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2016 FRGP REPORT

PRAIRIE CREEK MONITORING PROJECT 2015 Season

Fisheries Restoration Grants Program (Project Number: P1210321)

Prepared By

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DEDICATION

This report is dedicated to the memory of Lucille Vinyard (1918 – 2015), an ardent conservationist and friend, who played a key role in the formation of Redwood National and State Parks.

Photograph of Michael Sparkman (CDFW) and Lucille Vinyard at lower Redwood Cr smolt trap, Orick, CA. 2008.

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ABSTRACT

This report presents results from monitoring Coho Salmon (*Oncorhynchus kisutch*) in Prairie Creek, Humboldt County, California during 2014/15. The focus of this study was to determine overwinter survival (apparent) and growth of juvenile Coho Salmon, and estimate population abundances of Coho Salmon, Chinook Salmon (*O. tshawytscha*), Steelhead Trout (*O. mykiss*), and Cutthroat Trout (*O. clarki clarki*) smolts emigrating from the Prairie Creek basin in 2015.

Juvenile Coho Salmon in Prairie Creek were marked with PIT tags during 2014 to monitor fall/winter redistribution and estimate overwinter survival and growth. The Cormack-Jolly-Seber model and Program MARK were used to estimate overwinter survival using plate and loop designed pit tag antenna arrays and rotary screw trap captures. A separate estimate of overwinter survival was determined using the rotary screw trap and mark/recapture experiments to determine overwinter survival as well. We found that 5.6% of the pit tagged juvenile Coho Salmon were detected migrating past the lower antenna during fall and winter before the smolt trap was deployed. Apparent overwinter survival of juvenile Coho Salmon using pit tag antennas and trap captures equaled 33% (95% CI = 29 – 38%), compared to the trap derived estimate of 29% (95% CI = 23 – 34%). On average, pit tagged juvenile Coho Salmon experienced 0.14 mm increase in length per day, and overwinter growth in 2014/15 was very similar to growth in 2013/14.

We operated a five foot diameter rotary screw trap from February 26 – July 25, 2015 to estimate smolt abundances, and captured 329 0+ Coho Salmon, 11,355 1+ Coho Salmon, 10,900 0+ Chinook Salmon, 3 1+ Chinook Salmon, 939 0+ trout, 2,288 1+ Steelhead Trout, 783 2+ Steelhead Trout, 1 0+ Pink Salmon, and 2,398 juvenile Coastal Cutthroat Trout to total 28,996 individuals. An additional 35 adult Coastal Cutthroat Trout (FL > 250 mm) and two Eulachon (*Thaleichthys pacificus*) were also captured. Number of pit tagged 1+ Coho Salmon captures equaled 168, and comprised 1.4% of the total 1+ Coho Salmon catch. The population abundance (with 95% CI's) of 0+ Coho Salmon equaled 1,601 (1,033 – 2,169), and for 1+ Coho Salmon equaled 21,536 (20,260 – 22,813). Population abundances equaled 22,562 (20,795 – 24,328) for 0+ Chinook Salmon, 7,786 (7,023 – 8,549) for 1+ Steelhead Trout, 4,520 (3,513 – 5,527) for 2+ Steelhead Trout, and 8,572 (7,425 – 9,719) for juvenile Coastal Cutthroat Trout. Trends in smolt abundances from 2011 – 2015 were not significant ($p > 0.05$), except for 1+ Steelhead Trout, which showed a positive increase over time ($p < 0.05$). The two most important months for migration in 2015 were March/April for 0+ Coho Salmon and 2+ Steelhead Trout, March/May for 0+ Chinook Salmon, and April/May for 1+ Coho Salmon, 1+ Steelhead Trout, and juvenile Coastal Cutthroat Trout.

Daily captures and weekly population abundances of pit tagged 1+ Coho Salmon closely reflected the pattern for the population of 1+ Coho Salmon smolts for the second year in a row, and indicate that pit tagging juvenile Coho Salmon did not affect migratory behavior during the smolt migration period.

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[1]This paper should be referenced as: Wilzbach, M.A., M.D. Sparkman, P.Y. Drobny, M.E. Gordon, and C.M.G. Boone. 2016. Prairie Creek Monitoring Project, 2015 Season: a report to the Fisheries Restoration Grants Program (Project No. P1210321), 98 pps.

INTRODUCTION

Population monitoring of Pacific Salmon (*Oncorhynchus* spp.) is vital in California, where many Evolutionarily Significant Units (ESUs) are listed under the Federal Endangered Species Act. In many of northern California's coastal river systems, the California Coastal Chinook Salmon (*O. tshawytscha*) ESU, Southern Oregon/Northern California Coasts Coho Salmon (*O. kisutch*) ESU, and Northern California Steelhead Trout (*O. mykiss*) DPS are listed as threatened (http://www.nmfs.noaa.gov/pr/species/fish/). A lack of reliable monitoring makes it impossible to know the true extent of their decline (Brown et al. 1994; Korman et al. 2002).

Declines in abundance of salmon throughout the Pacific Northwest (Nehlsen et al. 1991) have led to the identification of critical freshwater habitat requirement for the species (Sandercock 1991). The amount of summer and winter habitat (Nickleson et al. 1992), stream temperature and discharge (Shirvell 1994, Giannico and Healey 1998, Giannico and Hinch 2003), and intra and interspecific interactions (Harvey and Nakamoto 1996) are among the factors that have been shown to affect growth and survival of juvenile Coho Salmon in freshwater. Mortality in freshwater can be substantial (Sandercock 1991, Bradford 1995, Solazzi et al. 2000) and has been documented to decrease with increased juvenile size prior to increased winter discharge (Bradford 1995, Brakensiek and Hankin 2002).

Conditions in the Pacific Ocean vary temporally with Pacific Decadal Oscillations as well as annually. Variations in ocean conditions influence the survival and abundance of salmon (Botsford et al. 2005, Mueter et al. 2002, Mueter et al. 2005). Recognizing this phenomenon, the California Coastal Salmonid Monitoring Plan (Adams et al. 2011) called for monitoring both adult salmonid escapement to and salmonid smolt production from freshwater habitats.

In this report, we report estimates of juvenile Coho Salmon overwinter survival and growth, and the abundance of downstream migrating juvenile salmonids in Prairie Creek. Determining and tracking smolt numbers over time is an acceptable, useful, and quantifiable measure of salmonid populations which many agencies (both state and federal), universities, consultants, tribal entities, and timber companies perform each year. Juvenile salmonid out-migration can be used to assess: 1) the number of parents that produced the Cohort (Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2006), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003, Roni et al. 2006), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003, Ebersole et al. 2009, Sparkman et al. 2014), and 6) future recruitment to adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000). In addition to data on downstream migrating salmonids, we present overwinter survival and growth data on juvenile Coho Salmon tagged throughout Prairie Creek in the fall of 2014.

Prairie Creek is close to being in a pristine condition, and thus the data we report will be useful for comparing data collected in similar sized streams that have undergone anthropogenic effects (e.g. timber management). Prairie Creek would then serve as a control for future comparisons.

Site Description

Prairie Creek is a low gradient, fourth-order tributary whose confluence with Redwood Cr (RC) occurs near Orick, California (Fig. 1). Draining a watershed of 34.4 km^2, this stream flows for 20 km and is located almost entirely within the boundaries of Redwood National and State Parks (Cannata et al. 2006). The climate of the study area is characterized by dry, foggy summers and rainy winters with rare snowfall. The mean annual precipitation is 177 cm, most of which falls between November and March (77%). Only 5% of yearly rain falls between June and September, and 30 day periods without precipitation are common during these months. The area's proximity to the Pacific Ocean helps maintain a mild climate and stable year-round temperatures (Janda et al. 1975).

Most of the RC drainage basin is underlain by metamorphic and sedimentary rocks of the Franciscan assemblage of Late Jurassic and Early Cretaceous age and by shallow marine and alluvial sedimentary deposits of late Tertiary and Quaternary age (Cashman et al. 1995). However, a large portion of the Prairie Creek sub-basin of RC is underlain by ancient beach deposits. The entire watershed is situated in a tectonically active and geologically complex area, and is considered to have some of the highest uplift and seismic activity rates in North America (CDFW NCWAP 2004).

The Prairie Creek watershed supports a variety of plant and animal species. Coast redwood (*Sequoia sempervirens*) dominate the old growth forests, though the following trees can also be found in the area: Sitka spruce (*Picea sitchensis*), tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), big-leaf maple (*Acer macrophyllum*), California bay laurel (*Umbellularia californica*), and red alder (*Alnus rubra*). Sword fern (*Polystichum munitum*) and redwood sorrel (*Oxalis oregana*) are common in the understory, along with rhododendron (*Rhododendron macrophyllum*), huckleberry (*Vaccinium* spp.), salal (*Gaultheria shallon*), and azalea (*Rhododendron occidentale*) (NPS 2010).

Prairie Creek hosts several species of anadromous salmonids, including Steelhead Trout (*Oncorhynchus mykiss*), Coastal Cutthroat Trout (*O. clarki clarki*), Coho Salmon (*O. kisutch*), and Chinook Salmon (*O. tshawytscha*). This study, and smolt trapping in Redwood Creek also show that small runs of Pink Salmon (*O. gorbuscha*) are present in Redwood Creek. Runs of Coho Salmon, Chinook Salmon, and Steelhead Trout in northern California are listed as threatened under the Federal Endangered Species Act (NOAA 2011). Threespine stickleback (*Gasterosteus aculeatus*), coast range sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), Pacific lamprey (*Entosphenus tridentata*), and brook lamprey (*Lampetra richardsoni*) are also found in Prairie Creek (Sparkman et al. 2014).

While upper Prairie Creek is characterized by shallow runs and riffles, lower Prairie Creek has numerous deep pools. Trees and thick understory surround upper Prairie Creek, which has particularly dense canopy cover in the upstream reaches. Lower Prairie Creek is located in an area with more open prairie and cattle grazing on private land.

Purpose

The purpose of this project was to determine juvenile Coho Salmon overwinter survival and growth using pit tag antenna arrays and smolt trap captures, and to quantify juvenile salmonid downstream migration from Prairie Creek using mark/recapture techniques and a rotary screw trap (Fig. 1). The long-term goal is to provide information on the status and trends of Coho Salmon and other salmonids that may be used in Viable Salmonid Population (VSP) analysis. Additionally, our data can be used as a benchmark for data collected in other, similar sized streams because Prairie Creek is in a near-pristine condition.

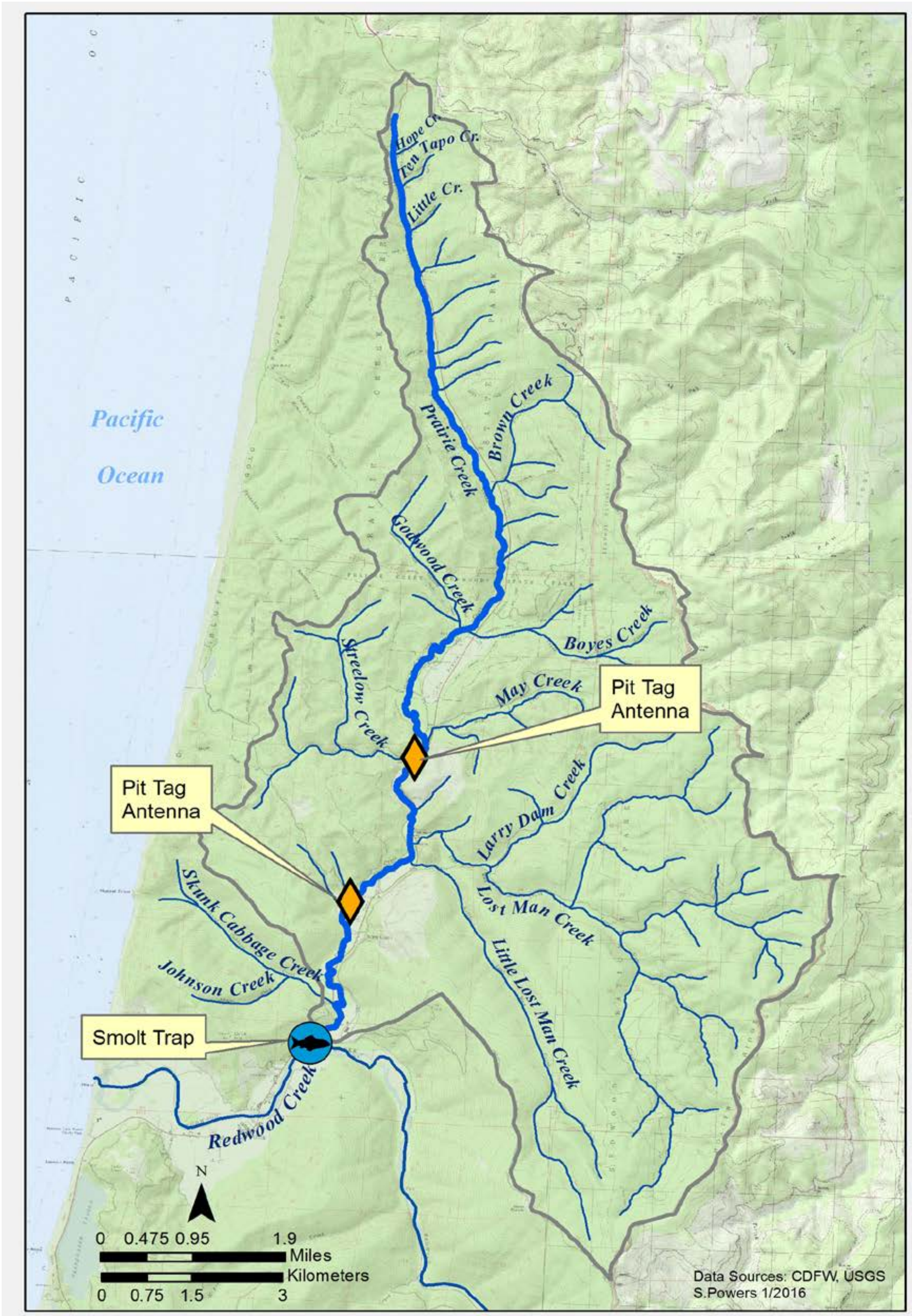

Figure 1. Prairie Creek watershed with pit tag antennas and rotary screw trap locations, Humboldt County, CA.

METHODS AND MATERIALS

Estimation of Overwinter Survival

Fish Handling and Tagging

Fish sampling and handling procedures were approved under Humboldt State University IACUC protocols (No. 12/13.F.74-A and 13/14.F.125-A). Fish were captured in each sampled pool using a seine net during late summer/fall low flow periods in 2014. Captured fish were sedated in a 25 mg/L solution of tricaine methane sulfonate (MS-222) buffered to neutral pH before a random sample of up to 30 fish were measured for length (±1 mm) and mass (±0.1 g). Up to 15 Coho Salmon greater than or equal to 60 mm fork length per pool were implanted with passive integrated transponder (PIT) tags. Captured fish were recovered from anesthesia before being released to the location of capture.

Fish handling and tagging was done in two events. The first tagging event started on July 25th 2014 and extended through August 30th 2014 and was done in tandem with snorkel and habitat surveys. Snorkel and habitat methodology are described in detail in Drobny (2016). A second tagging event started on October 3rd, 2014 and extended through October 20th, 2014. During the second tagging event, fish were sampled from previously seined pools and from previously un-sampled pools. The second tagging event allowed for recapture of previously tagged fish and capture and tagging of additional fish. The numbers of tags per tagging event and number of tags applied per stream reach are given in Table 1 below. Table 2 describes reach GPS coordinates and pool sampling strategy.

Table 1. Number of PIT tags applied to juvenile Coho Salmon in Prairie Creek by reach location and tagging event, 2014.

Location	**Tag Event 1 (summer)**	**Tag Event 2 (fall)**	**Total Tags**
Prairie Creek Reach 69	83	114	197
Prairie Creek Reach 70	0	140	140
Prairie Creek Reach 71	81	97	178
Prairie Creek Reach 72	70	126	196
Prairie Creek Reach 73	0	164	164
Prairie Creek Reach 74	37	25	62
Boyes Creek	27	0	27
Streelow Creek	97	0	97
Total Fish Tagged:	395	666	1061

Table 2. Sampling locations (NAD 83 UTM coordinates) and number of pools sampled in each location. Sampling strategy and number of pools with tagging per reach varied to spread tags evenly throughout a given reach. * denotes an additional 9 pools were sampled for tagging, but fish were not captured due to poor seining access.

Location	Sampling Strategy	Depth Criteria (cm)	# of Pools with tagging	Lowest Coordinate	Upper Coordinate
Prairie Creek Reach 69	Every 4th Pool	50	7	10 T 0412688 E 4574613 N	10 T 0413706 E 4575816 N
Prairie Creek Reach 70	Every 4th	50	7	10 T 0413706 E 4575816 N	10 T 0413779 E 4577510 N
Prairie Creek Reach 71	Every 6th	40	14	10 T 0413779 E 4577510 N	10 T 0414580 E 4579737 N
Prairie Creek Reach 72	Every 6th	30	13	10 T 0414573 E 4579725 N	10 T 0414743 E 4582238 N
Prairie Creek Reach 73	Every 6th	30	21	10 T 0414743 E 4582238 N	10 T 0413831 E 4584578 N
Prairie Creek Reach 74	Every 6th	30	11	10 T 0413831 E 4584578 N	10 T 0413831 E 4586645 N
Boyes Creek	Every 4th	30	12	10 T 0414575 E 4579736 N	10 T 0415461 E 4579825 N
Streelow Creek	Every 4th	30	14	10 T 0413657 E 4577529 N	10 T 0412943 E 4577568 N
Total Pools sampled:			99*		

Fish Growth and Apparent Overwinter Survival Modeling

Emigration of tagged fish from Prairie Creek was detected by two radio-frequency identification (RFID) PIT tag antenna arrays in the main stem of Prairie Creek (10 T 0413779 E, 4577510 N and 10T 0412688 E, 4574613 N) and from a rotary screw trap located just upstream of the mouth of Prairie Creek. RFID antenna arrays detect unique tag numbers, time and date of detection, and directionality of movement. Antennas were kept running by battery power all year with exception of mid/late summer during periods of low flow and little observable movement. We operated a 5 foot diameter rotary screw trap just upstream of the mouth of Prairie Creek during the spring/summer migration period (2/26/15 – 7/27/15) for Coho Salmon and other juvenile salmonid species. All Coho Salmon captured at the rotary screw trap were scanned for the presence of a PIT tag. Tagged fish were measured for fork length ($\pm$ 1 mm) and weight ($\pm$ 0.1 g). Summer growth was estimated between the two tagging events. Overwinter growth was estimated from fish length at capture in October, 2014 until recapture at the screw trap during spring/summer 2015. We reported a variety of growth metrics to facilitate comparisons with other studies. Absolute growth rate (AGR) was determined as:

$$AGR = \frac{l_{t2} - l_{t1}}{t_2 - t_1}$$

and specific growth rate (SGR) was determined using lengths as:

$$SGR = \frac{(ln\,(l_{t2}) - ln\,(l_{t1})}{t_2 - t_1} * 100$$

where l_{t2} is the final fork length, l_{t1} is the initial fork length, t_2 is the time at final measurement, and t_1 is the time at initial measurement. Equations for relative growth rate (mm/mm/d), and percent change in length (mm) were provided by Busacker et al. (1990).

A Cormack-Jolly-Seber (CJS) model run in program MARK (Cooch and White 2014) was used to estimate capture probability at recapture points and to estimate apparent survival based on maximum-likelihood estimation (Horton and Letcher 2008, White and Burnham 1999). Estimated survival rates are considered apparent rather than actual because it was not always possible to distinguish between death and undetected emigration (Pess et al. 2011).

A capture history was compiled for each tagged fish as a sequence of 0's and 1's used to indicate whether a fish was captured or detected at each detection point or occasion (two tagging events, two antenna arrays, and a rotary screw trap). A 1 represented detection and a 0 represented absence of detection. For example, a capture history of 111 would represent an individual marked on occasion one and resighted on occasion 2 and 3, while 010 would mean the individual was not observed on occasion one, marked on occasion two, and not resighted on occasion three. A fish that was not detected at an occasion either did not survive to that occasion or was alive but not detected.

In the model, apparent survival rates between capture occasions are represented by φ, and recapture rates are represented by p. For example, φ_1 would be the survival rate between the first and second capture occasions, while p_2 would be the recapture rate at the second capture occasion. The survival and recapture rates can be used to calculate the probability of an encounter history. For example, the probability of encounter history 101 would be $\varphi_1(1 - p_2)\varphi_2\, p_3$. The model is based on the following assumptions (Amstrup et al. 2005):

1. All fish in the population that are alive at the time of sampling have homogenous probabilty of detection at a given capture occasion;

2. All fish in the population have homogenous survival for a given interval except as accounted for by covariates;

3. No errors are associated with PIT tagging (i.e. no tag loss, misread tags, or tag mortality);

4. Sampling is instantaneous;

5. All emigration from the population is permanent; and

6. The fate of each fish is independent of any other fish except as accounted for by covariates.

This CJS model had five occasions with the first two occasions being the summer and fall tagging events. Fish were either marked on the first capture occasion in summer or the second occasion in fall. The 3rd, 4th, and 5th encounter occasions included detection at the upper antenna, lower antenna, and capture in the rotary screw trap, respectively. The beginning of the spring migration period was set at February 27th, 2015 as this was the first day the screw trap was operating. Because of the limitation imposed by the timeframe of operation of the screw trap, only antenna detections from the same period were included in the analysis. In CJS models, the last φ and p parameters are not separately identifiable (Lebreton et al. 1992). Because the last φ and p are confounded, the detection efficiency (p) of the screw trap was fixed to 0.55 based on an independent estimate of the Prairie Creek screw trap capture efficiency of juvenile Coho Salmon. We estimated the trapping efficiency of yearling Coho Salmon throughout the trapping season using a subset of captured juvenile Coho Salmon that were marked and released upstream of the trap site. Most of the marked fish were released upstream of the trap site at night. Trap efficiency estimates were then obtained using mark-recapture methods described in Carlson et al. (1998).

The φ for the period between the fall occasion and detection at the upstream antennas represents overwinter survival rate for all fish, both those tagged above the upstream antennas (reaches 71-74, Boyes Creek, and Streelow Creek) and those tagged below (reaches 69-70). Although fish tagged in reaches 69 and 70 were not as likely to be encountered at the upstream antennas during outmigration, they could still potentially be detected at recapture points subsequent to the upstream antenna event, i.e. at the confluence antenna (fourth recapture occasion) and rotary screw trap (fifth recapture occasion), and thus considered to be overwinter survivors. Since the CJS model assumes an equal probability of recapture for all individuals and fish tagged in reaches 69 and 70 were not as likely to be detected at the upper antenna, recapture efficiency estimation of the upstream antenna could be biased. To account for this potential bias, a grouping variable was applied to the recapture model, based on whether a fish was tagged above or below the upstream antennas (g_2) to allow the recapture efficiency of the upstream antennas to be estimated separately for fish tagged above and below the antennas. Another grouping variable (g_1) was included that allowed for recapture efficiency at occasion 2 (p_2) to vary based on whether the pool was being sampled a second time on occasion 2 or not. (Table 3).

The median ĉ goodness of fit test in Program MARK was used to estimate the over dispersion parameter, ĉ. The overdispersion parameter is a measure of how much extra variation exists in the data relative to model structure. Because this test in Program MARK is unable to handle models containing individual covariates, the general starting model *φ(interval)p(interval* + g_1 + g_2*)* was used to assess general goodness of fit. Although this model doesn't include covariates, it does include the grouping variables (g_1 and g_2) and interval parameterization built into the MARK design matrix. This test runs repeated simulations of ĉ at different values and outputs values of deviance ĉ. MARK then fits a logistical regression to the simulated values of deviance ĉ under different simulated ĉ values with a binary response of above or below the observed model deviance ĉ calculated by MARK. The model overdispersion parameter ĉ is then the simulated value of ĉ where there is an equal number of simulated deviance ĉ's above and below the calculated model deviance ĉ. The median of these simulated ĉ values is the overdispersion parameter (Cooch and White 2014).

