California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2018

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Sea Grant California

UNIVERSITY OF CALIFORNIA

RUSSIAN RIVER SALMON & STEELHEAD MONITORING PROGRAM

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) (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 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 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 2017 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 three release groups; spring, fall, and smolt. Fish in the spring release group were stocked as young-of-the-year (yoy) in June 2017, fish from the fall release group were stocked as yoy in November and December 2017, and fish from the smolt release group were stocked as age-1 smolts in March through May 2018. All fish in the spring and fall releases were planted directly into the release streams. In Willow, 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 14 to 20 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, ACOE staff stocked fish into individual pools throughout reaches characterized by suitable salmonid habitat (Figure 1, Figure 2). For smolt releases, when streamflows were high enough to allow fish to disperse naturally throughout the streams, fish were released at point locations. (Figure 2).

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

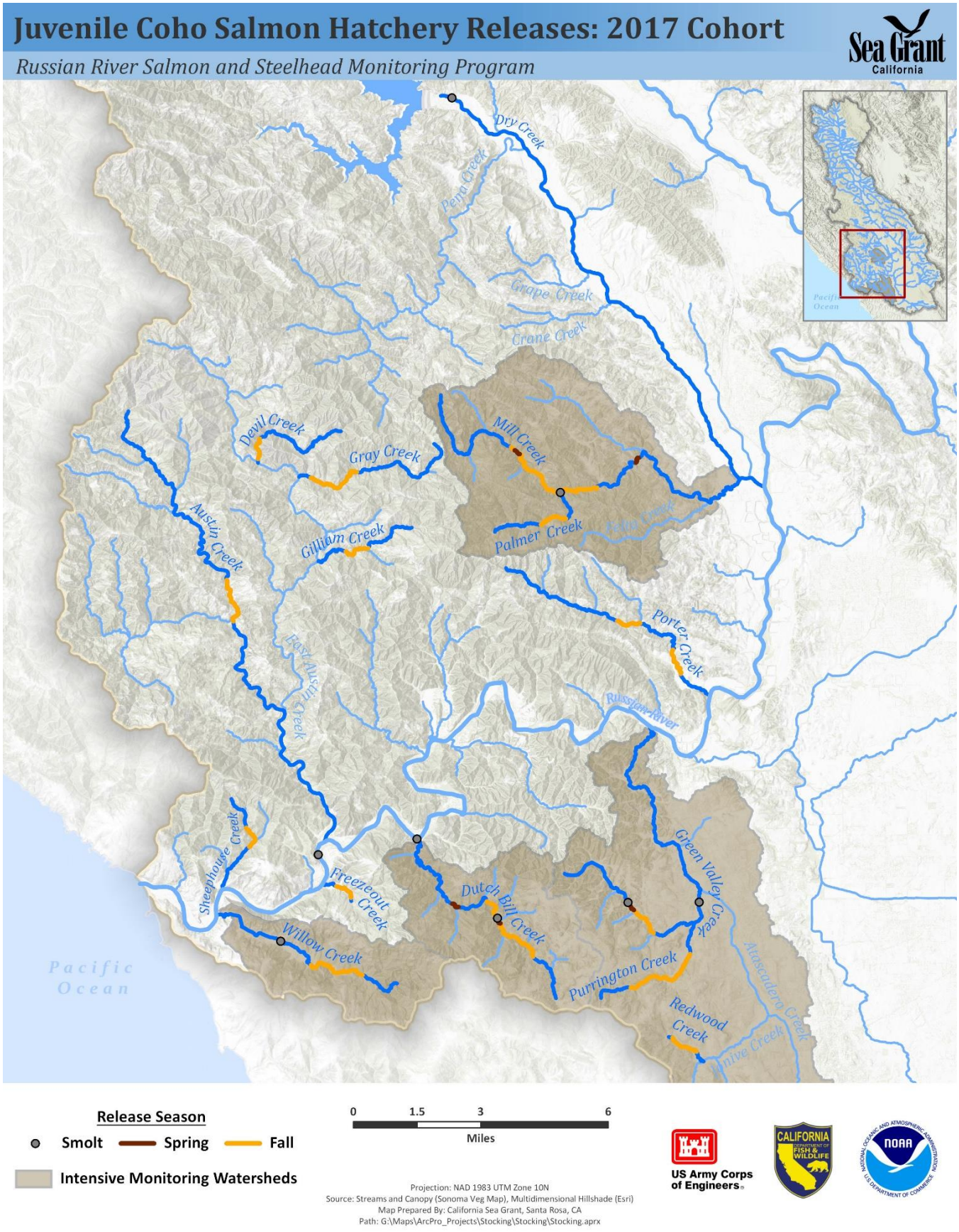


Figure 2. Map of juvenile coho salmon stocking locations for 2017 cohort (hatch year).

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 Dutch Bill, Green Valley, and Mill creeks 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.

Table 1. Number and percent of PIT-tagged juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creek watersheds for the 2017 cohort.

		Number Released (% PIT-tagged)			
Release Season	**Release Dates**	**Willow Creek**	**Dutch Bill Creek**	**Green Valley Creek**	**Mill Creek**
Spring	**Jun 16, 2017**	0	995 (100%)	454 (100%)	1,006 (100%)
Fall	**Nov 15 - Dec 7, 2017**	10,075 (20%)	7,077 (20%)	11,110 (20%)	13,095 (20%)
Smolt	**Mar 28 - May 23, 2018**	8,876 (20%)	5,258 (20%)	14,066 (20%)	5,312 (21%)
Total Released		18,951	13,330	25,630	19,413

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 are also operated 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. 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 2017 through June 2018, 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.

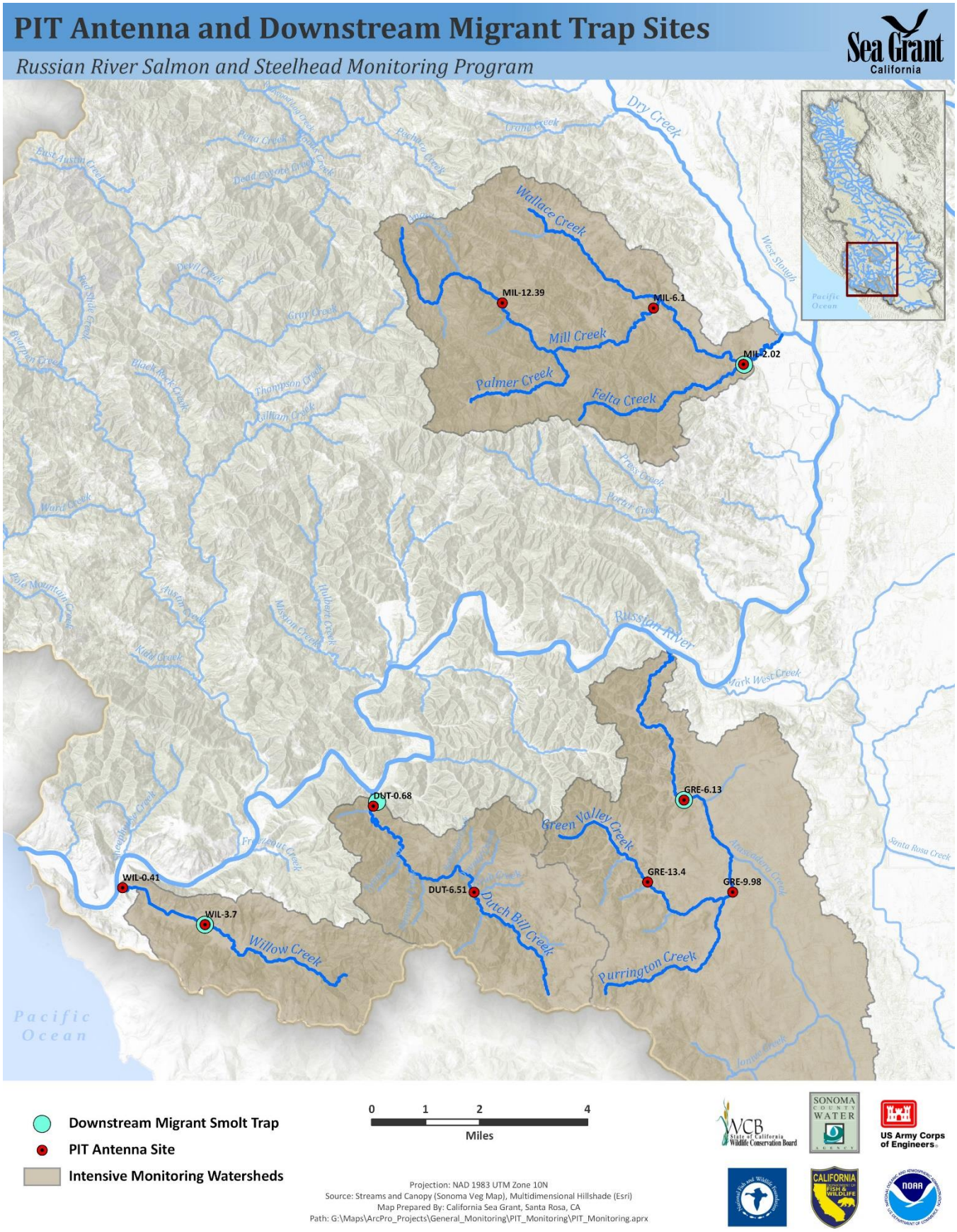


Figure 3. Map showing PIT antenna and smolt trap locations on Broodstock Program monitoring streams, with antenna site codes.

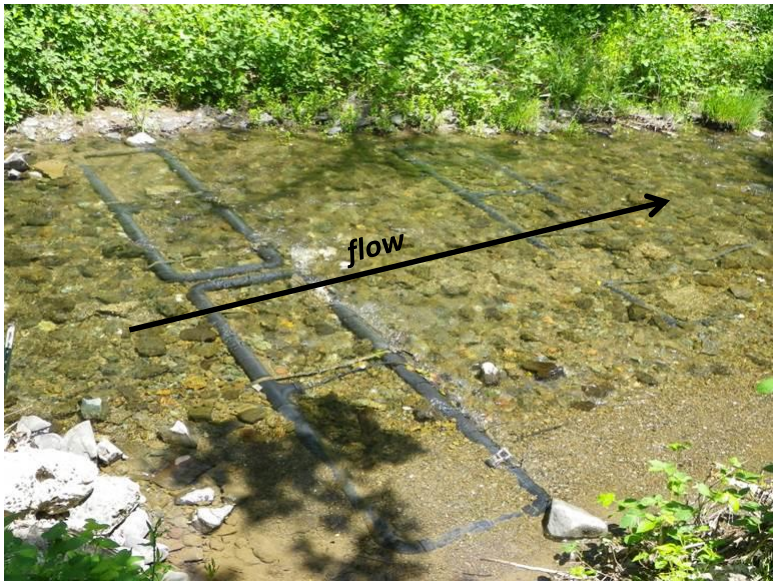


Figure 4. Paired flat-plate PIT tag antenna array on Mill Creek at spring base flows.

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 2018, 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 tag (CWT)s. 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 those 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). 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.

For Dutch Bill Creek, we used an alternate method for estimating 2018 smolt abundance because trap removals to avoid capturing smolt release fish violated critical assumptions for estimating abundance using DARR. For this stream, we multiplied release-specific freshwater survival estimates by the number of fish released from each group to estimate the total number of hatchery smolts from each group. To estimate the total number of natural-origin smolts, we multiplied the estimated ratio of natural-origin to hatchery-origin fish by the estimated number of hatchery smolts. Estimated hatchery and natural-origin smolts from each release group were then summed for a total estimated abundance.

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 6/30/18 and emigration prior to 3/1/18 for multiple release groups (i.e., spring, fall, 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, 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. 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 predict the size at release for all fish in each release group.

Results

Trap Operation

In 2018, the traps were installed on 3/9 and operated until the site became disconnected from flow or through 6/22. Traps and weir panels were 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 Mill 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.

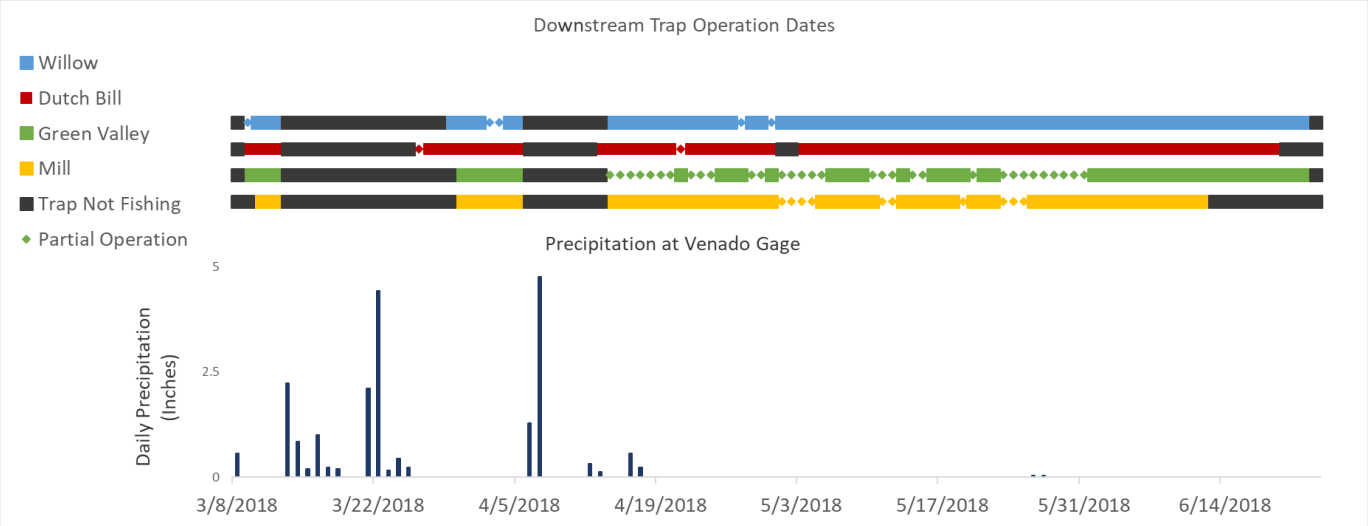


Figure 6. Trap operation dates in relation to precipitation at Venado rain gage in upper Mill Creek watershed. Daily rain totals from raw gage data posted on NOAA's California Nevada River Forecast Center website (http://www.cnrfc.noaa.gov/formPrecipMap.php).

