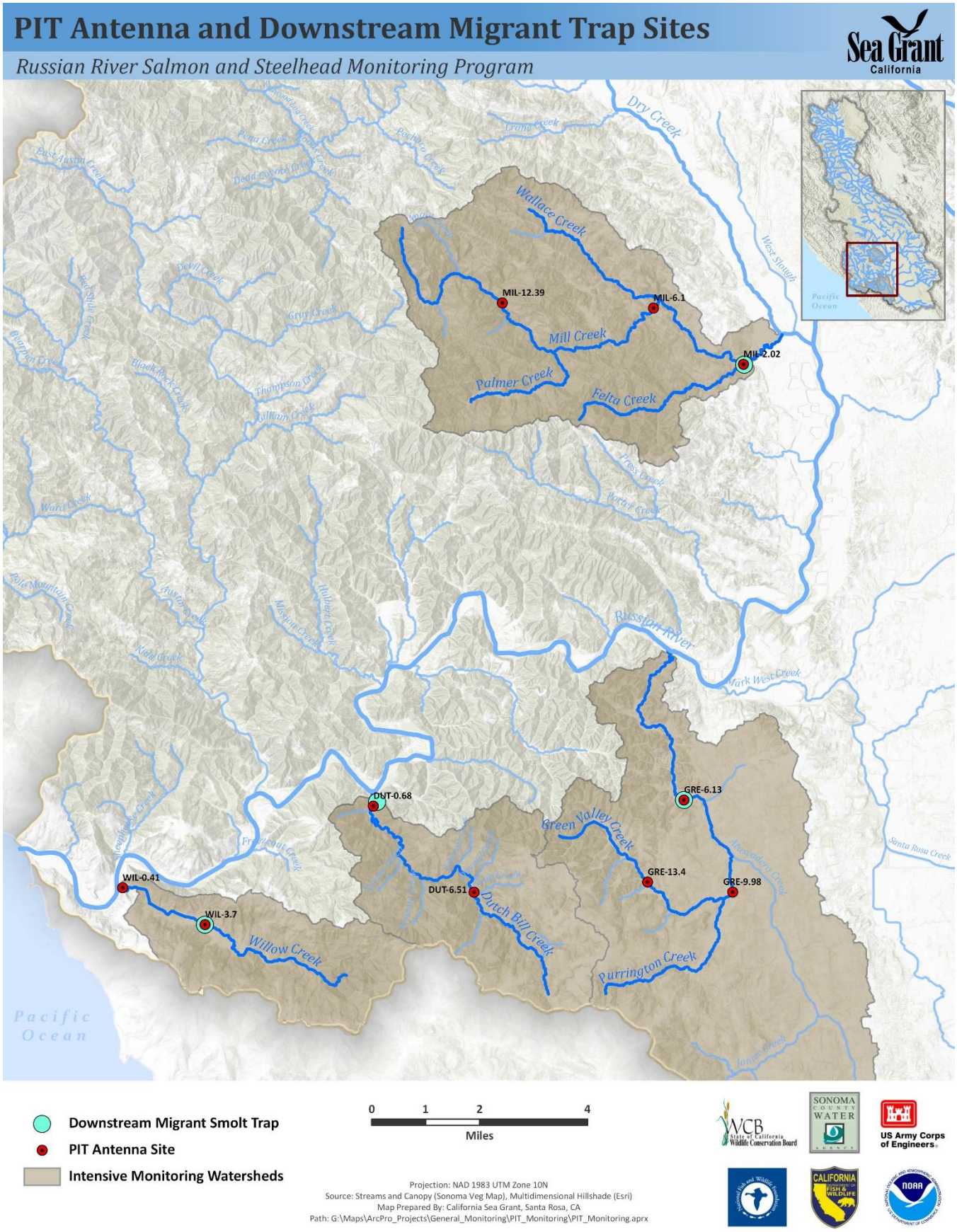


Figure 3. Map showing PIT antenna and smolt trap locations on Broodstock Program monitoring streams, with antenna site codes.

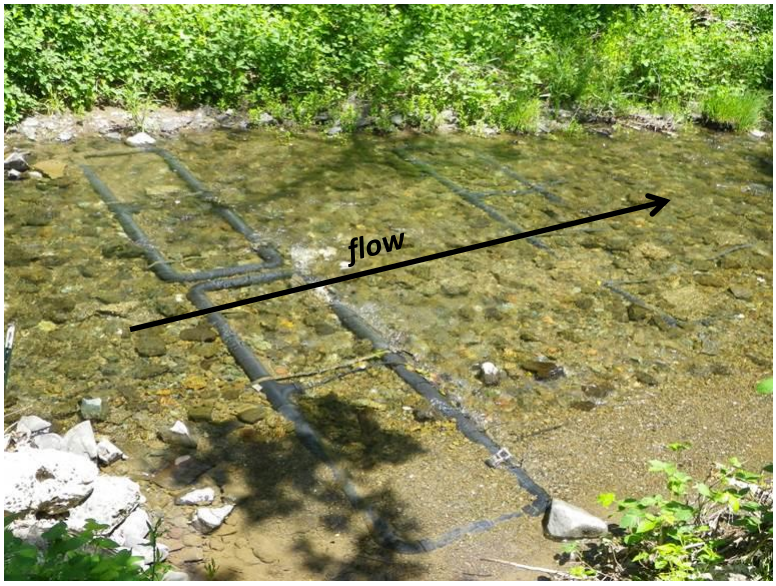


Figure 4. Paired flat-plate PIT tag antenna array on Mill Creek at spring base flows.

Downstream Migrant Trapping

Downstream migrant (funnel and/or pipe) traps were operated by UC on Willow, Green Valley, and Mill creeks between April and June 2019, 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 (Figure 5). 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). 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 5. Mill Creek downstream migrant trap at spring base flows.

Data Analysis

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 the origin recorded at the time of tagging was assigned. These data were used to develop ratios of natural- to hatchery-origin smolts for each stream.

Smolt Abundance

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

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. 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 6/30/19 and emigration prior to 3/1/19 for multiple release groups (i.e., spring, fall, pre-smolt, and smolt) in the four Broodstock Program monitoring streams.

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, or smolt) passing the site each week. Total weekly sums were then plotted by week from October 29 (earliest known reconnection date) through June 30.

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 fish as $(FL_2-FL_1)/(t_2-t_1)$ where FL_1= fork length at hatchery prior to release, FL_2= fork length at the smolt trap, t_1=date measured at hatchery, and t_2= date captured in the smolt trap. Individual growth rates were then averaged by stream and release group. Growth rates were also calculated in a similar manner for fall-release fish dating back to 2011. From 2011 to 2014, water levels and logistical considerations led to fish being tagged and measured several months before being released from the hatchery. In order to account for growth at the hatchery during this period, a subsample of fish from each release group were measured within two weeks of the release and an average growth rate was calculated for these fish and used to predict the size at release for all fish in each release group.

Results

Trap Operation

In 2019, the traps were installed on 4/8 and operated until the site became disconnected from flow, or through 6/28. Installations in 2019 occurred almost a full month later than average due to very high spring flows. Traps and weir panels were also removed due to high flows from storm events for several days throughout the season (Figure 6). In addition, weir panels were partially removed following smolt releases in Green Valley and Dutch Bill creeks in order to reduce capture efficiency and avoid overcrowding in the trap box (Figure 6). A small opening was also left in the weir panels to allow adult steelhead and Pacific lamprey passage throughout the trapping season.

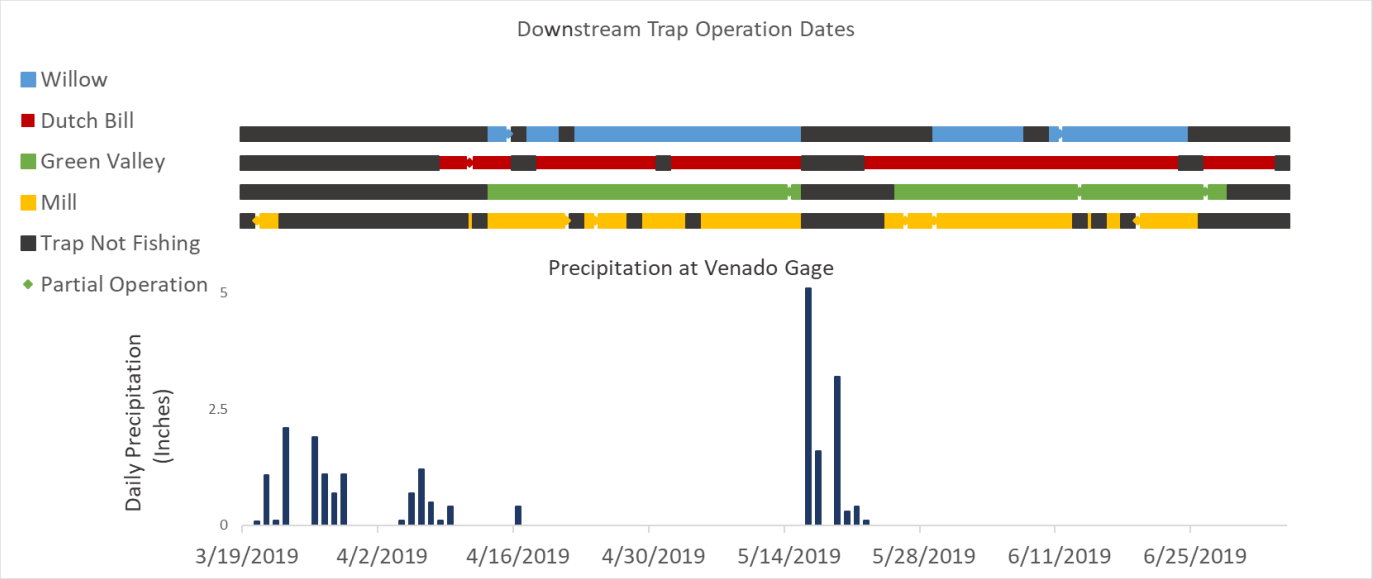


Figure 6. Trap operation dates in relation to precipitation at Venado rain gage in upper Mill Creek watershed. Daily rain totals from raw gage data posted on NOAA's California Nevada River Forecast Center website (http://www.cnrfc.noaa.gov/formPrecipMap.php).

Trap Counts

Coho salmon smolt counts from downstream migrant traps on all four study streams in 2019 ranged from 230 in Mill Creek to 4,887 in Green Valley Creek, with 368 in Dutch Bill Creek and 457 in Willow Creek (Table 2). The percentage of coho smolts of natural-origin ranged from 1.3% in Mill Creek to 11.5% in Willow Creek (Table 2).

When compared to previous years, coho salmon smolt counts were average in Green Valley Creek and low in Willow, 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 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 outmigrant seasons, incidental capture of steelhead and Chinook occurred in 2019 (Table 3). The number of steelhead smolts captured in the traps in 2019 was low, ranging from zero to 12, with the greatest number on Green Valley Creek (Table 3). Chinook salmon smolts (six) were only observed on Dutch Bill Creek (Table 3). Incidental capture of steelhead yoy also occurred and was likely influenced by proximity of redds to the trap site.

A low diversity of species was captured in Willow Creek relative to other streams, with sculpin (1,455) and three-spined stickleback (69) being the only non-salmonids captured in 2019 (Table 4). In Dutch Bill Creek, the three most abundant non-salmonids were sculpin (452), three-spined stickleback (307), and Sacramento Pikeminnow (23), in Green Valley Creek they were three-spined stickleback (2,191), bluegill (551), and sculpin (368), and in Mill Creek they were sculpin (359), California roach (149), and green sunfish (42) (Table 4). Thirty freshwater shrimp were captured in Green Valley Creek in 2019, similar to the three previous years (Table 4). Willow and Dutch Bill creeks had no or low numbers of non-native species while hundreds were observed in Green Valley and Mill

creeks (Table 4). The most prevalent non-native species included bluegill, green sunfish, and fathead minnow (Table 4).

Table 2. Coho salmon smolts captured in traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2019 downstream migrant season.