Quasi-Akaike's Information Criterion ($QAIC_c$) model selection (Burnham and Anderson 2002) was used to evaluate the effect of body length, Coho Salmon and trout densities, location, and habitat attributes on overwinter survival (Table 3). A lower bound of 1 was used in the median ĉ test, as this indicates perfect model fit. An upper bound was conservatively set at 10 as the upper bound is generally set just above the observed deviance ĉ (Cooch and White 2014). The default in MARK is set to simulate 10 intermediate points between lower and upper bounds and 10 replicates at each design point. Again to be conservative, 500 intermediate points between lower and upper bounds and 500 replicates at each design point were used. The ĉ value was then used to account for any over-dispersion in the data using $QAIC_c$ model selection. Model selection was based on Quasi-Akaike's Information Criterion corrected for sample size ($QAIC_c$), as follows (Amstrup et al. 2005):

$$QAIC_c = \frac{-2log_e(L(\hat{\theta})|x)}{\hat{c}} + 2K + \frac{2K(K+1)}{n-K-1}$$

where $L(\hat{\theta})|x$ is a likelihood function given the data x that indicates lack of model fit, K is the number of estimable parameters, and n is the effective sample size. For this study, the best models were considered to be the simplest model within approximately four $QAIC_c$ values of the best fitting model. The additional term $\frac{2K(K+1)}{n-K-1}$ is suggested by Amstrup et al. (2005) and is a correction for a finite sample size. The logit link function was used for all models, restricting survival and recapture rate estimates to the interval (0,1) (Lebreton et al. 1992). Because fish less than 60 mm were not able to be tagged because of NOAA 4 (d) Rule Take restrictions, inference can only be made on fish 60 mm or larger and not on the population as a whole. The proportion of fish in the population that were large enough for tagging (≥ 60mm) during the study was determined through random length measurements at each sampled pool. The proportion of the population that the overwinter survival estimate represents (P_{ows}) was calculated by:

$$P_{ows} = \frac{(T_s * P_s) + (T_f * P_f)}{T_s + T_f}$$

where T_s is the number of tagged fish in summer, T_f is the number of tagged fish in fall, P_s is the proportion of fish ≥ 60mm in the summer, and P_f is the proportion of fish ≥ 60mm in the fall.

Table 3. Model parameters used in the overwinter survival estimate. The term φ refers to a parameter that affects survival, and p refers to a parameter that affects recapture rate in the CJS model.

Model Parameter	Parameter Description
φ (Area)	Individual pool covariate measured by multiplying maximum pool length by average pool width.
φ (Length)	Individual covariate that described the fork length of the fish at the time of tagging. For fish which were only measured in summer length was adjusted for summer growth so that fish length was more comparable between fish tagged in the summer and fall events.
φ (Depth)	Individual pool covariate that described the residual pool depth to the nearest centimeter, measured by subtracting the maximum depth of the riffle crest exiting the pool from the maximum pool depth of the sample unit.
φ (LWD)	Individual pool covariate that described the number of logs greater than 30cm in diameter and greater than 2m in length occurring in (or suspended ≤ 1 meter directly above) the wetted area of the sampled unit.
φ (Cover Rating)	Individual pool covariate defined as a ranking of cover (from 1-5) of all cover available to salmonids in relation to the total pool volume. Ranking is based on visual estimation.
φ (Watershed Area)	Individual pool covariate that referred to amount of watershed area above a given pool calculated using ARC GIS.
φ(Small.trout)	Individual pool covariate that described counts of trout <150 mm divided by the pool area.
φ(Large.trout)	Individual pool covariate that described counts of trout >150 mm divided by the pool area.
φ(Coho)	Individual pool covariate that used N-mixture model pool abundance estimates of juvenile Coho Salmon divided by pool area (m^2).
φ(Interval)	Survival parameter that allowed survival rate to vary between each capture occasion.
p (Interval)	Recapture parameter that allowed recapture rate to vary by capture occasion (ie.seining,each antenna detection, and screw trap capture).
p (g_1)	A grouping variable that allowed for recapture efficiency at occasion 2 to vary based on whether the pool was sampled again on occasion 2 or not.
p (g_2)	A grouping variable that allowed for recapture efficiency at occasion 3 to vary based on whether a fish was tagged above or below the upper antenna.

Sampling Methodology

Sampling of fish and habitat was restricted to pools, which constitute the preferred habitat of juvenile Coho Salmon (Nickelson et al. 1992). All pools that met pool selection criteria in the main stem of Prairie Creek and in Streelow and Boyes Creeks were censused in a spatially balanced way. Pool selection criteria were adapted from regional CDFW juvenile Coho Salmon monitoring protocols (S. Ricker pers. comm., 2014). Sampling locations and the number of pools sampled at each location are given in Table 2. Reach distinctions within Prairie Creek were pre-established by the California Department of Fish and Wildlife, based on breaks in stream gradients.

For a pool to be included as a potential sampling unit, it needed to meet pool depth categories that were defined for each reach in advance by CDFW personnel. Stream flows $< 0.1\ m^3 \cdot s^{-1}$ had pool depth criteria of 25 cm, $0.1 - 1.0\ m^3 \cdot s^{-1}$ had depth criteria of 30 cm, $1.0 - 1.5\ m^3 \cdot s^{-1}$ had depth criteria of 40 cm, and $> 1.5\ m^3 \cdot s^{-1}$ had depth criteria of 50 cm. These criteria were used to avoid excessive sampling in marginal quality habitats in larger stream reaches (S. Ricker pers. comm., 2014). Additional criteria for a pool to be selected included having a minimum surface area of 3 m^2 for streams with wetted channel width < 3 m and a width of at least one-half the wetted channel width. For streams with wetted widths > 3 m, a pool had to have a minimum surface area of 6 m^2 and a width of at least one-half the wetted channel width. Backwater pools did not need to equal at least one-half the channel width and had to have a minimum surface area of at least 3 m^2. Smaller side channels were included in the survey after the primary channel had been surveyed up to where it rejoins the side channel. Units needed a minimum depth of 30 cm, a surface areas of 3 m^2 and a width of at least one-half the wetted channel to be selected.

Pool boundaries were defined based on hydrologic and geomorphic breaks or obstructions that would impede fish from passing from one unit to the next between dive passes. In some cases distinct breaks were not present and breaking the unit became somewhat subjective. Snorkel counts of juvenile fish were made and habitat attributes were measured in each pool selected for fish tagging.

Smolt Abundances

The methods and materials used to quantify smolt abundances in 2015 were the same as those used in lower Prairie Creek in YRS 2011 – 2014, upper RC (n = 16 years) and lower RC (n = 12 years) (Sparkman 2016, Sparkman et al. 2016). A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in lower Prairie Creek (NAD 83 41.29475300, -124.03773270; Rm 0.04) in YRS 2011 – 2015, just upstream of the confluence of Prairie Creek with RC.

Trap Operations

We operated the rotary screw trap continually (24 hrs/day, 7 days a week) each trapping season, with exception to days of missed trapping. Days missed trapping usually occurred during very high stream flows, when logs, large branches, and various debris (sticks, leaves) floated downstream. We used standard statistical techniques to estimate the number of fish moving downstream when the trap was inoperable (Roper and Scarnecchia 1999). During periods of lesser stream flows, we installed weir panels to force all migrating fish into the cone area of the trap, and to keep the trap operable. Weir panels were lined with smooth plywood to further increase stream flow into the cone. The weir panels also helped maintain good trapping efficiencies. When stream flows were too low, we installed sandbags below the trap's pontoons to ensure the cone would not be damaged by the stream bed. We operated the rotary screw trap throughout the trapping season in 2015, and a fyke net/pipe trap was not used. Trapping was discontinued each trapping season when the catch distribution for each species at age reached zero, or when relatively few individuals were captured in consecutive days. The trapping seasons can be characterized as: 1) closely monitoring the trap over the course of each season to minimize mortality of captured fish from floating debris, 2) frequently visiting the trap at night to remove debris from within the trap's livebox, 3) releasing marked fish for trap efficiency trials at night, 4) making frequent adjustments to the trap configuration to maintain cone revolutions and trapping efficiencies, 5) maintaining the trap's position in the thalweg, 6) extensively using weir panels to keep the screw trap in operation, and 7) installing a fyke net/pipe trap to finish the trapping season during low stream flow periods in certain years.

Biometric Data Collection

Fishery technicians frequently removed debris (e.g. alder cones, leaves, sticks, detritus, etc.) from within the livebox at night to reduce trapping mortalities the following morning. The trap's livebox was emptied at 09:00 every morning by 2 - 4 technicians. Debris was once again inspected and carefully removed so that the smaller fish would not be released into the stream with the debris.

Young of year fish were removed first and processed before 1+ and 2+ fish to decrease predation or injury to the smaller fish. Captured fish (0+ fish first, then 1+ and older) were placed into 5 gal. buckets and carried to the processing station. Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the buckets for examination, enumeration, and biometric data collection. Each individual fish was counted by species at age, and observed for trap efficiency trial marks. The marks used for each species at age in Prairie Creek were different than those used for the trap in lower RC (Sparkman et al. 2016). Technicians also scanned all 1+ and older fish for pit tags that were either tagged from the smolt traps in RC, or within the Prairie Creek basin during the previous fall months (Coho Salmon overwinter survival component to study).

Fork Lengths/Weights

Fish were anesthetized with MS-222 prior to data collection in 2 gal. dishpans. Biometric data collection included 30 measurements of fork length (mm) and wet weight (g) for random samples of 0+ Chinook Salmon (0+ KS), 1+ Chinook Salmon (1+ KS, if present), 1+ and greater Cutthroat Trout (CT), 1+ Steelhead Trout (1+ SH), 2+ and greater Steelhead Trout (2+ SH), 0+ Coho Salmon (0+ CO), 1+ Coho Salmon (1+ CO), and 0+ Pink Salmon (0+ PK) (if present). Only fork lengths were taken from 0+ trout (0+ TR). A 160 and 350 mm measuring board ($\pm$ 1 mm), and an Ohaus Scout ll digital scale ($\pm$ 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ trout and 1+ and 2+ Steelhead Trout, Coho Salmon, and Chinook Salmon were used to determine age-length relationships at various times throughout the trapping periods. Scales were occasionally read to verify age class cutoffs. 0+ Chinook Salmon, 1+ Steelhead Trout, 1+ Coho Salmon, and Cutthroat Trout weights were taken 2 - 7 times per week; and 0+ Coho Salmon and 2+ Steelhead Trout weights were taken nearly every day of trap operation and collection due to expected, low sample sizes. Individuals were weighed in a tared plastic pan (containing water) on the electronic scale. The scale was calibrated every day prior to data collection, and placed in a large plastic bin when weighing fish to prevent any influences from wind. After biometric data was collected, fish were placed into 5 gal. recovery buckets which periodically received fresh stream water by adding water to the buckets from the stream. During periods of increased catches, we used a bilge pump in the stream to deliver water to the processing station and recovery buckets (Sparkman et al., In progress). Young of year fish were kept in separate recovery buckets from age 1+ and older fish to decrease predation or injury. When fully recovered from anesthesia, 0+ juvenile fish were transported 50 m downstream of the trap site and released in the margin of the stream; and aged 1 and older fish were transported 75 m downstream of the trap site and released near the middle of the stream when possible.

Population Estimates

The number of fish captured by the trap represented only a portion of the total fish moving downstream in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly and seasonal basis for 0+ Chinook Salmon, 1+ Steelhead Trout, 2+ Steelhead Trout, juvenile Coastal Cutthroat Trout (FL < 250 mm), 0+ Coho Salmon, 1+ Coho Salmon, and pit tagged 1+ Coho Salmon using mark-recapture methods described by Carlson et al. (1998). Population estimation methods in YRS 2011 - 2015 were identical to those used in upper and lower RC (Sparkman 2016, Sparkman et al. 2016). Mark/recapture experiments were conducted 2 - 5 times per week, depending upon sample sizes, with most upstream releases occurring at night. Annual variation in both population abundances and catches over the current five year period were characterized by the standard deviation and standard error of the mean for each species at age.

Physical Data Collection

Stream temperatures were recorded with two Optic StowAway® Temp data loggers (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. The probes were placed into PVC cylinders with holes to ensure adequate ventilation and to prevent influences from direct sunlight. The probes recorded stream temperatures (^oC) every 15 minutes, and recorded 14,496 measurements per probe in 2015. Data from one probe is reported because both probes gave similar results, with the difference between averages equaling 0.05 ^oC. The shallowest stream depth during which measurements were taken (end of trapping periods) was about 1.5 feet.

Statistical Analyses

The statistical analyses for smolt trapping conducted in 2015 were the same as those used for smolt trapping in lower Prairie Creek in YRS 2011 – 2014 (Sparkman et al. 2015). Numbers Cruncher Statistical System software (NCSS 97) (Hintze 1998) was used for linear correlation, regression/ANOVA output, and descriptive statistics. Linear regression was used to estimate the catch for each species at age for days when the trap was not fishing by using data before and after the missed day(s) catch. The estimated catch (except for 1+ Chinook Salmon and 0+ trout) was then added to the known catch in a given stratum and applied to the population model for that stratum (Roper and Scarnecchia 1999). Linear correlation slope and p values were used to determine if population abundances of a given species at age were increasing or decreasing over the five years of study. The tests are considered preliminary, and more data will be required to detect trends in population abundances over years.

Descriptive statistics were used to characterize the average FL (mm) and Wt (g) of each species at age on a study year basis. If data violated tests of statistical assumptions ($n = 4$ tests for ANOVA, $n = 3$ tests for regression and correlation; NCSS 97), data was transformed with Log (x +1) to approximate normality (Zar 1999). The term 'transformed' in this paper refers to the log (x +1) transformation. Power is defined as the probability of correctly rejecting the null hypothesis when it is false; and can also be thought of as the probability of detecting differences that truly exist (Zar 1999). The level of significance (alpha) was set at 0.05 for statistical analyses.

Trap Derived Estimate of Juvenile Coho Salmon Overwinter Survival

We used mark/recapture methods to estimate the total number of pit tagged 1+ Coho Salmon that passed the trapping site on a weekly and seasonal basis using Carlson et al. (1998) population model. Upon first capture of pit tagged 1+ Coho Salmon with the smolt trap, technicians recorded the pit tag number, and measured and weighed each fish. The captured fish were then taken upstream of the trap site, and released at night, along with non-pit tagged 1+ Coho Salmon. Upon recapture the following day(s), the tagged fish were recorded for pit tag number(s), and data was recorded separately from non-tagged recaptured 1+ Coho Salmon. We then divided the mark/recapture population point estimate by the number of 1+ Coho Salmon that were pit tagged in the fall (n = 1,061) to derive an overwinter survival rate. We determined 95% CI's for the trap derived overwinter survival estimate by dividing the upper and lower 95% CI associated with the population point estimate by the number of Coho Salmon that were pit tagged in late summer/fall.

We also compared the migration pattern of pit tagged 1+ Coho Salmon with non-pit tagged 1+ Coho Salmon by graphical and statistical analyses of daily catch and weekly population data between the two groups to evaluate a possible effect of pit tagging on smolt migratory behavior.

RESULTS

Juvenile Coho Salmon Overwinter Survival and Growth

Apparent Overwinter Survival of Juveniles

A total of 395 fish were captured and tagged in the summer tagging event, and 666 fish were captured and tagged in the fall. A total of 52 previously captured and tagged fish in the summer were also captured in the fall. The estimated percentage of the population that was large enough for tagging (FL $\geq$ 60 mm) represented 53.8% of the population. Thus, inference from the overwinter survival data can be made to 53.8% of the population. During the spring migration 142 fish were detected at the upper antenna, 159 fish were detected at the lower antenna, and 168 fish were captured by the rotary screw trap in 2015. The smolt trap also captured six 2+ Coho Salmon that were pit tagged in the fall of 2013, and based upon trapping efficiencies, expanded to nine 2+ Coho smolts. We estimate that 1.5% of the pit tagged fish (age-0) from 2013 emigrated at age-2 in 2015. Age-2 Coho Salmon smolts represented 2.9% of the total abundance of pit tagged Coho smolts passing the trap site in 2015. Compared to the total population of Coho Salmon smolts, which includes pit tagged and non-pit tagged smolts, age-2 pit tagged Coho Salmon smolts represented 0.04%. A summary of all Coho Salmon captures is given in Appendix 2. Additional fish were detected at both antennas prior to the installation of the screw trap in spring, however, antenna detections prior to screw trap deployment were not included in analysis.

The top model describing overwinter survival was found to be φ (Length+Watershed Area+ Interval) p (g1+g2+Interval) (Table 4). Although $\hat{c}$ was estimated to be relatively close to 1, we decided to be conservative and expected over-dispersion, and hence opted to proceed with $QAIC_c$. As expected, length at tagging showed a strong relationship with survival (Fig. 2). While watershed area was in the top model, survival varied across the watershed area by less than 2%, suggesting that this finding lacked any biological significance. Increasing Coho Salmon density decreased survival probability (Fig. 3). Although Coho Salmon density was not in the top model, it was in half the models with a delta $QAIC_c$ less than 4, and had a delta $QAIC_c$ weight totaling 0.38.

Survival was estimated for four separate intervals (Table 5). The first interval ($\varphi 1$) was between the summer tagging event and fall tagging event and was interpreted as summer survival. Summer survival was found to be 0.84 (95% CI 0.558- 0.957). The second interval ($\varphi 2$) was between the fall tagging event and the upper antenna and was interpreted as overwinter survival. Overwinter survival was found to be 0.33 (95% CI 0.29-0.38). The third and fourth intervals ($\varphi 3$ and $\varphi 4$) are the intervals between the upper antennas and lower antennas and between the lower antennas and rotary screw trap. These estimates are shown in Table 5, and are both estimated to be close to 100% survival. We did not include these intervals in the overwinter survival estimate because the majority of overwinter loss occurred during $\varphi 2$. In addition, any fish that survived $\varphi 3$ *or* $\varphi 4$ also had to survive overwinter ($\varphi 2$). For example, a fish that was tagged on the first occasion and not detected again until the last occasion must have survived the winter, even though it was not detected at the antennas. A similar model structure was used in estimating overwinter survival of juvenile Coho Salmon in Prairie Creek during 2012-2013 (Moore 2014) and 2013 - 2014 (Sparkman et al. 2015).

Table 4. QAICc results for over-winter model selection. Full description of each term can be referenced in Table 3. All models containing $p(g_1+g_2+\text{Interval})$ in addition to φ parameterization, except the null model.

Model	$QAIC_c$	Delta $QAIC_c$	$QAIC_c$ Weights	Num. Par	QDeviance
φ (Length+Watershed Area+ Interval)	2207.00	0	0.249	11	2184.81
φ (Length+Watershed Area+Coho+Interval)	2207.70	0.696	0.176	12	2183.47
φ (Length+Watershed Area+Small.trout+Interval)	2208.86	1.865	0.098	12	2184.64
φ (Length+Watershed Area+Large.trout+Interval)	2208.88	1.884	0.097	12	2184.66
φ (Length+Watershed Area+Coho+Small.trout+Interval)	2209.20	2.199	0.083	13	2182.94
φ (Length+Watershed Area+Coho+Large.trout+Interval)	2209.49	2.496	0.071	13	2183.23
φ (Length+Watershed Area+Coho+Depth+LWD+Cover Rating+Interval)	2210.40	3.403	0.045	15	2180.06
φ (Length+Watershed Area+Small.trout+Large.trout+Interval)	2210.79	3.789	0.037	13	2184.53
φ (Length+Watershed Area+Coho+Small.trout+Large.trout+Interval)	2211.07	4.072	0.032	14	2182.77
φ (Length+Watershed Area+Depth+LWD+Cover Rating+Interval)	2211.41	4.410	0.027	14	2183.11
φ (Length+Watershed Area+Coho+Small.trout+Depth+LWD+Cover Rating+Interval)	2211.49	4.487	0.026	16	2179.10
φ (Length+Watershed Area+Coho+Large.trout+Depth+LWD+Cover Rating+Interval)	2211.92	4.919	0.021	16	2179.53
φ (Length+Watershed Area+Large.trout+Depth+LWD+Cover Rating+Interval)	2213.13	6.130	0.012	15	2182.79
φ (Length+Watershed Area+Coho+Small.trout+Large.trout+Depth+LWD+Cover Rating+Interval)	2213.22	6.219	0.011	17	2178.78
φ (Length+Watershed Area+Small.trout+Depth+LWD+Cover Rating+Interval)	2213.44	6.442	0.010	15	2183.10
φ (Length+Watershed Area+Small.trout+Large.trout+Depth+LWD+Cover Rating+Interval)	2215.17	8.176	0.0042	16	2182.79
φ (Interval)	2248.02	41.023	0	9	2229.89
Null	2553.02	346.017	0	2	2549.01

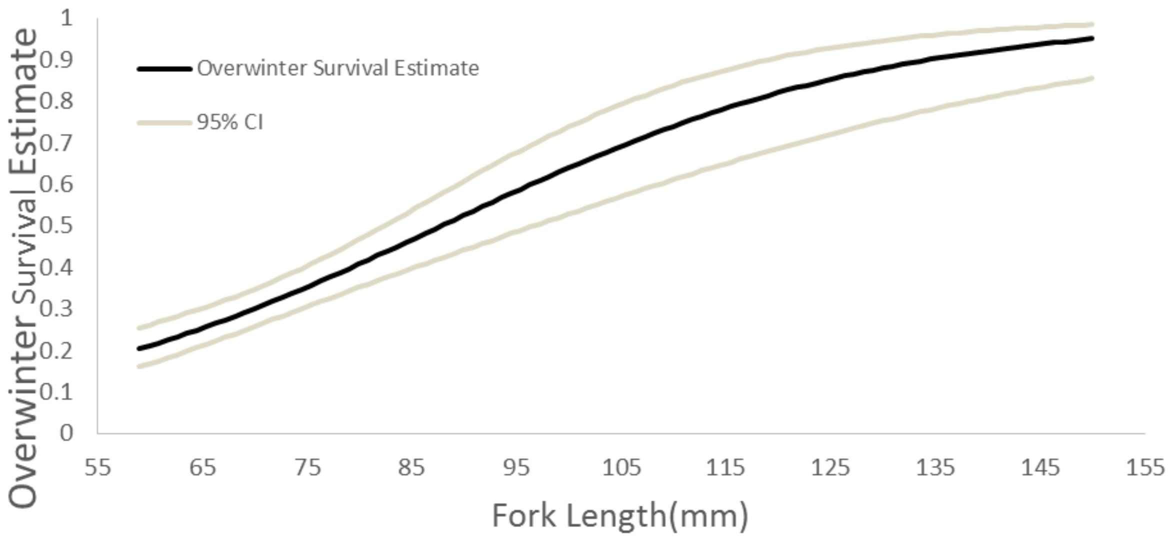

Figure 2. Relationship of overwinter survival with fall fork length (mm) at tagging. Length of fish tagged in the summer and not observed in the fall had their fork lengths adjusted using the observed summer growth to account for differences in tagging time. Taken from the top model {*φ* (Length+Watershed Area + Interval) p(g_1+g_2+Interval)}, Prairie Creek, Humboldt County, CA.

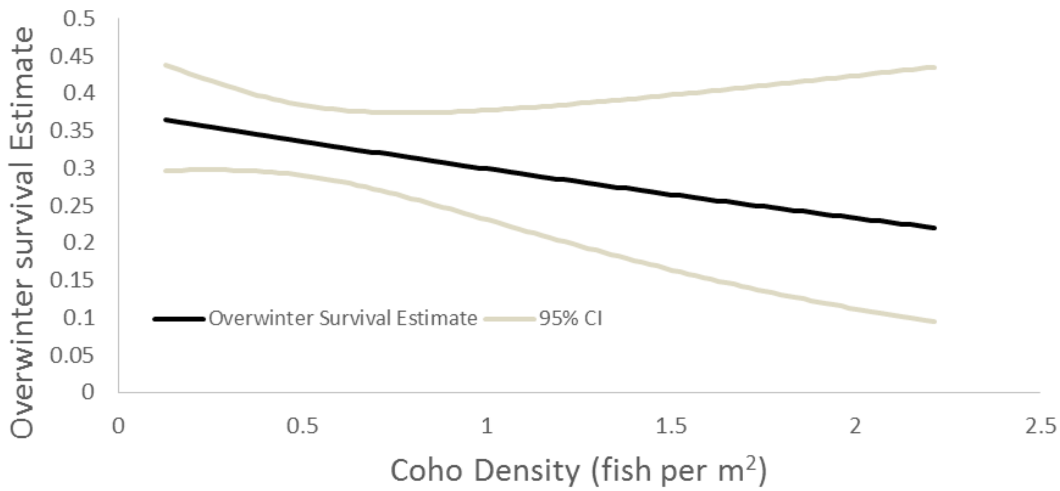

Figure 3. Relationship of overwinter survival with Coho Salmon Density. Taken from the model {φ (Length+Watershed Area+Coho+Interval) p (g_1+g_2+Interval)}, Prairie Creek, Humboldt County, CA.

