2015 Annual Report for the Green Valley Creek Winter Refugia Enhancement Project

September 2015

Prepared By: Amelia Johnson and Mariska Obedzinski
UC Cooperative Extension/California Sea Grant Coho Salmon Monitoring Program
133 Aviation Boulevard, Suite 109
Santa Rosa, CA 95403

Introduction

Green Valley Creek

The University of California Cooperative Extension and California Sea Grant (UC) coho salmon program has monitored wild and hatchery coho salmon populations in the Russian River watershed since 2004 as part of the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP). Part of the hatchery stocking and monitoring efforts occur in Green Valley Creek, one of the last tributaries in the Russian River watershed with known wild coho. As part of its coho recovery efforts, the RRCSCBP releases juvenile coho into the Green Valley Creek basin in the spring and fall seasons, as well as one-year old smolts in early spring. Beginning in February 2014, a pre-smolt release was added due to the relatively high quality habitat in the Green Valley watershed, determined partially by high summer survival rates, relatively robust coho salmon spawning return numbers, and large coho smolts observed at spring downstream migrant smolt traps (UC 2012). From Fall 2014 through Spring 2015, approximately 37,000 juvenile hatchery coho were released in Green Valley watershed, primarily upstream of the Green Valley Creek Winter Refugia Enhancement Project (enhancement reach). To monitor stocking efforts, the UC operates Passive Integrated Transponder (PIT) antennas at multiple locations throughout the watershed, including three sites in Green Valley Creek (Figure 1). Since a known percentage of hatchery release coho are PIT tagged (about fifteen percent per release group), it is possible to estimate the total number of hatchery coho migrating out of antenna monitored reaches, including in the Green Valley Creek enhancement reach. The PIT antenna monitoring infrastructure provides a unique foundation for evaluating the effects of the enhancement reach on the coho populations in Green Valley Creek by providing movement data for PIT-tagged coho through Green Valley Creek and across the lower Russian River watershed.

Project Objectives

The objective of the Green Valley Creek Winter Refugia Enhancement Project is to improve off channel habitat to provide velocity refugia habitat for overwintering juvenile coho salmon. The project reach floods readily in the winter, so much so that stream flows may be too swift for the area to provide adequate refuge. Creating off-channel habitat provides this needed slow flow refugia to juvenile salmonids during winter high flow events.

The biological monitoring objectives of this project are to assess habitat use by coho prior to and after the enhancement project. From November 2013 through Spring 2014, pre-enhancement monitoring occurred in the reach (Year One). The off-channel enhancement was completed during the summer of 2014 and the post-enhancement monitoring began that fall (Year Two).

Year One Project Accomplishments

Pre-Enhancement flow and fish passage data were collected from November 2013 through June 15, 2014. Data was collected through the use of PIT antenna arrays, a pressure transducer flow gauge, and in-stream flow measurements in the Green Valley Creek main channel site adjacent to the planned off-channel enhancement. Data was summarized to quantify coho salmon movement and residence timing through the enhancement reach prior to any habitat modifications. Preliminary conclusions are that juvenile coho did not rely upon this study reach for winter refuge habitat, but instead migrated through the reach in the spring, after winter flows subsided. The vast majority of coho salmon moved through the reach relatively quickly, with 93% passing through the reach in less than 30 minutes. This suggests that the project reach prior to enhancement did not provide winter refuge habitat, but was only utilized as a migration corridor by coho salmon smolts.

Year Two Project Accomplishments

The enhancement project construction was completed in the summer of 2015. Once off-channel dimensions were confirmed that summer, the monitoring program designed and constructed two additional PIT antenna monitoring sites, GRE-6.09 and GRE-6.03 (Figure 2, Figure 3). These arrays were added to the off-channel inlet and outlet in November 2014 to capture movement of PIT-tagged individuals into and through the off-channel habitat, including Thomas Creek. The main channel arrays from the pre-project phase remained in operation to continue to capture movement of fish through the main channel section of the enhancement reach. A pressure transducer gauge was also added to the off-channel habitat to allow for comparisons between main and off-channel stream stage and flows. Gauge placement was just upstream of the PIT antenna array GRE-6.03 to capture stream flow through the off-channel habitat when fully connected.

Methods

PIT Tagged Individuals

Monitoring of overwinter habitat use for the project reach was based on two coho hatchery release groups: juvenile coho released into the watershed prior to winter rains (Spring 2014 and Fall 2014 release groups) and juvenile coho released in mid-February that partially reared in winter stream habitat (Pre-Smolt 2015). The Spring 2014 and Fall 2014 individuals are especially beneficial to the study of winter rearing behavior since they have the opportunity to acclimate to the stream environment prior to winter rains and spend the entire winter season in the watershed. Pre-smolt release fish do not provide as complete of a picture of winter rearing behavior since many hatchery release fish exhibit a flight behavior upon stocking, which may mask natural winter habitat use patterns for these individuals.

PIT Antenna Detection

Data was collected continuously on the main channel PIT antenna arrays (GRE-6.01 and GRE-6.13) (Figure 2) from the time of PIT antenna installation in November 2013 through September 2015. The antennas at site GRE-6.01 were temporarily turned off between July and November 2014 during off-channel construction, however, the antennas at site GRE-6.13 collected data through the project construction to track any potential summer movement (n = 1). Following project construction, additional antennas were installed in the new off-channel habitat (sites GRE-6.03 and GRE-6.09) (Figure 2, Figure 3) and they were operated from November 2014 through September 2015. This post-project start date was prior to winter rains, so that the full season of winter flows and coho salmon movement could be captured.

Antenna data consists of the date, time, and unique tag number of each detected PIT-tagged fish, as well as the individual antenna within an array that a detection occurs. All antenna data within the enhancement reach was collected by one data logger powered with solar-charged batteries. This allowed for easier data management since all detection times are comparable within the enhancement reach. The data logger time was compared to Pacific Standard Time on an atomic watch approximately every two weeks during PIT antenna maintenance checks. This time comparison was then used to calculate an adjusted time for each tag detection in the enhancement reach, which allows for more accurate PIT tag detection time comparisons across the watershed. Downloaded antenna data was then uploaded to a UC Microsoft Access database, where antenna location (upstream or downstream within an array) and antenna site (GRE-6.13, GRE-6.09, GRE-6.03, or GRE-6.01) were included along with the PIT tag number, adjusted detection time, and date of detection. This database also includes all PIT-tagged fish release information for the Russian River watershed. Since each PIT number is unique to an individual fish, each tag detection at an antenna was linked to the initial tagging and release of that fish from the hatchery. Fish origin, stocking season, and age could then be determined. Known ratios of PIT-tagged individuals to non-tagged individuals for each release group could then be used to expand the

number of unique detections on the antenna arrays to estimate the total number of fish passing each antenna.