Stream	Hatchery	Natural	Unknown Origin	Total	Percent Natural
Willow Creek	401	52	4	457	11.5
Dutch Bill Creek	352	12	4	368	3.3
Green Valley Creek	4,595	282	10	4,887	5.8
Mill Creek	224	3	3	230	1.3

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in downstream migrant traps, years 2005-2019. 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
Willow Creek	Coho Salmon	Smolt	NA	NA	NA	NA	NA	NA	NA	864	3,405	916	707	2,028	1,729	3,486	457
		YOY	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0	27	2
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0	0	0	0
		Parr/YOY	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603	77	111	238
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5	3	0
Dutch Bill Creek	Chinook Salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2	8	6
	Coho Salmon	Smolt	NA	NA	NA	NA	NA	185	2,908	1,987	823	1,939	201	2,681	3,678	1,276	368
		YOY	NA	NA	NA	NA	NA	0	5	0	2	0	0	18	2	3	1
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0	0	2
		Parr/YOY	NA	NA	NA	NA	NA	58	31	21	79	1,138	13	74	524	22	140
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6	1	5
Green Valley Creek	Chinook Salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	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
		YOY	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2	3	2
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1	1	0
		Parr/YOY	1,723	NA	36	497	1	5	3	NA	NA	NA	38	356	11	15	46
		Smolt	49	NA	70	29	43	0	1	NA	NA	NA	3	3	12	17	12
Mill Creek	Chinook Salmon	Smolt	70	128	2	31	1	1	0	11	0	22	0	0	1	1	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
		YOY	24	314	58	43	0	4	329	515	530	0	10	10	30	63	8
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	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
		Smolt	116	49	266	176	118	190	97	41	32	13	17	15	32	22	6

Table 4. Annual downstream migrant trap counts for common non-salmonid species, years 2005-2019. 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
WILLOW CREEK																
Non-native	Bluegill	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0
	Bullfrog	NA	NA	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0
	Fathead Minnow	NA	NA	NA	NA	NA	NA	NA	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
Native	California Roach	NA	NA	NA	NA	NA	NA	NA	0	1	1	7	0	1	0	0
	Freshwater Shrimp	NA	NA	NA	NA	NA	NA	NA	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
	Sacramento Sucker	NA	NA	NA	NA	NA	NA	NA	1	24	1	46	2	9	4	0
	Sculpin Sp	NA	NA	NA	NA	NA	NA	NA	339	4,206	680	2,462	548	2,898	653	1,455
	Three-spined Stickleback	NA	NA	NA	NA	NA	NA	NA	383	268	296	193	71	496	157	69
	Western Brook Lamprey	NA	NA	NA	NA	NA	NA	NA	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
	Bullfrog	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0	0	1
	Fathead Minnow	NA	NA	NA	NA	NA	0	0	0	0	0	2	98	2	0	0
	Green Sunfish	NA	NA	NA	NA	NA	0	1	0	0	5	20	8	21	3	4
Native	California Roach	NA	NA	NA	NA	NA	130	129	59	725	3	252	94	28	14	1
	Freshwater Shrimp	NA	NA	NA	NA	NA	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
	Sacramento Sucker	NA	NA	NA	NA	NA	8	178	1	307	4	25	106	265	51	7
	Sculpin Sp	NA	NA	NA	NA	NA	8	393	437	1,204	136	974	440	323	276	452
	Three-spined Stickleback	NA	NA	NA	NA	NA	9	7	56	517	2	5	46	4	2	307
	Western Brook Lamprey	NA	NA	NA	NA	NA	0	0	1	0	0	1	1	1	18	16
GREEN VALLEY CREEK																
Non-native	Bluegill	627	NA	68	21	59	155	1	NA	NA	NA	3	137	472	659	551
	Bullfrog	10	NA	42	7	5	57	1	NA	NA	NA	4	11	171	37	8
	Fathead Minnow	15	NA	14	0	22	89	54	NA	NA	NA	96	59	65	32	5
	Green Sunfish	40	NA	4	0	31	12	0	NA	NA	NA	25	32	133	209	35
Native	California Roach	211	NA	497	498	298	776	53	NA	NA	NA	314	54	51	48	92
	Freshwater Shrimp	8	NA	0	1	9	36	4	NA	NA	NA	318	33	26	13	30
	Sacramento Pikeminnow	62	NA	104	95	93	17	32	NA	NA	NA	70	7	14	6	33
	Sacramento Sucker	53	NA	79	178	90	3	3	NA	NA	NA	64	25	36	24	2
	Sculpin Sp	371	NA	474	370	602	420	24	NA	NA	NA	192	62	365	145	368
	Three-spined Stickleback	1,699	NA	253	1,497	409	5,606	56	NA	NA	NA	373	167	11,931	2,309	2,191
	Western Brook Lamprey	5	NA	69	44	71	105	0	NA	NA	NA	109	160	148	48	52
MILL CREEK																
Non-native	Bluegill	54	11	1	2	7	66	120	127	3	29	4	56	71	72	17
	Bullfrog	666	20	27	52	56	462	84	300	65	41	11	12	74	73	11
	Fathead Minnow	22	13	13	6	109	150	25	4	4	0	14	103	68	128	22
	Green Sunfish	35	5	1	0	12	6	5	1	3	5	6	22	16	12	42
Native	California Roach	110	65	84	60	341	198	116	151	363	20	258	114	453	146	149
	Freshwater Shrimp	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
	Sacramento Sucker	100	38	38	89	47	99	81	33	36	0	68	3	71	6	17
	Sculpin Sp	895	4,066	414	704	431	372	398	669	966	60	105	675	719	542	359
	Three-spined Stickleback	0	0	0	0	0	1	7	17	1	1	3	2	6	5	1
	Western Brook Lamprey	3	3	9	9	11	8	0	0	0	0	0	1	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.*

Natural Production

In all four streams, the number of natural-origin smolts was among the lowest observed during the past five years, ranging from three in Mill Creek to 282 in Green Valley Creek (Table 5). The percentage of natural-origin smolts

was also generally lower than average relative to the last five years, though not as dramatically low as the absolute numbers (Table 5).

Table 5. Number and percent of natural-origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2019. 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

Smolt Abundance

Smolt abundance estimates indicate that thousands of smolts emigrated from each of the four Broodstock Program monitoring tributaries during the spring of 2019 (Table 6). Smolt abundance was highest in Green Valley Creek but Green Valley Creek also had the highest number of total fish released and the highest number of smolts released (Table 6). Abundance was lowest in Willow and Mill creeks; however, this was to be expected as the pre-smolt or smolt release on those streams took place below the downstream trap and these fish were therefore not included in the abundance estimate.

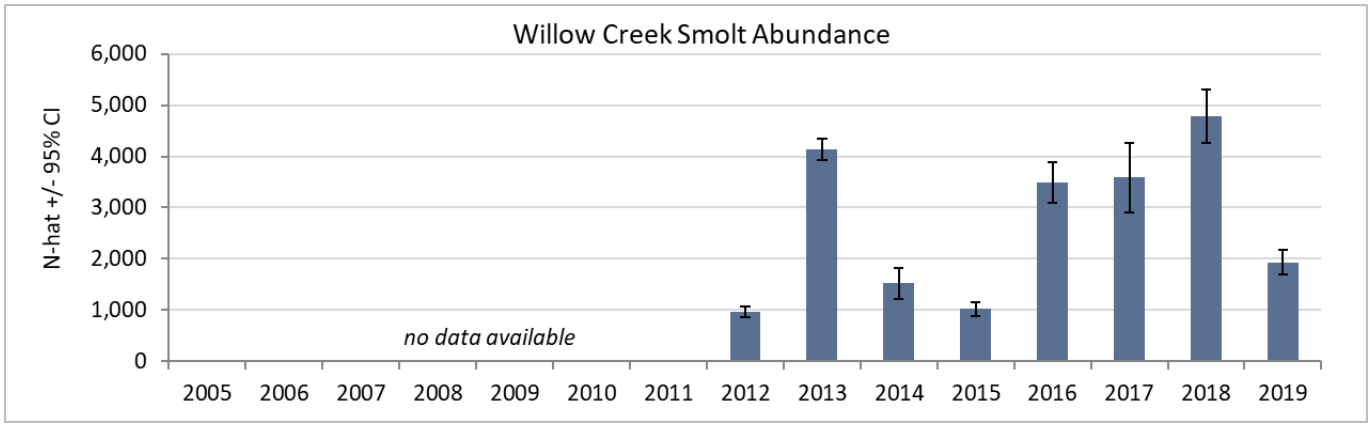
When compared with previous years' estimates, Mill Creek had the lowest abundance observed in the past 10 years (Figure 7). Willow, Dutch Bill and Green Valley creek abundance estimates were low compared to the past two years but within range of estimates observed since 2012 (Figure 7).

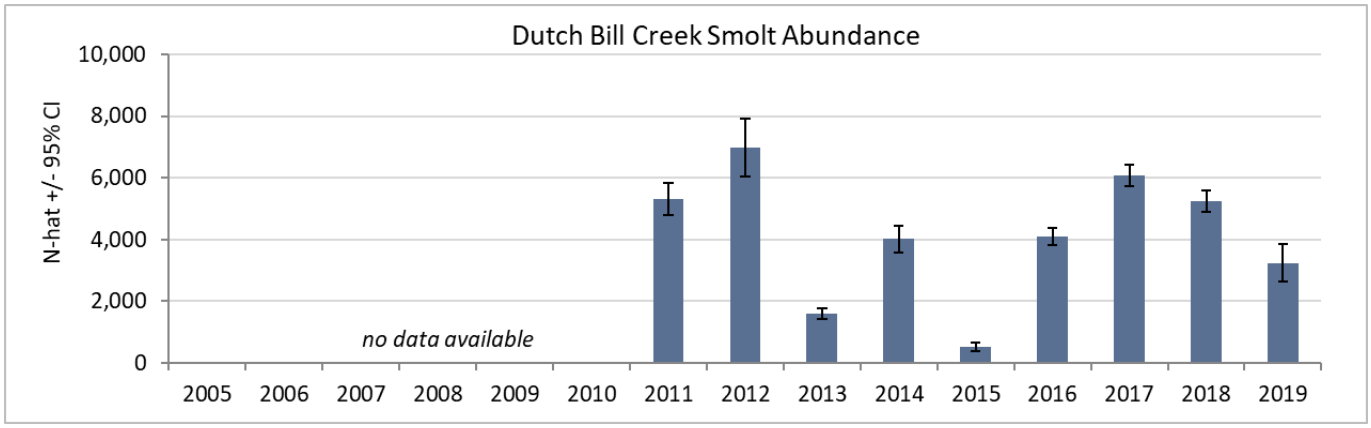
Table 6. Number of cohort 2018 juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creeks and estimated number of coho salmon smolts emigrating from each tributary during spring of 2019. Abundance estimates include both marked and unmarked smolts.

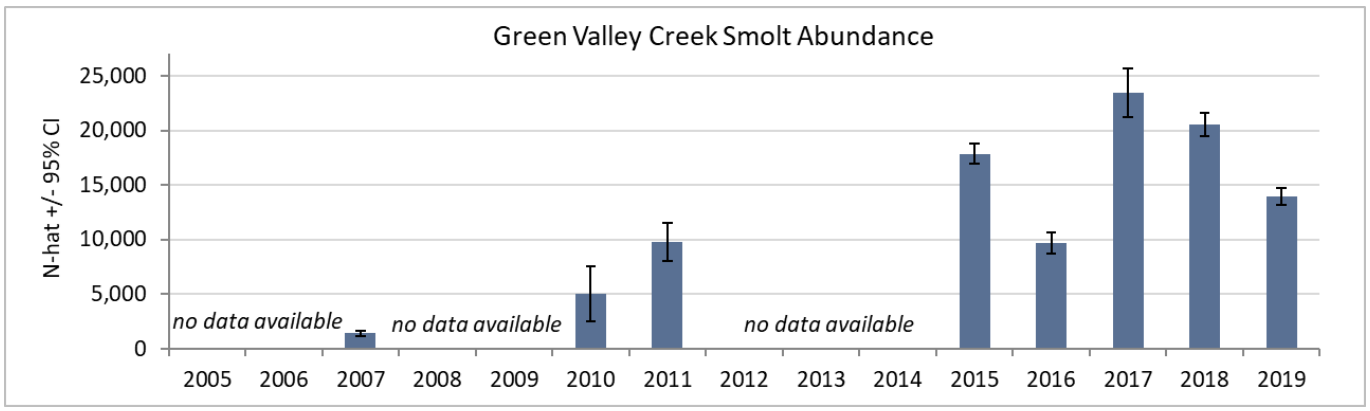
	Number Released						
Tributary	Spring	Fall	Pre-Smolt	Smolt	Total	Total Released Upstream of Trap	Estimated Smolt Abundance (95% CI)
Willow Creek	0	8,194	7,111 [1]	0	15,305	8,194	1,931 (462)
Dutch Bill Creek	0	7,062	0	5,047	12,109	12,109	3,242 (616)
Green Valley Creek	0	10,079	8,054	5,077	23,210	23,210	13,949 (762)
Mill Creek	1,010	13,237	0	5,087 [2]	19,334	14,247	2,294 (482)

[1] *Pre-Smolt release on Willow Creek took place downstream of the trap site so these fish were unlikely to be detected at the trapsite.*

[2] *Smolt release on Mill Creek took place downstream of the trap site so the fish were unlikely to be detected at the trapsite*







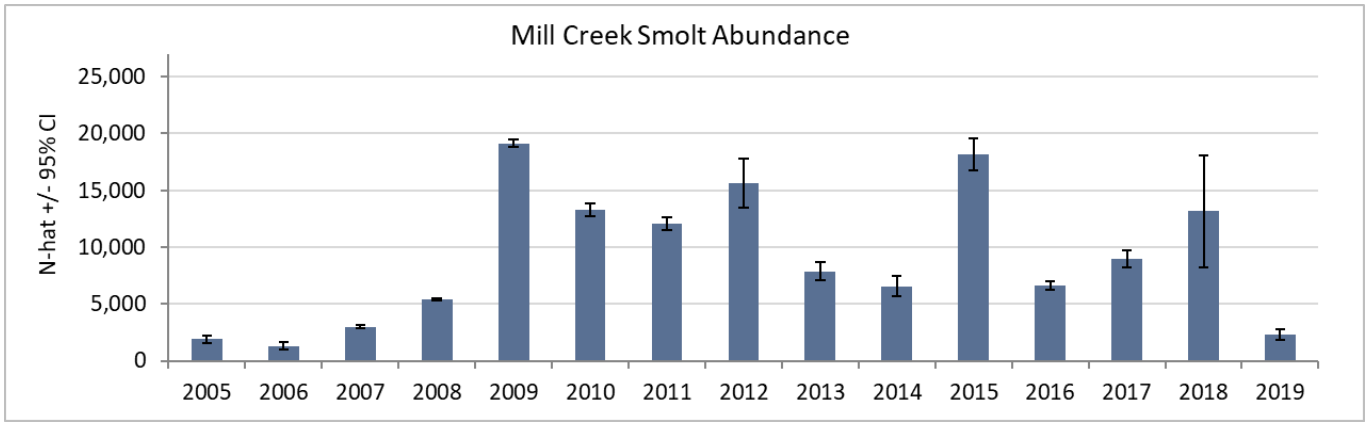


Figure 7. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2019.

