UC Coho Salmon and Steelhead Monitoring Report: Spring 2016

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Sea Grant California

Russian River Coho Salmon Monitoring Program

UC CE

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. University of California Cooperative Extension and California Sea Grant (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 stream flow and juvenile coho survival as part of the Russian River Coho Water Resources Partnership (Coho Partnership) (http://www.cohopartnership.org), an effort to improve stream flow 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 2015 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 (USACE) personnel at the Don Clausen Fish Hatchery (a.k.a., Warm Springs Hatchery) and released as juveniles into selected Broodstock Program streams in three release groups; spring, fall, and smolt. Fish in the spring-release group were released as young-of-the-year (yoy) in June 2015, fish from the fall-release group were released as yoy in November and December 2015, a month later than planned due to drought conditions that lingered into the fall, and fish from the smolt release group were released as age-1 smolts in April and May 2016. Because fish released as smolts often outmigrate immediately upon being stocked, different strategies were employed to encourage smolts to imprint on the release streams. In Dutch Bill Creek, smolts were held in a stream-side acclimation tank for 13 days prior to release and, in Mill Creek, a subset of the smolts were held in a pool created by an instream flashboard dam for 27 days prior to being released downstream. Fish released in the spring and fall were planted directly into the stream.

PIT Tagging

Prior to release, approximately 30% of all hatchery juvenile coho salmon were implanted with 12.5 mm full duplex (FDX) PIT tags at Don Clausen Fish Hatchery. In previous years, a 15% tag rate was applied; however, due to the relatively low number of hatchery fish released for the 2015 cohort (70,510 vs. the previous 5-year average of 179,050), a higher tag rate was used to ensure an adequate sample size for monitoring purposes. Coho salmon destined for tagging were randomly selected from holding tanks, 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 coho salmon released into Willow, Dutch Bill, Green Valley, and Mill creeks for the 2015 cohort.

		Number Released (% PIT-tagged)			
Release Season	**Release Dates**	**Willow Creek**	**Dutch Bill Creek**	**Green Valley Creek**	**Mill Creek**
Spring	**Jun 18-19, 2015**	0	1,008 (100%)	305(100%)	509 (100%)
Fall	**Nov 19-Dec 10, 2015**	9,032 (30%)	8,989 (30%)	8,989 (30%)	8,969 (30%)
Smolt	**Apr 15-May 19, 2016**	0	5,018 (30%)[1]	4,864 (30%)	4,775 (30%)
Total Released		9,032	15,015	14,158	14,253

[1] *1,638 of the 5,018 fish that were held in an acclimation tank for 13 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 1). Multiplexing transceivers, capable of reading FDX tags, were placed in waterproof boxes on the stream bank and powered using AC power with DC conversion systems (Willow, Dutch Bill, and Mill creeks) or solar power (Green Valley Creek). Sixteen by two-and-a-half foot antennas, housed in four-inch PVC, were placed flat on top of the streambed and secured with duck bill anchors. The antennas were placed in paired (upstream and downstream), channel-spanning arrays (Figure 2) so that detection efficiency could be estimated and the movement direction of individuals could be determined. Based on test-tag trials at the time of installation, read-range in the water column above the antennas ranged from 10" to 20" during baseflow conditions. During significant storm events, it is possible that stream depths exceeded 20", so if PIT-tagged fish were travelling in the water column above that depth, they would not be detected on the antennas. To account for undetected fish, the paired arrays were used to estimate antenna efficiency. From October 2015 through June 2016, 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.

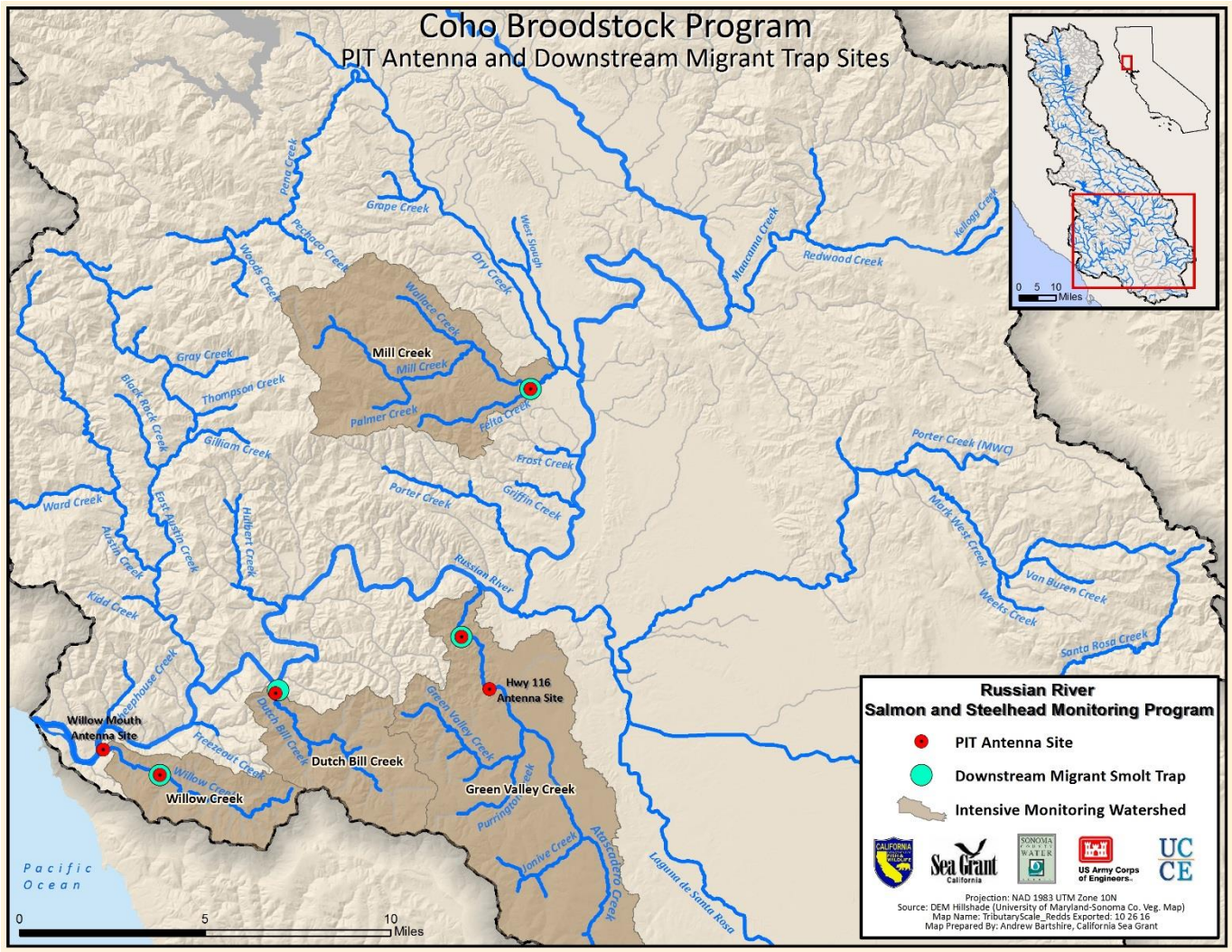


Figure 1. Map showing PIT antenna and smolt trap locations on Broodstock Program monitoring streams.

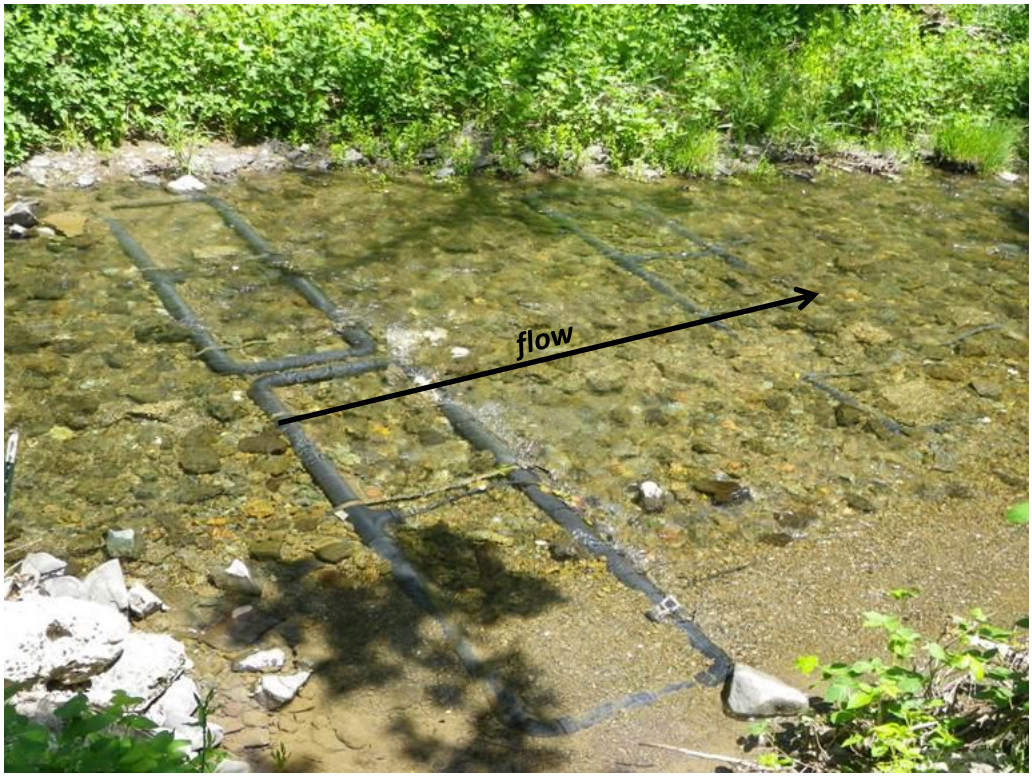


Figure 2. Paired flat-plate PIT tag antenna array on Mill Creek at spring base flows.

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 2016 to coincide with coho salmon smolt outmigration (Figure 3). The Sonoma County Water Agency (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.

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 to prevent injury to fish, avoid loss of equipment, and ensure personnel safety.

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 then counted, scanned for PIT and CWT tags, and the first 30 coho salmon smolts with a CWT were measured for fork length (mm) and weight (g). Coho salmon smolts with a CWT and no PIT tag beyond the first 30 were tallied by CWT location, and all PIT-tagged smolts were measured and weighed. Every fourth CWT-only (no PIT) smolt was also measured and weighed and a PIT tag was applied (25% of all CWT-only fish). All natural origin coho smolts (no PIT or CWT) were measured and weighed, and a PIT tag was applied to every other fish; half of natural origin smolts. A genetics sample was collected for every CWT 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 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. Data were entered into field computers, downloaded and error-checked upon return to the office, and uploaded into a SQL database.

Figure 3. Mill 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 leaving each creek during the time that each downstream migrant trap was in operation. An antenna array located immediately upstream of a given 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 and emigration prior to 3/1/16 for multiple release groups (i.e. spring, fall 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 1), 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 or smolt) passing the site each week. Total weekly sums were then plotted by week from October 29 (earliest known date that streams reconnect 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 (FL2-FL1)/(t2-t1) where FL1= fork length at hatchery prior to release, FL2= fork length at the smolt trap, t1=date measured at hatchery, and t2= date captured in the smolt trap. Individual growth rates were then averaged by stream and release group.

