Habitat conditions, stream flow, temperature, and monthly survival of juvenile coho stocked into two stream reaches in the Mill Creek watershed during the summer dry season, 2009.

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ACKNOWLEDGEMENTS

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INTRODUCTION

Coho Partnership

In response to the precipitous decline of coho salmon in the Russian River watershed, a group of agencies and organizations formed the Russian River Coho Water Resources Partnership (Partnership) to specifically address low streamflows that are limiting coho recovery in Russian River tributaries. The Partnership is funded by the National Fish and Wildlife Foundation (NFWF) and includes Center for Ecosystem Management and Restoration (CEMAR), Gold Ridge Resource Conservation District, Occidental Arts and Ecology Center WATER Institute, Sotoyome Resource Conservation District, Trout Unlimited, University of California Research and Extension Center Hopland GIS Lab and UC Cooperative Extension. The goal of the Partnership is to improve streamflow for coho as well as water supply reliability for landowners and water users. The multidisciplinary team is using a science-based approach to identify stream reaches that have the greatest potential for successful implementation and benefit to coho populations, and will work with landowners in these areas to implement alternative water management strategies. Initial efforts will focus on five priority streams where streamflow is known to limit coho survival and where cooperative projects could provide opportunities for both salmon and water users. The five priority streams include Dutch Bill, Grape, Green Valley, Mark West, and Mill Creeks.

This project is a component of NFWF's Russian River Coho Salmon Keystone Initiative, a multi-strategy plan to return a viable, self-sustaining population of coho salmon to the Russian River watershed. Key strategies for this plan include 1)development and implementation of a water management plan, 2)riparian/instream habitat restoration, conservation, and augmentation, and 3)population augmentation, monitoring, and evaluation. The Partnership is implementing Key Strategy 1 of this initiative.

Monitoring goals

To evaluate the effects of changes in flow management that result from Partnership activities, the Partnership's long-term goal is to monitor juvenile coho salmon survival in treatment (flow-impaired) and reference (non-flow impaired) reaches in each of the five priority creeks sampled before and after changes in flow management. In both reference and treatment reaches, estimates of monthly survival during the dry season will be compared with measurements of flow, temperature, and habitat condition. Data will be used to document improvements in flow and survival that result from project implementation in flow impaired reaches.

The monitoring goals for 2009 were to test sampling methods for long-term data collection of monthly survival in relation to flow, temperature, and habitat conditions during the dry season, and to collect baseline data in two reference reaches in the Mill Creek watershed. Baseline data will be used to set targets for survival in flow impaired stream reaches.

METHODS

Study reaches

Two 375 m reference stream reaches were selected in the Mill Creek watershed for baseline data collection and to test methods for a long term monitoring strategy. One reach was between 12.33 and 12.70 km upstream from the confluence of Mill and Dry Creeks. The second reach was in Palmer Creek, a tributary of Mill Creek and ran from 1.83 and 2.20 river kilometers upstream of the confluence of Mill Creek (**Figure 1**). Both reaches were in relatively flow unimpaired portions of the watershed.

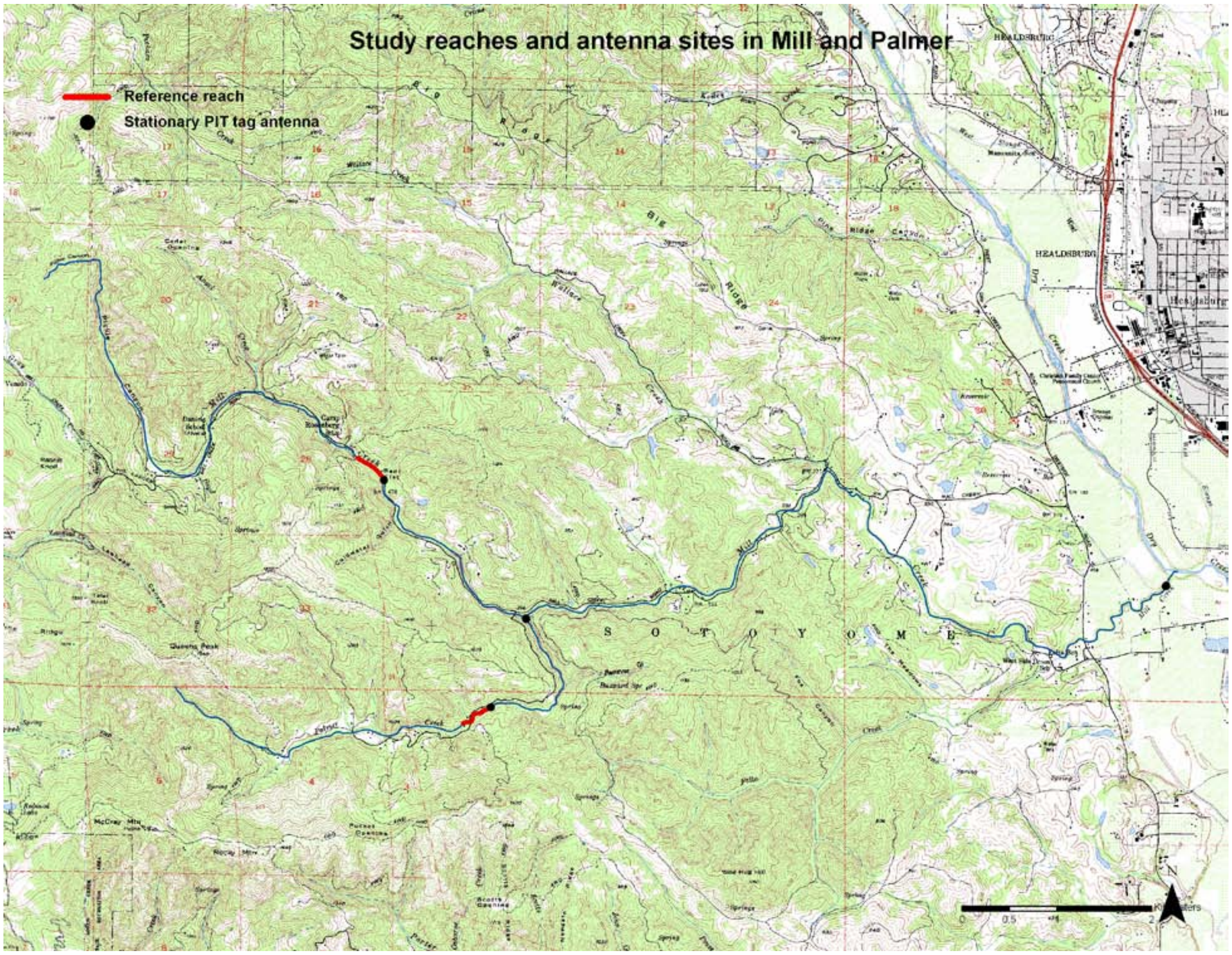

Figure 1. Reference reaches and stationary PIT tag detection sites in Mill and Palmer Creeks. 2009.