Probability of Survival and Early Winter Emigration

The estimated probability of survival of spring-release juvenile coho salmon from the time of release in mid-June 2018 through 6/30/19 (approximately one year later) was 0.05 on Mill Creek (Table 7), which was low compared to previous years on Mill Creek (average of 0.12 over 11 years; UC unpublished data). In 2018, the Broodstock Program released only 1,010 fish in the spring in Mill Creek for the purpose of continuing a summer survival study conducted by UC through the Russian River Coho Water Resources Partnership. These coho salmon were released on 6/15/2018 into two 250 m-long, long-term study reaches in Mill Creek rather than distributed evenly throughout the watershed, as with the fall release. It is important to recognize that the spring-release survival estimates presented in Table 7 only represent survival of fish stocked into these reaches and therefore inferences cannot be made about survival in the entire stream.

The estimated probability of survival of fall-release juvenile coho from the time of release in late November/early December 2018 through 6/30/19 was higher than for the spring release, ranging from 0.15 on Mill Creek to 0.55 on Green Valley Creek (Table 7). When comparing fall-release survival estimates with previous years' estimates, survival during the winter of 2018/19 was the second lowest recorded on Mill Creek, average for Dutch Bill and Willow creeks and the highest recorded on Green Valley Creek (Figure 8). As in most years, overwinter survival was highest in Green Valley Creek (Figure 8).

The estimated probability of survival of pre-smolt release group fish ranged from 0.61 to 0.64, and the estimated probability of survival for smolt-release group fish ranged from 0.80 to 0.94 (Table 8). Green Valley Creek was the only stream that had both pre-smolt and smolt releases and the estimated probability of survival for smolt releases, 0.80 to 0.92, was significantly higher than that of the pre-smolt release, 0.64 (Table 8).

The estimated probability of spring-release juvenile coho salmon emigrating from Mill Creek prior to March 1 was 0.06 (Table 9). For the fall release group, estimates of winter emigration ranged from 0.00 in Green Valley Creek to 0.16 in Dutch Bill Creek (Table 9). In Willow Creek, where paired antennas were operated year-round at the trap site (upstream of 3rd Bridge) and at the mouth (Figure 3), 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 0.28, but past the antennas at the mouth was 0.01, suggesting that fish that moved downstream below the trap site prior to 3/1/19 did not immediately emigrate out of Willow Creek and into the Russian River. Compared with previous years, estimated probabilities for pre-March 1 emigration for the fall release groups were similar to previous years with minimal or no emigration from Green Valley Creek or the mouth of Willow Creek, relatively high emigration from Dutch Bill Creek, and moderate emigration from Mill Creek (Table 9, Figure 9).

Table 7. Estimated probability of juvenile coho salmon survival from the date of release in 2018 through 6/30/19 for 2018 spring and fall release groups. 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	11/20/2018	222	0.22 (0.20-0.24)[1]
Dutch Bill Creek	NA	NA	NA	12/5/2018	207	0.28 (0.25-0.30
Green Valley Creek	NA	NA	NA	12/6/2018	206	0.55 (0.52-0.57)
Mill Creek	6/15/2018	380	0.05 (0.04-0.07)	11/15/2018	227	0.15 (0.14-0.17)

[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 0.20 (0.18-0.23).*

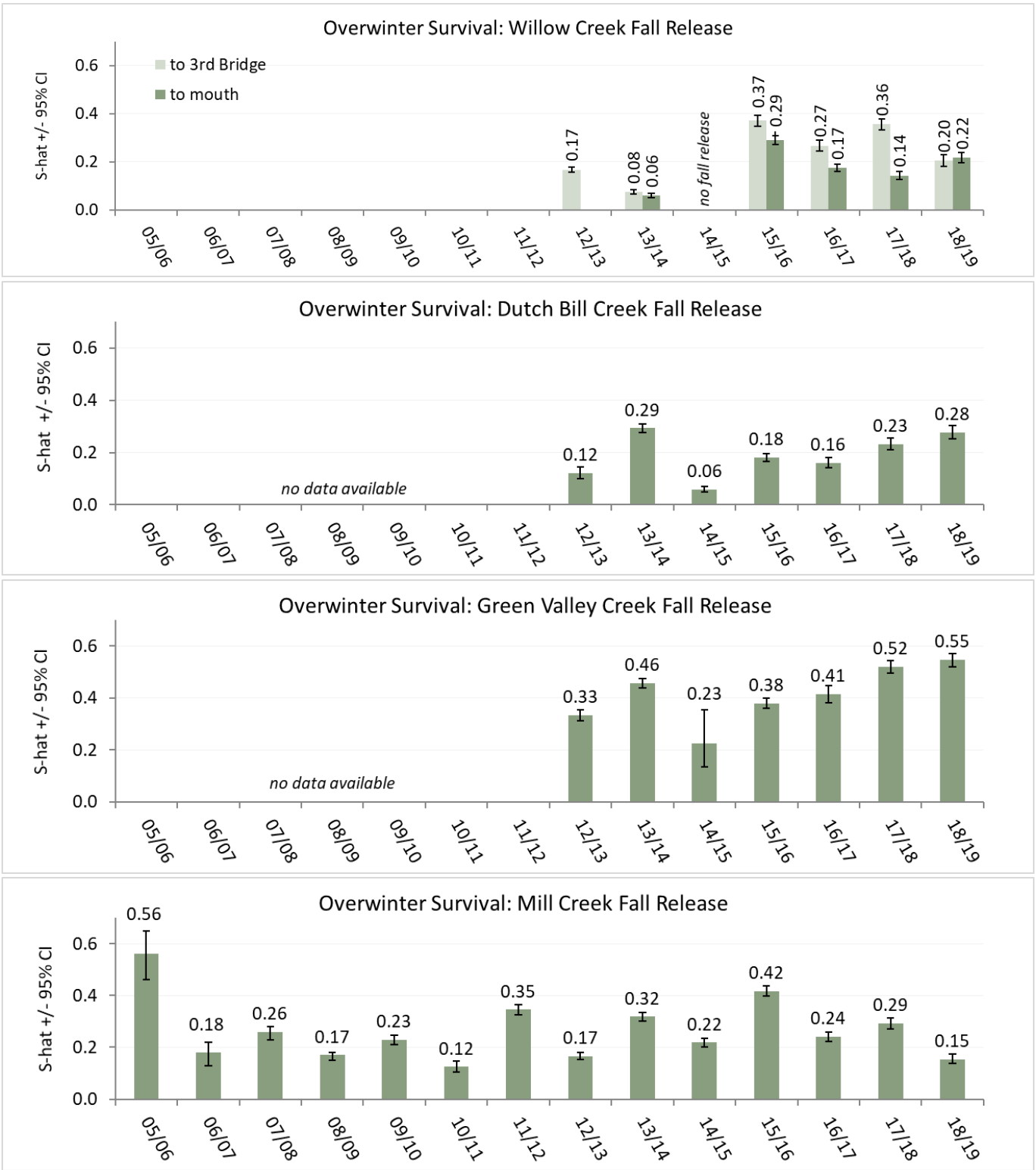


Figure 8. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.

Table 8. Estimated probability of juvenile coho salmon survival from the date of release through 6/30/19 for each pre-smolt and smolt release group. NA=not applicable; fish were released downstream of antennas and traps so survival could not be estimated.

Tributary	Release Group	Release Type	Release Site	River km	Release Date	Days Imprinted	Survival interval	Probability of Survival (95%CI)
Willow Creek	pre-smolt	stream	Third Bridge	3.48	3/5/2019	0	117	0.61 (0.58-0.63)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	4/1/2019	17	90	0.94 (0.86-0.97)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	4/15/2019	12	76	0.92 (0.88-0.94)
Dutch Bill Creek	smolt	tank	Monte Rio boat launch	16.5	4/29/2019	12	62	0.94 (0.90-0.96)
Green Valley Creek	pre-smolt	stream	GRE Iron Horse Bridge	7.8	3/7/2019	0	115	0.64 (0.62-0.67)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/1/2019	0	90	0.80 (0.75-0.84)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/15/2019	0	76	0.92 (0.89-0.95)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/29/2019	0	62	0.89 (0.85-0.91)
Mill Creek	smolt	stream	below smolt trap	1.99	4/1/2019	0	90	NA
Mill Creek	smolt	stream	below smolt trap	1.99	4/15/2019	0	76	NA
Mill Creek	smolt	stream	below smolt trap	1.99	4/29/2019	0	62	NA

Table 9. Estimated probability of juvenile coho salmon emigrating from each tributary prior to 3/1/19. NA indicates that no fish were released.

Tributary	Probability of Emigration Prior to 3/1 (95% CI)	
	Spring Release	Fall Release
Willow Creek	NA	0.01 (0.01-0.02) [1]
Dutch Bill Creek	NA	0.16 (0.14-0.18)
Green Valley Creek	NA	0.00 (0.00-0.01)
Mill Creek	0.06 (0.05-0.08)	0.08 (0.06-0.09)

[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 3/1/19 was 0.28 (0.26-0.30).*

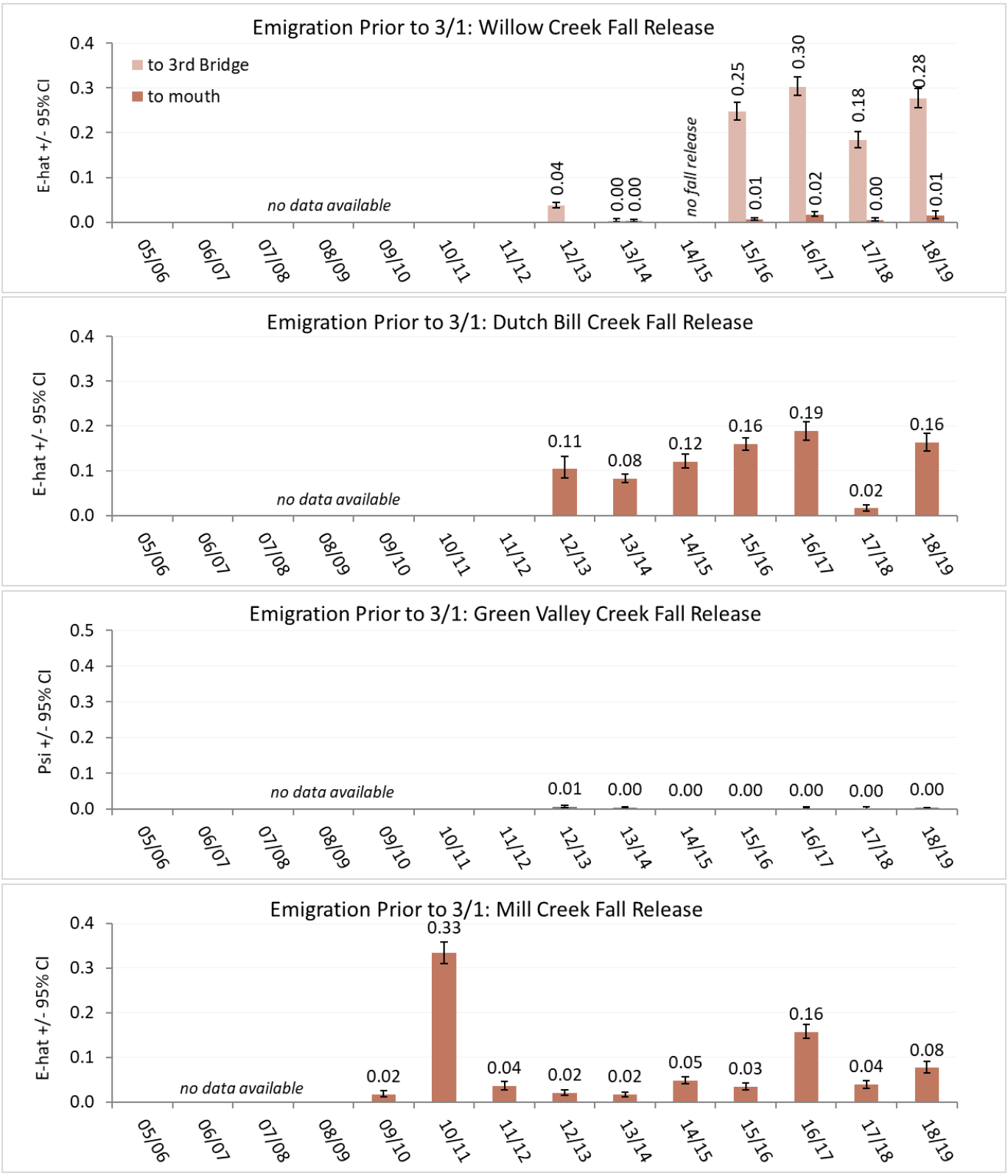


Figure 9. Probability of emigration (E-hat) past antenna sites prior to 3/1. Willow, Dutch Bill, Green Valley, and Mill creeks.

Migration Timing

Weekly totals of outmigrating smolts were plotted by release group and antenna site within the watershed for the period of October 29, 2018 to June 30, 2019 and compared with stream depth (stage) data from each creek (Figure 10 - Figure 22; note the difference in the y-axes scales). Antennas at multiple locations within each stream (Figure 3) 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.

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 for all release groups (Figure 11, Figure 14, Figure 17, Figure 21 - Figure 22). The proportion of juvenile coho salmon migrating out of each creek during the winter (i.e., past the downstream-most antenna array) varied by stream, with higher winter emigration occurring in Dutch Bill and Mill creeks and lower in Willow and Green Valley creeks. Pulses of emigration in Dutch Bill and Mill creeks were correlated with the first two significant rain events of the season in mid December and early January (Figure 13 - Figure 14, Figure 20 - Figure 22).