Antenna status reports are also stored in four hour increments by the data logger to track any changes in PIT antenna detection efficiency based on antenna current, solar power supply, and electrical interference. Lower antenna currents and high electrical interference can decrease antenna detection efficiency and are considered in daily status values for sites. Power supply issues can turn off antennas, thus reducing the probability of PIT tag detection to zero. These status reports, in combination with PIT tag detections were used to troubleshoot problems related to power supply and/or electrical interference.

Since arrays consist of upstream and downstream antennas, the migration rate, direction (upstream or downstream from an antenna array), and detection efficiency between the arrays can be determined. Migration rates through the enhancement reach were estimated for coho detected at both main channel antenna arrays and were based on the first detection of each PIT tagged fish at each array. Migration rates through the off-channel enhancement were calculated the same way, but from detection data at GRE-6.09 and GRE-6.03. Antenna efficiencies were estimated for each array by calculating the percentage of tagged individuals detected at the upstream antennas in comparison to both upstream and downstream antennas in a single PIT array. Antenna efficiencies along with known proportions of tagged to untagged hatchery coho were then used to estimate the total number of hatchery juvenile coho salmon migrating past the enhancement corridor.

Stream Flow

The pressure transducer gauges collect water pressure (PSI), temperature (°C), and depth (feet) of the logger in fifteen minute intervals. This data was then compared to cross section flow surveys that were conducted adjacent to the gauge sites in the main channel and off-channel at a range of stages and flows (Somers and Buchanan, 1969). Calculated flow was summarized as minimum, maximum, and daily flow averages (cubic feet per second) per day. Stream flow data was also compared to a U.S. Geological Survey flow monitoring site in Austin Creek, which has comparable precipitation and stream flow patterns to Green Valley Creek. This comparison increased confidence in trends at the enhancement reach flow sites.

Results

PIT Antenna Detection

Main channel antenna efficiency was comparable to the previous season (Table 1) and to other UC PIT antenna sites in the watershed. Within arrays, antenna efficiency was 88% for GRE-6.13 and 84% for GRE-6.01. Lower efficiency at GRE-6.01 is likely due to the staggered placement of the antennas at this site, which allows for full-channel coverage, but a gap where both antennas span the same stream section. Lower antenna detection efficiencies than the previous year could also be due to antenna power supply issues during the winter and higher peak flow events during the post-enhancement phase of monitoring.

Due to the drought conditions during both monitoring years, winter flows were extremely limited and thus so was winter fish movement data. Prior to peak juvenile coho passage this spring, only four overwintering PIT tagged coho were detected at any antenna sites in the enhancement reach (Figure 4). Based on calculated flow in the enhancement reach, the off-channel enhancement was also only likely fully connected for about 26 days between November 2014 and June 2015 (Figure 6). Due to this limited window of habitat availability, sample size for the off-channel antenna sites was extremely limited (n = 2

for GRE-6.03 and n = 12 for GRE-6.09). Additionally, detection efficiency for antennas is calculated based on the assumption that fish are moving past the entire PIT antenna array. This may not be true for fish detected in the off-channel habitat since these individuals may only be holding at the inlet or outlet of the off-channel habitat rather than passing through the full side channel. This would reduce calculated detection efficiency at the off-channel antenna sites because there would only be a detection opportunity at half of each antenna array. Furthermore, there is some uncertainty in whether or not antennas were fully operational during mid-January due to limited PIT detections and antenna status reports (Figure 5). However, PIT tagged coho detections were also fairly limited at GRE-9.98, the antenna site upstream of the enhancement reach. About 33% of PIT tagged overwintering coho were detected at this antenna site during the winter season (December 2014 – February 2015) and only two individuals were detected during the period of low antenna status certainty at the enhancement reach. These data suggest that little fish movement was occurring in the system overall, and the likelihood of missing many fish moving through the enhancement reach is relatively low in comparison to the spring smolt run.

Stream Flow

The UC conducted 18 cross section flow surveys in the main stream channel and six cross section flow surveys in the off-channel sections of the enhancement reach at a variety of flow conditions. However, high flow events were often unsafe to measure during cross section flow surveys, which reduces the range of the measured flow rating curve. Since the maximum measured flow during a cross section survey at the main channel gauge site was 61 cubic feet per second (cfs) at 2.51 foot stage depth, calculated flow data at flows greater than this maximum measured point are presented with high uncertainty (Figure 6).The maximum cross-section flow measurement for the off-channel gauge site was 15 cfs at 3.12 stage depth, so calculated flows greater than this maximum measured point are also presented with high uncertainty. To address these uncertainties, Green Valley Creek flow data was compared to the U.S. Geological Survey Austin Creek flow site, since these sites have similar precipitation and hydrology patterns. Flow trends between the sites compared well (Figure 7), thus improving confidence in comparing general stream condition patterns in flow and depth to coho migration timing through the enhancement reach.

Migration and Residency Timing

The majority of fish passage through the enhancement reach occurred after winter peak flows resided and the off-channel habitat was only partially connected or disconnected from the main channel (Figure 4). Residence time increased slightly when compared to the pre-enhancement data set for overwintering juvenile coho: the majority of fish (72%) migrated through the enhancement reach in less than 30 minutes compared to 94% of fish migrating through in the same time frame prior to enhancement (Table 2).

There were no overwintering PIT-tagged juveniles detected at both main channel antenna arrays and an off-channel array nor were there any overwintering PIT-tagged juveniles detected migrating through the off-channel enhancement. Instead, fish released as part of the pre-smolt release group were used to study the effect of off-channel residency on total residence time in the enhancement reach since many accessed the project reach when the off-channel habitat was fully or partially connected to the main channel. The pre-smolt release fish did reside longer on average than the fully overwintering fish: only 55% of this release group migrated through the project reach in less than 30 minutes versus 72% of overwintering fish. While less than 1% of overwintering juveniles resided for more than 24 hours in the project reach, 6% of pre-smolt individuals moving downstream resided for multiple days, with an average of more than three weeks (Table 2).