Habitat surveys

Between June and October, habitat surveys were conducted monthly in each reach (**Table 1**). During the first survey, distinct habitat units were classified and flagged as pools, riffles or flatwaters (Level 2 classification, Flosi, et. al.1998). During monthly habitat surveys, each unit was measured for length, average width, and maximum depth. Additionally, in all pool and flatwater units, a qualitative instream cover rating was assigned as well as an estimate of the percent instream coverage (Flosi, et. al.). Length and average width measurements were used to calculate average wetted area (length x average width), and instream cover rating and percent instream coverage were used to calculate instream shelter rating (instream cover rating x percent instream coverage).

Table 1. Survival and habitat sampling dates between June and November, 2009.

Sample type	June		July		August		September		October		November	
	M	P	M	P	M	P	M	P	M	P	M	P
Wand			7/16	7/15	8/19	8/19	9/18	9/18	10/11, 10/12	10/11, 10/12	11/5, 11/6	11/5, 11/6
Electrofishing							9/23-9/25	9/28-9/30				
Habitat	6/9	6/9	7/15	7/14	8/18	8/18	9/19	9/19	10/8	10/8		
Flow	6/30	6/16, 6/30	7/15, 7/21, 7/28	7/15, 7/21, 7/28	8/12, 8/19, 8/26	8/12, 8/19, 8/26	9/2	9/2, 9/9, 9/16	10/1, 10/14	10/1, 10/14		

Flow data collection

Each month and opportunistically between June and October, flow measurements were taken in each reach using a USGS Pygmy current meter (**Table 1**). Additionally, CEMAR installed a stage height data logger in each reach in late August to measure stage height continuously every 15 minutes for the remainder of the study. The Palmer gauge was located inside the study reach, approximately 30m upstream of the stationary PIT tag antenna. The Mill gauge was placed approximately 300m downstream of the study reach. Flow measurements from point samples were correlated with continuous stage data to estimate continuous flow in cfs between August and October.

Temperature data collection

On June 15, continuously recording temperature loggers were deployed within the two study reaches. The Mill Creek logger was deployed at river km 12.57, and the Palmer Creek logger at river km 2.13. Temperature loggers were calibrated prior to deployment and collected temperature data hourly until they were removed after October 15.

Data collection for estimating juvenile coho survival

In coordination with the Russian River Coho Salmon Captive Broodstock Program, 1,642 hatchery coho young-of-the-year (yoy) $\geq$ 56 mm and 2 g were PIT tagged and measured for fork length (+/- 1mm) and weight (+/- 0.1g) on 6/2/09 and 6/3/09. These fish were held in tanks until 6/16/09 when they were transported to Mill and Palmer Creeks in hatchery trucks and released into the reference reaches. A total of 822 coho were released into the Mill Creek reach and 820 into the Palmer Creek reach. The fish were transported from the holding tank in the hatchery truck to the creeks in aerated backpack containers, and each pool or flatwater unit was stocked with the number of fish to reach a density of approximately 1 fish/m^2.

Prior to releasing the coho, a stationary PIT tag detection system was constructed and placed at the downstream end of each reach in order to document emigration from the study reaches throughout the summer survival interval (**Figure 2a**). Migration upstream from each reach was impeded by natural flow barriers. In addition, two block seines were placed in each reach, one at the downstream reach boundary, and one at the midpoint of the reach. The block seines were left in the reaches for one week to prevent the stocked coho from immediately moving out of the reach as a flight response often observed during the first few days after stocking events.

In order to estimate monthly survival of stocked coho between June and October, a total of five PIT tag "wanding" samples were completed on each reach using a portable PIT tag detection system (**Figure 2b, Table 1**). Surveys were conducted from downstream to upstream, by wading each habitat unit and waving a portable PIT tag "wand" through the water column to detect PIT tagged fish. All PIT tags detected using this method were recorded on a portable PIT tag transceiver. From July through September, a single wand pass was conducted each month, and in October and November two passes were conducted per sample to improve estimates of survival. A one-pass electrofishing sample was also conducted at the end of September to collect size data on PIT tagged coho. Program MARK was used to estimate monthly survival for each reach between June and October (White and Burnham 1999).

Figure 2. Stationary (a) and portable (b) PIT tag detection systems used to detect movement and presence of PIT tagged coho in Mill and Palmer study reaches.

Mouth closures during 2010 smolt migration

Significant and consistent rainfall during the winter and spring of 2009 - 2010 prevented the need to make weekly visits to the confluences of Green Valley and Mill Creeks to check for mouth closures. Low flows were not a barrier to migration between the onset of the smolt migration in March and May 31. We do not anticipate closure before the end of the smolt run, which is typically in the middle of June (Obedzinski et. al. 2009).

RESULTS

Habitat

In general, conditions in pool and flatwater habitat remained similar throughout the summer dry season with slight declines in wetted area and depth (**Table 2, Figure 3, Figure 5, Figure 6**). Within streams, shelter rating was similar in all samples. All units except one riffle in Mill Creek remained wet for the duration of the dry season, however, wetted area in riffles decreased by 45% in Mill and 36% (**Table 3**). This was more dramatic than the decline observed in wetted area of pool and glide habitat; 15% in Mill and 20% in Palmer (**Table 2**). By August, the low flows in riffle habitat between pool and flatwater units likely inhibited movement within the reaches.

Average stream width and depth was similar between Mill and Palmer reaches (**Table 2, Table 3**). Maximum depths were higher and more variable in Mill Creek (**Table 2, Figure 6**). Wetted area was similar between reaches, but more variable in Palmer (**Figure 3, Figure 4**). Shelter rating was generally higher and more variable in Palmer Creek (**Table 2, Figure 7**).