Winter migration past antenna arrays located higher up in each watershed occurred in all creeks and 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 11). In Dutch Bill Creek, we observed a large pulse of fish moving past both antenna sites (river km 6.51 and 0.68) in December, then continuous movement throughout the winter and spring, with a second pulse in the spring on the lower antenna (Figure 14). 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 17). In Mill Creek, we observed fall-release fish moving past the upper two arrays (river km 12.39 and 6.10) within the first two weeks of being released (Figure 22). Some of these fish were observed on the lower array (river km 2.01) after the first large storm of the season in early January but many appear to have overwintered in the lower reaches of Mill Creek above river km 2.01.

Pre-smolt and Smolt Release Groups

Movement patterns for the pre-smolt and smolt release groups varied by stream (Figure 12, Figure 15, Figure 18 - Figure 19). In Willow Creek, a small proportion of the pre-smolt release fish were detected on the lower array within the first week of release, but the majority of fish were detected over a month after the release (Figure 12). Interestingly, there were many detections of pre-smolt release fish immediately following the release on the upper antennas, which are located approximately 200 m upstream of the pre-smolt release site. In Dutch Bill Creek, the smolt-release fish left the streams immediately (Figure 15). In Green Valley Creek, a portion of the pre-smolt release group was detected on the lower antenna array within the first two weeks of the release but the majority were detected between mid-April and the end of May (Figure 18). A small number of pre-smolt fish were

detected moving upstream of their release site (Figure 18). The majority of all three Green Valley Creek smolt release groups (released at river km 13.82) were detected at the upper antenna array almost immediately after release and at the middle antenna array within two weeks (Figure 19). Although a limited number of fish were detected on the lower antenna within two weeks, the majority of detections on the lower antenna didn't take place until mid-April, nearly a month after smolt releases(Figure 19). This implies that a significant number of smolt-release fish are remaining in Green Valley Creek for several weeks before out-migrating.

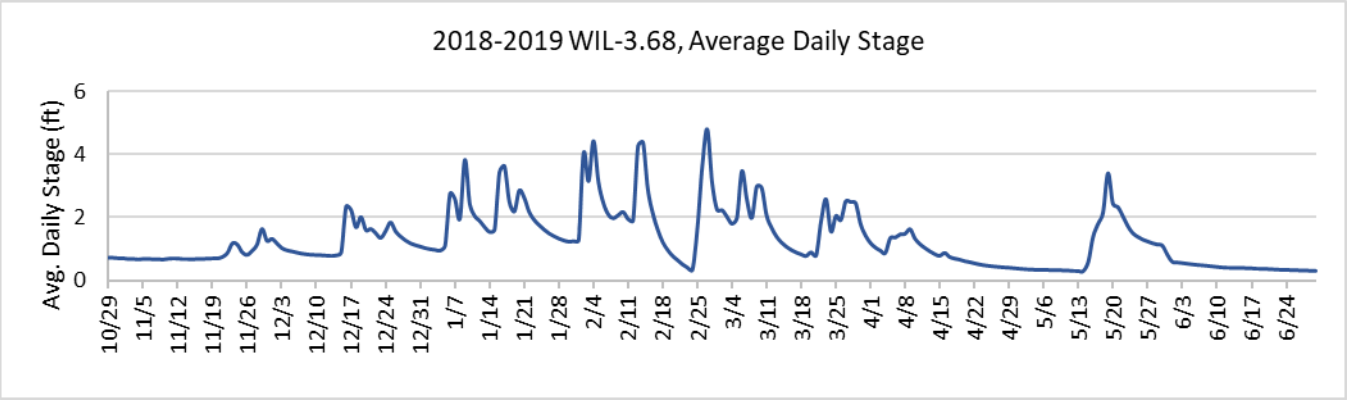


Figure 10. Average daily stage height at the Willow Creek smolt trap site (river km 3.68) between October 29, 2018 and June 30, 2019.

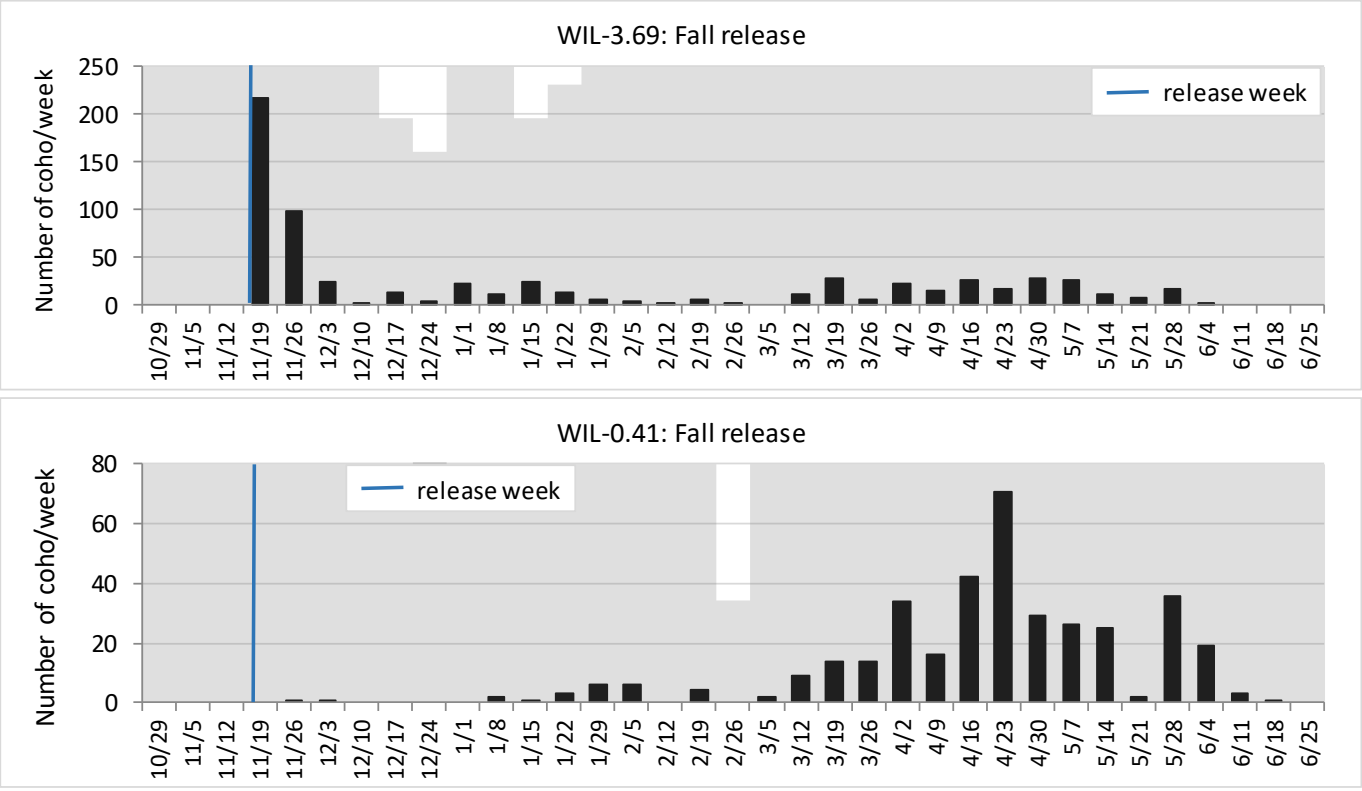


Figure 11. Number of fall-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 5.38 to 7.40.

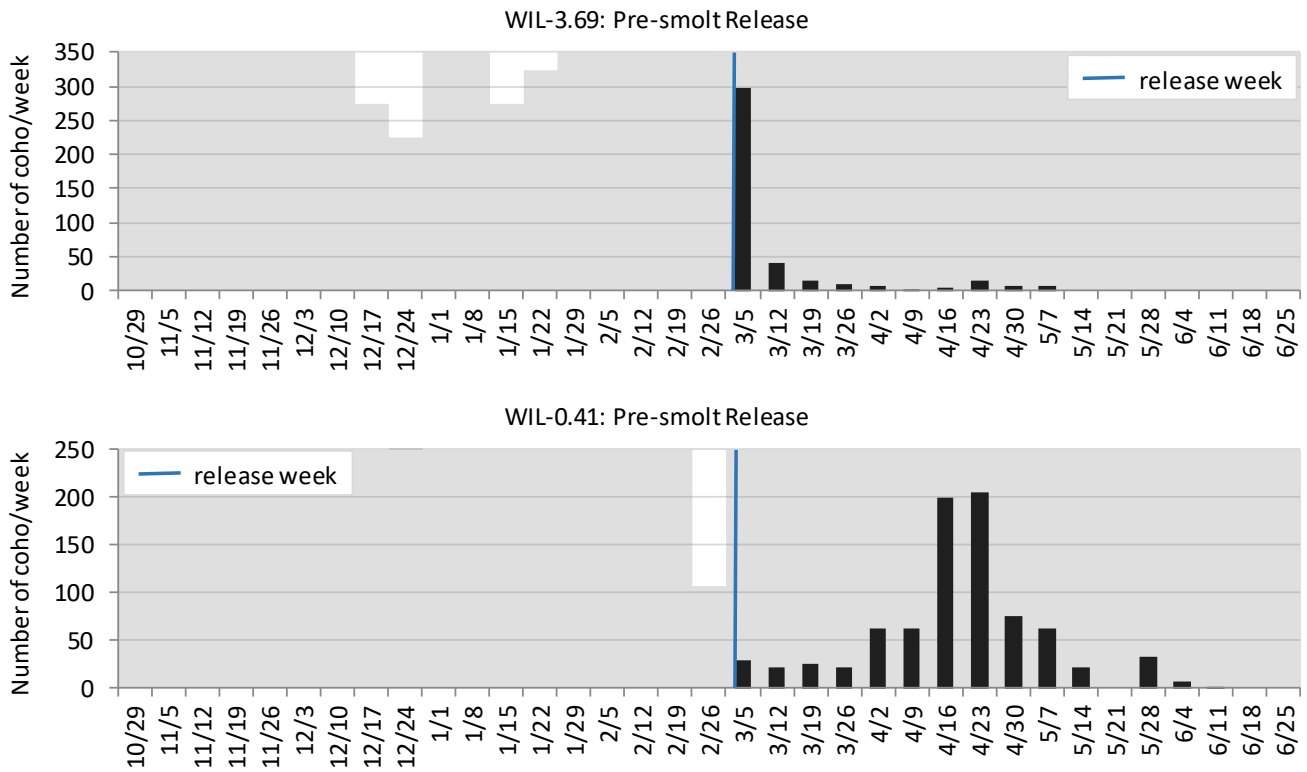


Figure 12. Number of pre-smolt-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 3.48.

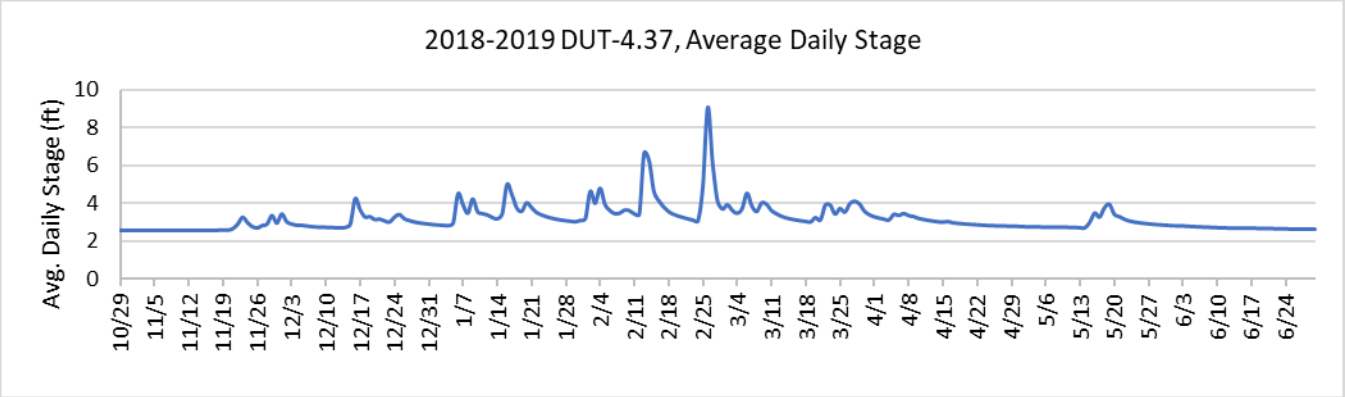


Figure 13. Average daily stage height at the Dutch Bill Creek river km 4.37 between October 29, 2018 and June 30, 2019.