Table 5. CJS model survival and detection efficiency estimates, with standard error (SE) and 95 % confidence intervals. * *p* for the rotary screw trap was fixed (average weekly trapping efficiency) because survival and detectability at the last occasion were confounded.

Model Parameter	Description	Estimate	SE	95% Confidence Interval	
φ1	Survival rate between summer and fall tagging occasions(summer survival)	0.84	0.098	0.558	0.957
φ2	Survival rate between fall tagging and upstream antennas (overwinter survival)	0.334	0.024	0.288	0.383
φ3	Survival rate between upper antenna and lower antenna	0.9425	.064	0.617	0.994
φ4	Survival rate between the lower antennas and the rotary screw trap.	0.9462	0.072	0.519	0.997
p2(same habitat)	Recapture rate for fish in fall tagging occasion where tagging occurred in same pool in summer tag event.	0.301	.0478	0.216	0.402
p2(new habitat)	Recapture rate for fish in fall tagging occasion where tagging did not occur in same pool in summer.	0.0314	0.0135	0.0134	0.0720
p3(above)	Recapture rate at the upstream antennas for fish tagged above the upstream antenna	0.689	0.0414	0.602	0.763
p3(below)	Recapture rate at the upstream antennas for fish tagged below the upstream antenna	0.0544	0.0199	0.0262	0.109
p4	Recapture rate at the lower antenna	0.492	0.0391	0.417	0.569
p5	Recapture rate at the rotary screw trap	0.55*	-	-	-

Overwinter Movement

Prior to spring migration and smolt trap deployment in 2015, the pit tag antenna array in lower Prairie Creek detected 67 out of 1,061 tagged fish moving downstream. Eight (unexpanded) of the tagged fish were later captured by the smolt trap in 2015, thus 59 (unexpanded) (or 5.6% of the tagged fish) may have left Prairie Creek, or stayed downstream of the lower most antenna in Prairie Creek to rear.

Fish Size Distribution

Fish sizes were based on fork length (mm) measured on randomly selected fish from each sampled pool, and the size distribution of juvenile Coho Salmon during each tagging occasion shows that fish tagged during the summer were smaller than fish tagged in the fall (Fig. 4). The long right skew was likely composed of 1+ juveniles, or age-0 juveniles that experienced higher growth rates.

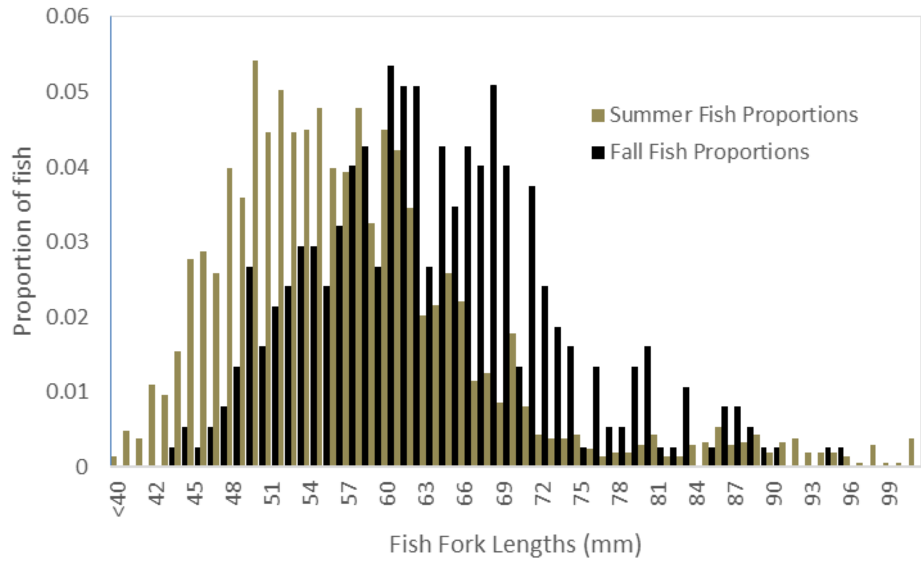

Figure 4. Size distribution of juvenile Coho Salmon randomly selected for length measurements throughout all tagging locations during summer and fall tagging events. Sample sizes for summer measurements were 2,088, and for fall 374, Prairie Creek, Humboldt County, CA. 2014.

<u>Summer Growth</u>

The proportion of fish that were of taggable size (FL mm $\geq$ 60 mm) in the summer represented 35% of juveniles present within the sampling locations, thus our summer growth estimates apply only to 35% of the summer population. Summer growth was analyzed using the PIT tagged Coho Salmon tagged in the summer and later recaptured during the fall tagging event. Time (d) from first tagging (summer) to second tagging events (fall) ranged from 43 - 67 days, and averaged 50.6 days (n = 52 fish, SD = 9.49, SE = 1.32). Absolute growth rate averaged 0.16 mm/d (n = 52 fish, SD = 0.13, SE = 0.02), and specific growth rate averaged 0.21 % mm/d (n = 52 fish, SD = 0.17, SE = 0.02) (Table 6). The absolute growth between summer tagging and fall capture averaged 7.2 mm (n = 52 fish, SD = 5.5, SE = 0.76), and 7.2 mm was used in the overwinter survival analysis to adjust the length covariate (for fish tagged in summer) to account for the expected growth between summer and fall tagging events.

Table 6. Growth statistics for pit tagged age-0 Coho Salmon (n = 52, FL $\geq$ 60 mm) tagged in the summer and recaptured in the fall, 2014, Prairie Creek, Humboldt County, CA.

Summer Growth Statistics		Pit Tagged 0+ Coho Salmon
		(n = 52)
Absolute Growth Rate (mm/d)		
Average		0.16
Minimum		-0.02
Maximum		0.47
Relative Growth Rate (mm/mm/d)		
Average		0.0023
Minimum		-0.0002
Maximum		0.0069
Percent Change in FL (mm)		
Average		10.48
Minimum		-1.14
Maximum		30.30
Specific Growth Rate (% mm/d)		
Average		0.21
Minimum		-0.02
Maximum		0.61

Overwinter Growth

Overwinter growth from October, 2014 to spring capture at the smolt trap in 2015 was analyzed using the fall PIT tagged and recaptured Coho Salmon and spring recapture at the rotary screw trap. This analysis excluded fish with unknown fall lengths captured at the trap (i.e. fish tagged in the summer). Time (d) from October measurement to trap capture ranged from 155 – 250 days, and averaged 204 days (n = 103 fish, SD = 19.0, SE = 1.9). Size (FL, mm) at time of trap capture ranged from 76 – 121 mm, and averaged 102.4 mm (n = 103 fish, SD =9.7, SE = 1.0). Average growth between October and spring/summer screw trap capture was 28.9 mm (n = 103 fish, SD = 10.7, SE = 1.06). Absolute growth rate averaged 0.14 mm/d (n = 103 fish, SD = 0.05, SE = 0.005), and specific growth rate averaged 0.16 % mm/d (n = 103 fish, SD = .06, SE = 0.006) (Table 7). Averages in over-winter growth statistics in 2014 and 2015 were similar (Table 7).

Table 7. Various over-winter growth statistics (FL mm) for pit tagged juvenile Coho Salmon captured by the smolt trap in 2014 and 2015, Prairie Creek, Humboldt County, CA.

Growth Statistics		Pit Tagged 1+ Coho Salmon	
		2014 (n = 126)	2015 (n = 103)
Absolute Growth Rate (mm/d)			
Average		0.13	0.14
Minimum		0.03	0.02
Maximum		0.24	0.28
Relative Growth Rate (mm/mm/d)			
Average		0.0018	0.0020
Minimum		0.0004	0.0002
Maximum		0.0029	0.0046
Percent Change in FL (mm)			
Average		43.65	41.03
Minimum		8.70	3.03
Maximum		72.55	93.54
Specific Growth Rate (% mm/d)			
Average		0.15	0.16
Minimum		0.04	0.02
Maximum		0.24	0.32

Smolt Abundances

Smolt Trap Deployment

The rotary screw trap operated from 2/26/15 – 7/25/15 and trapped 146 days/nights out of a possible 149. The trapping rate in 2015 was 98%, compared to 95% for the previous four year average (ranged from 86 – 99%).

Species Captured

Juvenile Salmonids

Species captured in 2015 included: juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), juvenile Coho Salmon (*O. kisutch*), juvenile Steelhead (*O. mykiss*), and juvenile (and adult) Coastal Cutthroat Trout (*O. clarki clarki*). A total of 28,996 juvenile salmonids were captured in 2015 (Fig. 5). In addition, 35 adult Coastal Cutthroat Trout were also captured.

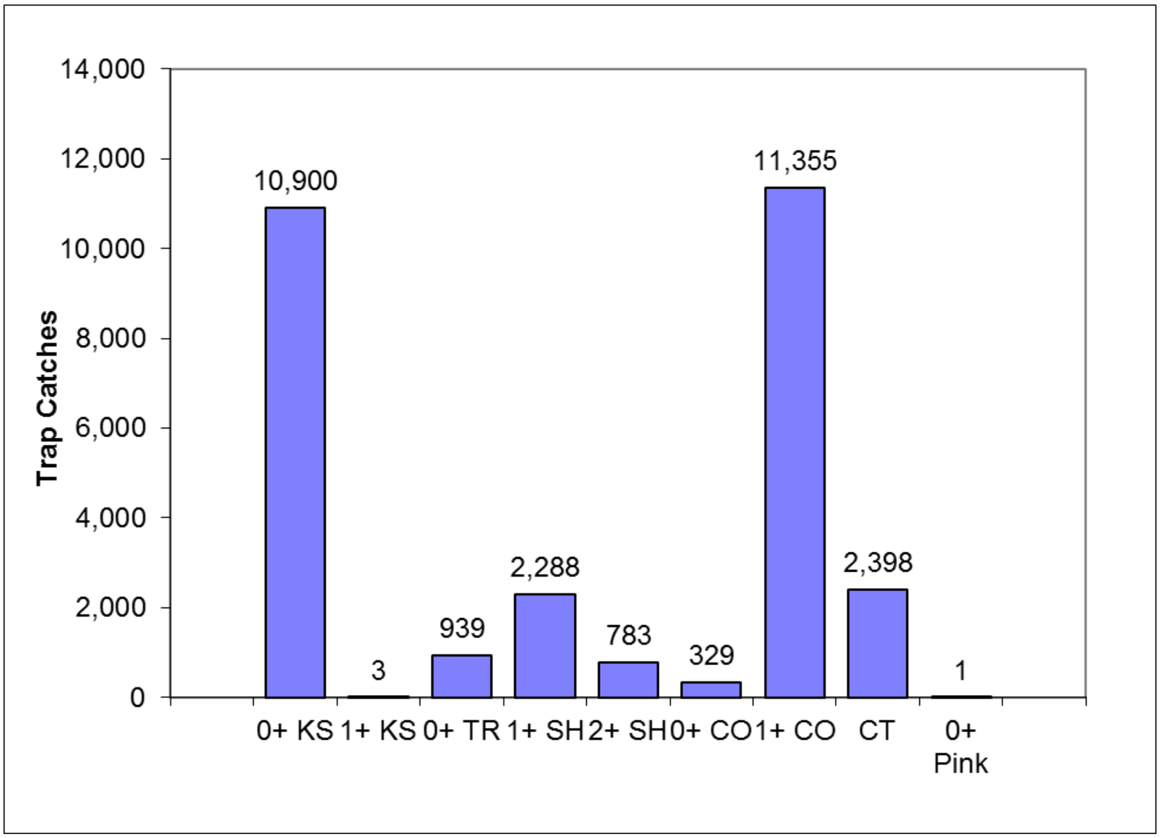

Figure 5. Total juvenile salmonid trap catches (n = 28,996) from February 27th through July 25th, 2015, Prairie Creek, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook Salmon, 1+ KS = age-1 Chinook Salmon, 0+ TR = young-of-year Steelhead and Cutthroat Trout, 1+ SH = age-1 and older Steelhead Trout, 2+ SH = age-2 and older Steelhead Trout, 0+ CO = young of year Coho Salmon, 1+ CO = age-1 and older Coho Salmon, CT = juvenile Cutthroat Trout, 0+ Pink = young-of-year Pink Salmon.

The average total catch by study year equaled 29,068 (n = 5, SD = 19,119; SEM = 8,550). The five year average catch equaled 15,038 (SD = 14,800; SEM = 6,619) for 0+ Chinook Salmon, 3 (SD = 2; SEM = 1) for 1+ Chinook Salmon, 2,254 (SD = 1,527; SEM = 683) for 0+ trout, 1,436 (SD = 758; SEM = 339) for 1+ Steelhead Trout, 480 (SD = 295; SEM = 132) for 2+ Steelhead Trout, 1,022 (SD = 1,078; SEM = 482) for 0+ Coho Salmon, 7,342(SD = 4,419 SEM = 1,976) for 1+ Coho Salmon, 1,487 (SD = 650; SEM = 291) for juvenile Cutthroat Trout, and 0.4 (SD = 0.5; SEM = 0.2) for 0+ Pink Salmon. The average catch by study year for adult Cutthroat Trout equaled 24 (n = 5, SD = 12; SEM = 5).

Miscellaneous Species

The trap caught numerous miscellaneous species in 2015, including: prickly sculpin (*Cottus asper*), coast range sculpin (*Cottus aleuticus*), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus*), juvenile (ammocoete) lamprey, and adult Pacific Lamprey (*Entosphenus tridentatus*), among other species (Table 8). Eulachon (*Thaleichthys pacificus*) were captured (n = 2) for the first time in 2015. Juvenile captures occurred for Prickly Sculpin (n = 43), Coast Range Sculpin (n = 309), Three-Spined Stickleback (n = 40), and Pacific/Brook Lamprey (n = 627). Gravid sculpins (both species) were also captured.

Table 8. Comparison of miscellaneous species captured by the smolt trap in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

Species Captured	Prev. 4 Yr Avg.	2015
Prickly Sculpin	1,356	1,062
Coast Range Sculpin	2,026	3,757
Sucker	202	277
Three-Spined Stickleback	2,591	2,251
Bullhead	0	0
Eulachon	0	2
Adult Pac. Lamprey	28	62
Juvenile Lamprey*	625	427
Brook Lamprey	88	72
Pac. Giant Salamander	3	1
Rough Skinned Newt	2	2
Red-Legged Frog	1	0
Yellow-Legged Frog	0.3	0
Tailed Frog**	7	0
Western Toad	3	2
Crawfish	4	3
Bull Frog	0	0

* Ammocoete stage, may include brook lamprey ammocoetes. ** Includes adult and tadpole stage.

Days Missed Trapping

Two days were not trapped during the course of study in 2015 when stream flows (and debris loads in the trap's livebox) were too high to safely trap (n = 2), and one day when we observed the 4th of July. The three days of missed trapping would not have influenced the total catch or population estimate of any species at age to any large degree (Table 9).

Table 9. The estimated catch and expansion (population level) of juvenile anadromous salmonids considered to have been missed due to trap not being deployed (n = 3 d) during the emigration period of February 26th through July 25th (as a percentage of total without missed days catch in parentheses), Prairie Creek, Humboldt County, CA., 2015.

Age/spp*	Catch	Population Level
0+ KS	180 (1.68%)	615 (2.80%)
1+ KS	0 (0.00%)	-
0+ TR	8 (0.86%)	-
1+ SH	12 (0.53%)	33 (0.43%)
2+ SH	14 (1.82%)	108 (2.45%)
0+ CO	15 (4.78%)	63 (3.94%)
1+ CO	78 (0.69%)	333 (1.57%)
CT	17 (0.71%)	41 (0.48%)

* Age/species abbreviations are the same as in Figure 2.
Note: Regression methods were used to estimate the number of fish caught when the trap was not operating. The estimated catches were then added the known catches for a given stratum (week) and used in the population estimate for that stratum (Roper and Scarnecchia 1999).

Trapping Efficiencies

The average trapping efficiency by week and seasonal trapping efficiency for 0+ Chinook Salmon, 1+ Steelhead, 2+ Steelhead, 0+ Coho Salmon, 1+ Coho Salmon, pit tagged 1+ Coho Salmon, and Coastal Cutthroat Trout fell within the range of 13 to 59% (Table 10).

Table 10. Average weekly and seasonal trapping efficiencies for 0+ Chinook Salmon, 1+ Steelhead, 2+ Steelhead, 0+ Coho Salmon, 1+ Coho Salmon, and Cutthroat Trout in 2015, Prairie Creek, Humboldt County, CA.

	Trapping Efficiency (percentage)	
Study Year	Average Weekly	Seasonal
0+ Chinook Salmon	51.5	56.6
1+ Chinook Salmon	-	-
1+ Steelhead Trout	31.1	28.8
2+ Steelhead Trout	25.3	17.3
0+ Coho Salmon	15.4	13.4
1+ Coho Salmon	54.7	55.3
1+ Coho Salmon*	52.6	59.3
Cutthroat Trout	45.0	36.9

* Pit tagged fish that were captured, released upstream of trap site, and recaptured.

Population Estimates

0+ Chinook Salmon

The population abundance (or production) of 0+ Chinook Salmon emigrating past the trap in lower Prairie Creek in 2015 equaled 22,562 with a 95% CI of 20,795 – 24,328 (Fig. 6). Population estimate error (or uncertainty) equaled ± 7.8% (CV = 3.9%), or 1,766 individuals. Population abundance in 2015 was 44% less than the previous four year average ($N_{avg\ 4yr}$ = 39,996), and 1.5 times greater than abundance in 2014. The average population abundance over the current five year period equaled 36,509 (SD = 34,483; SEM = 15,421).

Linear correlation failed to detect a significant relationship of population abundances over study years (n = 5, p = 0.98, r = 0.014, power = 0.10, alpha = 0.05) (Fig. 6).

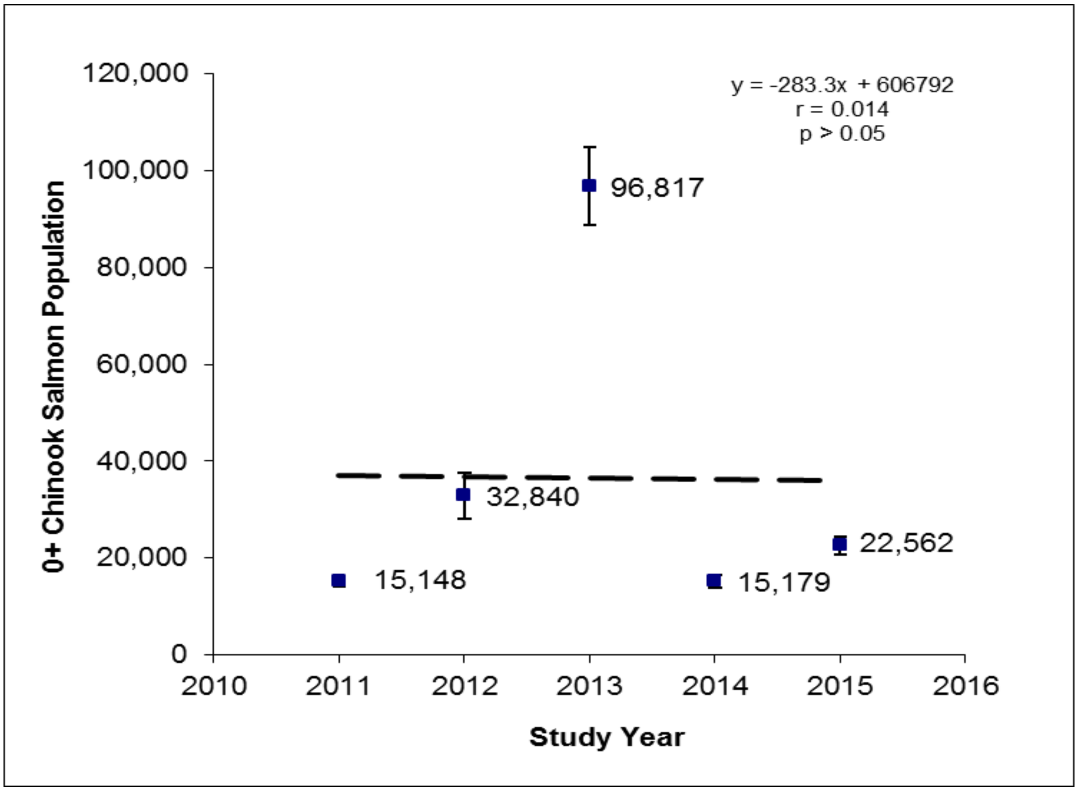

Figure 6. 0+ Chinook Salmon population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly population abundances in 2015 contrasted the pattern for the previous four year average (Fig. 7). Migration in March, 2015 was 13.5 times greater than migration in March for the previous four year average. The most important month for emigration was May (28% of total) in 2015, and May (49% of total) for the previous four year average. May (65% of total) was also the most important month in 2014. The two most important months for 0+ Chinook Salmon population emigration were March/May (53% of total) in 2015 and April/May (72% of total) for the previous four year average (Fig. 7). In 2014, April/May (81% of total) were also the two most important months.

The largest peak in weekly population emigration in 2015 occurred in March, much earlier than peaks in previous study years (Table 11, Fig. 8). The percentage of fry during peak migration in 2015 equaled 99%.

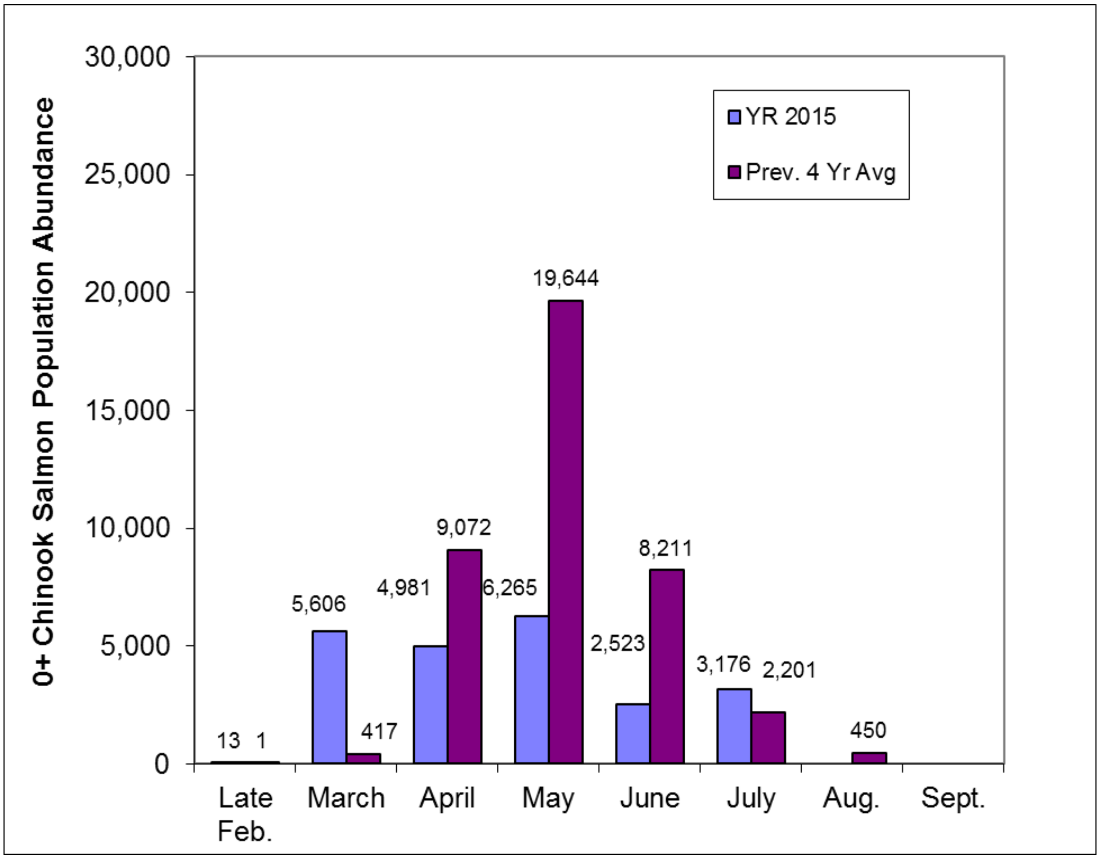

Figure 7. Comparison of 0+ Chinook Salmon population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

Table 11. Date of peak weekly 0+ Chinook Salmon population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA.

