UC Coho Salmon and Steelhead Monitoring Report: Spring 2017

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UNIVERSITY OF CALIFORNIA

RUSSIAN RIVER SALMON & STEELHEAD MONITORING PROGRAM

Contents

I. Background 1

II. Downstream Migrant Trapping and Operation of PIT Tag Antenna Arrays 2

Goals 2

Methods 2

Coho Releases 2

PIT Tagging 3

Field Methods 4

Results 8

Trap Operation 8

Trap Counts 8

Natural Production 11

Smolt Abundance 11

Probability of Survival and Early Winter Emigration 13

Migration Timing 18

Size 29

Growth 33

Discussion and Recommendations 35

III. References 38

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: Dutch Bill, Green Valley, Mill, and Willow 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) (http://www.cohopartnership.org), an effort to improve streamflow and water supply reliability to water-users in five flow-impaired Russian River tributaries. In 2013, we partnered with the Sonoma County Water Agency (Water Agency) 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 40 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 at http://ca-sgep.ucsd.edu/russianrivercoho.

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 2016 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 2016, fish from the fall release group were stocked as yoy in November 2016, fish from the pre-smolt release were stocked as age-1 pre-smolts in early March, and fish from the smolt release group were stocked as age-1 smolts in March through May 2017. All fish in the spring, fall and pre-smolt releases were planted directly into the release streams. In Green Valley and Mill creeks, the smolt release group fish were also released directly into the streams. In Dutch Bill Creek, smolts were held in a stream-side acclimation tank for 12 to 14 days prior to release.

During the spring and fall seasons, when streamflows were low and thought to impede natural dispersal of fish, ACOE staff stocked fish into individual pools throughout reaches characterized by suitable salmonid habitat (Figure 1, Figure 2). For pre-smolt and smolt releases, when streamflows were higher and fish had sufficient flows to disperse naturally throughout the streams, fish were released at point locations (Figure 2).

Figure 1. ACOE biologists releasing juvenile coho salmon into the stream environment.

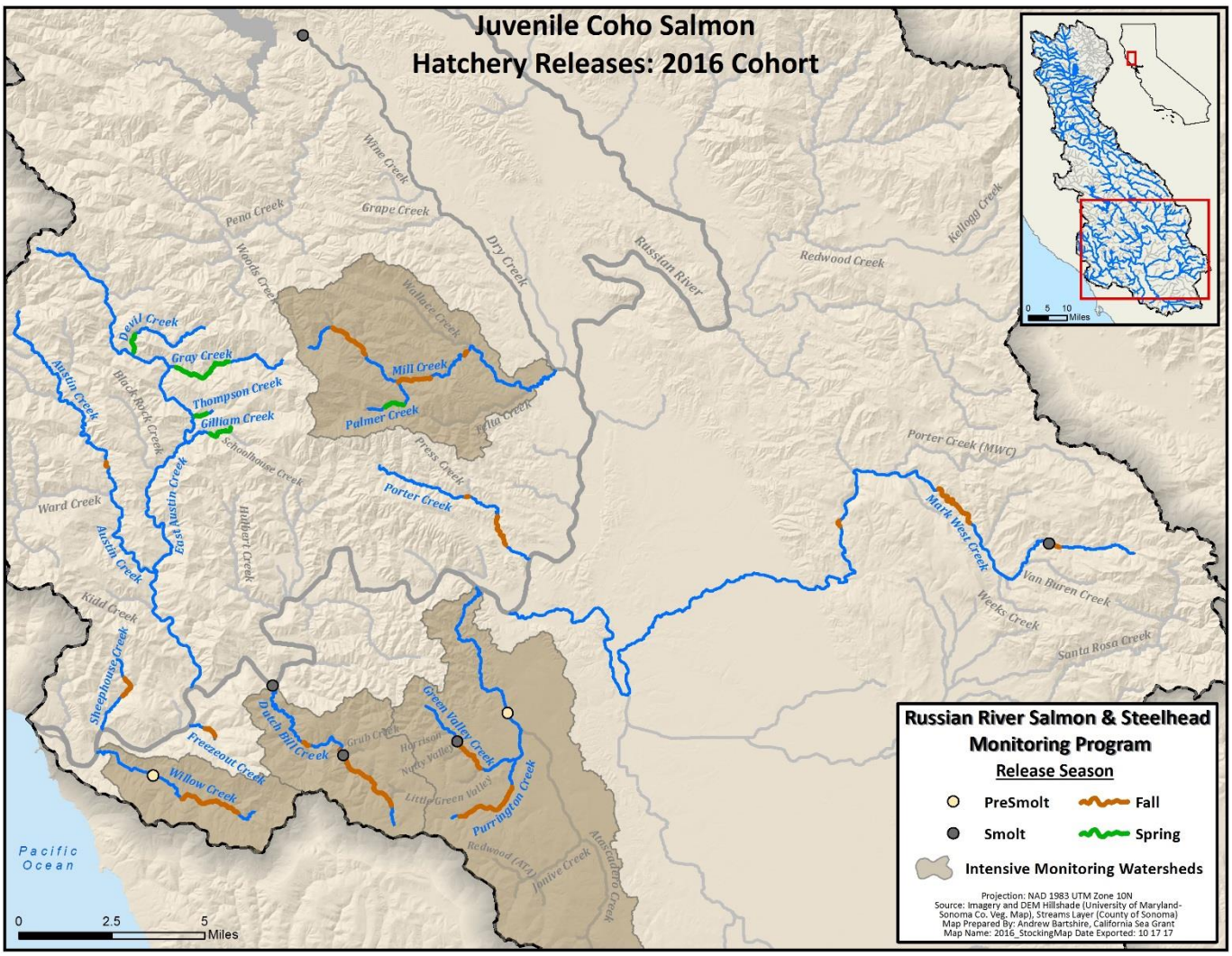


Figure 2. Map of juvenile coho salmon stocking locations for 2016 cohort (hatch year).

PIT Tagging

Prior to release, approximately 15% 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 (Table 1). As part of an oversummer survival study, 100% of all juveniles released in the spring into specific reaches of Dutch Bill, Green Valley, and Mill creeks were also PIT tagged (Table 1). 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.

Table 1. Number and percent of PIT-tagged juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creek watersheds for the 2016 cohort.

Release Season	Release Dates	Number Released (% PIT-tagged)			
		Willow Creek	Dutch Bill Creek	Green Valley Creek	Mill Creek
Spring	**Jun 17-20, 2016**	0	1,016 (100%)	452(100%)	4,557 (25%)[1]
Fall	**Nov 2-30, 2016**	15,273 (15%)	9,911 (15%)	9,258 (15%)	16,094 (15%)
Pre-Smolt	**Mar 1-3, 2017**	7,961 (15%)	0	8,443 (15%)	0
Smolt	**Apr 24-May 22, 2017**	0	6,063 (15%)[2]	6,064(15%)	6,079 (15%)
Total Released		23,234	16,990	24,217	26,730

[1] *100% of 509 fish released into mainstem Mill Creek were PIT tagged and 15% of 4,048 fish released into Palmer Creek were PIT tagged.*

[2] *2,039 of the 6,063 fish that were held in an acclimation tank for 12 days in Dutch Bill Creek were released into the Russian River at the Monte Rio Boat Launch.*

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 (Figure 3). In all but Dutch Bill Creek, additional antennas were also operated upstream of the mouth in 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. Sixteen 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. The 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 2016 through June 2017, 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.

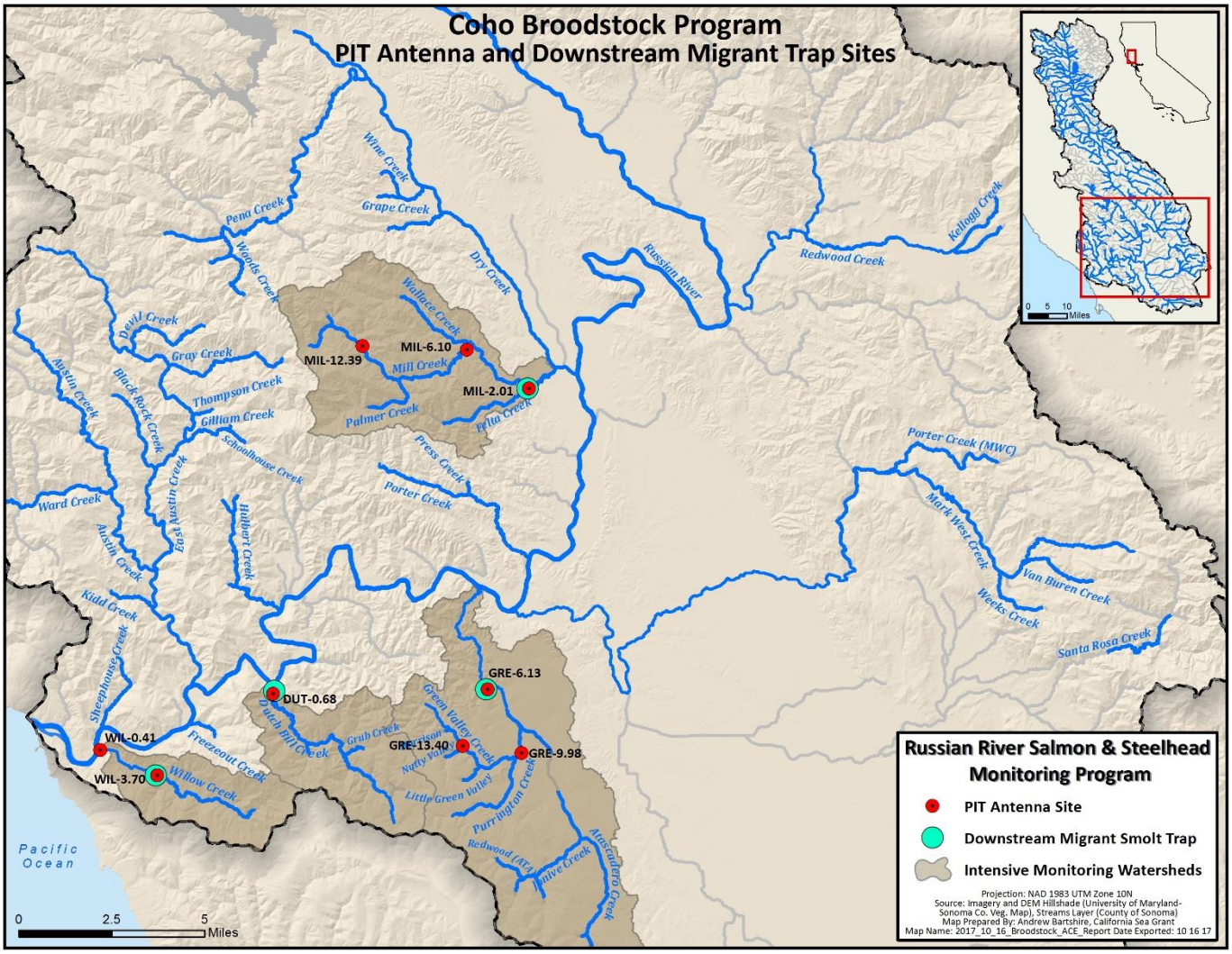


Figure 3. Map showing PIT antenna and smolt trap locations on Broodstock Program monitoring streams, with antenna site codes.

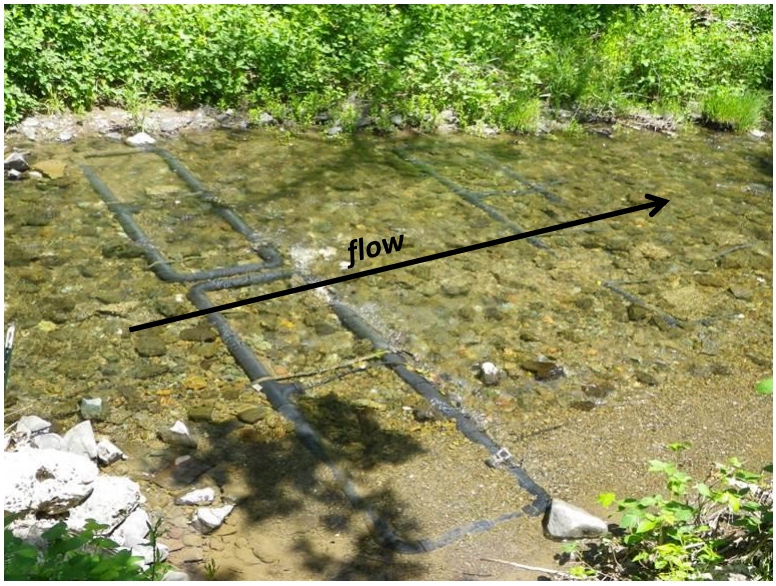


Figure 4. Paired flat-plate PIT tag antenna array on Mill Creek at spring base flows.

Downstream Migrant Trapping

Downstream migrant (funnel and/or pipe) traps were operated by UC on Willow, Green Valley, and Mill creeks between March and June 2017, 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). The Water Agency 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. Due to changes in landowner access permissions, the trap site for Green Valley was moved to river kilometer 6.04 for the 2017 season from its previous location at river kilometer 2.82 in years 2015 and 2016.

Between March and June, traps were tended daily with additional checks during peak outmigration and high flows. During significant storm events, the traps were opened up or removed to prevent injury to fish, avoid loss of equipment, and ensure personnel safety.

During each trap tend, captured coho salmon smolts were carefully netted out of the trap box, placed into aerated buckets, and anesthetized using a solution of 0.3 g of tricaine methane-sulphonate (MS-222) per two gallons of water. All fish were counted and scanned for PIT and coded wire tags (CWTs). All PIT-tagged smolts were measured for fork length (mm) and weight (g). Additionally, the first 30 coho salmon smolts with a CWT were measured, regardless of presence of a PIT tag. 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 (no PIT tag) smolt (25% of all CWT-only fish) and measurements were taken on each of those fish. All natural-origin coho smolts (no PIT or CWT) 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 stored, and will be sent to NMFS' Southwest Fisheries Science Center for analysis.

All captured steelhead smolts were scanned for PIT tags and measured for fork length (mm) and weight (g). Tallies were made of all other vertebrates and crustaceans captured.

Figure 5. Willow Creek downstream migrant trap at spring base flows.

Data Analysis

Smolt Abundance

A two-trap mark-recapture design (Bjorkstedt 2005; Bjorkstedt 2010) was used to estimate the total number of coho salmon smolts emigrating from each creek during the time that each downstream migrant trap was in operation. 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.

Natural Production

Fish origin (natural or hatchery) 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. These data were used to develop ratios of natural to hatchery origin smolts for each stream.