Results

Trap Operation

In 2016, the Willow Creek trap was installed on 3/24 and operated through 6/15. The trap was only partially fishing on 3/25 through 3/29, 4/12, and 4/24 through 4/27 due to scour from storm events and clogging at the intake pipe from excessive debris.

The Dutch Bill Creek trap was installed on 3/28 and was operated through 6/23. The trap was only partially fishing on 5/21 due to a clogged pipe.

The Green Valley Creek trap was installed on 3/30 and was operated through 6/15. The trap was only partially fishing on 4/9, 4/14, 4/22, 4/25, 4/26, and 5/3 due to scouring around the weir panels.

The Mill Creek trap was installed 4/9 and was operated through 6/15. The trap was only partially fishing on 4/25, 4/30, 5/1, 5/3, and 5/8 due to storm events and debris jams that clogged the intake pipe.

Trap Counts

Coho salmon smolt counts from downstream migrant traps on all four study streams in 2016 ranged from 2,028 to 3,573 (Table 2). The greatest number of coho smolts were captured on Green Valley Creek, followed by Dutch Bill,

Mill, and Willow creeks, respectively (Table 2). A notably high number of natural origin coho smolts were observed in the Willow Creek trap, representing more than 20% of the total count (Table 2). Though more than 200 natural origin smolts were captured in the Green Valley trap, this comprised only 6% of all coho smolts captured (Table 2). See the Natural Production section of this report for a multi-year comparison.

When compared to previous years, coho smolt trap counts were relatively high on Willow and Dutch Bill creeks and relatively low on Mill Creek (Table 3). The number of coho smolts captured in the Green Valley Creek trap was significantly lower than in 2016, but the trap was not operated from 2012 through 2014, 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 are summarized in the Smolt Abundance section of this report.

The total number of steelhead smolts captured in the traps in 2016 was low, ranging from three to 15, with the greatest number on Mill Creek (Table 3). In addition, 1,941 steelhead parr and YOY were captured in Mill Creek in 2016, which is the largest number since the 2008 trapping season (Table 3). Chinook salmon smolts (15) were only observed on Dutch Bill Creek (Table 3). Downstream migrant smolt traps are not operated for the full steelhead and Chinook outmigrant seasons, and yoy capture is incidental and generally based on proximity of redds to the trap site.

A relatively low diversity of species were captured in Willow Creek with sculpin (548), three-spined stickleback (71), and Sacramento pikeminnow (8) as the most abundant non-salmonids (Table 4). The three most abundant non-salmonids in Dutch Bill Creek were sculpin (440), Sacramento sucker (106), and fathead minnow (98), and in Green Valley Creek three-spined stickleback (167), Western brook lamprey (160), and bluegill (137) were the most abundant non-salmonids (Table 4). Thirty-three freshwater shrimp were captured in Green Valley Creek this year, which is much lower than in 2015 when 317 shrimp were captured (Table 4). The three most abundant non-salmonids captured in Mill Creek were sculpin (675), California roach (114), and fathead minnow (103)(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 captured during the 2016 downstream migrant season.

Stream	Hatchery	Natural	Unknown Origin	Total	Percent Natural
Willow Creek	1,579	427	22	2,028	21%
Dutch Bill Creek	1,723	85	873[1]	2,681	3%
Green Valley Creek	3,335	231	7	3,573	6%
Mill Creek	2,396	24	8	2,428	1%

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

Table 3. Chinook salmon, coho salmon, and steelhead captured at UC downstream migrant traps 2005-2016.

Tributary	Species	Life Stage	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Willow Creek	Coho Salmon	Smolt	NA	NA	NA	NA	NA	NA	NA	864	3,405	916	707	2,029
		YOY	NA	NA	NA	NA	NA	NA	NA	0	0	0	7	0
	Steelhead	Adult	NA	NA	NA	NA	NA	NA	NA	0	1	0	1	0
		Parr/YOY	NA	NA	NA	NA	NA	NA	NA	26	142	866	462	603
		Smolt	NA	NA	NA	NA	NA	NA	NA	5	25	11	22	8
Dutch Bill Creek	Chinook Salmon	Smolt	NA	NA	NA	NA	NA	4	34	13	0	10	0	15
	Coho Salmon	Smolt	NA	NA	NA	NA	NA	185	2,908	2,017	823	1,939	201	2,681
		YOY	NA	NA	NA	NA	NA	0	5	2	2	0	0	18
	Steelhead	Adult	NA	NA	NA	NA	NA	0	2	0	0	0	0	0
		Parr/YOY	NA	NA	NA	NA	NA	58	31	33	79	1,138	13	74
		Smolt	NA	NA	NA	NA	NA	5	47	11	18	0	3	8
Green Valley Creek	Chinook Salmon	Smolt	925	NA	226	40	0	14	16	NA	NA	NA	0	0
	Coho Salmon	Smolt	16	NA	625	309	608	348	231	NA	NA	NA	6,810	3,573
		YOY	0	NA	0	0	0	0	1	NA	NA	NA	2	0
	Steelhead	Adult	1	NA	8	1	0	1	0	NA	NA	NA	2	1
		Parr/YOY	1,723	NA	36	497	1	5	3	NA	NA	NA	0	49
		Smolt	55	NA	70	29	43	0	1	NA	NA	NA	3	3
Mill Creek	Chinook Salmon	Smolt	70	128	2	31	1	1	0	11	0	18	0	0
	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
		YOY	24	314	58	43	0	4	329	515	530	0	10	10
	Steelhead	Adult	11	5	31	15	2	1	0	1	5	1	2	0
		Parr/YOY	1,903	438	2,272	3,571	583	355	521	859	443	108	29	1,941
		Smolt	116	49	266	176	118	190	97	41	32	8	17	15

Table 4. 2005-2016 annual downstream migrant trap counts for common non-salmonid species. NA indicates no trapping occurred during that year.

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

Other species captured 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

A significantly higher percentage of natural origin coho smolts (defined as having no CWT or PIT tag) were captured in the Willow Creek downstream migrant trap, when compared to other streams; this represents the second highest number of natural origin smolts in Willow over the past five years, proportionally (Table 5). The relative occurrence of natural origin coho salmon smolts was relatively low on Dutch Bill and Mill creeks, with the second lowest percentages documented over the past five years since natural origin coho have been observed in relatively higher abundance (Table 5). The percentage of natural origin coho smolts observed at the Green Valley Creek trap was generally average, though the trap was not operated for three of the past five years, so recent comparative estimates are limited (Table 5).

Table 5. Percent of natural origin (no CWT present) coho salmon smolts captured annually in downstream migrant traps. NA indicates that no trap was operated in a given year.

	Willow Creek		Dutch Bill		Green Valley		Mill Creek	
Year	Total Captured	Percent Natural Origin	Total Captured	Percent Natural Origin	Total Captured	Percent Natural Origin	Total Captured	Percent Natural Origin
2005	NA	NA	NA	NA	15	60.0	636	0.3
2006	NA	NA	NA	NA	NA	NA	648	0.2
2007	NA	NA	NA	NA	509	0.2	2,408	0.0
2008	NA	NA	NA	NA	299	0.0	4,760	0.0
2009	NA	NA	NA	NA	608	0.2	14,754	0.4
2010	NA	NA	185	0.5	348	0.0	5,060	0.2
2011	NA	NA	2,908	0.0	231	0.9	7,256	0.3
2012	864	0.0	2,017	1.7	NA	NA	4,801	3.2
2013	3,405	0.4	823	12.9	NA	NA	2,019	0.1
2014	916	36.1	1,939	13.5	NA	NA	1,448	11.6
2015	701	2.9	201	4.0	6,810	11.7	5,397	2.7
2016	2,028	21.1	2,681	3.2	3,573	6.5	2,428	1.0

Smolt Abundance

Smolt abundance estimates indicate that thousands of smolts emigrated from each of the four Broodstock Program monitoring tributaries during the spring of 2016 (Table 6). Smolt abundance was higher in Green Valley than Dutch Bill 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, Willow Creek abundance was the second highest observed in all years of data collection, Dutch Bill appeared to be average, and Green Valley and Mill creeks were low (Figure 4).

Table 6. Number of cohort 2015 juvenile coho salmon released into Willow, Dutch Bill, Green Valley, and Mill Creeks and estimated number of coho salmon smolts emigrating each tributary during spring of 2016. Abundance estimates include both marked and unmarked smolts.

Tributary	Number Released				Estimated Smolt Abundance (95% CI)
	Spring	Fall	Smolt	Total	
Willow Creek	0	9,032	0	9,032	3,487 (394)
Dutch Bill Creek	1,008	8,989	5,018 [1]	15,015	4,097 (265)
Green Valley Creek	305	8,989	4,864	14,158	9,685 (952)
Mill Creek	509	8,969	4,775	14,253	6,655 (365)

[1] *Following tank imprinting for 13 days, the last group of 1,638 smolts were released into the Russian River at the Monte Rio Boat launch on 5/19/16 and had no possibility of being detected at the trapsite.*