Study Year	Date of peak in weekly emigration (number in parentheses)
2011	6/18 – 6/24 (1,608)
2012	5/07 – 5/13 (10,057)
2013	4/30 – 5/06 (26,769)
2014	4/30 – 5/06 (3,199)
2015	3/19 – 3/25 (2,736)

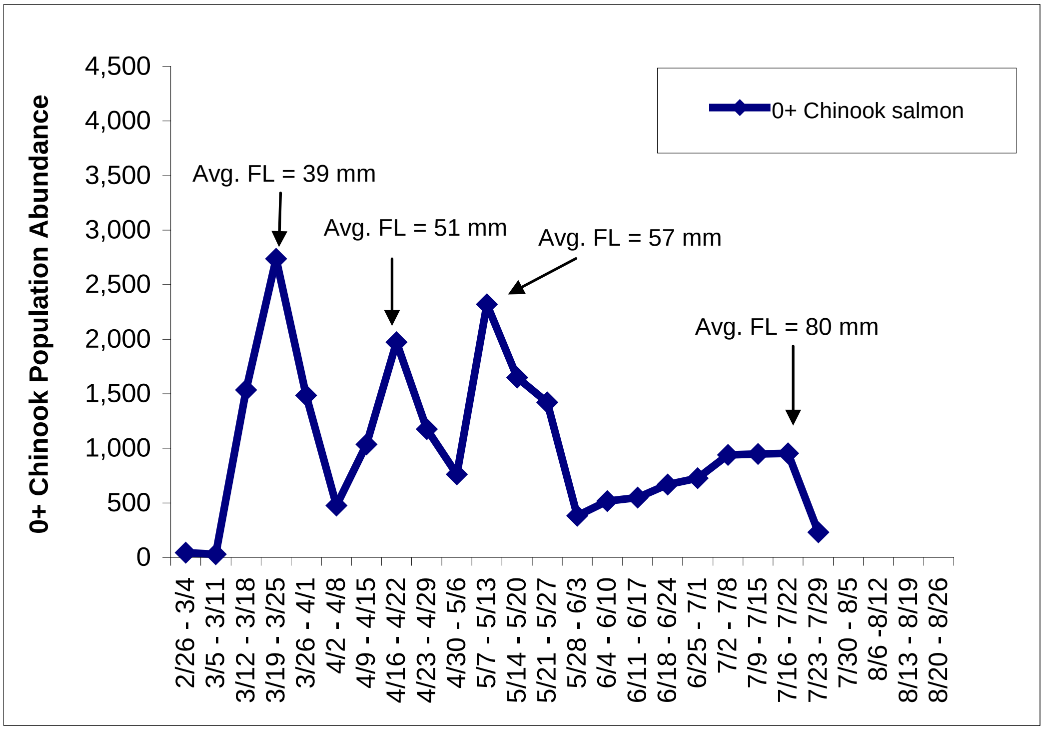

Figure 8. 0+ Chinook Salmon population abundance by week in 2015, Prairie Creek, Humboldt County, CA.

0+ Chinook Salmon downstream migrants consisted of fry (FL < 45 mm) and fingerlings (FL > 44 mm), and the number and percentage of 0+ Chinook Salmon migrants grouped into fry or fingerling categories varied among study years (Table 12). In 2015, fry (Avg. FL = 40 mm) comprised 30.1% and fingerlings (Avg. FL = 61 mm) comprised 69.9% of the total Chinook Salmon population abundance (Table 12).

The migration of Chinook Salmon fry and fingerlings in 2015 showed temporal overlap from 3/26 – 4/29 (Fig. 9). Fry migration peaked in March, and fingerling migration peaked in April, May, and July (Fig. 9). Fry migration peaked during 3/19 – 3/25 (N = 2,710) and fingerling migration peaked 5/07 – 5/13 (N = 2,255) (Fig. 9).

Fry migration ended in mid-May in 2015, and fingerling migration reached low values by late July, 2015 (Fig. 9).

Table 12. Production of 0+ Chinook Salmon partitioned into fry and fingerling categories each study year and for the previous four year average (expressed as a percentage in

parentheses for 2015 and the previous four year average), Prairie Creek, Humboldt County, CA.

Study Year	0+ Chinook Salmon production as: Fry (FL < 45mm)	Fingerling (FL > 44 mm)
2011	1,157	13,991
2012	22,469	10,371
2013	43,607	53,210
2014	5,767	9,412
Avg.	18,250 (45.6)	21,746 (54.4)
2015	6,785 (30.1)	15,777 (69.9)

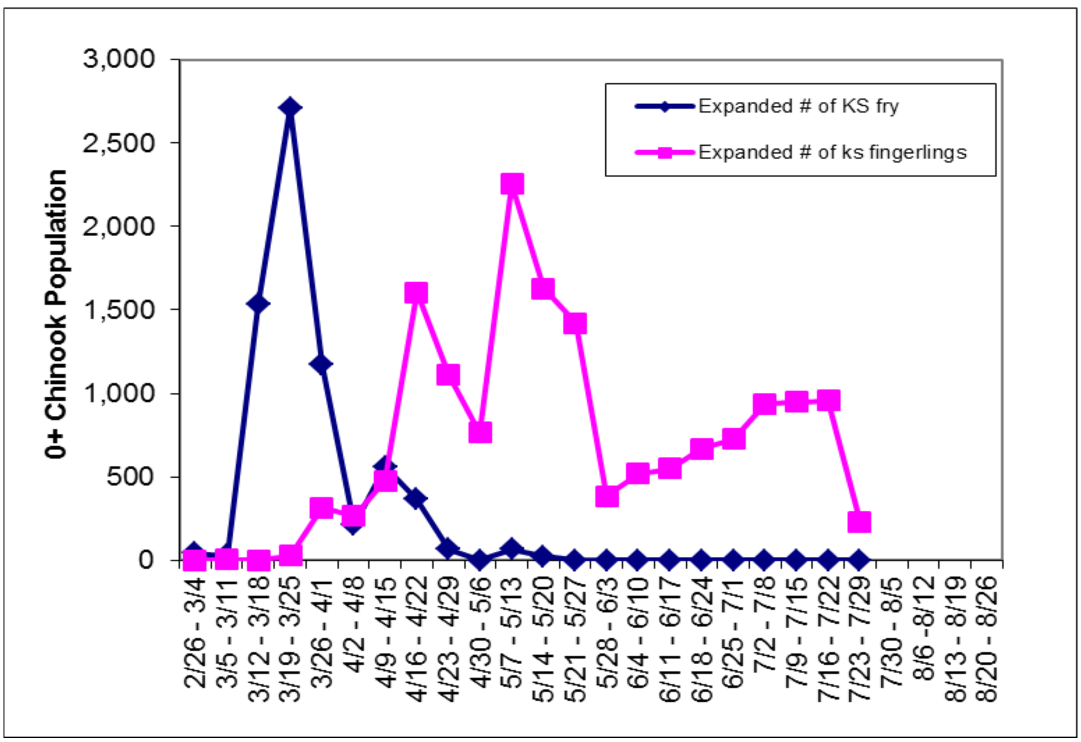

Figure 9. 0+ Chinook Salmon fry and fingerling population migration in 2015, Prairie Creek, Humboldt County, CA.

1+ Steelhead Trout

The population abundance (or production) of 1+ Steelhead emigrating past the trap in lower Prairie Creek in 2015 equaled 7,786 with a 95% CI of 7,023 – 8,549 (Fig. 10). Population estimate error equaled 9.8% (CV = 4.9%) or 763 individuals. Population abundance in 2015 was 1.5 times greater than the previous four year average ($N_{avg\ 4yr}$ = 5,209), and 1.1 times greater than abundance in 2014. The average population abundance over the current five year period equaled 5,724 (SD = 2,208; SEM = 987). Annual population abundances significantly increased over study years (n = 5, p = 0.04, r = 0.89, power = 0.83) (Fig. 10).

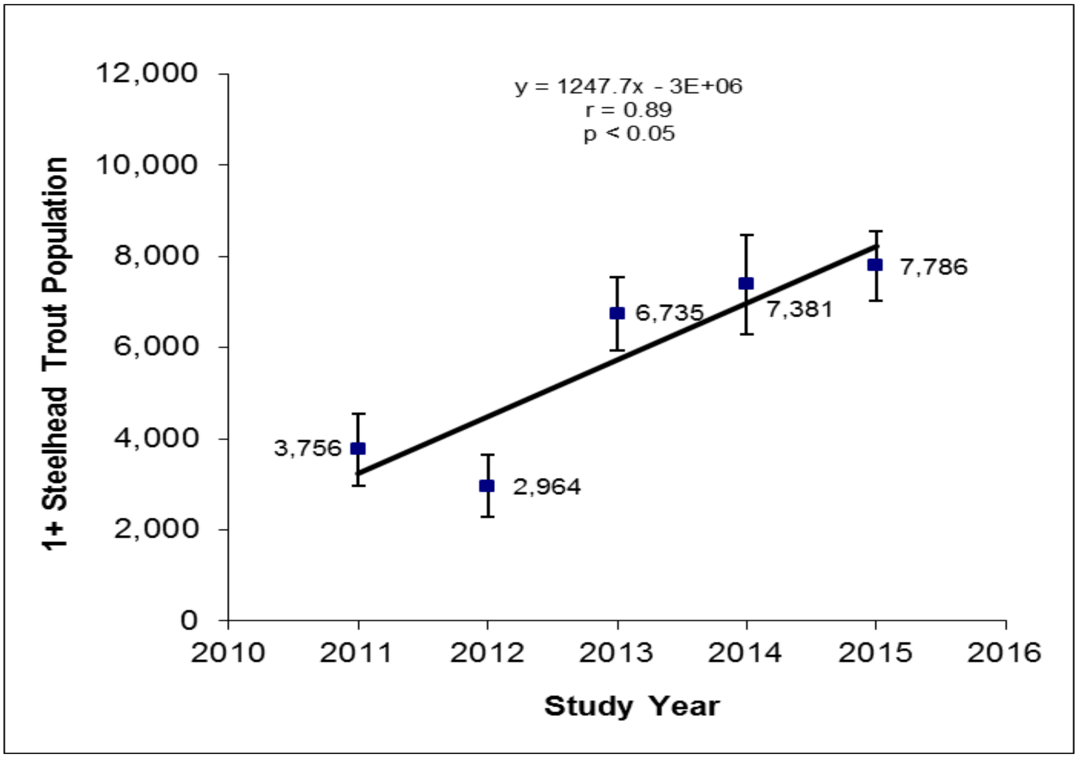

Figure 10. 1+ Steelhead population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly 1+ Steelhead Trout population abundances in 2015 was similar to the pattern for the previous four year average (Fig. 11). The most important month for emigration was May (53% of total) in 2015, May (43% of total) for the previous four year average, and April (41% of total) in 2014. The two most important months 1+ Steelhead Trout population emigration were April/May (84% of total) in 2015 and April/May (71% of total) for the previous four year average (Fig. 11). In 2014, April/May (81% of total) were also the two most important months.

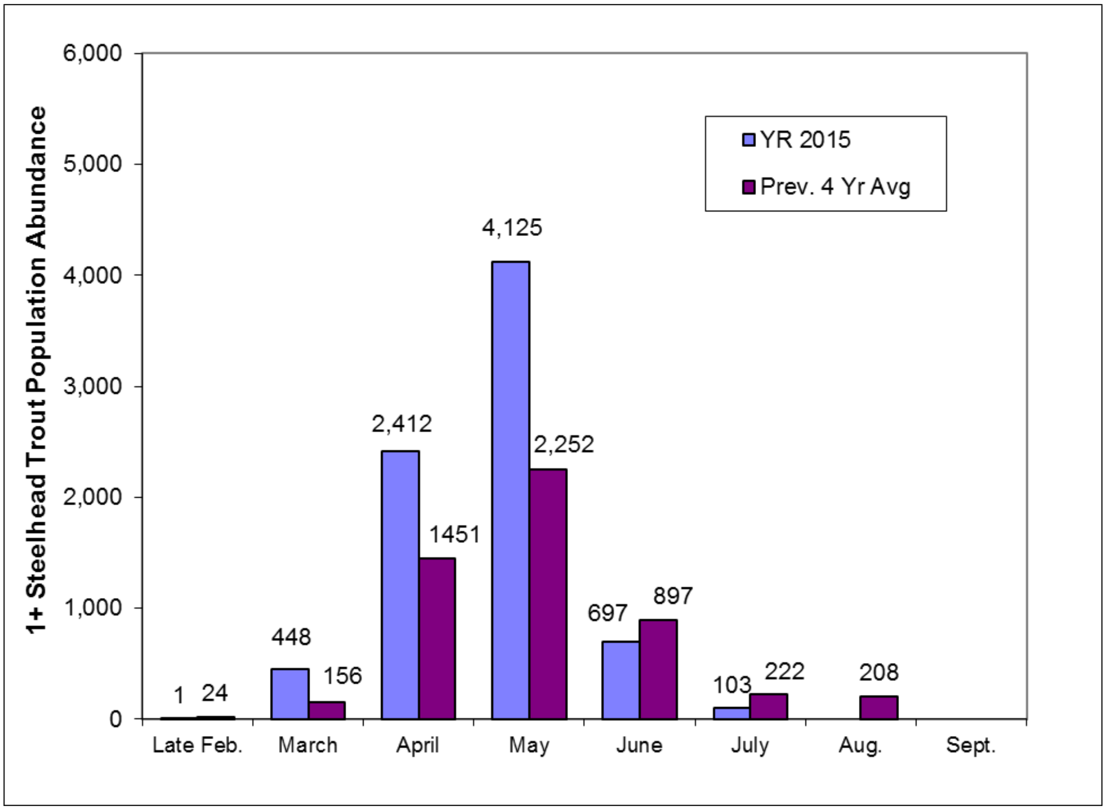

Figure 11. Comparison of 1+ Steelhead population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

The peak in weekly population emigration in 2015 occurred in 5/07 – 5/13 (Table 13). Weekly peaks in abundance over five years occurred in late April/early May and May.

Table 13. Date of peak weekly 1+ Steelhead population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA.

Study Year	Date of peak in weekly out-migration (number in parentheses)
2011	5/07 - 5/13 (751)
2012	5/21 - 5/27 (388)
2013	4/30 - 5/06 (1,700)
2014	5/21 - 5/27 (1,129)
2015	5/07 - 5/13 (1,197)

2+ Steelhead Trout

The population abundance (or production) of 2+ Steelhead Trout emigrating past the trap in lower Prairie Creek in 2015 equaled 4,520 with a 95% CI of 3,513 – 5,527 (Fig. 12). Population estimate error equaled 22.3% (CV = 11.2%) or 1,007 individuals. Population abundance in 2015 was 2.4 times greater than the previous four year average ($N_{avg\ 4yr}$ = 1,850), and 2.4 times greater than abundance in 2014. The average population abundance over the current five year period equaled 2,384 (SD = 1,819; SEM = 814).

Linear correlation failed to detect a significant relationship of population abundances over study years (n = 5, p = 0.18, r = 0.71, power = 0.39) (Fig. 12).

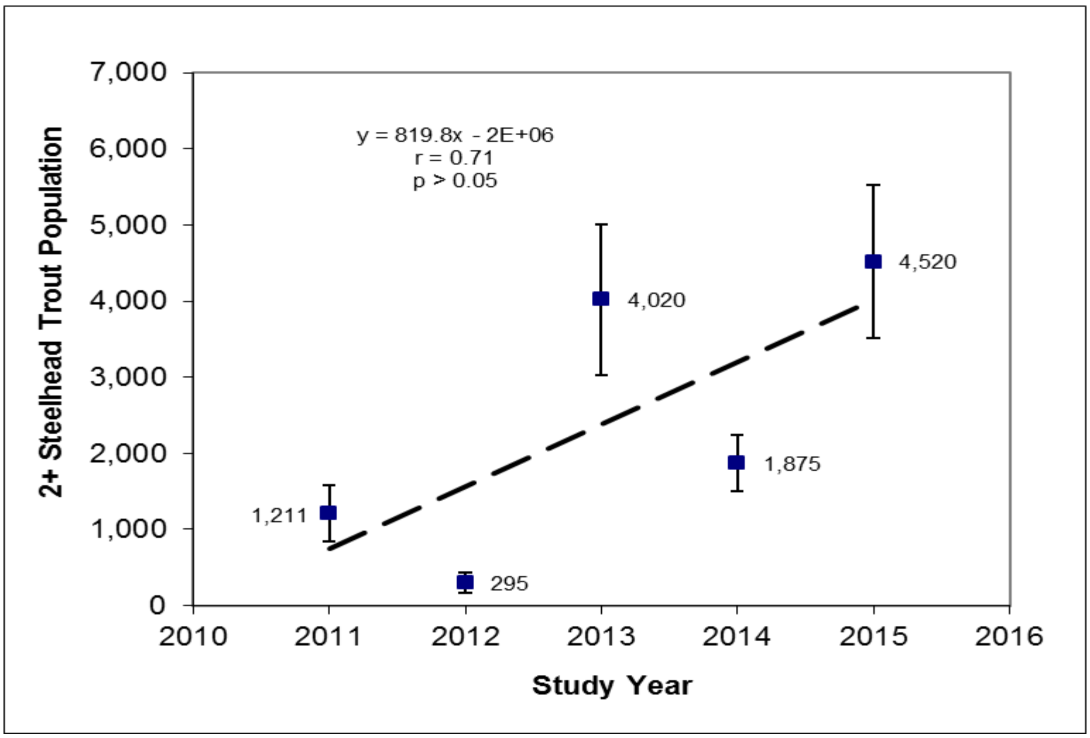

Figure 12. 2+ Steelhead population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly population abundances in 2015 was skewed to the left compared to the previous four year average (Fig. 13). Migration in March/April, 2015 was 16.7 and 4.0 times greater than migration in March/April for the previous four year average. The most important month for emigration was April (40% of total) in 2015, May (48% of total) for the previous four year average, and April (38% of total) in 2014. The two most important months 2+ Steelhead Trout population emigration were March/April (79% of total) in 2015, April/May (73% of total) for the previous four year average (Fig. 13). In 2014, April/May (67% of total) were also the two most important months.

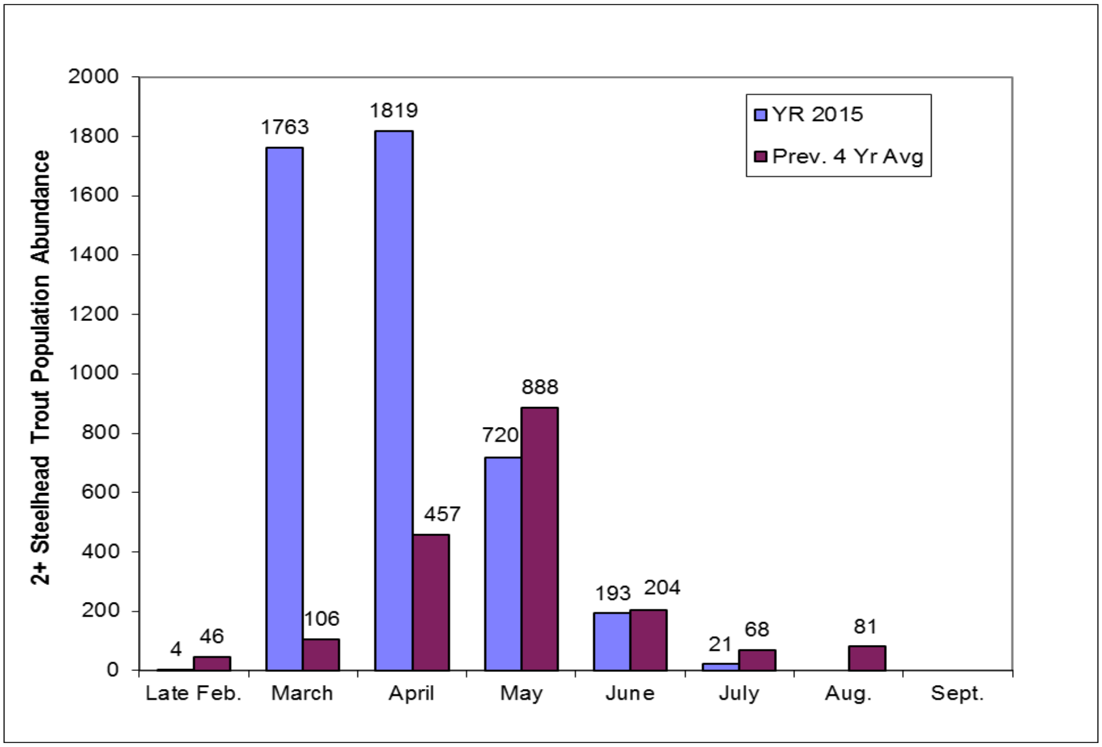

Figure 13. Comparison of 2+ Steelhead population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

The peak in weekly population emigration in 2015 occurred 4/16 – 4/22, the same week as in 2014 (Table 14).

Table 14. Date of peak weekly 2+ Steelhead population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA**.**

Study Year	Date of peak in weekly out-migration (number in parentheses)
2011	5/07 - 5/13 (299)
2012	2/26 - 3/04 (112)
2013	4/30 - 5/06 (1,170)
2014	4/16 - 4/22 (299)
2015	4/16 - 4/22 (925)

0+ Coho Salmon

The population abundance (or production) of 0+ Coho Salmon emigrating past the trap in lower Prairie Creek in 2015 equaled 1,601 with a 95% CI of 1,033 – 2,169 (Fig. 14). Population estimate error equaled 35.5% (CV = 17.8%) or 568 individuals. Population abundance in 2015 was 76% less than the previous four year average ($N_{avg\ 4yr}$ = 6,634), and 89% less than abundance in 2014. The average population abundance over the current five year period equaled 5,627 (SD = 5,605; SEM = 2,507).

Linear correlation failed to detect a significant relationship of population abundances over study years (n = 5, p = 0.73, r = 0.21, power = 0.11) (Fig. 14).

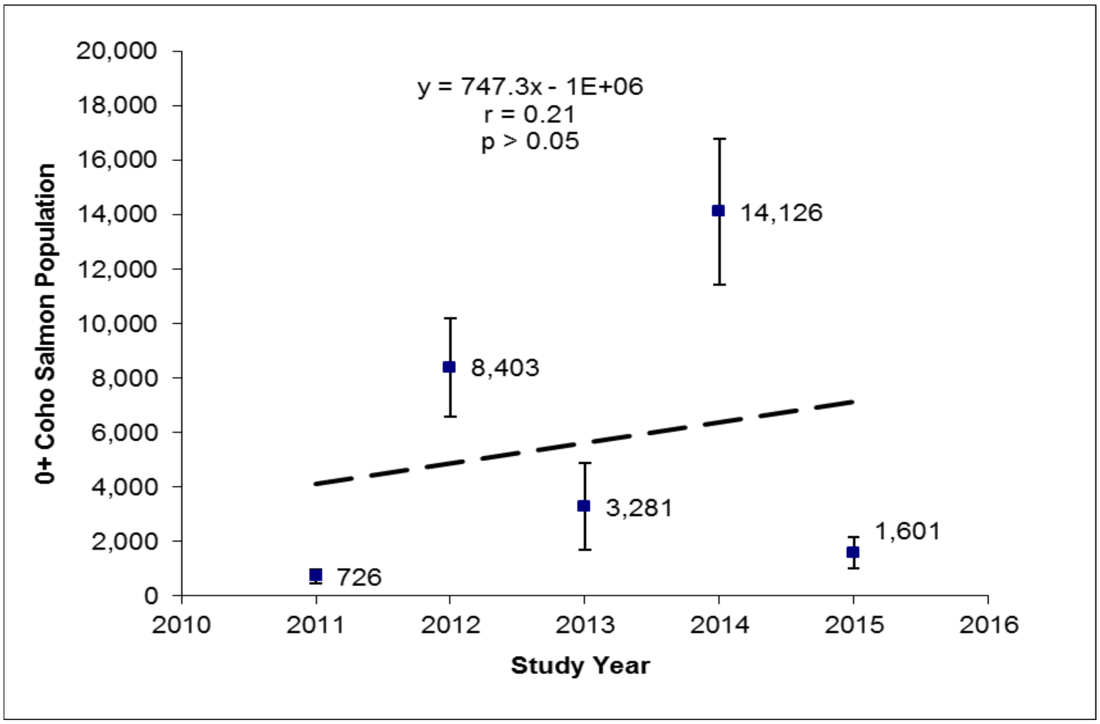

Figure 14. 0+ Coho Salmon population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly population abundances in 2015 contrasted the pattern for the previous four year average (Fig. 15). The most important month for emigration was April (65% of total) in 2015, compared to May (49% of total) for the previous four year average. May (70% of total) was the most important month in 2014. The two most important months 0+ Coho Salmon population emigration were March/April (99% of total) in 2015 and April/May (86% of total) for the previous four year average (Fig. 15). In 2014, April/May (94% of total) were also the two most important months.