Estimated Number of Coho Salmon

From the antenna installation in November 2014 through June 15, 2015, 437 unique PIT tagged overwintering juvenile coho were detected in the enhancement reach. Based on these detections, the estimated number of overwintering hatchery coho migrating through the project reach is 2,767 for the post-enhancement study period (Table 3). This excludes the pre-smolt and smolt release detections, which add an additional 2,142 unique PIT tag detections and 14,280 estimated juvenile coho salmon migrants, which raises the total number of juvenile coho salmon detected in the project reach to 2,579 and the estimated total to 17,047.

A few juvenile coho salmon were detected at just one off-channel enhancement antenna, indicating at least partial use of the off-channel enhancement. Overwintering juvenile coho were detected at GRE-6.03 (n = 1) and GRE-6.09 (n = 2), in addition to a smolt release (n = 1) and some pre-smolt individuals (n = 11) at GRE-6.03. Based on these detections, the estimated number of juvenile coho salmon utilizing at least partial off-channel habitat is 94, or just 0.55% of the total estimated number of juvenile coho salmon passing through the enhancement reach from November 2014 through June 2015.

Adult Use of Off-Channel Habitat

Returning adult coho often move into spawning tributaries during high winter flow events, which means they may benefit as well from the enhancement reach in lower Green Valley Creek. This past winter, ten PIT tagged adult coho were detected moving through the enhancement reach during the early December and February storm events. Five of these adults were detected in the off-channel habitat, although only at the off-channel enhancement upstream array (GRE-6.09). This suggests that upstream spawning adults may benefit from the enhancement project, most likely as a resting opportunity before continuing upstream to spawning habitat in Green Valley Creek. Eight of the adult coho detected at the enhancement reach were also detected at upstream antennas after passing through the enhancement reach, which indicates that they successfully reached spawning habitat.

Discussion

Migration and Residency Timing

Pre and post-enhancement monitoring has only occurred during drought years, and thus movement timing and residency patterns of overwintering coho observed may not be typical of average or wet winters in the watershed due to lower peak and baseline flow conditions. Overwintering juvenile coho salmon appear to rely on rearing habitat upstream of the project site since most fish are not detected moving through until after winter base flows reside, in April and May. This is true of both Purrington and Green Valley Creek release groups, although a larger proportion of Purrington Creek fish were detected moving between the two Green Valley antenna arrays downstream of Purrington Creek (GRE-9.98 and GRE-6.13) in the early winter than fish released in Green Valley Creek. This suggests that less winter rearing habitat may be available in Purrington Creek than upper Green Valley (Table 4). Potential winter rearing habitat upstream of the enhancement reach could include the Atascadero Creek sub-basin, which connects to Green Valley Creek about 1.5 river kilometers downstream of the GRE-9.98 PIT antenna site and includes wide, inundated floodplain habitat during flood events. Additional winter habitat could include ephemeral tributaries in Green Valley Creek upstream of GRE-9.98 where wild coho salmon young-of-year were observed this spring (UC published data). Spawning habitat in Green Valley Creek has primarily been observed upstream of GRE-9.98, which may further provide winter rearing benefits through additional food resources for juvenile coho. Food resources could be directly

from spawner carcasses and eggs or increased stream productivity due to decomposing carcasses, which in turn could increase macroinvertebrate biomass.

The addition of a pre-smolt release during the post-project phase did allow for some understanding of how juvenile coho may utilize off-channel habitat when available during the winter. Off-channel habitat was found to correlate with slower average migration times through the project reach for the February, pre-smolt release group. This suggests that if fish move through when off-channel habitat is available, this additional habitat does correlate with slower migration times. This could be due to refugia benefits for juvenile coho salmon provided by the inundated off-channel enhancement. Benefits provided by the off-channel enhancement could be reduced stream flows, predation pressure, or niche space competition, as well as increased feeding opportunities that are not provided in the main channel component of the enhancement reach.

Watershed Context

The majority of detected overwintering coho salmon in the enhancement reach were initially released in the Green Valley Creek basin as juveniles: 323 detected overwintering fish were released into Green Valley Creek and 112 were released into Purrington Creek. The remaining detected fish were released in Pena (n = 1) and Freezeout Creek (n = 1) in Fall 2014. Additional juvenile coho from outside the Green Valley Creek basin were detected downstream of the enhancement project at the Green Valley Creek smolt trap: a single PIT-tagged juvenile fish from Freezeout Creek, Mill Creek, and Dutch Bill were each detected moving downstream in March and April, suggesting their residency in lower Green Valley Creek prior to the trap installation on March 10, 2015. Although these fish represent a very small percentage of total overwintering fish, their presence does support cross-stream connectivity and use of Green Valley Creek as winter rearing habitat for coho across the lower Russian River watershed. This is comparable to the pre-enhancement data, which included one PIT tagged fish each from Mill Creek and Pena Creek in the Dry Creek basin of the watershed.

An additional consideration is the movement of juvenile coho salmon through the Green Valley Creek basin as a whole. When comparing detection timing at the enhancement project to two PIT antenna sites upstream, there is a noticeable pattern in movement rate over the course of the winter and spring. Fish moving out of upper Green Valley Creek early in the winter move primarily with initial winter flow increases and then take more days to reach the next antenna site in comparison to fish that leave upper Green Valley after winter flows reside in the spring during the typical smolt migration window of March through June (Figure 8). Furthermore these fish seem to be separated into three distinct groups: early winter migrators (December – January), mid-winter migrators (February – March), and spring migrators (April – June). These groupings most likely correspond to a storm event in early December (early-winter), a storm event in early February (mid-winter) and the typical smolt migration period (spring). By looking at the movement timing of individual early and mid-winter migrators that were detected at all three antenna sites, it appears that the majority of the fish spent multiple weeks in the reach between GRE-13.40 and GRE-9.98 *or* in the reach between GRE-9.98 and GRE-6.13, but did not spend multiple weeks in both (Figure 9). These extended residency times in both reaches imply that there is suitable overwinter habitat between both sets of antenna arrays upstream of the enhancement project.