Trap Counts

Coho salmon smolt counts from downstream migrant traps on all four study streams in 2018 ranged from 1,271 in Mill Creek to 5,840 in Green Valley Creek, with 1,276 in Dutch Bill Creek and 3,486 in Willow Creek (Table 2). The percentage of coho smolts of natural-origin ranged from 3% in Mill Creek to 19% in Willow Creek (Table 2).

When compared to previous years, coho salmon smolt counts were high in Willow Creek, average in Green Valley Creek and low in Dutch Bill and Mill Creeks (Table 3). The number of coho smolts captured in the Green Valley Creek trap was higher than in 2016 and 2017, but the trap was not operated from 2012 through 2014 and the trap location changed to its 2018 location in 2017, so it is not possible to accurately evaluate 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 2018 (Table 3). The number of steelhead smolts captured in the traps in 2018 was low, ranging from one to 22, with the greatest number on Green Valley and Mill creeks (Table 3). Chinook salmon smolts were only observed on Dutch Bill and Mill creeks (eight and one fish, respectively) (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 were captured in Willow Creek relative to other streams, with sculpin (653), three-spined stickleback (157), and Sacramento pikeminnow (99) being the most abundant non-salmonids (Table 4). In Dutch Bill Creek the three most abundant non-salmonids were sculpin (276), Sacramento pikeminnow (156), and Sacramento sucker (51), in Green Valley Creek they were three-spined stickleback (2,309), bluegill (659), and green sunfish (209), and in Mill Creek they were sculpin (542), California roach (146), and Sacramento pikeminnow (128) (Table 4). Thirteen freshwater shrimp were captured in Green Valley Creek this year, which is fewer than the three previous years; however, because of a new trap location (as of 2017), these numbers are not

directly comparable with 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 2018 downstream migrant season.

Stream	Hatchery	Natural	Unknown Origin	Total	Percent Natural
Willow Creek	2,821	663	2	3,486	19.0
Dutch Bill Creek	1,220	40	16	1,276	3.2
Green Valley Creek	5,302	529	9	5,840	9.1
Mill Creek	1,231	39	1	1,271	3.1

Table 3. Total number of coho salmon, steelhead, and Chinook salmon captured in UC downstream migrant traps, years 2005-2018. 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
Willow Creek	Coho Salmon	Smolt	NA	NA	NA	NA	NA	NA	NA	864	3,405	916	707	2,028	1,729	3,486
		YOY	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0	0	27
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0	0	0
		Parr/YOY	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603	77	111
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8	5	3
Dutch Bill Creek	Chinook Salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15	2	8
	Coho Salmon	Smolt	NA	NA	NA	NA	NA	185	2,908	1,987	823	1,939	201	2,681	3,678	1,276
		YOY	NA	NA	NA	NA	NA	0	5	0	2	0	0	18	2	3
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0	0	0
		Parr/YOY	NA	NA	NA	NA	NA	58	31	21	79	1,138	13	74	524	22
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8	6	1
Green Valley Creek	Chinook Salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	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
		YOY	0	NA	0	0	0	0	1	NA	NA	NA	2	0	2	3
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1	1	1
		Parr/YOY	1,723	NA	36	497	1	5	3	NA	NA	NA	38	356	11	15
		Smolt	49	NA	70	29	43	0	1	NA	NA	NA	3	3	12	17
Mill Creek	Chinook Salmon	Smolt	70	128	2	31	1	1	0	11	0	22	0	0	1	1
	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
		YOY	24	314	58	43	0	4	329	515	530	0	10	10	30	63
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	2	0	2	0
		Parr/YOY	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941	898	75
		Smolt	116	49	266	176	118	190	97	41	32	13	17	15	32	22

Table 4. Annual downstream migrant trap counts for common non-salmonid species, years 2005-2018. 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
WILLOW CREEK															
	Bluegill	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0
	Bullfrog	NA	NA	NA	NA	NA	NA	NA	0	1	0	0	0	0	0
	Fathead Minnow	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0
Non-native	Green Sunfish	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	1	0
Native	California Roach	NA	NA	NA	NA	NA	NA	NA	0	1	1	7	0	1	0
	Freshwater Shrimp	NA	NA	NA	NA	NA	NA	NA	0	0	0	1	0	0	0
	Sacramento Pikeminnow	NA	NA	NA	NA	NA	NA	NA	0	219	0	198	8	36	99
	Sacramento Sucker	NA	NA	NA	NA	NA	NA	NA	1	24	1	46	2	9	4
	Sculpin Sp	NA	NA	NA	NA	NA	NA	NA	339	4,206	680	2,462	548	2,898	653
	Three-spined Stickleback	NA	NA	NA	NA	NA	NA	NA	383	268	296	193	71	496	157
	Western Brook Lamprey	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0
DUTCH BILL CREEK															
	Bluegill	NA	NA	NA	NA	NA	0	0	0	0	2	0	4	19	1
	Bullfrog	NA	NA	NA	NA	NA	0	1	0	0	0	0	0	0	0
	Fathead Minnow	NA	NA	NA	NA	NA	0	0	0	0	0	2	98	2	0
Non-native	Green Sunfish	NA	NA	NA	NA	NA	0	1	0	0	5	20	8	21	3
Native	California Roach	NA	NA	NA	NA	NA	130	129	59	725	3	252	94	28	14
	Freshwater Shrimp	NA	NA	NA	NA	NA	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
	Sacramento Sucker	NA	NA	NA	NA	NA	8	178	1	307	4	25	106	265	51
	Sculpin Sp	NA	NA	NA	NA	NA	8	393	437	1,204	136	974	440	323	276
	Three-spined Stickleback	NA	NA	NA	NA	NA	9	7	56	517	2	5	46	4	2
	Western Brook Lamprey	NA	NA	NA	NA	NA	0	0	1	0	0	1	1	1	18
GREEN VALLEY CREEK															
	Bluegill	627	NA	68	21	59	155	1	NA	NA	NA	3	137	472	659
	Bullfrog	10	NA	42	7	5	57	1	NA	NA	NA	4	11	171	37
	Fathead Minnow	15	NA	14	0	22	89	54	NA	NA	NA	96	59	65	32
Non-native	Green Sunfish	40	NA	4	0	31	12	0	NA	NA	NA	25	32	133	209
Native	California Roach	211	NA	497	498	298	776	53	NA	NA	NA	314	54	51	48
	Freshwater Shrimp	8	NA	0	1	9	36	4	NA	NA	NA	317	33	26	13
	Sacramento Pikeminnow	62	NA	104	95	93	17	32	NA	NA	NA	70	7	14	6
	Sacramento Sucker	53	NA	79	178	90	3	3	NA	NA	NA	64	25	36	24
	Sculpin Sp	371	NA	474	370	602	420	24	NA	NA	NA	192	62	365	145
	Three-spined Stickleback	1,699	NA	253	1,497	409	5,606	56	NA	NA	NA	373	167	11,931	2,309
	Western Brook Lamprey	5	NA	69	44	71	105	0	NA	NA	NA	109	160	148	48
MILL CREEK															
	Bluegill	54	11	1	2	7	66	120	127	3	29	4	56	71	72
	Bullfrog	666	20	27	52	56	462	84	300	65	41	11	12	74	73
	Fathead Minnow	22	13	13	6	109	150	25	4	4	0	14	103	68	128
Non-native	Green Sunfish	35	5	1	0	12	6	5	1	3	5	6	22	16	12
Native	California Roach	110	65	84	60	341	198	116	151	363	20	258	114	453	146
	Freshwater Shrimp	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
	Sacramento Sucker	100	38	38	89	47	99	81	33	36	0	68	3	71	6
	Sculpin Sp	895	4,066	414	704	431	372	398	669	966	60	105	675	719	542
	Three-spined Stickleback	0	0	0	0	0	1	7	17	1	1	3	2	6	5
	Western Brook Lamprey	3	3	9	9	11	8	0	0	0	0	0	1	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

The percentage of natural-origin coho salmon smolts captured on Willow Creek in 2018 (19%) was average compared to the past six years but the number of natural-origin smolts (663) was the highest recorded since trapping started (Table 5). The percentage and number of natural origin coho smolts observed at the Green Valley Creek trap was also average; however, the trap was not operated for three of the past seven 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 lower than average 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 (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

Smolt Abundance

Smolt abundance estimates indicate that thousands of smolts emigrated from each of the four Broodstock Program monitoring tributaries during the spring of 2018 (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 Creek; however, this was to be expected as the smolt release took place below the downstream trap and these fish were therefore not included in the abundance estimate.

When compared with previous years' estimates, Willow Creek had the highest abundance observed since monitoring started, and the Green Valley Creek estimate was the second highest observed over all years of trap operation (Figure 7). Mill and Dutch Bill creek abundance estimates were average compared to previous years (Figure 6). The confidence interval surrounding the estimate in Mill Creek was much larger than in previous years which can likely be attributed to the fact that the trap was opened up during the smolt releases which greatly reduced capture efficiency during those periods.

Table 6. Number of cohort 2017 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 2018. Abundance estimates include both marked and unmarked smolts.

Tributary	Number Released					Estimated Smolt Abundance (95% CI)
	Spring	Fall	Smolt	Total	Total Released Upstream of Trap	
Willow Creek	0	10,075	8,876 [1]	18,951	10,075	4,783 (519)
Dutch Bill Creek	995	7,077	4,044 [2]	12,116	10,905	5,240 (339)
Green Valley Creek	454	8,069	14,066	22,589	22,589	20,565 (1,068)
Mill Creek	1,006	10,063	5,312	16,381	16,381	13,184 (4,934)

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

[2] *Following tank imprinting for 20 days, the last group of 1,211 smolts were released into the Russian River at the Monte Rio Boat launch on 5/23/18 and had no possibility of being detected at the trapsite.*

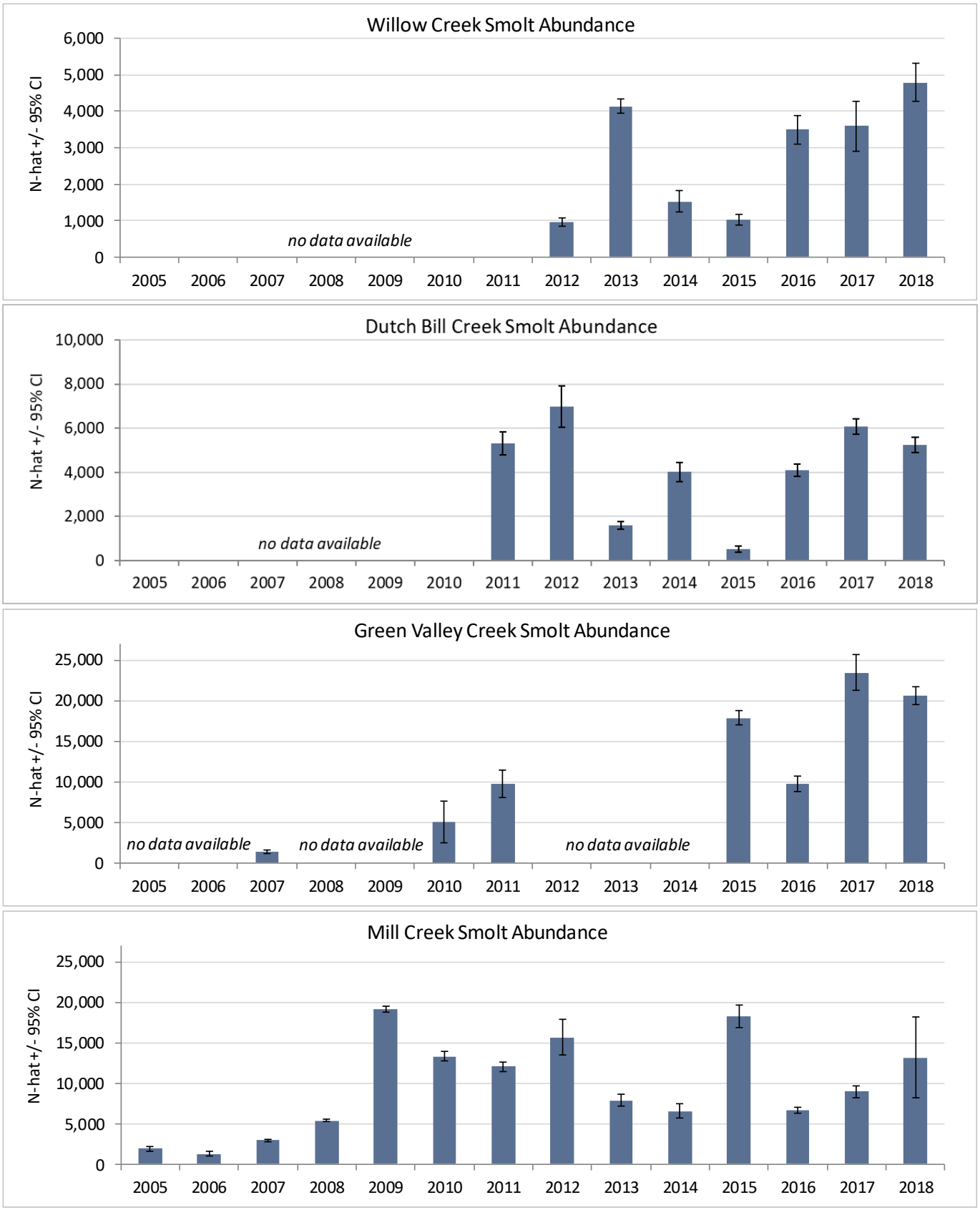


Figure 7. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2018.

Probability of Survival and Early Winter Emigration

The estimated probability of survival of spring-released juvenile coho salmon from the time of release in mid-June 2017 through 6/30/18 (approximately one year later) ranged from 0.01 on Green Valley Creek to 0.15 on Mill Creek (Table 7). In 2017, the Broodstock Program released only 2,455 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 survival in the entire stream systems.

The estimated probability of survival of fall-release juvenile coho from the time of release in late November/early December 2017 through 6/30/18 was generally higher than for the spring release, ranging from 0.14 on Willow Creek to 0.52 on Green Valley Creek (Table 7). When comparing fall-release survival estimates with previous years' estimates, survival during the winter of 2017/18 was low on Willow, average for Dutch Bill and Mill 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 smolt-release group fish ranged from 0.56 to 0.96 (Table 8). Among streams, survival estimates for the smolt release groups were generally higher in Green Valley and Mill Creeks and lowest in Willow Creek (Table 8). In Green Valley and Mill creeks, survival estimates for releases that occurred in May were lower than releases that occurred earlier in the season (Table 8).