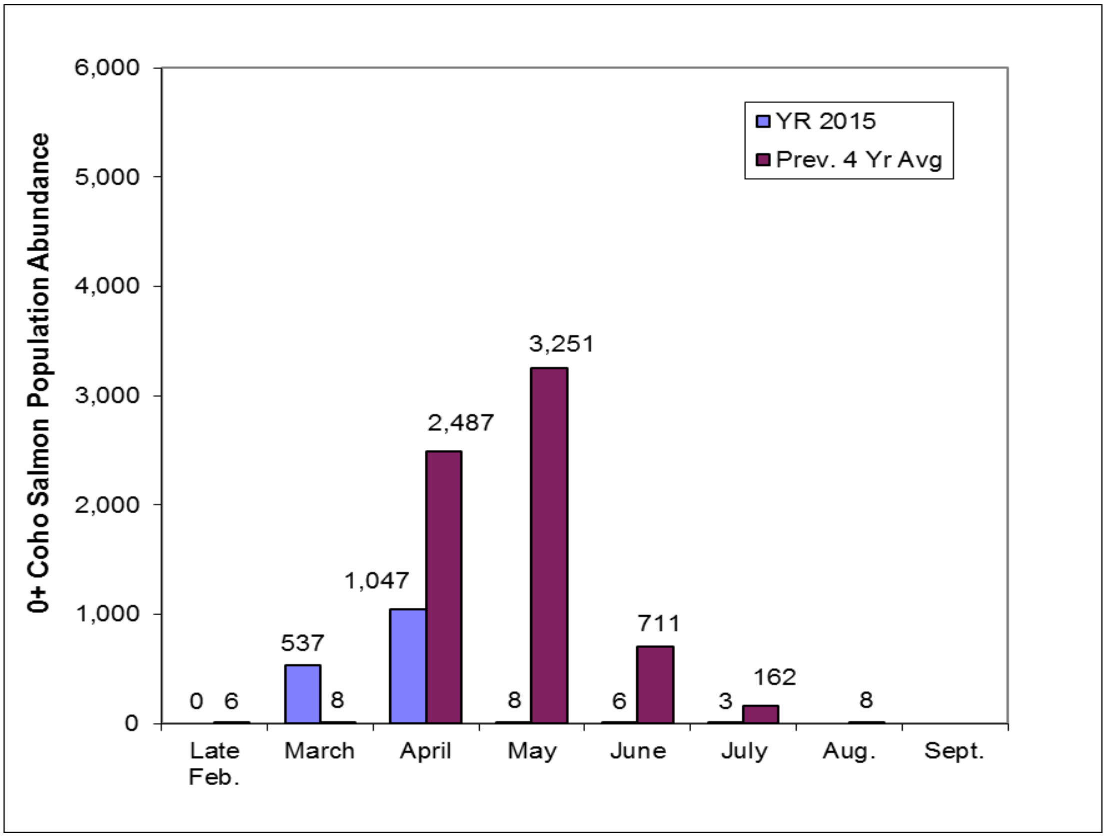

Figure 15. Comparison of 0+ Coho Salmon population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

The peak in weekly abundance in 2015 occurred 3/19 – 3/25, much earlier than previous study years (Table 15). Fry comprised 100% of the migrants during peak migration in 2015.

Table 15. Date of peak weekly 0+ Coho Salmon population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA.

Study Year	Date of peak in weekly out-migration (number in parentheses)
2011	4/30 - 5/06 (119)
2012	4/23 - 4/29 (1,836)
2013	4/09 - 4/15 (1,229)
2014	4/30 - 5/06 (5,191)
2015	3/19 – 3/25 (481)

0+ Coho Salmon downstream migrants consisted of fry (FL < 40 mm) and parr (FL > 39 mm) life history forms (Table 16). In 2015, fry (Avg. FL = 36 mm) comprised 98.4% and parr (Avg. FL = 56 mm) comprised 1.6% of the total 0+ Coho Salmon downstream migrant population estimate (Table 16).

Table 16. Production of 0+ Coho Salmon migrants partitioned into fry and parr categories each study year and for the previous four year average (expressed as a percentage in parentheses for 2015 and the previous four year average), Prairie Creek, Humboldt County, CA.

	0+ Coho Salmon production as:	
Study Year	Fry (FL < 40mm)	Parr (FL > 39 mm)
2011	359	367
2012	6,561	1,842
2013	3,144	167
2014	12,939	1,187
Avg.	5,751 (86.6)	891 (13.4)
2015	1,576 (98.4)	25 (1.6)

Coho Salmon fry and parr migrants showed little temporal overlap in migration in 2015 (Fig. 16). Fry migration peaked during 3/19 – 3/25 (N = 481) and parr migration peaked during 4/16 – 4/22 (N = 8).

Fry migration ended in mid-May in 2015, and parr migration reached low values by late July, 2015 (Fig. 16).

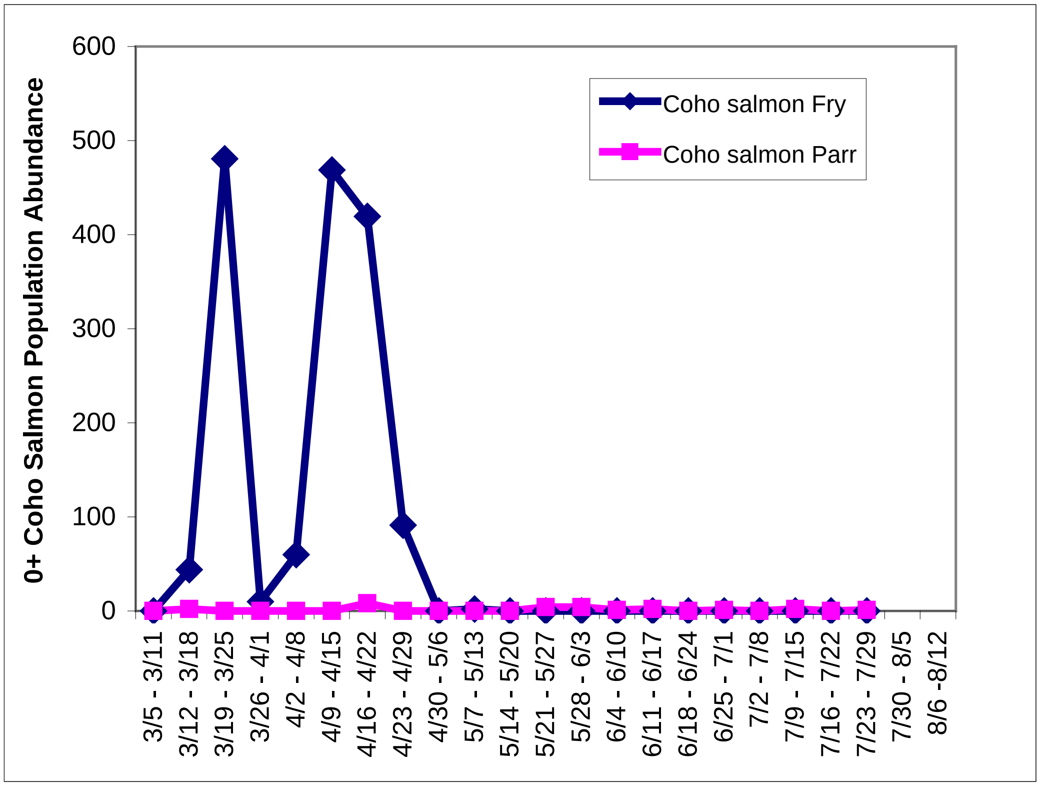

Figure 16. Comparison of 0+ Coho Salmon fry and parr migration in 2015, Prairie Creek, Humboldt County, CA.

1+ Coho Salmon

The population abundance (or production) of 1+ Coho Salmon emigrating past the trap in lower Prairie Creek in 2015 equaled 21,536 with a 95% CI of 20,260 – 22,813 (Fig. 17). Population estimate error equaled 5.9% (CV = 2.95%) or 1,277 individuals. Population abundance in 2015 was 1.2 times greater than the previous four year average ($N_{avg\ 4yr}$ = 17,804), and 1.1 times greater than abundance in 2014. The average population abundance over the current five year period equaled 18,550 (SD = 5,897; SEM = 2,637).

Linear correlation failed to detect a significant relationship of population abundances over study years ($n = 5$, $p = 0.21$, $r = 0.65$, power = 0.34) (Fig. 17).

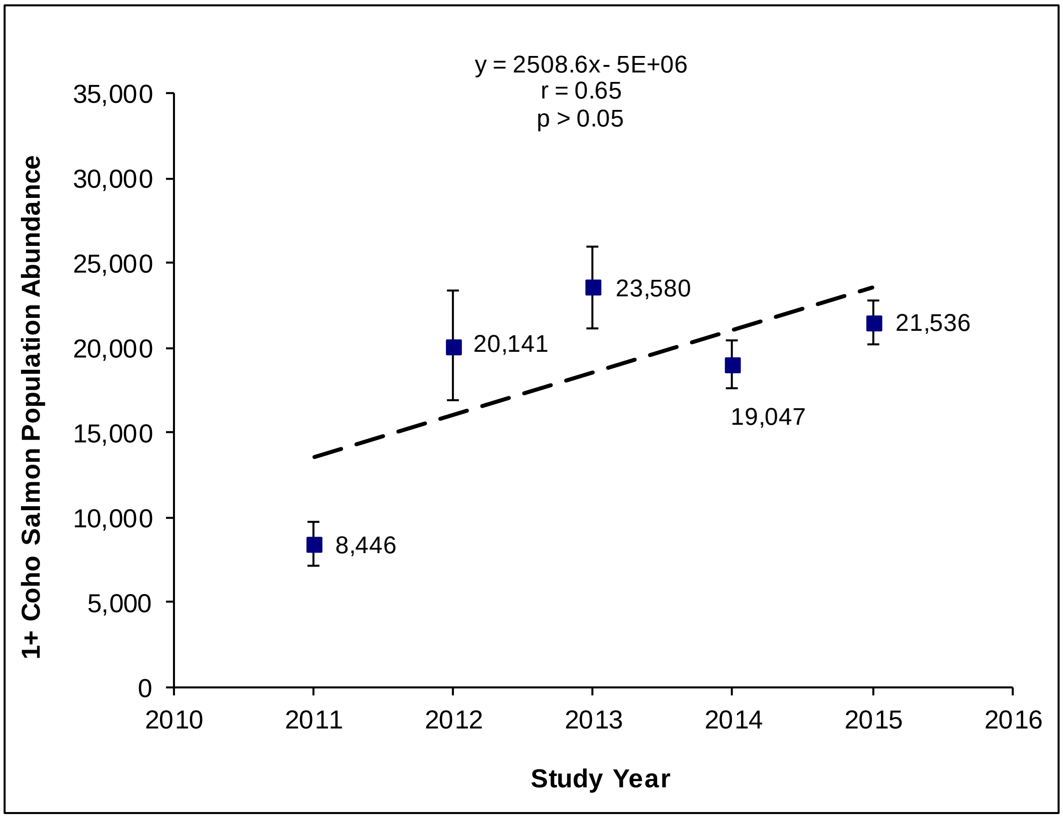

Figure 17. 1+ Coho Salmon population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly population abundances in 2015 showed similarities to the pattern for the previous four year average (Fig. 18). The most important month for emigration was April (42% of total) in 2015, and May (46% of total) for the previous four year average. May (51% of total) was the most important month in 2014. The two most important months 1+ Coho Salmon population emigration were April/May (82% of total) in 2015 and April/May (77% total) for the previous four year average (Fig. 18). In 2014, April/May (86% of total) were also the two most important months.

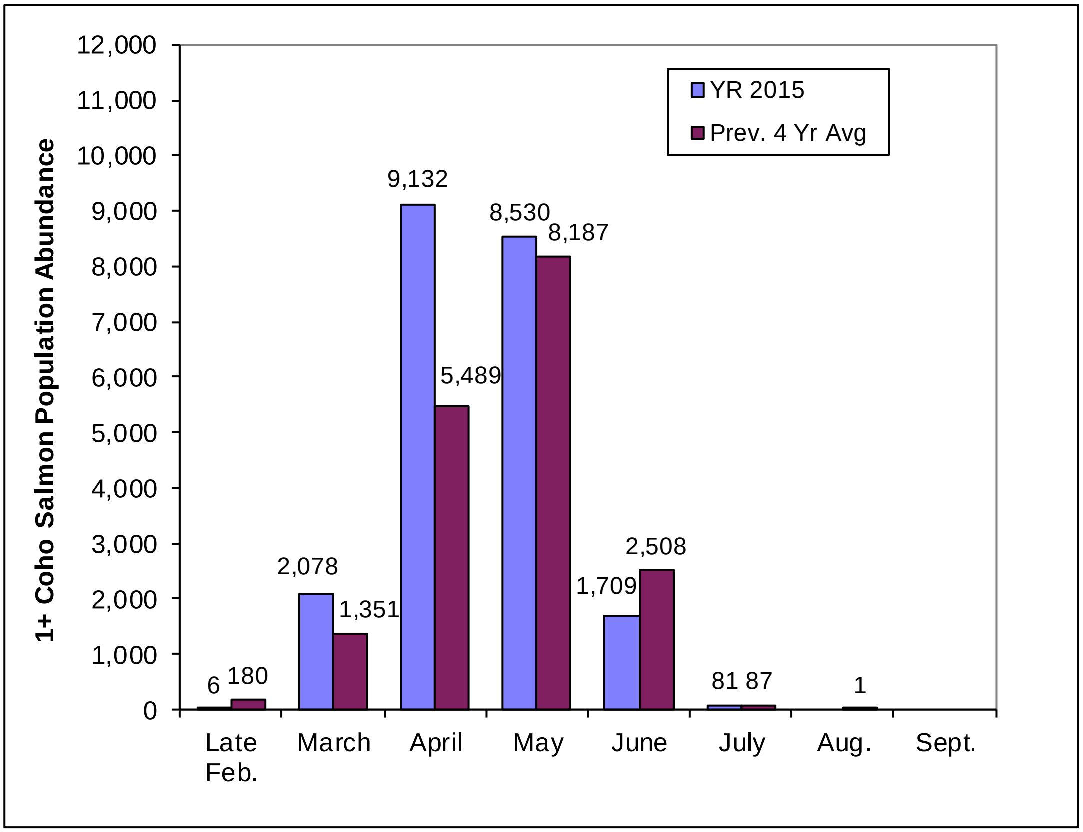

Figure 18. Comparison of 1+ Coho Salmon population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

The peak in weekly population emigration occurred 4/23 – 4/29 in 2015 (Table 17).

Table 17. Date of peak weekly 1+ Coho Salmon population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA.

Study Year	Date of peak in weekly out-migration (number in parentheses)
2011	5/21 - 5/27 (2,305)
2012	5/14 - 5/20 (3,334)
2013	4/23 - 4/29 (4,364)
2014	4/30 - 5/06 (3,725)
2015	4/23 - 4/29 (4,090)

Coastal Cutthroat Trout (juveniles)

The population abundance (or production) of juvenile Cutthroat Trout emigrating past the trap in lower Prairie Creek in 2015 equaled 8,572 with a 95% CI of 7,425 – 9,719 (Fig. 19). Population estimate error equaled 13.4% (CV = 6.7%) or 1,147 individuals. Population abundance in 2015 was 1.7 times greater than the previous four year average ($N_{avg\ 4yr}$ = 5,084), and 1.9 times greater than abundance in 2014. The average population abundance over the current five year period equaled 5,782 (SD = 1,595; SEM = 713).

Linear correlation failed to detect a significant relationship of population abundances over study years (n = 5, p = 0.31, r = 0.57, power = 0.25) (Fig. 19).

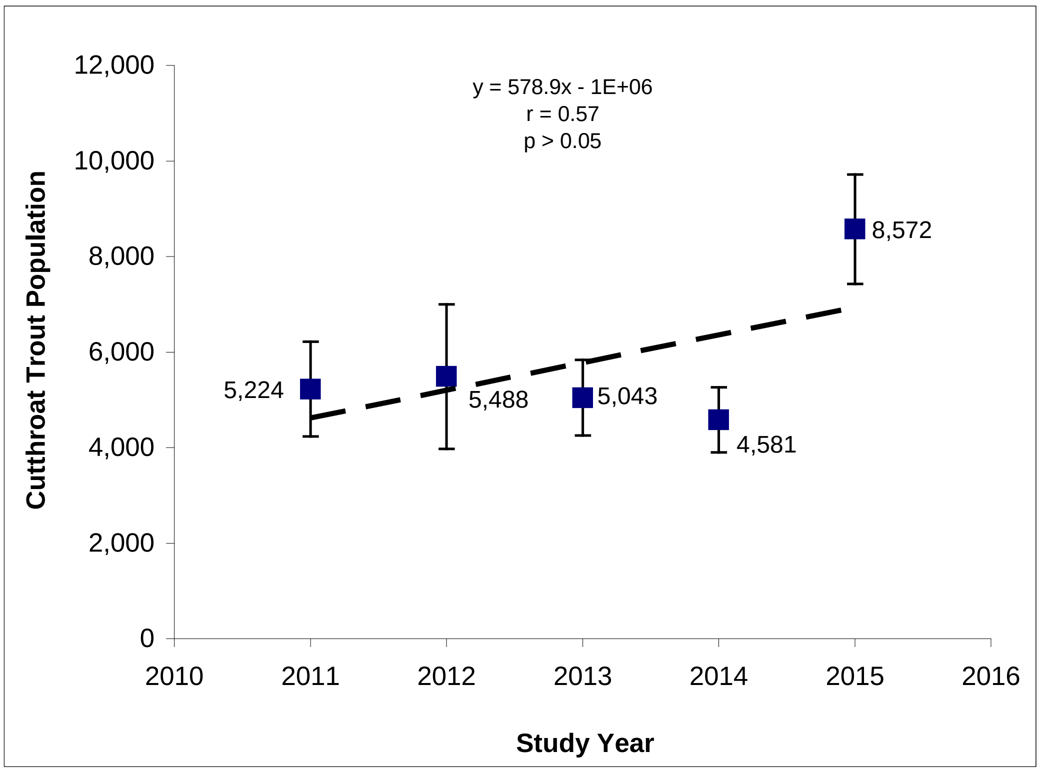

Figure 19. Coastal Cutthroat Trout population abundance estimates in Prairie Creek, Humboldt County, CA from 2011 – 2015. Error bars represent 95% confidence intervals.

The pattern in monthly population abundances in 2015 contrasted the pattern for the previous four year average (Fig. 20). Migration in April 2015 was 3.1 times greater than migration in April for the previous four year average (Fig. 20). The most important month for emigration was April (61% of total) in 2015, compared to May (49% of total) for the previous four year average. April (51% of total) was the most important month in 2014. The two most important months for Cutthroat Trout population emigration were April/May (87% of total) in 2015 and April/May (83% of total) for the previous four year average (Fig. 20). In 2014, April/May (86% of total) were also the two most important months.

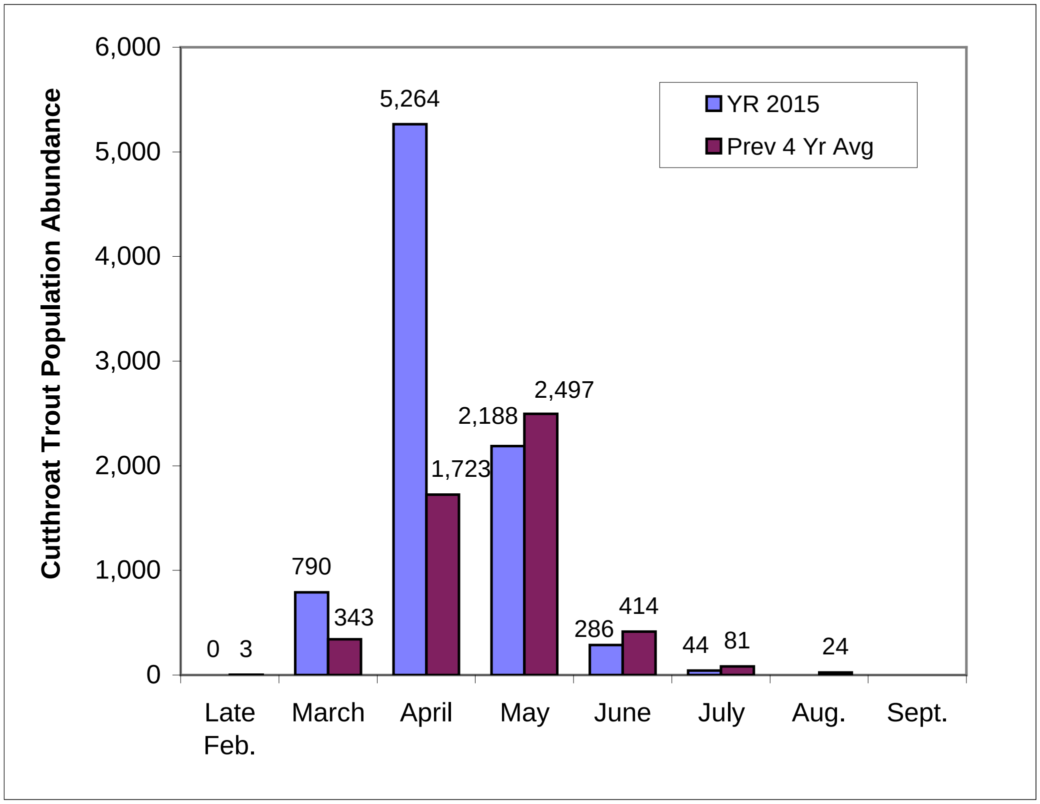

Figure 20. Comparison of Coastal Cutthroat Trout population abundance by month in 2015 with the previous four year average, Prairie Creek, Humboldt County, CA.

The peak in weekly abundance in 2015 occurred 4/23 – 4/29, one week earlier than peaks in 2013 and 2014 (Table 18).

Table 18. Date of peak weekly Cutthroat Trout population emigration by study year (number of individuals in parentheses), Prairie Creek, Humboldt County, CA.

Study Year	Date of peak in weekly out-migration (number in parentheses)
2011	5/07 - 5/13 (1,742)
2012	5/21 – 5/27 (1,320)
2013	4/30 - 5/06 (1,011)
2014	4/30 - 5/06 (713)
2015	4/23 - 4/29 (2,284)

Age Composition of Age-1 and older Juvenile Steelhead Trout

Far more 1+ Steelhead Trout migrated downstream than 2+ Steelhead Trout in any given year (Table 19). Pooling population abundances across years, 1+ Steelhead Trout comprised 71% and 2+ Steelhead Trout comprised 29% of age-1 and older Steelhead Trout smolt abundances (Table 19).

The ratio of 1+ Steelhead Trout to 2+ Steelhead Trout equaled 3:1 in 2011, 10:1 in 2012, 1.7:1 in 2013, 3.9:1 in 2014, and 1.7:1 in 2015.

Table 19. Percent composition of age-1 and older Steelhead Trout population abundances in YRS 2011 – 2015, Prairie Creek, Humboldt County, CA.

	Percent Composition	
Study Year	1+ Steelhead	2+ Steelhead
2011	75.6	24.4
2012	90.9	9.1
2013	62.6	37.4
2014	79.7	20.3
Average	77.2	22.8
2015	63.3	36.7
All Years Pooled	70.6	29.4

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 3,759 and weighed (g) 2,651 0+ Chinook Salmon in 2015 (Table 20). Average FL (60.8 mm) and Wt (2.75 g) in 2015 were slightly greater than the previous four year average (Table 20). Average FL over five study years equaled 58.5 mm (SD = 4.7 mm; SEM = 2.1 mm), and for Wt equaled 2.70 g (SD = 0.85 g mm; SEM = 0.38 g).