Table 2. Habitat characteristics measured monthly in pool and flatwater units in Mill and Palmer study reaches between June and October, 2009.

Tributary	Date	Number of units	Total wetted area (m^2)	Avg width (m) +/- 1 SD	Avg depth (m) +/- 1 SD	Max depth (m) +/- 1SD	Avg of shelter rating +/- 1 SD
Mill	6/9	18	836	3.4 +/- 0.8	0.3 +/- 0.1	0.7 +/- 0.3	23.6 +/- 16.5
	7/15	18	831	3.3 +/- 0.8	0.3 +/- 0.1	0.6 +/- 0.3	24.2 +/- 14.2
	8/18	18	738	3.0 +/- 0.6	0.2 +/- 0.1	0.6 +/- 0.3	24.7 +/- 13.8
	9/17	18	716	3.0 +/- 0.7	0.2 +/- 0.1	0.6 +/- 0.3	24.7 +/- 13.8
	10/8	18	710	3.0 +/- 0.8	0.2 +/- 0.1	0.6 +/- 0.3	24.7 +/- 13.8
Palmer	6/9	20	814	3.5 +/- 1.1	0.3 +/- 0.1	0.5 +/- 0.2	39.0 +/- 39.1
	7/14	20	763	3.2 +/- 1.0	0.2 +/- 0.1	0.5 +/- 0.2	37.8 +/- 36.9
	8/18	19	697	3.2 +/- 1.1	0.2 +/- 0.1	0.4 +/- 0.2	36.1 +/- 37.8
	9/17	19	676	3.2 +/- 0.9	0.2 +/- 0.1	0.4 +/- 0.2	38.2 +/- 39.6
	10/8	19	649	3.1 +/- 0.8	0.2 +/- 0.1	0.4 +/- 0.2	38.4 +/- 42.1

Table 3. Habitat characteristics measured monthly in riffle units in Mill and Palmer study reaches between June and October, 2009.

Tributary	Date	Number of units	Total wetted area (m^2)	Avg width (m) +/- 1 SD	Avg depth (m) +/- 1 SD	Max depth (m) +/- 1SD
Mill	6/9	16	463	3.4 +/- 1.0	0.08 +/- 0.02	0.19 +/- 0.11
	7/15	16	340	2.5 +/- 0.9	0.06 +/- 0.02	0.14 +/- 0.10
	8/18	16	284	2.2 +/- 0.6	0.04 +/- 0.02	0.13 +/- 0.09
	9/17	15	272	2.0 +/- 0.5	0.03 +/- 0.02	0.12 +/- 0.10
	10/8	15	253	1.9 +/- 0.4	0.03 +/- 0.02	0.12 +/- 0.09
Palmer	6/9	16	550	2.9 +/- 0.8	0.09 +/- 0.02	0.19 +/- 0.06
	7/14	16	432	2.2 +/- 0.6	0.04 +/- 0.02	0.14 +/- 0.06
	8/18	18	422	2.0 +/- 0.7	0.05 +/- 0.02	0.14 +/- 0.07
	9/17	18	393	1.8 +/- 0.5	0.04 +/- 0.02	0.14 +/- 0.07
	10/8	18	354	1.7 +/- 0.3	0.04 +/- 0.02	0.14 +/- 0.07

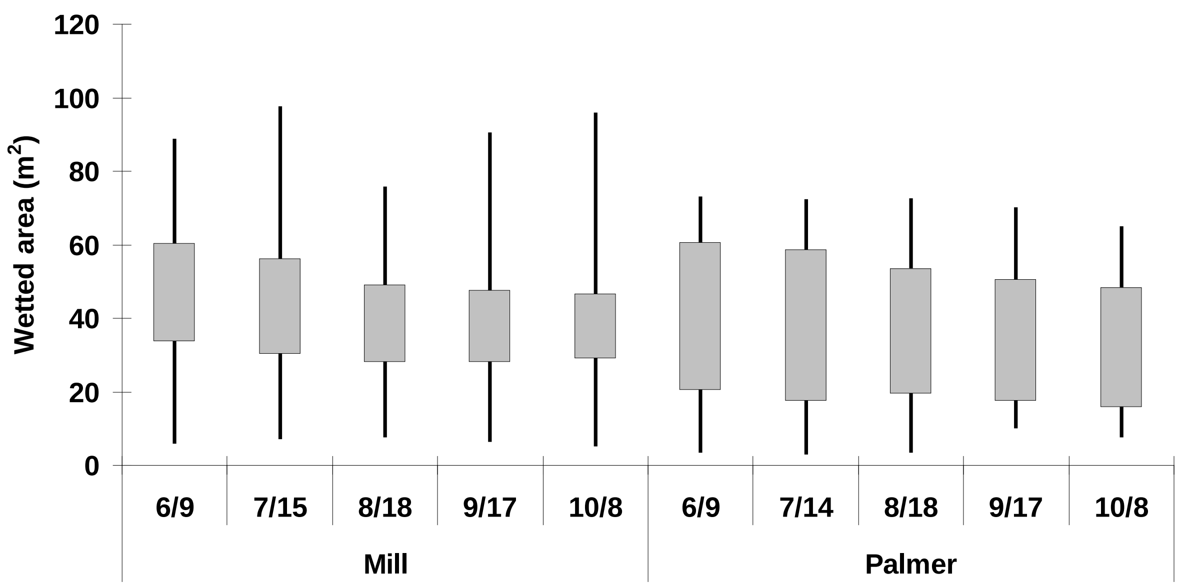

Figure 3. Minimum, maximum, 25 percentile, and 75 percentile of wetted area of pool and flatwater units measured in study reaches sampled monthly between June and October, 2009.