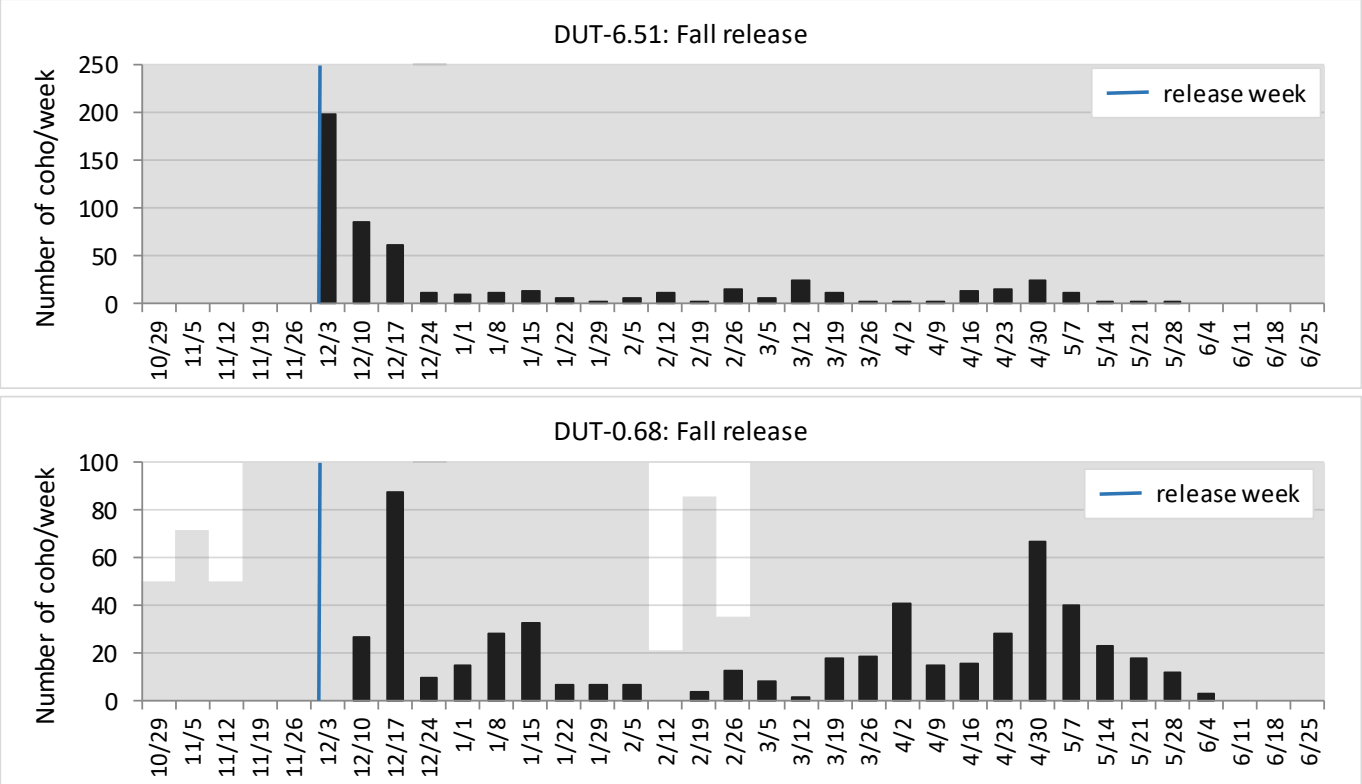


Figure 14. Number of fall-release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and the smolt trap site (DUT-0.68) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 6.11 to 9.71.

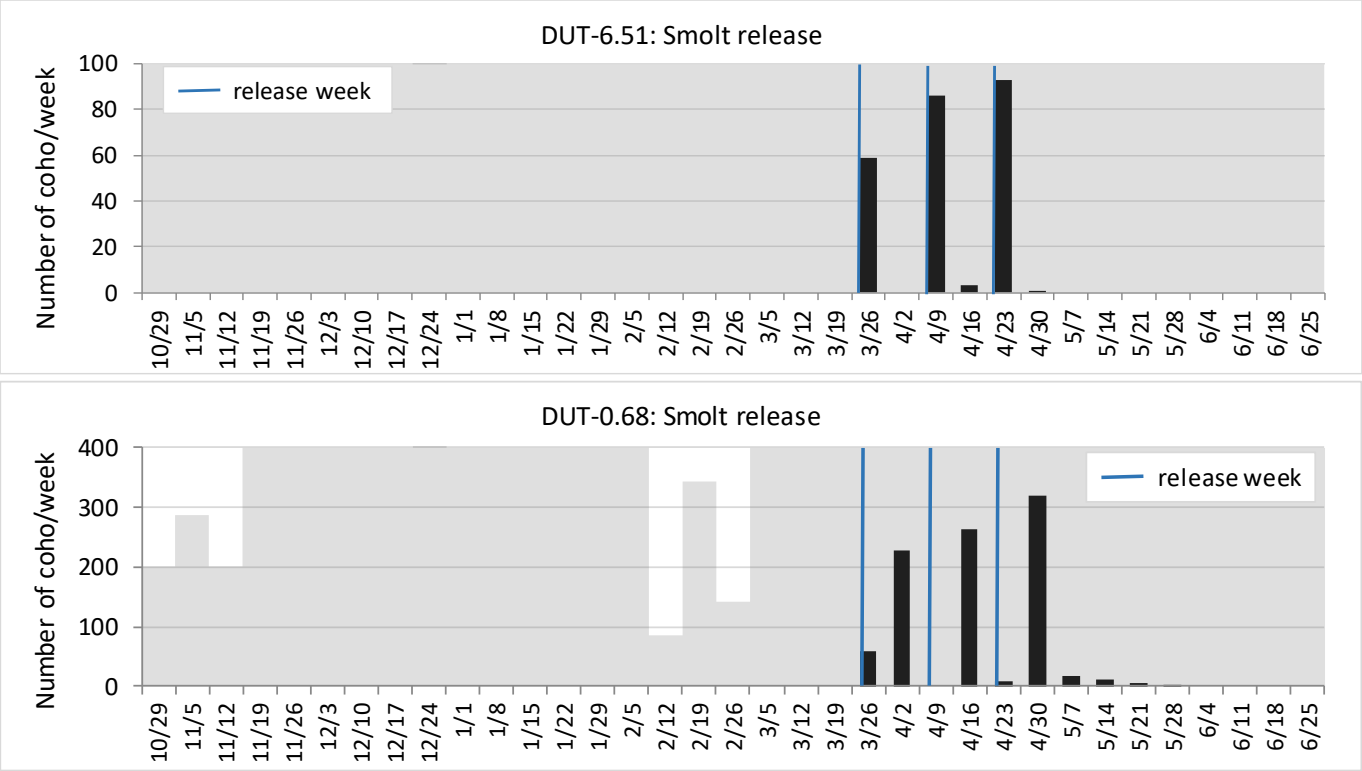


Figure 15. Number of smolt-release coho salmon that moved past the upper Dutch Bill Creek antenna site (DUT-6.51) and the smolt trap site (DUT-0.68) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 6.52.

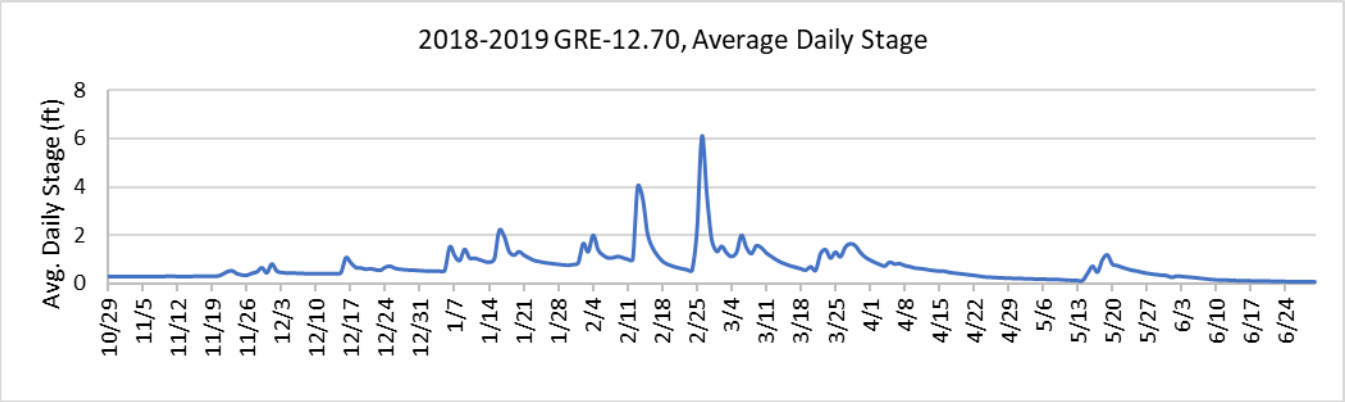


Figure 16. Average daily stage on Green Valley Creek (river km 12.70) between October 29, 2018 and June 30, 2019.

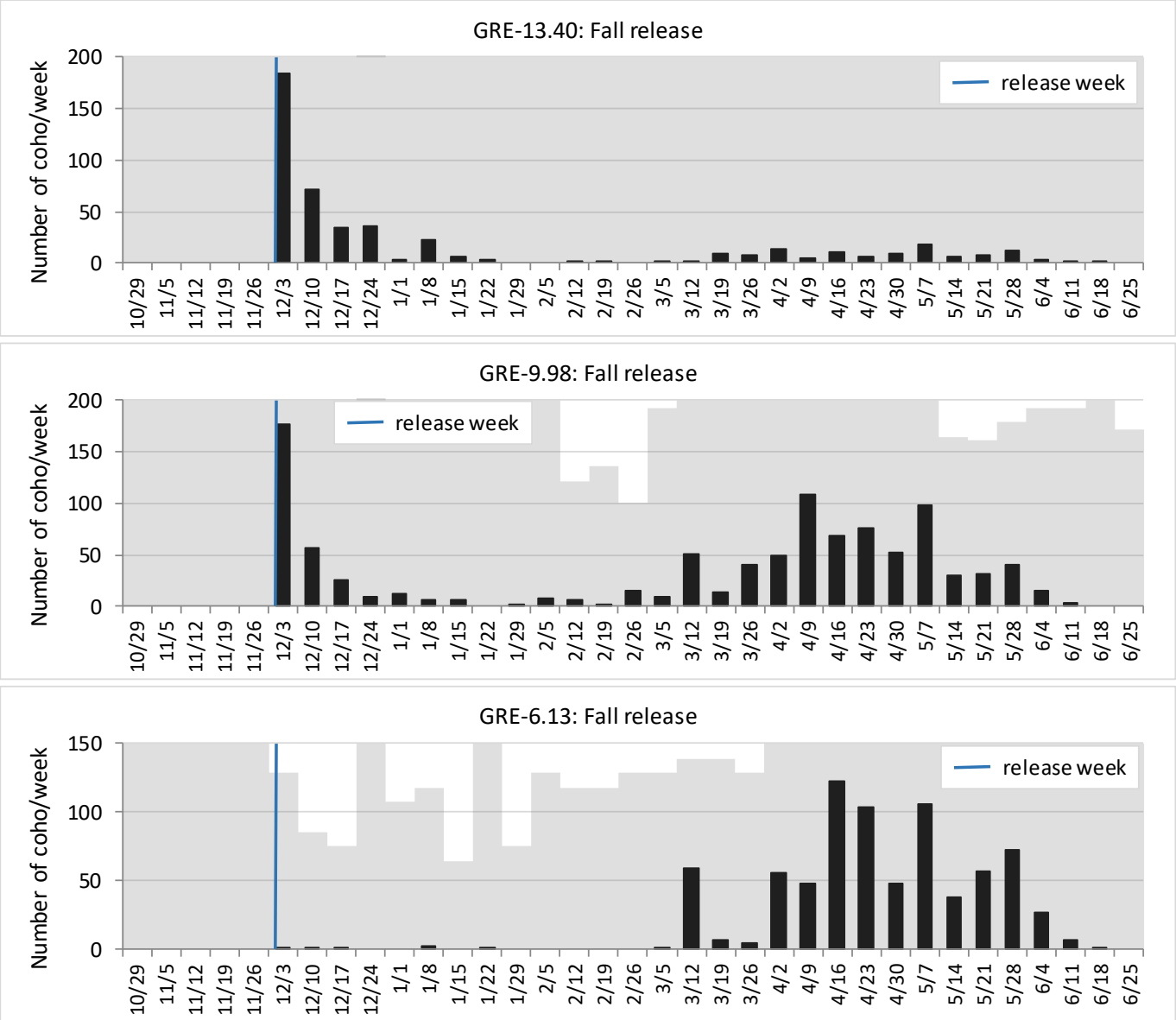


Figure 17. Number of fall-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2018 and June 30, 2019. Total

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 14.36.