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 in Willow, Dutch Bill, Green Valley, and Mill creeks. 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 6/30/17 and emigration prior to 3/1/16 for multiple release groups (i.e., spring, fall, pre-smolt and smolt) in the four Broodstock Program monitoring streams.

Migration Timing

To evaluate migration timing of hatchery-released juvenile coho salmon past specific antenna and trapping locations (Figure 3), first the minimum detection date following release into the stream was selected for each individually PIT-tagged fish at each site of interest. This dataset of unique detections by site was then used to sum the total number of individuals detected 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 date that streams reconnected to Dry Creek or the mainstem of the river) 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 size and weight of fish for each release group and stream prior to release. All PIT-tagged coho salmon smolts captured in the downstream migrant traps were measured and 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. Specific 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 assign an estimated size at release to all fish in each release group.

Results

Trap Operation

In 2017, the Willow Creek trap was installed on 3/7 and operated through 6/23, with the exception of 3/20-3/30 and 4/6-4/20, when it was removed due to high flows from storm events. The Dutch Bill Creek trap was installed on 3/29 and was operated through 5/31, with the exception of 4/6-4/10 and 4/13-4/20, when it was removed due to high flows from storm events. The Green Valley Creek trap was installed on 3/15 and was operated through 6/20, with the exception of 3/20-4/3 and 4/6-4/26, when it was removed due to high flows from storm events. The Mill Creek trap was installed on 3/8 and was operated through 6/20 with the exception of 3/20-4/4 and 4/6-4/25, when it was removed due to high flows from storm events. In addition, weir panels were removed following smolt releases in Green Valley and Mill creeks in order to reduce capture efficiency and avoid overcrowding in the trap box; therefore, the trap was operated at partial efficiency for a total of 24 days (Green Valley) or 12 days (Mill Creek) over the trapping season.

Trap Counts

Coho salmon smolt counts from downstream migrant traps on all four study streams in 2017 ranged from 1,729 in Willow Creek to 4,880 in Green Valley Creek (Table 2). The greatest number of coho smolts were captured in Green Valley Creek, followed by Dutch Bill, Mill, and Willow creeks, respectively (Table 2). The percentage of coho smolts of natural origin ranged from 2% in Willow Creek to 8% in Green Valley Creek (Table 2).

When compared to previous years, coho salmon smolt counts were average in Willow Creek, high in Dutch Bill Creek and low in Mill Creek (Table 3). The number of coho smolts captured in the Green Valley Creek trap was higher than in 2016, but the trap was not operated from 2012 through 2014 and the trap location changed in 2017, so it is difficult to gauge relative counts over time (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 2017 (Table 3). The number of steelhead smolts captured in the traps in 2017 was low, ranging from five to 32, with the greatest number on Mill Creek (Table 3). Chinook salmon smolts were only observed on Mill and Dutch Bill creeks (1 and 2 fish, respectively) (Table 3). Incidental capture of yoy also occurred and was likely influenced by proximity of redds to the trap site.

A low diversity of species were captured in Willow Creek relative to other streams, with sculpin (2,898), three-spined stickleback (496), and Sacramento pikeminnow (36) being the most abundant non-salmonids (Table 4). In Dutch Bill Creek the three most abundant non-salmonids were sculpin (323), Sacramento sucker (265), and California roach (28), in Green Valley Creek they were three-spined stickleback (11,931), bluegill (472), and sculpin (365), and in Mill Creek they were sculpin (719), California roach (453), and Sacramento pikeminnow (152) (Table 4). Twenty-six freshwater shrimp were captured in Green Valley Creek this year, which is less than the two previous years; however, because of the new trap location, these numbers are not directly comparable (Table 4).

Willow Creek had the lowest number of non-native species of the four tributaries where downstream migrant trapping was conducted and Green Valley Creek had the highest (Table 4).

Table 2. Coho salmon smolts captured in traps on Willow, Dutch Bill, Green Valley and Mill creeks during the 2017 downstream migrant season.

Stream	Hatchery	Natural	Unknown Origin	Total	Percent Natural
Willow Creek	1,684	43	2	1,729	2%
Dutch Bill Creek	3,090	150	425[1]	3,665	4%
Green Valley Creek	4,469	396	15	4,880	8%
Mill Creek	2,394	159	6	2,559	6%

[1] *PIT tagged coho smolts were not scanned for presence of CWTs, but these fish are likely to be of hatchery*

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in UC downstream migrant traps, years 2005-2017. 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
Willow Creek	Coho Salmon	Smolt	NA	NA	NA	NA	NA	NA	NA	864	3,405	916	707	2,029	1,729
		YOY	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0	0
		Parr/YOY	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603	77
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5
Dutch Bill Creek	Chinook Salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2
	Coho Salmon	Smolt	NA	NA	NA	NA	NA	185	2,908	2,017	823	1,939	201	2,681	3,665
		YOY	NA	NA	NA	NA	NA	0	5	2	2	0	0	18	2
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0
		Parr/YOY	NA	NA	NA	NA	NA	58	31	33	79	1,138	13	74	254
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6
Green Valley Creek	Chinook Salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	0	0	0
	Coho Salmon	Smolt	16	NA	625	309	608	348	231	NA	NA	NA	6,810	3,573	4,880
		YOY	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1
		Parr/YOY	1,723	NA	36	497	1	5	3	NA	NA	NA	0	356	11
		Smolt	55	NA	70	29	43	0	1	NA	NA	NA	3	3	12
Mill Creek	Chinook Salmon	Smolt	70	128	2	31	1	1	0	11	0	18	0	0	1
	Coho Salmon	Smolt	800	892	2,963	5,425	14,756	5,061	7,258	4,802	2,019	1,451	5,715	2,428	2,559
		YOY	24	314	58	43	0	4	329	515	530	0	10	10	30
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	2	0	2
		Parr/YOY	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941	898
		Smolt	116	49	266	176	118	190	97	41	32	8	17	15	32

Table 4. Annual downstream migrant trap counts for common non-salmonid species, years 2005-2017. NA indicates that no trap was in operation.

Origin	Species [1]	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
WILLOW CREEK														
	Bluegill	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0
	Bullfrog	NA	NA	NA	NA	NA	NA	NA	0	1	0	0	0	0
	Fathead Minnow	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0
Non-native	Green Sunfish	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	1
Native	California Roach	NA	NA	NA	NA	NA	NA	NA	0	1	1	7	0	1
	Freshwater Shrimp	NA	NA	NA	NA	NA	NA	NA	0	0	0	1	0	0
	Sacramento Pikeminnow	NA	NA	NA	NA	NA	NA	NA	0	219	0	198	8	36
	Sacramento Sucker	NA	NA	NA	NA	NA	NA	NA	1	24	1	46	2	9
	Sculpin Sp	NA	NA	NA	NA	NA	NA	NA	339	4,206	680	2,462	548	2,898
	Three-spined Stickleback	NA	NA	NA	NA	NA	NA	NA	383	268	296	193	71	496
	Western Brook Lamprey	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0
DUTCH BILL CREEK														
	Bluegill	NA	NA	NA	NA	NA	0	0	0	0	2	0	4	19
	Bullfrog	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0
	Fathead Minnow	NA	NA	NA	NA	NA	0	0	0	0	0	2	98	2
Non-native	Green Sunfish	NA	NA	NA	NA	NA	0	1	0	0	5	20	8	21
Native	California Roach	NA	NA	NA	NA	NA	130	129	59	725	3	252	94	28
	Freshwater Shrimp	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0
	Sacramento Pikeminnow	NA	NA	NA	NA	NA	22	95	1	412	0	27	50	18
	Sacramento Sucker	NA	NA	NA	NA	NA	8	178	1	307	4	25	106	265
	Sculpin Sp	NA	NA	NA	NA	NA	8	393	437	1,204	136	974	440	323
	Three-spined Stickleback	NA	NA	NA	NA	NA	9	7	56	517	2	5	46	4
	Western Brook Lamprey	NA	NA	NA	NA	NA	0	0	1	0	0	1	1	1
GREEN VALLEY CREEK														
	Bluegill	627	NA	68	21	59	155	1	NA	NA	NA	3	137	472
	Bullfrog	10	NA	42	7	5	57	1	NA	NA	NA	4	11	171
	Fathead Minnow	15	NA	14	0	22	89	54	NA	NA	NA	96	59	65
Non-native	Green Sunfish	40	NA	4	0	31	12	0	NA	NA	NA	25	32	133
Native	California Roach	211	NA	497	498	298	776	53	NA	NA	NA	314	54	51
	Freshwater Shrimp	8	NA	0	1	9	36	4	NA	NA	NA	317	33	26
	Sacramento Pikeminnow	62	NA	104	95	93	17	32	NA	NA	NA	70	7	14
	Sacramento Sucker	53	NA	79	178	90	3	3	NA	NA	NA	64	25	36
	Sculpin Sp	371	NA	474	370	602	420	24	NA	NA	NA	192	62	365
	Three-spined Stickleback	1,699	NA	253	1,497	409	5,606	56	NA	NA	NA	373	167	11,931
	Western Brook Lamprey	5	NA	69	44	71	105	0	NA	NA	NA	109	160	148
MILL CREEK														
	Bluegill	54	11	1	2	7	66	120	127	3	29	4	56	71
	Bullfrog	666	20	27	52	56	462	84	300	65	41	11	12	74
	Fathead Minnow	22	13	13	6	109	150	25	4	4	0	14	103	68
Non-native	Green Sunfish	35	5	1	0	12	6	5	1	3	5	6	22	16
Native	California Roach	110	65	84	60	341	198	116	151	363	20	258	114	453
	Freshwater Shrimp	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
	Sacramento Sucker	100	38	38	89	47	99	81	33	36	0	68	3	71
	Sculpin Sp	895	4,066	414	704	431	372	398	669	966	60	105	675	719
	Three-spined Stickleback	0	0	0	0	0	1	7	17	1	1	3	2	6
	Western Brook Lamprey	3	3	9	9	11	8	0	0	0	0	0	1	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

The percentage of natural-origin coho salmon smolts captured on Willow Creek was low compared to percentages observed during the last four years (Table 5). The percentage of natural origin coho smolts observed at the Green Valley Creek trap was average; however, the trap was not operated for three of the past five years, so recent comparative estimates are limited (Table 5). The percentage of natural origin coho smolts observed at the Dutch Bill and Mill Creek traps were slighty higher to higher (respectively) than the previous two years but within the range of the past four years (Table 5).

Table 5. Percent of natural origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps, years 2005-2017. NA indicates that no trap was in operation.

	Willow Creek			Dutch Bill Creek			Green Valley Creek			Mill Creek		
Year	Number Natural Origin	Total Captured	Percent Natural Origin	Number Natural Origin	Total Captured	Percent Natural Origin	Number Natural Origin	Total Captured	Percent Natural Origin	Number Natural Origin	Total Captured	Percent Natural Origin
2005	NA	NA	NA	NA	NA	NA	9	15	60.0	2	636	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	608	0.2	65	14,754	0.4
2010	NA	NA	NA	1	185	0.5	0	348	0.0	9	5,060	0.2
2011	NA	NA	NA	0	2,908	0.0	2	231	0.9	22	7,256	0.3
2012	0	864	0.0	35	2,017	1.7	NA	NA	NA	154	4,801	3.2
2013	12	3,405	0.4	106	823	12.9	NA	NA	NA	3	2,019	0.1
2014	331	916	36.1	262	1,939	13.5	NA	NA	NA	168	1,448	11.6
2015	20	701	2.9	8	201	4.0	797	6,810	11.7	148	5,397	2.7
2016	430	2,028	21.1	85	2,681	3.2	231	3,573	6.5	24	2,428	1.0
2017	43	1,729	2.5	150	3,665	4.1	396	4,880	8.1	159	2,559	6.2

Smolt Abundance

Smolt abundance estimates indicate that thousands of smolts emigrated from each of the four Broodstock Program monitoring tributaries during the spring of 2017 (Table 6). Smolt abundance was significantly higher in Green Valley than Willow and Mill creeks, despite similar juvenile releases (Table 6). Abundance was lowest in Willow Creek; however, this was to be expected as no smolts were released into this stream.

When compared with previous years' estimates, abundance estimates in Willow, Dutch Bill, and Mill creeks appeared average, and the Green Valley Creek estimate was the highest observed over all years of trap operation (Figure 6).

Table 6. Number of cohort 2016 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 2017. Abundance estimates include both marked and unmarked smolts.

	Number Released					Estimated Smolt
Tributary	Spring	Fall	Pre-smolt	Smolt	Total	Abundance (95% CI)
Willow Creek	0	15,273	7,961	0	23,234	3,588 (674)
Dutch Bill Creek	1,016	9,911	0	6,063 [1]	16,990	6,079 (333)
Green Valley Creek	452	9,258	8,443	6,064	24,217	23,438 (2,238)
Mill Creek	4,557	16,094	0	6,079	26,730	8,961 (779)

[1] *Following tank imprinting for 12 days, the last group of 2,039 smolts were released into the Russian River at the Monte Rio Boat Launch on 5/22/17 and had no possibility of being detected at the trap site.*

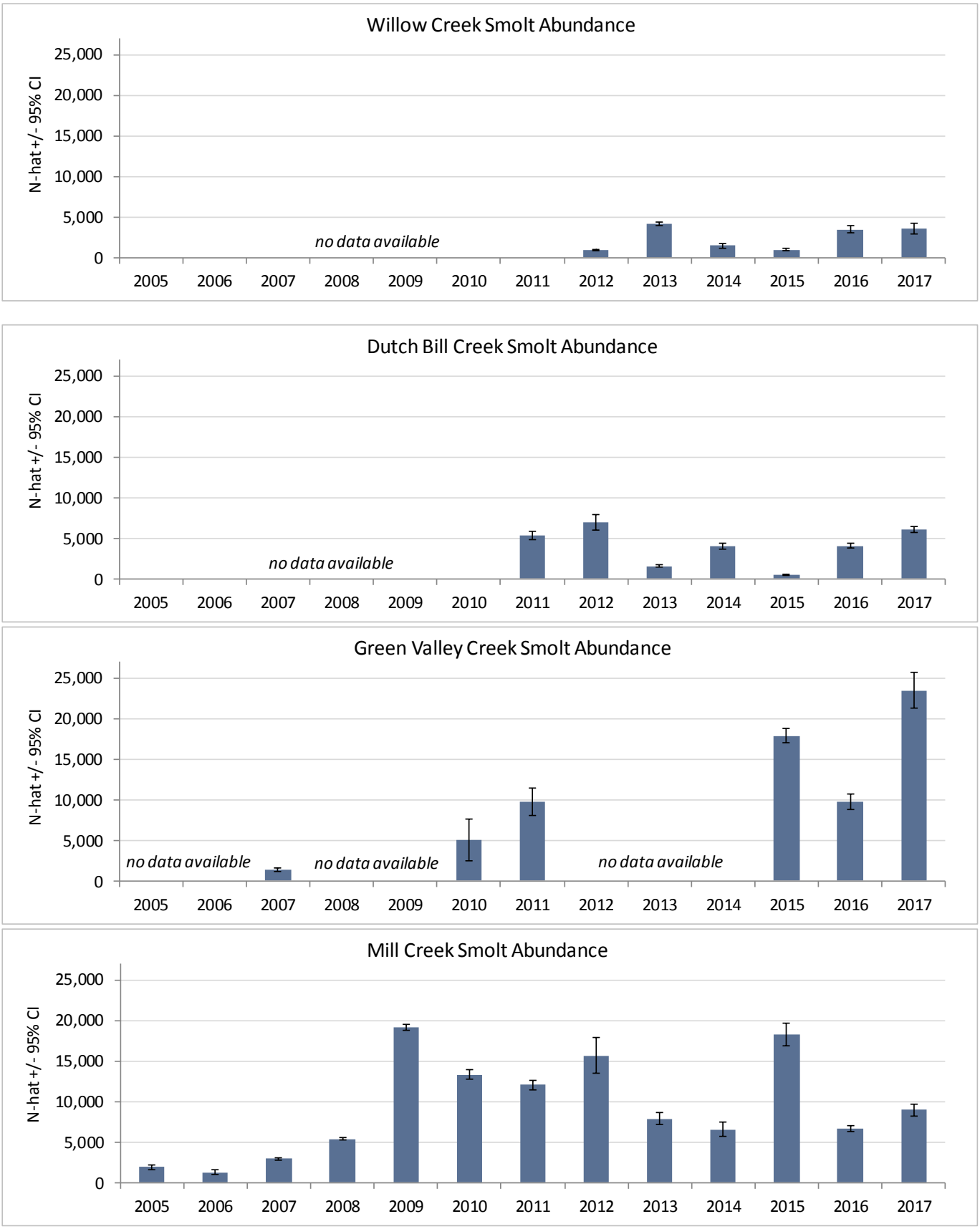


Figure 6. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2017.