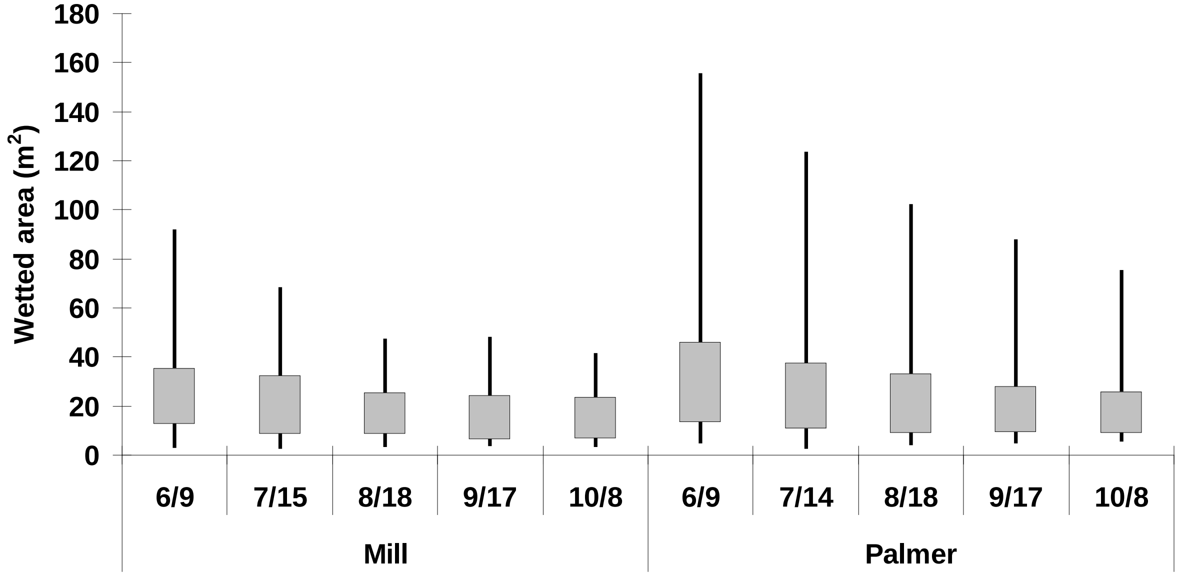

Figure 4. Minimum, maximum, 25 percentile, and 75 percentile of wetted area of riffle units measured in study reaches sampled monthly between June and October, 2009.

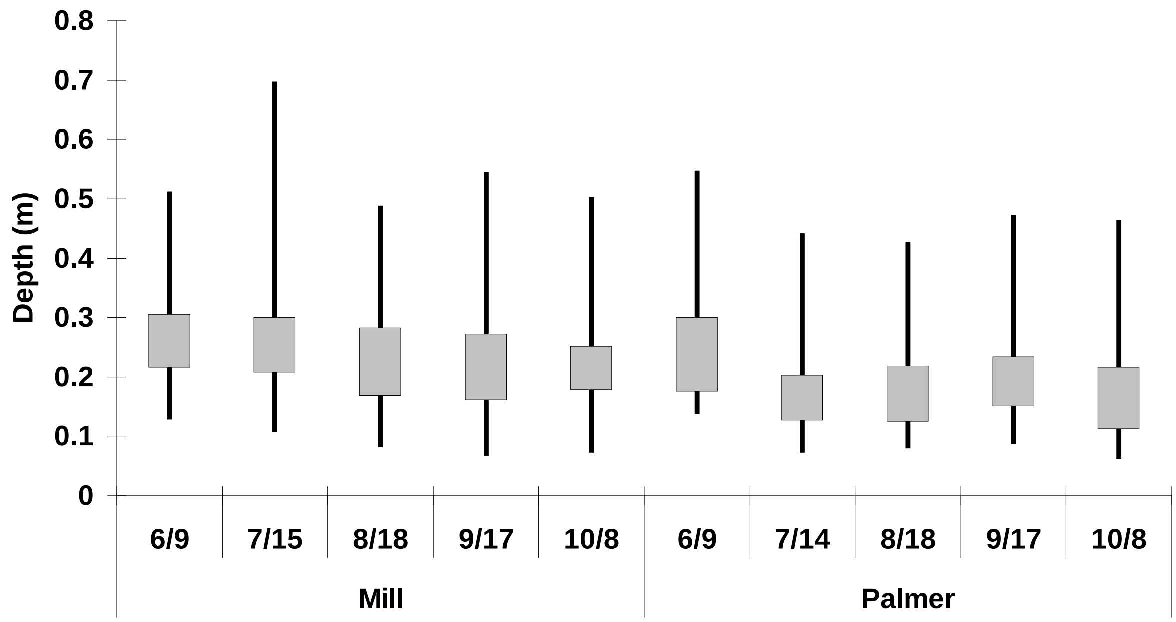

Figure 5. Minimum, maximum, 25 percentile, and 75 percentile of average width of pool and flatwater units measured in study reaches sampled monthly between June and October, 2009.

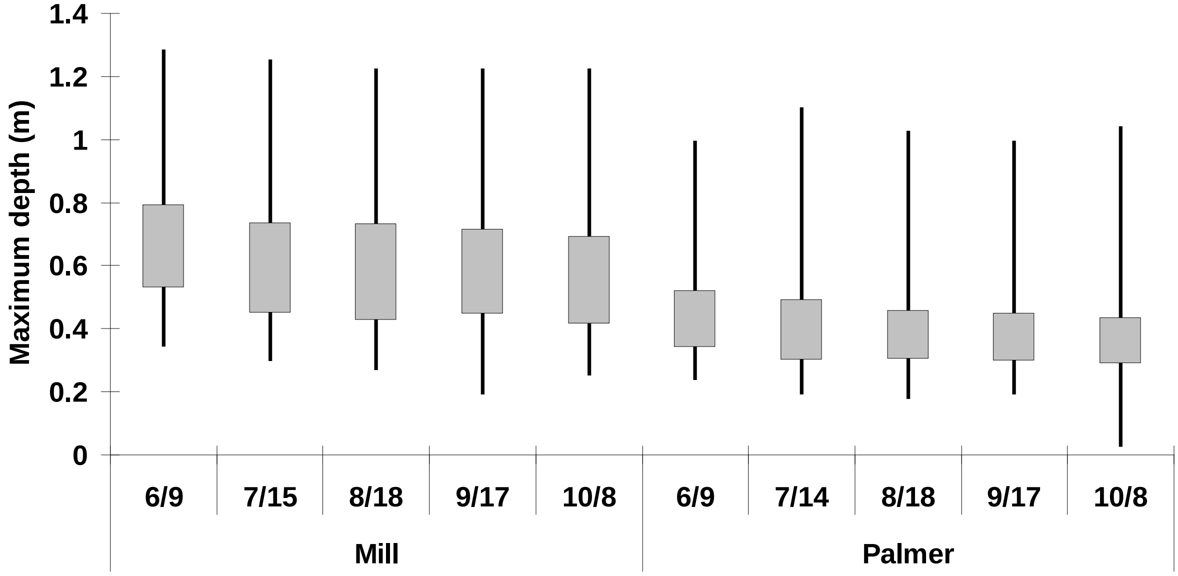

Figure 6. Minimum, maximum, 25 percentile, and 75 percentile of maximum depth of pool and flatwater units measured in study reaches sampled monthly between June and October, 2009.