The estimated probability of spring-release juvenile coho salmon emigrating from their respective release streams prior to March 1 ranged from 0.00 in Green Valley Creek to 0.02 in Dutch Bill Creek (Table 9). For the fall release group, estimates of winter emigration ranged from 0.00 in Willow and Green Valley creek to 0.04 in Mill 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 0.18, but past the antennas at the mouth was zero, suggesting that fish that moved downstream below the trap site prior to 3/1/18 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 spring and fall release groups were low, ranging from zero to 0.04 among all streams and both releases (Table 9, Figure 9). These low rates were consistent with previous years' observations in Willow and Green Valley creeks, but low for Dutch Bill and Mill creeks, where we have observed more variation among years (Table 9, Figure 9).

Table 7. Estimated probability of juvenile coho salmon survival from the date of release in 2017 through 6/30/18 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	11/22/2017	220	0.14 (0.13-0.16)[1]
Dutch Bill Creek	6/16/2017	379	0.14 (0.12-0.17)	12/7/2017	205	0.23 (0.21-0.25)
Green Valley Creek	6/16/2017	379	0.01 (0.00-1.00)[2]	12/6/2017	206	0.52 (0.50-0.55)
Mill Creek	6/16/2017	379	0.15 (0.13-0.17)	11/16/2017	226	0.29 (0.27-0.31)

[1] *For comparison with other streams, probability of survival to the mouth of Willow Creek was included in the table; probability of survival to 3rd Bridge was 0.36 (0.33-0.38).*

[2] *Only seven Green Valley spring release fish were detected leaving as smolts so CIs could not be calculated.*

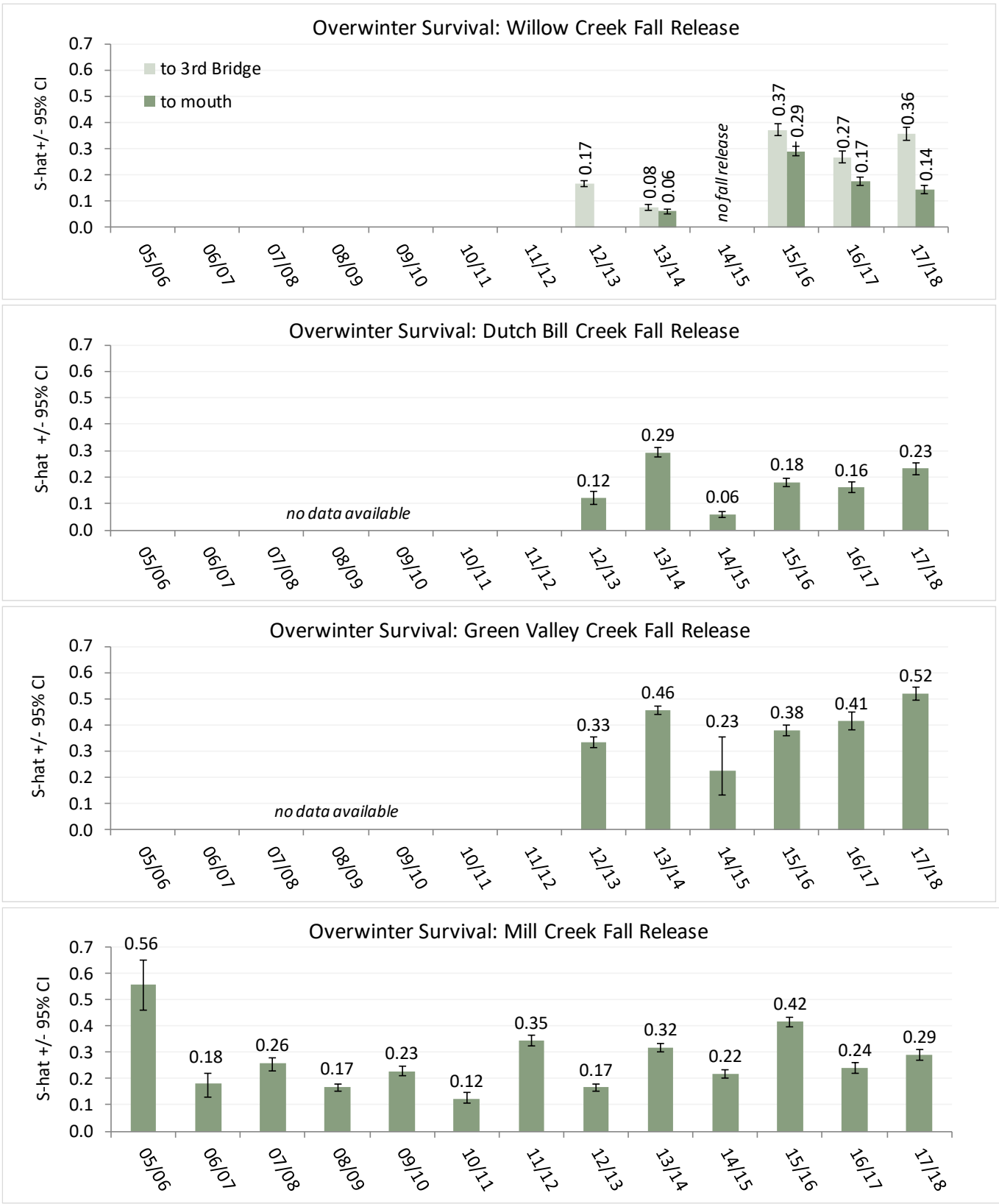


Figure 8. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) 2018 in Willow, Dutch Bill, Green Valley, and Mill creeks.

Table 8. Estimated probability of juvenile coho salmon survival from the date of release through 6/30/18 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	smolt	stream	Third Bridge	3.48	4/4/2018	0	87	0.56 (0.53-0.58)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	4/11/2018	14	80	0.80 (0.76-0.84)
Dutch Bill Creek	smolt	tank	Westminster Woods	6.52	4/30/2018	14	61	0.87 (0.84-0.90)
Dutch Bill Creek	smolt	tank	Monte Rio boat launch	16.5	5/23/2018	20	38	NA
Green Valley Creek	smolt	stream	Lower Green Valley Rd Crossing	9.32	3/28/2018	0	94	0.91 (0.90-0.92)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/11/2018	0	80	0.91 (0.88-0.94)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	4/30/2018	0	61	0.92 (0.89-0.94)
Green Valley Creek	smolt	stream	Upper Green Valley Rd crossing	13.82	5/22/2018	0	39	0.74 (0.68-0.79)
Mill Creek	smolt	stream	Palmer confluence	9.98	4/11/2018	0	80	0.94 (0.91-0.96)
Mill Creek	smolt	stream	Palmer confluence	9.98	4/30/2018	0	61	0.96 (0.94-0.98)
Mill Creek	smolt	stream	Palmer confluence	9.98	5/22/2018	0	39	0.86 (0.81-0.90)

Table 9. Estimated probability of juvenile coho salmon emigrating from each tributary prior to 3/1/18. NA indicates that no fish were released.

Tributary	Probability of Emigration Prior to 3/1 (95% CI)	
	Spring Release	Fall Release
Willow Creek	NA	0.00 (0.00-0.01)[1]
Dutch Bill Creek	0.02 (0.01-0.03)	0.02 (0.01-0.02)
Green Valley Creek	0.00 (0.00-1.00)[2]	0.00 (0.00-0.00)
Mill Creek	0.01 (0.01-0.02)	0.04 (0.03-0.05)

[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 3/1/18 was 0.18 (0.17-0.20).*

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

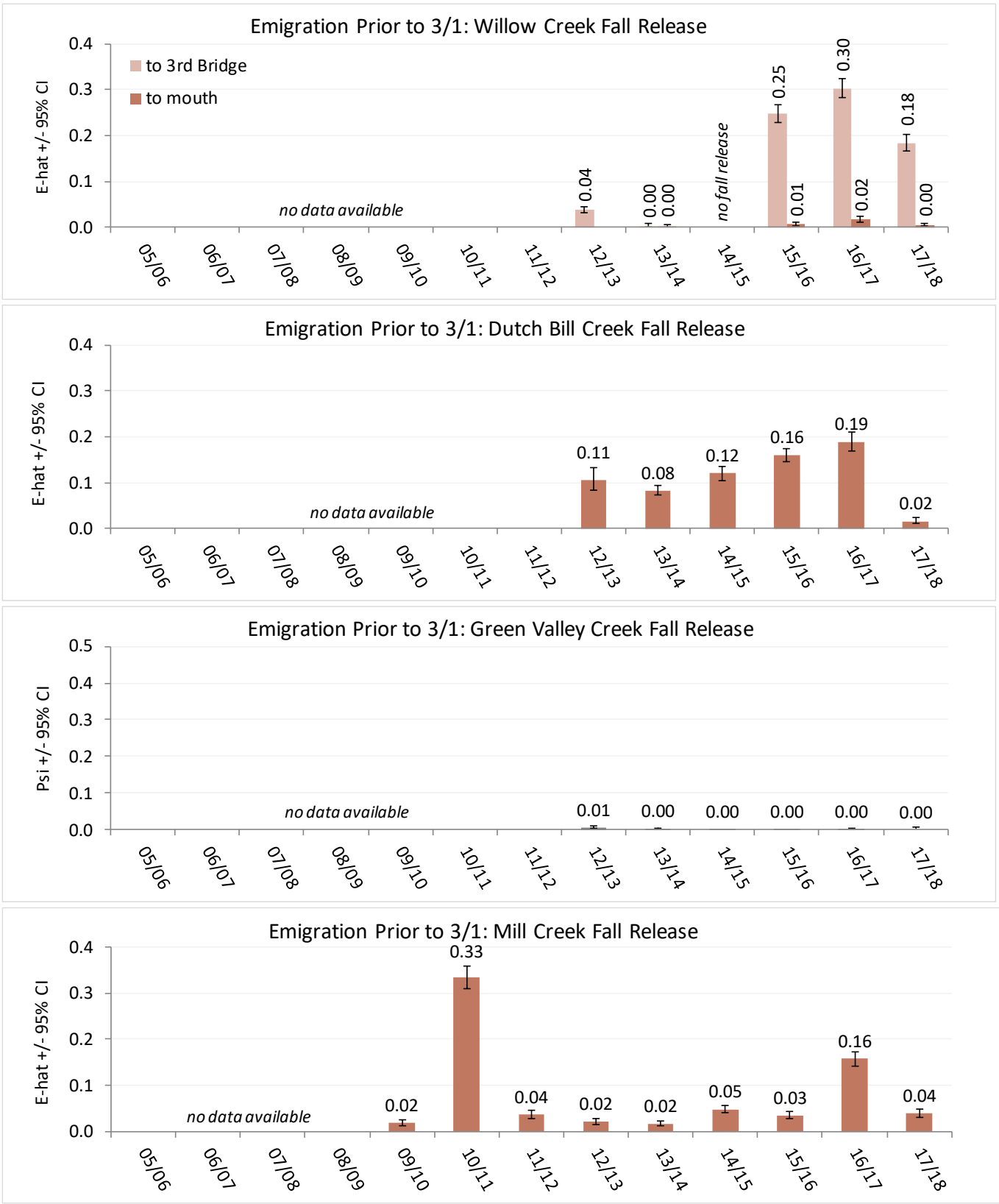


Figure 9. Probability of emigration (E-hat) past antenna sites prior to 3/1. Willow, Dutch Bill, Green Valley, and Mill creeks.

Migration Timing

Weekly totals of outmigrating smolts were plotted by release group and antenna site within the watershed for the period of October 29, 2017 to June 30, 2018 and compared with stream depth (stage) data from each creek (Figure 10 - Figure 24; 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 (Figure 11, Figure 14 - Figure 15, Figure 18 - Figure 19, Figure 22 - Figure 23). In general, winter movement coincided with storms in November and January. 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.

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. Similarly, in Green Valley Creek, we observed fish moving downstream past the upstream antenna array (river km 13.40) during the winter season, but only minimally past the lower antennas (river km sites 9.98 and 6.13), suggesting that a portion of the spring and fall release groups overwintered lower in the watershed 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. In both Dutch Bill and Mill creeks, there were many detections of spring and fall release fish at the upper array during the winter season, with some of these fish leaving the stream altogether, but the majority of the fish were not detected on the lower arrays until after March 1.

Smolt Release Groups

Movement patterns for the smolt release groups also varied by stream (Figure 12, Figure 16, Figure 20, Figure 24). In Willow Creek, about one third of the smolt release group was detected on the lower antenna array within the first week of release, with the remaining fish staying in Willow Creek for up to a month and a half (Figure 12). Interestingly, there were detections of smolt release fish on the upper antennas, which are located approximately 200 m upstream of the smolt release point. In Dutch Bill and Mill creeks, the smolt release fish left the streams immediately (Figure 16, Figure 20). In Green Valley Creek, the first smolt release group (released at river km 9.32, downstream of the upper arrays) was detected almost immediately at the lowest antenna array. Subsequent releases (at river km 13.82) were detected almost immediately on the upstream antenna arrays, but appeared to remain in the stream for a longer period of time, as evidenced by the later detections on the lower array (Figure 24).

