State of California
The Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

2011 – 2013 FRGP REPORT

PRAIRIE CREEK MONITORING PROJECT 2011 - 2013 Seasons

Fisheries Restoration Grants Program (Project Number: P1010302)

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March 31, 2014

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ABSTRACT

This report presents results from monitoring coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, California, during 2011 to 2013. It includes results from estimation of escapement using redd counts during the 2011/2012 and 2012/2013 spawning seasons, results from juvenile sampling in 2012 and 2013, and estimates of smolt production during 2011 to 2013.

Juvenile coho salmon in Prairie Creek, California and its tributaries were marked during 2012 and 2013 using PIT tags to monitor winter redistribution and estimate overwinter growth and survival. The Cormack-Jolly-Seber model and Program MARK were used to examine how rearing location, size at tagging, habitat unit depth, and volume of large woody debris affected overwinter survival in 2012/2013. We found that 98.6% of juveniles in 2012 were age 0, and apparent overwinter survival was 39.4%. On average, juveniles experienced a 0.13% increase in length per day and 0.35% increase in weight per day, with the smallest fish experiencing the highest growth rates. Fish that were larger in fall and tagged closer to the confluence of Prairie Creek had higher apparent overwinter survival, but habitat depth and quantity of large woody debris did not appear to impact survival probability. Large juveniles appeared to have low survival near the confluence of Prairie Creek; however, the model could not distinguish deaths from emigration, meaning the high mortality rate for large juveniles near the mouth may actually reflect a pattern of early emigration from the study area. The down time (39 d) associated with the antenna near the confluence likely contributed to not detecting early migrants. Since juveniles that migrate to sea prior to spring trapping or during antennae downtime are typically treated as mortalities, these results have important implications for the way managers estimate freshwater survival for coho salmon.

We operated a five foot diameter rotary screw trap in lower Prairie Creek during 2011 – 2013 to estimate smolt abundances for juvenile coho salmon, Chinook salmon, steelhead trout, and coastal cutthroat trout during the spring/summer emigration periods. The smolt trap also served for collecting pit tagged juvenile coho salmon, and allowed for determining growth rates from fall tagging to time of capture. The trapping rate among years ranged from 86 – 99%, and averaged 94%. Trap catches ranged from 13,931 to 61,138 per year, with 0+ Chinook salmon comprising the majority of catches each year. Population abundances of 1+ coho salmon smolts in 2011 – 2013 ranged from 8,446 to 23,580 and averaged 17,389 per year; for 0+ coho salmon ranged from 726 to 8,403 and averaged 4,137 per year, for 0+ Chinook ranged from 15,148 to 96,187 and averaged 48,268 per year, for 1+ steelhead trout ranged from 2,964 to 6,735 and averaged 4,485

per year, for 2+ steelhead trout ranged from 295 to 4,020 and averaged 1,842 per year, and for coastal cutthroat trout ranged from 5,043 to 5,488 and averaged 5,252 per year. The two most important months for migration, depending upon study year, were April/May and May/June for 1+ coho salmon, April/May for 0+ coho salmon, April/May and May/June for 0+ Chinook salmon and 1+ steelhead trout, March/April, April/May and May/July for 2+ steelhead trout, and April/May and May/June for coastal cutthroat trout.

Adult spawning surveys were conducted in the Prairie Creek Life Cycle Monitoring sub-basin during 2011/2012 and 2012/2013. In 2011/2012, the average time between surveys on 15 individual reaches was 17 days (range of 15 – 22 days), and in 2012/2013 the average time between surveys was 12 days (range of 11 -14 days). Prairie Creek and its tributaries were surveyed an average of 8 times in 2011/2012 and 11 times in 2012/2013. In 2011/2012, we estimated a total of 379 coho salmon, 105 Chinook salmon, and 11 steelhead redds for all reaches within the Prairie Creek Life Cycle Monitoring sub-basin. In 2012/2103, we estimated a total of 363 coho salmon, 305 Chinook salmon, and 67 steelhead redds for all reaches within the Prairie Creek Life Cycle Monitoring sub-basin. The spawning ground survey period did not encompass the entirety of the spawning period for steelhead, and therefore the estimates presented should be considered only for the length of the study.

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[1]This paper should be referenced as: Sparkman, MD, WG Duffy and TR Moore. 2014. Prairie Creek Monitoring Project, 2011-2013 Seasons: a report to the Fisheries Restoration Grants Program (Project No. P01010302).

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 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 Healy 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 increased winter discharge (Bradford 1995, Brakensiek 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. 2007). 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 the abundance of downstream migrating salmonids and adult salmonid escapement to 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), 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). Estimates of adult escapement integrate life time mortality sources and are invaluable in tracking population trends since numbers of spawning adults reflect ultimate population trends (Adams et al. 2011). In addition to data on downstream migrating salmonids and adult escapement using redd counts as indices, we present data on juvenile coho salmon tagged throughout the Prairie Creek watershed over two years. These data will, in the future, prove useful in estimating survival in freshwater during the winter and between smolt migration and return of adults.

Site Description

Prairie Creek is a fourth-order tributary whose confluence with Redwood Creek occurs near Orick, California (Figure 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 (Duffy 2011). 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 Redwood Creek 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 Redwood Creek 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 or 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, and Chinook salmon (*O. tshawytscha*). 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*), and Pacific lamprey (*Entosphenus tridentata*) are also found in Prairie Creek (Cannata et al. 2006).

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. Prairie Creek's primary tributaries were also included in this study, including Streelow Creek, Boyes Creek, Browns Creek, Godwood Creek, Lost Man Creek and Little Lost Man Creek.

Purpose

The purpose of this project is to describe adult salmonid escapement, juvenile coho salmon marking/overwinter survival, and juvenile salmonid downstream migration from Prairie Creek. Escapement using redd counts provides an index of adult abundance, while sampling juvenile migrants provides estimates of population abundances for multiple salmonid species and age classes. The long-term goal of monitoring in this Life Cycle Station 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.

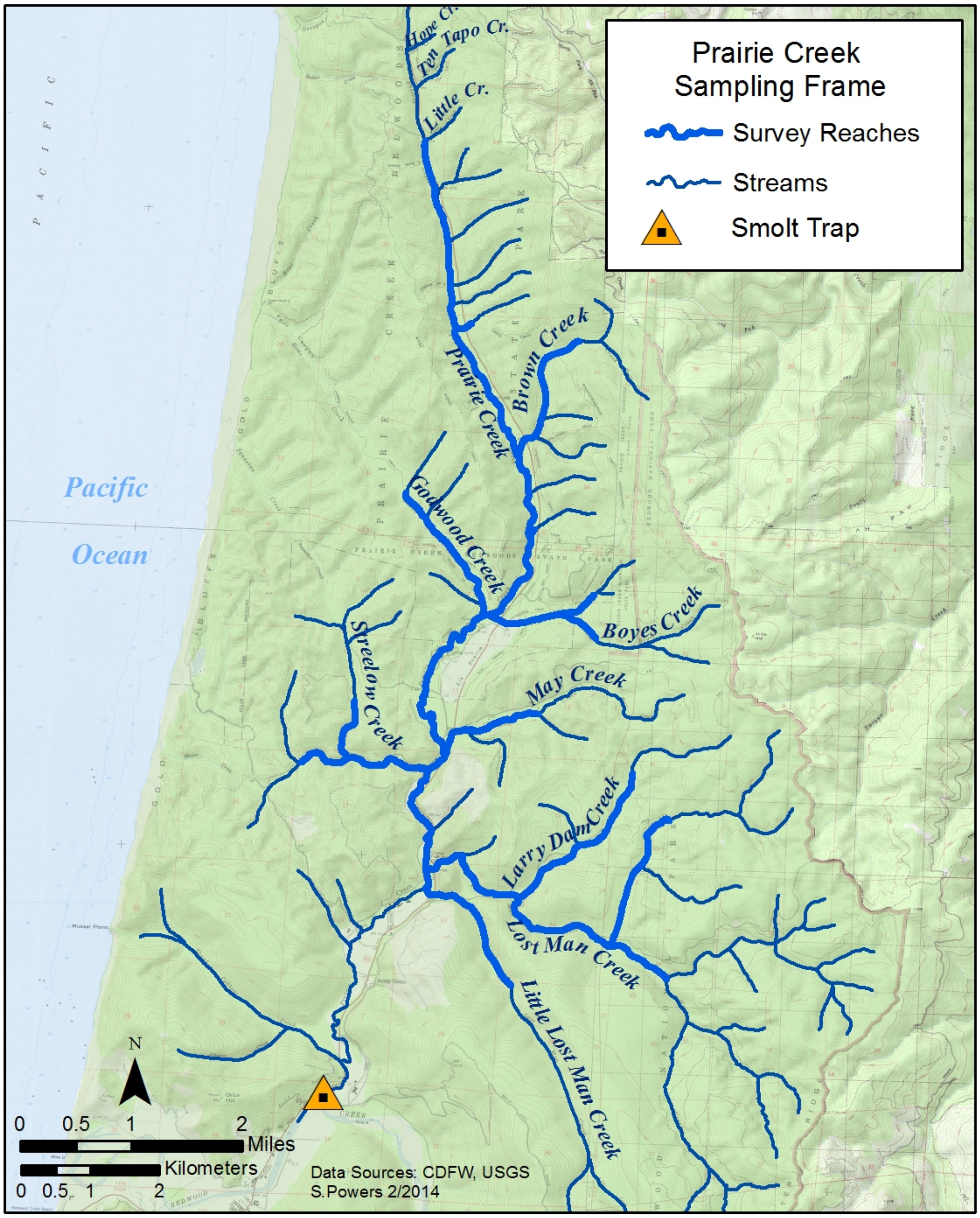

Figure 1. Prairie Creek basin with rotary screw trap location and redd survey reaches, Humboldt County, CA.