Monitoring Conclusions

The Green Valley Creek Winter Refugia Enhancement Project did reduce winter stream flows in the project reach by providing additional habitat to dissipate large winter storm flow conditions. Although very few overwintering coho were detected in the newly-created off-channel during the winter of 2014-2015, this is primarily explained by the fact that there were rarely flow conditions high enough to wet

the off-channel enhancement. Additionally, almost no fish passed through the off-channel enhancement until the beginning of the smolt migration in March. Based on winter movement patterns observed during early winter in other years and tributaries, it was expected that more juveniles would move through the project reach during early winter storm events, such as the one that occurred during the first week of December. For instance, winter monitoring encompasses both average and dry years in Willow Creek in the Russian River watershed and there are pronounced differences in winter movement behavior between these dry and wet winter seasons with more early winter fish movement downstream occurring in the wet winter of 2012-2013 than in the last two drought winters of 2013-2014 and 2014-2015 (UC unpublished data). The UC did observe movement from the stocking locations to the upper and middle reaches of Green Valley during the December and February storms, but did not detect these fish as far downstream as the project site until spring, suggesting that suitable winter habitat was encountered upstream of the project reach. The pre-smolt release fish in Green Valley Creek migrated through the enhancement reach when the off-channel was at least partially activated, unlike the majority of overwintering juvenile coho. These individuals were found to utilize the off-channel habitat slightly differently than overwintering juveniles, with partial off-channel enhancement residency and longer residence times overall in the enhancement reach. Furthermore, riparian plantings in the enhancement reach have yet to fully establish. As the riparian zone continues to mature, biological productivity in the enhancement reach could also increase due to additional nutrient and allocthonous macroinvertebrate inputs, which may improve winter rearing habitat by providing additional energy resources for juvenile coho.

Reference

Buchanan, T.J., and Somers, W.P. 1969. Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A8, 65 p. (Also available at http://pubs.usgs.gov/twri/twri3a8/.)

University of California Cooperative Extension and California Sea Grant. 2012. Recovery Monitoring of Endangered Coho Salmon in the Russian River: Final Report for US Army Corps of Engineers Contract W912P7-10-C-0011, March 2012. Santa Rosa, CA.

Figures

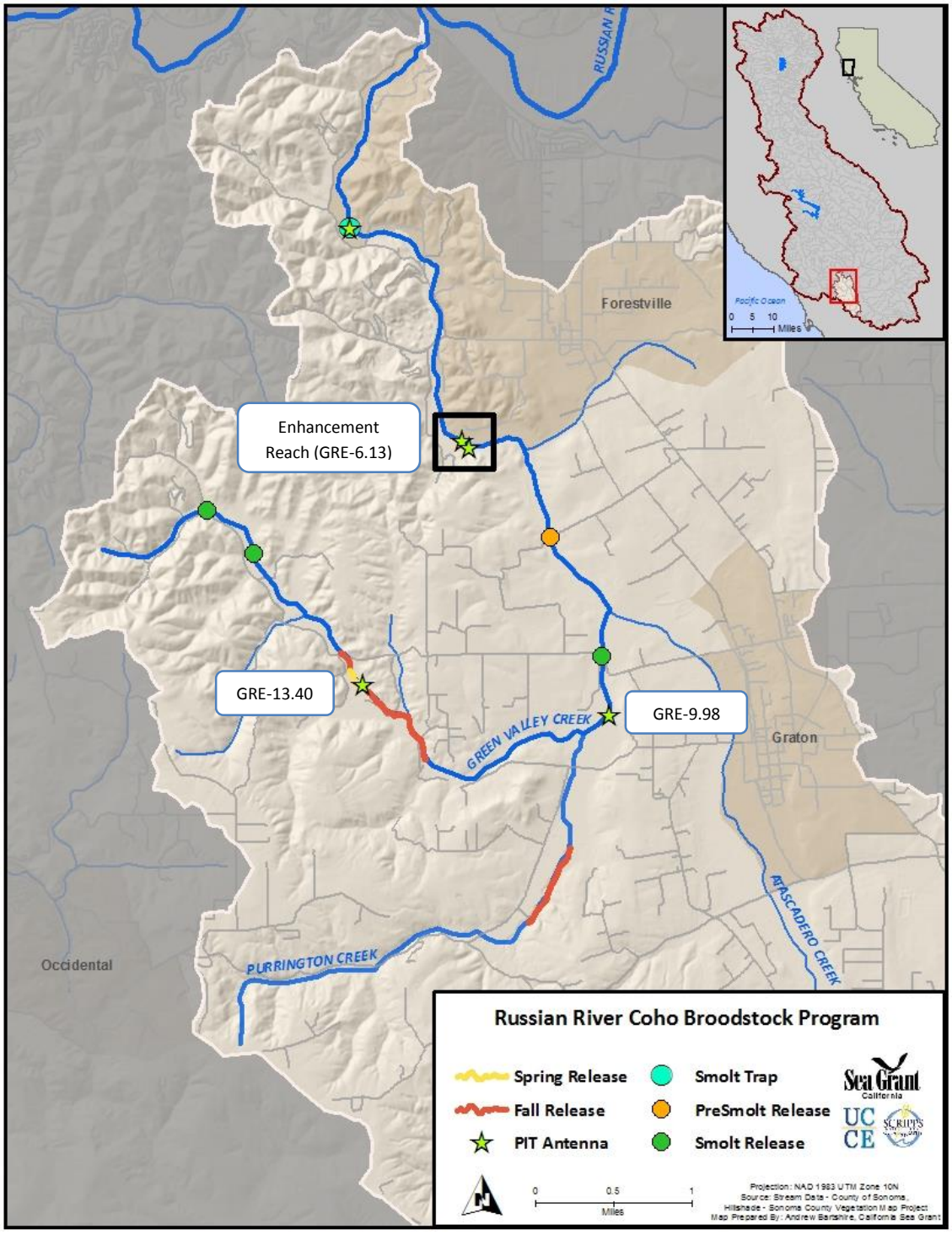

Figure 1. Green Valley Creek watershed year-round PIT antenna monitoring sites, spring downstream migrant smolt trap, and seasonal stocking reaches and sites for 2014-2015 monitoring time period. Antenna sites are named for their river kilometer location upstream from the mouth of Green Valley Creek.