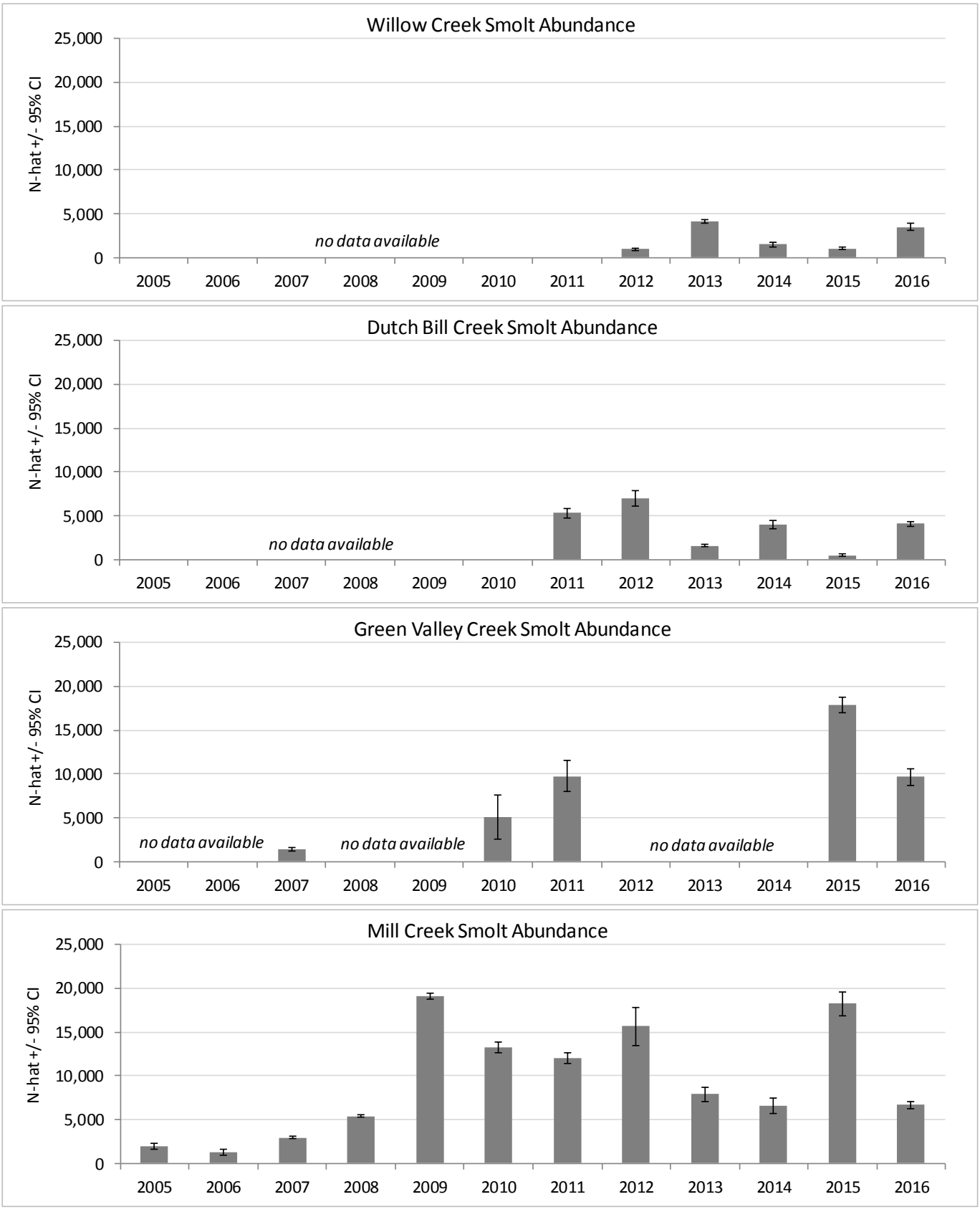


Figure 4. Estimated abundance (N-hat) of smolts emigrating from Willow, Dutch Bill, Green Valley, and Mill creeks each spring, years 2005-2016.

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 2015 through 6/30/16 (approximately one year later) was extremely low, ranging from 0.00 on Green Valley Creek to 0.10 on Mill Creek (Table 7). The estimated probability of survival of fall-released juvenile coho from the time of release in late November/early December 2015 through 6/30/16 was higher, ranging from 0.18 on Dutch Bill Creek to 0.42 on Mill Creek (Table 7). When comparing fall-release survival estimates with previous years' estimates, it appears that survival during the winter of 2015/16 was above average (Figure 5). As in the previous three years, overwinter survival was higher in Green Valley and Mill Creeks as compared to Dutch Bill Creek, and with the exception of winter 2013/14, Willow Creek was higher than Dutch Bill, lower than Green Valley and lower than or equal to Mill Creek (Figure 5).

The estimated probability of survival of smolt-release group fish was generally high, ranging from 0.78 to 0.96 (Table 8). In Green Valley and Mill creeks, release timing did not appear to influence survival and in Dutch Bill Creek the 5/2/16 release group survived at a higher rate than the 4/18/16 release group (0.85 and 0.78, respectively) (Table 8).

The estimated probability of juvenile coho salmon emigrating from their respective release streams prior to March 1 was zero or near- zero in Willow, Green Valley and Mill creeks for both spring and fall release groups (range 0.00 to 0.03), and was significantly higher for the Dutch Bill fall-release group (0.16) (Table 9). On Willow Creek, where antennas were operated year-round at the trap site (upstream of 3rd Bridge) and at the mouth (Figure 1), we had the ability to estimate early winter emigration from the release reach (upstream of 3rd Bridge) to both the trap site and to the mouth. Interestingly, early winter emigration probability past the antennas at the trap site was 0.25, but past the antennas at the mouth was only 0.01, suggesting that fish that moved downstream below the trap site prior to 3/1/16 did not immediately emigrate out Willow Creek and into the Russian River.

When compared with previous years' early winter emigration estimates for the fall release group, probabilities were consistently higher in Dutch Bill Creek than in the other three streams (Table 9, Figure 6). In almost all years in Mill Creek, early winter emigration probability was low (0.02 – 0.05) with the exception of winter 2010/11 when the probability was estimated at 0.33 (Figure 6). Probability of early emigration from Green Valley Creek or from Willow Creek (past the mouth) was approximately zero in all years of data collection (Figure 6).

Table 7. Estimated probability of juvenile coho salmon survival from the date of release in 2015 through 6/30/16 for spring and fall release groups. NA=not applicable (no fish were released).

	Spring Release			Fall Release		
Tributary	**Release Date**	**Interval Days**	**Probability of Survival (95%CI)**	**Release Date**	**Interval Days**	**Probability of Survival (95%CI)**
Willow Creek	NA	NA	NA	12/7/2015	206	0.29 (0.27-0.31) [1]
Dutch Bill Creek	6/17/2015	379	0.03 (0.02-0.04)	12/10/2015	203	0.18 (0.16-0.20)
Green Valley Creek	6/18/2015	378	0.00 (0.00-0.02)	12/9/2015	204	0.38 (0.36-0.40)
Mill Creek	6/18/2015	378	0.10 (0.07-0.12)	11/25/2015	218	0.42 (0.40-0.44)

[1] *For comparison with other streams, probability of survival to the mouth of Willow Creek was included in the table; probabillity of survival to 3rd Bridge was 0.37 (0.35-0.39).*

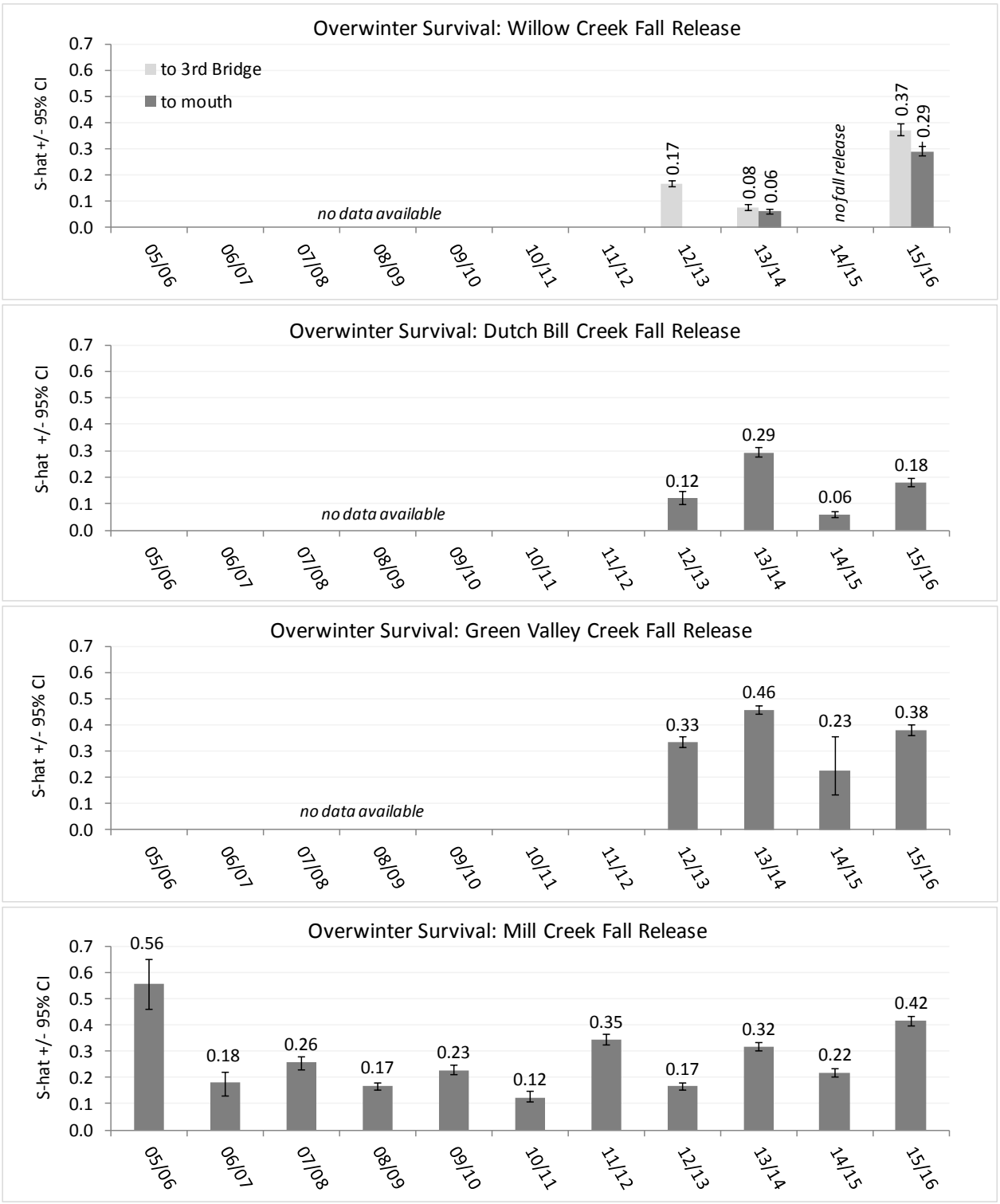


Figure 5. Probability of survival (S-hat) from the time of fall release through detection at the lower antenna/trap sites in spring (3/1 - 6/30) in Willow, Dutch Bill, Green Valley, and Mill creeks.

Table 8. Estimated probability of juvenile coho salmon survival from the date of release through 6/30/16 for each smolt release group. NA=not applicable (fish were not released into the tributary).

Tributary	Release Type	Release Site	River km	Release Date	Days Imprinted	Survival interval	Probability of Survival (95%CI)
Dutch Bill Creek	tank	Westminster Woods	6.52	4/18/2016	13	73	0.78 (0.74-0.81)
Dutch Bill Creek	tank	Westminster Woods	6.52	5/2/2016	13	59	0.85 (0.82-0.88)
Dutch Bill Creek	tank	Monte Rio boat launch	16.5	5/19/2016	13	NA	NA
Green Valley Creek	stream	lower Green Valley Rd Crossing	9.32	4/18/2016	0	73	0.96 (0.94-0.98)
Green Valley Creek	stream	lower Green Valley Rd Crossing	9.32	5/2/2016	0	59	0.95 (0.93-0.96)
Mill Creek	stream	Palmer confluence	9.98	4/25/2016	0	66	0.86 (0.84-0.89)
Mill Creek	pond	pond acclimation site	15.54	5/4/2016 [1]	27 (0) [1]	57 (84) [1]	0.86 (0.83-0.88)

[1] *Pond-release smolts were placed in the pond on 4/7/16 with the intention of holding them in the pond until 5/4/16; however individuals from this group were detected on the lower Mill antennas beginning on 4/9/16, suggesting that they were able to escape the pond (see movement timing graphs).*

Table 9. Estimated probability of juvenile coho salmon emigrating from each tributary prior to 3/1/16. NA=not applicable (no fish were released).