METHODS AND MATERIALS

Redd Surveys

Periodic foot surveys of the spawning grounds were conducted by Ricker et al. (2014a, b) using the protocols of Gallagher et al. (2007). Teams of two surveyors walked stream reaches in an upstream direction identifying redds and flagging their location for identification on subsequent surveys. Surveys were scheduled to be conducted every 10-14 days beginning after the onset of rains in November through late March as stream flows and/or weather conditions permitted.

When possible, redds were identified to species by identifying observed fish either digging or actively guarding a redd. All other redds, regardless of fish seen in the area, but not on a redd, were considered unknown species. All newly observed redds were measured for physical size, substrate size in the pot and tail spill areas, depth of pot in relation to the surrounding undisturbed substrate, geo-referenced, and physically marked with flagging tied to riparian vegetation in close proximity. The flagging indicated the unique record number of the redd, the distance and bearing from the flag to the redd, and a categorical 'Age' of (1) defined as: 'New since last survey'. On subsequent survey occasions new redds were flagged in the same manner and existing flags reconciled to the individual redds they marked, red record numbers recorded from the flag, and re-assigned a categorical 'age' variable to reflect if the redd was: (2) still visible and measurable, (3) still visible but not measurable, (4) no longer visible, or (5) unknown due to visibility constraints.

The probability of redds of unknown species being constructed by steelhead, coho salmon or Chinook salmon was estimated using logistic regression models incorporating a suite of variables reflecting redd dimensions, substrate, location, and time (Ricker et al. 2014a). Total redd abundance within the watershed was estimated using a simple random sample estimator for total as described in (Adams et al. 2011).

All live and dead fish were identified to species if possible. Carcasses were assigned a condition code reflecting how fresh they appeared, measured to fork length when possible, inspected for external clips or marks, and tagged with a uniquely numbered metal disk fixed to the jaw with a metal staple (jaw tag). The jaw tag number of re-observed carcasses was recorded on subsequent surveys. All carcasses were left in the location they were found. More detailed descriptions of escapement estimate techniques and results may be found in Ricker et al. (2014a, b).

Summer Juvenile Distribution and Marking

Habitat Surveys

Sampling efforts for juvenile coho salmon were focused on habitat units that contained pools (areas of deep, low velocity water) since these are the preferred habitat of juvenile coho salmon (Bisson et al. 1988). Pool habitats may be further separated into categories based on how the pool was formed; scour pools are formed where fluvial processes scour a hole in the sediment, plunge pools are characterized by the movement of water over an object which scours the streambed below, and dam pools are created when a partial blockage in the stream results in pool of backed up water (Flosi et al. 2010). For this study, each of the 70 habitat units sampled in 2012 and 40 sampled in 2013 was defined as a scour pool, plunge pool, or dam pool and the following measurements were taken: length, two widths, two depths, a maximum depth (deepest point in the habitat unit), and a pool tail depth. Moving in an upstream direction from the beginning of the reach, every third habitat unit was sampled provided the unit was a pool. If the unit was not a pool, the closest pool upstream was sampled. Large woody debris in each habitat unit was also recorded according to protocols outlined by Bouwes et al. (2011), modified for this study. Qualifying large woody debris included wood pieces measuring at least 10 cm in diameter that extended into the water 1 m during summer flow conditions. Each piece was classified into one of three length classes (1 to 3 m, 3.1 to 6 m, and > 6 m) and one of three diameter classes (10 to 15 cm, 16 to 30 cm, and > 30 cm). After sampling was completed, habitat units were flagged with the date, habitat unit number, and number of fish tagged in the unit. GPS coordinates of each unit were recorded using a Garmin GPS unit (model GPSMAP 60CSx).

Marking Techniques

Fish were marked using Passive Integrated Transponder (PIT) tags made by Oregon RFID, 12 x 2.12 mm electronic tags (half-duplex) that can be injected into a fish's body cavity. All tagging and handling procedures were approved by the Humboldt State University Institutional Animal Care and Use Committee (permit number 11/12 F14A). Each tag contained a unique code, which could be detected by a reader without having to sacrifice or handle the fish. Fish were collected using a 3 x 1.2 m seine net with 4.7 mm mesh and all processing and tagging was done streamside. All fish were anesthetized using MS-222 (tricaine methanesulfonate) prior to handling. In 2012, five juvenile coho salmon were randomly selected from each habitat unit for obtaining length and weight measurements in order to estimate the average size of juveniles throughout the watershed. Five coho salmon having a fork length (FL) $\geq$ 60 mm were then selected from the unit for tagging. Each fish receiving a tag was weighed, measured, and given a secondary mark prior to tagging. In 2013, five juvenile coho salmon < 60 mm FL were measured for size distribution and all or most fish ≥ 60 mm FL were selected for tagging. Tags were inserted by making a small (1 mm) incision on the fish's abdomen using a sanitized razor blade and immediately sliding a sterilized PIT tag into this incision. Scale samples were collected from one-third of tagged fish using a sanitized razor to remove approximately ten scales from the area posterior to the dorsal fin. After handling was complete, fish were allowed to fully recover in a mesh basket placed in an area of the stream with abundant circulation and released into the habitat unit from which they were collected.

Capture Occasions

For the purpose of estimating PIT tag mortality, fish were tagged in two events approximately 30 days apart following methods outlined by Brakensiek and Hankin (2007). In 2012, 277 coho salmon were tagged during the August event (August 1, 2012 to August 19, 2012) and 123 were tagged in September (September 1, 2012 to September 30, 2012). In 2013, 608 coho salmon were tagged during the first event (August 15, 2013 to September 17, 2013) along with 48 coastal cutthroat trout and 353 of these tagged coho salmon were re-sighted during the second sampling event (September 23, 2013 to October 18, 2013). Numbers of tagged fish marked within each stream reach are summarized in Table 1.

A set of dual pass through antennas with Oregon RFID half duplex PIT tag readers were located at the start of reach one and were considered to be the dividing line between upper and lower Prairie Creek (Figure 1). Constructed using 10 m x 1 m loops of eight gauge copper wire, antennas were placed in pairs approximately 20 m apart to allow for determining directional movement. In 2012/2013, the antennae collected data from August 1, 2012 until August 1, 2013 with the exception of days when the equipment was inoperable due to high flows (2 days in November, and 10 days in December) and technical problems (5 days in October, 3 in December, 1 in June and 1 in July). In 2013/14, the antennae began collecting data on 1 September 2013 and are still operating.

A second set of two antennas were placed at the bridge on Bald Hills Road, 500 m upstream of the mouth of Prairie Creek, for the purpose of monitoring spring migrants. In 2012/2013, these antennas were in operation from August 8, 2012 until August 1, 2013, although monitoring was suspended due to high flows for 7 days in November, 20 days in December, 2 days in March, 2 days in April, and for technical problems 2 days in September, 3 days in October, and 3 days in May. Spring migration to the ocean was also monitored by a five foot rotary screw trap installed at the mouth of Prairie Creek operated

Table 1. Number of juvenile coho salmon tagged with PIT tags in each stream reach of Prairie Creek during 2012 and 2013. Numbers in parentheses behind reach names are reaches designated in CDFW Mad-Redwood GRSs database.

Reach/Tributary	**Aug 2012**	**Sept 2012**	**Aug-Sept 2013**
Lower Prairie Creek (70A)	42	20	81
Lower Prairie Creek (70B)	39	20	89
Lost Man Creek (84, 85)	10	0	53
Upper Prairie Creek (71)	40	20	74
Upper Prairie Creek (72)	40	22	75
Upper Prairie Creek (73)	40	19	70
Upper Prairie Creek (74)	35	22	76
Streelow Creek (103, 104)	10	0	93
Boyes Creek (114)	10	0	
Brown Creek (119)	1	0	
Godwood Creek (111)	10	0	

from March 10, 2013 until August 13, 2013. All juvenile coho salmon collected at the trap were scanned for PIT tags using a RS601 series portable PIT tag reader (Allflex, DFW Airport, TX). Overwinter tag shed rate was obtained by calculating the percentage of fish observed with a clipped adipose fin but no PIT tag. In 2013/2014, this second set of antannae were moved to a site 100 m below Davidson Road and began operation on 1 September 2013.