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 2016 through 6/30/17 (approximately one year later) ranged from 0.12 on Dutch Bill and Mill creeks to 0.32 on Green Valley Creek (Table 7). In 2016, the Broodstock Program released only approximately 2,400 fish in the spring for the purpose of continuing a summer survival study conducted by UC through the Russian River Coho Water Resources Partnership in Dutch Bill, Green Valley, and Mill creeks. As a part of this study, coho salmon were released into 250 m-long, long-term study reaches in Dutch Bill (two reaches), Green Valley (one reach), and Mill Creek (two reaches) rather than distributed evenly throughout the watersheds, as with the fall releases. 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 the entire stream systems.

The estimated probability of survival of fall-release juvenile coho from the time of release in late November/early December 2016 through 6/30/17 was generally higher than for the spring release, ranging from 0.16 on Dutch Bill Creek to 0.41 on Green Valley Creek (Table 7). When comparing fall-release survival estimates with previous years' estimates, it appears that survival during the winter of 2016/17 was average on Willow, Dutch Bill and Mill creeks and slightly above average on Green Valley Creek (Figure 7). As in most years, overwinter survival was highest in Green Valley Creek (Figure 7).

The estimated probability of survival of the pre-smolt groups through 6/30/17 was 0.60 on Willow Creek and 0.51 on Green Valley Creek (Table 8). The estimated probability of survival of smolt-release group fish was higher than the pre-smolt groups, ranging from 0.78 to 0.98 (Table 8). In general, the later the smolt release group fish were released, the lower the survival with the exception of Green Valley Creek, where the earliest smolt release group had the lowest survival (Table 8). Survival estimates for the smolt release groups were generally higher in Dutch Bill and Mill Creeks as compared to Green Valley Creek (Table 8).

The estimated probability of spring-release juvenile coho salmon emigrating from their respective release streams prior to March 1 ranged from 0.02 in Green Valley Creek to 0.07 in Dutch Bill Creek (Table 9). For the fall release group, estimates of winter emigration ranged from 0.00 in Green Valley Creek to 0.19 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. Interestingly, early winter emigration probability past the antennas at the trap site was 0.30, but past the antennas at the mouth was only 0.02, suggesting that fish that moved downstream below the trap site prior to 3/1/17 did not immediately emigrate out of Willow Creek and into the Russian River.

As in previous years, estimated probabilities for pre-March 1 emigration for the fall release group were near zero in Willow and Green Valley creeks and notably higher in Dutch Bill Creek (Table 9, Figure 8). Estimated probabilities for early emigration from Mill Creek were higher in the winter of 2016/17 than in the past five years, and emigration probabilities for that stream were most variable over all years of data collection (Table 9, Figure 8).

Table 7. Estimated probability of juvenile coho salmon survival from the date of release in 2016 through 6/30/17 for spring and fall release groups. NA indicates that 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	11/9/2016	233	0.17 (0.16-0.19)[1]
Dutch Bill Creek	6/17/2016	378	0.12 (0.11-0.15)	11/28/2016	214	0.16 (0.14-0.18)
Green Valley Creek	6/17/2016	378	0.32 (0.28-0.36)	11/14/2016	228	0.41 (0.38-0.45)
Mill Creek	6/17/2016	378	0.12 (0.10-0.16)	11/30/2016	212	0.24 (0.22-0.26)

[1] *For comparison with other streams, probability of survival to the mouth of Willow Creek was included in the table; probability of survival to 3rd Bridge was 0.27 (0.25-0.29).*

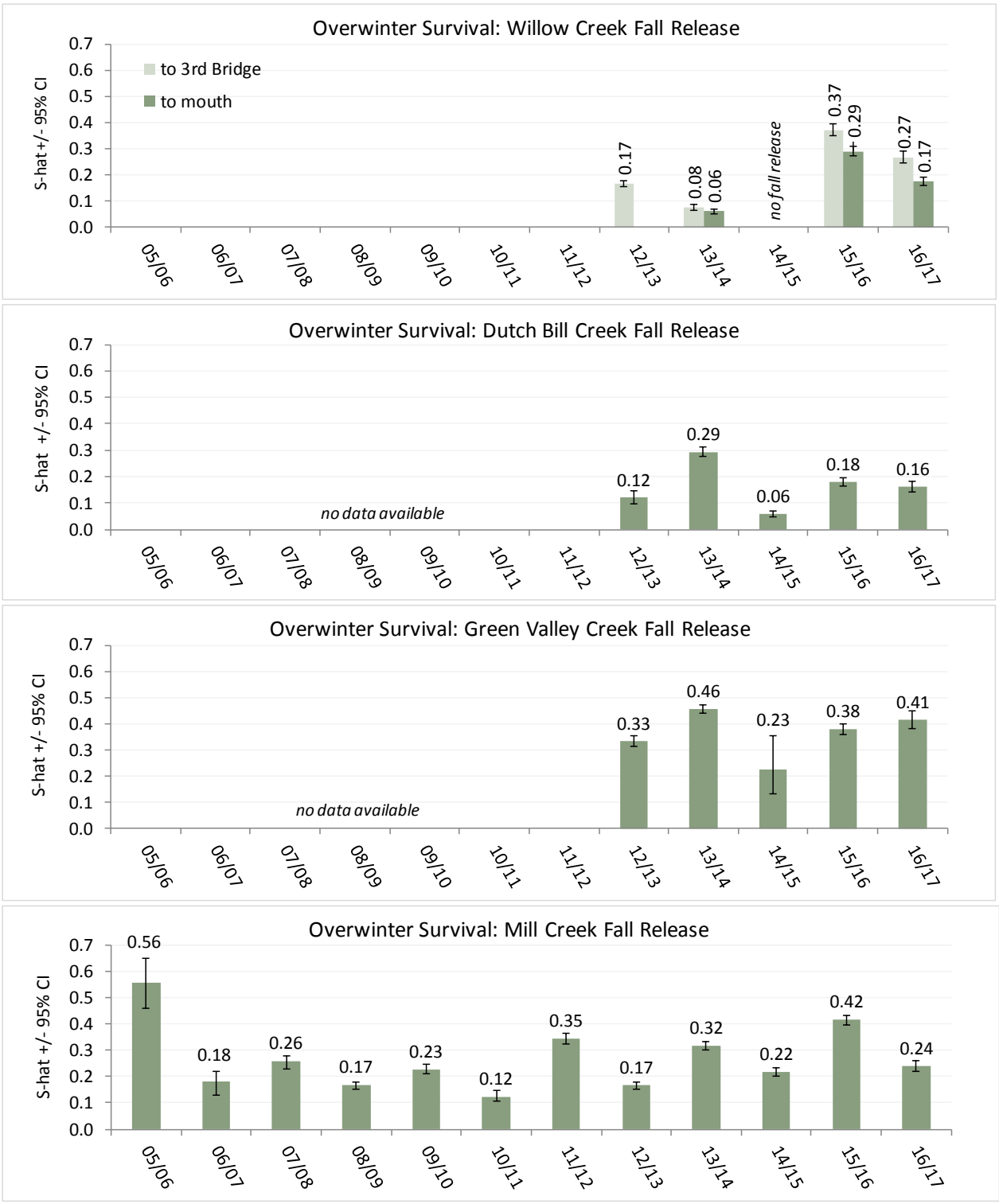


Figure 7. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) 2017 in Willow, Dutch Bill, Green Valley, and Mill creeks.

Table 8. Estimated probability of juvenile coho salmon survival from the date of release through 6/30/17 for each smolt release group on Willow, Dutch Bill, Green Valley, and Mill creeks. NA indicates that fish were not released upstream of the antenna arrays and survival estimates could not be generated.

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	3/3/2017	0	119	0.60 (0.57-0.63)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	4/24/2017	14	67	0.97 (0.94-0.98)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	5/8/2017	12	53	0.94 (0.91-0.96)
Dutch Bill Creek	smolt	tank	Monte Rio boat launch	16.5	5/22/2017	12	NA	NA
Green Valley Creek	pre-smolt	stream	Ross Station Road crossing	7.8	3/1/2017	0	121	0.51 (0.48-0.53)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/24/2017	0	67	0.78 (0.70-0.85)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	5/8/2017	0	53	0.90 (0.85-0.94)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	5/22/2017	0	39	0.81 (0.76-0.86)
Mill Creek	smolt	stream	Palmer confluence	9.98	4/24/2017	0	67	0.98 (0.94-0.99)
Mill Creek	smolt	stream	Palmer confluence	9.98	5/8/2017	0	53	0.95 (0.91-0.97)
Mill Creek	smolt	stream	Palmer confluence	9.98	5/22/2017	0	39	0.90 (0.86-0.93)

Table 9. Estimated probability of juvenile coho salmon emigrating from each tributary prior to 3/1/17. NA indicates that no fish were released.

Tributary	Probability of Emigration Prior to 3/1 (95% CI)	
	Spring Release	Fall Release
Willow Creek	NA	0.02 (0.01 - 0.02)[1]
Dutch Bill Creek	0.07 (0.05-0.09)	0.19 (0.17-0.21)
Green Valley Creek	0.02 (0.00-1.00)[2]	0.00 (0.00-0.01)
Mill Creek	0.06 (0.04-0.10)	0.16 (0.14-0.17)

[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 3/1/17 was 0.30 (0.28-0.32).*

[2] *Only one individual was detected emigrating prior to 3/1 so 95% CIs could not be calculated.*

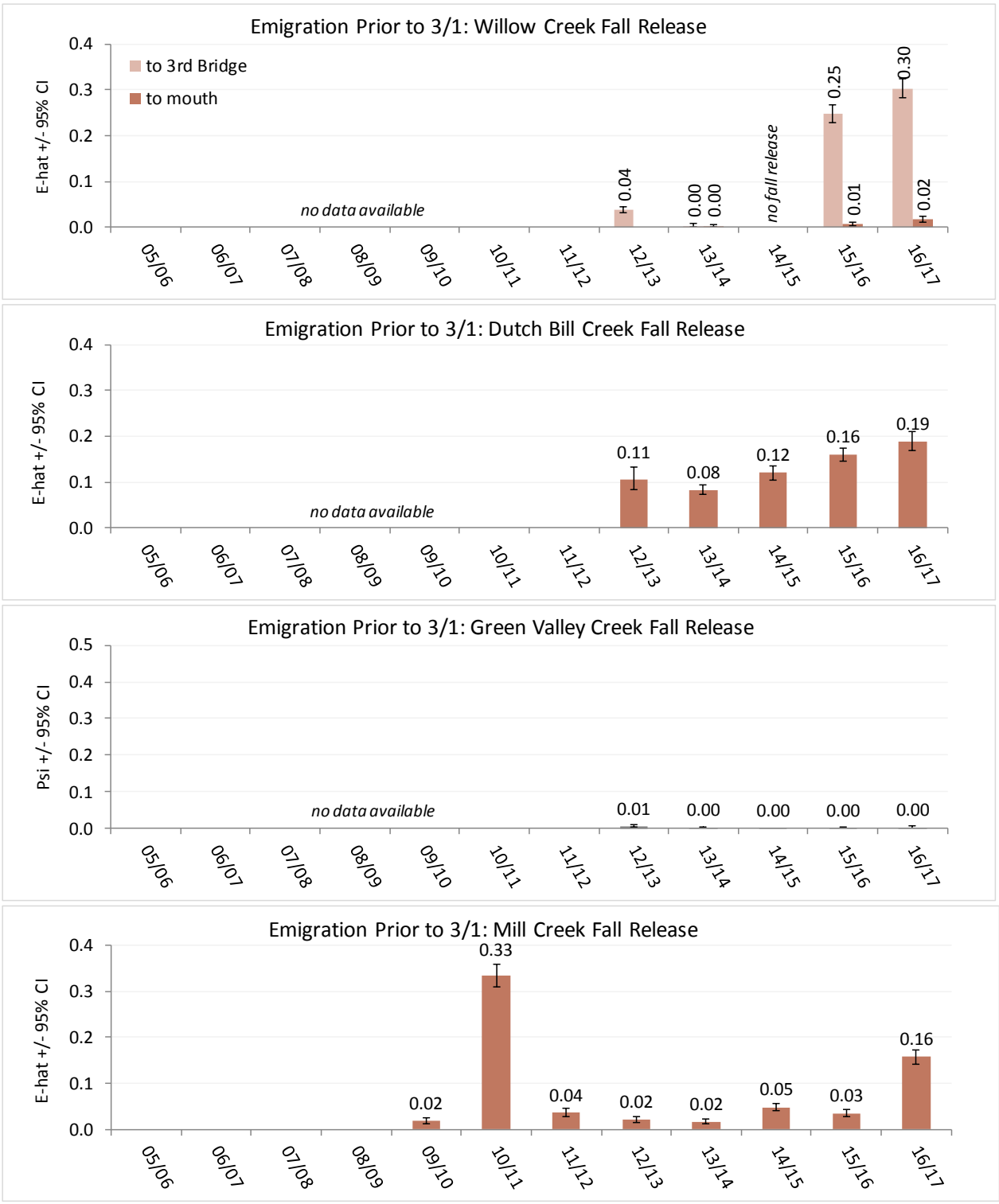


Figure 8. Probability of emigration (E-hat) past antenna sites prior to 3/1. Willow, Dutch Bill, Green Valley, and Mill creeks.