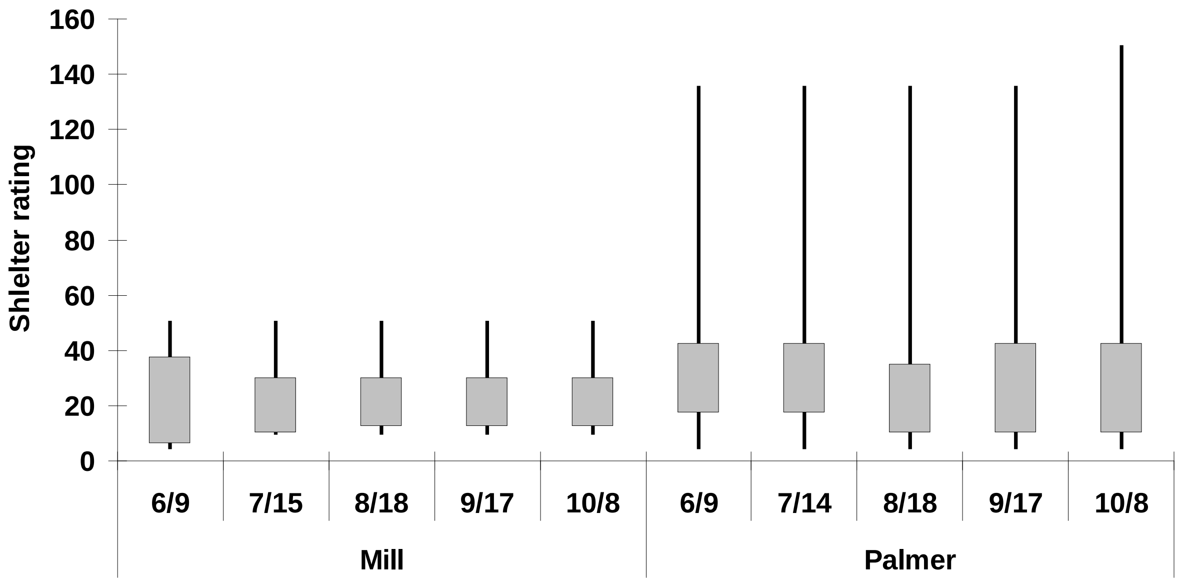

Figure 7. Minimum, maximum, 25 percentile, and 75 percentile of shelter rating of pool and flatwater units in study reaches sampled monthly between June and October, 2009. Shelter rating was calculated as instream cover rating (0-3) x percent instream cover.

Streamflow

For the duration of the study, stream discharge remained below 0.3 cfs until the first fall rainstorm on October 12, 2009. Flows in the Mill Creek reach declined gradually between July and early September and then began to increase again in late September (**Figure 8**). Flows in the Palmer reach remained stable between July and early September when they began to gradually increase (**Figure 9**). Flows peaked on October 13 at 6.91 cfs in the Mill study reach and 1.26 cfs in the Palmer study reach.

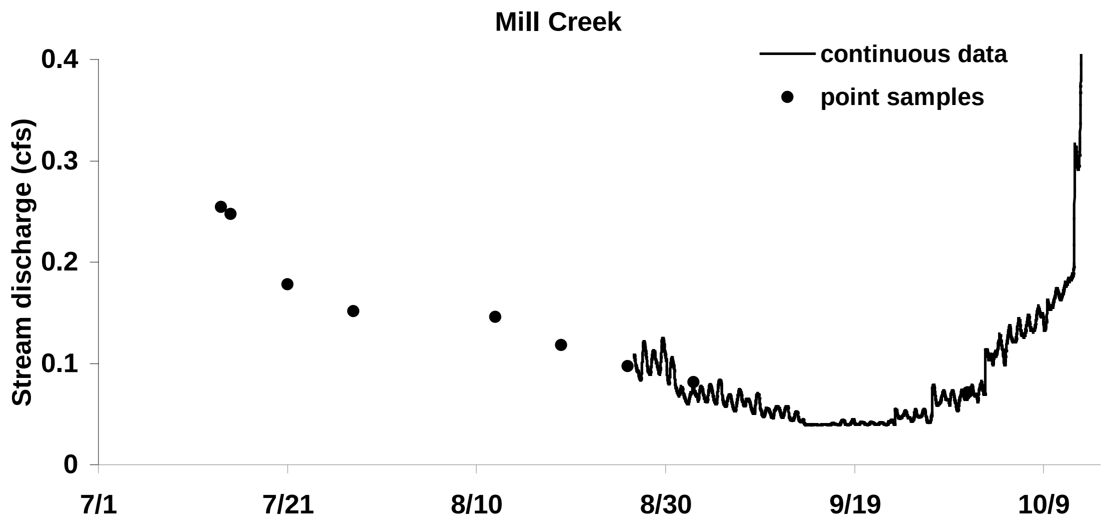

Figure 8. Stream discharge data collected from point samples and a continuous stage height data logger in the Mill Creek study reach in 2009.