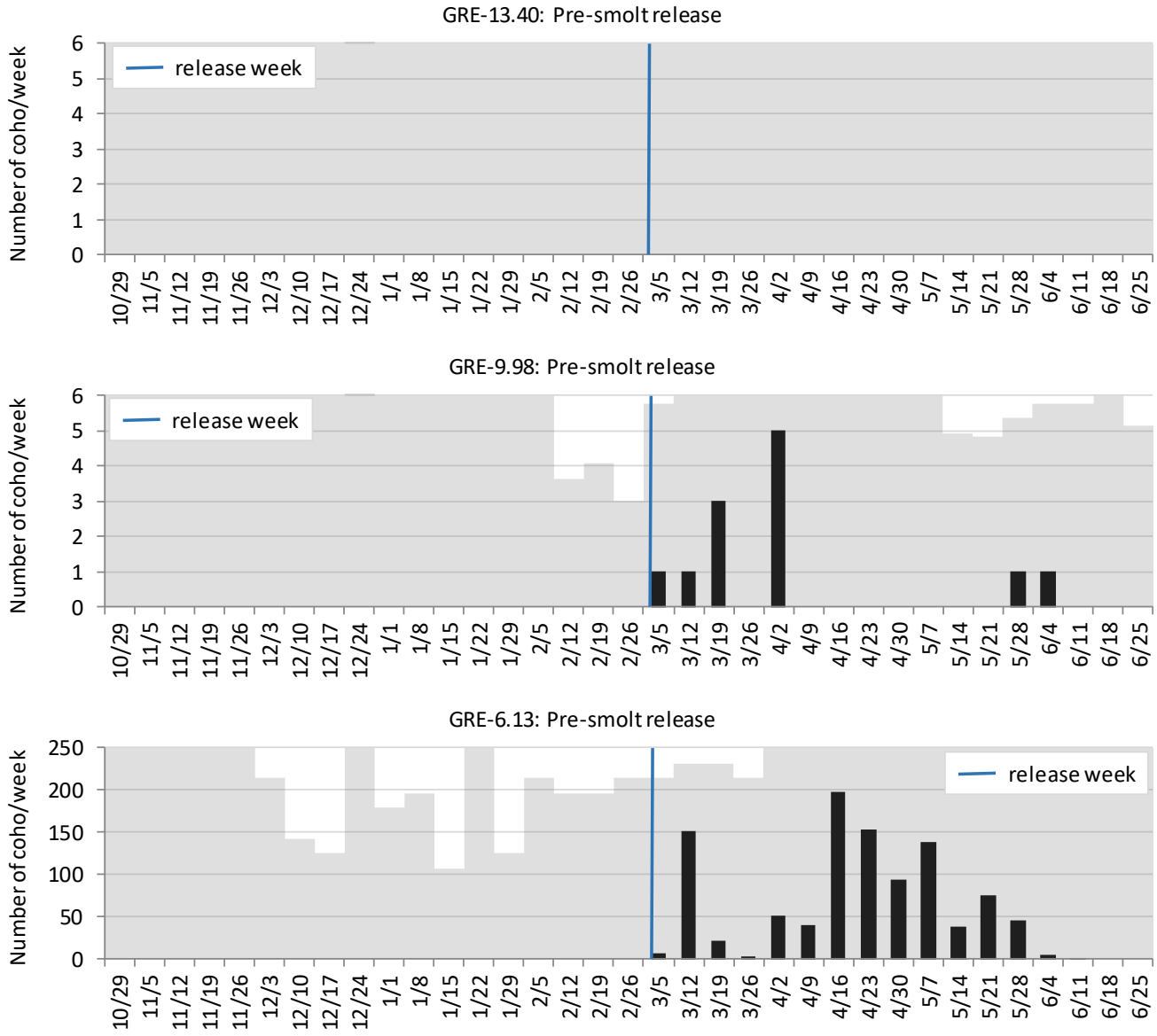


Figure 18. Number of pre-smolt-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day 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.

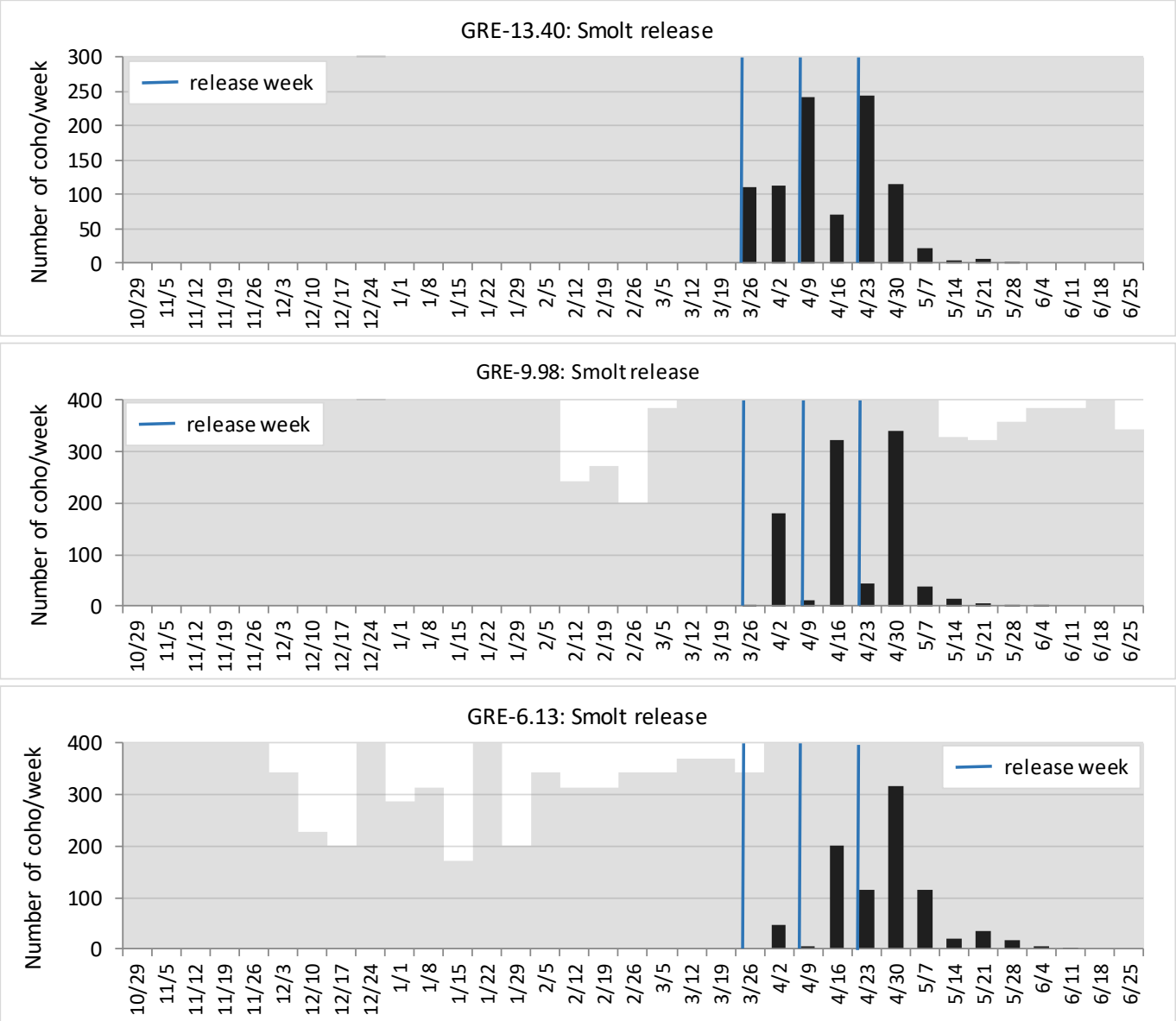


Figure 19. Number of smolt-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 13.82.

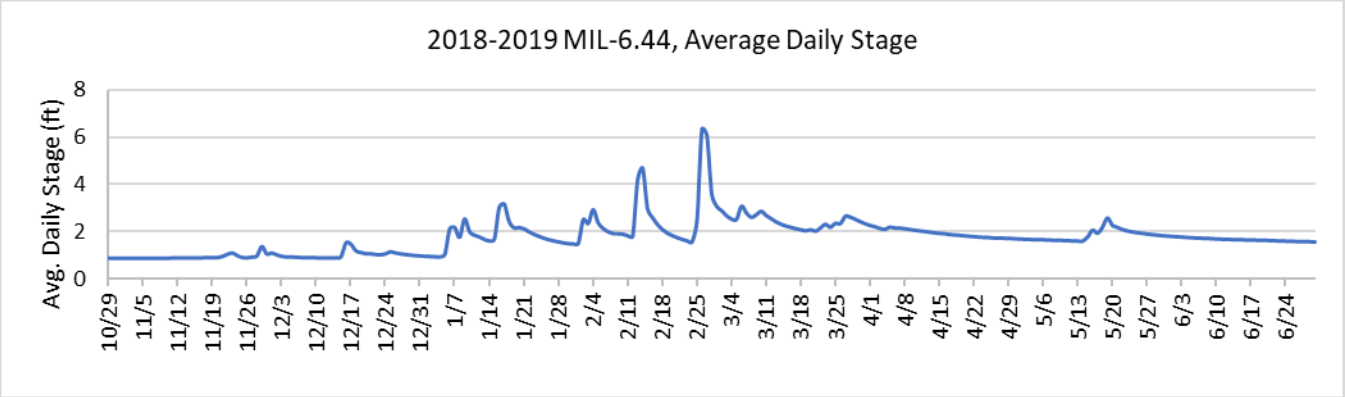


Figure 20. Average daily stage at the Mill Creek smolt trap site (river km 3.11) between October 29, 2018 and June 25, 2019.

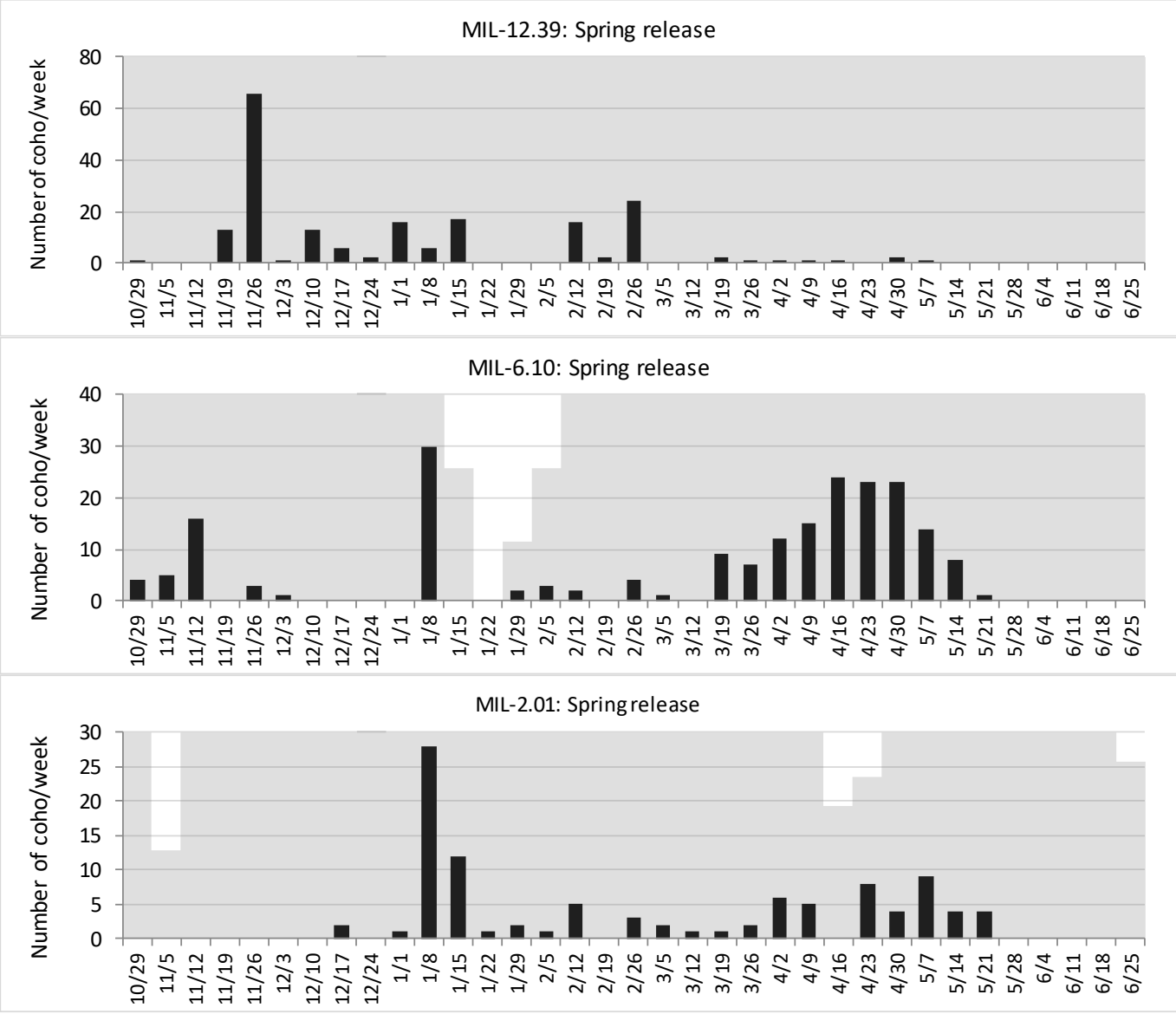


Figure 21. Number of spring-release coho smolts that moved past the upper- (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 6.10 to 12.63.