Apparent Overwinter Survival Analysis

Apparent overwinter survival and recapture probabilities were estimated using the Cormack-Jolly-Seber model. The model is based on the following assumptions (Pollock and Alpizar-Jara 2005).

1. All animals in the population that are alive at the time of sampling have an equal chance of being captured.
2. All animals in the population have an equal chance of survival for a given time interval.
3. No errors are associated with tagging (i.e. no tag loss or misread tags).
4. Sampling is instantaneous.
5. If an animal emigrates from the study site, it does not return.

In the Cormack-Jolly-Seber model, a series of 0's and 1's are used to code the capture history of each animal. A "1" means the animal was sighted, and a "0" means the animal was not seen, either because the animal is dead or because it was alive but not resighted on that occasion. The first "1" in the series indicates when the animal was marked. For example, a capture history of 111 would represent an individual marked on occasion one and resighted on the subsequent two occasions, while 010 would mean the individual was marked on occasion two, and not resighted on occasion three. Survival rates between capture occasions are represented by φ, and encounter rates are represented by p. For example, φ_1 would be the survival rate between t_1 and t_2, the first and second capture occasions, while p_2 would be used to indicate recapture rate at t_2. 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 last two parameters, in this case φ_2 and p_3, can be represented by β_3 and are are not separately identifiable (Lebreton et al. 1992).

In this study, fish were either marked on the first capture occasion in August or the second occasion in September. Observations at the other three encounter occasions, the upstream antennas, confluence antennas, or rotary screw trap, represent whether or not the fish was encountered at these sites during the spring migration to the ocean. The beginning of the spring migration period was considered to be March 4, 2013 since this was the first day a fish migrating downstream was encountered at either set of antennas. The φ for the period between the September occasion and the upstream antennas represents overwinter survival rate for all fish, both those tagged above the upstream antennas and those tagged below. Although fish tagged in reaches A and B were not likely to be encountered at the upstream antennas during spring migration, they could still potentially be detected at the recapture points following the upstream antenna: the confluence antennas (fourth recapture occasion) and rotary screw trap (fifth recapture occasion), and thus considered to be overwinter survivors. For example, a fish with the encounter history 10001 (seen at the August and trap occasions only) is still considered to survive the overwinter period (September – upstream antenna) because it was encountered on at least one subsequent occasion after the upstream antennas. Furthermore, survival between the upstream and confluence antennas was nearly 100%, and survival between the confluence antennas and rotary screw trap was fixed to 100% due their close proximity (less than 500 m) and the need to estimate the confounded last recapture parameter. This means any overwinter mortality experienced by fish from reaches A and B likely occurred during the period between the upstream antennas and September, further confirming the decision to use this period to define overwinter survival. However, this approach significantly biases the recapture efficiency of the upstream antennas, since the Cormack-Jolly-Seber model assumes an equal probability of recapture for all individuals. To account for this, a grouping variable based on whether the fish was tagged above or below upstream antennas (tagged) was applied to the recapture model (described in greater detail below). This allowed the recapture efficiency of the upstream antennas to be calculated separately for fish tagged above and below the antennas.

The overwinter survival analysis was conducted by building models using the RMark package (Laake 2012) found in R (R Development Core Team 2011), and importing these models into Program MARK (Cooch and White 2011). Candidate models were assessed using Akaike's Information Criterion (AIC) calculated as follows (Anderson 2008):

$$AIC = -2\log_e(L(\hat{\theta})|x) + 2K$$

where $L(\hat{\theta})|x$ is a likelihood function given the data x that indicates lack of model fit and K is the number of estimable parameters. The likelihood function can by minimized by adding more parameters, however, adding more parameters is penalized by the "2K" term, thus this form of model selection balances predictive power with parsimony. For this study, the best model was considered to be the simplist model within approximately two AIC values (Δ_i) of the best fitting model. Anderson (2008) suggests using a variant of AIC, AICc, which includes an additional bias correction term ((2K(K+1))/(n-K-1)) that improves preformance with small sample sizes. The logit link function was used for all models, restricting survival and recapture rate estimates to the interval (0,1) (Lebreton et al. 1992).

Prior to conducting the full overwinter survival analysis, a preliminary assesment of PIT tag mortality was made by comparing the overwinter survival rate for the two tagging cohorts. Since PIT tag mortality was assumed to happen in the first month after tagging, the survival interval between September and spring for the August tagging cohort was considered to represent true overwinter mortality, uncontaminated with PIT tag mortality. In contrast, this time period for the September tagging group included both natural overwinter mortality and PIT tag mortality, meaning a lower survival rate for the September tagging group would indicate a tagging effect. This analysis, conducted in Program MARK, compared the model *φ(time) p(time)* with the model *φ(time + tag month) p(time)*, where *tag month* was a grouping variable that represented whether the fish was tagged in the August or September. The time period between the September capture occasion and the upstream antennas encounter was the only parameter with the group effect in the *φ(time + tag month) p(time)* model. Since the *φ(time + tag month)* *p(time)* model was 2.31 AIC values lower than the model without the group effect (Table 2), the tag month grouping variable was included in the overwinter survival analysis.

In addition to the *tag month* grouping variable, overwinter survival models in this study included combinations of the following covariates: fork length at time of tagging, maximum depth (deepest point in fall habitat unit), large woody debris present in the habitat, and some form of location, either as distance from the confluence of Prairie Creek or as a grouping variable that categorized fish based on whether they were tagged above or below the upstream antennas. Models with a length/locations interaction (length:distance or length:grouping variable, never both) were also included in the analysis. Large woody debris was quantified by using the median value for each length and diameter category to calculate volume of wood in m^3, and dividing this amount by the length (m) of the habitat unit. Temporal variation in survival was included in all models so that survival rate was allowed to vary by time interval. This was necessary since time intervals between capture occasions ranged from an entire season (φ_2), to several days (φ_3).

The recapture rate model used with all survival models included time, the location grouping variable *tagged* (above or below the upstream antennas) and the interaction of *tagged* with the p_2 and p_3 recapture occasions ($p(time + tagged + tagged{:}p_2 + tagged{:}p_3)$).

Table 2. Preliminary models used to assess PIT tag mortality. The *tag month* grouping variable represents whether a fish was tagged in August or September. In the model $\varphi(time + tag\ month)$, the grouping variable was applied to the overwinter survival period only. Since the model $\varphi(time + tag\ month)p(time)$ had a lower AICc value, the tag month grouping variable was included in the full overwinter survival analysis.

Survival model	AICc	Δ AICc	AICc Weights	K
$\varphi(time + tag\ month)p(time)$	1291.36	0.00	0.76	8
$\varphi(time)p(time)$	1293.67	2.31	0.24	7

The *time* parameter was included to allow recapture rate to vary by capture event since a different recapture method was used for each occasion. The interaction terms $tagged{:}p_2$ and $tagged{:}p_3$ were used since location at time of tagging would have an impact on the recapture rates p_2 and p_3 only. The recapture rate in September was affected by whether or not fish were tagged above the upstream antennas due to logistical difficulties with seining the deep water in lower Prairie Creek. Also, fish tagged above the upstream antennas (p_3) were far more likely to pass by this location when migrating in spring than fish marked below these antennas, which would have to swim upstream to be detected. The decision to use this model was confirmed by a preliminary comparison of models: the full time*tagged interactive model and the more parsimonious model with the tagged interaction applied to p_2 and p_3 only. This analysis revealed that the full model was always ranked lower than its counterpart that had fewer interactions, with an AICc value of less than 3 values higher. Also, the alternative models (*p(time + tagged)* and *p(time))* received less than 0.00001 model weight when compared to $p(time + tagged + tagged{:}p_2 + tagged{:}p_3)$, further confirming the usage of the the latter model for the survival analysis. Covariates used in overwinter survival analyses are summarized in Table 3. The parametric bootstrapping and the median ĉ goodness of fit tests in Program MARK were used to estimate the variance inflation factor, ĉ. Because these tests in Program MARK are unable to handle models containing individual covariates, the general starting model *φ(time)p(time)* was used to assess general goodness of fit. A ĉ greater than 3 indicates either there is excess variation in the data or the model does not accurately reflect the structure of the data (Lebreton et al. 1992).

<u>1+ Life History</u>

All scale samples were collected during the first round of tagging to minimize the amount of size at age variation in the age length key. Multiple scales from each fish were dry mounted on glass slides, viewed at a magnification of 63x using Nikon SMZ800 stereomicroscope (Nikon Corp., Tokyo, Japan), and photographed using an attached Spot Insight 2 megapixel digital camera and Spot software version 4.6 (Spot Imaging Solutions, Sterling Heights, Michigan). Twenty five percent of the scales were aged by a second person to assess the accuracy of age determination. A second individual was also consulted if the presence of annuli was in question. To minimize aging bias, scales were aged without prior knowledge of the fish’s characteristics (size or location at time of tagging).