Migration Timing

Weekly totals of outmigrating smolts were plotted by release group and antenna site within the watershed for the period of October 29, 2016 to June 30, 2017 (Figure 10, Figure 11, Figure 13, Figure 15 - Figure 18, Figure 20 - Figure 22; note the difference in the y-axes scales). Multiple antennas on Willow, Green Valley and Mill creeks allowed us to document movement patterns throughout the watersheds in all but Dutch Bill Creek (Figure 3). Average daily stream depth was plotted for the same time period to allow for comparisons of fish movement to streamflow (Figure 9, Figure 12, Figure 14, Figure 19). 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 (Figure 10, Figure 13, Figure 15 - Figure 16, Figure 20 - Figure 21). 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 the greatest proportion of winter emigration occurring in Dutch Bill Creek and the least in Green Valley Creek. In general, most winter movement occurred with the early winter storms (but not necessarily the largest storms).

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 of the fish may have overwintered in the lower gradient habitat between the two antenna sites.

Although no antennas were operated in the upper reaches of Dutch Bill Creek, we can deduce that many fish did not remain in the upper reaches of Dutch Bill throughout the winter because they were detected migrating past the antenna located at river km 0.68, near the mouth.

In Green Valley Creek, we observed fish moving downstream past the antenna arrays at river km sites 13.40 and 9.98 during the winter season, but not past the antennas at river km 6.13, suggesting that a portion of the spring and fall release groups overwintered in the reach that encompasses the confluence with Atascadero Creek. This reach is thought to provide suitable winter habitat for juvenile coho salmon because of its low gradient and backwater habitat during high flows. Interestingly, we observed more downstream winter movement passed GRE-9.98 antennas in the fall release group as compared to the spring release group.

In Mill Creek, we observed spring- and fall-release fish moving downstream past the upper antenna arrays at river kms 12.39 and 6.10, with a smaller proportion of fish moving past the antenna array nearest the mouth at river km 2.01, suggesting that a portion of both releases overwintered in the lower reaches of Mill Creek, between sites MIL-6.10 and MIL-2.01.

Pre-smolt and Smolt Release Groups

Movement patterns for the Willow and Green Valley Creek pre-smolt release groups differed (Figure 11, Figure 17). In Willow Creek, a small portion of fish were detected upstream of their release point while the majority emigrated passed the mouth during the first two weeks following release (Figure 11). In contrast, in Green Valley Creek, only three fish were detected at an antenna site upstream of their release point and the peak of migration past the downstream-most antennas occurred in late April, a month after they were released (Figure 17).

Movement patterns for the smolt release groups also varied by stream (Figure 13, Figure 18, Figure 22). In Dutch Bill Creek, the 4/24 release group left Dutch Bill Creek immediately, whereas movement of the 5/8 release group peaked during the second week following release (Figure 13). In Green Valley Creek, movement past both GRE-13.40 and GRE-9.98 antennas peaked during the first week following release for all smolt releases; however, movement passed GRE-6.13 was later, suggesting that at least some fish spent several days between the 6.13 and 9.98 antenna arrays (Figure 18). In Mill Creek, movement past MIL-2.01 occurred immediately following release for all three smolt release groups (Figure 22).

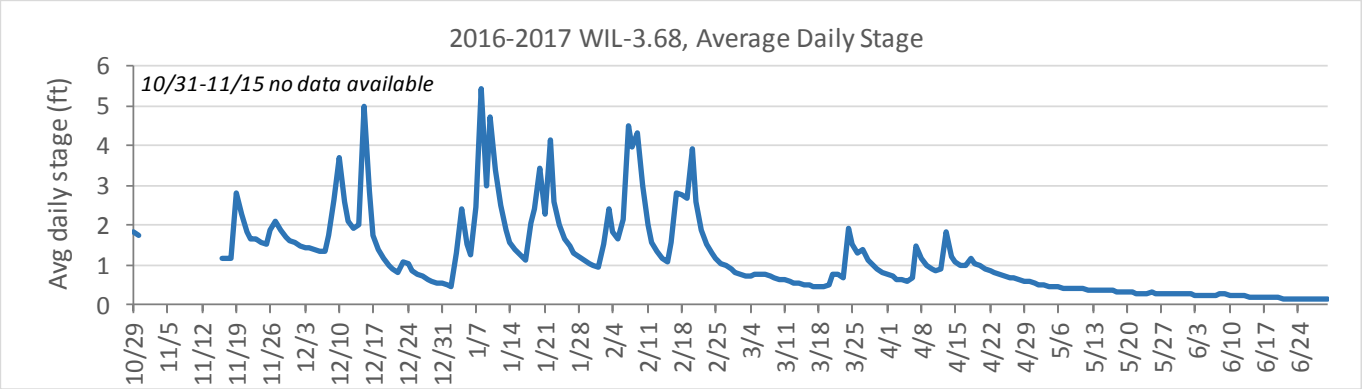


Figure 9. Average daily stage height at the Willow Creek smolt trap site (river km 3.68) between October 29, 2016 and June 30, 2017. Data is missing for the early part of the reporting period due to a technical failure.

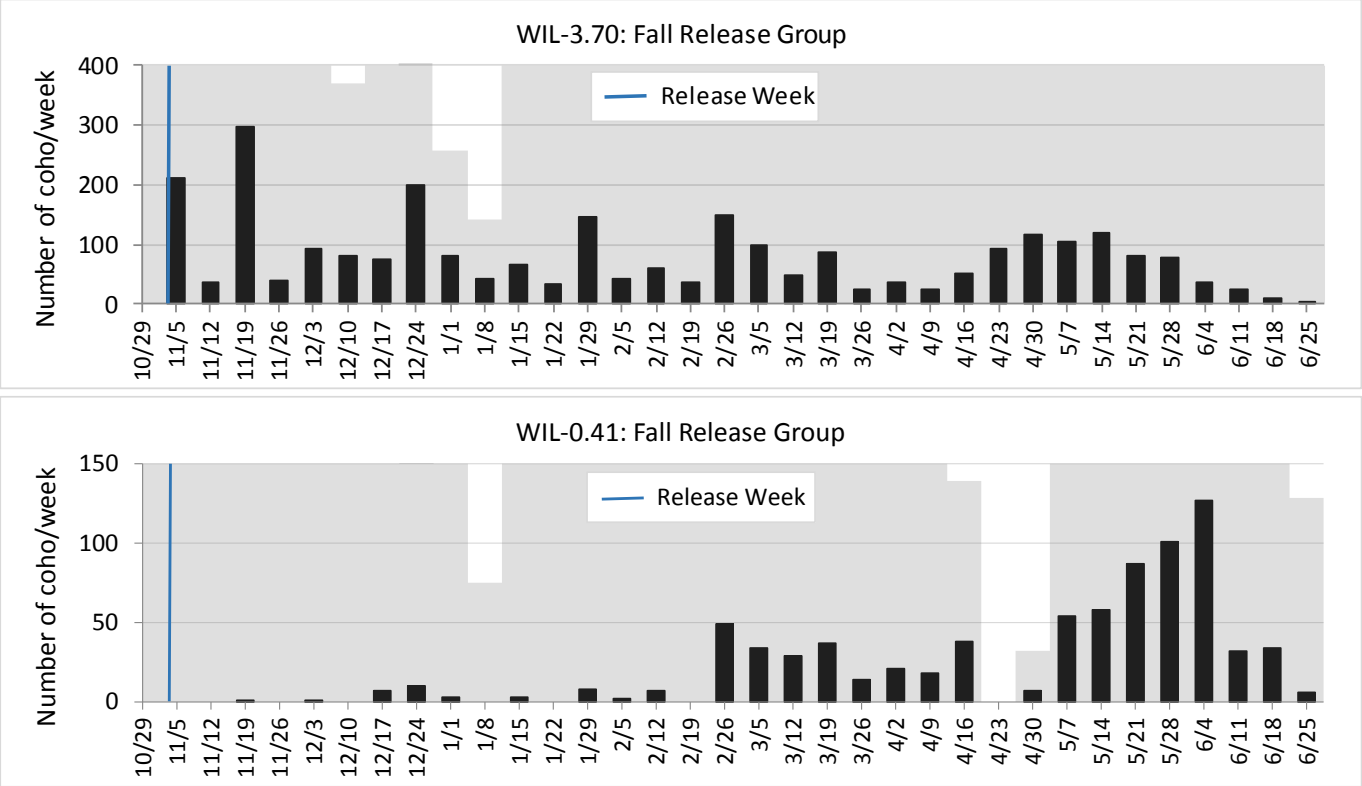


Figure 10. Number of fall-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

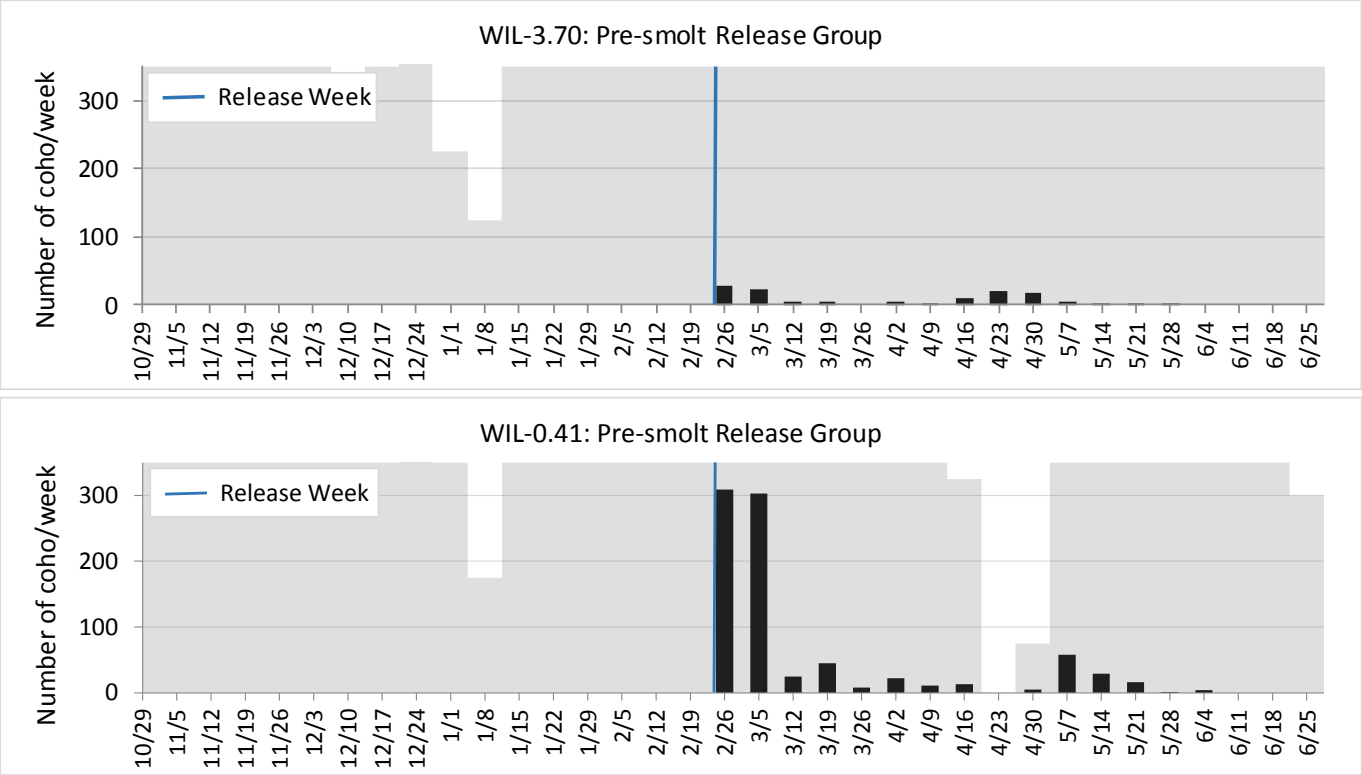


Figure 11. Number of pre-smolt-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

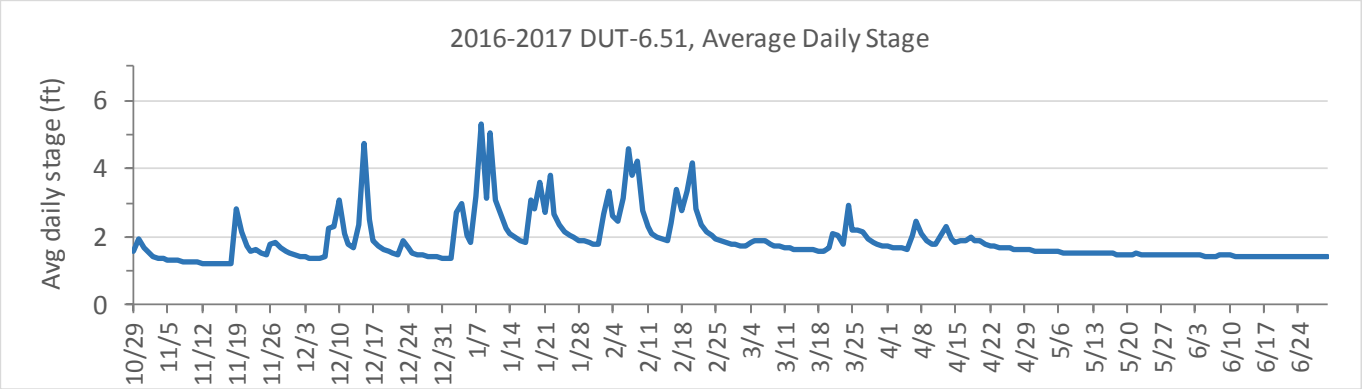


Figure 12. Average daily stage height at the Dutch Bill Creek smolt trap site between October 29, 2016 and June 30, 2017.