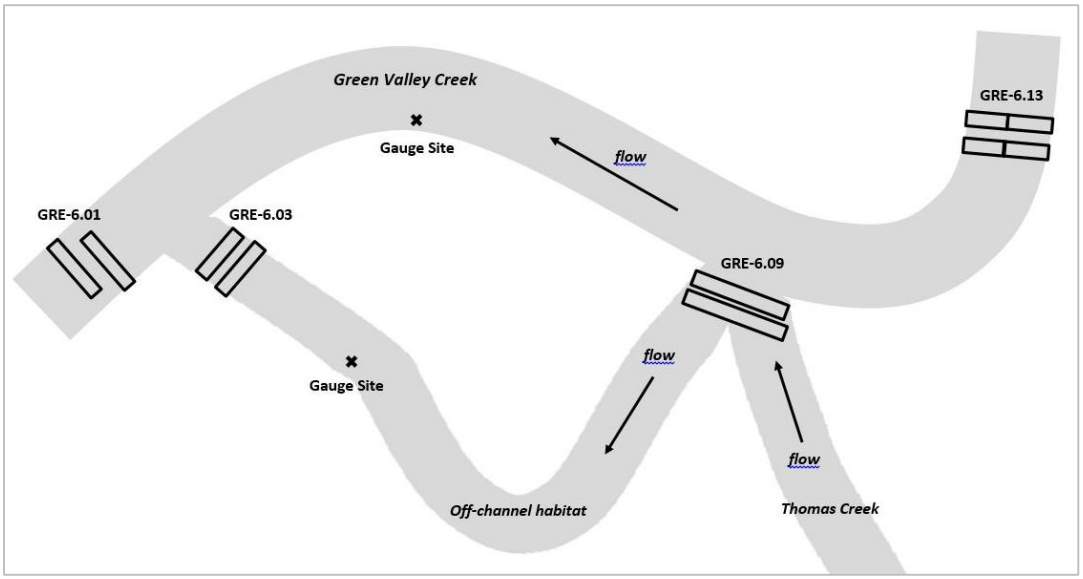

Figure 2. PIT antenna arrays and pressure transducer gauges in the Green Valley Creek Winter Refugia Enhancement Project. PIT antenna arrays GRE-6.13 and GRE-6.01 were established in Fall 2013, along with the main channel flow gauge. PIT antenna arrays GRE-6.09 and GRE-6.03 were installed along with the off-channel gauge site following the completion of off-channel construction in Fall 2014.

Figure 3. Off-Channel PIT antenna sites prior to winter flows (top two photos) and after the habitat was activated (bottom two photos). The off-channel inlet array, GRE-6.09, is on the right and the off-channel outlet array, GRE-6.03, is on the left.

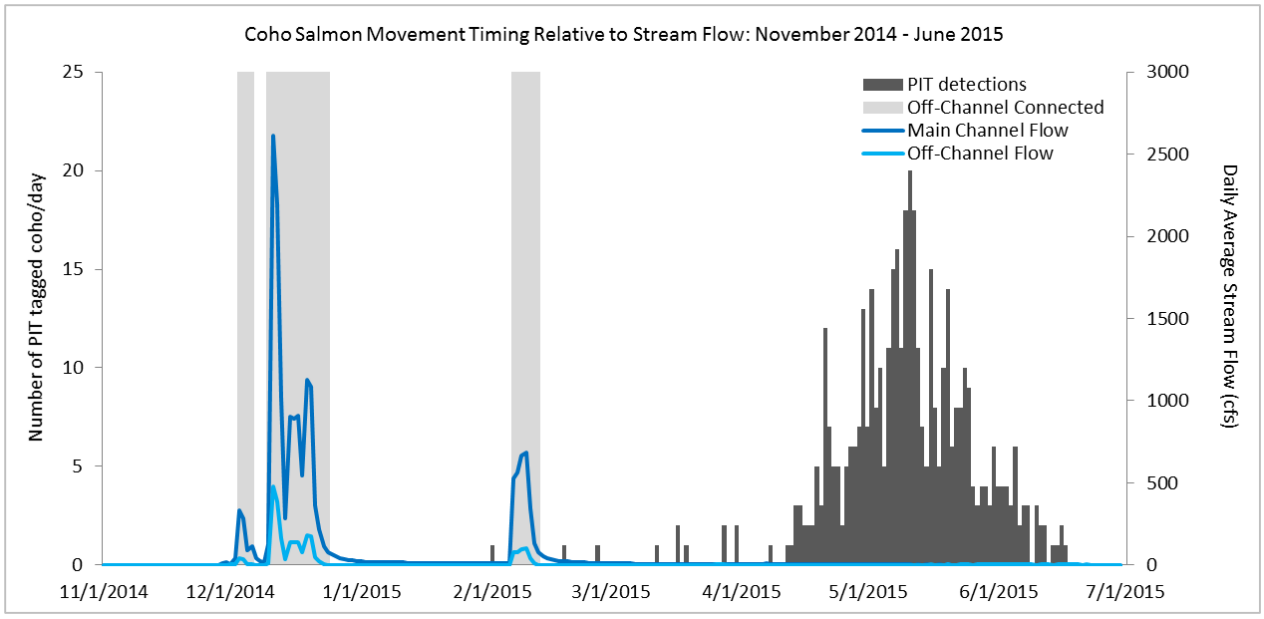

Figure 4. Number of unique PIT tagged hatchery coho salmon juveniles detected in the enhancement reach per day (n = 437) relative to daily calculated stream flow through the main channel of Green Valley Creek and the off-channel enhancement project. Detection date is based on the first date of detection for each individual. Light gray bars signify days that the off-channel enhancement site was fully connected and accessible for complete fish passage, based on flow conditions. Only overwintering hatchery coho salmon (spring and fall release groups) are depicted in this figure.