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

Model Parameter	Parameter Description
φ (Time)	Survival parameter that allows survival rate to vary by time interval
φ (Length)	Individual covariate that describes the fork length of the fish at the time of tagging
φ (Max depth)	Individual covariate describing the deepest point in the habitat unit where the fish was tagged
φ (LWD)	Individual covariate that describes the volume of of large woody debris present in the habitat divided by the length of the habitat
φ (Distance)	Individual covariate that refers to the habitat unit where the fish was tagged in the fall. Indicates the habitat unit's distance from the confluence of Prairie Creek
φ (Tagged)	A grouping variable that refers to whether the fish was tagged above or below the upstream antennas. Models included *φ (Tagged)*, *φ (Distance)*, or neither *φ (Tagged)* or *φ (Distance)*, never both.
φ (Tag month)	A grouping variable that refers to the month the fish was tagged and assesses tagging effect.
p (Time)	Recapture parameter that allows recapture rate to vary by capture occation
p (Tagged)	A grouping variable that refers to whether the fish was tagged above or below the upstream antennas.
p (Tagged:p_2*)*	Recapture parameter that refers to the interaction between the the recapture occasion p_2 and the location grouping variable *tagged*
p (Tagged:p_3*)*	Recapture parameter that refers to the interaction between the the recapture occasion p_3 and the location grouping variable *tagged*

Smolt Abundances

The methods and materials used to quantify smolt abundances in YRS 2011 - 2013 were the same as those used in upper Redwood Creek (n = 14 years) and lower Redwood Creek (n = 10 years) (Sparkman, In progress$_a$). 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 – 2103, just upstream of the confluence of Prairie Creek with Redwood Creek.

<u>Trap Operations</u>

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. Weir panels were lined with smooth plywood to further increase stream flow into the cone. The weir panels also helped maintain good trapping efficiencies. 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, and 6) extensively using weir panels.

<u>Biometric Data Collection</u>

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 Redwood Creek (Sparkman, In progress$_a$). Technicians also scanned all 1+ and older fish for pit tags that were either tagged from the smolt traps in Redwood Creek, 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 (± 1 mm), and an Ohaus Scout ll digital scale (± 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 placed in a large plastic bin when weighing fish to prevent any influences from wind, and was calibrated every day prior to data collection. 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. 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, coastal cutthroat trout, 0+ coho salmon, and 1+ coho salmon using mark-recapture methods described by Carlson et al. (1998). Population estimation methods in YRS 2011 - 2013 were identical to those used in upper and lower

Redwood Creek (Sparkman, In progress$_a$). 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 three 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 an Optic StowAway® Temp data logger (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. The probe was placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight. The probe recorded stream temperatures (^{o}C) every 30 minutes, and recorded 6,192 measurements in YR 2011, 7,776 in YR 2012, and 7,440 in YR 2013. 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 YRS 2011 - 2013 were the same as those used for smolt trapping in upper and lower Redwood Creek (Sparkman, In progress$_a$). 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, 0+ trout, and 0+ pink salmon) 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 three years of study. The tests are considered very preliminary, and more data will be required to detect the 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 0.10 for statistical analyses.

RESULTS

Redd Surveys

In 2011/2012, average time between surveys on 15 individual reaches of the Prairie Creek watershed was 17 days (range 15-22 days) (Table 4). The number of surveys completed on these reaches in 2011/2012 averaged 8 (range 5-9). In 2012/2013, average time between surveys on these same reaches of Prairie Creek was 12 days (range 11-14 days) (Table 4). The number of surveys completed on these reaches in 2012/2013 averaged 11 (range 9-13).

Table 4. Mean number of days between survey occasions and total number of surveys (N) completed within stream reaches of the Prairie Creek watershed during the 2011/2012 and 2012/2013 spawning seasons.

		2011/2012		2012/2013	
Location code	Stream name	Mean	N	Mean	N
70	Prairie Creek	17	9	11	12
71	Prairie Creek	17	7	12	12
72	Prairie Creek	19	6	12	12
73	Prairie Creek	17	6	11	13
74	Prairie Creek	18	5	11	11
81	Little Lost Man Creek	15	9	12	11
84	Lost Man Creek	16	7	13	11
85	Lost Man Creek	21	5	13	11
88	Larry Dam Creek	16	8	12	10
91	Lost Man Trib-U	16	8	12	10
103	Streelow Creek	16	8	12	11
108	May Creek	22	9	14	9
111	Godwood Creek	15	9	12	11
114	Boyes Creek	15	9	12	11
119	Browns Creek	16	8	13	9

In, 2011/2012, a total of 180 live coho salmon, 469 live Chinook salmon, 28 live steelhead and 87 unidentified live fish were observed over the entire survey period in the entire Redwood Creek watershed (Table 5). In, 2012/2013, a total of 146 live coho salmon, 884 live Chinook salmon, 36 live steelhead and 59 unidentified live fish were observed over the entire survey period in the entire Redwood Creek watershed (Table 6).

The live fish counts do not represent actual population abundances because some fish could have been counted multiple times while surveying various reaches. During both spawning seasons, more than 90% of the live coho salmon were observed in Prairie Creek.

Table 5. Counts of live fish observed during the 2011/2102 spawning season. Counts are for the entire Redwood Creek sampling frame for surveyable reaches, and for a given week may not represent all 15 reaches that could be surveyed*.

Week beginning	Chinook	Coho	Steelhead	Unidentified	Total
10/31/11	5	0	0	0	5
11/7/11	0	0	0	0	0
11/14/11	30	1	0	1	32
11/21/11	11	0	0	0	11
11/28/11	35	0	0	4	39
12/5/11	145	0	0	1	146
12/12/11	9	0	0	0	9
12/19/11	129	8	1	64	202
12/26/11	9	0	0	0	9
1/2/12	71	34	1	5	111
1/9/12	15	17	0	4	36
1/16/12	0	0	0	0	0
1/23/12	7	77	6	6	96
1/30/12	3	37	8	2	50
2/6/12	0	4	3	0	7
2/13/12	0	0	0	0	0
2/20/12	0	1	7	0	8
2/27/12	0	1	0	0	1
3/5/12	0	0	1	0	1
3/12/12	0	0	0	0	0
3/19/12	0	0	1	0	1
Total	469	180	28	87	764

* Although live fish observation data represent the entire Redwood Creek sampling frame, almost all coho salmon were observed in Prairie Creek (S. Ricker, CDFW, personal communication).

Table 6. Counts of live fish observed during the 2012/2103 spawning season. Counts are for the entire Redwood Creek sampling frame for surveyable reaches, and for a given week may not represent all 15 reaches that could be surveyed *.

Week beginning	Chinook	Coho	Steelhead	Unidentified	Total
11/5/12	150	0	0	1	151
11/12/12	53	0	0	0	53
11/19/12	24	1	0	4	29
11/26/12	335	13	0	4	352
12/3/12	147	7	0	6	160
12/10/12	65	3	0	1	69
12/17/12	75	18	4	3	100
12/24/12	15	34	3	7	59
12/31/12	12	18	0	6	36
1/7/13	8	30	0	4	42
1/14/13	0	2	0	3	5
1/21/13	0	12	0	5	17
1/28/13	0	4	0	1	5
2/4/13	0	4	2	3	9
2/11/13	0	0	4	4	8
2/18/13	0	0	1	6	7
2/25/13	0	0	4	1	5
3/4/13	0	0	0	0	0
3/11/13	0	0	11	0	11
3/18/13	0	0	7	0	7
3/25/13	0	0	0	0	0
Total	884	146	36	59	1125

* Although live fish observation data represent the entire Redwood Creek sampling frame, almost all coho salmon were observed in Prairie Creek (S. Ricker, CDFW, personal communication).

The estimated number of coho salmon redds constructed in the Prairie Creek watershed during 2011/2012 and 2012/2013 was 379 and 363, respectively (Table 7). Number of redds constructed by Chinook salmon were relatively low in 2011/2012 but similar to coho salmon in 2012/2013. Fewer redds were attributed to steelhead during both years, however, the survey period did not cover the entire steelhead spawning period.

Table 7. Estimated total number of redds by species. Components of estimated variance are broken down into that due to: estimation of the number of redds within the reach, and estimation of redds by expanding the sample reaches to the entire frame (sample error).

	Chinook		Coho		Steelhead*	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Est. Number	105	305	379	363	11	67
SE	3.89	7.84	5.82	6.01	0.00	1.76
95% C.I.	97-113	290-321	367-390	351-375	11-11	63-70

* Note: Steelhead redd counts do not cover entire spawning season.