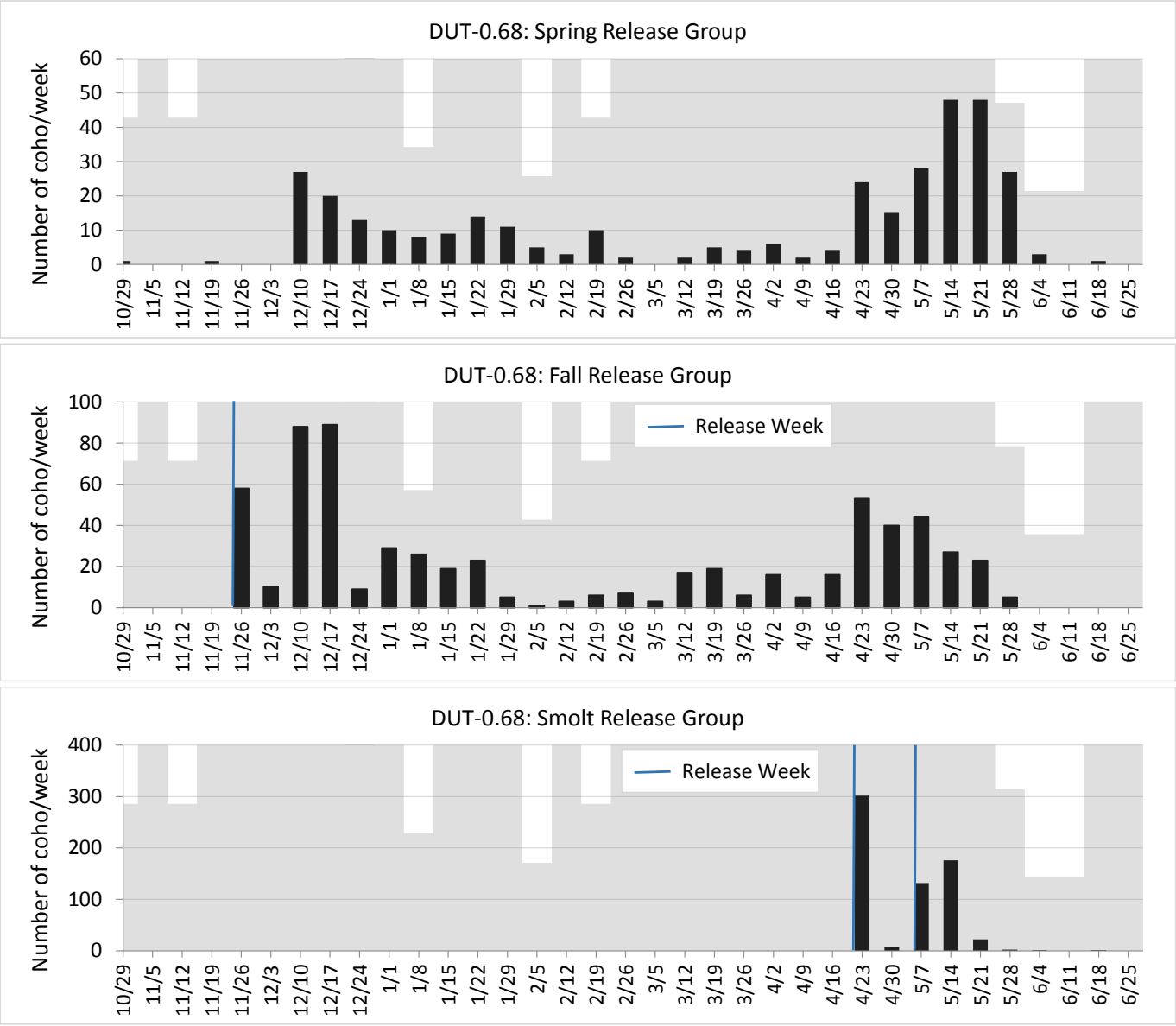


Figure 13. Number of spring, fall, and smolt-release coho salmon that moved past the Dutch Bill Creek smolt trap site (DUT-0.68) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

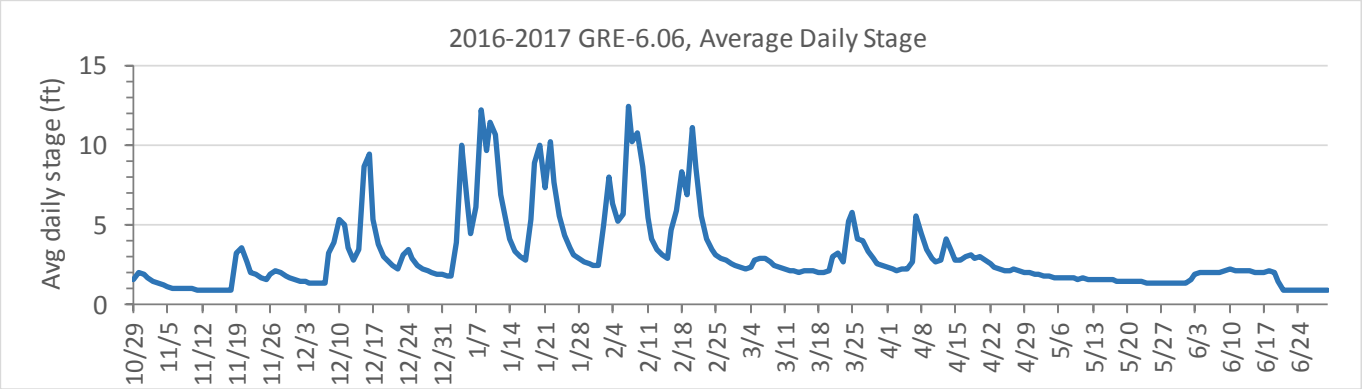


Figure 14. Average daily stage on Green Valley Creek (river km 6.06) between October 29, 2016 and June 30, 2017.

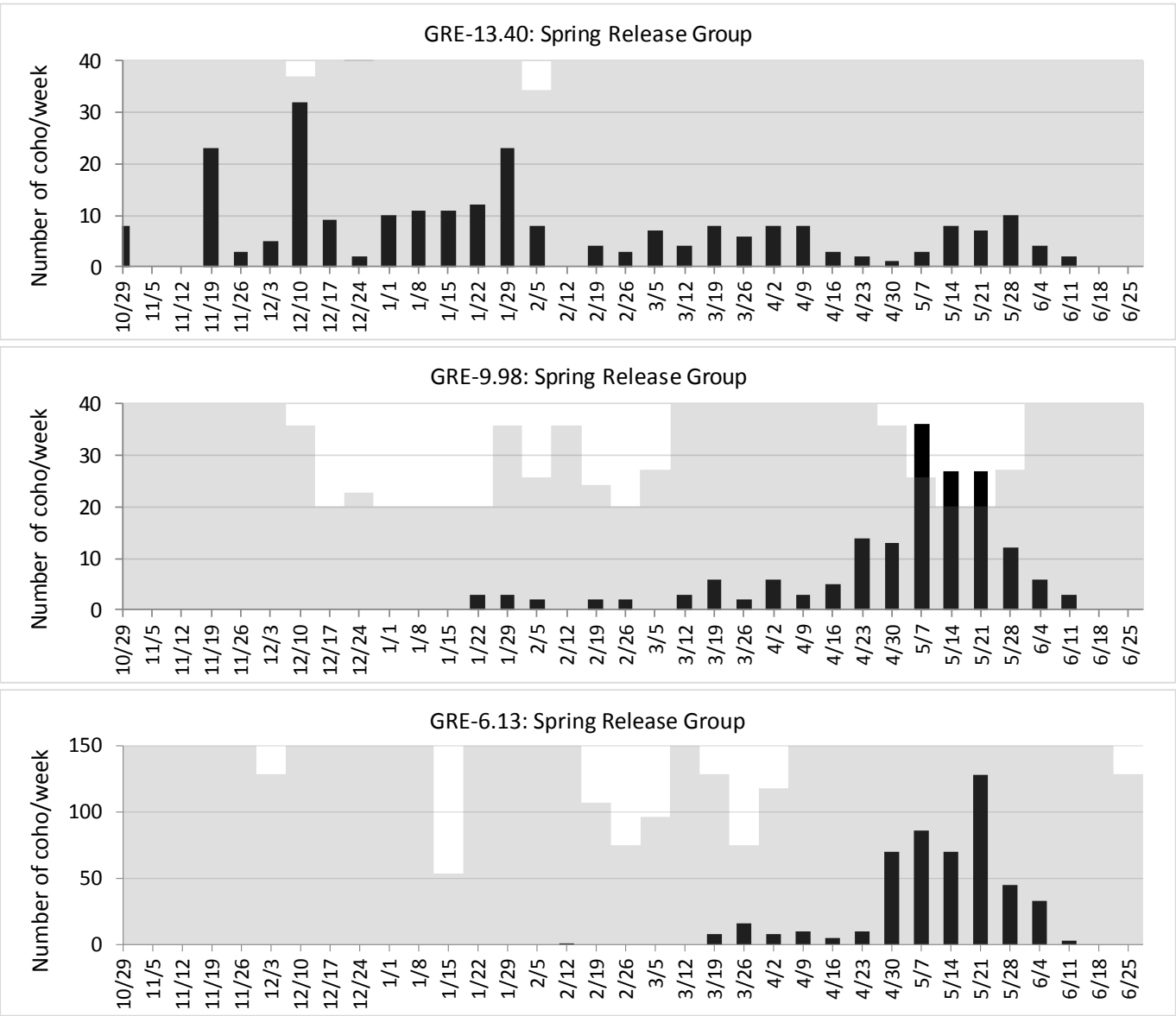


Figure 15. Number of spring-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