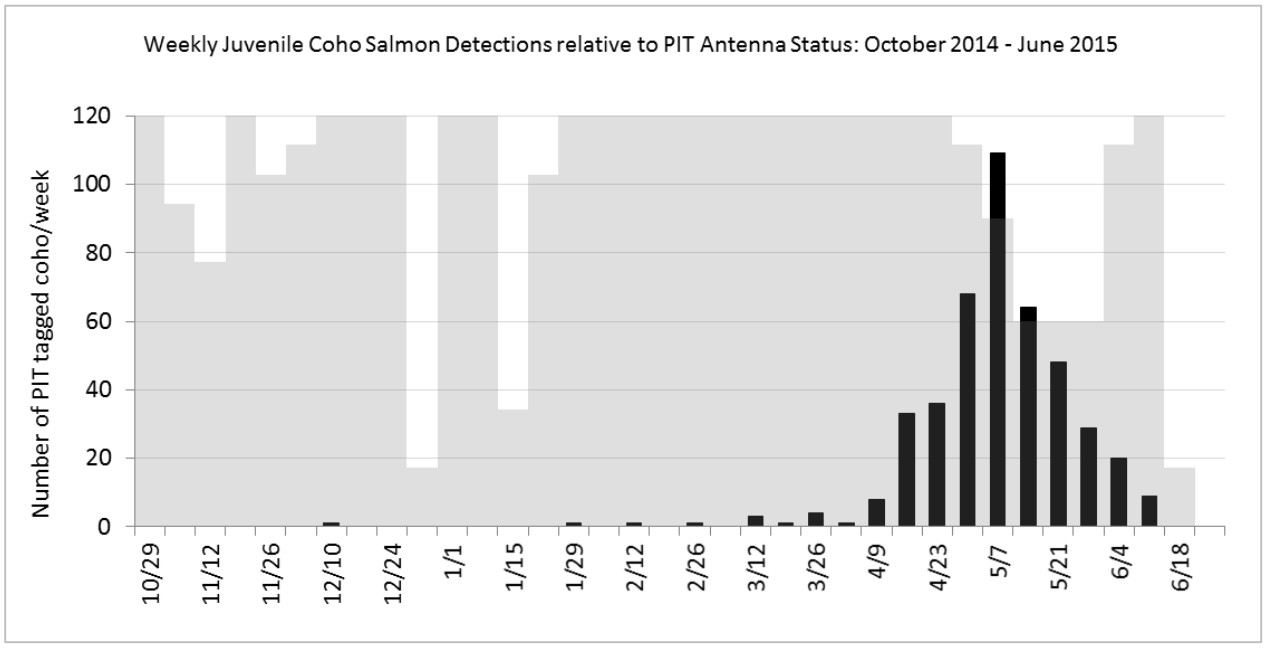

Figure 5. The weekly cumulative number of PIT-tagged overwintering juvenile coho salmon per week detected in the enhancement reach with antenna detection status shown in the gray background bars. Full detection status for a given week is represented by a full gray bar while partial to no detection status is shown by the gaps in gray bars (n = 437).

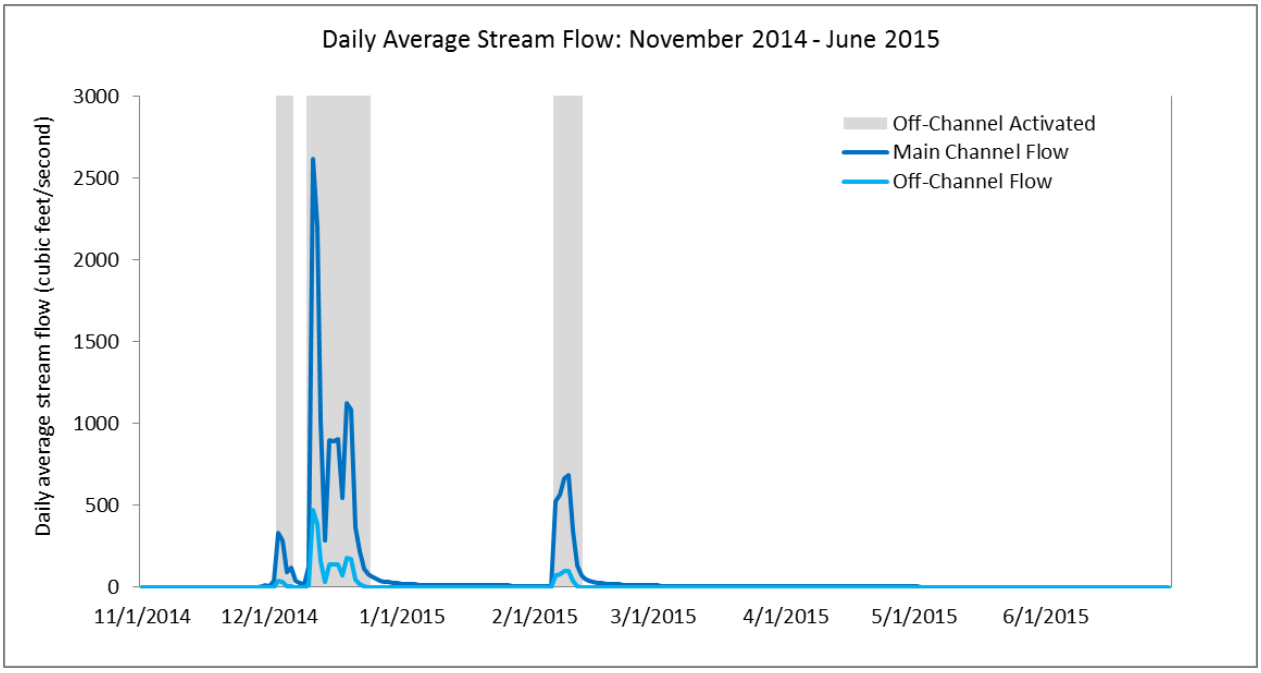

Figure 6. Daily average flow (cfs) through the enhancement reach. Gray bars note time periods when the off-channel habitat was fully connected to the main channel, based on flow conditions. Maximum stream flow confidence levels are 61 cfs for main channel flow and 15 cfs for off-channel flow due to in-stream flow surveys not occurring above these conditions.