Summer Juvenile Distribution and Marking

Apparent Overwinter Survival of Juveniles

During spring migration to sea in 2012/2013, 66, 97, and 26 unique fish were encountered at the upstream antennas, confluence antennas, and the screw trap, respectively (Table 8). The top ranked overwinter survival models (lowest AICc) out of the candidate set were *φ(time + max depth + length * distance)*, *φ(time + length * distance)*, *φ(time + tag month + length * distance)*, and *φ(time + tag month + length * distance)*, with AICc weights of 0.24, 0.18, 0.17, and 0.14, respectively (Table 9). However, the best model was considered to be (*φ(time + length * distance)*) and excluded the *max depth*, *tag month*, and *LWD* parameters. The AICc values for the model *φ(time + length * distance)* and the corresponding models with these parameters were very similar (approximately 2 AICc values in difference), with (*φ(time + length * distance)* being the more parsimonious model. Furthermore, in the top models that included *max depth*, *tag month*, *LWD*, the confidence intervals of the beta estimates of these parameters bounded zero, implying there was not a significant *max depth* or *LWD* effect at the nominal α = 0.05 level. The parameter *length* (fork length at the time of tagging) was present in every top ranked model, and corresponding models without this parameter had less than 0.00001 AICc weight, indicating the fork length of the fish at the time of tagging was most likely an important predictor of survival through winter. Since the top model with the grouping variable *tagged* (*φ(time + max depth + length + tagged)* had an AICc weight of only 0.01 *distance* was most likely a better parameter for describing the relationship between apparent overwinter survival and location at the time of tagging.

Table 8. M-array table summarizing the number of fish marked and recaptured at each occasion. A total of 400 juvenile coho salmon were marked in Prairie Creek, California over two tagging events (August and September 2012). Fish could then potentially be encountered at the upstream antennas, confluence antennas, and the rotary screw trap at the confluence of Prairie Creek. Recapture occasions are: N = number released, 2nd = resighted on 2nd occasion in September, 3rd – resighted on 3rd occasion at upstream antenna, 4th = resighted on 4th occasion at confluence antenna, 5th = resighted on 5th occasion at rotary screw trap, Total = total number resighted for the first time, and Never = never resighted.

			Spring Recapture Occasion					
Releases	Number (R_i)		2nd	3rd	4th	5th	Total (r_i)	Never ($R_i - r_i$)
August (initial [1])	**277**		140	16	16	1	**173**	**104**
September	**263**							
		[11]	140	31	24	2	57	83
		[01]	123	19	16	0	35	88
			263				**92**	**171**
Upstream antennas	**66**							
			[101]	16	10	1	11	5
			[111]	31	16	4	20	11
			[011]	19	15	1	16	3
				66			**47**	**19**
Confluence antennas	**97**							
				[1001]	16	3	3	13
				[1101]	24	4	4	20
				[1011]	10	2	2	8
				[1111]	16	2	2	14
				[0101]	16	4	4	12
				[0111]	15	2	2	13
					97		**17**	**80**

Table 9.AICc table for the overwinter survival analysis. The model for recapture rate (*p*) for all models is *p(time + tagged + tagged:*p_2 *+ tagged:*p_3*)*.

Survival model	AICc	Δ AICc	AICc Weights	K
*φ (~time + max depth + length*distance)*	1222.95	0.00	0.23900	13
*φ (~time + length*distance)*	1223.55	0.60	0.17700	12
*φ (~time + tag mo. + length*distance)*	1223.62	0.67	0.17100	13
*φ (~time + tag mo. + max depth + length*distance)*	1224.00	1.05	0.14100	14
*φ (~time + LWD + max depth + length*distance)*	1224.96	2.01	0.08720	14
*φ (~time + LWD + length*distance)*	1225.55	2.60	0.06510	13
*φ (~time + LWD + tag mo. + length*distance)*	1225.64	2.69	0.06210	14
φ (~time + max depth + length + tagged)	1228.74	5.79	0.01320	12
*φ (~time + max depth + length*tagged)*	1229.84	6.89	0.00762	13
φ (~time + max depth + length + distance)	1230.05	7.10	0.00685	12
φ (~time + length + tagged)	1230.52	7.57	0.00543	11
φ (~time + length + distance)	1230.57	7.62	0.00530	11
φ (~time + LWD + max depth + length + tagged)	1230.62	7.67	0.00516	13
*φ (~time + length*tagged)*	1231.42	8.47	0.00345	12
*φ (~time + LWD + max depth + length*tagged)*	1231.73	8.78	0.00296	14
φ (~time + LWD + max depth + length + distance)	1232.08	9.13	0.00249	13
φ (~time + LWD + length + tagged)	1232.35	9.40	0.00217	12
φ (~time + LWD + length + distance)	1232.58	9.63	0.00194	12
*φ (~time + LWD + length*tagged)*	1233.29	10.34	0.00136	13
φ (~time + length)	1237.16	14.21	0.00020	10
φ (~time + max depth + length)	1237.89	14.94	0.00014	11
φ (~time + LWD + length)	1239.08	16.13	0.00007	11
φ (~time + LWD + max depth + length)	1239.81	16.86	0.00005	12
φ (~time + max depth + tagged)	1247.17	24.22	0.00000	11
φ (~time + LWD + tagged)	1248.51	25.56	0.00000	11
φ (~time + max depth + distance)	1248.62	25.67	0.00000	11
φ (~time + LWD + max depth + tagged)	1249.07	26.12	0.00000	12
φ (~time + LWD + distance)	1249.45	26.50	0.00000	11
φ (~time + LWD + max depth + distance)	1250.61	27.66	0.00000	12
φ (~time + max depth)	1250.66	27.71	0.00000	10

The top seven models (combined 0.94 model weight) included the *length* and *distance* interaction, and the model *φ(time + length + distance)* had approximately 33 times less weight than its corresponding equivalent with the *length* and *distance* interaction. These results indicated that overall survival increased with length, but this effect was more pronounced for fish higher in the watershed than fish near the confluence (Figure 3). Larger fish tagged at the maximum (20,350 m) and mean (7,150 m) distances from the confluence had the highest survival, while at the minimum distance from confluence (660 m), smaller fish appeared to have better survival. However, since the Cormack-Jolly-Seber model cannot distinguish mortalities from emigration, the survival of larger fish near the confluence may be artificially low due to early emigration. To test for any potential confounding issues involving fork length and location (for example, if fish in downstream habitats were larger), a linear regression was used to examine the average length of fish throughout the watershed. The general linear model *length ~ distance*, produced a value of -0.0002555 for the *distance* coefficient (SE = 0.0001063), suggesting that any confounding effect was negligible.

The apparent overwinter survival estimate for the best model (*φ(time + length * distance)*) was 0.39 (SE = 0.04) (Table 10). This value may be multiplied by 100 to estimate the percentage of fish that survived the winter. Of the 30 fish encountered at the trap, 4 had shed their tags. Since these fish could not be uniquely identified, they were excluded from the survival analysis, thus true apparent survival may be 13.3% higher. The apparent overwinter survival estimate also does not include fish that may have migrated from Prairie Creek earlier than March 4th (including the three fish that were detected at the confluence antennas in fall and never encountered again), or fish that would be spending a second winter in Prairie Creek as 1+ fish (at least one fish was encountered in September 2013), hence the term “apparent” survival.

The parametric bootstrap test (100 simulations) in Program Mark was was used to estimate two values of ĉ for the general model *φ(time)p(time)*. For the first approach, the deviance of the data was divided by the deviance of the simulated data, producing a ĉ value of 0.89. The second approach consisted of dividing the observed ĉ (model deviance/deviance degrees of freedom) by the mean ĉ from the bootstrap simulations. This method estimated ĉ to be 0.86. The median ĉ test in Program MARK also produced a ĉ of less than 1 (0.88, SE = 0.06), suggesting the data was not overdispersed.

Overwinter Movement

Prior to the spring migration (March 4th), detections at the upstream antennas were limited to 10 encounters of eight unique fish, three from the reach immediately upstream from the upper antennas (reach 1), three from the reach immediately downstream of the upper antennas (reach B), one from a habitat unit in the tributary Streelow Creek (less than 300 m from the upper antennas), and one fish tagged close to the confluence antennas. The first detection at the upstream antennas occurred on October 16, 2012 and

Table 10. Survival and recapture rate estimates for the model, *φ(time + length * distance), p(time + tagged + tagged:p_2 + tagged:p_3)*. Survival between the confluence antennas and rotary screw trap (φ_4) was fixed to 1 since survival between these encounter occasions was assumed to be 100%. Since Program MARK had difficulty estimating parameters that are close to 1, survival for the time period between the upstream and confluence antennas (φ_3), probably close to 100%, is not listed.

Parameter		Estimate	Standard Error
φ_1	Survival rate between August and September tagging occasions	0.91	0.06
φ_2	Survival rate between September and upstream antennas (overwinter survival)	0.39	0.04
φ_4	Survival rate between the confluence antennas and the rotary screw trap.	1.0*	-
p_2(above)	Recapture rate during the September tagging occasion for fish tagged above the upstream antennas	0.63	0.05
p_3(above)	Recapture rate at the upstream antennas for fish tagged above the upstream antennas	0.68	0.06
p_4(above)	Recapture rate at the confluence antennas for fish tagged above the upstream antennas	0.69	0.05
p_5(above)	Recapture rate at the rotary screw trap for fish tagged above the upstream antennas	0.21	0.04
p_2(below)	Recapture rate during the September tagging occasion for fish tagged below the upstream antennas	0.44	0.06
p_3(below)	Recapture rate at the upstream antennas for fish tagged below the upstream antennas	0.08	0.03
p_4(below)	Recapture rate at the confluence antennas for fish tagged below the upstream antennas	0.51	0.07
p_5(below)	Recapture rate at the rotary crew trap for fish tagged below the upstream antennas	0.11	0.03

**Fixed to 1*

half of the unique fish detected before spring migration were encountered between December 26, 2012 and January 6, 2013. At the confluence antennas, a total of three fish were encountered before spring migration; one during August, one during October, and one during November. The first two fish were both encountered at the upstream loop in the confluence antenna set, then immediately detected at the downstream loop, implying the fish was swimming downstream. Since neither fish was encountered again, they may have left the system.