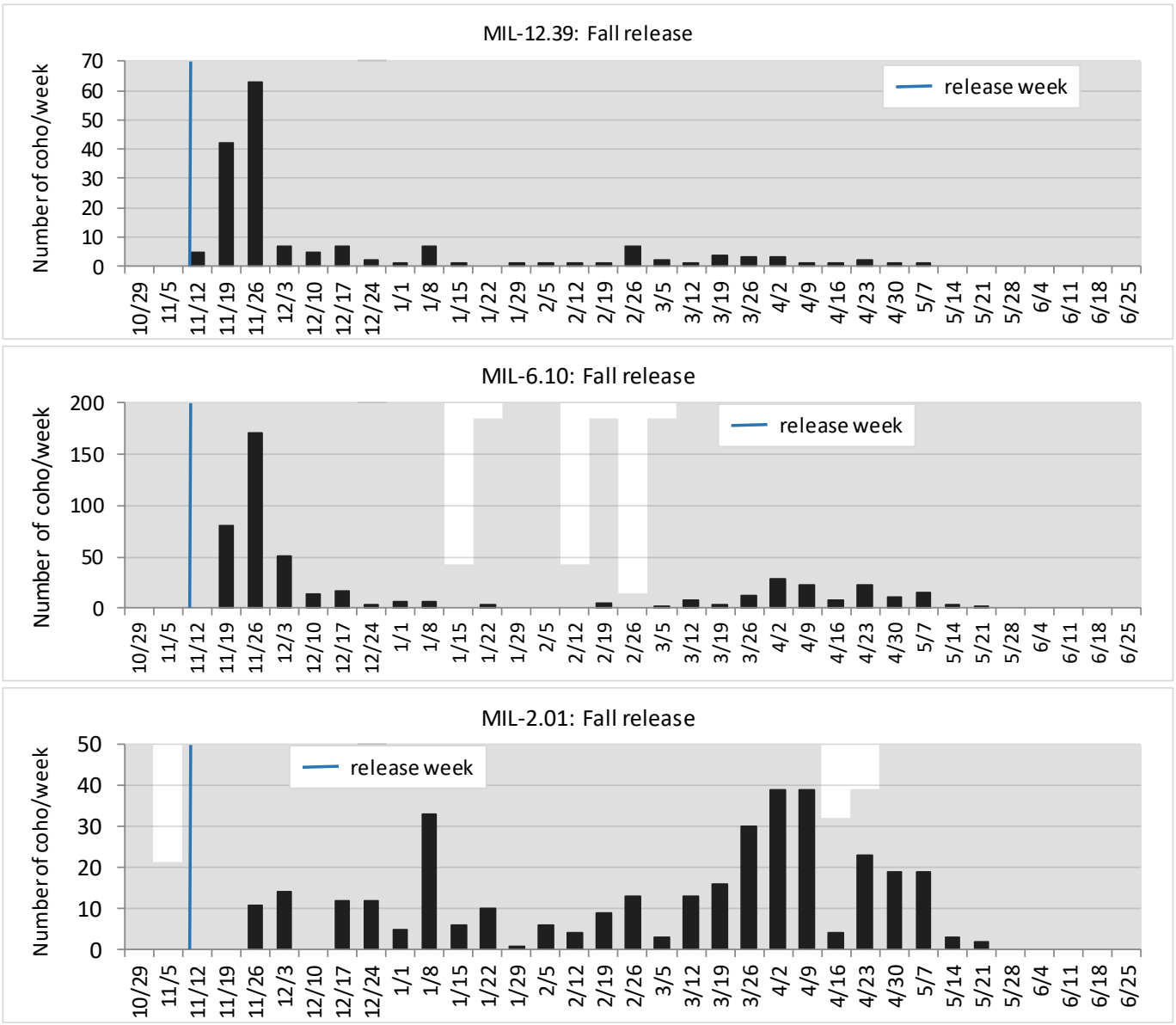


Figure 22. Number of fall-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2018 and June 30, 2019. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 9.04 to 13.55.

Size

In all Broodstock Program monitoring streams, the average size *at release* increased progressively with the age of the fish (spring < fall < pre-smolt < smolt), and within release groups only slight differences were observed among streams (Table 10). Release group average sizes for all 2018 cohort Broodstock Program release streams combined were 63.4 mm and 3.2 g (spring), 94.3 mm and 10.5 g (fall), 104.9 mm and 14.5 g (pre-smolt) and 114.3 mm and 17.6 g (smolt).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 106.3 mm and 13.1 g in Mill Creek to 125.9 mm and 21.7 g in Green Valley Creek (Table 11). Average fork length and weight of smolts captured in Willow Creek (111.2 mm and 14.4 g) and Dutch Bill Creek (118.9 mm and 16.9 g) were intermediate (Table 11).

There was generally a wide range in fork length distribution of recaptured hatchery fish within each release group on each stream (Figure 23). Only six fish were recaptured from the spring release in Mill Creek and they were smaller than fish recaptured from other releases (Figure 23). Fish captured in Green Valley were larger than those from other streams across all release groups (Figure 23). Smolt releases only took place in Dutch Bill and Green Valley creeks and sizes were similar across both creeks, as would be expected given the short time between release and recapture (Figure 23).

Hatchery-origin coho salmon smolts were larger than their natural-origin counterparts in all streams but these differences were generally minimal (Table 11). Such differences were not observed in past years. Green Valley Creek hatchery smolts were the largest among all groups, averaging 126.1 mm and 21.8 g (Table 11).

Table 10. Average fork length (mm) and weight (g) of cohort 2018 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	93 (±9.2)	10 (±3.1)	1,615
	Pre-Smolt	104.5 (±11.3)	14.1 (±4.9)	1,382
Dutch Bill Creek	Fall	95.7 (±8.7)	11 (±3.2)	1,406
	Smolt	111.8 (±9.3)	16.5 (±4.2)	1,004
Green Valley Creek	Fall	97 (±9)	11.6 (±3.5)	1,401
	Pre-Smolt	105.2 (±12.3)	14.8 (±5.3)	1,598
	Smolt	115 (±10)	18.2 (±4.7)	1,012
Mill Creek	Spring	63.4 (±4.5)	3.2 (±0.9)	1,007
	Fall	92 (±9)	9.8 (±3)	1,616
	Smolt	116 (±9.7)	18.2 (±4.6)	1,014

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 2019 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	111.8 (±9)	14.6 (±3.3)	344
Natural	107.2 (±9.3)	13.1 (±3)	52
All Smolts	111.2 (±9.2)	14.4 (±3.3)	396
Dutch Bill Creek			
Hatchery	119 (±10.4)	16.9 (±4.4)	301
Natural	114.7 (±9.4)	15.4 (±3.4)	12
All Smolts	118.9 (±10.4)	16.9 (±4.4)	313
Green Valley Creek			
Hatchery	126.1 (±11.4)	21.8 (±6.3)	2,724
Natural	123.6 (±12.7)	20.7 (±6.5)	282
All Smolts	125.9 (±11.6)	21.7 (±6.4)	3,006
Mill Creek			
Hatchery	106.3 (±8.9)	13.1 (±3.5)	226
Natural	103.7 (±2.5)	11.5 (±1.7)	3
All Smolts	106.3 (±8.9)	13.1 (±3.5)	229

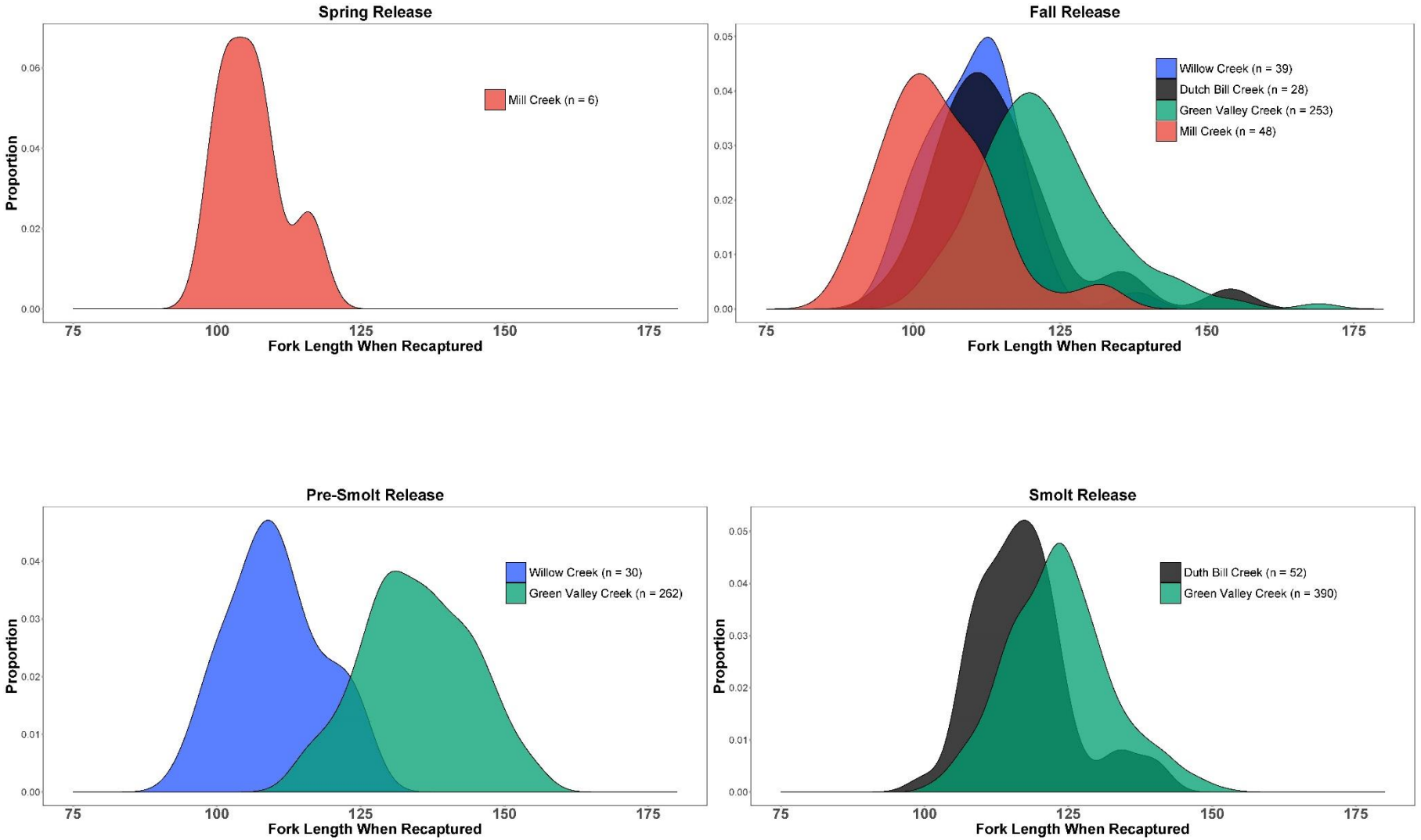


Figure 23. Length-frequency distribution of PIT-tagged coho salmon smolts captured in the spring of 2019 in downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, by release season.

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 12, Figure 24). 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 both size since release (Table 12) and average daily growth rate (Figure 25). Pre-smolt release fish grew in both Willow and Green Valley creeks; however, estimating growth for Willow Creek pre-smolts was only possible for fish that migrated upstream from the release point so averages are not representative of the majority of the release which migrated down from the release point. Pre-smolt release fish in Green Valley Creek showed the highest growth rates of any release groups, and had a greater total increase in total size than fall-release fish in the same stream despite being in the stream for only half the number of days. Smolt-release fish, which spent the least number of days in the stream environment, generally grew in length, particularly in Green Valley Creek, but increased very little or even decreased in weight (Table 12, Figure 26).

Growth rates for cohort 2018 fall-release fish captured in the downstream migrant traps in 2019 were higher than in 2018 across all streams, and generally higher than average relative to previous years (Figure 25). 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 show a steady decrease in growth rate with later release dates (Figure 26).

Table 12. Average growth in fork length (mm) and weight (g) of recaptured PIT-tagged coho salmon smolts during the 2019 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	19.5 (±8.8)	4.9 (±2.6)	39	185 (±16)
Pre-Smolt	11.7 (±5.2)	2.2 (±2)	30	36 (±8)
Dutch Bill Downstream Migrant Trap				
Fall	18.6 (±8.4)	3.9 (±2.9)	28	152 (±11)
Smolt	3.5 (±3.8)	-1.0 (±1.4)	54	22 (±7)
Green Valley Downstream Migrant Trap				
Fall	25.9 (±10.9)	8.9 (±6.4)	253	162 (±17)
Pre-Smolt	29.8 (±10.1)	12.9 (±5.8)	262	81 (±15)
Smolt	7.5 (±7.4)	1.5 (±3.4)	390	33 (±22)
Mill Downstream Migrant Trap				
Spring	41.2 (±11.8)	9.2 (±2.6)	5	345 (±3)
Fall	18 (±6.7)	4.2 (±2.7)	48	186 (±13)

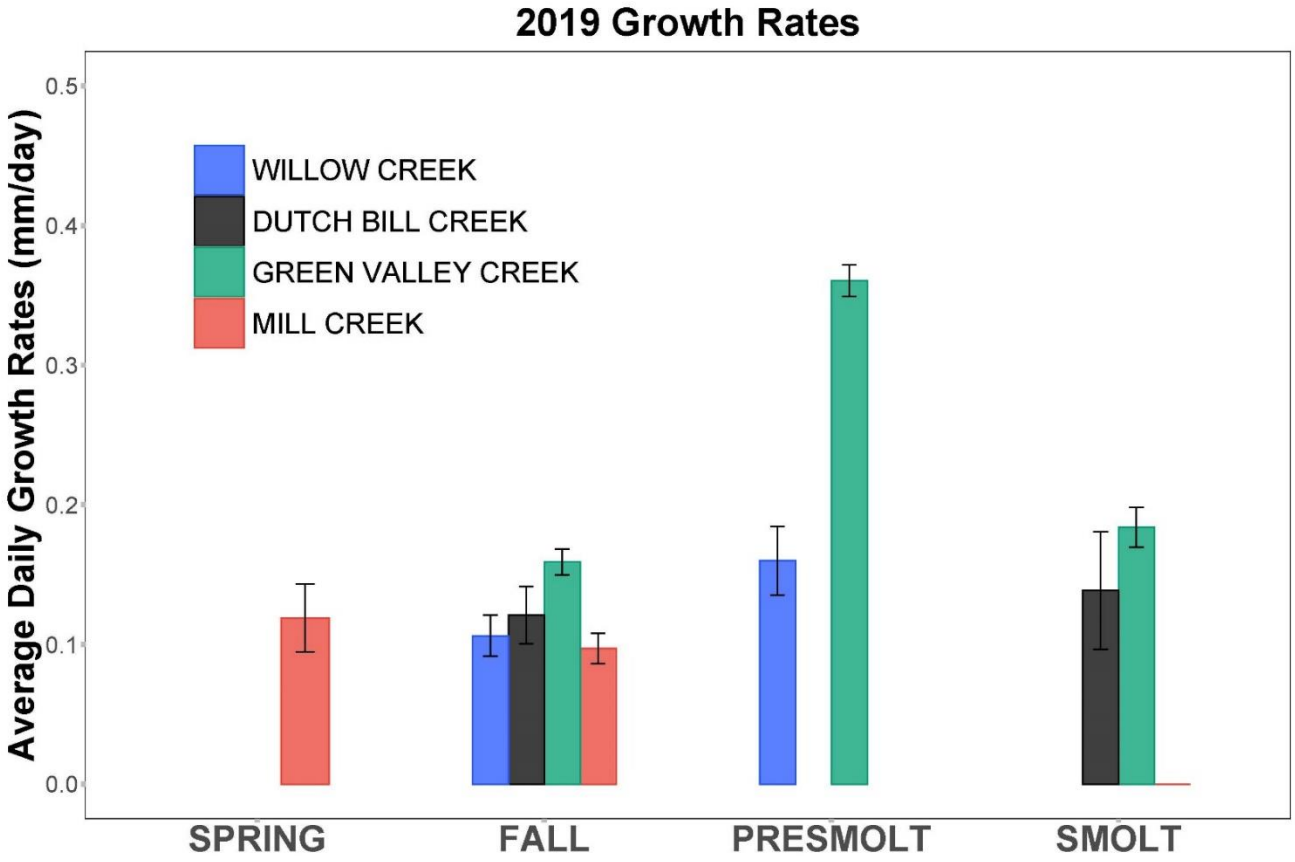


Figure 24. Average daily growth rates in fork length (mm) of PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2019 season, by stream and release season.