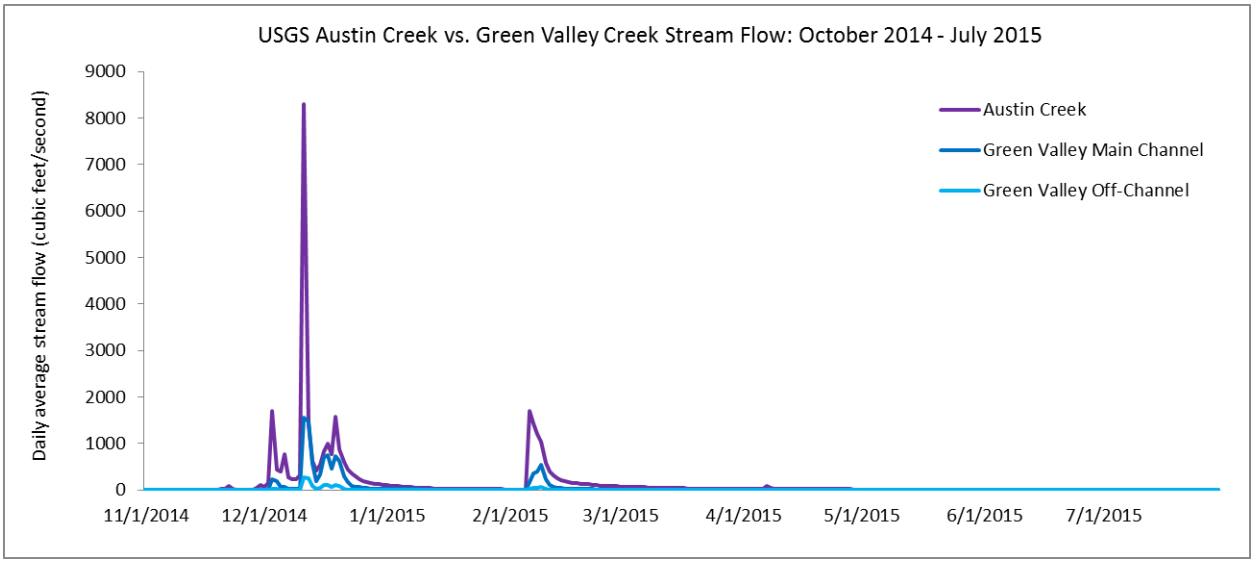

Figure 7. Calculated stream flow comparison between the two Green Valley Creek enhancement reach flow gauges and the USGS Austin Creek flow site.

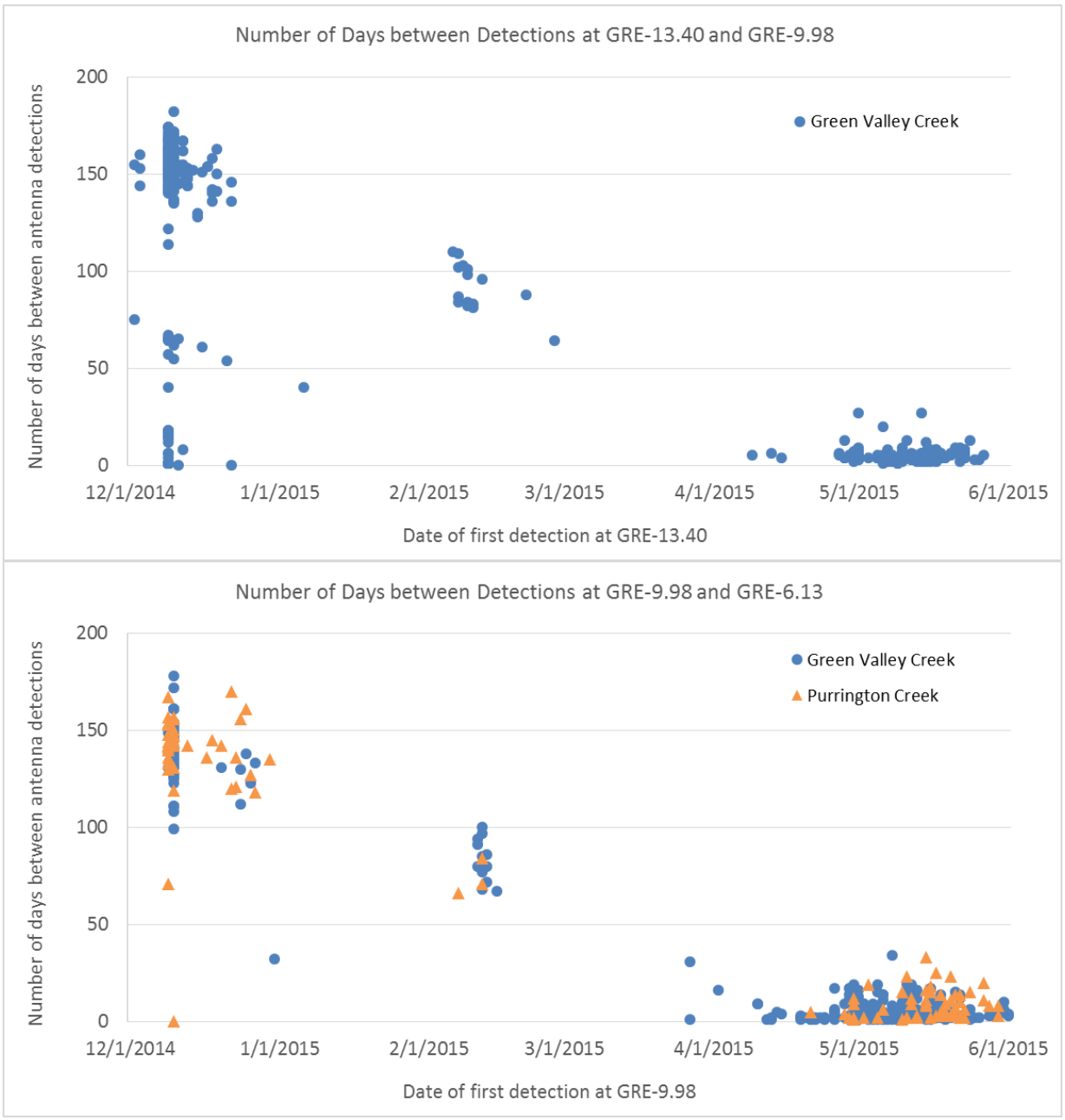

Figure 8. Number of days between initial PIT tag detection at Green Valley Creek PIT antenna sites: December 2014 - June 2015. Sites are moving downstream through Green Valley Creek, with GRE-13.40 located the farthest upstream (13.40 rKm from the mouth of Green Valley Creek), then GRE-9.98 located just downstream of Purrington Creek, and the enhancement reach at GRE-6.13. Data is for fish released in Green Valley Creek and Purrington Creek, although no Purrington Creek fish were detected at GRE-13.40. GRE-9.98 is just downstream of the mouth of Purrington Creek and can thus account for movement from juvenile coho salmon released in both streams.