Tributary	Probability of Emigration prior to 3/1 (95% CI)	
	Spring Release	Fall Release
Willow Creek	NA	0.01 (0.00 - 0.01)
Dutch Bill Creek	0.04 (0.03-0.05)	0.16 (0.15-0.17)
Green Valley Creek	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Mill Creek	0.02 (0.02-0.04)	0.03 (0.03-0.04)

[1] *For comparison with other streams, probability of emigration from the mouth of Willow Creek was included in the table; probabillity of emigrating downstream of 3rd Bridge prior to 3/1/16 was 0.25 (0.23-0.27).*

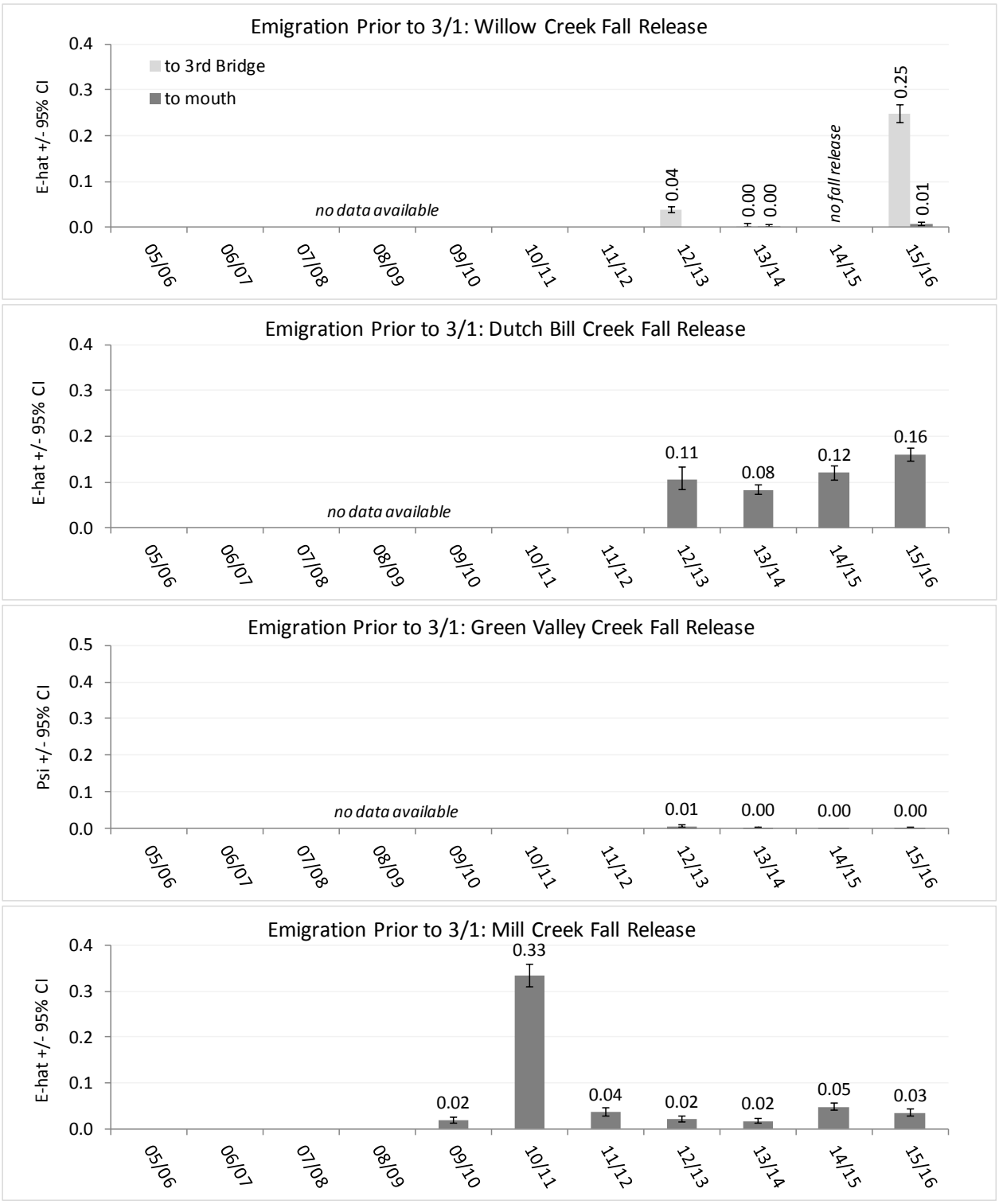


Figure 6. Probability of emigration (E-hat) past antenna sites prior to 3/1. Willow, Dutch Bill, Green Valley, and Mill creeks.

Migration Timing

Weekly totals of outmigrating smolts were plotted by release group for the period of October 29, 2015 to June 30, 2016 (Figure 7, Figure 9, Figure 11, and Figure 13; note the difference in the y-axes scales). Average daily stream depth or discharge (where available) was graphed for the same time period to allow for comparisons of fish movement to streamflow (Figure 8, Figure 10, Figure 12, and Figure 14). In general, coho salmon in all streams emigrated between the weeks of December 10, 2015 and June 18, 2016, with the Dutch Bill run ending earlier on May 21 (Figure 7, Figure 9, Figure 11, and Figure 13). Pulses in fish movement prior to March most commonly occurred on the receding end of the hydrograph (Figure 7 through Figure 14).

Due to 2015 drought conditions, there was not sufficient wetted habitat to support fish in Willow Creek until after early winter rains so the fall-release fish were not planted until December 7. There was a dramatic spike in the number of fish detected the week of December 17 at the upper antenna site, possibly a post-stocking flight response, a pattern commonly observed in Broodstock Program streams in previous years (Obedzinski 2012) (Figure 7). This December pulse was not observed at the lower antenna site at the mouth of Willow Creek (Figure 7). After the week of December 24, winter outmigration was low, with only a small number of individuals detected at the upper and lower antenna sites each week until the main pulse of fish which ran from late March through mid-May and peaked the weeks of April 2 and April 9, as the hydrograph receded (Figure 7, Figure 8)

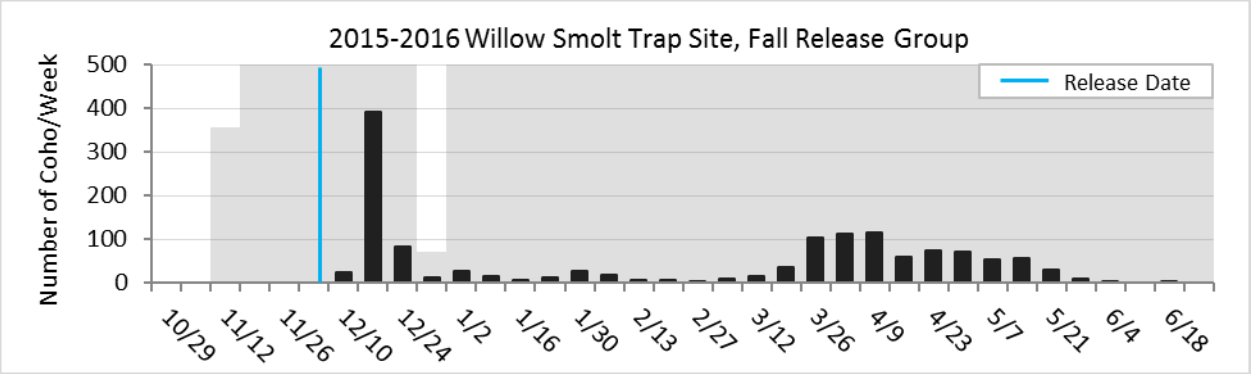
To examine the fate of the individuals that were detected at the upper Willow antenna site prior to March, we selected all fish that were detected at the upper antenna site prior to March (627) *and* subsequently detected at the lower antenna site (276). Of the fish that were detected at both sites, 97% were not detected again at the mouth until after March 1, indicating that they over-wintered in the low-gradient mainstem or off-channel habitat in lower Willow Creek. We also compared survival of early emigrating fish to survival of all fish released in Willow and found that it was higher for the early emigrants (0.43 and 0.29, respectively).

Dutch Bill Creek spring-release fish movement was highest on the week of December 17th, when approximately one-quarter of the juveniles emigrated (Figure 9). The spring peak occurred the week of May 7, shortly before the end of the smolt run on May 21 (Figure 9). The fall-release fish were planted into Dutch Bill Creek on December 10, 2015 and many were detected moving downstream past the trap site the second week after being planted (Figure 9). While this could be attributed to a common flight response, it's interesting to note that this movement corresponded to the peak spring-release fish migration, about one week after a storm event (Figure 9, Figure 10). The fall-release migration also peaked in the winter—on the week of January 2—and continued at a relatively high rate for the next two weeks (Figure 9). The spring pulse of the fall-released fish peaked the week of April 2 (Figure 9). While migration patterns were different for the spring and fall release groups, they exhibited similar seasonal timing, with large pulses of fish moving downstream before March 1 (Figure 9). The smolt release group was planted in two groups on April 18 and May 3, 2016 and moved out in large pulses on the weeks of April 16 and April 30, within a few days to two weeks of being planted (Figure 9).

Only one spring-release fish was detected at the Green Valley antenna site upstream of Highway 116 (river km 6.13) over the entire migration season (Figure 11). The lack of spring release smolts underscores the very low oversummer survival in Green Valley Creek in 2015. There was minimal smolt movement in Green Valley Creek over the winter and there was no flight response observed in the late fall-release group planted on December 9, 2015 (Figure 11). The vast majority of fall-release fish migrated in a large pulse between late March and late May, with the run peaking the week of April 30, about one week after the last spring storm to drop more than one inch

of rain (Figure 11, Figure 12). As in Dutch Bill Creek, the vast majority of smolt-release fish—planted on April 18 and May 2, 2016—mostly moved out in high numbers on the weeks of April 16 and April 30, within a few days to two weeks of being planted (Figure 11).

Only a small proportion of the Mill Creek spring- and fall-release fish were detected at the smolt trap site over the winter and there was no flight response observed in the late fall-release group planted on November 25, 2015 (Figure 13, Figure 14). Most fish overwintered in Mill Creek and migrated in large pulses between mid-March and May (Figure 13). The spring-release group run peaked the week of April 30, on the falling hydrograph of a small spring storm, and the fall-release group run peaked the week of March 26, about two weeks after the largest storm of the season (Figure 13, Figure 14). Most of the smolt release fish, which were placed in the instream acclimation pond on April 7 or at the confluence of Mill and Palmer on April 25, left in large numbers on the weeks of April 9 and April 23, immediately after being released (Figure 11).