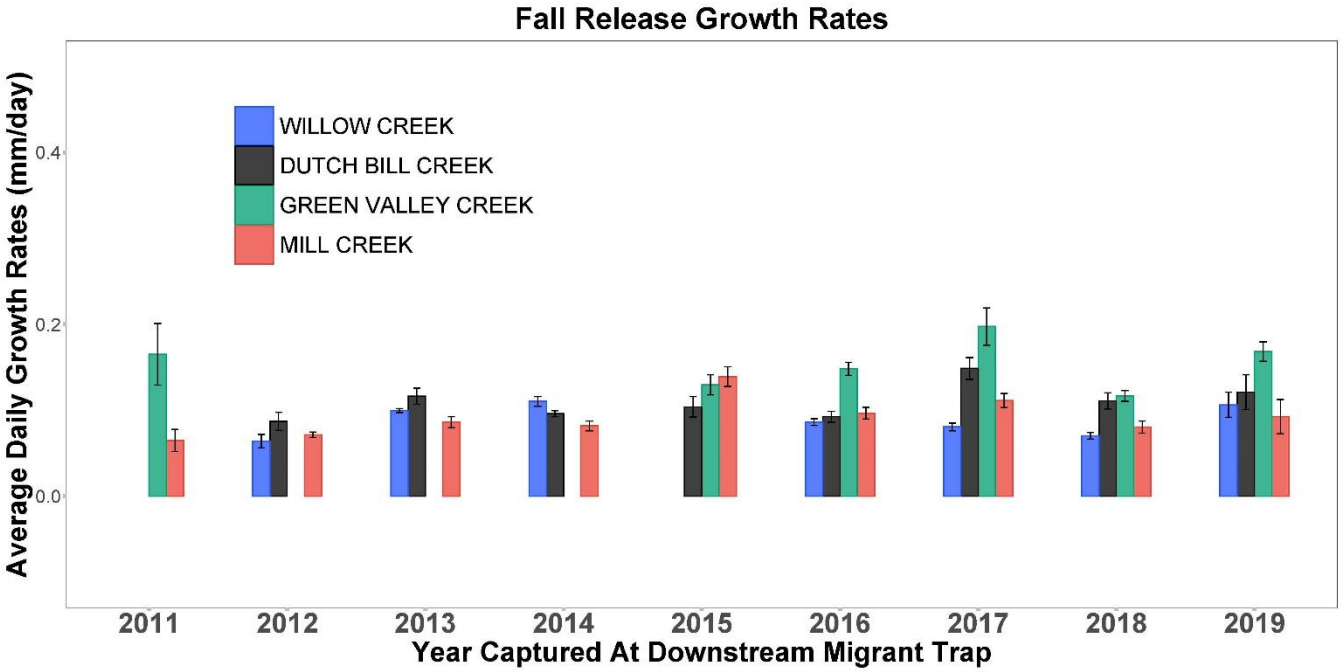


Figure 25. Average daily growth rates in fork length (mm) of fall-release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2019.

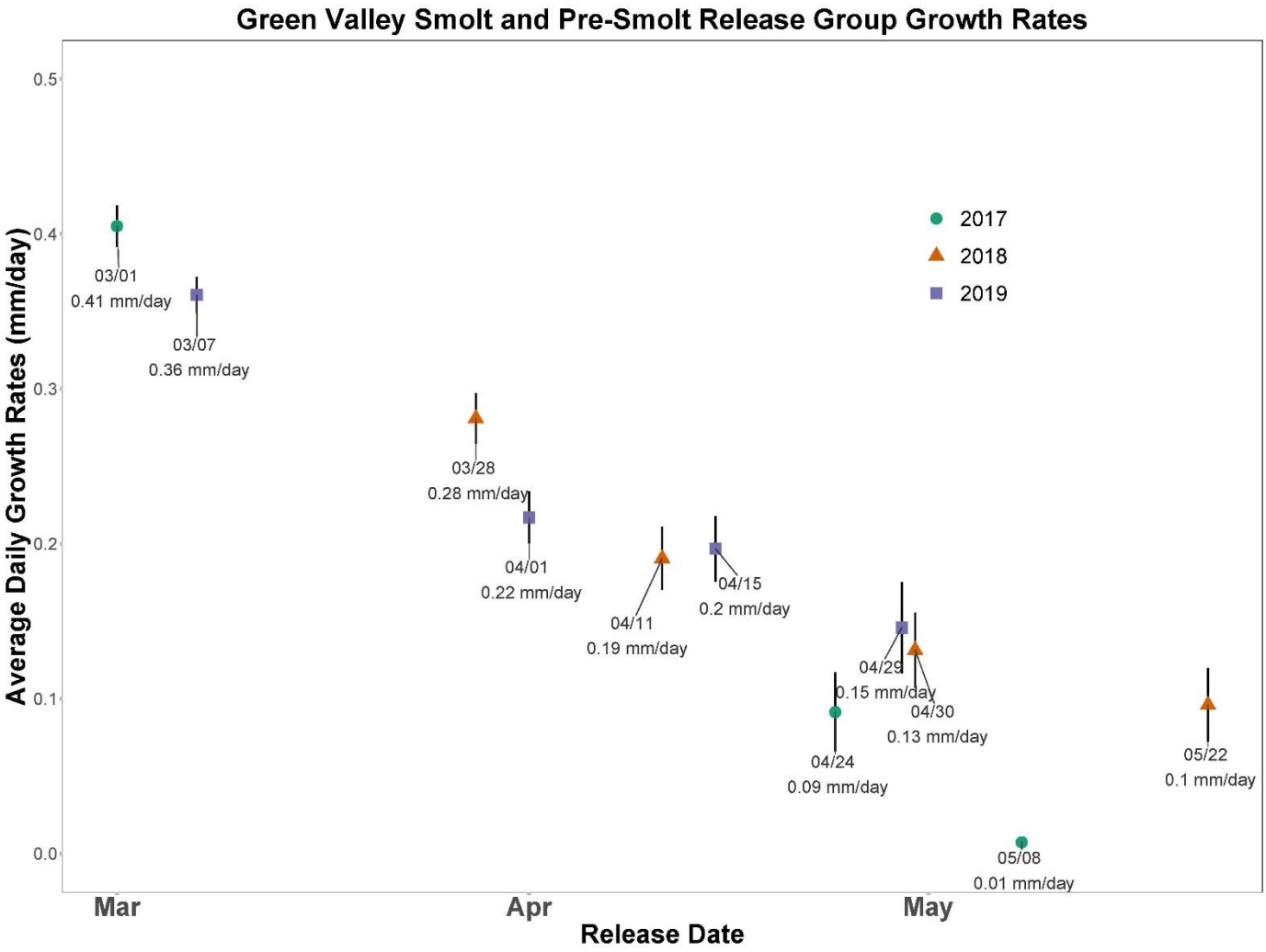


Figure 26. Average growth rates for pre-smolt and smolt release groups in Green Valley Creek over the past three years, by release date.

Discussion and Recommendations

Rainfall during the winter of 2018/19 was above average compared to recent years, with October to June precipitation at the Venado gage in the headwaters of Mill Creek reaching 85.6 inches, 32.3 inches higher than the 10-year average (according to raw gage data from NOAA's California Nevada River Forecast Center). In addition to large storms in January and February, there was significant rainfall in March and April which meant that we were unable to start operating traps until mid-April. Anothersignificant storm in mid-May required us to pull traps during the peak of smolt season. PIT antenna data indicated that large numbers of smolts left Mill, Green Valley and Dutch Bill creeks before we were able to operate traps, as well as during the May storm when traps were out.

In 2019, coho salmon smolt abundance in the four Broodstock Program life-cycle monitoring streams was below the five-year average, and in Mill Creek abundance was the lowest observed in the past 10 years. Mill Creek abundance estimates were strongly influenced by both changes in stocking practices and trap operation dates. In past years, hatchery smolt releases had taken place upstream of the trap in Mill Creek, but in 2019 they were released downstream. In Mill and Dutch Bill creeks, antenna data indicated that a large portion of fish out-

migrated during the winter before traps were installed. That, along with the gaps due to late trap installation and storm events likely contributed to the overall low abundance estimates observed.

The proportion of natural-origin smolts captured across all streams was 5.9% in the 2019 trap year (349 natural-origin smolts/5,921 total known-origin smolts captured). This proportion was lower than the average proportion over the previous five years. Additionally, the 349 natural-origin smolts captured in all streams was the lowest number since 2013 and only 1/3 of the number captured in 2018. In Mill Creek, there were so few natural-origin fish captured (3 total) that it is possible that these were actually hatchery fish that shed their CWT tags, or that the CWTs were otherwise not detected. The decrease in natural recruitment observed in 2019 relative to the past five years is a reversal of what had been a positive trend in natural recruitment. Summer 2018 coho yoy counts in the broodstock streams were only slightly below average for the past three years (UC, unpublished data), so low abundance could be attributed to gaps in trap operation, low overwinter survival and/or high levels of winter outmigration, depending on stream.

Overwinter survival of fall-release fish was high compared to previous years of data collection in Green Valley and Dutch Bill creeks, average in Willow Creek and very low in Mill Creek (Figure 8, Table 7). Poor overwinter survival is therefore a possible explanation for the low abundance estimates in Mill Creek, in addition to gaps in trap operation. Large differences in stock-to-smolt survival rates for fall-release fish were observed between streams, with Green Valley Creek survival rates almost twice as high as those in Dutch Bill Creek, the next highest stream, and nearly four times higher than those in Mill Creek (Table 7). Spring releases only took place in Mill Creek and those fish had very low stock-to-smolt survival. To promote increases in oversummer survival, we recommend supporting efforts to increase streamflow during the dry season, and to increase overwinter survival, we recommend supporting habitat enhancement projects that increase low-gradient overwintering habitat.

The spatial pattern of Willow Creek fall-release fish survival estimates this year differed from that of the past three years (Figure 8). In the previous three years we observed significantly higher survival to the trap than to the mouth of Willow Creek but in 2019 we observed slightly higher survival rates to the mouth (Figure 8). The survival estimate to the trap only includes fish that overwinter upstream of the trap, while estimated survival to the mouth includes all fish that overwintered upstream of the mouth of Willow Creek. In previous years, where the survival discrepancy was observed between sites, we speculated that survival to the mouth of Willow Creek was lower due the highly braided channel in lower Willow Creek that potentially poses a navigational challenge to outmigrating smolts, especially during low spring flows. In 2019, the higher spring flows may have removed this bottleneck and, in turn, increased survival to the mouth of the creek. We recommend further investigating potential low-flow passage bottlenecks in lower Willow Creek, as well as habitat enhancement work that could improve passage at low flows.

Growth rates over the winter of 2018/19 were above average in most tributaries (Figure 25). Fish released into Mill Creek in the fall had relatively low overwinter growth rates compared to previous years while Willow, Dutch Bill, and Green Valley creeks were higher than previous years (Figure 25). Freshwater growth in Green Valley Creek was the highest of any of the Broodstock Program monitoring streams, as observed in the previous three years (Figure 25). Although growth rates for natural-origin fish are unknown, the average size of Green Valley natural-origin fish was greater than natural-origin fish captured in the other creeks. This suggests that natural-origin fish are also benefitting from the conditions in Green Valley Creek that are producing the high growth rates observed in hatchery fish released into that stream. We continue to recommend further study to identify what aspects of Green Valley Creek are driving these high growth rates.

The staggered smolt and pre-smolt release in Green Valley Creek provided an opportunity to compare growth and survival rates across different release timings. For the past three years, earlier smolt release groups have had significantly higher growth rates and spent more time in the stream relative to later release groups (Figure 26, Table 8). The consistency of this pattern across multiple years provides strong support for early smolt releases in low gradient streams. We recommend releasing fish at the pre-smolt stage in low gradient watersheds such as Willow, Green Valley, and Mark West creeks, and moving up the timing of the smolt releases so that the first release occurs in late March/early April and the final release is at the end of April.

In summary, during the spring of 2019, 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 high flows 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 unpredictable weather and climate patterns and associated variation in survival among years and streams. Finally, 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.

III. References

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