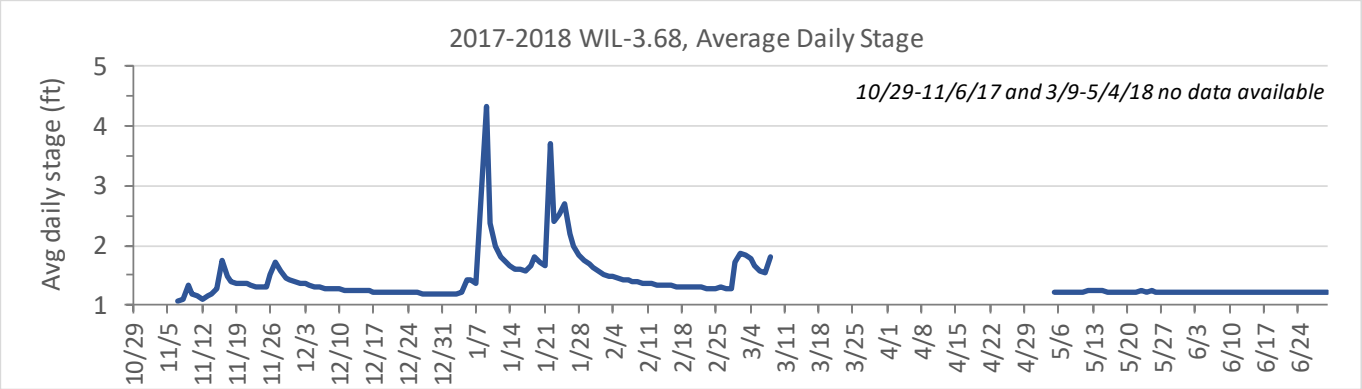


Figure 10. Average daily stage height at the Willow Creek smolt trap site (river km 3.68) between October 29, 2017 and June 30, 2018. Data is missing for two periods due to a technical failure.

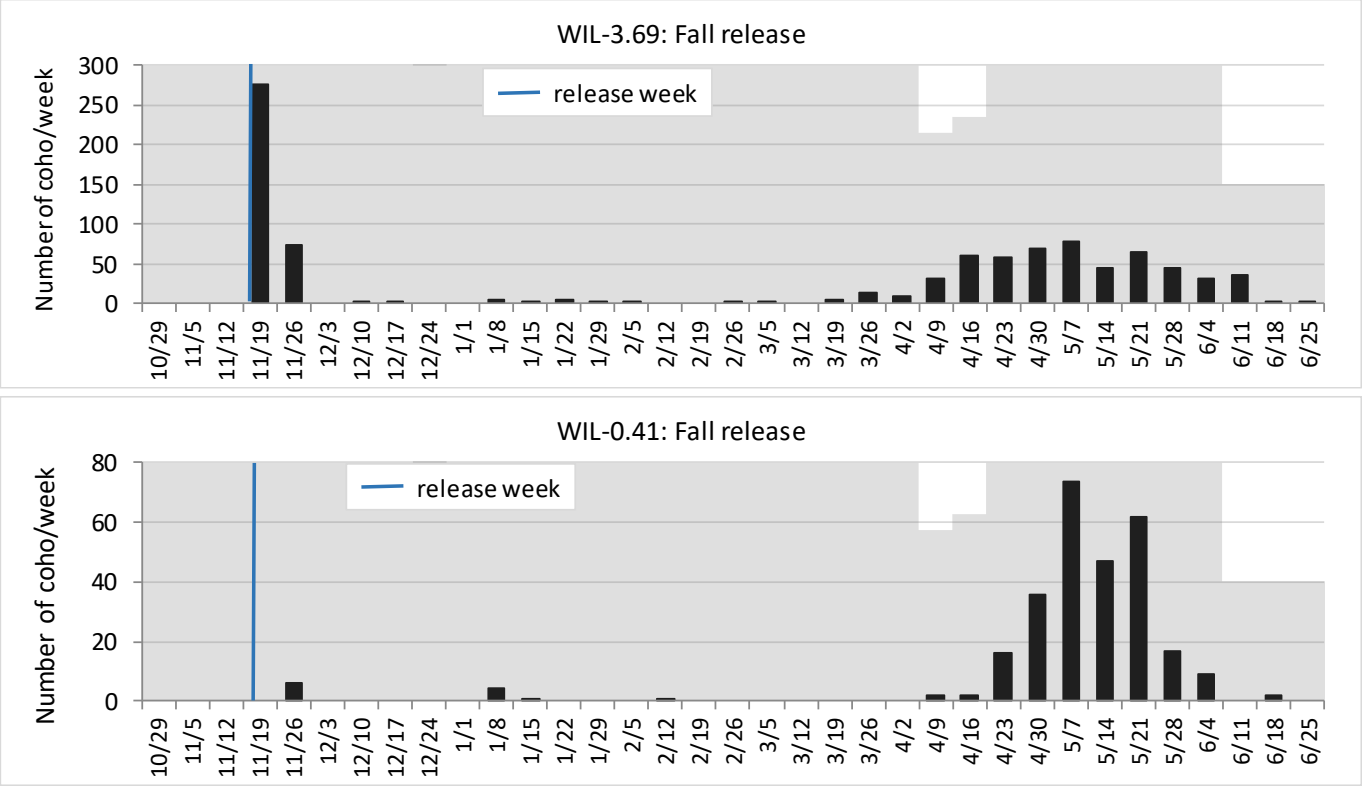


Figure 11. Number of fall-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 4.95 to 7.45.

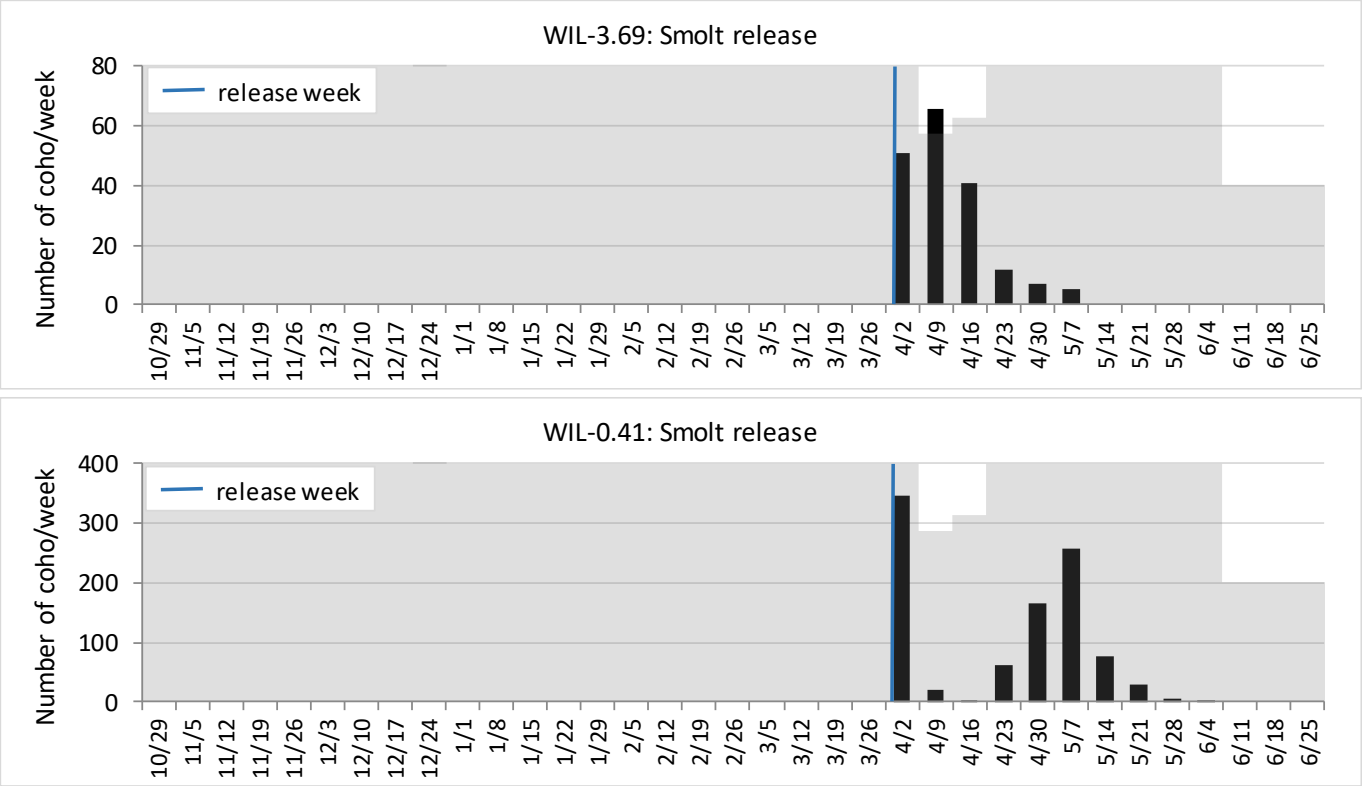


Figure 12. Number of smolt-release coho salmon that moved past the Willow Creek smolt trap site (WIL-3.69) and the antenna site near the mouth of Willow Creek (WIL-0.41) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 3.48.

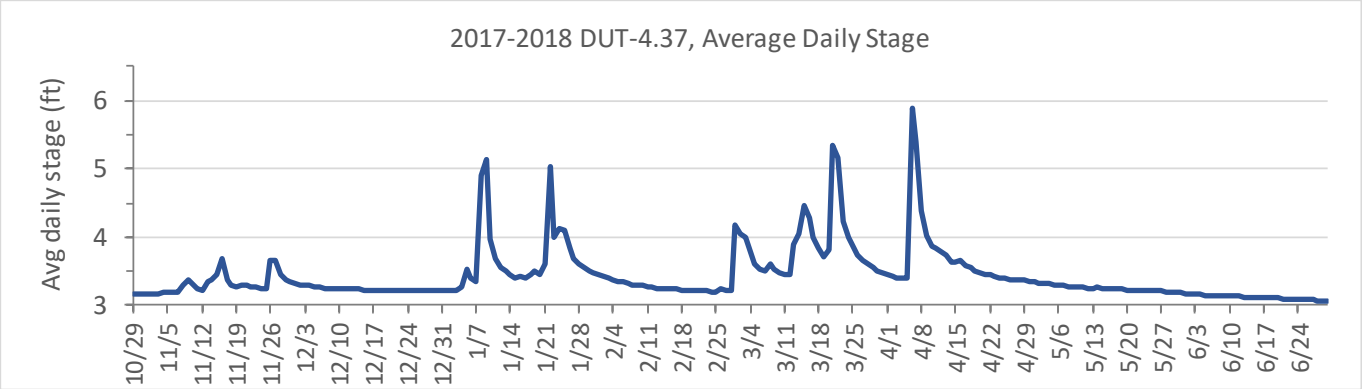


Figure 13. Average daily stage height at the Dutch Bill Creek river km 4.37 between October 29, 2017 and June 30, 2018.

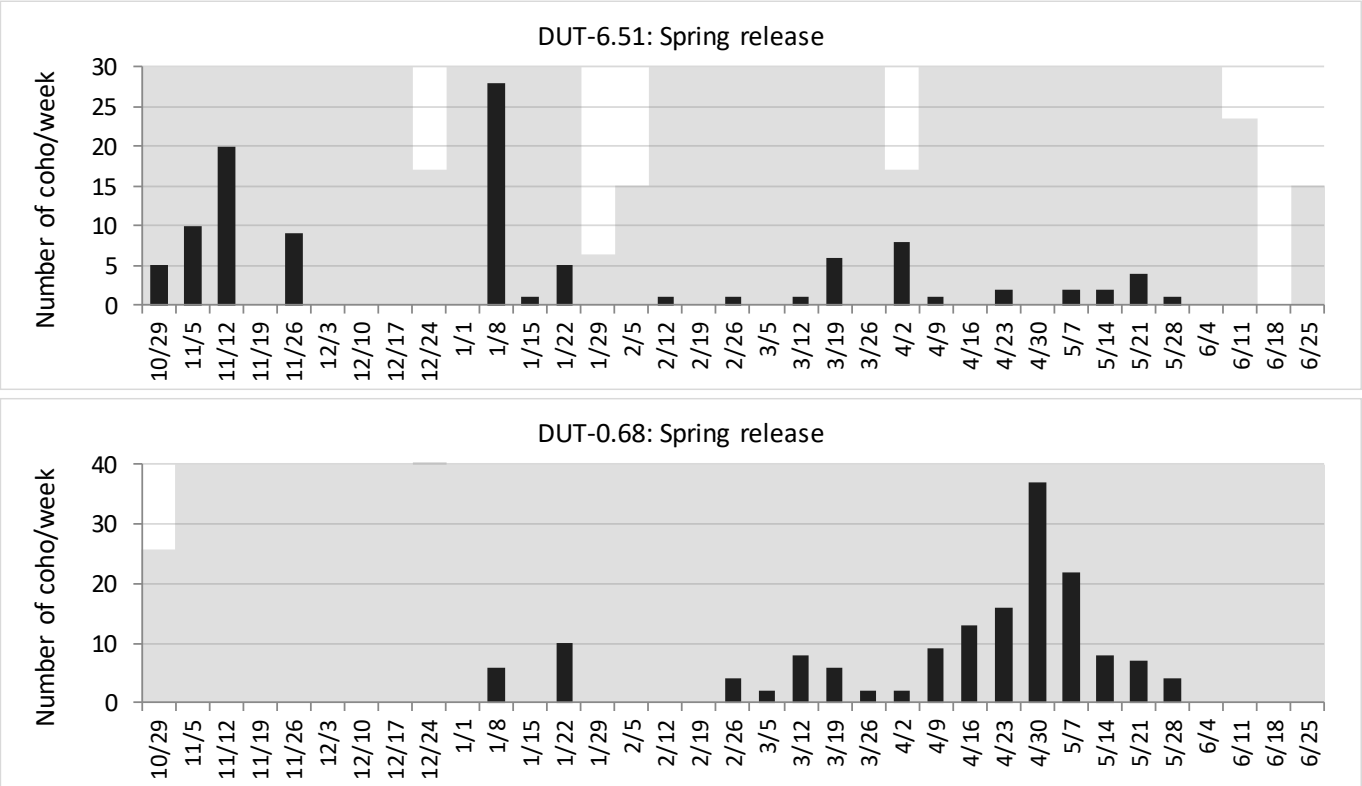
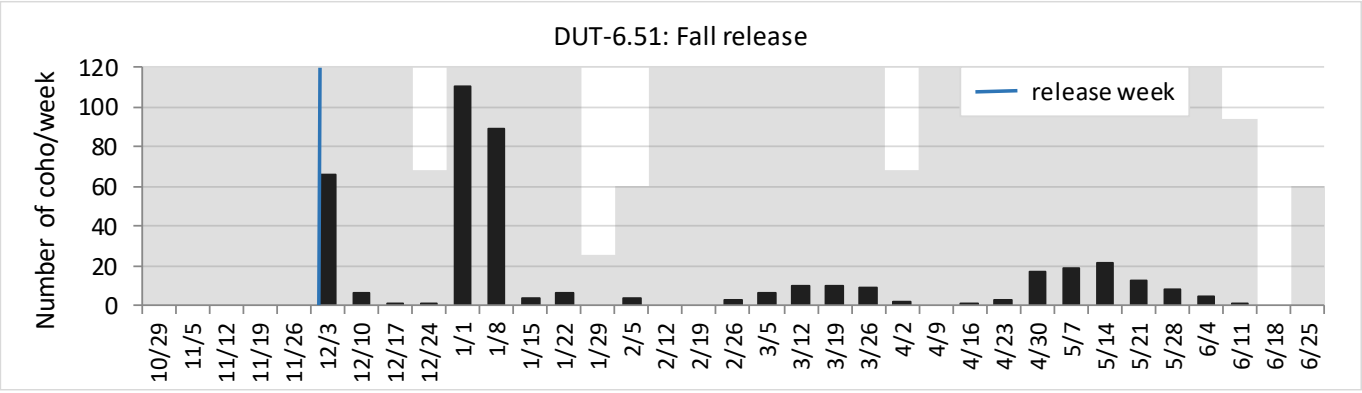


Figure 14. Number of spring-release coho salmon that moved past the Dutch Bill Creek smolt trap site (DUT-0.68) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 3.87 to 6.77.