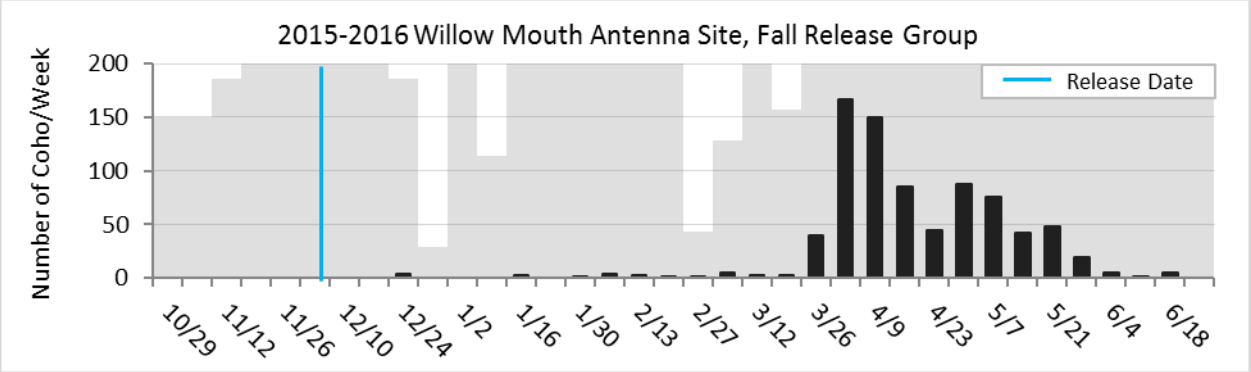


Figure 7. Number of fall-released coho salmon smolts that moved past the Willow Creek smolt trap site and the antenna site near the mouth of Willow each week between October 29, 2015 and June 25, 2016. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

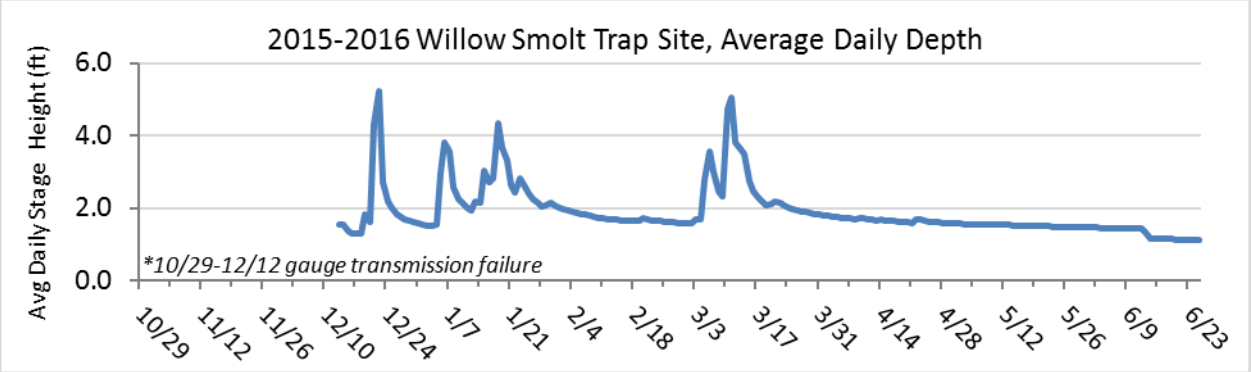
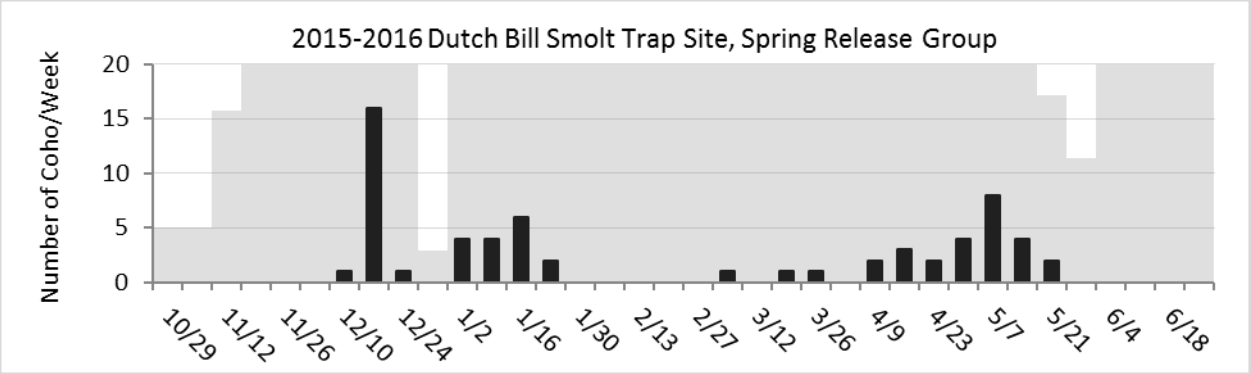
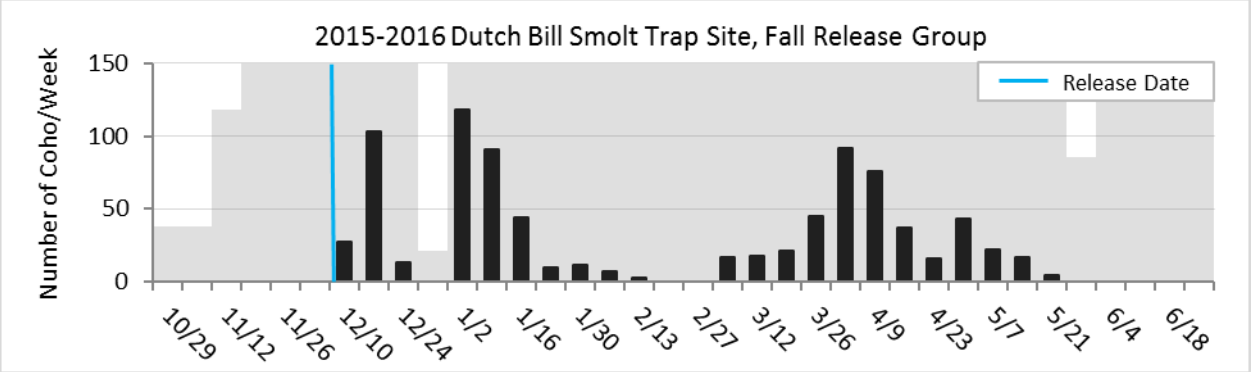


Figure 8. Average daily stage height at the Willow Creek smolt trap site between October 29, 2015 and June 25, 2016. Data is missing for the early part of the reporting period due to a technical failure.





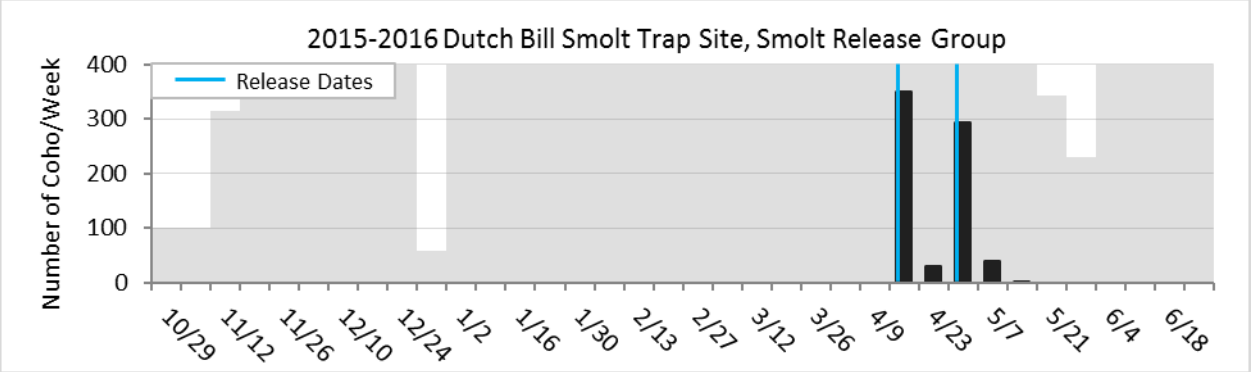


Figure 9. Number of spring-, fall-, and smolt-released coho smolts that moved past the Dutch Bill Creek smolt trap site each week between October 29, 2015 and June 25, 2016. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

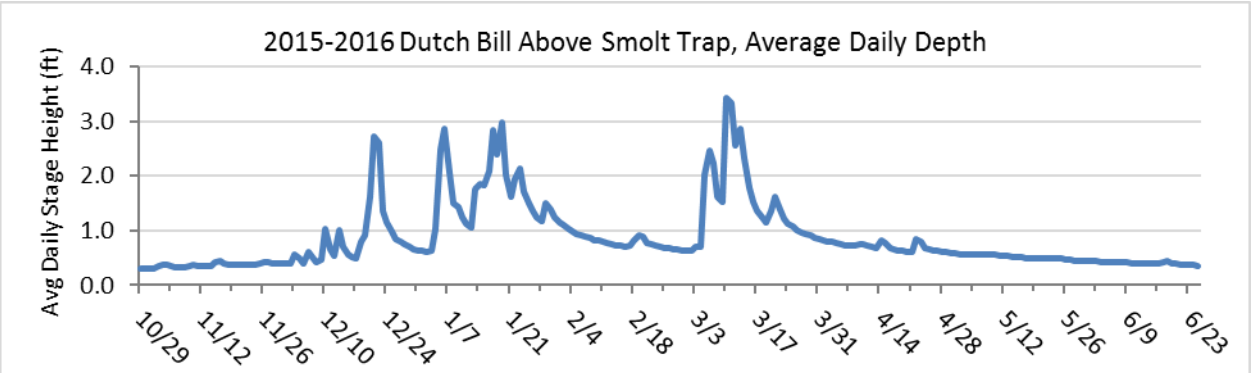
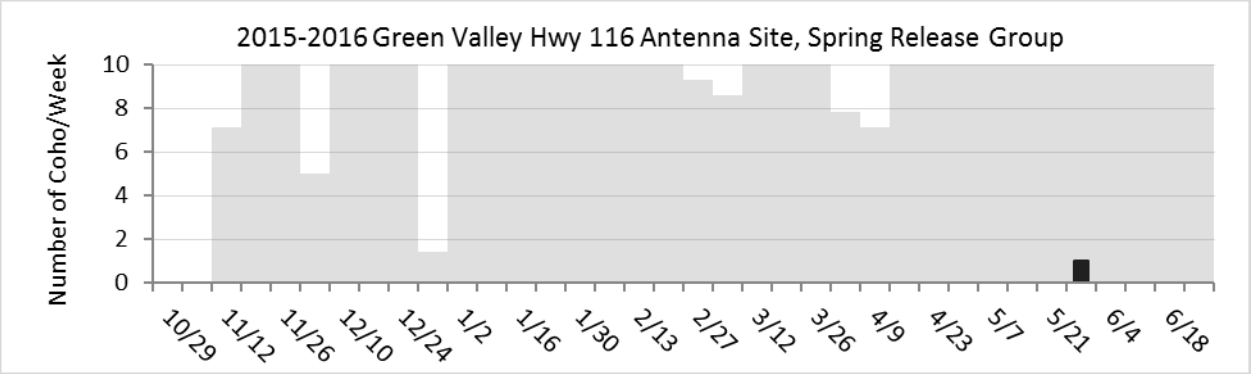
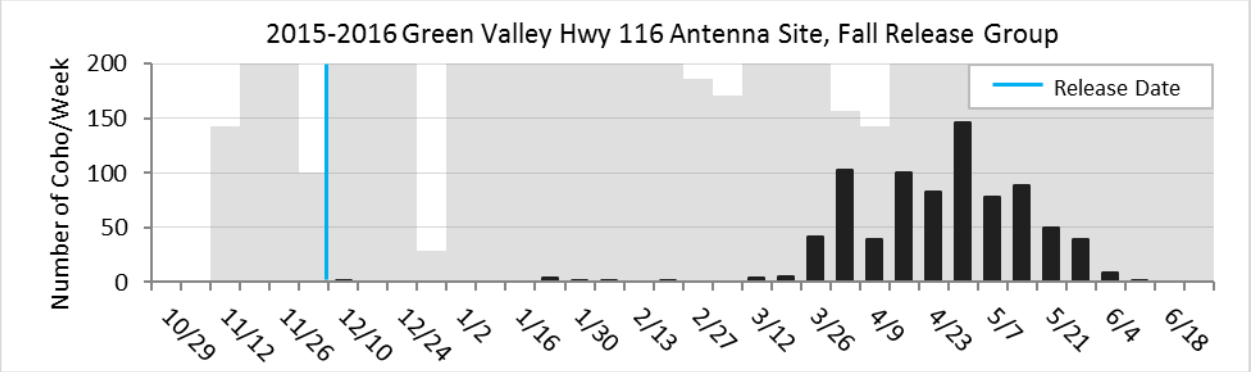


Figure 10. Average daily stage height at the Dutch Bill Creek smolt trap site between October 29, 2015 and June 25, 2016.