Because the antennas were inoperable during high flows, the sparse detection history may not accurately reflect the amount of winter movement. During these periods, some fish may have migrated into Lower Prairie or left Prairie Creek entirely. To assess the possibility of missed movement from upper Prairie Creek during high flows, the 66 spring detections at the upstream pair of antennas were used to construct a three encounter recapture history. All fish were “marked” on the first occasion (“1” for all fish in the encounter history), and the other two occasions represent which antennas encountered the fish. Since only fish that were encountered in the spring were used in this analysis, survival was set to 1 for both the interval between the initial marking and the first antenna and the interval between the antennas. For the 66 spring detections, Program MARK estimated the efficiency of the antennas to be 0.65 and 0.79, meaning the chance of being detected by at least one antenna was 1-(1-0.65)*(1-0.79), or 0.93. The top survival model (φ(time + length * distance), (p(time + tagged + tagged:p2 + tagged:p3)), estimated the spring antenna efficiency for fish tagged above the upstream antennas to be much lower (0.68). Though not definitive, these results indicate that some portion of the fish tagged in upper Prairie Creek moved into lower Prairie Creek before the spring migration period, making the spring antenna efficiency seem artificially low.

<u>Overwinter Growth</u>

Overwinter growth was analyzed using the 26 fish recaptured at the rotary screw trap that had retained their PIT tags. Specific growth rates were calculated using the following formulas (Busacker et al. 1990):

$$G\ (\text{length}) = ((\log_e FL2 - \log_e FL1)/(T2 - T1)) \times 100$$
$$G\ (\text{weight}) = ((\log_e WT2 - \log_e WT1)/(T2 - T1)) \times 100$$

where G is overwinter growth in percentage per day, FL1 and WT1 represents initial fork length and weight, FL2 and WT2 represents spring fork length and weight, T1 represents the date of the initial tagging event and T2 represents the date the fish was recaptured at the trap. The effects of fall fork length and tagging location on growth in length were analyzed using the following general linear model in R: growth = fork length + distance + fork length:distance. A normal probability plot of the residuals (Q-Q plot) and a residuals versus fitted plot revealed no departures from normality or violations of the assumption of homogeneity of variance. The full model (F statistic = 33.33; df = 3,22; p = 2.321 x 10-08; adjusted R2 = 0.795) and the fork length effect (p = 8.31 x 10-06) were significant, and the distance and fork length:distance interaction were not (p = 0.222 and p = 0.248, respectively). Fish that were smaller at the time of tagging experienced a greater increase in length (Figure 2). For fish captured at the trap, mean fall fork length in 2012 was 77.0 mm (SD = 12.5 mm) and mean spring fork length in 2013 was 108.5 mm, with a average daily growth rate of 0.13%/day (SD = 0.05%). Using the specific growth rate calculation for weight (second expression), growth rate in weight in 2012/2013 was estimated at 0.35%/day (SD = 0.16%), ranging from 0.10%/day to 0.73%/day. Juveniles recaptured at the rotary screw trap in 2013 had a mean fall weight of 5.9 g and mean spring weight of 13.5 g.

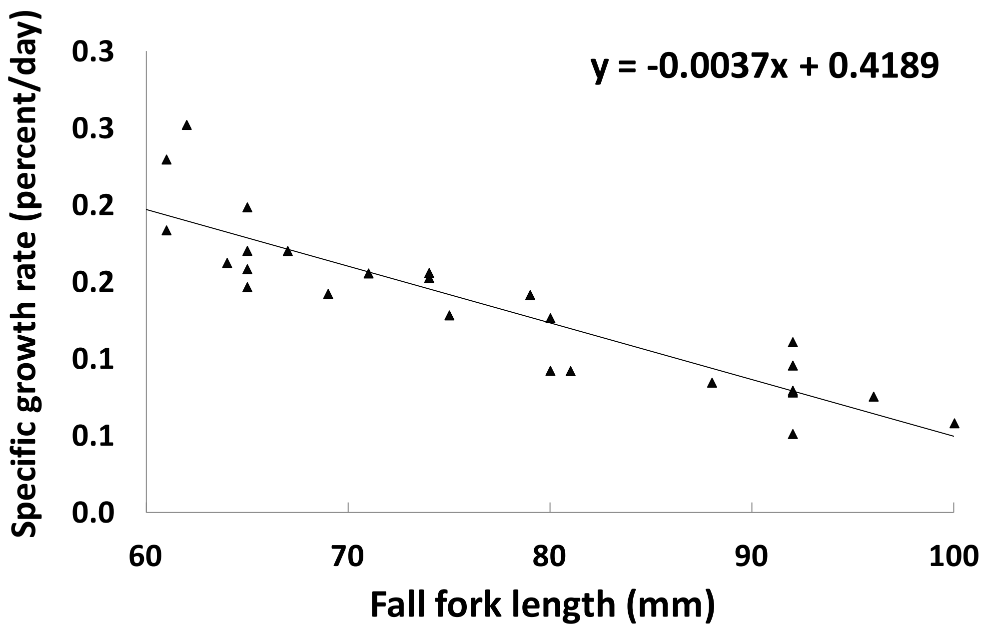

Figure 2. Effect of fall fork length on specific growth rates of juvenile coho salmon over winter (percentage increase in length per day).

1+ Life History

In 2012, an age length key was constructed using 132 scales samples and lengths from 314 randomly measured fish from throughout the watershed (5 per habitat unit, unless less than five were found in the unit) (Table 11). Scales samples were only collected from fish that were 60 mm and greater since smaller fish were assumed to be age 0. Based on the random population sample, mean fish size was estimated at 57.7 mm (SD = 10.1 mm). The average size of 1+ (two year freshwater resident) juveniles in the scale sample analysis was 86.2 (SD = 6.5 mm), and the age length key estimated the percentage of fish exhibiting a 1+ life history to be 1.4%. There was some overlap in the age classes, with the largest age 0 fish being 82 mm and the smallest age 1+ fish being 74 mm (Figure 3). A second person that aged 25% of the scale samples was in agreement with the primary individual aging the scales 90.9% of the time. In 2013, average fork length of 606 fish PIT tagged was 74.2 mm (SD 10.6 mm) and average weight was 5.3 g (SD = 2.6 g). Fish not tagged in 2013 had an average fork length of 54.7 mm (SD = 6.1 mm) and weight of 2.0 g (SD = 0.8).

Table 11. Size (fork length) distribution of 317 juvenile coho salmon from the Prairie Creek watershed. Data for 2012 include tagged fish and a random sample of fish. Data for 2013 include tagged fish and fish not tagged.

Size	2012 Tagged	2012 Random	2013 Tagged	2013 Not tagged
38	0	1	0	0
40	0	1	0	1
42	0	6	0	2
44	0	18	0	4
46	0	19	0	7
48	0	29	0	13
50	0	19	0	19
52	0	26	0	18
54	0	22	0	21
56	0	24	0	16
58	0	40	1	22
60	36	22	32	13
62	50	14	38	8
64	49	12	62	0
66	40	13	50	2
68	48	15	64	0
70	29	8	51	1
72	17	3	49	0
74	13	2	44	1
76	18	3	24	0
78	13	3	34	0
80	20	5	24	0
82	9	2	27	0
84	9	1	12	0
86	8	0	11	0
88	12	2	12	1
90	7	1	15	0
92	10	3	13	0
94	2	0	14	0
96	4	0	3	0
98	0	0	7	0
100	3	0	7	0
102	0	0	6	0
104	1	0	4	0
106	0	0	0	0
108	0	0	2	0
Total	398	314	606	149