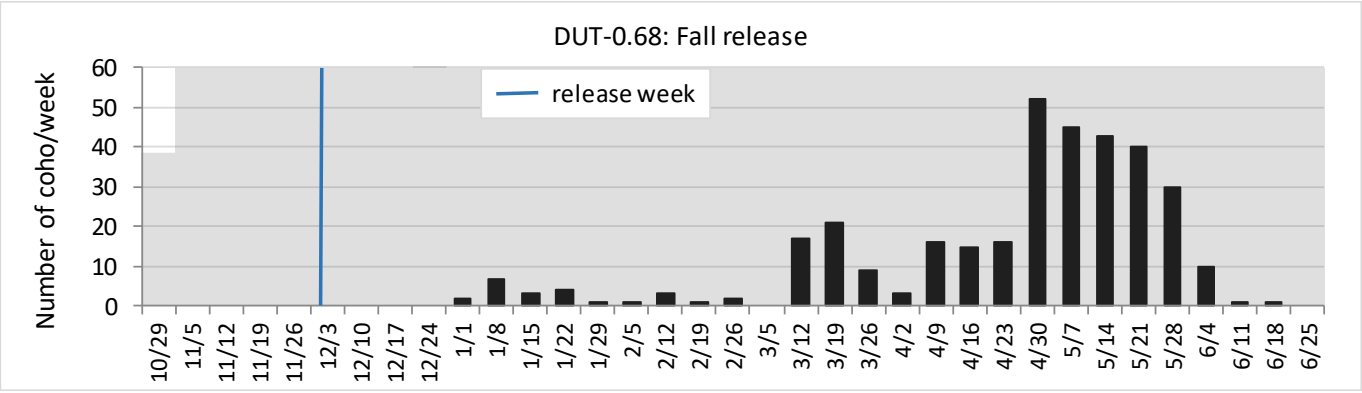


Figure 15. Number of fall-release coho salmon that moved past the Dutch Bill Creek smolt trap site (DUT-0.68) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 6.01 to 9.41.

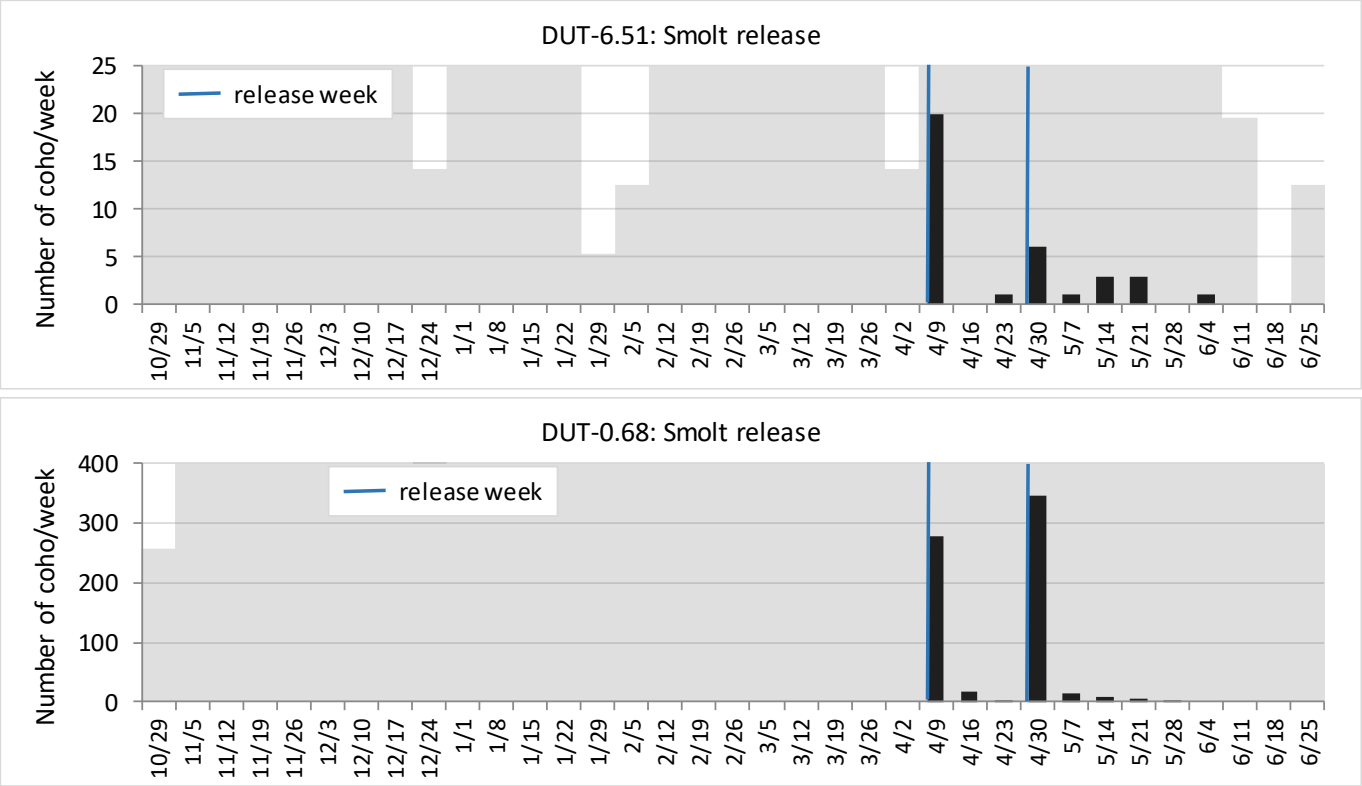


Figure 16. Number of smolt-release coho salmon that moved past the Dutch Bill Creek smolt trap site (DUT-0.68) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 6.52.

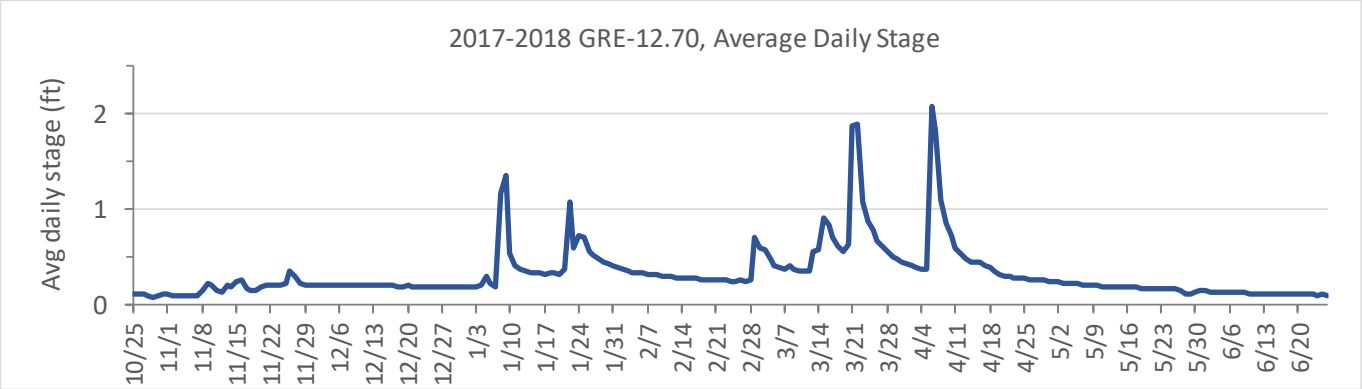


Figure 17. Average daily stage on Green Valley Creek (river km 12.70) between October 29, 2017 and June 30, 2018.

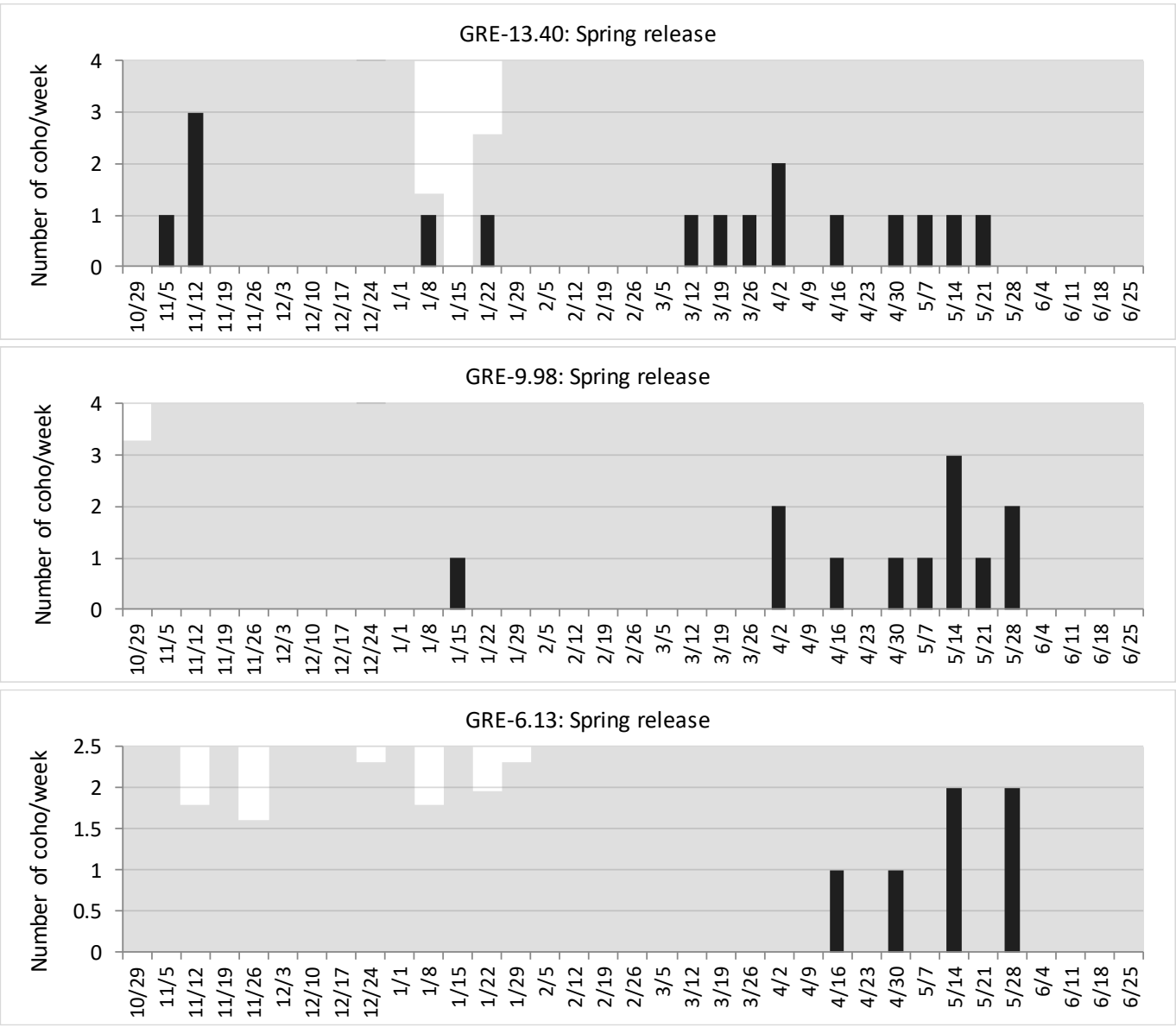


Figure 18. Number of spring-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 13.40 to 13.62.

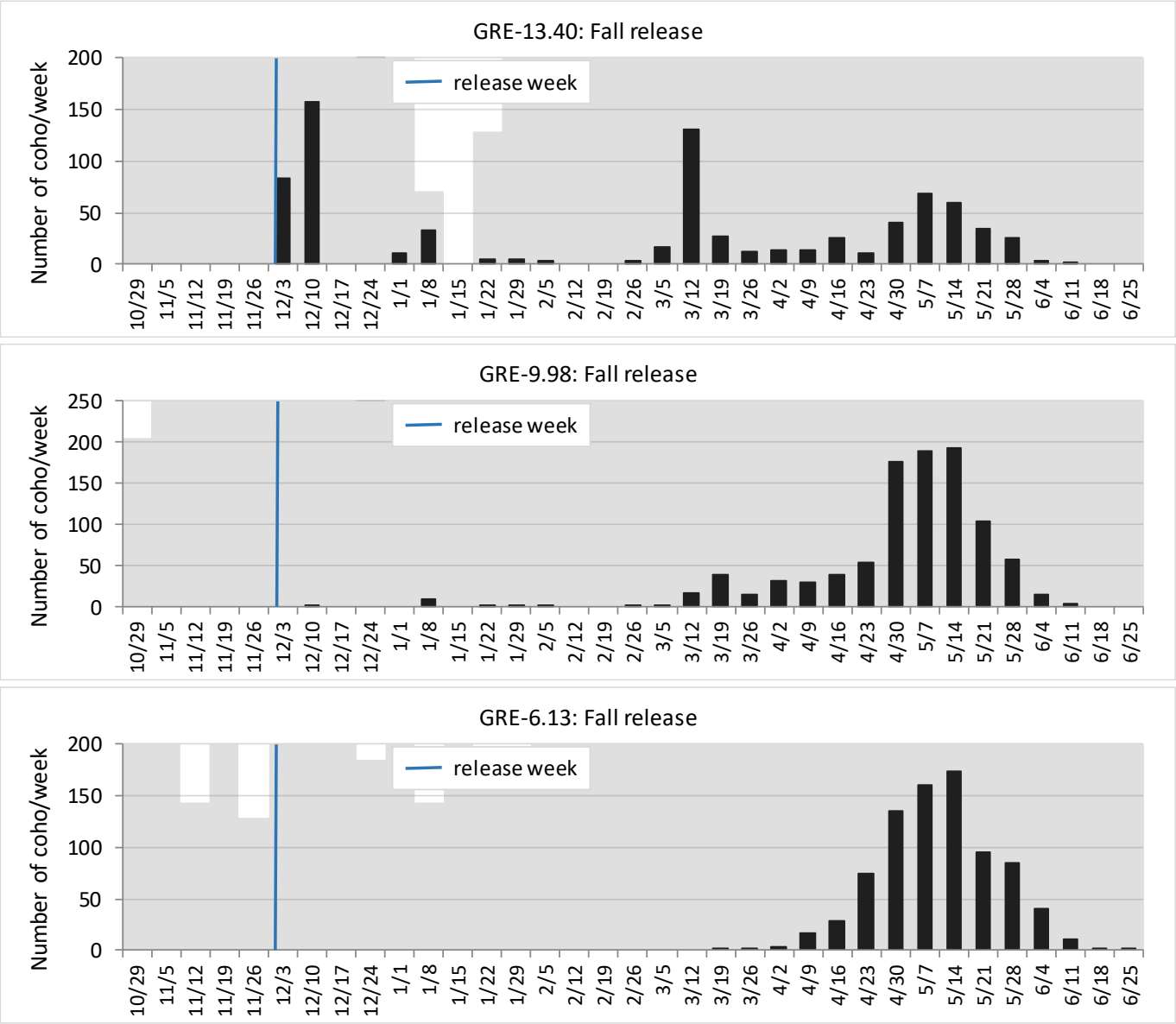


Figure 19. Number of fall-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 12.65 to 14.37.