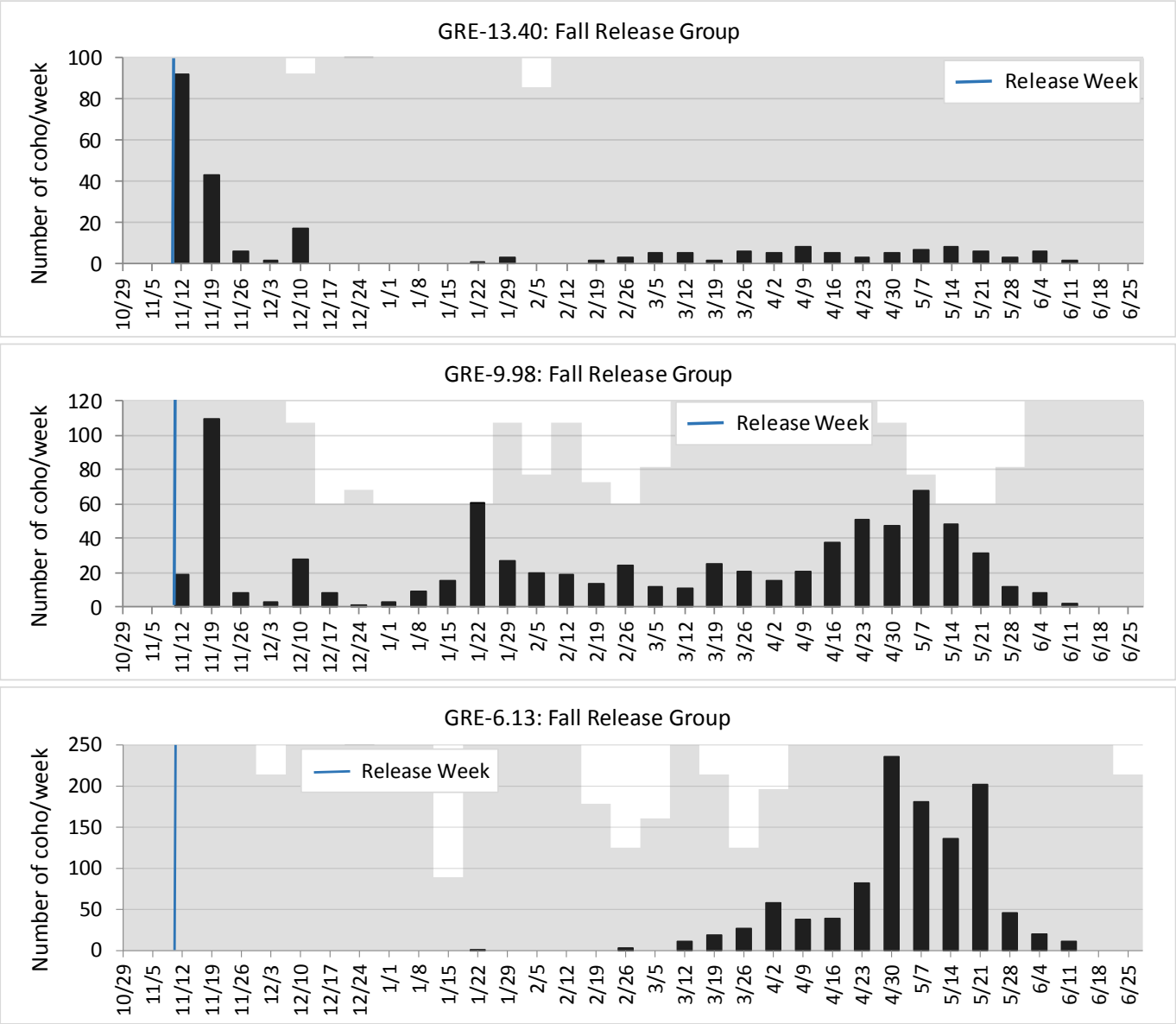


Figure 16. Number of fall-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

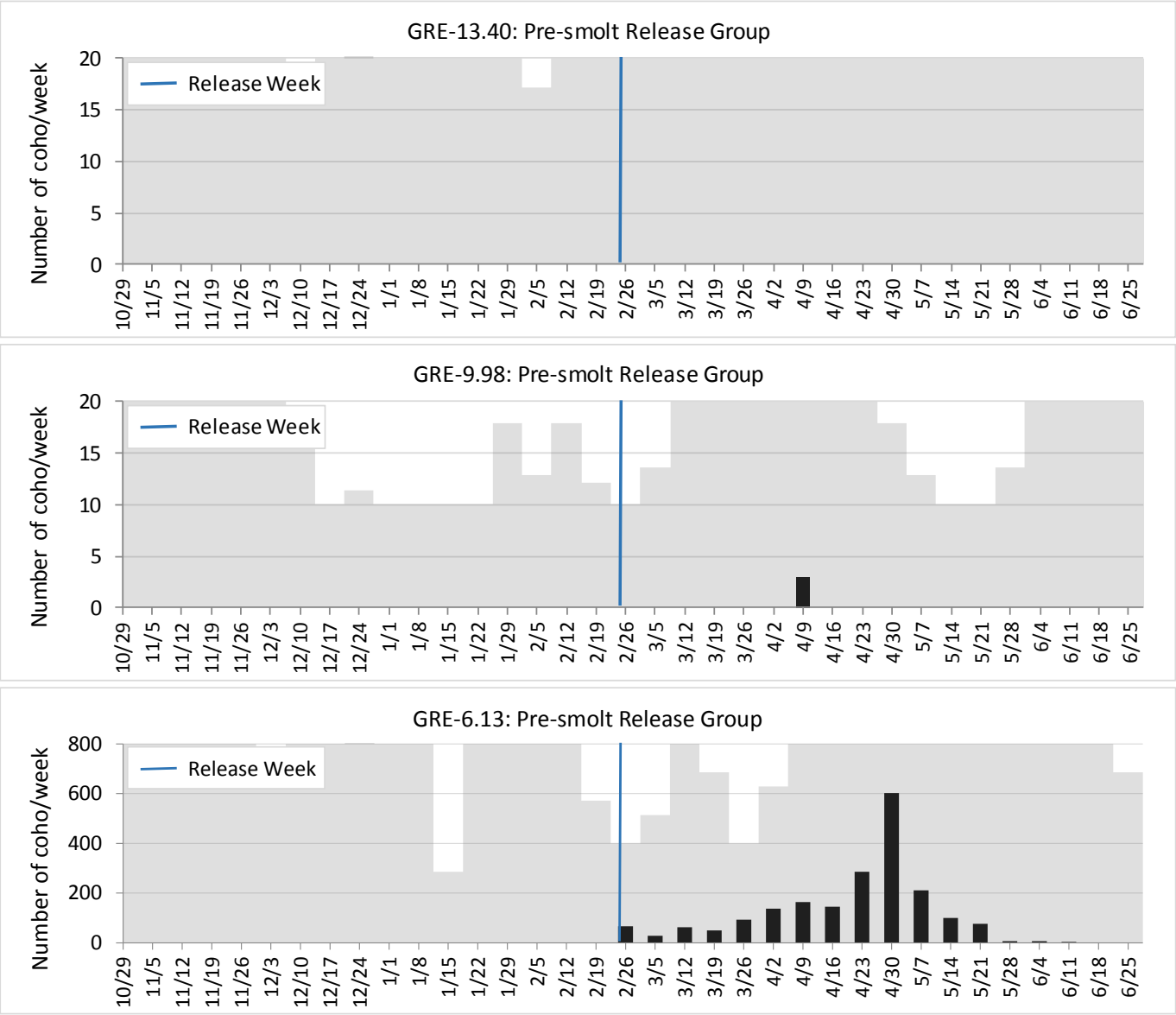


Figure 17. Number of pre-smolt-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

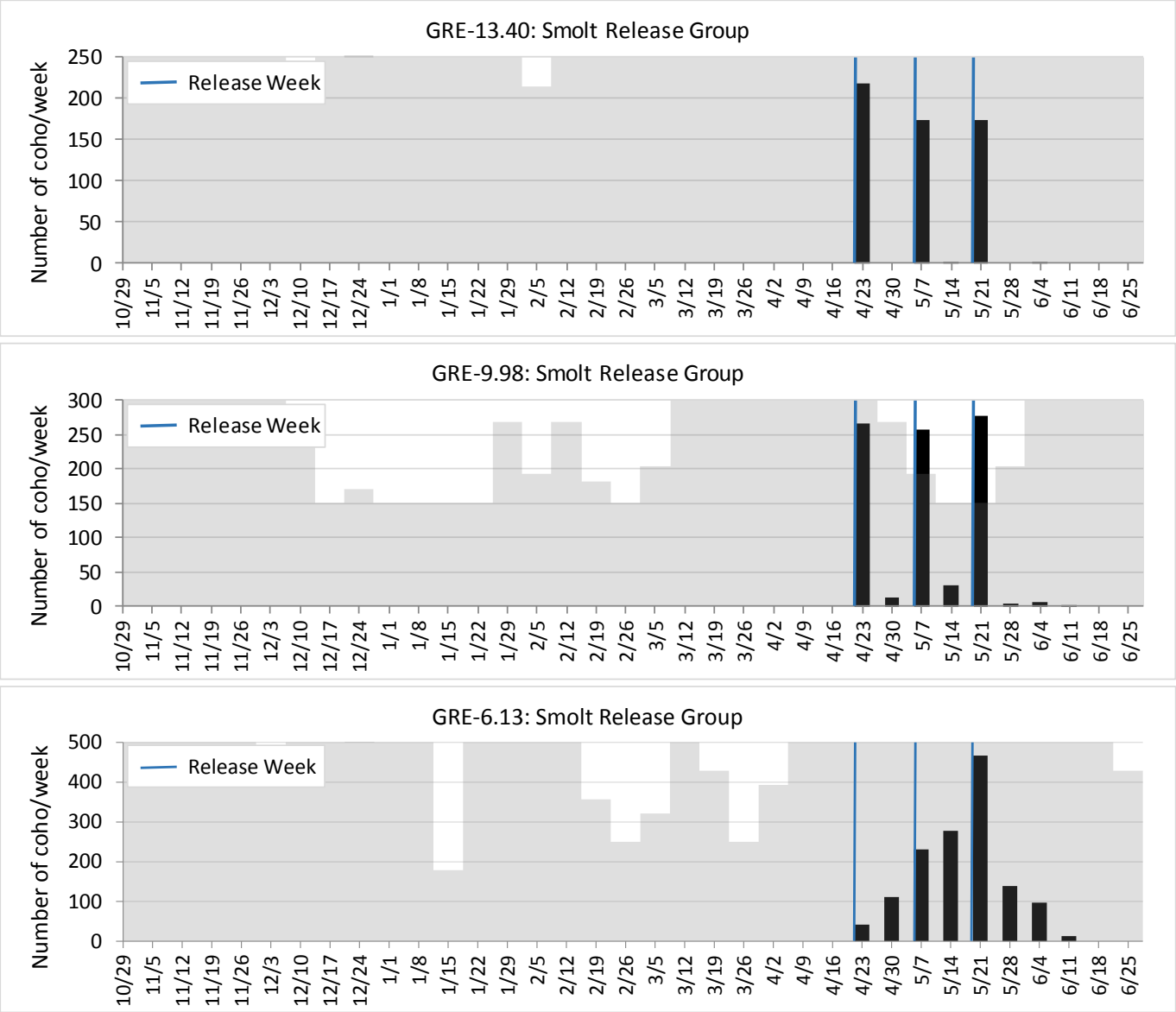


Figure 18. Number of smolt-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

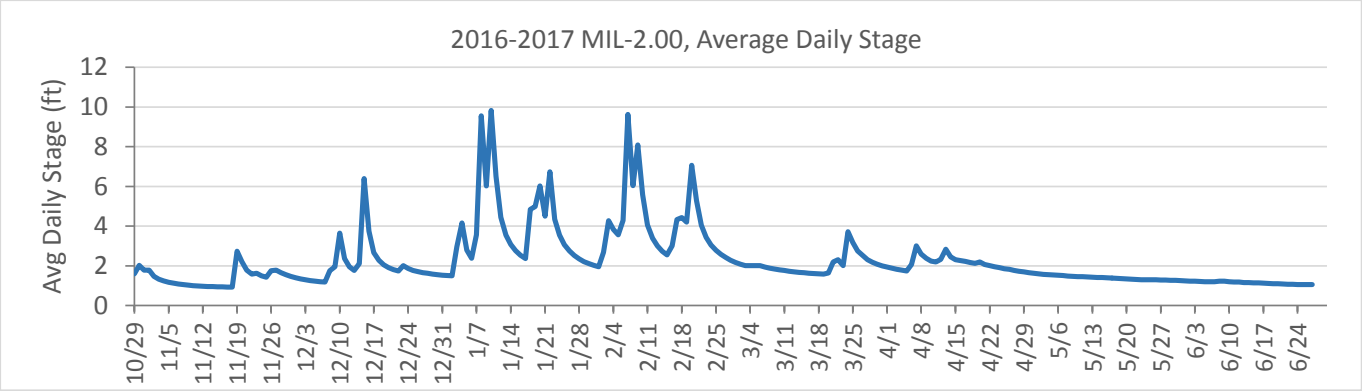


Figure 19. Average daily stage at the Mill Creek smolt trap site (river km 2.00) between October 29, 2016 and June 25, 2017.

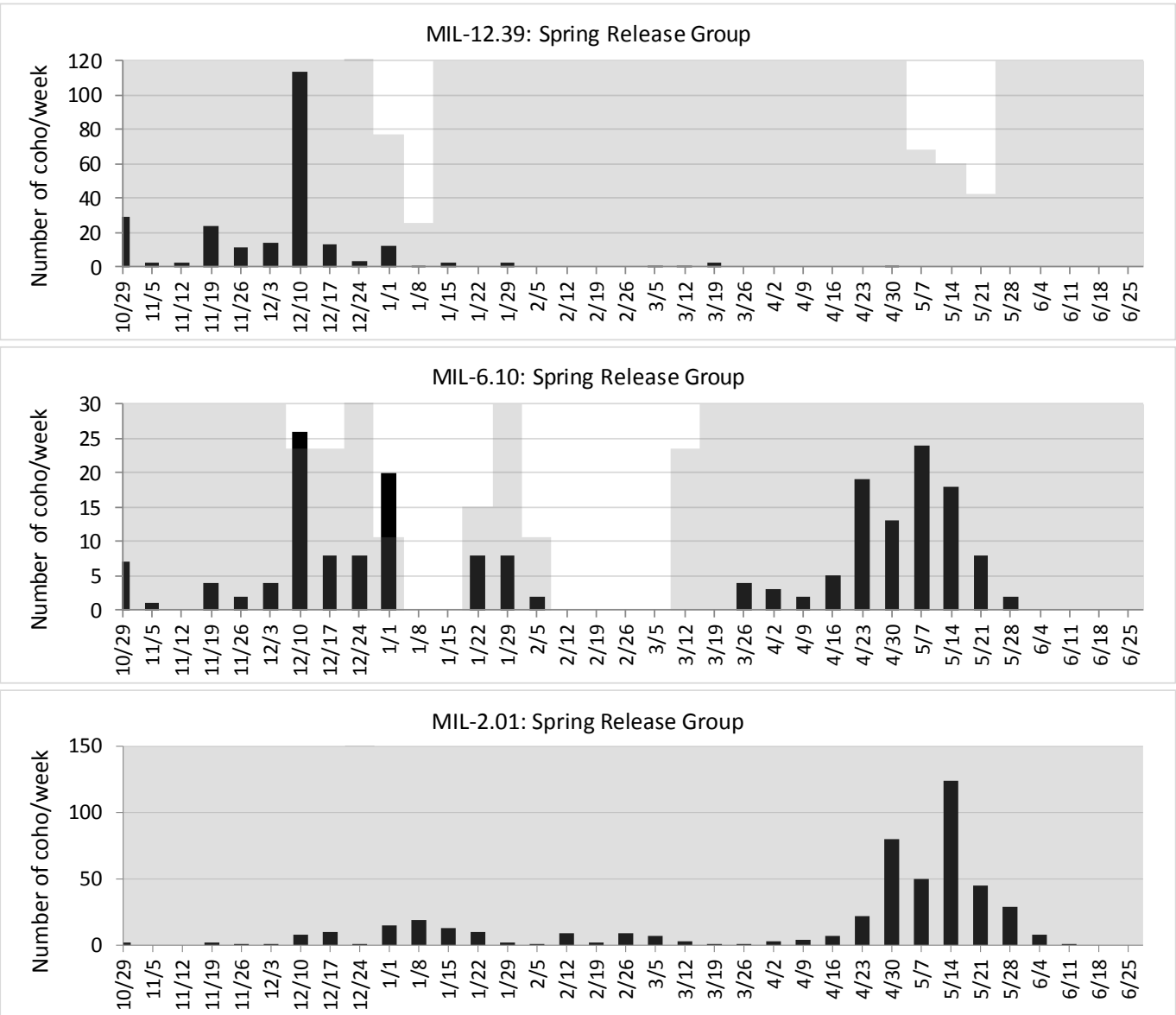
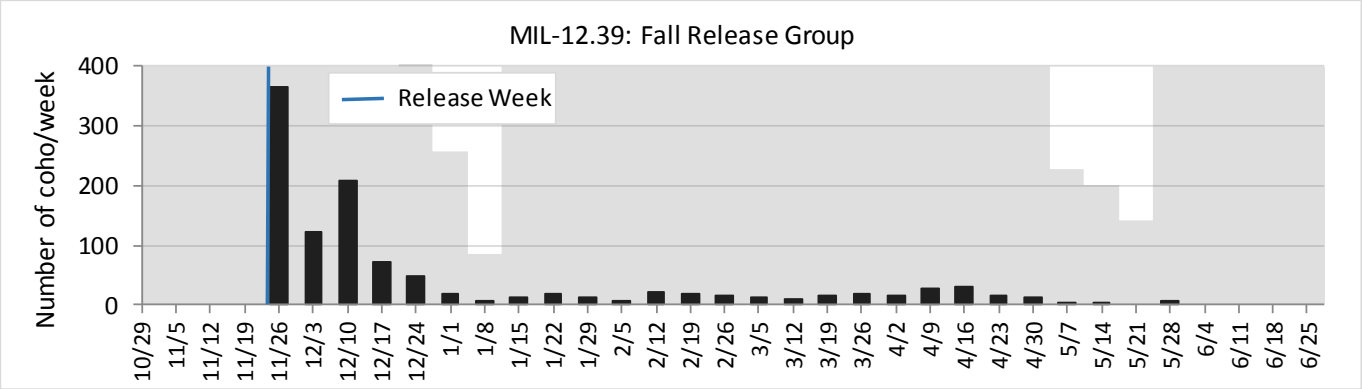
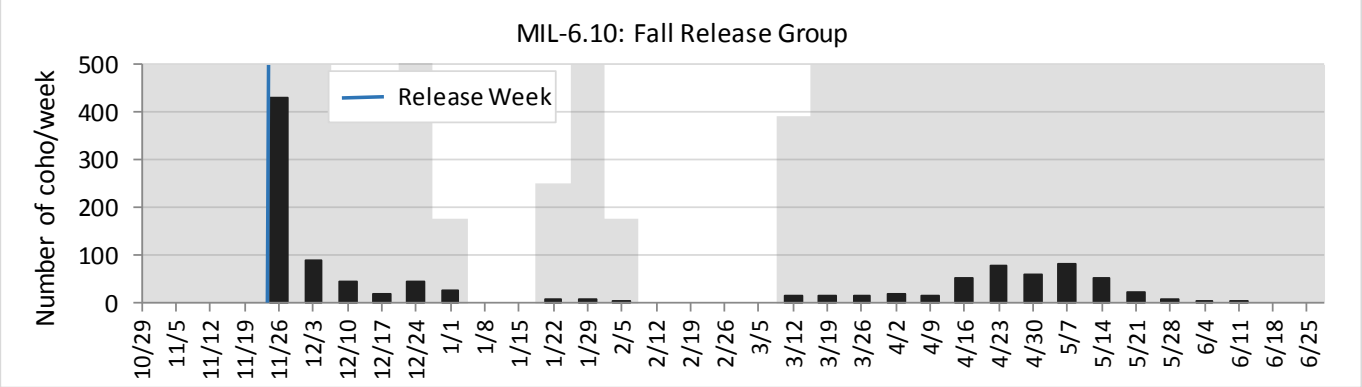


Figure 20. Number of spring-release coho smolts that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.