1+ Chinook Salmon

Average FL (mm) equaled 122 mm (n = 2) in 2011, and average FL (mm) and Wt (g) equaled 100.6 mm (n = 5) and 17.5 g (n = 3) in 2012. One 1+ Chinook Salmon was captured in 2013, with a FL of 108 mm, and a Wt of 11.5 g. In 2014, average equaled 88 mm (n = 2), and average Wt equaled 8.05 g (n = 2), and in 2015 average FL equaled 107.7 mm (n = 3), and average Wt equaled 14.13 g (n = 3).

Table 20. 0+ Chinook Salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

		0+ Chinook Salmon					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	15,148	3,124	65.1	63.0	1,443	4.09	3.50
2012	32,840	2,652	52.7	51.0	2,049	1.83	1.40
2013	96,817	4,038	56.4	53.0	2,486	2.31	1.60
2014	15,179	2,492	57.4	57.0	2,303	2.53	2.10
Avg.			57.9			2.69	
2015	22,562	3,759	60.8	59.0	2,651	2.75	2.10

0+ Trout

We measured (FL mm) 891 0+ trout in 2015 (Table 21). Average FL (60.7 mm) in 2015 was much greater than the previous four year average (Table 21). Average FL over five study years equaled 44.9 mm (SD = 10.1 mm; SEM = 4.6 mm), and corresponded to the parr life history stage.

Table 21. 0+ trout average and median fork lengths (mm) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	0+ Trout*						
		Fork Length (mm)			Weight (g)		
YR	Catch	n	Avg.	Median	n	Avg.	Median
2011	1,228	816	44.3	30.0	-	-	-
2012	1,481	1,100	32.5	29.0	-	-	-
2013	4,552	1,474	43.4	30.0	-	-	-
2014	3,068	2,039	43.4	33.0			
Avg.			40.9				
					-	-	-
2015	939	891	60.7	62.0			

* Includes an unknown number of 0+ Cutthroat Trout.

1+ Steelhead Trout

We measured (FL mm) 1,771 and weighed (g) 1,425 1+ Steelhead Trout in 2015 (Table 22). Average FL (99.5 mm) and Wt (10.81 g) in 2015 were greater than the previous four year average (Table 22). Average FL over five study years equaled 96.8 mm (SD = 2.9 mm; SEM = 1.3 mm), and for Wt equaled 10.26 g (SD = 0.67 g mm; SEM = 0.30 g).

2+ Steelhead Trout

We measured (FL mm) 760 and weighed (g) 736 2+ Steelhead Trout in 2015 (Table 23). Average FL (151.2 mm) and Wt (36.48 g) in 2015 were greater than the previous four year average (Table 23). Average FL over five study years equaled 149.1 mm (SD = 6.1 mm; SEM = 2.7 mm), and for Wt equaled 34.70 g (SD = 3.10 g mm; SEM = 1.39 g).

Table 22. 1+ Steelhead Trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	3,756	761	98.9	100.1	297	10.75	10.30
2012	2,964	463	92.2	92.0	428	9.21	8.60
2013	6,735	1,350	97.2	96.0	1,056	10.52	9.70
2014	7,381	1,458	96.4	95.5	1,260	10.02	9.40
Avg.			96.2			10.13	
2015	7,786	1,771	99.5	99.0	1,425	10.81	10.10

Table 23. 2+ Steelhead Trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	2+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	1,211	279	148.9	142.0	125	37.00	31.60
2012	295	79	157.9	154.0	56	36.89	30.90
2013	4,020	708	145.6	141.0	691	33.21	30.00
2014	1,875	475	141.8	137.0	470	29.91	26.25
Avg.			148.6			34.25	
2015	4,520	760	151.2	144.0	736	36.48	29.90

0+ Coho Salmon

We measured (FL mm) 264 and weighed (g) 210 0+ Coho Salmon in 2015 (Table 24). Average FL (37.6 mm) and Wt (0.57 g) in 2015 were less than the previous four year average (Table 24). The average size in 2015 corresponded to a fry life history stage. The average FL in 2012 and 2013 also corresponded to the fry stage, and in 2011 and 2014 corresponded to the parr life history stage. Average FL over five study years equaled 41.1 mm (SD = 4.7 mm; SEM = 2.1 mm), and for Wt equaled 0.96 g (SD = 0.65 g mm; SEM = 0.29 g).

Table 24. 0+ Coho Salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	0+ Coho Salmon						
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	726	197	49.2	44.0	86	2.11	1.35
2012	8,403	1,221	39.8	37.0	1,099	0.67	0.50
2013	3,281	352	38.4	36.0	341	0.62	0.40
2014	14,126	1,180	40.6	37.0	915	0.85	0.50
Avg.			42.0			1.06	
2015	1,601	264	37.6	36.0	210	0.57	0.40

1+ Coho Salmon

We measured (FL mm) 2,827 and weighed (g) 1,984 1+ Coho Salmon in 2015 (Table 25). Average FL (101.9 mm) and Wt (11.37 g) in 2015 were slightly less than the previous four year average (Table 25). Average FL over five study years equaled 103.8 mm (SD = 3.1 mm; SEM = 1.4 mm), and for Wt equaled 12.08 g (SD = 0.97 g mm; SEM = 0.43 g). The regression of population abundances on average FL’s (mm) was significantly negative (n = 5, p = 0.006, R2 = 0.93, power = 0.99, alpha = 0.05).

Cutthroat Trout

We measured (FL mm) 1,720 and weighed (g) 1,406 Cutthroat Trout in 2015 (Table 26). Average FL (151.3 mm) and Wt (37.76 g) in 2015 were slightly greater than the previous four year average (Table 26). Average FL over five study years equaled 146.9 mm (SD = 4.1 mm; SEM = 1.8 mm), and for Wt equaled 36.00 g (SD = 2.95 g mm; SEM = 1.32 g).

Table 25. 1+ Coho Salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	1+ Coho Salmon						
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	8,446	1,401	108.8	109.0	553	13.47	13.10
2012	20,141	1,789	102.4	104.0	1,404	12.07	12.20
2013	23,580	2,793	101.2	102.0	1,915	11.01	10.80
2014	19,047	2,366	104.9	105.0	1,716	12.50	12.40
Avg.			104.3			12.18	
2015	21,536	2,827	101.9	103.0	1,984	11.37	11.30

Table 26. Coastal Cutthroat Trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	Cutthroat Trout						
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Avg.	Median	n	Avg.	Median
2011	5,224	997	142.2	139.0	390	32.70	28.10
2012	5,488	547	142.8	140.0	484	33.19	29.25
2013	5,043	1,323	148.5	145.0	1,055	39.49	34.80
2014	4,581	1,216	149.5	146.0	1,083	36.85	31.80
Avg.			144.8			35.56	
2015	8,572	1,720	151.3	149.0	1,406	37.76	33.95

Developmental Stages

1+ Chinook Salmon

All 1+ Chinook Salmon captured in YRS 2011 - 2015 were in a smolt stage.

1+ and 2+ Steelhead Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt designations (developmental stages) for 1+ and 2+ Steelhead Trout captured each study year (Table 27). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt). The combined percentage of pre-smolts and smolts in YRS 2011 - 2015 for 1+ Steelhead Trout was nearly 100%, and for 2+ Steelhead Trout equaled 100% (Table 27).

Table 27. Developmental stages of captured 1+ and 2+ Steelhead Trout in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	Developmental Stage (as percentage of total catch)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2011	1.2	76.0	22.8	0.0	31.2	68.8
2012	3.6	86.6	9.8	0.0	22.5	77.5
2013	0.0	58.6	41.4	0.0	4.9	95.1
2014	0.1	59.6	40.3	0.0	14.9	85.1
Avg.	1.2	70.2	28.6	0.0	18.4	81.6
2015	0.0	67.3	32.7	0.0	23.1	76.9

1+ Coho Salmon and Juvenile Coastal Cutthroat Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt designations (developmental stages) for 1+ Coho Salmon and 1+ and older Cutthroat Trout captured each study year (Table 28). The majority of 1+ Coho Salmon were classified as smolts, and for Cutthroat Trout, the majority were classified as smolts in 2011 and 2013. (Table 22).

Table 28. Developmental stages of captured 1+ Coho Salmon and Coastal Cutthroat Trout in YRS 2011 - 2015, Prairie Creek, Humboldt County, CA.

	Developmental Stage (as percentage of total catch)					
	1+ Coho Salmon			Cutthroat Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2011	0.0	4.0	96.0	0.0	39.0	61.0
2012	0.0	22.3	77.7	0.2	68.5	31.3
2013	0.0	16.8	83.2	0.0	35.6	64.4
2014	0.0	18.8	81.2	0.0	53.3	46.7
Avg.	0.0	15.5	84.5	0.0	49.1	50.9
2015	0.0	23.3	76.7	0.0	51.5	48.5

Trapping Mortality

The mortality of fish that were captured in the trap and subsequently handled was closely monitored over the course of each trapping period. Trapping mortality (includes handling mortality) for a given species at age in 2015 ranged from 0.00 – 0.32% (Table 29). Mortalities were low in 2015 because logs or branches did not jam the trap's cone.

Percent mortality over five study years ranged from 0.08 – 0.73%, and using all data (pooling) equaled 0.38% of the total captured and handled (Table 30). The major factors in mortality were associated with storm events, high debris loading in the trap's livebox, and whether or not large branches or logs jammed the trap's cone.

Table 29. Trapping mortality for juvenile and adult salmonids captured in 2015, Prairie Creek, Humboldt County, CA.

	Trapping Mortality in 2015		
Age/spp.	No. captured*	No. of mortalities	Percent mortality
0+ Chinook	10,720	19	0.18
1+ Chinook	3	0	0.00
0+ Steelhead	931	2	0.21
1+ Steelhead	2,276	0	0.00
2+ Steelhead	769	0	0.00
Cutthroat Trout	2,381	0	0.00
Adult CT Trout	35	0	0.00
0+ Coho	314	1	0.32
1+ Coho	11,277	0	0.00
0+ Pink	1	0	0.00
Overall:	28,707	22	0.08

* Not expanded for missed day(s) catch during periods of trap non-deployment

Table 30. Comparison of trapping mortality of juvenile salmonids in five consecutive study years, Prairie Creek, Humboldt County, CA.

	Trapping Mortality		
Study Year	No. captured*	No. of mortalities	Percent mortality
2011	13,783	82	0.59
2012	14,531	106	0.73
2013	61,023	185	0.30
2014	25,929	155	0.60
2015	28,707	22	0.08
Avg.	28,795	110	0.46
Pooled	143,973	550	0.38

* Not expanded for missed day(s) catch during periods of trap non-deployment

Trap Derived Estimate of Juvenile Coho Salmon Overwinter Survival

1+ Coho Salmon (Pit Tagged in Fall as 0+ Parr)

The smolt trap captured 168 pit tagged 1+ Coho Salmon (second Y axis) in 2015, and the pattern of daily captures reflected the pattern of daily captures of non-pit tagged 1+ Coho Salmon (first Y axis) (Fig. 21). Daily trap catches of pit tagged (transformed) and non-pit tagged 1+ Coho Salmon smolts (transformed) during the migratory period were well correlated (Linear correlation, n = 147, p = 0.000001, r = 0.74, power = 1.00).

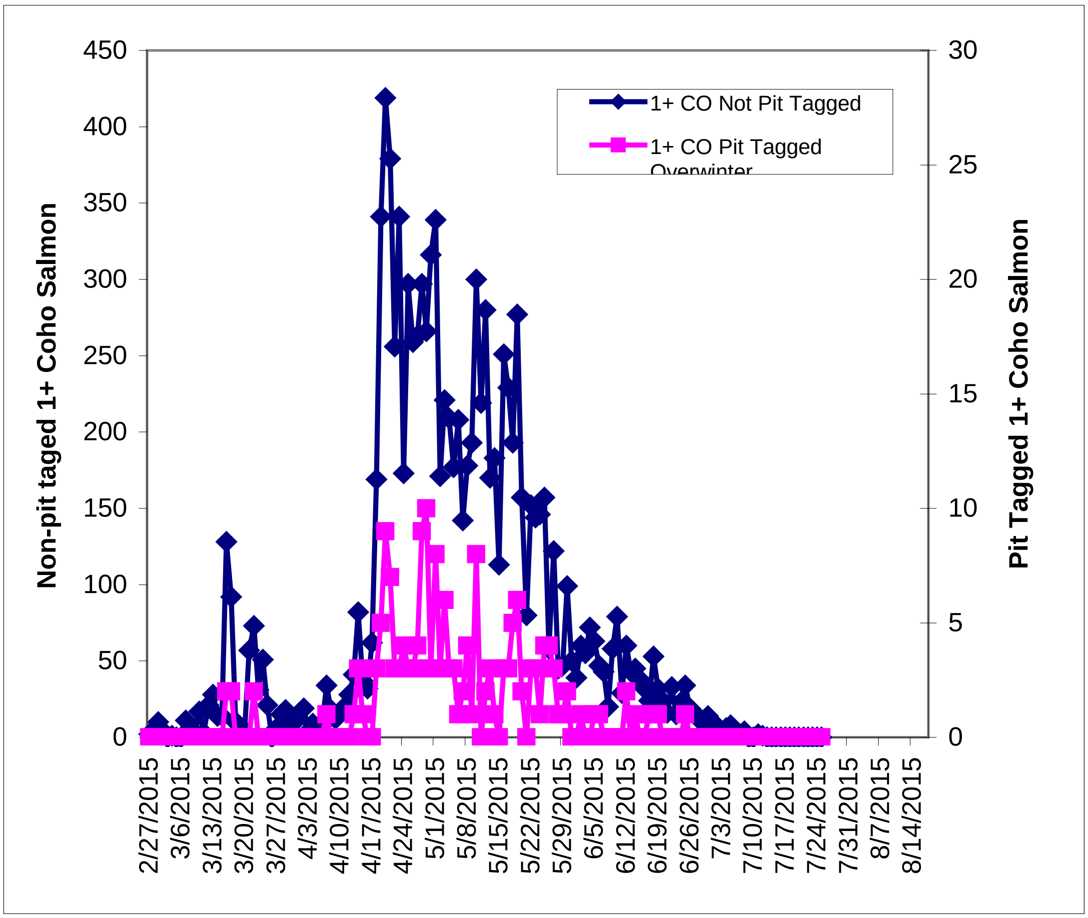

Figure 21. Comparison of daily trap catches of non-pit tagged 1+ Coho Salmon (first Y axis) with pit tagged 1+ Coho Salmon (second Y axis) in 2015, Prairie Creek, Humboldt County, CA.

The estimated population abundance of pit tagged 1+ Coho Salmon emigrating past the trap site in 2015 equaled 303 (95% CI = 241 - 366). Population estimate error equaled

20.6%. The mark/recapture trap derived estimate of overwinter survival equaled 28.6% with a 95% CI of 22.7 – 34.5%. The error for overwinter survival estimate equaled 20.6% (CV = 10.3%). Compared to the 1+ Coho Salmon population estimate, which includes pit tagged and non-pit tagged 1+ Coho Salmon, the number of surviving pit tagged 1+ Coho Salmon equaled 1.4% of total abundance. In 2014, the mark/recapture trap derived estimate of overwinter survival equaled 35.2% (Sparkman et al. 2015).

The population migration (weekly) of pit tagged 1+ Coho Salmon (second Y axis) reflected the population migration of non-pit tagged 1+ Coho Salmon (first Y axis) (Fig. 22). Weekly abundances were highly correlated (n = 22 weeks, p = 0.00001, r = 0.96, power = 1.0), although for the two observable peaks pit tagged smolts migrated one week earlier than non-pit tagged smolts (Fig. 22).

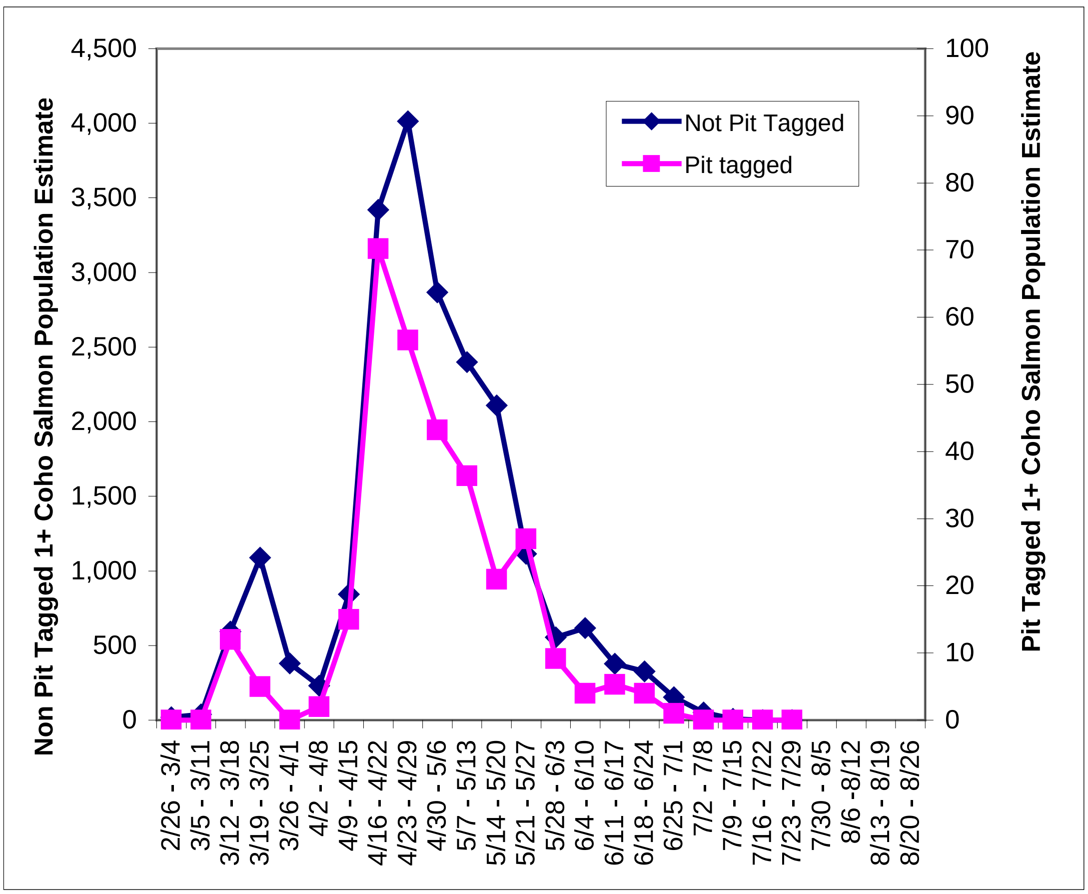

Figure 22. Comparison of non-pit tagged 1+ Coho Salmon population abundances (first y axis) with pit tagged 1+ Coho Salmon population abundances (second y axis) by week in 2015, Prairie Creek, Humboldt County, CA.

Stream Temperatures

Average daily (24 hr period) stream temperature at the trapping site during trap deployment (2/27 – 7/25) in 2015 ranged from 9.1 – 15.9 ^{o}C, and averaged 12.5 ^{o}C (95% CI = 12.2 – 12.8 ^{o}C) (Table 31). Average daily stream temperatures during the trapping periods in YRS 2011 – 2015 were similar, with the largest difference among years equaling 1.8 ^{o}C. The highest average daily stream temperature over a given trapping period occurred in 2014 (Table 31).

Average daily stream temperatures (truncated or extended for equal comparisons among study years) are significantly increasing over study years (Correlation, n = 5, p = 0.003, r = 0.98, power = 1.0) (Table 32).

Table 31. Average, minimum, and maximum stream temperatures (^{o}C, ^{o}F) (standard error of mean in parentheses) at the trap site during the trapping periods in YRS 2011 – 2015, Prairie Creek, Humboldt County, CA.

	Stream Temperature (^{o}C)					
	Celsius			Fahrenheit		
Study Year	Avg.	Min.	Max.	Avg.	Min.	Max.
2011	11.9 (0.1)	7.9	15.2	53.5 (0.3)	46.2	59.4
2012	10.8 (0.2)	6.4	14.6	51.5 (0.3)	43.5	58.3
2013	12.0 (0.2)	6.6	15.9	53.5 (0.3)	49.9	60.6
2014*	12.6 (0.2)	7.9	16.1	54.7 (0.3)	46.2	61.0
2015*	12.5 (0.2)	8.2	16.7	54.5 (0.3)	46.8	62.1
Avg.	12.0 (0.3)			53.5 (0.6)		

* Severe drought year in California.

Table 32. Average daily stream temperature (ºC) (truncated or extended to end period) at the trap site in YRS 2011 – 2015, Prairie Creek, Humboldt County, CA.

Study Year	Average Daily Stream Temperature (4/13 – 8/05) (ºC)	(ºF)
2011	11.7	53.1
2012	11.8	53.3
2013	12.6	54.7
2014*	13.0	55.4
2015*	13.6	56.5

* Severe drought year in California.

Average monthly stream temperatures during the majority of trap deployments were highest in 2015 (Table 33).

Table 33. Average monthly stream temperature (Celsius) during the majority of trap deployments, lower Prairie Creek, Humboldt County, CA.

	Average Monthly Stream Temperature (Celsius)					
	YR 2011	YR 2012	YR 2013	YR 2014	YR 2015	Avg.
April	9.37	9.73	10.10	10.46	10.76	10.08
May	10.49	11.03	11.84	12.08	12.35	11.56
June	12.08	11.91	13.23	13.26	14.31	12.96
July	13.60	13.21	14.01	14.70	15.34	14.17
Avg.	11.39	11.47	12.30	12.62	13.19	12.19

Average daily stream temperatures (ºC) increased over study periods each year (Fig. 22).

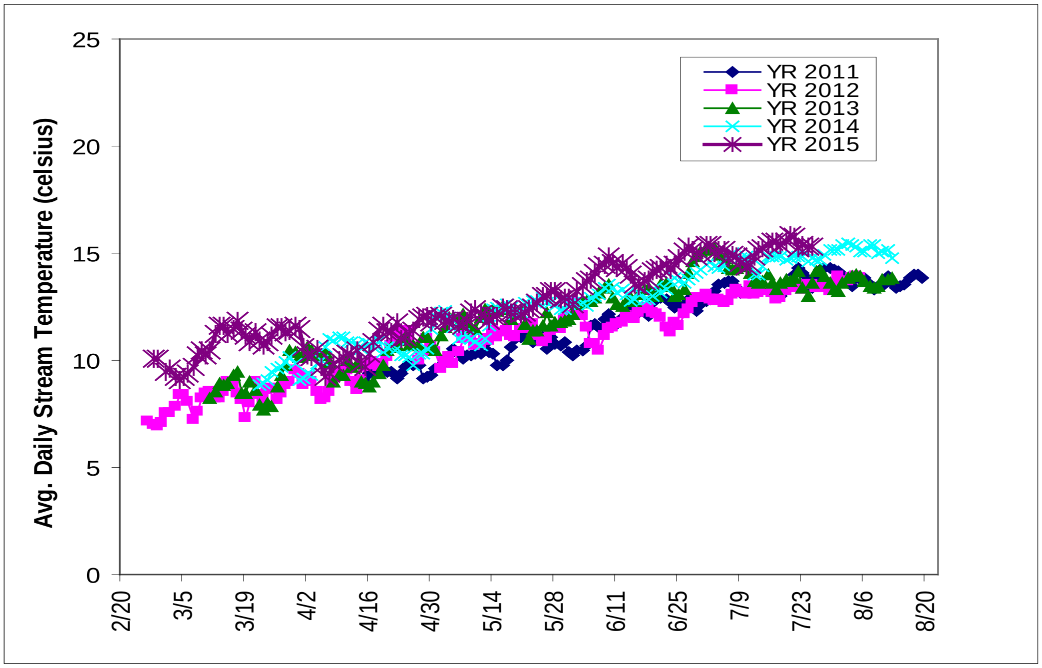

Figure 23. Average daily stream temperatures (°C) in YRS 2011 – 2015, Prairie Creek, Humboldt County, CA.

MWAT during the trapping period in 2015 equaled 15.6 °C and occurred on 7/18/15, and MWMT equaled 16.4 °C and occurred on 7/18/15 (Table 34). The highest MWAT and MWMT occurred in 2015 (Table 34).

Table 34. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site during trap deployments in Prairie Creek, Humboldt County, CA., study years 2011 – 2015.