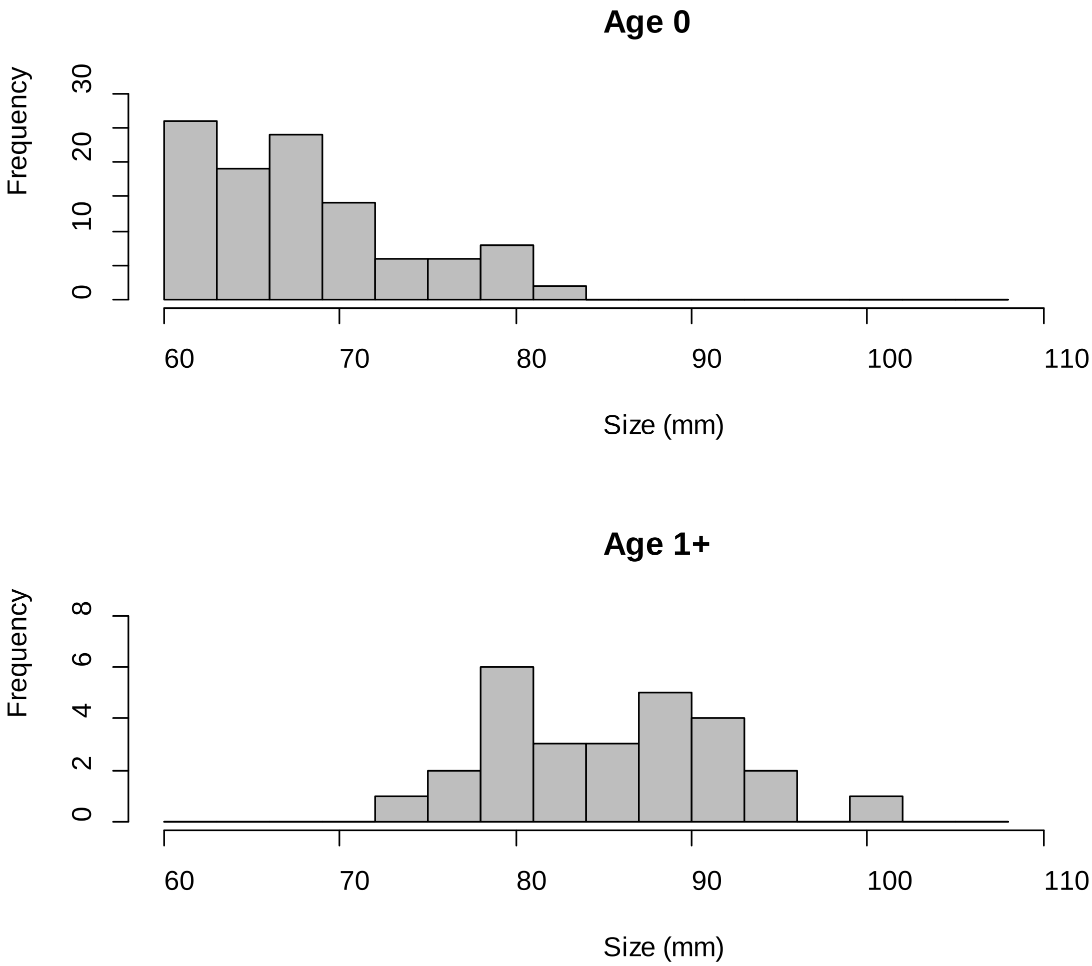

Figure 3. Size (FL) distribution of age 1+ juveniles and age 0 juveniles greater than 60 mm. Distributions are based on 132 scales samples collected throughout the Prairie Creek watershed in 2012.

Smolt Abundances

Smolt Trap Deployment

The rotary screw trap was first deployed on April 11th in YR 2011, February 25th in YR 2012, and March 10th in YR 2013 (Table 12). The trapping rate in YRS 2011 – 2013 ranged from 86 – 99%, and averaged 94% (Table 12).

Table 12. Period of smolt trap deployment in YRS 2011 - 2013, Prairie Creek, Humboldt County, CA.

Study Year	Period of Trap Deployment	Total Trapping Days	No. of Missed Days	Trapping Rate (%)
2011	4/11 – 8/19	130	4	96.9
2012*	2/25 – 8/25	162	22	86.4
2013	3/10 – 8/13	156	1	99.4
Average		149	9	94.2

* Above average rainfall and streamflow in February/early March.

Species Captured

Juvenile Salmonids

Species captured in YRS 2011 - 2013 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile coho salmon (*O. kisutch*), juvenile steelhead trout (*O. mykiss*), juvenile coastal cutthroat trout (*O. clarki clarki*), adult coastal cutthroat trout (*O. clarki clarki*), and juvenile pink salmon (*O. gorbuscha*). 0+ Chinook salmon were the most numerous migrant captured each study year (Table 13). Total trap catches ranged from 13,931 – 61,138 individuals per year, and averaged 30,038 (Table 1).

Table 13. Rotary screw trap catches in YRS 2011 - 2013, Prairie Creek, Humboldt County, CA.

Age/Species	Study Year 2011	2012	2013	Avg.	SD	SEM
0+ Chinook Salmon	7,743	8,225	41,379	19,116	19,282	11,132
1+ Chinook Salmon	2	5	1	3	2	1
0+ Trout*	1,228	1,481	4,552	2,420	1,850	1,068
1+ Steelhead Trout	778	505	1,820	1,034	694	401
2+ Steelhead Trout	283	95	743	374	333	192
0+ Coho Salmon	223	1,430	384	679	655	378
1+ Coho Salmon	2,455	2,621	10,447	5,174	4,567	2,637
Cutthroat Trout	1,198	668	1,793	1,220	563	325
Adult Cutthroat Trout	21	8	18	16	7	4
0+ Pink Salmon	0	8	1	3	4	3
TOTAL:	13,931	15,046	61,138	30,038	26,939	15,553

* Includes steelhead trout and cutthroat trout.

Miscellaneous Species

The smolt trap caught numerous miscellaneous species in YRS 2011 - 2013, 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 specie (Table 14). Adult and juvenile captures occurred for prickly sculpin, coast range sculpin, sucker, 3-Spined Stickleback, and Pacific Lamprey. Many gravid sculpins (both species) were also captured.

Table 14. Miscellaneous species captured by the smolt trap in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

Species Captured	YR 2011	YR 2012	YR 2013
Prickly Sculpin	1,693	668	2,403
Coast Range Sculpin	1,498	977	4,280
Sucker	120	58	540
3-Spined Stickleback	1,011	398	3,565
Bullhead	0	0	0
Adult Pac. Lamprey	34	23	25
Juvenile Lamprey*	1,335	276	263
Brook Lamprey	73	54	18
Pac. Giant Salamander	1	1	7
Rough Skinned Newt	1	2	0
Red-Legged Frog	1	0	2
Yellow-Legged Frog	1	0	0
Tailed Frog**	0	8	3
Western Toad	0	4	2
Crawfish	0	1	5
Bull Frog	0	0	0

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

Days Missed Trapping

We missed four days of trapping in YR 2011, 22 days in YR 2012, and one day in YR 2013. The estimate of missed days trapping for catches ranged from 0 – 94 individuals in YR 2011, 0 – 192 in YR 2011, and 0 – 64 in YR 2013 (Table 15). The estimate of fish missed (during missed days trapping) for population abundances ranged from 13 – 342 in YR 2011, 49 – 1,156 in YR 2012, and 7 – 576 in YR 2013 (Table 15). On a percentage basis where numbers are compared to the unadjusted total catch or population estimate per species at age, the estimate for missed days trapping for catches ranged from 0 – 13% in YR 2011, 0 – 22% in YR 2012, and 0 – 4% in YR 2013. The estimate for missed days trapping for population abundances ranged from 0.2% – 12% in YR 2011, 0.8 – 20% in YR 2012, and 0.2 – 2% in YR 2013 (Table 15).

Table 15. The estimated catch and expansion (population level) of juvenile anadromous salmonids considered to have been missed due to trap not being deployed during the trapping periods in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

	YR 2011		YR 2012		YR 2013	
Age/Sp.	Catch	Population	Catch	Population	Catch	Population
0+ KS	94	342	82	268	64	576
1+ KS	0	N/A	0	N/A	0	N/A
0+ TR	5	N/A	4	N/A	0	N/A
1+SH	10	50	44	327	2	7
2+SH	4	13	15	49	1	7
0+CO	25	90	59	482	13	165
1+CO	6	17	192	1,156	29	209
CT	4	16	119	700	6	21
0+ PNK	0	N/A	0	N/A	0	N/A

* Age/species definitions are given in methods section of FL/Wt's. **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 efficiencies by week and seasonal trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, 1+ coho salmon and cutthroat trout in YRS 2011 – 2013 fell within the range of 11 to 55% (Table 16).

Table 16. Average weekly and season trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, 1+ coho salmon, and cutthroat trout in YRS 2011 - 2013, Prairie Creek, Humboldt County, CA.

	Trapping Efficiencies (Percentage)					
	YR 2011		YR 2012**		YR 2013	
Age/Spp.*	Avg Wkly	Seasonal	Avg Wkly	Seasonal	Avg Wkly	Seasonal
0+ KS	50.3	54.5	36.1	40.0	49.1	54.3
1+ SH	22.6	19.6	14.3	13.9	20.9	25.4
2+ SH	22.2	20.3	10.7	10.9	19.4	17.6
0+ CO	28.6	25.3	22.1	23.2	30.0	16.3
1+ CO	37.0	32.9	16.4	12.7	47.6	51.6
CT	34.9	24.3	17.5	10.0	40.8	40.0

* Age/species definitions are given in methods section of FL/Wt's. ** Denotes relatively higher stream discharge.