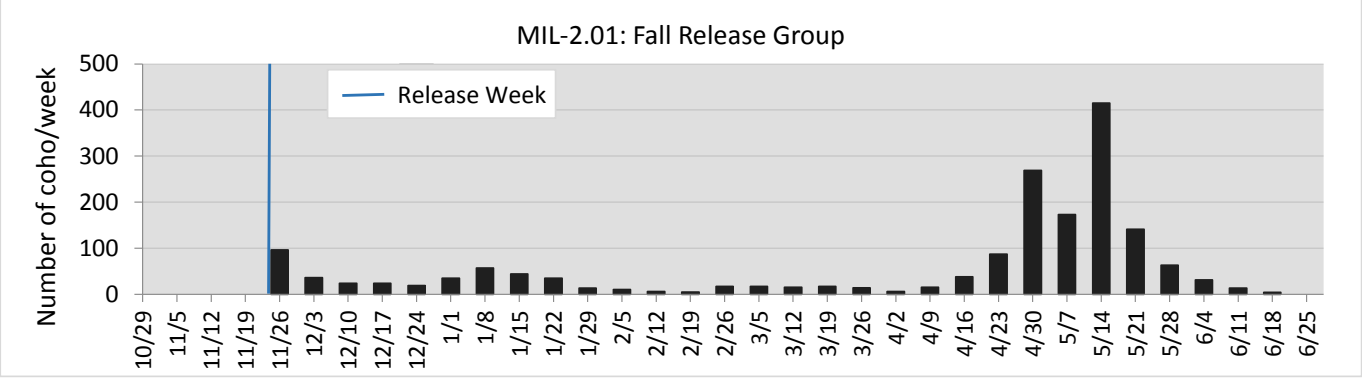


Figure 21. Number of fall-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

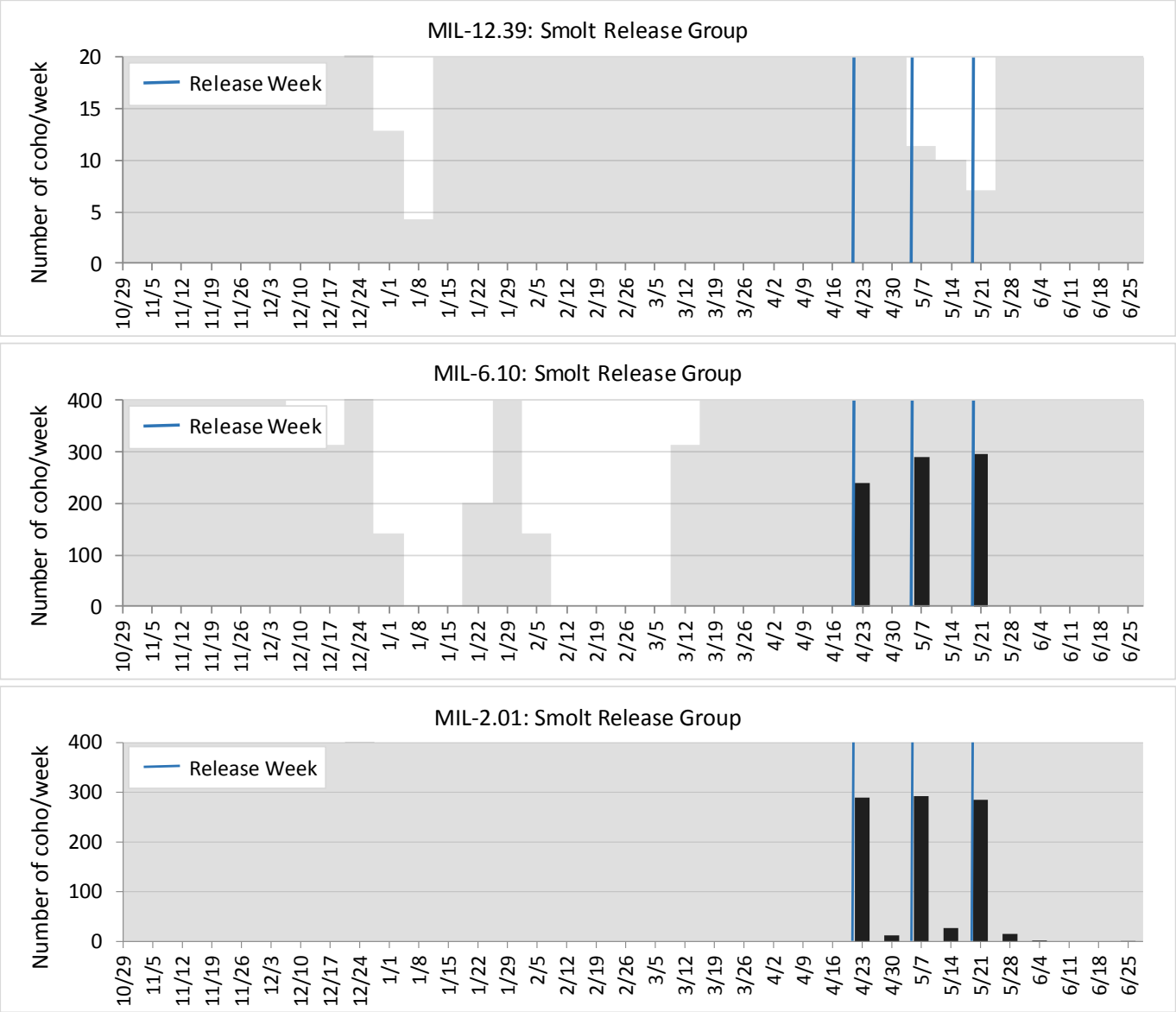


Figure 22. Number of smolt-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2016 and June 30, 2017. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

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 averages for all 2016 cohort Broodstock Program release streams combined were 69.9 mm and 4.1 g (spring), 85.6 mm and 7.5 g (fall), 111.2 mm and 15.8 g (pre-smolt), and 122.1 mm and 19.7 g (smolt).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 104.2 mm and 11.9 g in Willow Creek to 128.2 mm and 23.1 g in Green Valley Creek (Table 11). Average fork length and weight of

smolts captured in Dutch Bill Creek (118.6 mm and 17.3 g) was slightly higher than in Mill Creek (114.9 mm and 16 g) (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). The spring release had similar size distributions across all streams, although Mill Creek fish were slightly smaller and a portion of Green Valley Creek fish were much larger than average (Figure 23). Fall release fish captured in Green Valley were much larger than other streams and had a much wider distribution of fork lengths (Figure 23). Pre-smolt release fish from Green Valley were the largest of any group and were significantly larger than Willow Creek pre-smolt fish, although only six fish from the pre-smolt release were captured in Willow Creek and they were fish that moved upstream from the release point to the trap location (Figure 23). Smolt release fish were similar in size across all streams, as would be expected given the short time between release and recapture (Figure 23).

Size variation between natural and hatchery origin coho salmon smolts differed among streams but was generally minimal (Table 11). In Dutch Bill and Green Valley creeks, hatchery origin smolts were slightly larger than natural origin smolts, in Mill Creek sizes were similar, and in Willow Creek natural origin smolts were slightly larger than hatchery smolts (Table 11). Green Valley Creek hatchery origin smolts were the largest among all groups, averaging 128.2 mm and 23.1 g (Table 11).

Table 10. Average fork length (mm) and weight (g) of cohort 2016 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	85.4 (±8.3)	7.4 (±2.2)	2,291
	Pre-smolt	110.6 (±9.6)	16.1 (±4.2)	1,199
Dutch Bill Creek	Spring	69.5 (±4.8)	4 (±0.9)	1,016
	Fall	87.6 (±7.9)	8 (±2.2)	1,494
	Smolt	120.5 (±9.8)	19.3 (±4.9)	914
Green Valley Creek	Spring	70.3 (±4.8)	4.2 (±1)	452
	Fall	83.5 (±7.1)	7.1 (±1.8)	929
	Pre-smolt	111.8 (±9.5)	15.5 (±5)	1,273
	Smolt	122.9 (±9.8)	19.9 (±4.9)	913
Mill Creek	Spring	70.4 (±4.9)	4.1 (±1)	510
	Fall	85.4 (±8.4)	7.5 (±2.3)	2,384
	Smolt	122.9 (±9.8)	20 (±5)	915

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 2017 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	104.2 (±8.9)	11.9 (±3.1)	1,436
Natural	107.0 (±9.7)	12.6 (±3.4)	43
All Smolts	104.2 (±9)	11.9 (±3.1)	1,479
Dutch Bill Creek			
Hatchery	119.2 (±9.9)	17.5 (±4.3)	1,036
Natural	114.3 (±9)	15.4 (±3.4)	149
All Smolts	118.6 (±9.9)	17.3 (±4.3)	1,185
Green Valley Creek			
Hatchery	128.2 (±14.8)	23.1 (±8.7)	2,424
Natural	124.0 (±16.7)	21.0 (±9.1)	382
All Smolts	127.7 (±15.2)	22.8 (±8.8)	2,806
Mill Creek			
Hatchery	114.8 (±12.7)	16.0 (±5.4)	1,606
Natural	115.9 (±9.2)	16.3 (±3.8)	158
All Smolts	114.9 (±12.4)	16.0 (±5.3)	1,764

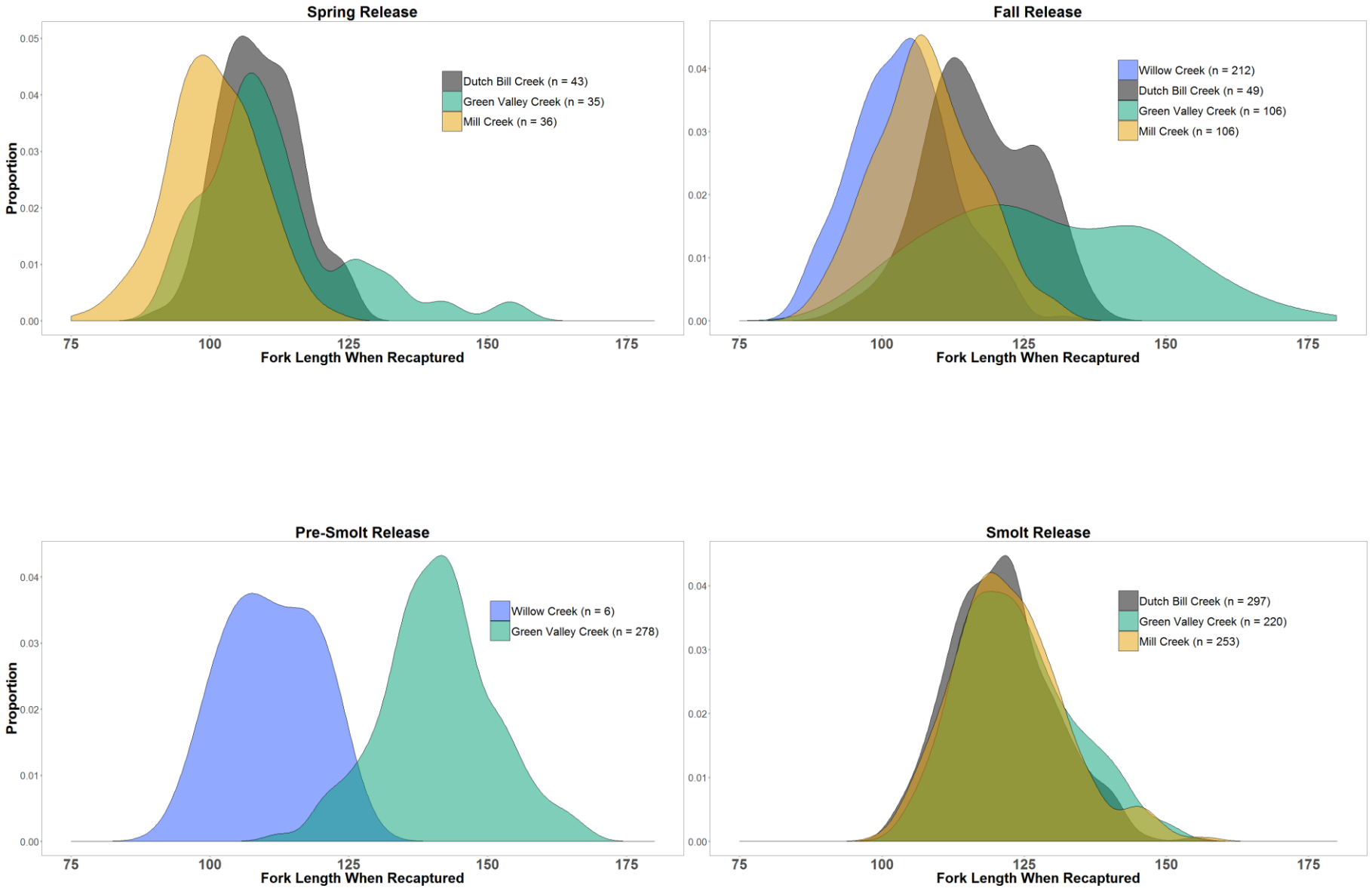


Figure 23. Length-frequency distribution of PIT-tagged coho salmon smolts captured in the spring of 2017 in downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks by release season.

Growth

Average growth (mm and g gained) from release and average daily growth rates (mm/day) 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 increasing in length and weight more than the fall-release fish in Dutch Bill and Mill Creek (Table 12). Spring-release fish in Green Valley Creek grew slightly less than fall-release fish, despite residing in the stream for an average of 140 days longer (Table 12). In the fall release group, PIT-tagged smolts recaptured in Green Valley Creek grew significantly more than those from the other three study streams in both total increase in size since release (Table 12) and average daily growth rate (Figure 24). Smolt release fish, which spent the least number of days in the stream environment, generally grew slightly in length, but grew very little or even decreased in weight (Table 12).

Growth rates in Dutch Bill Creek were greater than those in Mill Creek for the spring, fall, and smolt releases (Figure 24). Pre-smolt releases only took place in Green Valley and Willow Creek and the Willow Creek release took place downstream of the trap site so any fish captured swam upstream and may not be representative of the release group. The Green Valley Creek pre-smolt fish showed, by far, the highest growth rate of any release group (Figure 24).