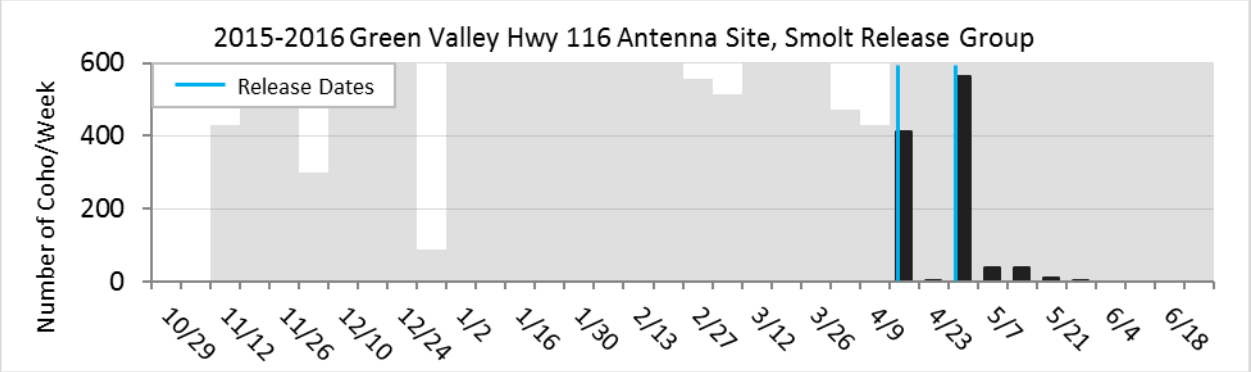


Figure 11. Number of spring-, fall-, and smolt-released coho smolts that moved past the Green Valley Creek antenna site upstream of Highway 116 each week between October 29, 2015 and June 25, 2016. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

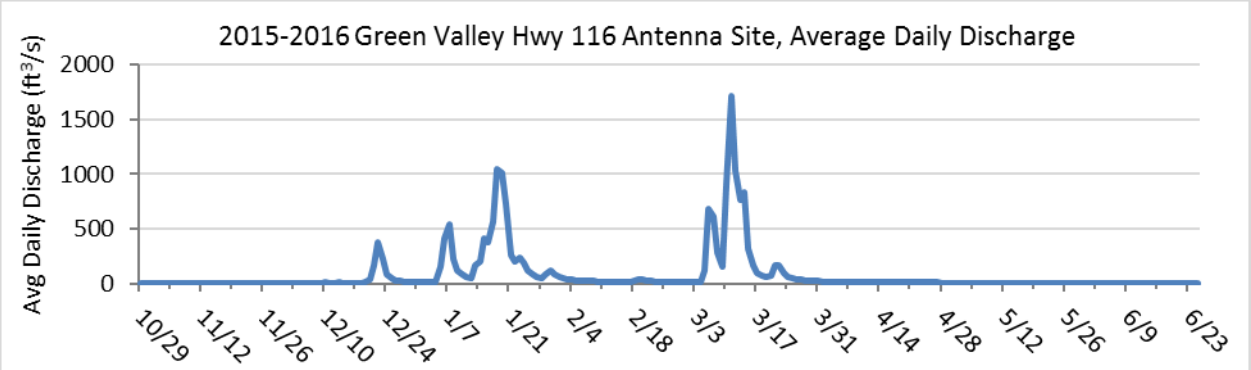
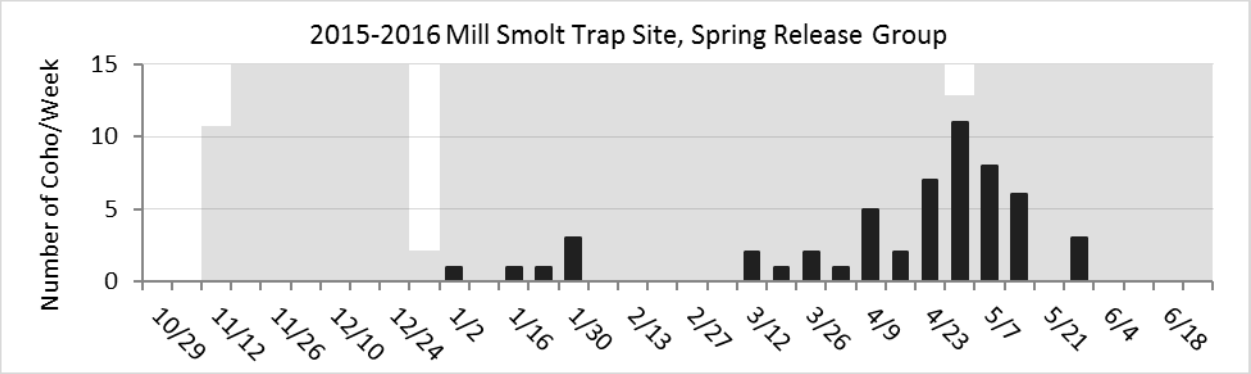
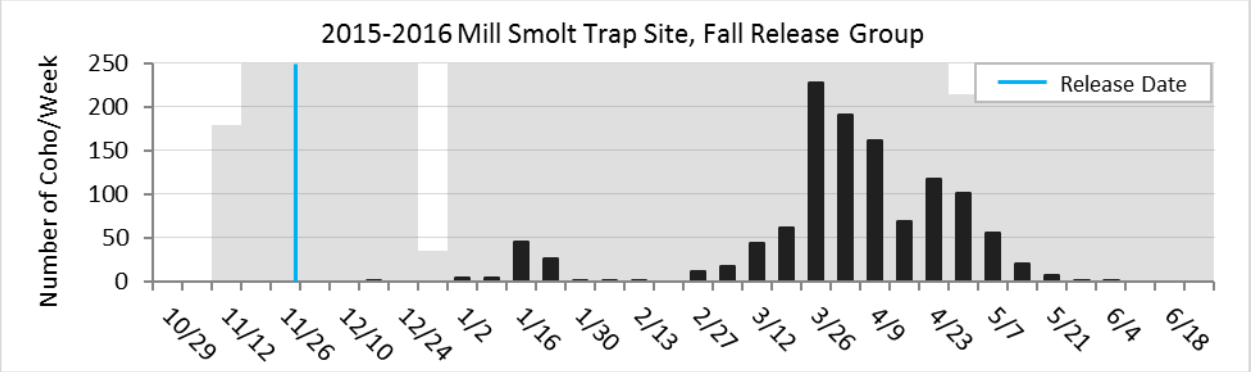


Figure 12. Average daily discharge at the Green Valley Creek antenna site upstream of Highway 116 between October 29, 2015 and June 25, 2016. High flow data is extrapolated above 56 ft^3/s and presented with low confidence.





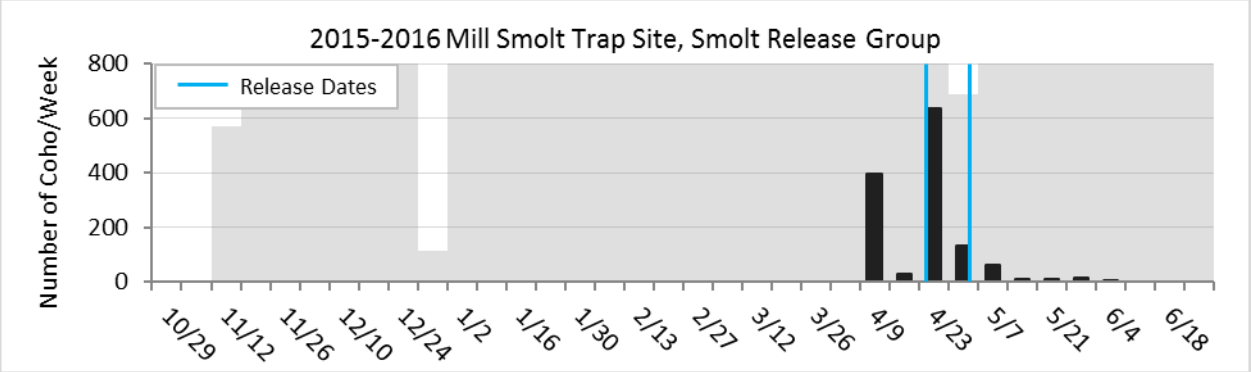


Figure 13. Number of spring-, fall-, and smolt-released coho smolts that moved past the Mill Creek smolt trap site each week between October 29, 2015 and June 25, 2016. Total number of fish/week is assigned to the first day of each seven-day period. Shaded background indicates proportion of the week that the antennas and/or traps were in operation.

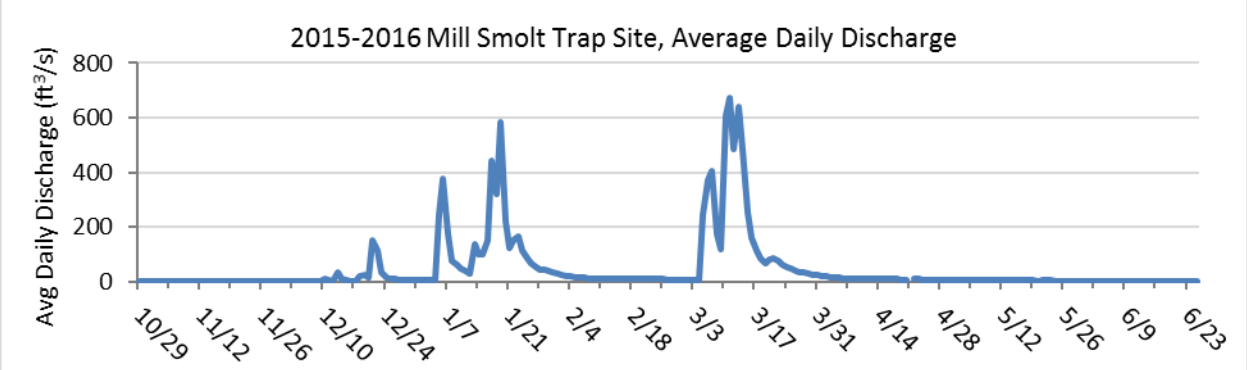


Figure 14. Average daily discharge at the Mill Creek smolt trap site between October 29, 2015 and June 25, 2016. High flow data is extrapolated above 96 ft^3/s and presented with low confidence.