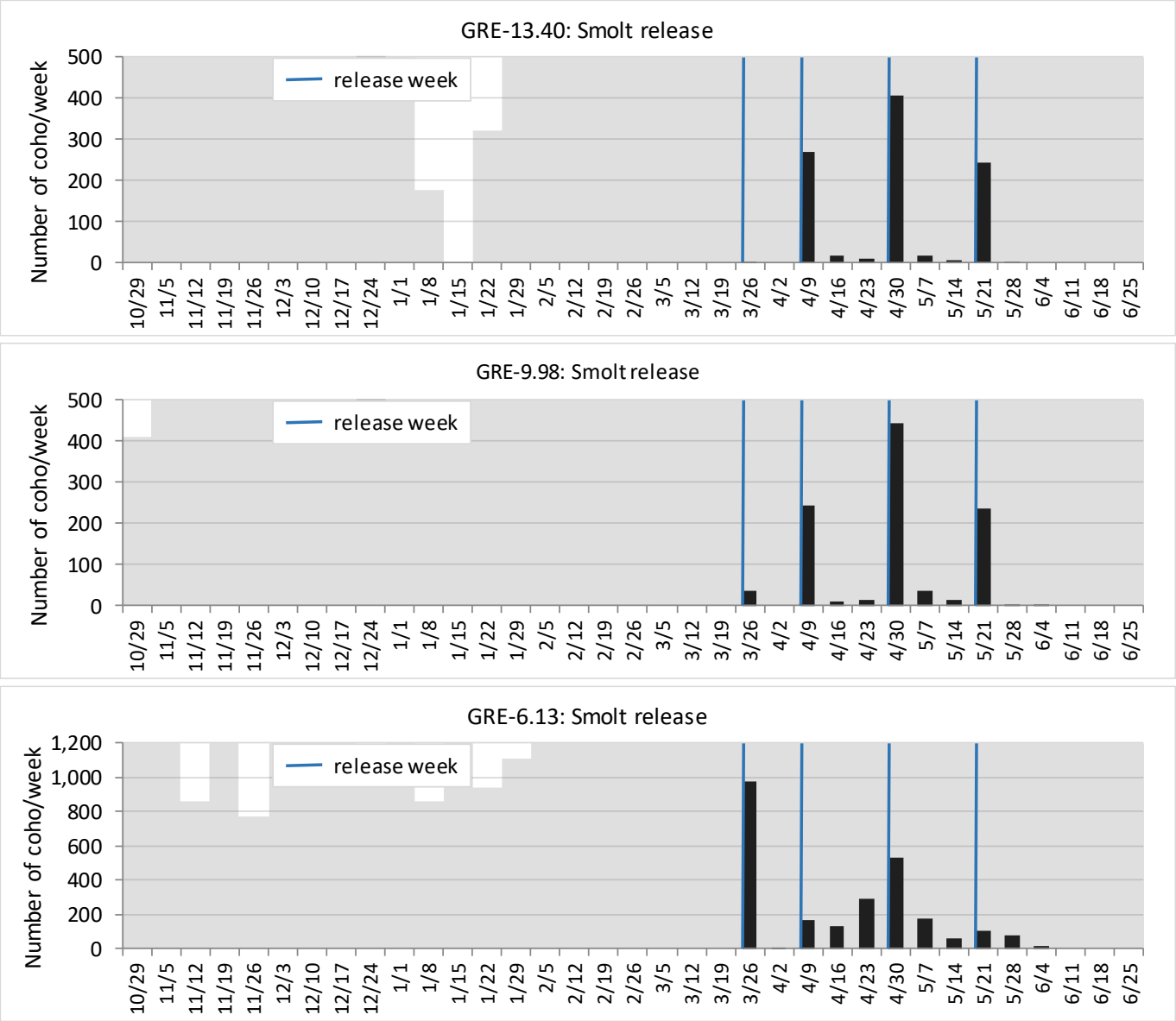


Figure 20. Number of smolt-release coho salmon that moved past the upper (GRE-13.40) and mid- (GRE-9.98) Green Valley Creek antenna sites and the smolt trap site (GRE-6.13) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 9.32 on 3/28/18 and at river km 13.82 on all subsequent releases.

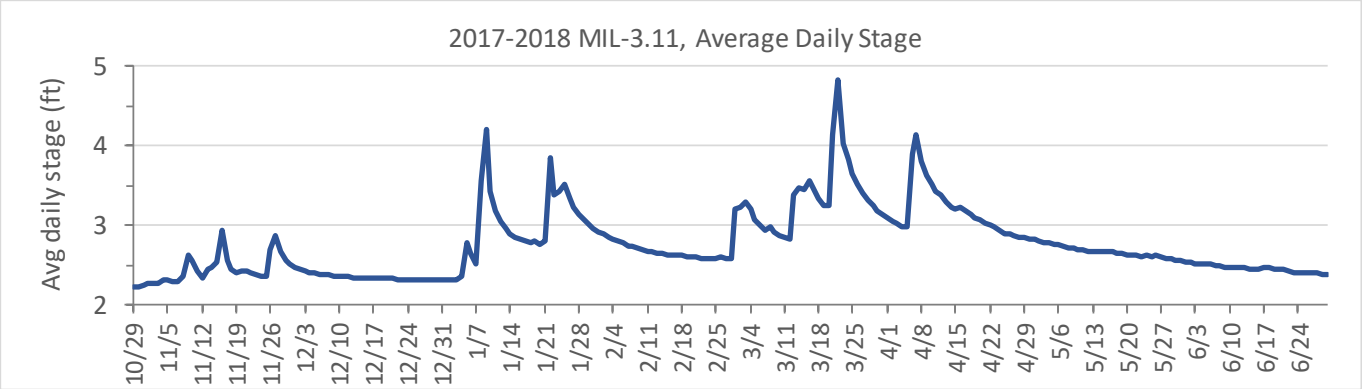


Figure 21. Average daily stage at the Mill Creek smolt trap site (river km 3.11) between October 29, 2017 and June 25, 2018.

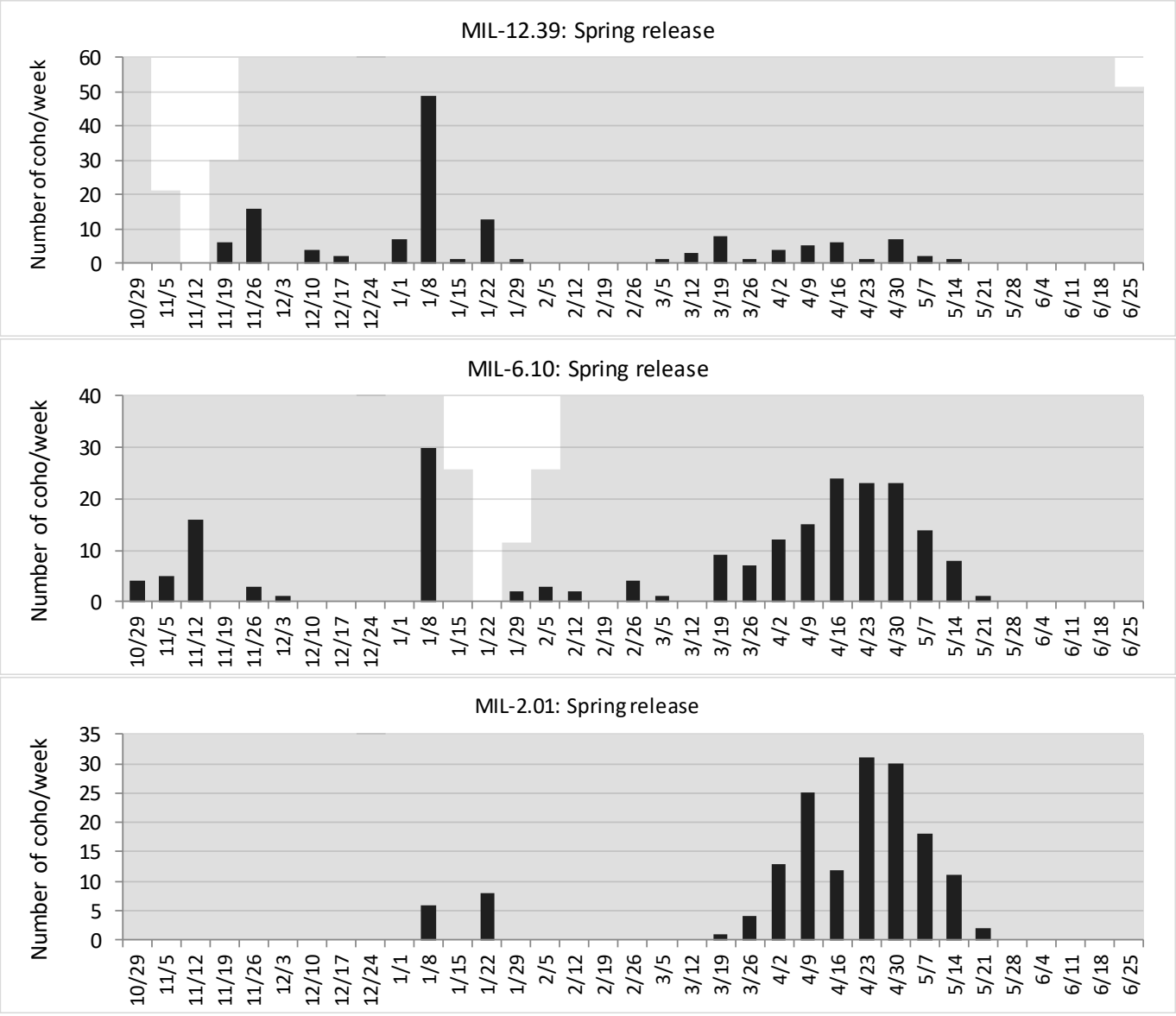


Figure 22. Number of spring-release coho smolts that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. 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.

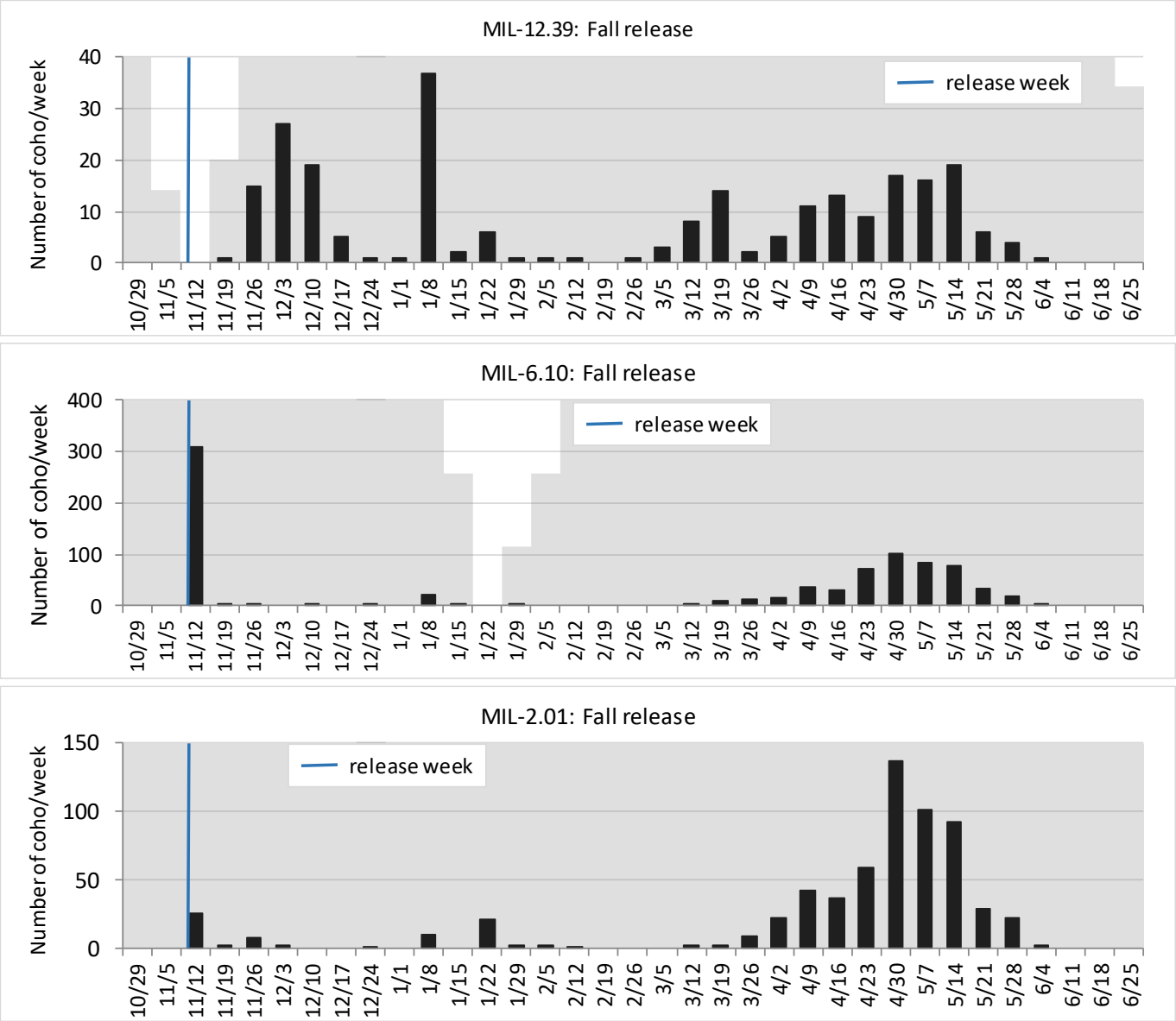


Figure 23. Number of fall-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released from river km 9.05 to 13.73.