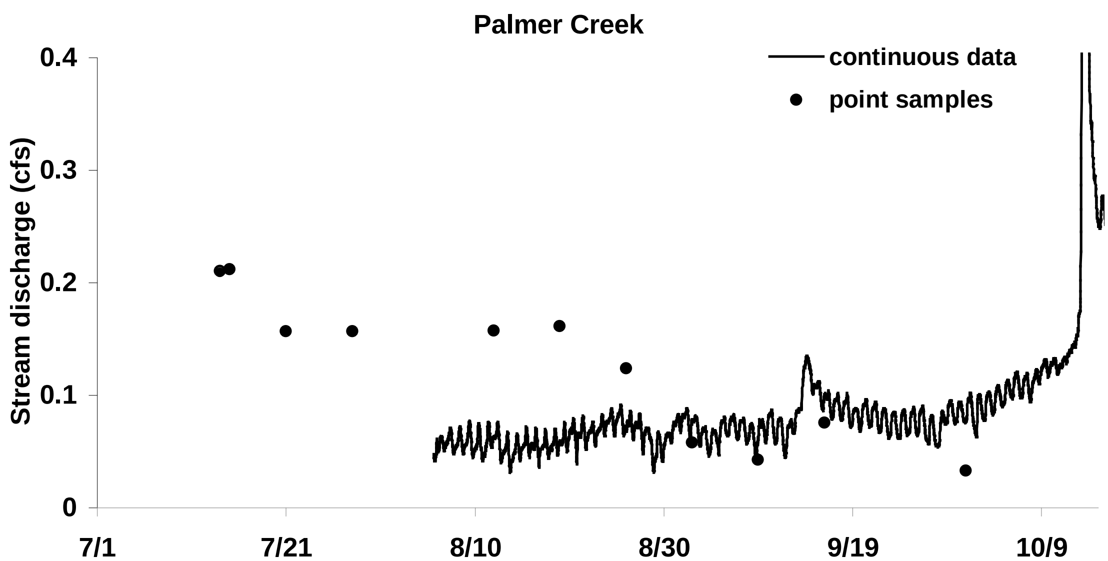

Figure 9. Stream discharge data collected from point samples and a continuous stage height data logger in the Palmer Creek study reach in 2009.

Temperature

Temperatures in Mill and Palmer study reaches remained consistently cool between June 15 and October 15, with the warmest peaks in late June and late July, and the lowest temperatures observed in early October (**Figure 10**). The maximum temperature observed in either reach was 19°C (**Table 4**). In general, temperatures in Palmer Creek were slightly cooler than in Mill Creek.

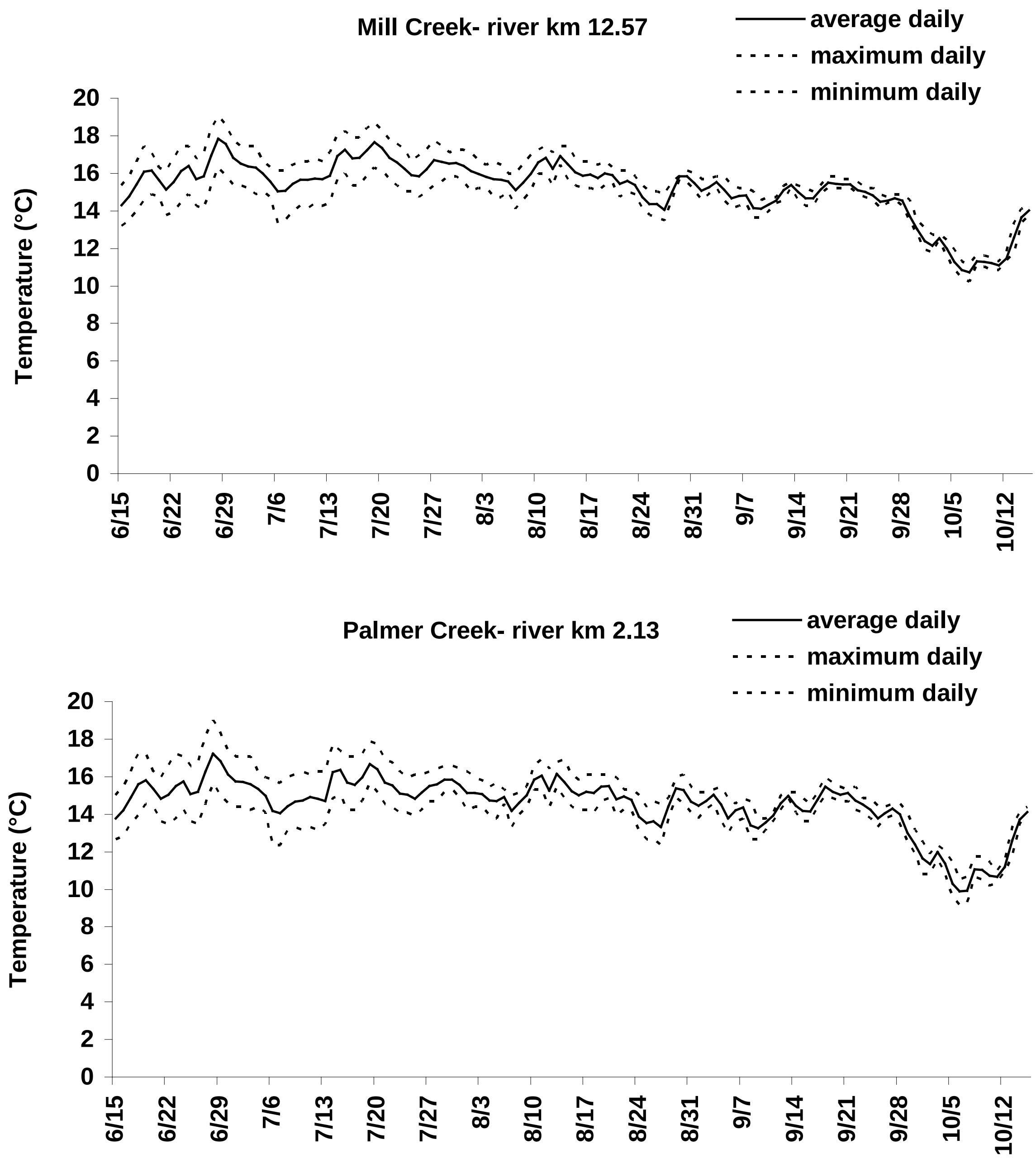

Figure 10. Average daily, maximum daily, and minimum daily temperatures in Mill and Palmer Creek study reaches between June 15 and October 15, 2009.

Table 4. Temperature metrics between June 15 and October 15 in Mill and Palmer study reaches, 2009.

Stream	River km	Avg temp(°C)	Min temp(°C)	Max temp(°C)	MWAT (°C)	MWMT (°C)
Mill	12.57	15.2	10.2	19.0	17.2	18.2
Palmer	2.13	14.5	9.1	19.0	16.2	17.7

* Maximum weekly average temperature (MWAT) was calculated as the maximum of the running weekly average temperatures between June 15 and October 15. Maximum weekly maximum temperature (MWMT) was calculated as the maximum of the running weekly maximum temperatures between June 15 and October 15.