	MWAT		MWMT	
Study Year	Date of Occurrence	°C (°F)	Date of Occurrence	°C (°F)
2011	7/29/11	14.2 (57.6)	7/29/11	14.9 (58.8)
2012	8/02/12	13.8 (56.8	8/02/12	14.4 (57.9)
2013	7/02/13	15.0 (59.0)	7/01/13	15.7 (60.3)
2014*	8/05/14	15.3 (59.5)	7/31 and 8/01	16.0 (60.8)
2015*	7/18/15	15.6 (60.0)	7/18/15	16.4 (61.5)

* Severe drought year in California.

DISCUSSION

Overwinter Survival

In northern California, Coho Salmon are listed as threatened and are continuing to experience population declines (Ly et al. 2011). This study contributes to the understanding of factors that influence survival during freshwater residency, a period when juveniles may experience high mortality due to winter flow events (Sandercock 1991) and lack of winter habitat (Solazzi et al. 2000). Our C-J-S survival model estimate did not include potential outmigration from the study reaches before the screw trap was installed in February. This could be problematic as Rebenack et al. (2015) showed that early migration in the fall can be an important life history pattern in one Northern California stream. They reported that up to 27% of juvenile Coho Salmon emigrated from Freshwater Creek in fall and overwintered in a tidally influenced marsh, with the percentage of early movement varying among years and location within the watershed. In East and West Rivers, Washington, Roni et al. (2012) observed that more than 50% of juveniles migrated to sea in fall, with a consistent peak of downstream movement in early November. In contrast, 5.6% of the tagged fish in Prairie Creek were detected moving downstream of the lower most antenna prior to smolt trap operation in February 27th, while 15.0% of tagged fish were detected at the lower most antenna following trap operation. However, the 5.6% of tagged fish moving downstream prior to trap placement did not encounter overwinter conditions (and mortality) as did the survivors that represented the 15% of detections following trap operation. Sparkman et al. (2015) estimated that 4% of the tagged Coho Salmon in Prairie Creek in 2013 migrated past the lower most antenna prior to screw trap operation in 2014. The early emigrant fish may not have migrated out of the Prairie Creek basin because the antenna array was two miles upstream of the smolt trap and habitat quality between the antenna array and smolt trap is considered high. For example, eight of the fish detected moving downstream in the fall/winter 2014 were not considered early migrants because they were still captured by the smolt trap in the spring of 2015. The smaller percentage of fall downstream movement observed in Prairie Creek during 2013-2014 and 2014-2015 may reflect greater availability of suitable overwintering habitat. Furthermore, the high quality of overwintering habitat in Prairie Creek and the diminished quality of the lower section of RC and estuary, may select for a juvenile Coho Salmon life history that favors remaining in Prairie Creek during the fall/winter.

Evidence that some juvenile Coho Salmon in Prairie Creek spend two years in freshwater instead of one (Bell and Duffy 2007, Ransom 2007, Moore 2014) may also affect the accuracy of over winter survival estimates. Fish that survive and spend a second year in Prairie Creek are treated in this model as if they did not survive, and thus our model has the potential to underestimate survival. Moore (2014) estimated that only 1.4% of the

Coho Salmon juveniles tagged in 2012 in Prairie Creek were age-1, and we did not capture any pit tagged Coho Salmon in 2014 that were tagged in 2012 as young of year (Sparkman et al. 2015). However, we did capture six 2+ Coho Salmon in 2015 that were pit tagged in the fall of 2013, and based upon trapping efficiencies during weeks of capture, expanded to nine 2+ Coho smolts. We estimated that 1.5% of the tagged fish (age-0) in 2013 showed the 2+ life history, and 2.9% of the total pit tagged Coho Salmon smolts passing the trap site in 2015 were age-2 smolts. Thus, although the 2+ life history was present within Prairie Creek, the percentage was low and not likely to bias our over-winter survival estimates to any large degree. A final caveat is that our survival estimate only applies to fish that were large enough to tag (FL $\geq$ 60 mm), and in the fall of 2014, roughly 46% of the captured young of year Coho Salmon were too small to pit tag.

Survival estimates were similar for both methodologies (33% for the C-J-S model and 29% for the trap estimate) which is consistent with the previous season (Sparkman et al. 2015). Overwinter survival estimates for juvenile Coho Salmon in 2014/2015 in Prairie Creek were also similar to the 2012/2013 and 2013/2014 seasons. Moore (2014) estimated that apparent overwinter survival of Coho Salmon in Prairie Creek during 2012/2013 was 39% and we estimated overwinter survival during 2013/2014 to be 33% (Sparkman et al. 2015). The apparent overwinter survival rates for juvenile Coho Salmon in Prairie Creek during 2012/2013 (39%), 2013/14 (33% for C-J-S and 35% for trap), and 2014/2015 (33% for C-J-S and 29% for trap) were within the broad range of overwinter survival rates (5 - 74%) published from other studies throughout the Coho Salmon range (Bustard and Narver 1975; Quinn and Peterson 1996; Solazzi et al. 2000; Ebersole et al. 2006; Pess et al. 2011; Roni et al. 2012; Hauer 2013). In addition, our survival rates were within the broad range of Prairie Creek overwinter survival estimates (15.3 – 82.3%) reported by Duffy (2012) from 1999-2010 despite differing methodologies.

Smolt Abundances

The main goal of our smolt study in Prairie Creek is to estimate and monitor the production of Chinook Salmon, Steelhead Trout, Coho Salmon, and Cutthroat Trout smolts from the Prairie Creek watershed in a reliable, long-term manner. The long term goal is to monitor trends in smolt abundance and smolt size in relation to watershed conditions (pristine) in the basin, and to assist with determining overwinter survival and growth of juvenile Coho Salmon. In 2015, we independently determined the population abundance of pit tagged 1+ Coho Salmon smolts passing the smolt trap (using mark/recapture techniques) for the second year in a row, and by comparing abundance with the number tagged in the fall, were able to estimate overwinter survival as well.

Quantifying smolt populations is frequently considered the most direct assessment of stock performance in freshwater (Seiler et al. 2004), and smolt numbers can also relate to past (Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2006) and future adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000). In addition, the smolt study in Prairie Creek is necessary to provide smolt numbers that can be added to the smolt numbers determined in lower RC (Sparkman et al. 2016) to provide a basin wide estimate for smolt production in RC on an annual basis. Adult escapement to the RC basin is determined using a DIDSON sonar unit, and when combined with smolt production estimates, allows for determining the number of smolts produced per adult. The smolt/adult metric is useful for critically evaluating freshwater population dynamics in light of habitat quality and adult returns. The DIDSON sonar unit can also be used to potentially calibrate or assess accuracy of redd counts (Metheny and Sparkman 2015). To date, redd counts within the RC basin appear to lack both precision and accuracy compared to sonar counts of adults (Metheny and Sparkman 2015). With respect to determining Coho Salmon overwinter survival, the smolt trap also provides data on size (FL, Wt) for recaptured pit tagged Coho Salmon smolts that can be used to determine various growth indices (on an individual basis) from fall to the time of trap capture. Prairie Creek is considered to be in a pristine condition, and thus the data we collected can be used to compare with streams that have undergone human disturbances.

The five consecutive years of trapping in lower Prairie Creek occurred under varying environmental conditions (e.g. streamflow). Trapping in 2012 was the most difficult year to operate the smolt trap because of high streamflows and high debris loading within the livebox and on the trap itself. The environmental conditions (stream flow) for downstream migrant trapping in 2015 were moderate, we only missed two days of trapping in late March due to high flows, and one day in July to observe the 4th of July holiday. However, low flows in the mid to later part of the season were difficult to keep the trap's cone from bottoming out on the stream bed. Instead of digging streambed substrate from under the cone to create clearance as in past years, we placed sand bags and wooden pallets under the four corners of the pontoons to stabilize the screw trap during decreasing flows. This method worked very well, and was much less labor intensive. In addition, drought conditions in 2015 forced us to use extensive weir panels much earlier than previous years to keep the rotary screw trap operating. The estimates for catch and subsequent expansions to the population level, based on the three missed trapping days, were negligible for each species at age; the greatest impact on a population estimate was estimated at 4.8%, and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point estimate (not reported in text). The number of fish missed when the trap was inoperable would not have greatly impacted population estimates. Thus, smolt trapping in lower Prairie Creek in 2015 resulted in very good estimates of wild Coho Salmon, Chinook Salmon, Steelhead Trout, and juvenile Cutthroat Trout smolt abundances from the entire Prairie Creek basin.

0+ Chinook Salmon

Ocean-type type juvenile Chinook Salmon were the most numerous downstream migrant captured in three of five study years, and were also the most numerous migrant at the population level in 2011 – 2013, and 2015. The population abundance equaled 22,562 in 2015, and was 44% lower than the previous four year average, and 1.5 times greater than abundance in 2014. Population abundances over five study years totaled 182,546 individuals, ranged from 15,148 to 96,817 each year, and averaged 36,509. In comparison 0+ Chinook Salmon population abundances in upper RC from 2011 – 2015 totaled 1,477,110 individuals, ranged from 3,470 to 680,747 and averaged 295,422 (Sparkman 2016). Abundances through lower RC in 2011 – 2015 totaled 1,429,617 individuals, ranged from 147,719 – 566,859, and averaged 285,923 (Sparkman et al. 2016). Abundances in 2015 equaled 575,353 in upper RC, and 295,664 in lower RC. For each trap location, the highest abundance of record occurred in 2013. Stream flows during the adult Chinook Salmon migratory period in 2014/2015 in RC were suitable for passage, and we suspect the low number of 0+ Chinook migrants emigrating from Prairie Creek in 2015 was due to adults passing Prairie Creek to migrate upstream into RC.

Linear correlation failed to detect a significant trend in abundances in Prairie Creek over five consecutive study years ($p > 0.05$). The lack of a significant trend was likely due to low sample size ($n = 5$), and the low abundances determined in 2014 and 2015. Testing trends in abundance often requires numerous years of data to determine a statistically, reliable trend. Trends with low sample sizes not only preclude statistical significance, but limit inferences on population status because the slope of the trend line can change with the addition or omission of a single data point. Based upon data collected in upper RC, it may take 16 plus years to determine a reliable, significant trend in 0+ Chinook Salmon population abundances (Sparkman 2016).

0+ Chinook Salmon population abundances by month in 2015 in Prairie Creek ranged from 13 (February 2015) to 6,265 (May 2015). Population abundances peaked in May (N = 6,265) in 2015, the same month as for the previous four year average (N = 19,644). The two most important months were March/May (53% of total) in 2015, and April/May (72% of total) for the previous four year average. The two most important months for population emigration in 2015 were March/April (67% of total) in upper RC, and May/June (79% of total) in lower RC. The peak in weekly abundances in 2015 occurred

3/19 – 3/25 (N = 2,736) in Prairie Cr, 3/19 – 3/25 (N = 100,492) in upper RC, and 6/04 – 6/10 (N = 46,295) in lower RC.

Each study year 0+ Chinook Salmon (ocean-type) emigrating from Prairie Creek (and RC, Sparkman 2016; Sparkman et al. 2015) exhibited two different juvenile life histories (fry and fingerling) based on size and time of downstream migration. The fry (Avg. FL = 40 mm in 2015) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (or smolts) (Avg. FL = 61 mm in 2015) which have reared in the stream for a longer period of time prior to passing the trap site. Although there was some overlap in the timing of fry and fingerling downstream migration in Prairie Creek in 2015, temporal differences were evident. Fry migration peaked 3/19 – 3/25 (n = 2,710) and fingerling migration peaked 5/07 – 5/13 (N = 2,255) in 2015. In comparison, fry migration peaked 3/19 – 3/25 (N = 101,492) and fingerling migration peaked 5/07 – 5/13 (N = 43,856) in upper RC in 2015 (Sparkman 2016), and fry migration peaked 3/19 – 3/25 (N = 14,516) and fingerling migration peaked 6/04 – 6/10 (N = 46,295) in lower RC in 2015 (Sparkman et al. 2016). Factors that can influence the temporal component to fry and fingerling migration are: 1) time of adult spawning, 2) how far upstream of the trap site the adults spawned, 3) time from egg deposition to fry emergence from redds, and 4) travel rate, among other factors.

The percentage of fry in the population varied each year, with the lowest abundance having the lowest percentage of fry (8%), and the highest abundance having nearly equal numbers of fry (45%) and fingerlings (55%). Fry comprised 44% of the population migrating through lower Prairie Creek over five study years, and totaled 79,785 out of a total of 182,546 migrants. The population of fry in 2015 comprised 30% of total abundance (N = 22,562), compared to 64% of total abundance for upper RC (N = 575,353), and 9% of total abundance for lower RC (N = 295,664) in 2015. The fry migrating from Prairie Creek (and RC) must continue to migrate and rear in lower RC and estuary, which are considered impaired due to sedimentation, channelization, lack of large woody debris, and a minimal riparian zone. Thus, the condition of lower RC and estuary can impact survival and growth of 0+ Chinook Salmon prior to ocean entry, which in turn can negatively influence the abundance of adult Chinook Salmon returns to Prairie Creek (and RC).

The average size of Prairie Creek 0+ Chinook Salmon migrants ranged from 53 – 65 mm FL, and across all years averaged 59 mm FL. The average FL in 2015 equaled 61 mm. The relatively small size of Chinook migrants emigrating from Prairie Creek suggests they need to continue rearing in lower RC and estuary in order to attain a size that increases marine survival (Martin et al. 1989, Nicholas and Hankin 1989, Duffy and Beauchamp 2010, Claiborne et al. 2011, Tipping 2011). In comparison, 0+ Chinook Salmon emigrating from upper RC ranged from 50 – 56 mm FL (Avg. FL = 52 mm) in

YRS 2011 – 2015 and in 2015 FL averaged 50 mm (Sparkman 2016). 0+ Chinook Salmon migrants passing through lower RC ranged from 61 – 71 mm FL (Avg. FL = 65 mm) in YRS 2011 – 2015, and in 2015 FL averaged 64 mm (Sparkman et al. 2016). The small, average size of 0+ Chinook Salmon in both RC and Prairie Creek provides evidence that lower RC and estuary are important areas where juvenile Chinook Salmon need to increase growth to increase survival. Several authors have reported the importance of estuaries for ocean-type Chinook Salmon juveniles with respect to growth and survival to adulthood (Carl and Healey 1984, Allen and Hassler 1986, Healey 1991, Myers et al. 1998). Unfortunately, lower RC and estuary are currently in an impaired condition, and most likely limit any increases in freshwater growth (and survival) that 0+ Chinook Salmon need to increase smolt to adult survival rates (Martin et al. 1989, Nicholas and Hankin 1989, Duffy and Beauchamp 2010, Claiborne et al. 2011, Tipping 2011). Our data of size, in comparison with lower RC, suggests that Prairie Creek 0+ Chinook Salmon need to increase size in the estuary more so than Chinook Salmon passing through lower RC.

<u>1+ Chinook Salmon</u>

One year old juvenile Chinook Salmon (stream-type) in Prairie Creek represent the third juvenile Chinook Salmon life history. 1+ Chinook Salmon can be confused with 1+ Coho Salmon because they appear very similar. However, 1+ Chinook Salmon have wider parr marks, and an anal fin that appears as a triangle or pyramid when held upright (horizontal) and out of water. 1+ Coho Salmon have narrower parr marks, and an anal fin that has a leading edge that extends beyond the posterior insertion point of the fin. The most difficult juvenile salmonids to identify are distinguishing 1+ Chinook Salmon and 1+ Coho Salmon; however, crew members have extensive experience identifying the two juvenile species. Stream-type juvenile Chinook Salmon are easily differentiated from ocean-type Chinook Salmon by size at time of downstream migration, and general appearance. The average size (FL mm) in February 2012, for example, was 79 mm for 1+ Chinook Salmon and 37 mm for 0+ Chinook Salmon. 1+ Chinook Salmon in Prairie Creek appear to be in very low abundance as evidenced by trap catches totaling 13 individuals over five consecutive study years. 1+ Chinook Salmon were captured in June and July in 2011, February, May, and June in 2012, May in 2013, March and May in 2014, and April and May in 2015.

When present, 1+ Chinook Salmon in Prairie Creek are more likely to be progeny of fall/winter-run Chinook Salmon adults than from spring-run adults because no spring-run Chinook Salmon have ever been documented in Prairie Creek to the best of our knowledge. Low stream flows during late spring/summer months in Prairie Creek can become so low that adult upstream passage is considered problematic. Thus, a spring run of Chinook Salmon adults was probably not responsible for the production of yearling Chinook Salmon juveniles in Prairie Creek. Bendock (1995) also found both stream-type and ocean-type juvenile Chinook Salmon in an Alaskan stream which only has one adult Chinook Salmon race, and Conner et al. (2005) reported that fall Chinook Salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history. Zimmerman et al. (2015) reported that for six spawning populations (spring, summer, and fall) of Chinook Salmon in the Skagit River, Washington all produced progeny showing ocean-type and stream-type life histories. Teel et al. (2000) found that for some populations of coastal Chinook Salmon, ocean-type and stream-type juveniles were genetically undifferentiated, and probably arose from a common ancestor. They further conclude that the stream-type life history probably evolved after the ocean-type colonized (post glacial period) the rivers in study.

The 1+ Chinook Salmon life history may be important for increased ocean survival of Chinook Salmon juveniles, and general species diversity (authors, Don Chapman pers. comm. 2003).

<u>0+ Trout</u>

Trap catches of 0+ trout included Steelhead Trout and Cutthroat Trout fry and parr because we could not visually separate the two species at this juvenile age and size. The number of young-of-year trout (Steelhead Trout and Cutthroat Trout) that can remain upstream of the trap site is considered to be some function of a fish's disposition to out-migrate (or not out-migrate) and habitat carrying capacity. Meehan and Bjornn (1991) comment that juvenile Steelhead Trout have a variety of migration patterns that can vary with local conditions, and that the trigger for out-migration can be genetic or environmental. They further state that some Steelhead populations normally migrate downstream soon after emergence from redds to occupy other rearing areas (we observe this as well in Prairie Creek and upper and lower RC). Passive downstream migration can also occur when stream discharge increases, and fish are displaced downstream. Habitat carrying capacity is generally thought to be related to environmental (hydrology, geomorphology, stream depth and discharge, stream temperatures, cover, sedimentation, etc.) and biological variables (food availability, predation, salmonid behavior), and any interactions between the two groups of variables (Murphy and Meehan 1991). The general idea is that when habitat carrying capacity is exceeded (e.g. over-seeding, surplus production), juvenile fish emigrate to find other areas to rear. A problem with the view of habitat carrying capacity's effect on migration is that it often fails to explain why juvenile salmonids (e.g. 0+ TR, 0+ CT, 0+ CO) emigrate at low, upstream densities or low, upstream population levels. The emigration of 0+ trout through lower Prairie Creek provides evidence that this life history trait is common, even in a relatively pristine stream like Prairie Creek.

Young-of-year trout downstream migration through lower Prairie Creek is considered to be stream redistribution (passive and active) because juvenile Steelhead Trout and Coastal Cutthroat Trout in California normally smolt and enter the ocean at one to two years old, with lesser numbers out-migrating at an age of 3^+ years (Busby et al. 1996, Sparkman et. al. 2016). Based upon experiments conducted in upper RC, Sparkman (2016) reported that marked 0+ Steelhead Trout released in upper RC were recaptured in lower RC in five separate study years. To the best of our knowledge, these were the first experiments to show 0+ Steelhead Trout may cover considerable distances (e.g. 29 mi.) while moving downstream in search of rearing areas.

Trap catches of 0+ trout over five years ranged from 939 – 4,522 and totaled 11,268. In 2015, 939 were captured, with most catches occurring in June/July (85% of total). Relatively high catches of young-of-year trout by downstream migrant traps in small and large streams is not uncommon (Sparkman 2016). For example, 0+ Steelhead Trout catches in upper RC from YRS 2000 – 2015 ranged from 32,585 - 128,885 and averaged 71,254 per year (Sparkman 2016). In 2015, a total of 100,007 0+ Steelhead Trout were captured moving downstream in upper RC (Sparkman 2016), and 39,779 were captured moving past the smolt trap in lower RC (Sparkman et al. 2016). The 0+ trout captured by the trap in lower Prairie Creek indicate these fish are going to rear for some time period in lower RC (including the estuary), before possibly migrating back upstream into Prairie Creek or RC. Although relatively few 0+ trout migrated downstream past the trap site in lower Prairie Creek in any given study year, the condition of lower RC and estuary can impact the survival and growth of 0+ trout, which in turn could influence the number of older, juvenile Steelhead Trout and juvenile Cutthroat Trout in following years.

<u>1+ Steelhead Trout</u>

One-year-old Steelhead Trout smolts were the most numerous juvenile Steelhead Trout age-1 and older migrating downstream through lower Prairie Creek each study year. The ratio of 1+ Steelhead Trout smolts to 2+ Steelhead Trout smolts (population level) over five years ranged from 1.7:1 to 10:1, and averaged 4:1. In 2015, the ratio equaled 1.7:1. For comparison, the ratio in 2015 equaled 7.5:1 in upper RC (Sparkman 2016), and 3:1 in lower RC (Sparkman et al. 2016). On a percentage basis, 1+ Steelhead Trout comprised 63 – 91% of the total juvenile Steelhead Trout age-1 and older population abundance in Prairie Creek each study year, and in 2015 1+ Steelhead Trout comprised 63% of age-1 and older Steelhead Trout population abundance.

Information in the literature indicates Steelhead smolting at age-1 is not uncommon, particularly in streams that are south of British Columbia (Quinn 2005, Busby et al. 1996). The percentage of 1+ Steelhead Trout showing parr characteristics in Prairie Creek was very low each study year (0.0 - 3.6%), and indicated that few 1+ Steelhead Trout migrated downstream in a stream-residence form (parr). In contrast, the majority of 1+ Steelhead Trout (59 – 87%) in a given study year were emigrating in a pre-smolt stage, with lesser numbers emigrating in a smolt stage (10 – 41%). A caveat to our visual determination of developmental stages is that fish were examined under a tarp (used as a roof for the processing station), and were shielded from direct sunlight. On several occasions we noticed that fish observed in direct sunlight were more smolt like than if observed in the shade. Thus, the percentage of pre-smolts would be lower if developmental stages were determined in direct sunlight, and the percentage of smolts would be higher. We assume that pre-smolt and smolt age-1 Steelhead Trout are actively emigrating from Prairie Creek to the estuary, and that some percentage will enter the Pacific Ocean. Empirical data collected from 1+ Steelhead Trout in RC indicate that 1+ Steelhead Trout are entering the estuary and ocean, and successfully returning to spawn as adults (Sparkman, In progress). Based upon studies in other streams, the number of returning adult Steelhead Trout that migrated to the ocean as one-year-old smolts is relatively low, and usually less than 29% (Pautzke and Meigs 1941, Maher and Larkin 1955, Busby et al. 1996, McCubbing 2002, McCubbing and Ward 2003).

The population abundances of 1+ Steelhead Trout passing through lower Prairie Creek over five years ranged from 2,964 to 7,786 and averaged 5,724 individuals. In comparison 26,612 to 36,964 (Avg. 31,721) 1+ Steelhead Trout emigrated from upper RC, and 20,501 to 56,020 (Avg. 34,331) emigrated through lower RC (upstream of confluence with Prairie Creek) over the same study years (Sparkman et al. 2016). 1+ Steelhead Trout population abundances in 2015 equaled 7,786 in Prairie Creek, 33,809 in upper RC, and 56,020 in lower RC (Sparkman et al. 2016). Abundances in 2015 were the highest of record for Prairie Creek and second highest of record for lower RC. The trend in population abundances over years was significantly positive in Prairie Creek, non-significant in lower RC (Sparkman et al. 2016), and significantly negative in upper RC when flood type flows during winter months were added to the linear model (Sparkman 2016).

Population abundances by month in 2015 in Prairie Creek ranged from 1 (February) to 4,125 (May), and peaked in May. The pattern in monthly abundances was similar to the previous four year average, and may indicate migration was not overly affected by the severe drought WY 2015. The peak month in migration from upper RC in 2015 was May (N = 16,623) and through lower RC the peak also occurred in May (N = 28,819). The two most important months in 2015 for migration in Prairie Cr were April/May (84% of total), compared to April/May (76% of total) in upper RC and May/June (82% of total) in lower RC (Sparkman et al. 2016). Unlike past study years, Prairie Creek 1+ Steelhead Trout smolts in 2015 generally entered the lower river and estuary at the same time as 1+ Steelhead Trout smolts from lower RC.