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 averages for all 2015 cohort Broodstock Program release streams combined were 68.6 mm and 3.9 g (spring), 91.3 mm and 9.3 g (fall), and 120.1 mm and 16.8 g (smolt).

Average lengths and weights of fish captured in the downstream migrant traps ranged from 106.5 mm and 12.7 g on Willow Creek to 119.4 mm and 17.8 g on Green Valley Creek (Table 11). Average fork length and weight in Mill Creek (113.3 mm and 15.6 g) was slightly larger than Dutch Bill Creek (111.7 mm and 14.5 g) (Table 11). Length frequency distributions displayed a large range in fork length within each release group on each stream (Figure 15- Figure 18). In all both Dutch Bill and Mill creeks, size distribution of the spring and fall release groups fell within a smaller range than the smolt release group (Figure 16, Figure 18). In Green Valley, the fall release group had a broad range from 90 mm to 158 mm (Figure 17, Figure 19).

Size variation between natural and hatchery origin coho salmon smolts differed among streams (Table 11). In Dutch Bill and Mill creeks, hatchery origin smolts were slightly larger than natural origin smolts, in Willow Creek sizes were similar, and in Green Valley Creek, natural origin smolts were larger than hatchery smolts (Table 11). Green Valley Creek natural origin smolts were the largest among all groups compared, averaging 122.7 mm and 19.3 g (Table 11).

Table 10. Average fork length (mm) and weight (g) of *pre-release* PIT-tagged coho salmon prior to the 2016 downstream migrant trapping season.

Stream	Release Season	Avg Fork Length (SD)	Average Weight (SD)	Number of Fish
Willow Creek	Fall	91.4 (±6.9)	9.2 (±2.0)	2,718
Dutch Bill Creek	Spring	69.9 (±5.1)	4.1 (±1.0)	1,008
	Fall	93.8 (±7.3)	10 (±2.3)	2,716
	Smolt	112.9 (±8.7)	16.2 (±3.8)	1,511
Green Valley Creek	Spring	67.7 (±3.5)	3.8 (±0.6)	305
	Fall	92.6 (±7.4)	9.6 (±2.3)	2,715
	Smolt	112.8 (±8.5)	16.4 (±4)	1,489
Mill Creek	Spring	66.6 (±3.3)	3.5 (±0.6)	509
	Fall	89.3 (±6.8)	8.7 (±2.0)	2,423
	Smolt	112.5 (±8.6)	16.6 (±4.1)	1,499

Table 11. Average lengths and weights of natural and hatchery-origin coho salmon smolts captured at downstream migrant traps during the 2016 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	106.5 (±8.8)	12.7 (±3.2)	1,413
Natural	106.5 (±11.2)	12.7 (±3.7)	403
All Smolts	106.5 (±9.4)	12.7 (±3.3)	1,817
Dutch Bill Creek			
Hatchery	111.8 (±8.4)	14.6 (±3.2)	1,467
Natural	108.7 (±7.9)	13.3 (±2.6)	83
All Smolts	111.7 (±8.4)	14.5 (±3.2)	1,550
Green Valley Creek			
Hatchery	119.1 (±10.1)	17.6 (±5.2)	2,278
Natural	122.7 (±12.9)	19.3 (±6.5)	228
All Smolts	119.4 (±10.5)	17.8 (±5.3)	2,506
Mill Creek			
Hatchery	113.4 (±10.4)	15.7 (±4.3)	1,716
Natural	111.8 (±10.5)	14.5 (±4.0)	24
All Smolts	113.3 (±10.4)	15.6 (±4.3)	1,740

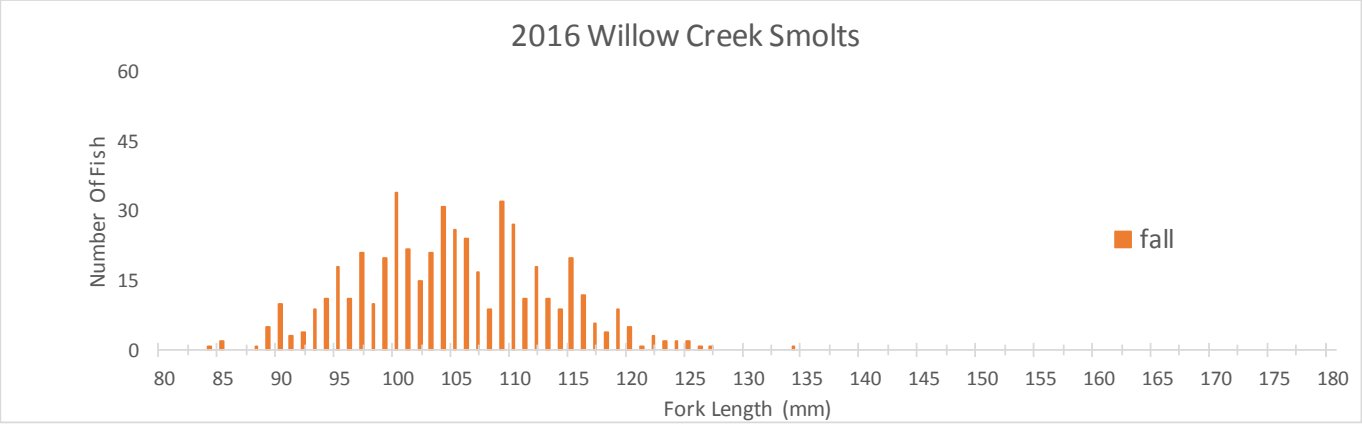


Figure 15. Length-frequency histogram of PIT-tagged coho salmon smolts captured in the Willow Creek downstream migrant trap in 2016. Smolts grouped by release season.

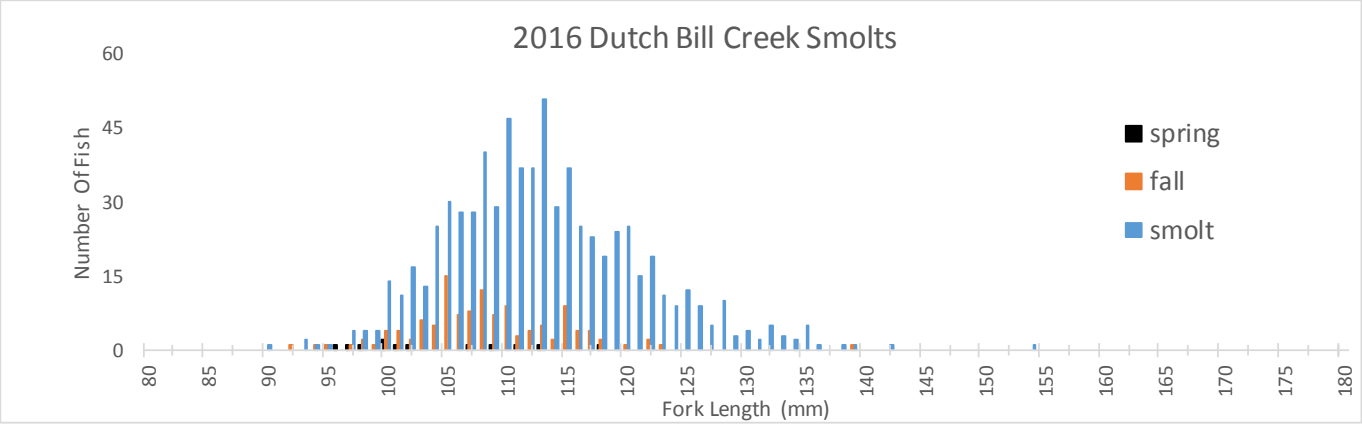


Figure 16. Length-frequency histogram of PIT-tagged coho salmon smolts captured in the Dutch Bill Creek downstream migrant trap in 2016. Smolts grouped by release season.

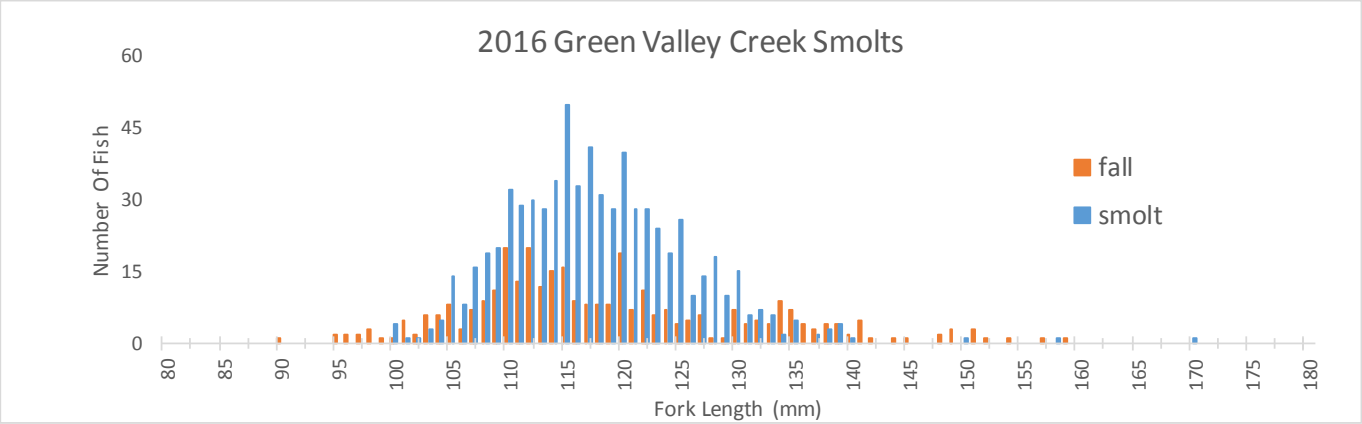


Figure 17. Length-frequency histogram of PIT-tagged coho salmon smolts captured in the Green Valley Creek downstream migrant trap in 2016. Smolts grouped by release season.