Movement from study reaches

With the exception of the first few days after stocking, very little movement was observed from the study reaches during the dry summer period between June and October (**Figure 11, Figure 12**). Despite the fact that block seines were placed at the downstream ends and midpoints of each reach for the first week after stocking, 14 coho were detected leaving the Palmer study reach. This was likely a result of a small hole in the block net at the downstream site. A snorkeling survey the day after stocking revealed a higher number of fish in the pools immediately upstream of the block seines than were stocked in the units directly upstream of them, suggesting that there was an initial tendency for fish to move downstream immediately after being released. After the block seines were removed, only three fish on Mill Creek and four fish on Palmer Creek were observed leaving the study sites between June and early October. Following the first fall rainstorm on October 12-13, 134 fish were detected leaving the Mill Creek study reach and 115 fish were detected leaving the Palmer Creek study reach between Oct 13 and the last wanding sample on November 6.

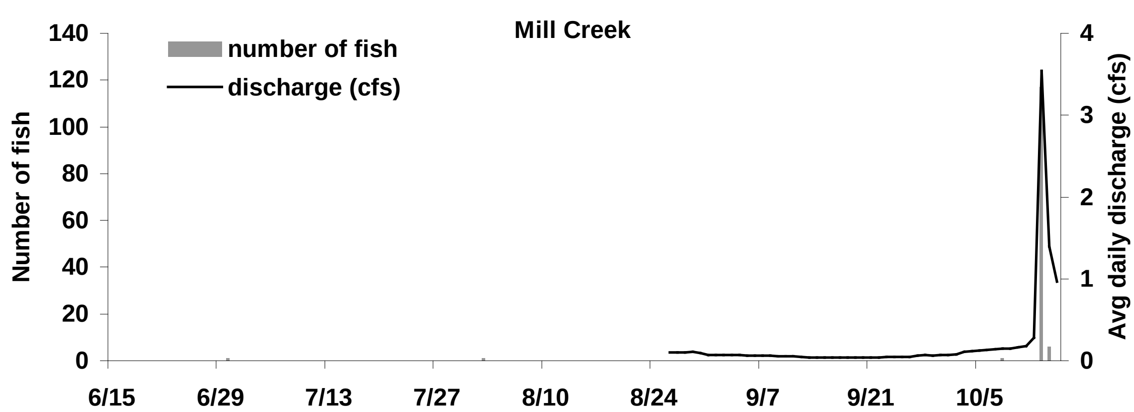

Figure 11. Stream discharge and number of unique PIT tagged coho detected leaving Mill Creek study site between June 16 and October 15, 2009.

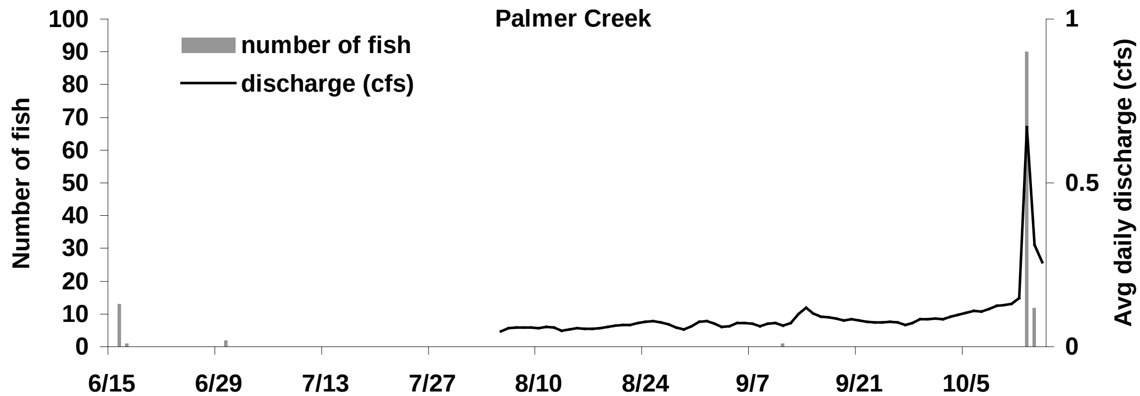

Figure 12. Stream discharge and number of unique PIT tagged coho detected leaving Palmer Creek study site between June 16 and October 15, 2009.

Oversummer survival

Estimates of monthly juvenile coho oversummer survival were consistently high in both study reaches (**Figure 13**), ranging from 0.81 to 0.98 in the Mill Creek reach and 0.88 to 0.99 in the Palmer Creek reach. Survival was lowest during the June to July interval, increased between July and August, and then remained consistent during the last two intervals with a slight decreasing trend. Overall survival between June and October was higher in the Palmer Creek study reach than the Mill Creek study reach (0.74 and 0.67, respectively). Estimates of survival in these two reaches were higher than streamwide estimates observed in Mill and Palmer Creeks from 2005 to 2008 (Obedzinski et. al. 2009, Obedzinski unpublished data).

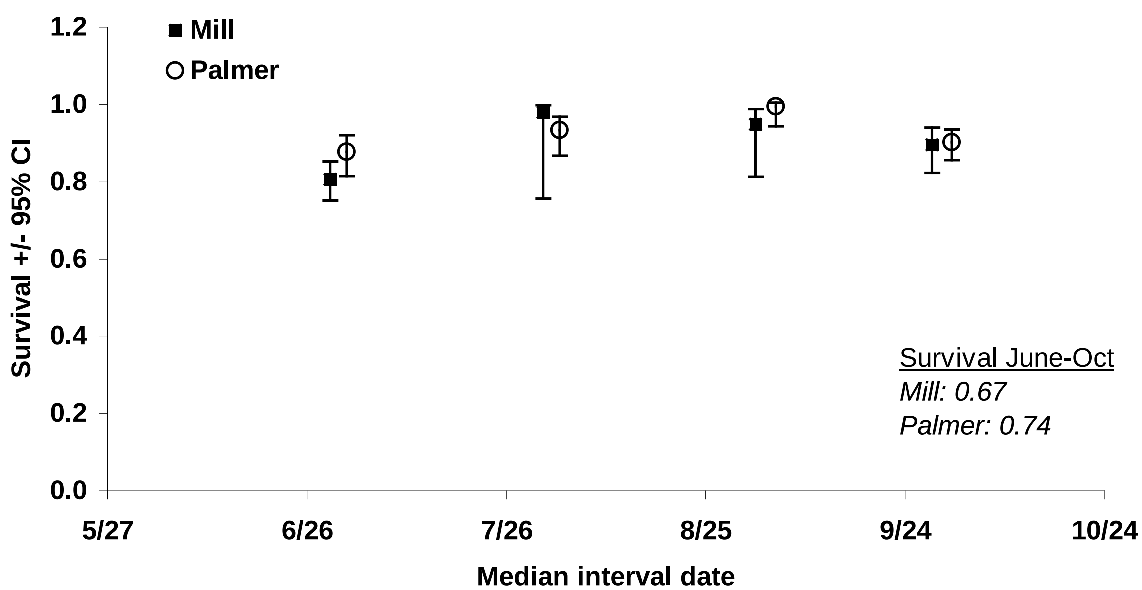

Figure 13. Monthly survival of juvenile coho stocked into Mill and Palmer Creek study reaches during summer of 2009.