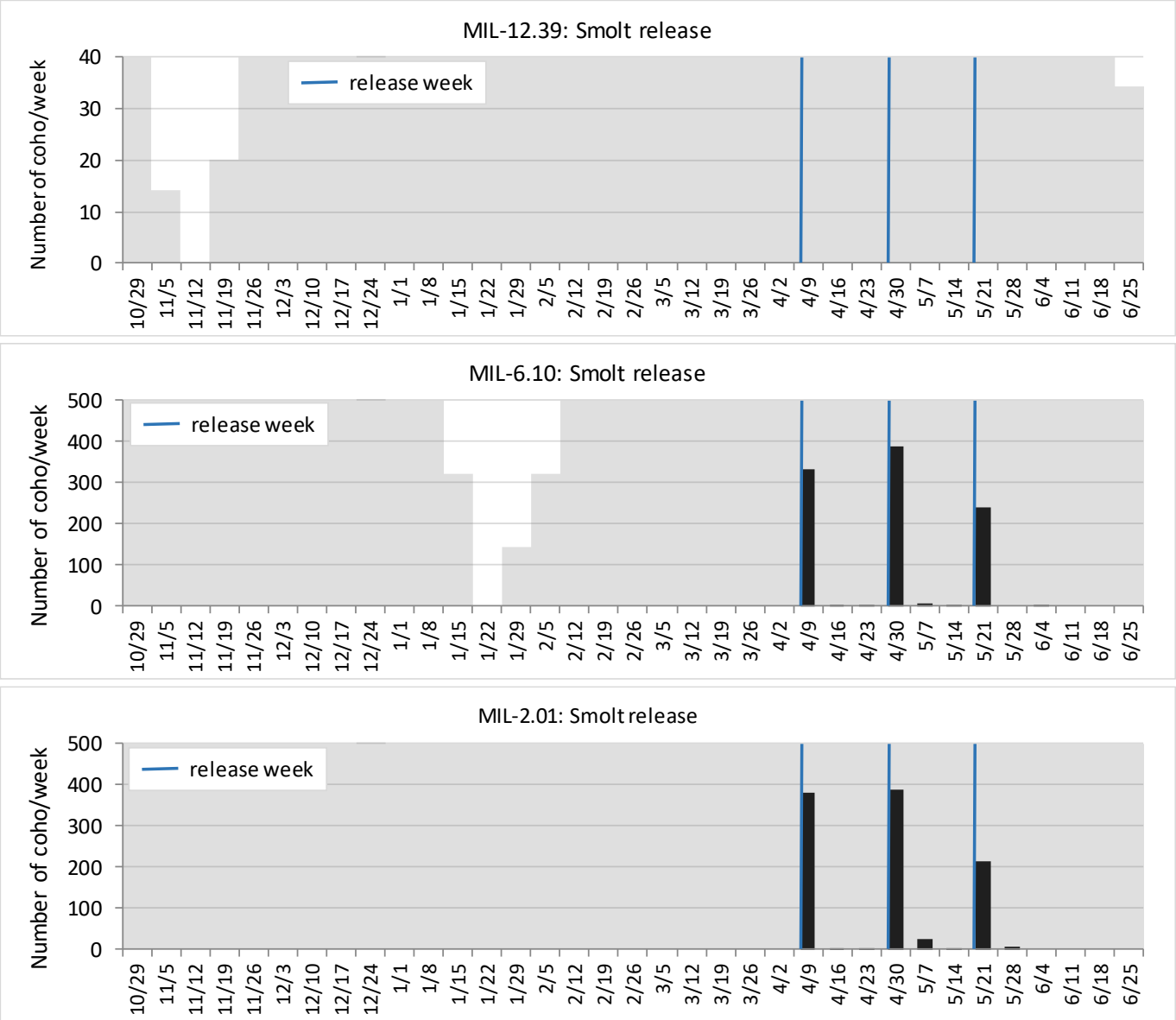


Figure 24. Number of smolt-release coho salmon that moved past the upper (MIL-12.39) and mid- (MIL-6.10) Mill Creek antenna sites and the smolt trap site (MIL-2.01) each week between October 29, 2017 and June 30, 2018. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation. Fish were released at river km 9.98.

Size

In all Broodstock Program monitoring streams, the average size *at release* increased progressively with the age of the fish (spring < fall < smolt), and within release groups only slight differences were observed among streams (Table 10). Release group average sizes for all 2017 cohort Broodstock Program release streams combined were 67.6 mm and 3.6 g (spring), 88.3 mm and 8.5 g (fall), and 114.4 mm and 17.6 g (smolt).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 104.1 mm and 12.2 g in Willow Creek to 119.1 mm and 18.1 g in Green Valley Creek (Table 11). Average fork length and weight of smolts captured in Dutch Bill Creek (113.9 mm and 15.4 g) and Mill Creek (113.4 mm and 16.3 g) were similar (Table 11).

There was generally a wide range in fork length distribution of recaptured hatchery fish within each release group on each stream (Figure 25). The spring release had similar size distributions across all streams, although Mill Creek fish were slightly smaller. The number of recaptures from the spring releases was low, with only two recaptures in Green Valley and six in Mill Creek (Figure 25). Fall release fish captured in Green Valley were larger than other streams but all streams had a similar distribution of fork lengths (Figure 25). Smolt release fish were similar in size across all streams, as would be expected given the short time between release and recapture (Figure 25, Table 12).

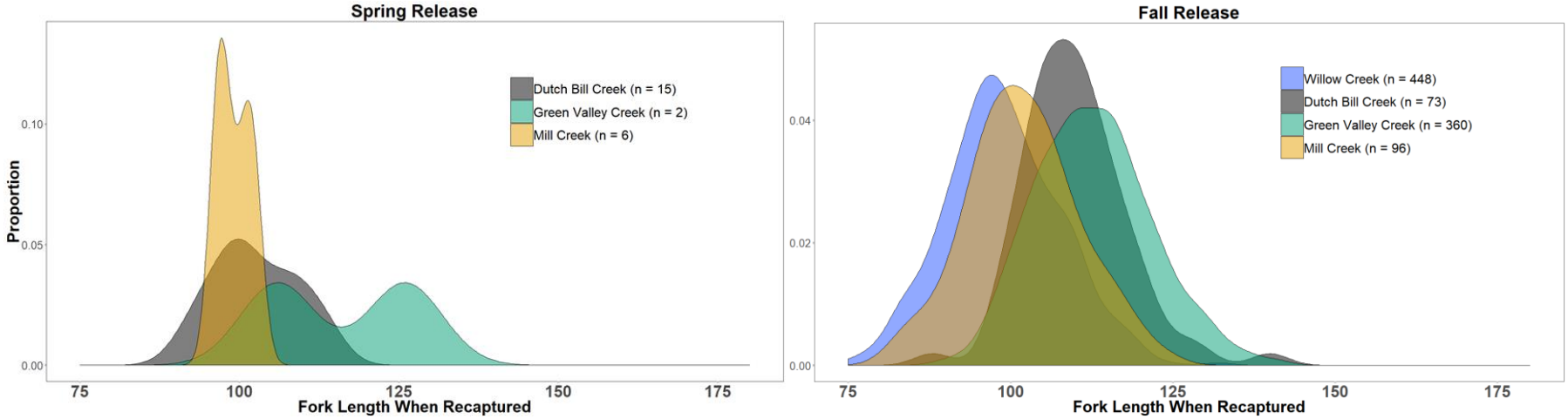
Size variation between natural and hatchery origin coho salmon smolts differed among streams but was generally minimal (Table 11). In Dutch Bill and Mill creeks, hatchery origin smolts were slightly larger than natural origin smolts and in Willow and Green Valley creeks natural origin smolts were slightly larger than hatchery smolts (Table 11). Green Valley Creek natural origin smolts were the largest among all groups, averaging 122.3 mm and 19.8 g (Table 11).

Table 10. Average fork length (mm) and weight (g) of cohort 2017 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	86.4 (±10)	7.9 (±2.9)	2,008
	Smolt	112.5 (±8.8)	17 (±4.1)	1,795
Dutch Bill Creek	Spring	67.3 (±3.5)	3.6 (±0.6)	995
	Fall	90.2 (±8.5)	9.2 (±2.7)	1,410
	Smolt	116.1 (±9.2)	18 (±4.2)	1,054
Green Valley Creek	Spring	67.6 (±3.4)	3.6 (±0.6)	454
	Fall	91.2 (±7.5)	9.3 (±2.4)	1,610
	Smolt	113.6 (±9.1)	17.3 (±4.1)	2,859
Mill Creek	Spring	67.8 (±3.2)	3.7 (±0.6)	1,006
	Fall	86.4 (±8.6)	8 (±2.4)	2,007
	Smolt	117.6 (±10.9)	18.8 (±5.3)	1,103

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 2018 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	103.5 (±11.4)	12.0 (±3.9)	2,391
Natural	106.4 (±10.5)	12.9 (±3.7)	647
All Smolts	104.1 (±11.3)	12.2 (±3.9)	3,038
Dutch Bill Creek			
Hatchery	114.1 (±9.1)	15.5 (±3.6)	609
Natural	110.7 (±14.2)	14.2 (±4.5)	37
All Smolts	113.9 (±9.4)	15.4 (±3.6)	646
Green Valley Creek			
Hatchery	118.5 (±10)	17.9 (±4.5)	3,156
Natural	122.3 (±11.9)	19.8 (±6.2)	528
All Smolts	119.1 (±10.3)	18.1 (±4.8)	3,684
Mill Creek			
Hatchery	113.5 (±14.1)	16.4 (±6.2)	904
Natural	110.8 (±17.6)	15.5 (±7.1)	38
All Smolts	113.4 (±14.3)	16.3 (±6.2)	942



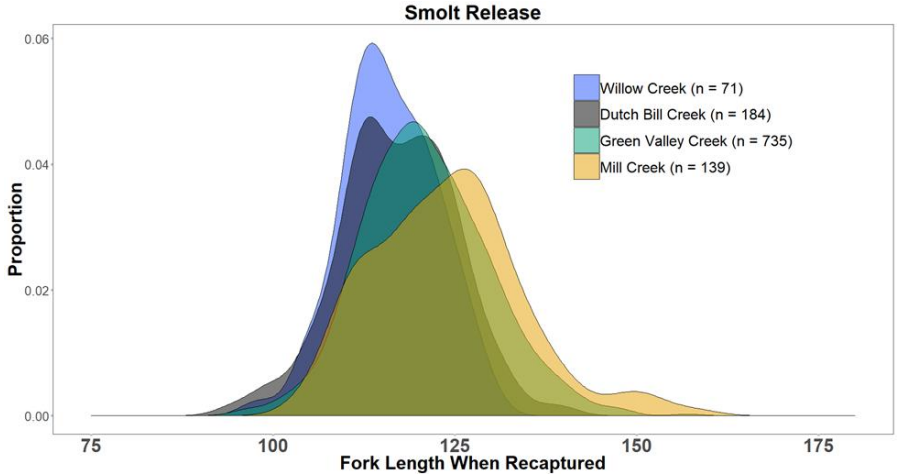


Figure 25. Length-frequency distribution of PIT-tagged coho salmon smolts captured in the spring of 2018 in downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks by release season.

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 26). 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 all creeks where a spring release took place (Table 12). In the fall release group, PIT-tagged smolts recaptured in Green Valley and Dutch Bill creeks grew more than those from Mill and Willow Creek in both total increase in size since release (Table 12) and average daily growth rate (Figure 25). Smolt release fish, which spent the least number of days in the stream environment, generally grew in length, particularly in Green Valley and Willow Creek, but increased very little or even decreased in weight (Table 12). Due to logistical considerations a subset of smolts was released earlier than usual (late March) in Green Valley and Willow creeks and these fish drove the unusually high smolt growth rates in these streams. In Green Valley Creek the smolt release was spread over four dates starting with March 28 and ending on May 22. The growth rate of these smolts steadily decreased from 0.28 mm/day for the late March release to 0.1 mm/day for the May release (Figure 28).

Growth rates for fall-release fish in 2018 were generally average relative to previous years (Figure 27). Growth rates were lower than 2017 across all streams with the largest reductions in Green Valley and Dutch Bill creeks (Figure 27). Mill and Willow Creek growth rates were similar to those of previous years (Figure 27).