The average size of 1+ Steelhead Trout migrants in Prairie Creek over five study years ranged from 92 – 100 mm (FL), and 9.2 – 10.8 g (Wt), and in 2015 average FL equaled 100 mm and average Wt equaled 10.81 g. On average, 1+ Steelhead Trout in Prairie Creek in 2015 were longer (by 6 mm) than those emigrating from upper RC (Sparkman 2016), and 3 mm less in length than emigrants passing through lower RC (Sparkman et al. 2016).

<u>2+ Steelhead Trout</u>

In several studies investigating Steelhead Trout life histories, the majority of the returning adult Steelhead spent two or more years as juveniles in freshwater prior to ocean entry (Pautzke and Meigs 1941, Maher and Larkin 1955, Busby et al. 1996, Smith and Ward 2000, McCubbing 2002, McCubbing and Ward 2003). Pautzke and Meigs (1941), for example, reported that 84% of returning adult Steelhead Trout in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult Steelhead they examined had spent two or more years in freshwater prior to entering the ocean, McCubbing (2002) reported 92% of Steelhead adults in a British Columbia stream had spent two or more years as juveniles in freshwater, and McCubbing and Ward (2003) reported that 71% of the adult returns in 2003 had entered the ocean as 2 or 3 year old smolts. If this applies to Steelhead Trout in Prairie Creek, then 2+ Steelhead Trout are the most important (and most direct) group of juvenile Steelhead Trout that contribute to future adult Steelhead Trout populations. The paradox for the 2+ Steelhead Trout smolts in Prairie Creek (and to a much larger degree in RC) is that they were far less abundant (by about 40 - 90%) than 1+ Steelhead Trout smolts in any given study year. In 2015, 2+ Steelhead Trout were 42% less in abundance than 1+ Steelhead Trout. With respect to the combined population of 1+ and 2+ Steelhead Trout smolts each year, 2+ Steelhead Trout comprised 9 – 37% of the population in Prairie Creek. In 2015 2+ Steelhead Trout comprised 37% of total age-1 and older Steelhead Trout abundance. The ratio of 2+SH:1+ SH equaled 0.3:1 in 2011, 0.1:1 in 2012, 0.6:1 in 2013, and 0.3:1 in 2014, and 0.6:1 in 2015.

The population abundances of 2+ Steelhead Trout emigrating from Prairie Creek over five years ranged from 295 – 4,520 individuals, and averaged 2,384. The peak in abundance occurred in 2015. In comparison 1,225 to 4,486 (Avg. 2,774) 2+ Steelhead Trout smolts emigrated from upper RC (Sparkman 2016), and 3,748 to 18,155 (Avg.

9,197) emigrated through lower RC (upstream of confluence with Prairie Creek) over the same study periods (Sparkman et al. 2016). In 2015, 4,520 2+ Steelhead Trout emigrated from Prairie Creek, compared to 4,486 from upper RC and 18,155 through lower RC (Sparkman et al. 2015). The abundances of 2+ Steelhead Trout at each trap location were the highest of recent record (2011 – 2015) in 2015, and indicate that the severe drought of 2014 did not drastically reduce survival.

Similar to most juvenile species at age, linear correlation failed to detect a significant trend over five study years. As discussed in the section for 0+ Chinook Salmon, testing trends in abundance often requires numerous, consecutive years of data to determine a reliable trend.

Population abundances by month in Prairie Creek in 2015 ranged from 0 (August) to 1,819 (April), and peaked in April. The pattern in monthly abundances differed from the previous four year average in that migration in March and April 2015 was much higher than average by a factor of 16.7 and 4.0, respectively. The two most important months for migration in Prairie Creek in 2015 were March/April (79% of total), compared to April/May for the previous four year average. In comparison, the two most important months in upper RC were April/May (84% of total), and in lower RC April/May (85% of total) in 2015 (Sparkman et al. 2016). Compared to lower RC populations, a higher percentage of the Prairie Creek 2+ Steelhead Trout smolts enter the lower river and estuary earlier than 2+ Steelhead Trout smolts passing through lower RC.

The average size of 2+ Steelhead Trout migrants in Prairie Creek over five study years ranged from 142 – 158 mm (FL), and 29.9 – 37.0 g (Wt), and in 2015 average FL equaled 151 mm and average Wt equaled 36.5 g. In comparison, the average FL (mm) in 2015 for 2+ Steelhead Trout smolts in upper RC equaled 151 mm, and for lower RC equaled 157 mm (Sparkman et al. 2016). Thus, Prairie Creek 2+ Steelhead Trout smolts in 2015 were the same average size as in upper RC, and slightly smaller than those passing through lower RC.

The percentage of 2+ Steelhead Trout emigrating from Prairie Cr showing parr characteristics was zero each study year, and indicate 2+ Steelhead Trout do not emigrate through lower Prairie Creek in a stream resident form. Rather, most of the 2+ Steelhead Trout were emigrating in a smolt form, and in 2015 77% were classified as smolts. In comparison, 99.7% were classified as smolts in upper RC in 2015, and 100% were classified as smolts in lower RC (Sparkman et al. 2016).

Although there are few studies that specifically look at Steelhead smolt to adult survival, Steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive, linear relationship between out-migrating 2+ smolts and returning adult Steelhead (Ward and Slaney 1988, Ward 2000, Ward et al. 2002). Ward (2000) cites other authors who report similar positive linear relationships between smolts and adults along the British Columbia coast as well (eg Smith and Ward 2000). Survival from smolt to adult in the Keogh River can be variable, and may range from an average of 15% (during 1976-1989) to an average of 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported Steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where Steelhead must overcome dams and travel long distances to reach spawning grounds. It is difficult to make specific inferences about 2+ Steelhead Trout smolt to adult survival for Prairie Creek Steelhead based upon successful studies in the literature because of differences in latitude/longitude, geography, ocean conditions (physical and biological), estuaries, and trap locations in the watershed. However, the belief that the number of 2+ smolts relates to future adults (and watershed conditions) is hard to dismiss or invalidate.

With respect to younger juvenile stages (0+ and 1+), the 2+ Steelhead Trout smolt is the best candidate for assessing Steelhead status, trends, and abundance when information on adult Steelhead is unavailable, un-attainable, or un-reliable. 2+ Steelhead Trout have overcome the numerous components of stream survival that younger Steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc), and 2+ Steelhead smolts are the most direct, juvenile recruit to adult Steelhead Trout populations. The 2+ Steelhead Trout are also an excellent indicator of watershed and stream conditions because they spend the longest amount of time in freshwater habitat prior to ocean entry, with exception to some Cutthroat Trout juveniles. Along these same lines, Ward et al. (2003) reported that the 2+ Steelhead smolt was a more reliable response variable with respect to stream restoration than late summer juvenile densities because of being less variable.

<u>Juvenile Coastal Cutthroat Trout</u>

Relatively large numbers of age-1 and older Coastal Cutthroat Trout were captured migrating downstream through lower Prairie Creek each study year. Seasonal trap catches ranged from 668 – 2,398 individuals, and averaged 1,487. The highest catch occurred in 2015 (n = 2,398). Few of the captured Cutthroat Trout were classified as parr (range = 0.0 – 0.2%), and nearly equal numbers were classified as pre-smolts (Avg 49.6%) or smolts (Avg. 50.4%) when averaged over five years. In 2015, 51% were considered pre-smolts, and 49% were considered smolts.

Juvenile Coastal Cutthroat Trout exhibited the most stable population abundance over study years, with exception to a peak in abundance in 2015. Correlation failed to detect a significant increase in abundance over years. The spring/summer population abundance of Coastal Cutthroat Trout emigrating from Prairie Creek over five years ranged from 4,581 – 8,572 individuals, and averaged 5,782. The population abundance in 2015 equaled 8,572 in Prairie Creek, and 825 in lower RC (Sparkman et al. 2016). For each trap location, the peak in abundances occurred in 2015. A total of 23 were captured moving downstream in upper RC (Sparkman 2016). Clearly, Prairie Creek is a stronghold for Coastal Cutthroat Trout within the RC basin.

Population abundances by month in Prairie Creek in 2015 ranged from 0 (August) to 5,264 (April), and peaked in April. Population abundance in April 2015 was 200% greater than the previous four year average abundance in April. The pattern in monthly abundances in 2015 was skewed to the left compared to the previous four year average, indicative of an earlier migration pattern. The earlier migration pattern in 2015 may be a response to drought conditions. The two most important months for migration in Prairie Creek in 2015 were April/May (87% of total), the same months for the previous four year average. In comparison, the two most important months in lower RC in 2015 were May/June (87% of total) (Sparkman et al. 2016). Compared to the lower RC population, a higher percentage of Prairie Creek juvenile Cutthroat Trout entered lower RC and estuary before RC smolts.

The average size of juvenile Coastal Cutthroat Trout migrants in Prairie Creek over five study years ranged from 142 – 151 mm (FL), and 32.7 – 39.5 g (Wt), and in 2015 average FL equaled 151 mm and average Wt equaled 37.8 g. On average, Cutthroat Trout juveniles in Prairie Creek in 2015 were 20 mm less in length than juvenile Cutthroat Trout passing through lower RC (Sparkman et al. 2016), and 16 mm less in length than those emigrating from upper RC (Sparkman 2016).

We used three characteristics to identify age-1 and older Coastal Cutthroat Trout: upper maxillary that extends past the posterior portion of the eye, slash marks on the lower jaws, and hyoid teeth; spotting is also usually more abundant on Coastal Cutthroat Trout compared to Steelhead Trout smolts. Hybrid juveniles, the product of mating between adult Steelhead Trout and Cutthroat Trout, are commonly noted to be missing one or two of these characters. Although we did observe (potential) hybridization, numbers were low compared to Cutthroat Trout that were identified with the three above mentioned characteristics. However, for smaller sized smolts (FL < 75 mm), we could not safely test the presence of hyoid teeth without the risk of harming an individual. We therefore assumed that if we observed an upper maxillary that extended past the posterior portion of the eye, slash marks on lower jaws, and heavy spotting, the individual was a Coastal Cutthroat Trout.

<u>0+ Coho Salmon</u>

Similar to 0+ trout, trap catches of 0+ Coho Salmon are not all inclusive because only a given percentage of the total number present upstream of the trapping site will migrate downstream, this also pertains to the population point estimate. Thus, catches and population estimates are for those fish that were migrating past the trapping site. Trap catches of 0+ Coho Salmon moving downstream is typical for most streams, including relatively, pristine streams like Prairie Creek. Koski (2009) called these migrating 0+ Coho Salmon 'nomads' and considered this life history strategy important for species resilience and diversity. More recently, Bennett et. al (2014) found that young of year Coho Salmon that migrate downstream within their first year of their life may enter the ocean and survive to contribute to adult populations.

Few 0+ Coho Salmon were captured by the trap in lower Prairie Creek in YRS 2011 - 2015 (total catch = 2,037 individuals, ranged from 223 – 2,742). In 2015, we captured 329 individuals which was 72% less than the previous four year average (Avg. = 1,195). The average catch over five years equaled 1,022, and was contrasted by much higher catches in middle Prairie Creek during mid to late 1990's. For example, trap catches of 0+ Coho Salmon in mid to upper Prairie Creek from 1996 – 1998 ranged from a low of 372 to a high of 25,492, and averaged 9,659 per trapping season (Roelofs and Sparkman 1999). The relatively low catches in lower Prairie Creek provide evidence that the higher catches in middle Prairie Creek were probably associated with stream re-distribution, and not emigration from the Prairie Creek watershed. In addition we did not observe large numbers of young of year Coho Salmon emigrate from the Prairie Creek basin during the trapping periods, which contrast the findings of Jones et al. (2014).

The population abundance of 0+ Coho Salmon passing through lower Prairie Creek over five years ranged from 726 – 14,126, and averaged 5,627 individuals. Population abundance in 2015 equaled 1,601 compared to an abundance of 303 in lower RC (Sparkman et al. 2016). The greatest abundance in Prairie Creek occurred in 2014, and may reflect: 1) higher adult numbers, 2) change in spatial distribution of adult spawners within the Prairie Creek watershed, 3) greater percentage of juveniles actively migrating downstream during lower stream flows, or 4) a combination of the three variables. Since Coho Salmon redd counts in 2013/14 were greater than previous years, the most likely reasons for increased downstream migration in 2014 were greater adult abundances, and an increase in active migration during low stream flows. We further hypothesize that drought conditions during the adult migratory period, in which Prairie Creek had low discharge and shallow stream depths, encouraged adults to spawn lower in the Prairie Creek basin. The young of year Coho Salmon then re-distributed downstream to be caught in relatively larger numbers. The percentage of fry (92%) in the population in 2014 was the second highest of record, and indicated that the time from fry emergence from redds to trap capture was relatively less compared to 2011 - 2013. The percentages of fry in the populations from 2011 – 2015 ranged from 49 – 98%, averaged 83%, and relationships with population abundances were not detected ($p > 0.05$). The highest percentage of fry (98%) occurred in 2015.

Population abundances by month in Prairie Creek in 2015 ranged from 0 (Late February) to 1,047 (April), and peaked in April. The pattern in monthly abundances in 2015 contrasted the pattern for the previous four year average in that monthly migration in 2015 quickly dropped to low values after April. Additionally, the two most important months for migration in Prairie Creek in 2015 were March/April (99% of total), compared to April/May (86%) for the previous four year average. In comparison, the two most important months in lower RC in 2015 were April/May (75% of total) (Sparkman et al. 2016). Unlike study year 2014, the migration of 0+ Coho Salmon from Prairie Creek in 2015 was basically over by late April, whereas for lower RC migration continued into early August.

The average size of 0+ Coho Salmon migrants in Prairie Creek over five study years ranged from 38 – 49 mm (FL), and 0.62 – 2.11 g (Wt), and in 2015 average FL equaled 38 mm and average Wt equaled 0.57 g. The average size in 2015 corresponded to the fry life history stage, which was expected because most of the trap captures were fry. The average FL over five years equaled 41 mm, and corresponded to a parr life history form that was small in size. However, the average sizes in 2012, 2013, and 2015 corresponded to the fry life history form, and in 2011 and 2014 corresponded to the parr life history form. On average, 0+ Coho Salmon downstream migrants in Prairie Creek in 2015 were much smaller than 0+ Coho Salmon (Avg FL = 56 mm; Avg. Wt = 2.36 g) migrating through lower RC in 2015 (Sparkman et al. 2016).

The migration of 0+ Coho Salmon through lower Prairie Creek indicate that these fish were moving downstream to rear, or possibly to enter the ocean at age-0. Thus, lower RC and the estuary may serve as important places for young-of-year Coho Salmon to rear.

<u>1+ Coho Salmon</u>

Large numbers of age-1 (and older) Coho Salmon smolts were captured migrating downstream through lower Prairie Creek each study year. Seasonal trap catches ranged from 2,455 – 11,355 individuals, and averaged 7,342. The greatest catch occurred in

2015, even though the population abundance in 2015 was the second highest of record. Trap catches in 2015 were higher than previous study years because: 1) population abundance was high, 2) few high flow events occurred , and 3) drought conditions forced us to install extensive weir panels much earlier than previous study years to keep the trap operating. The majority of 1+ Coho Salmon in 2011 – 2015 were classified as smolts (77 – 96%), and zero were observed as being in a parr stage.

Population abundances over the five year period ranged from 8,446 – 23,580, and averaged 18,550. Given that there are 24 miles of anadromy within the Prairie Creek basin, we suspect that population abundances/stream mile are higher in Prairie Creek than other streams in California. Linear correlation failed to detect a significant trend in abundances, even though the r value for the correlation test equaled 0.65. Similar to other species at age during YRS 2011 – 2015, the lack of a significant trend was likely due to low sample size (n = 5 years). Testing trends in abundance often requires numerous years of data to determine a statistically, reliable trend. Trends with low sample sizes not only preclude statistical significance, but limit inferences on population status because the trend line can change with the addition or omission of a single data point. However, data clearly showed there were relatively high numbers of 1+ Coho Salmon smolts emigrating from Prairie Creek relative to study year 2011. The abundance in Prairie Creek was considerably higher than 1+ Coho Salmon emigration through lower RC from 2011 - 2015. The population abundance in Prairie Creek in 2015 equaled 21,536 compared to a population abundance of 1,923 for 1+ Coho Salmon smolts emigrating through lower RC (Sparkman et al. 2016), and 42 in upper RC (Sparkman 2016). 1+ Coho Salmon abundances through lower RC from 2004 - 2015 ranged from 33 – 1,923 and averaged 486 individuals (Sparkman et al. 2015). Clearly, Prairie Creek is a stronghold for the production of 1+ Coho Salmon smolts within the RC basin.

Population abundances by month in Prairie Creek in 2015 ranged from 6 (Late February) to 9,132 (April). The pattern in monthly abundances in 2015 was similar to the pattern for the previous four year average, however migration in April 2015 was much higher than average, by a factor of 1.7. The two most important months for migration through lower Prairie Creek in 2015 were April/May (82% of total), the same months for the previous four year average, and study years 2012, 2013, and 2014. In comparison, the two most important months in lower RC in 2015 were April/May (97% of total) (Sparkman et al. 2016), and April/May (100% of total) for upper RC as well (Sparkman 2016).

The average size of 1+ Coho Salmon smolts in Prairie Creek over five study years was negatively related to population abundances ($p < 0.05$), such that with higher abundances we observed a decrease in FL’s (mm) (density-dependence). However, the largest difference between study years equaled 7.6 mm or 7.3% less than the five year average FL (mm), and differences among study years are unlikely to have biological meaning.

The average size over five years ranged from 101 – 109 mm (FL), and 11.01 – 13.47 g (Wt), and averaged 104 mm and 12.08 g. Average FL equaled 102 mm and average Wt equaled 12.08 g in 2015. In comparison, average FL (mm) and Wt (g) of 1+ Coho Salmon smolts passing through lower RC in 2015 equaled 106 mm and 12.47 g (Sparkman et al. 2016), and for upper RC equaled 112 mm and 14.71 g (Sparkman 2016). When comparing the size of 1+ Coho Salmon smolts in Prairie Creek to populations in other streams, it should be noted that Prairie Creek supports good numbers of 0+ Chinook Salmon, 1+ Steelhead Trout, 2+ Steelhead Trout, and Coastal Cutthroat Trout, which may compete for food resources and physical space with juvenile Coho Salmon in Prairie Creek.

<u>Trap Derived Estimates of Juvenile Coho Salmon Overwinter Survival</u>

The smolt trap captured 168 age-1 pit tagged 1+ Coho Salmon smolts in 2015, with a seasonal efficiency of 59%, and an average weekly efficiency of 53%. The efficiency of trap capture for pit tagged smolts was similar to non-pit tagged 1+ Coho Salmon trapping efficiency (seasonal = 55%, average weekly = 55%), and suggests that the presence of pit tags did not influence migratory behavior immediately upstream of the trapping site or probability of trap capture. Additionally, the patterns of daily captures and weekly population abundances of pit tagged and non-pit tagged smolts were very similar as well. Thus, our data showed that pit tags did not influence the migratory behavior of 1+ Coho Salmon smolts that migrated during the trapping period. The smolt trap also captured six age-2 pit tagged Coho Salmon smolts that were originally tagged in the fall of 2013. These fish were excluded from the smolt trap mark/recapture derived estimate of overwinter survival.

The smolt trap was more efficient at capturing pit tagged 1+ Coho Salmon than the pit tag antenna array was at detecting pit tagged Coho upstream of the trapping site. *A priori*, we assumed the antenna array would be more efficient than the smolt trap, however, stream velocity, stream depths, and orientation of pit tagged fish moving over the antenna plate-designed array (lower most antenna in stream) may have limited detection rates of pit tagged Coho Salmon. Although actual captures and detection rates were not equal, the expanded captures and detections (population level) were similar. The trap derived overwinter survival estimate equaled 29%, which was close to the pit tag antenna/trap capture overwinter survival estimate of 33%. The 95% CI for the trap derived estimate (23 – 34% survival) encompassed the pit tag antenna array/trap capture estimate. The pit tag antenna/trap estimate and trap derived estimate did not remove detections of early migration in the fall/winter (n = 59 or 5.6% of tagged fish in the fall) from the number originally tagged because the antenna array was located two miles upstream of the trap site, and there was good rearing habitat between the antenna and trap location. We could not assume that all of the early migrants migrated past the trapping site and out of the Prairie Creek basin, although it was quite likely some did. Additionally, the trap captured eight of the early migrants in the spring (which expanded to 20 individuals) that passed the antenna in the fall/winter before trap placement. As mentioned in the section for pit tagged Coho Salmon, Prairie Creek is a relatively pristine stream with high habitat complexity, abundant large woody debris, low stream gradients, and constant stream flow. High stream habitat quality, and impairment of Redwood Creek estuary, may select for a juvenile Coho Salmon life history that maximizes residency within the Prairie Creek basin before smolting and migrating out of the basin.

0+ Pink Salmon

Pink Salmon in California are recognized as a "Species of Special Concern", and California is recognized as the most southern border for the species (CDFG 1995). Although not in large numbers, Pink Salmon have been historically observed in the San Lorenzo River, Sacramento River and tributaries, Klamath River, Garcia River, Ten Mile River, Lagunitas River, Russian River, American River, Mad River, and once in Prairie Creek, which is tributary to RC at RM 3.7. Pink Salmon were observed spawning in the Garcia River in 1937 and the Russian River in 1955 (CDFG 1995). Fairly recently, adult Pink Salmon were seen spawning in the Garcia River in 2003 (Scott Monday pers. comm. 2004) and in Lost Man Creek (tributary to Prairie Creek) in 2004 (Baker Holden, pers. comm. 2005). More recently, adult Pink Salmon were observed and photographed in lower RC during the fall of 2010 (D. Anderson, pers. com. 2012), and visually observed in the nearby Mad River in fall of 2015 (S. Holt, pers. com. 2015). Juvenile Pink Salmon have been captured with the smolt trap in upper RC in YRS 2000, 2002, 2004, 2005, 2008, 2011, 2013, and 2015 (Sparkman 2016), and in lower RC in YRS 2005, 2013, 2014, and 2015 (Sparkman et al .2016). Based upon smolt trap data, adult Pink Salmon returned to spawn in both even and odd numbered years.

Low numbers of 0+ Pink Salmon were captured in lower Prairie Creek in 2013 (n = 1) and 2015 (n = 1). Thus, the parents (BY 2012, BY 2014) were present in an even numbered spawning year. The smolt trap in upper RC captured six in 2015, and the trap in lower RC captured one individual. It is hard to say if the parents of the juvenile Pink Salmon were strays or remnants of a historic run in Prairie Creek because adult Pink Salmon were only observed in one year (Baker Holden, pers. comm. 2005), even though adult redd counts have been conducted in Prairie Creek for over 18 consecutive (authors). The persistent occurrence of juveniles in RC and to a lesser degree, Prairie Creek, suggests that the presence of Pink Salmon is not a random event. According to the Habitat Conservation Planning Branch (HCPB) of CDFW, Pink Salmon are considered to be “probably extinct” in California (CDFG 1995). However, the HCPB does state that “more efforts need to be conducted to prove (or disprove) that reproducing populations exist anywhere in California” (CDFG 1995). Based upon our trapping data in Prairie Creek and RC (Sparkman 2016, Sparkman et al 2016), Pink Salmon are present and reproducing, albeit in low numbers.

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APPENDICES

Appendix 1. M-array table showing number of fish tagged and recaptured by occasion. An additional 67 fish (excluded from this analysis) were detected at the lower antenna array prior to trap installation, and indicates that some portion of the population was migrating downstream of the lower-most antenna in Prairie Creek prior to the spring migration. However, 8 of the 67 were captured in spring by the rotary screw trap indicating that some fish spent time rearing in lower Prairie Creek prior to the spring/summer smolt migration period.

Releases	Number Released (R_i)		Occasion 2	Occasion 3	Occasion 4	Occasion 5	Total Recap. for first time (r_i)	Never Recaptured (R_i-r_i)
Tag event 1	**395**		52	50	35	16	**153**	**242**
Tag event 2	**718**							
		[11]	52	10	5	6	21	31
		[01]	666	82	53	29	164	502
			718				**185**	**533**
Upper Antenna Array	**142**							
			[101]	50	23	13	36	14
			[111]	10	6	4	10	0
			[011]	82	37	17	54	28
				142			**100**	**42**
Lower Antenna Array	**159**							
				[1001]	35	21	21	14
				[1101]	5	2	2	3
				[1011]	23	15	15	8
				[1111]	6	4	4	2
				[0101]	53	26	26	27
				[0111]	37	15	15	22
					159		**83**	**76**