Size, condition, and oversummer growth

Between the first week of June when the coho were tagged and the electrofishing sample during the last week of September, on average coho increased in length, remained similar in weight, and decreased in condition factor (**Table 5, Table 6**). Average growth rates and fall lengths and weights were higher in the Palmer reach than in the Mill reach (**Table 6, Table 7**). On average, fish stocked in the Palmer reach increased 7.5mm and 0.58g, and in the Mill reach, fish increased 4.9mm and 0.1g. Condition factor decreased similarly in both reaches.

Table 5. Fork length (mm), weight (g) and condition factor (K) of juvenile hatchery coho two weeks prior to release. K was calculated as weight/fork length3 *100,000.

Tributary	Sample date	n	Avg fork length (mm) +/- 95% CI	Avg weight (g) +/- 95% CI	Avg K +/- 95% CI
Mill	6/2/09	822	66.5 +/- 0.2	3.68 +/- 0.04	1.23 +/- 0.003
Palmer	6/2/09	820	65.7 +/- 0.2	3.73 +/- 0.04	1.28 +/- 0.004

Table 6. Fork length (mm), weight (g) and condition factor (K) of juvenile coho captured during the fall electrofishing sample. K was calculated as weight/fork length3 *100,000.

Tributary	Sample date	n	Avg fork length (mm) +/- 95% CI	Avg weight (g) +/- 95% CI	Avg K +/- 95% CI
Mill	9/23/09	338	71.7 +/- 0.7	3.81 +/- 0.12	1.01 +/- 0.011
Palmer	9/28/09	407	73.4 +/- 0.9	4.32 +/- 0.44	1.02 +/- 0.009

Table 7. Specific growth rates of juvenile coho PIT tagged and stocked in June and recaptured in late September, 2009. Specific growth rate was calculated as g = $(\ln(W_2)-\ln(W_1))/t_2-t_1$ for weight and g = $(FL_2-FL_1)/t_2-t_1$ for fork length where W=average weight, FL= average fork length, and t=sample date.

Tributary	Avg pre-release tagging date	Avg electrofishing sample date	Specific growth rate fork length (mm/d) +/- 95% CI	Specific growth rate weight (ln(g)/d) +/- 95% CI
Mill	6/1/09	9/23/09	0.043 +/- 0.002	0.0002 +/- 0.0001
Palmer	5/31/09	9/28/09	0.062 +/- 0.006	0.0007 +/- 0.0002

DISCUSSION

Overall, there was little variation in habitat condition, temperature, flow, and survival between June and October in the Mill and Palmer study reaches. The lower survival observed during the June to July interval (when flow conditions could be considered most suitable) is likely a result of stress related to being transported from a hatchery environment to a natural environment rather than an indicator of decreased environmental conditions. After the first interval, very gradual decreasing trends in habitat conditions matched a slight decline in survival between July and October.

The fact that environmental conditions were stable between June and October in these prime reaches suggests that, provided suitable habitat, Russian River tributaries can support juvenile coho throughout the dry season. These baseline data will provide a reference for target survival rates in flow-impaired treatment reaches that the Partnership intends to improve through project implementation.

In general, sampling techniques were effective at documenting monthly survival and habitat conditions. In future samples, we recommend additional sampling of pool tail crest, canopy, and dissolved oxygen to account for additional factors that may be related to survival. For wanding samples, we recommend conducting paired samples each month in order to use the Robust design model in program MARK. Using this model, environmental variables can be incorporated as covariates in comparisons of survival between reference and treatment reaches.

STUDY DESIGN FOR FUTURE MONITORING

To evaluate the effects of changes in flow management that result from long-term Partnership activities described in the Russian River Coho Salmon Keystone Initiative, UCCE will monitor juvenile coho salmon survival in both treatment (flow-impaired) and reference (non-flow impaired) reaches sampled before and after changes in flow management in the five priority streams. Reference reaches will be placed in sections of each creek that are least likely to show an effect from project implementation, and treatment reaches will be located downstream of target implementation sites. Because there is significant annual variation in coho survival and environmental characteristics in Russian River tributaries (Obedzinski et. al. 2009), we will collect baseline data prior to project implementation so that relative differences in survival between reference and treatment reaches can be compared pre and post project implementation. In order to evaluate the effects of streamflow on survival specifically, we will also measure additional related and potentially confounding environmental characteristics that may also influence survival. We will use a similar methodology to that used in 2009 to measure survival, flow, temperature, and habitat conditions in both reference and treatment reaches with a few changes and additions:

Two hundred and fifty meter reaches will be selected in May; one reference and one treatment reach in each creek (three creeks in 2010 and five creeks beginning in 2011). Five hundred PIT tagged coho will be released into each reach in mid-June. Prior to release of coho, stationary PIT tag detection systems will be placed at the downstream ends of each reach to document movement out of the study reach. Between June and October, five monthly habitat surveys will be conducted. Habitat survey metrics include DFG’s Level 2 habitat unit classification as pools, flatwaters or riffles, length, width, average width, average depth, maximum depth, pool crest depth, instream cover rating, instream cover percentage, and percent canopy. Continuous staff height and water temperature loggers will be deployed in or near each reach, and dissolved oxygen samples will be taken monthly between 8:30 and 9:30 am in each reach. Flow samples will be taken monthly in each reach at the time of each habitat survey. Paired PIT tag wand samples will be conducted monthly to correspond with habitat samples. These data will be used to generate estimates of summer survival in reference and treatment reaches as well as identify relationships between streamflow, habitat conditions, and survival.

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