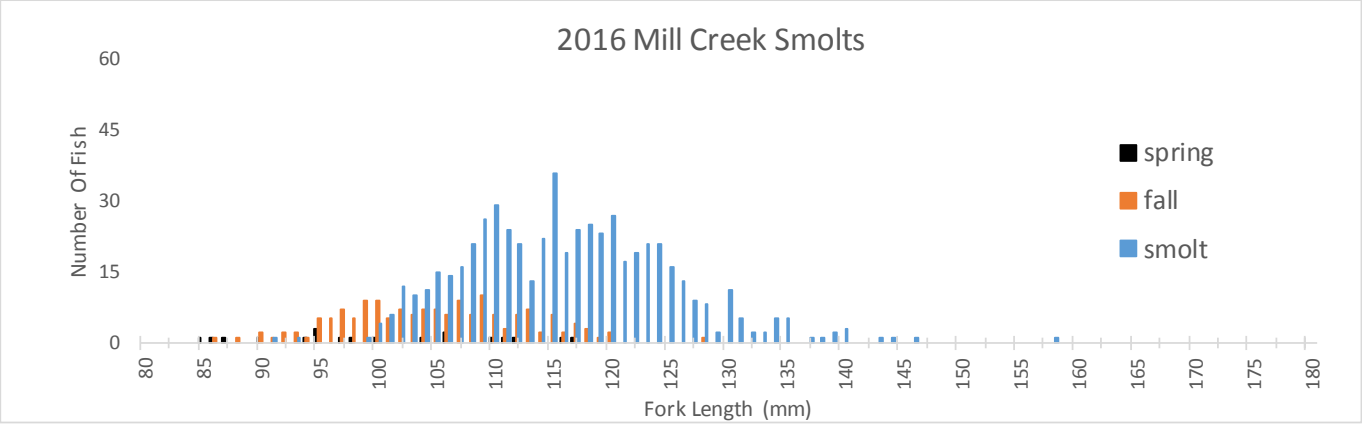


Figure 18. Length-frequency histogram of PIT-tagged coho salmon smolts captured in the Mill Creek downstream migrant trap in 2016. Smolts grouped by release season.

Figure 19. Smolt size variation among coho salmon captured in the Green Valley Creek downstream migrant trap in 2016.

Growth

As with size comparisons, variation in average growth (mm and g gained) and average daily growth rates varied among streams and release groups (Table 12, Figure 20). Spring release fish increased in length and weight more than the fall release fish which spent less time in the stream environment (Table 12). Smolt release fish, spending the least number of days in the stream environment, grew in length, but grew very little or even decreased in weight (Table 12).

In both fall and smolt release groups, PIT-tagged smolts recaptured in Green Valley Creek grew 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 20). Green Valley fish released in the fall of 2015 grew almost twice as much as those released at the same time in other streams, and Green Valley Creek also had the highest average rate of growth and total growth for the smolt-release group (Table 12, Figure 20). Growth rates in Mill and Dutch Bill creeks were similar for the spring and fall releases but much higher in Mill Creek for the smolt release. Fish were only released in Willow Creek during the fall and these fish showed similar, but slightly lower, growth rates to those in Mill and Dutch Bill creeks (Figure 20).

In addition to the fish recaptured from the 2015/16 hatchery release, several fish were recaptured that had been released in the fall or spring of 2014 and spent an additional year in fresh water before emigrating as smolts. In Willow Creek, 13 fish were recaptured from the spring 2014 release with an average growth in fork length of 45.0 mm, in Mill Creek 5 fish were recaptured from the fall 2014 release with an average growth of 34.2 mm and in Dutch Bill Creek one fish was recaptured from the fall 2014 release, which had grown 30 mm.

Table 12. Average daily growth rate and average growth 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	13.2 (±6.8)	2.9 (±2.6)	502	152 (±18)
Dutch Bill Downstream Migrant Trap				
Spring	34.4 (±7.8)	8.5 (±2.4)	12	336 (±10)
Fall	14.0 (±6.6)	3.0 (±2.6)	124	146 (±14)
Smolt	1.5 (±2.7)	-0.5 (±1.1)	725	25 (±4)
Green Valley Downstream Migrant Trap				
Fall	26.1 (±11.3)	8.4 (±6.1)	340	179 (±12)
Smolt	5.9 (±5.1)	0.9 (±2.1)	699	28 (±9)
Mill Downstream Migrant Trap				
Spring	33.5 (±8.3)	8.0 (±3.1)	19	347 (±8)
Fall	16.4 (±6.6)	3.9 (±2.5)	156	172 (±13)
Smolt	3.3 (±5.3)	0.2 (±2.2)	568	19 (±15)

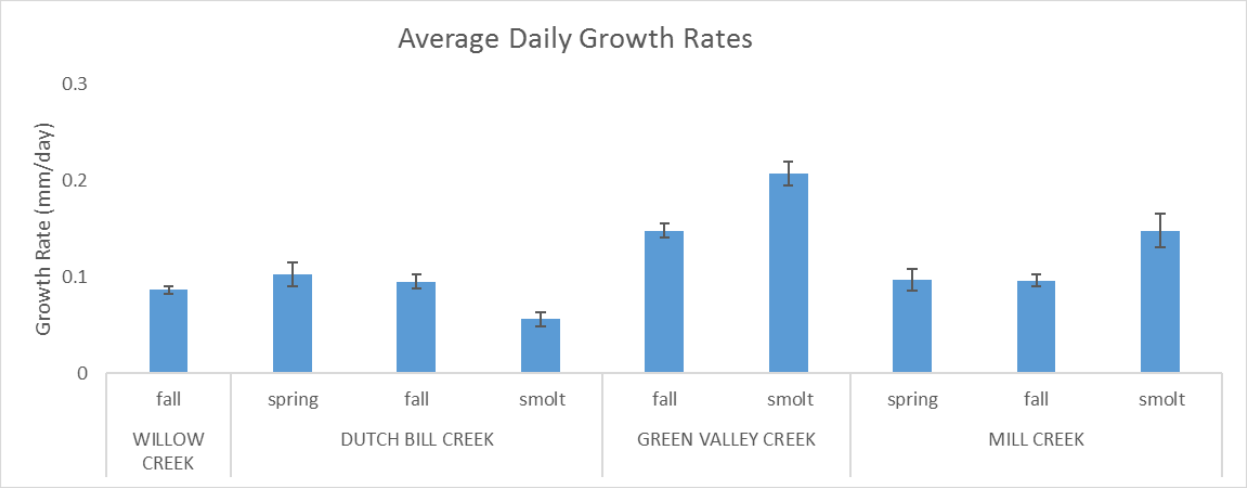


Figure 20. Average daily growth rates in fork length (mm) of PIT-tagged smolts that were recaptured at downstream migrant traps during the 2016 season, by stream and release season.

Discussion and Recommendations

During the 2016 smolt trapping season, we anticipated fewer hatchery coho salmon smolts emigrating from the Broodstock Program streams than in previous years due to the reduced number of fish released into the Russian River watershed for cohort 2015 (70,510, or 39% of the previous five-year average of ~179,050). While in recent years the Broodstock Program has been stocking 20 streams, the 2015 cohort was stocked into only seven streams, including Willow, Dutch Bill, Green Valley, and Mill creeks. Release numbers in these four Broodstock Program monitoring streams were reduced for the 2015 cohort; Green Valley and Dutch Bill creeks received approximately 80% of the fish they have received in recent years, and Willow and Mill creeks received

approximately half. In Mill Creek, estimated abundance (6,655 smolts) in 2016 was lower than the 12-year average of 9,252. In the other streams, however, 2016 estimated abundance was higher than each stream's respective long-term averages. In Willow Creek, for example, smolt abundance was the second highest observed in the last five years, yet it represented smolt production from the smallest release of coho salmon into Willow Creek. Relatively higher than average overwinter survival likely kept smolt abundance from decreasing as low as expected in each of the four streams (Table 7, Figure 5), and in Willow Creek, we suspect that a 21% natural origin rate (Table 5) may have also increased smolt abundance above anticipated values.

Survival of spring-released juvenile coho salmon from the time of release in mid-June 2015 to the smolt stage in spring 2016 was extremely low, approaching zero in Green Valley and Dutch Bill creeks (Table 7). In 2015, the Broodstock Program, in anticipation of a fourth year of drought during the summer of 2015, chose to release only approximately 1,800 fish in the spring for the purpose of continuing a summer survival study conducted by 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 (one reach) rather than distributed evenly throughout the watersheds, as with the fall releases. It is important to recognize that the 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. However, based on summer snorkeling survey and wetted habitat data collected during the summer of 2015, we concluded that survival of naturally-spawned and hatchery coho salmon present in the streams during summer of 2015 was likely close to zero in most reaches (Obedzinski et al. 2016).

The stock-to-smolt survival estimate for the Mill Creek spring release group was notably higher than fish released into reaches of Dutch Bill and Green Valley creeks (Table 7). The Mill Creek reach where these fish were released is located 12 km upstream of the mouth and has remained hydrologically connected every year since our survival study began in 2009, even in the most extreme drought years. Identifying, protecting, and ensuring that fish have access to these drought refuges is critical for reaching the Broodstock Program's long term goal of re-establishing self-sustaining runs of coho salmon. Based on the low summer survival observed in most streams in 2011 through 2015, we recommend that the Broodstock Program continue its strategy of reducing (or eliminating) spring releases during drought years. In non-drought years, we recommend spring-releases only in reaches that have been observed to hold water year-round (Obedzinski et al. 2016).

Overwinter survival was relatively high compared to previous years of data collection (Figure 5). Contributing factors may include lower stocking densities for the 2015 cohort, and the nature of the storm events during the winter of 2015/16. Precipitation was relatively consistent, with more frequent and less extreme storm events than in recent winters, which produced sufficient winter base flows and instream flow conditions that were, generally, less flashy and more well-suited for supporting overwintering juveniles.

Over the last four years of data collection, early winter emigration rates (prior to March 1) were significantly higher on Dutch Bill Creek than in the other three Broodstock Program monitoring streams (Figure 6). During the winter of 2015/16, both spring and fall release groups showed large pulses of emigration associated with winter storms occurring prior to March 1 on Dutch Bill Creek (Figure 9, Figure 10). Smaller winter pulses were observed at the Willow Creek smolt trap site and in Mill Creek (Figure 7, Figure 13); however, fish that moved downstream past the upper Willow antenna site were not detected at the lower site until after March 1. 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. Efforts by Gold Ridge Resource Conservation District are underway to increase wood structures in the middle reaches of Dutch Bill Creek, and this will hopefully begin to address this issue.

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). 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. Survival of coho salmon smolts from when they are removed from the tank and placed in the stream until they reach the antenna array near the mouth, has ranged from 0.64 to 0.82 since 2011 (0.73 average). Although the adult return sample size has been too small to fully evaluate imprinting success, we have observed tank-held smolts returning as adults to Dutch Bill Creek, suggesting that the fish are successfully imprinting.

Survival of smolt-released fish placed in the instream pond on Mill Creek for imprinting has been lower over the last few years, ranging from 0.32 to 0.58 from 2010 through 2014. We think that the higher probability of survival in 2016 (0.86) was due to the fact that fish were able to escape the pond and left Mill Creek within a few days (Table 8) rather than being subject to potentially mortality associated with being contained in a pond for a month. Although adult sample size has been too small to compare return rates of stream-released versus pond-released smolts, we have observed pond-release adults returning to Mill Creek, indicating some measure of imprinting success. However, due to the lower survival probability in previous years and the difficulties of containing fish within an instream pond, we recommend exploring locations where imprinting tanks could be placed and operated on Mill Creek; possibly at Westside School, which would also allow for educational opportunities.

Freshwater growth in Green Valley Creek was remarkably higher than in the other three Coho Broodstock Program monitoring streams (Figure 20). This was the only stream in which natural-origin coho salmon smolts (average 122.7 mm and 19.3 g) were larger than hatchery released smolts (average 119.1 mm and 17.6 g) (Table 11). 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 summary, during the spring of 2016, 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 expected, survival was lowest for the spring release group which spent a year in the stream environment during a severe drought, 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, and smolt release groups.

III. References

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