In addition to the fish recaptured from the 2016/17 hatchery release, in Willow Creek one fish was recaptured from the 2015 fall release and one was recaptured from the 2014 spring release. The fish from the 2015 release grew 38mm in length while the fish from the 2014 release grew 47mm in length and had spent 1,089 days in the stream when it was recaptured.

Growth rates for fall-release fish in 2017 were generally high relative to previous years (Figure 25). Fish released into Dutch Bill and Green Valley creeks had the highest growth rates since monitoring started on those streams in 2011 (Figure 25). Mill Creek growth rates in 2017 were similar to the previous two years, but higher than average historical growth rates (Figure 25). Willow Creek growth rates were similar to those of previous years (Figure 25).

Table 12. Average growth in fork length (mm) and weight (g) of recaptured PIT-tagged coho salmon smolts during the 2016 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	17.5 (±7.2)	4.3 (±2.5)	212	218 (±14)
Pre-smolt	7.8 (±4.8)	1.1 (±1.6)	6	82 (±9)
Dutch Bill Downstream Migrant Trap				
Spring	40.8 (±8.4)	10.2 (±2.9)	43	349 (±10)
Fall	29.7 (±8.6)	8.8 (±3.7)	49	204 (±14)
Smolt	1.6 (±2.4)	-0.7 (±1.8)	291	26 (±3)
Green Valley Downstream Migrant Trap				
Spring	40.1 (±14.1)	10.8 (±6.7)	35	358 (±17)
Fall	44.5 (±20.2)	17.2 (±11.7)	106	218 (±15)
Pre-smolt	30.9 (±8.6)	16.3 (±6.1)	277	77 (±7)
Smolt	0.9 (±2.3)	-0.5 (±1.4)	210	15 (±7)
Mill Downstream Migrant Trap				
Spring	31.5 (±10.1)	7.6 (±3.2)	36	345 (±14)
Fall	22.8 (±8.3)	5.4 (±2.8)	106	206 (±12)
Smolt	-0.1 (±1.4)	-0.3 (±0.8)	241	9 (±2)

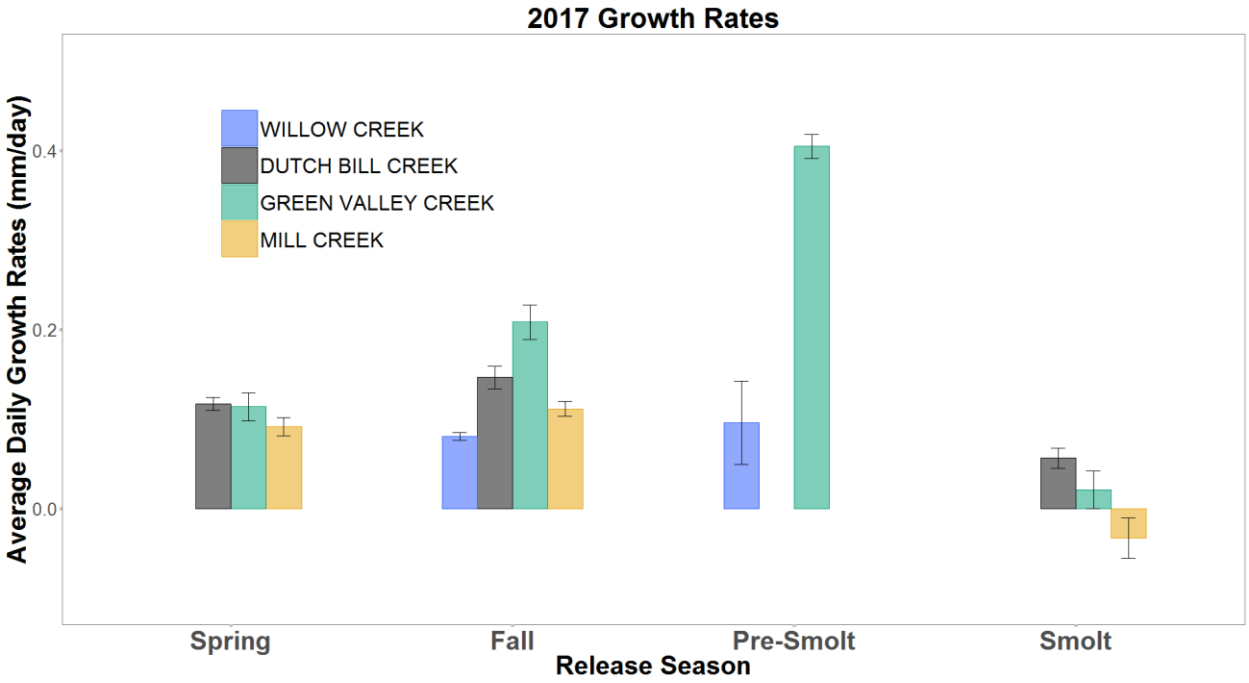


Figure 24. Average daily growth rates in fork length (mm) of PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2017 season, by stream and release season.

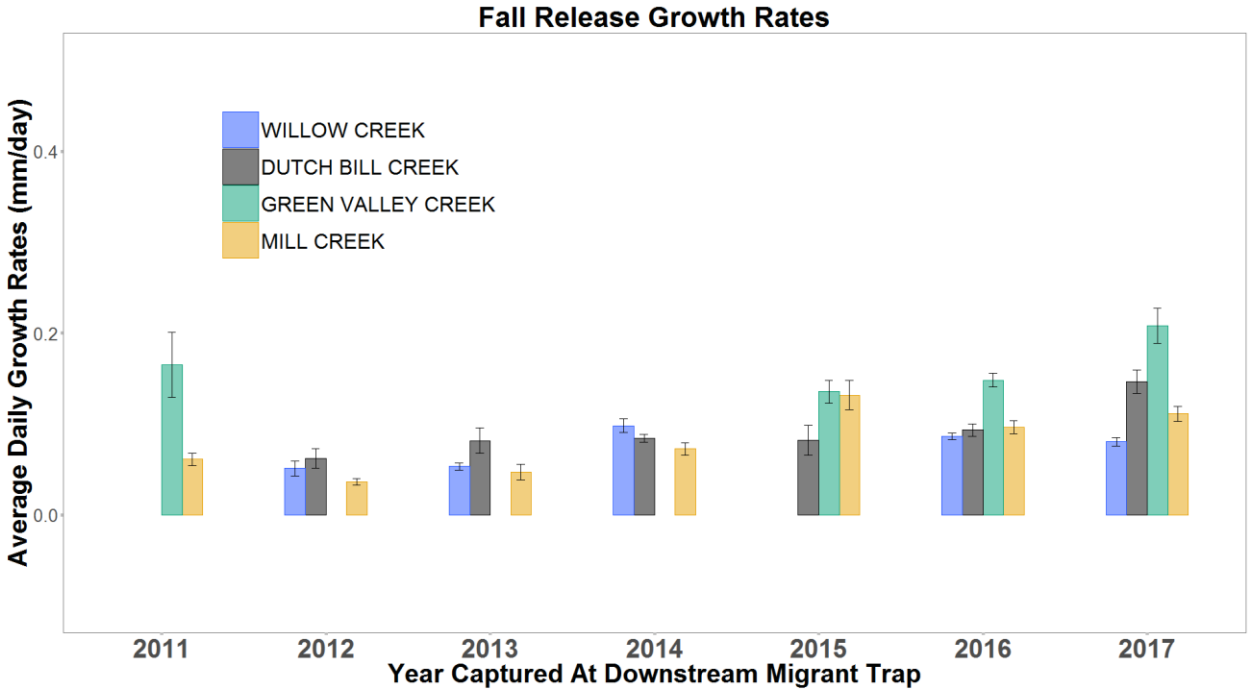


Figure 25. Average daily growth rates in fork length (mm) of fall-release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2017.

Discussion and Recommendations

The winter/spring of 2016/17 was the wettest in recent years, with October to June precipitation at the Venado gage in the headwaters of Mill Creek reaching approximately 87.7 inches, 40.9 inches higher than the 10-year average. Consequently, streamflow was also higher throughout the winter season. These hydrologic conditions appeared to influence movement timing; there was generally more movement observed in the winter of 2016/17 as compared to other years. Large pulses of emigration associated with winter storms occurred prior to March 1 on Dutch Bill Creek (Figure 12, Figure 13). Winter movement was also observed out of the upper reaches of Willow, Green Valley, and Mill creeks (Figure 10, Figure 15, Figure 16, Figure 20, Figure 21), though most fish did not move down past the lower antennas in these stream systems until after March 1, indicating that they likely overwintered in the low-gradient habitat in lower Willow and Mill creeks and mid-Green Valley Creek. One possible explanation for the higher winter emigration probability in Dutch Bill Creek is the lack of low-gradient juvenile salmon overwintering habitat as compared to the other three streams. Although creating off-channel, low gradient overwintering habitat is likely not feasible given the morphology of the Dutch Bill Creek watershed, efforts to create additional pools and instream cover could improve winter rearing habitat in Dutch Bill Creek and decrease the probability of overwinter juveniles emigrating in early winter.

Coho salmon smolt abundance in the four Broodstock Program life cycle monitoring streams was generally above average in 2017, when more than 40,000 smolts were estimated to have emigrated out of those systems, and over half of these fish were from Green Valley Creek (Table 6). In Willow and Dutch Bill creeks, estimated smolt abundance was 130% and 186%, respectively, of five-year averages. In Green Valley Creek, 2017 smolt abundance was 139% of the three-year average (no trap in previous two years); the highest observed since monitoring began there. In Mill Creek, estimated coho smolt abundance in 2017 was slightly below the five-year average (93%).

Higher stocking rates (106% of five-year average for all four streams, collectively) and above-average overwinter survival on Green Valley Creek likely contributed to this increase in abundance.

For all smolts captured in the four Broodstock Program monitoring streams combined, overall natural production was 6.0% in the 2017 trap year (748 natural origin smolts/12,385 total known origin smolts captured). This was slightly lower than the past three years (range of 761-973 natural-origin smolts representing 7.2%-17.8% of the total known origin smolts captured), but higher than years 2005-2013 which ranged from 1-189 natural-origin smolts representing 0.02% to 2.5% of the total known origin smolts captured. Theoretically, if hatchery adults are successfully spawning and producing natural-origin juveniles in these streams, we would expect to see an increasing proportion of natural-origin smolts each year with some fluctuation due to changes in stocking rates and annual variation in freshwater survival. The fact that the proportion has not increased over the last few years is likely attributed to the drought, when the majority of rearing juveniles perished with drying stream conditions (Obedzinski et al. 2016).

Overwinter survival of spring and fall release group fish was approximately average compared to previous years of data collection in Willow, Dutch Bill and Mill creeks, and as in most years, was highest in Green Valley Creek (Figure 7, Table 7). Stock to smolt survival rates for both release groups in Green Valley Creek were at least twice the rates of the other three streams for the 2016 cohort (Table 7). High survival in Green Valley Creek is likely attributed to the higher flows observed during the summer of 2016 as well as the abundance of low gradient juvenile overwintering habitat in the middle reaches of that stream. To promote increases in oversummer survival in these watersheds, 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 similar to that occurring in Green Valley Creek.

Growth rates over the winter of 2016/17 were high relative to historical averages (Figure 25). Fish released into Dutch Bill and Green Valley creeks in the fall had the highest overwinter growth rates ever recorded for those streams (Figure 25). Mill Creek growth rates were higher than average historical growth rates and Willow Creek growth rates were similar to those of previous years (Figure 25). Freshwater growth in Green Valley Creek was remarkably high relative to the other three Broodstock Program monitoring streams, and particularly in the pre-smolt release group (Figure 24). Large smolt size and high growth compared to other Russian River tributaries has been observed in previous years (Obedzinski 2012) and can be explained by the high abundance of benthic macroinvertebrates present in Green Valley Creek as compared to other Russian River tributaries (Obedzinski 2008).

In a previous study comparing different smolt release strategies, UC found that almost all juvenile coho salmon released as smolts directly into the stream emigrated from the stream within a few days of being released (Obedzinski 2012). To foster imprinting on designated release streams, the Broodstock Program has used two acclimation strategies for the smolt release, where possible; streamside tanks (Dutch Bill Creek) and stocking fish into an instream pond created by a flashboard dam (Mill Creek, most years between 2010 and 2016). Fish placed in the streamside tank on Dutch Bill Creek are held in the tank for approximately two weeks and then released into the stream if flow conditions are sufficiently high to allow passage downstream, or into the mainstem of the Russian River if flows are too low in Dutch Bill Creek. Based on the relatively low stock to smolt survival rates observed for the Mill Creek pond smolt release groups, ranging from 0.32 to 0.58 between 2010 and 2014, the Broodstock Program chose to release the Mill Creek smolt release group directly into the stream during the spring of 2017. As anticipated based on previous years' results, the smolt-release fish left Mill Creek virtually

immediately after planting (Figure 22). This contrasted to the more gradual movement observed by the second smolt-release group out of Dutch Bill and all smolt-release groups out of Green Valley (Figure 18) and presents a concern as to whether the Mill Creek smolt-release fish were able to imprint successfully. We recommend that an imprinting tank be placed and operated on Mill Creek at Westside School, which would likely allow for higher rates of smolt survival, while still allowing for a high level of imprinting in released fish.

Stocking fish at the pre-smolt life stage demonstrated promise as a successful release strategy, particularly in Green Valley Creek. Although survival was lower for the pre-smolt release group as compared to the smolt release group in Green Valley Creek (0.51 versus 0.78-0.90, respectively; Table 8), the pre-smolt release group spent more than twice the amount of time in stream (Figure 17, Figure 18) and increased in size at a remarkable rate (Figure 24). In Willow Creek, pre-smolt survival was higher than in Green Valley Creek (0.60 versus 0.51 respectively; Table 8); however, the majority of the fish emigrated from Willow Creek within two weeks of release (Figure 11). Because our trap site was located upstream of the pre-smolt release site (Figure 2, Figure 3), we were unable to properly evaluate growth of the pre-smolt release group. Based on these initial findings, we recommend continuation of this strategy in Green Valley and Willow Creeks, with an expansion into additional streams that have similar low gradient habitat, such as Mark West Creek.

In summary, during the spring of 2017, we observed thousands of coho salmon smolts emigrating from each of the four Broodstock Program monitoring streams, documenting successful production to the smolt stage. As in previous years, survival was lowest for the spring release group which spent a year in the stream environment, and survival was highest for the smolt release group which spent only days to weeks within the stream environment. Because of unpredictable weather and climate patterns and associated variation in survival among years and streams, we recommend that the Broodstock Program continue its bet-hedging strategy of stocking fish in spring, fall, pre-smolt, and smolt release groups.

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