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	12.9 (±7.6)	2.7 (±2.5)	448	185 (±16)
Smolt	7.5 (±4)	0.7 (±1.2)	71	36 (±8)
Dutch Bill Downstream Migrant Trap				
Spring	35.3 (±7.8)	7.9 (±2.3)	15	339 (±17)
Fall	18.7 (±7.1)	4.3 (±2.3)	73	168 (±14)
Smolt	2.4 (±3.8)	-0.6 (±1.6)	184	26 (±7)
Green Valley Downstream Migrant Trap				
Spring	44.5 (±13.4)	13.4 (±6.1)	2	362 (±9)
Fall	19.9 (±7.8)	5.6 (±3.5)	360	171 (±14)
Smolt	7.4 (±7.1)	1.7 (±3)	735	27 (±15)
Mill Downstream Migrant Trap				
Spring	32.3 (±3.9)	7.5 (±0.9)	6	339 (±11)
Fall	15.5 (±6.3)	3.7 (±2)	96	189 (±9)
Smolt	2.1 (±2.6)	-0.1 (±1.4)	139	15 (±8)

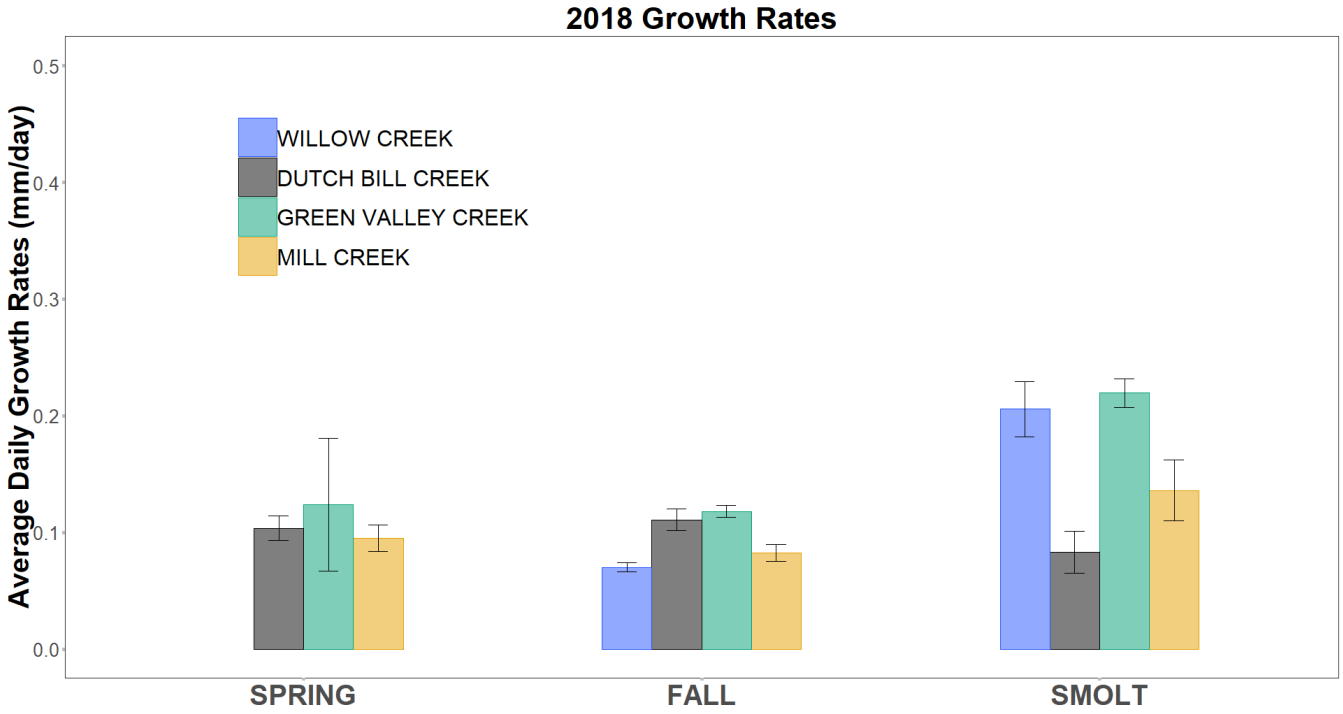


Figure 26. Average daily growth rates in fork length (mm) of PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks during the 2017 season, by stream and release season.

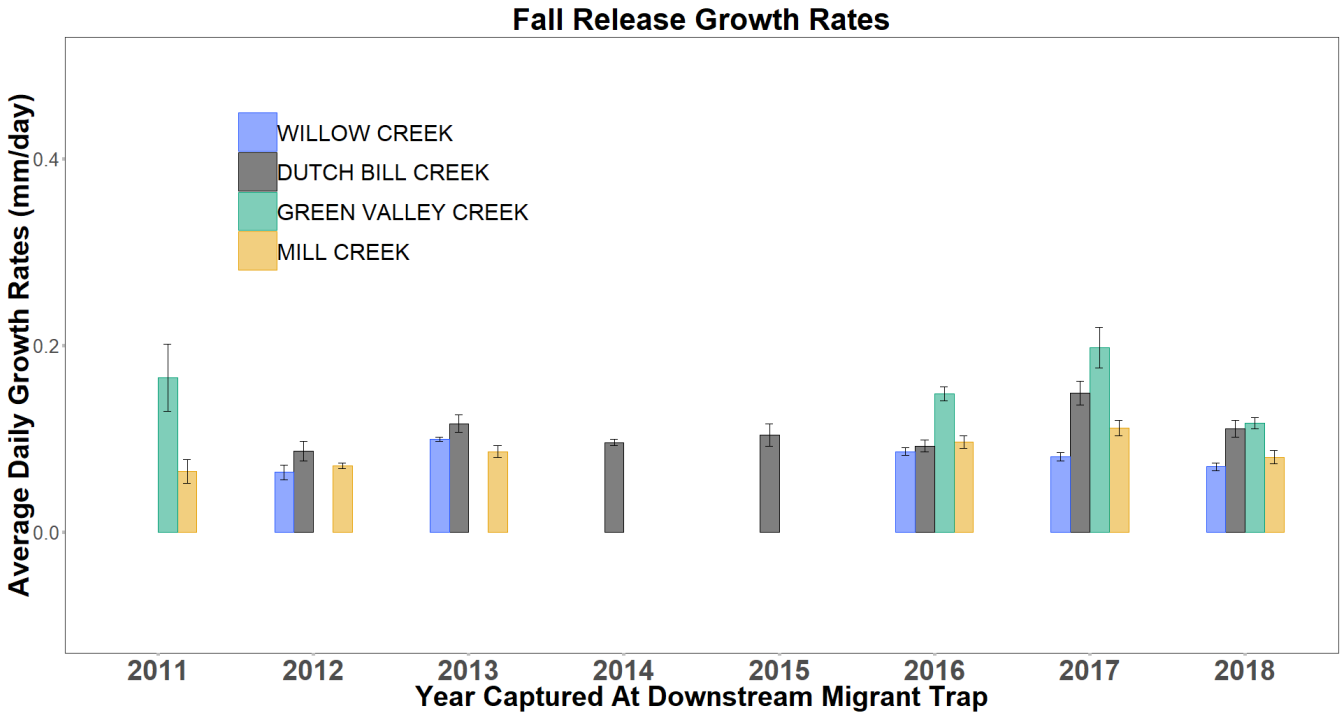


Figure 27. Average daily growth rates in fork length (mm) of fall-release PIT-tagged smolts recaptured at downstream migrant traps on Willow, Dutch Bill, Green Valley, and Mill creeks, years 2011-2017.

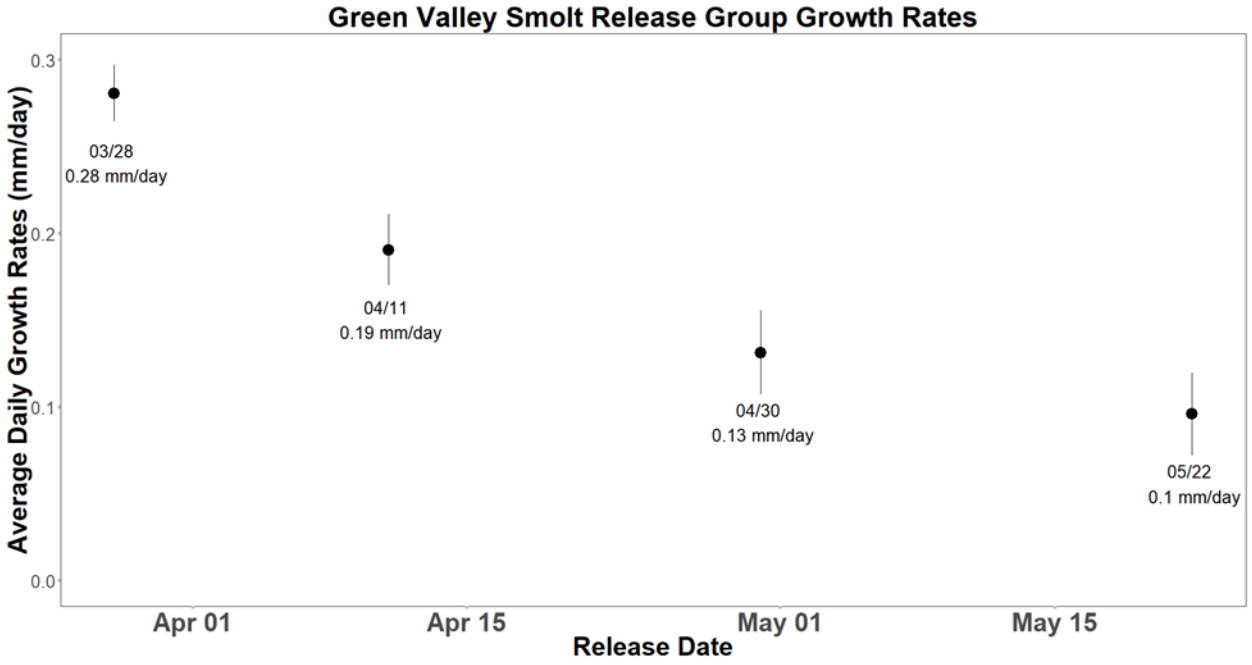


Figure 28. Average growth rates for the groups of fish released into Green Valley Creek during the 2018 smolt release.

Discussion and Recommendations

Rainfall during the winter of 2017/18 was slightly above average compared to recent years, with October to June precipitation at the Venado gage in the headwaters of Mill Creek reaching 52.2 inches, 4.6 inches higher than the 10-year average (according to raw gage data from NOAA's California Nevada River Forecast Center, http://www.cnrfc.noaa.gov/formPrecipMap.php) . Storm conditions during the winter months between November and February were less flashy than in recent years, with much of the precipitation occurring during the beginning of the smolt migration season in March (Figure 10, Figure 13, Figure 17, Figure 21). These rainfall events prevented full operation of our smolt traps until early April, after the flows had receded. PIT antenna data indicated that few smolts left the systems during these rain events and the peak of migration didn't occur until April, after flows stabilized and our traps were fully operational.

Coho salmon smolt abundance in the four Broodstock Program life cycle monitoring streams was above average in 2018, with all streams where historical data is available exceeding the five year average. In Willow Creek the smolt abundance estimate was the highest observed over all years of trap operation, while the Green Valley Creek estimate was the 2nd highest. In Dutch Bill and Mill creeks, estimated smolt abundances were similar to previous years' estimates but were still 161% and 137%, respectively, of five-year averages. Although stocking rates were slightly lower than in recent years (90% of five-year average for all four streams, collectively), above-average overwinter survival across all creeks, combined with an increase in natural production in Willow and Green Valley creeks, likely contributed to above-average abundance in all streams.

The proportion of natural-origin smolts captured across all streams was 10.7% in the 2018 trap year (1,271 natural-origin smolts/11,845 total known-origin smolts captured). This proportion was higher than the average proportion over the previous five years and was the second highest observed over all years of trap operation. Additionally, the 1,271 natural origin smolts captured was the highest number captured since the beginning of the

program. The increase in natural recruitment observed in 2018 relative to the past three years is consistent with the improved stream conditions in the summer of 2017 after above average rainfall in the winter of 2016-2017 and provides a positive indication that hatchery adults are successfully spawning and producing natural-origin juveniles in these streams.

Overwinter survival of fall-release fish was high compared to previous years of data collection in Willow, Dutch Bill and Green Valley creeks, and was average in Mill Creek (Figure 8, Table 7). Stock to smolt survival rates for these fish in Green Valley Creek were at least one and a half times higher than the rates of the other three streams for the 2017 cohort (Table 7). The high overwinter survival across all streams may be attributed to the absence of significant storms during the 2017-2018 winter. The survival rate for the spring release in Green Valley Creek was poor compared to Dutch Bill and Mill creeks, and compared to previous years in Green Valley Creek. This may have been due to locally poor conditions in the release reach where unusually low dissolved oxygen levels were observed during the summer of 2017. 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.

Although Willow Creek fall release fish had high overwinter survival to our trap site during the winter of 2017/18 (0.36), we estimated poor survival to the mouth of the creek (0.14). This continues a pattern observed over the previous three years in Willow Creek and indicates that there may be a survival bottleneck somewhere between 3rd bridge and the mouth of Willow Creek. One possible explanation is that the highly braided channel in lower Willow Creek poses a navigational challenge to outmigrating smolts, particularly during the low-flow conditions typical of late-spring. To help improve winter survival in Willow Creek we recommend investigating habitat improvement projects that would improve navigation potential in the lower reaches of Willow Creek.

Growth rates over the winter of 2017/18 were slightly below average (Figure 27). Fish released into Green Valley creek in the fall had relatively low overwinter growth rates compared to previous years while Willow, Dutch Bill, and Mill creeks were similar to previous years (Figure 27). Freshwater growth in Green Valley Creek was the highest of any of the Broodstock Program monitoring streams, as observed in the previous two years, but the difference was not as pronounced as in prior years (Figure 27). Although growth rates for natural-origin fish are unknown, the average size of Green Valley natural-origin fish was the largest of any group of fish captured. 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 in that stream. We recommend further study to identify what aspects of Green Valley Creek are driving these high growth rates.

The staggered smolt release in Green Valley Creek provided an opportunity to compare growth and survival rates across different release timings. Earlier releases had significantly higher growth rates, equal or better survival, and spent more time in the stream relative to later releases (Figure 28, Table 8). Combined with the high growth rates and survival observed for the pre-smolt releases from the previous years, this 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. Due to the lower survival and growth of the May release group, we do not think that fish should be released this late in the season.

As in previous years, the Mill Creek smolt release fish that were stocked directly into the stream were detected on the lower antenna array (exiting Mill Creek) immediately (Figure 24). As in previous reports, we recommend that an imprinting tank be placed and operated on Mill Creek at Westside School, which would increase the chances for imprinting on Mill Creek. If this is not feasible, we recommend discontinuing the Mill Creek smolt releases, as it is unlikely that the fish from these releases are imprinting on Mill Creek.

In summary, during the spring of 2018, 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 higher than in previous years, providing evidence of successful spawning that has resulted in production of natural-origin smolts. 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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