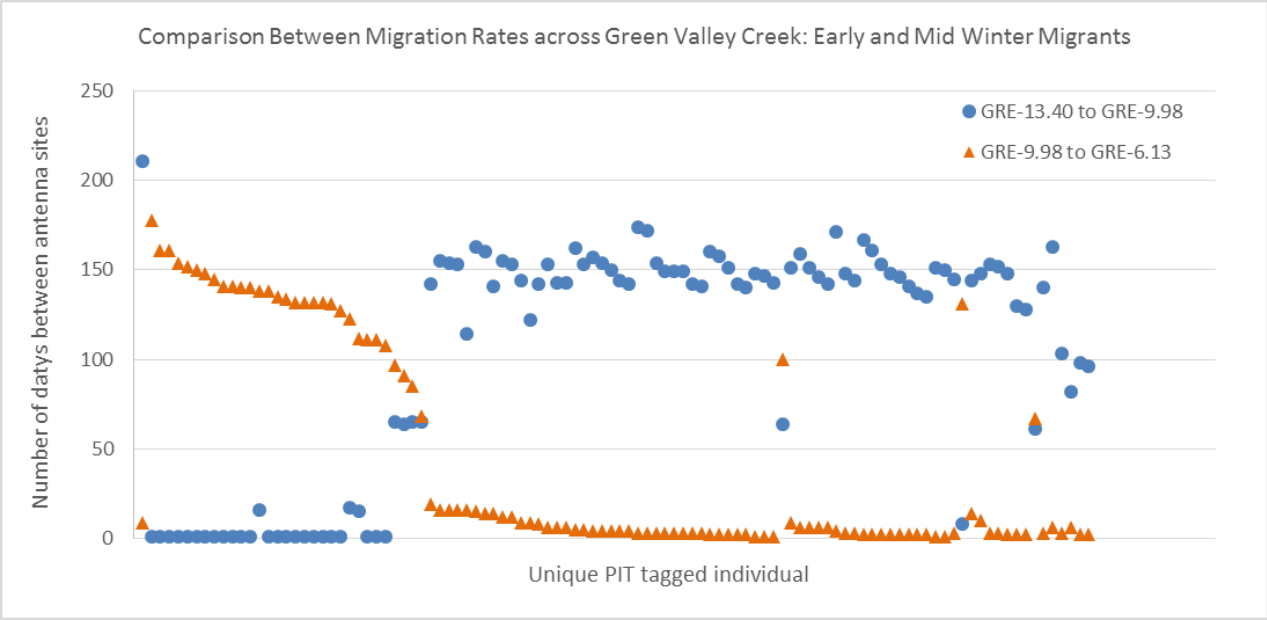

Figure 9. Migration speed of overwintering juvenile coho salmon between the three PIT antenna monitoring sites in Green Valley Creek (n = 106). Individuals included were detected at all three sites (GRE-13.40, GRE-9.98, and GRE-6.13) and were first detected at GRE-13.40 in the early or mid-winter (December 2014 – February 2015).

Tables

Table 1. Efficiency of PIT antenna arrays in the Green Valley Creek enhancement reach prior to and following the enhancement project. Detection efficiency was calculated based on all juveniles coho salmon detected at multiple antennas within the project reach.

Within Array Detection Efficiency						
Reach	Pre-Enhancement Project			Post-Enhancement Project		
	PIT Array	Efficiency	Sample Size	PIT Array	Efficiency	Sample Size
Main Channel	GRE-6.13	98%	2,060	GRE-6.13	88%	1,161
	GRE-6.01	77%	1,258	GRE-6.01	84%	1,767
Off-Channel	-	-	-	GRE-6.09	50%	2
	-	-	-	GRE-6.03	8%	12
Among PIT Array Detection Efficiency						
Reach	Pre-Enhancement Project			Post-Enhancement Project		
	PIT Array	Efficiency	Sample Size	PIT Array	Efficiency	Sample Size
Main Channel	GRE-6.13 to 6.01	99%	1,912	GRE-6.13 to 6.01	92%	2,059
	GRE-6.01 to 6.13	91%	1,912	GRE-6.01 to 6.13	79%	2,406

Table 2. Pre and post-project enhancement migration rates. Pre-Enhancement data is for overwintering juvenile coho salmon only while post-enhancement data is for overwintering juvenile coho salmon and pre-smolt coho salmon. Migration rate was only calculated for individual coho salmon that were detected at both the upstream and downstream main channel antenna arrays (GRE-6.13 and GRE-6.01).

	Migration Rate	Count	Percentage	Average Migration Rate (min.)	Average Migration Rate (days)
Pre-Enhancement Project	less than 30 minutes	1,791	93.9%	12	0.01
	30 to 60 minutes	57	3.0%	39	0.03
	1 to 24 hours	53	2.8%	471	0.33
	more than 24 hours	6	0.3%	17,877	12.41
Post-Enhancement Project (Overwinter Juveniles)	less than 30 minutes	248	72.3%	19	0.01
	30 to 60 minutes	63	18.4%	40	0.03
	1 to 24 hours	29	8.5%	573	0.40
	more than 24 hours	3	0.9%	17,495	12.15
Post-Enhancement Project (Pre-Smolts)	Upstream Migration	208	23%	12,920	8.97
	less than 30 minutes	506	55%	14	0.01
	30 to 60 minutes	80	9%	41	0.03
	1 to 24 hours	63	7%	418	0.29
	more than 24 hours	58	6%	34,057	23.65

Table 3. Total number of PIT tagged hatchery coho salmon detected in the project reach (n = 2,591). Fish are organized by release group and estimated number of individuals per group are calculated based on the percentage of PIT tagged coho/release.

Release Watershed	Release Stream	Release Season	Life Stage at Detection	Tag Count	Percent Tagged/ Release Group	Estimated Total	Number and Percent of Estimated Coho/ Release Watershed
Green Valley Creek	Green Valley Creek	Smolt 2012	Adult	2	20%	10	17,064 (99.88%)
		Fall 2013		6	42%	14	
		Spring 2014	Juvenile	26	100%	26	
		Fall 2014		297	15%	1,980	
		Pre-Smolt 2014		1,267	15%	8,447	
		Smolt 2014		875	15%	5,833	
	Purrington Creek	Fall 2013	Adult	1	15%	7	
		Fall 2014	Juvenile	112	15%	747	
Dry Creek	Dry Creek	Smolt 2012	Adult	1	15%	7	14 (0.08%)
	Pena Creek	Fall 2014	Juvenile	1	15%	7	
Freezeout Creek	Freezout Creek	Fall 2014	Juvenile	1	15%	7	7 (0.04%)
				Total: 2,589		**Total: 17,084**	

Table 4. The number and proportion of overwinter juvenile coho salmon per release tributary that were detected both at the GRE-9.98 and GRE-6.13 PIT antenna sites. Detections are divided into seasonal groups, with early winter (December 1, 2014 – January 31, 2015), mid winter (February 1 – March 31, 2015) and spring (April 1 – June 15, 2015).

Detection Season	Green Valley Creek		Purrington Creek	
Early Winter	59	20%	41	40%
Mid Winter	14	5%	3	3%
Spring	227	76%	59	57%
	Total: 300		**Total: 103**	