Population Estimates

0+ Chinook Salmon

The population abundance (or production) of 0+ Chinook salmon emigrating past the trap in lower Prairie Creek equaled 15,148 (± 6.6%) in YR 2011, 32,840 (± 14.7%) in YR 2012, and 96,817 (± 8.2%) in YR 2013 (Figure 4). Average population abundance over YRS 2011 – 2013 equaled 48,268 (SD = 42,965; SEM = 24,806).

Correlation of time (study year) on yearly population abundances indicated a non-significant, positive relationship (n = 3, p = 0.20, r = 0.95, power = 0.19) (Figure 4).

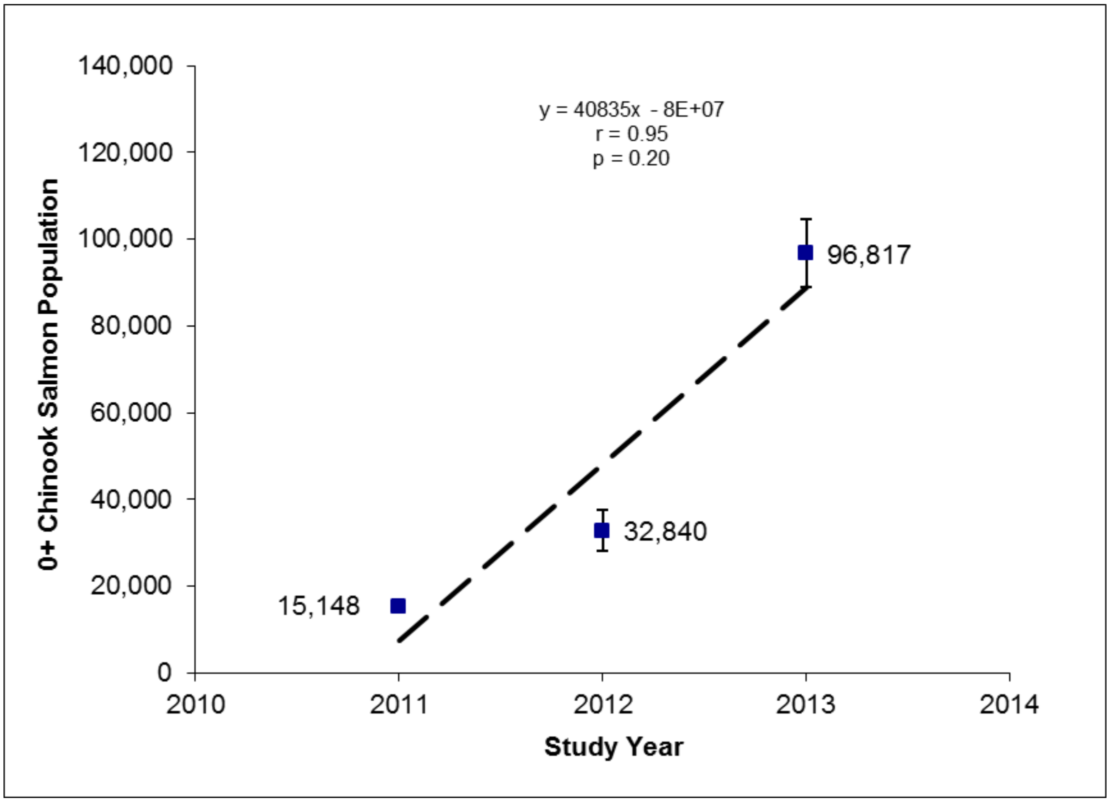

Figure 4. 0+ Chinook Salmon population abundance estimates (error bars are 95% confidence interval) in YRS 2011 – 2013. Lack of 95% CI for YR 2011 is due to scale of "Y" axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance) with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

The pattern in monthly population abundances varied over study years (Figure 5). The most important month for emigration was June (38% of total) in YR 2011, May (66% of total) in YR 2012, and May (44% of total) in YR 2013 (Figure 5). The two most important months for 0+ Chinook salmon population emigration were May/June (68% of total) in YR 2011, May/June (88% of total) in YR 2012, and April/May (76%) in YR 2013 (Figure 5).

The peaks in weekly population emigration in YRS 2011 – 2013 occurred in June (YR 2011), May (YR 2012), and late May/early June (YR 2013) (Table 17). The percentage of fry during peak migration equaled 0% in YR 2011, 93% in YR 2012, and 54% in YR 2013.

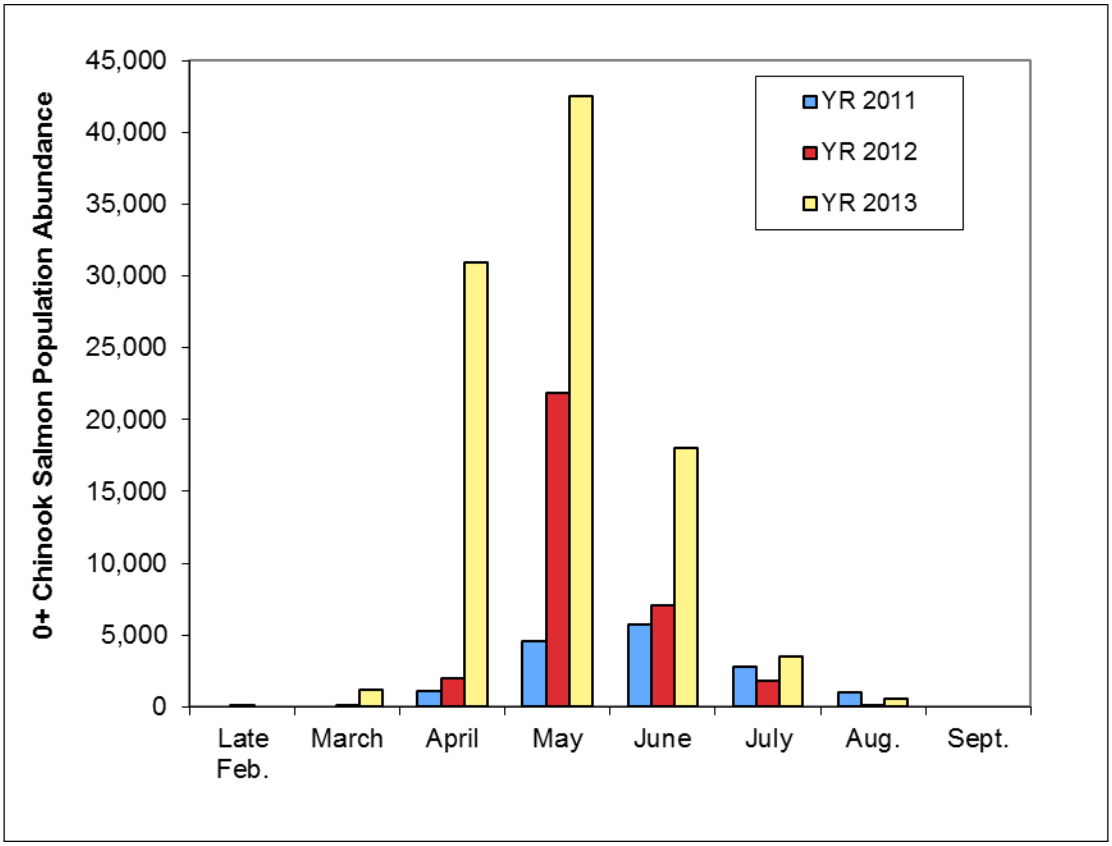

Figure 5. 0+ Chinook salmon population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

Table 17. 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)

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 18). The percentage of fry in the Chinook salmon population in YRS 2011 – 2013 ranged from 8 – 68%. Fry comprised 46% of the average population abundance over YRS 2011 – 2013, and the total production of fry equaled 46% of total Chinook salmon abundance (Table 18).

Table 18. Yearly, average, and total production of 0+ Chinook salmon partitioned into fry and fingerling categories (expressed as a percentage of total abundance in parentheses), Prairie Creek, Humboldt County, CA.

	0+ Chinook Salmon Production as:	
Study Year	Fry (FL < 45mm)	Fingerling (FL > 44 mm)
2011	1,157 (8)	13,991 (92)
2012	22,469 (68)	10,371 (32)
2013	43,607 (45)	53,210 (55)
Avg.	22,441 (46)	25,857 (54)
Total:	67,233 (46)	77,572 (54)

The migration of Chinook salmon fry and fingerlings showed temporal overlap (Figure 6). On average, fry migration peaked in April and May, and fingerling migration peaked in May and June (Figure 6). On an annual basis, fry migration peaked 4/30 – 5/06 (n = 408) in YR 2011, 5/07 – 5/13 (n = 9,339) in YR 2012, and 4/30 – 5/06 (n = 14,532) in YR 2013. Fry migration ended in June in YR 2011, and July in YRS 2012 - 2013. Fingerling migration peaked 6/18 – 6/24 (n = 1,608) in YR 2011, 6/04 – 6/10 (n = 2,378) in YR 2012, and 4/30 – 5/06 (n = 12,237) in YR 2013.

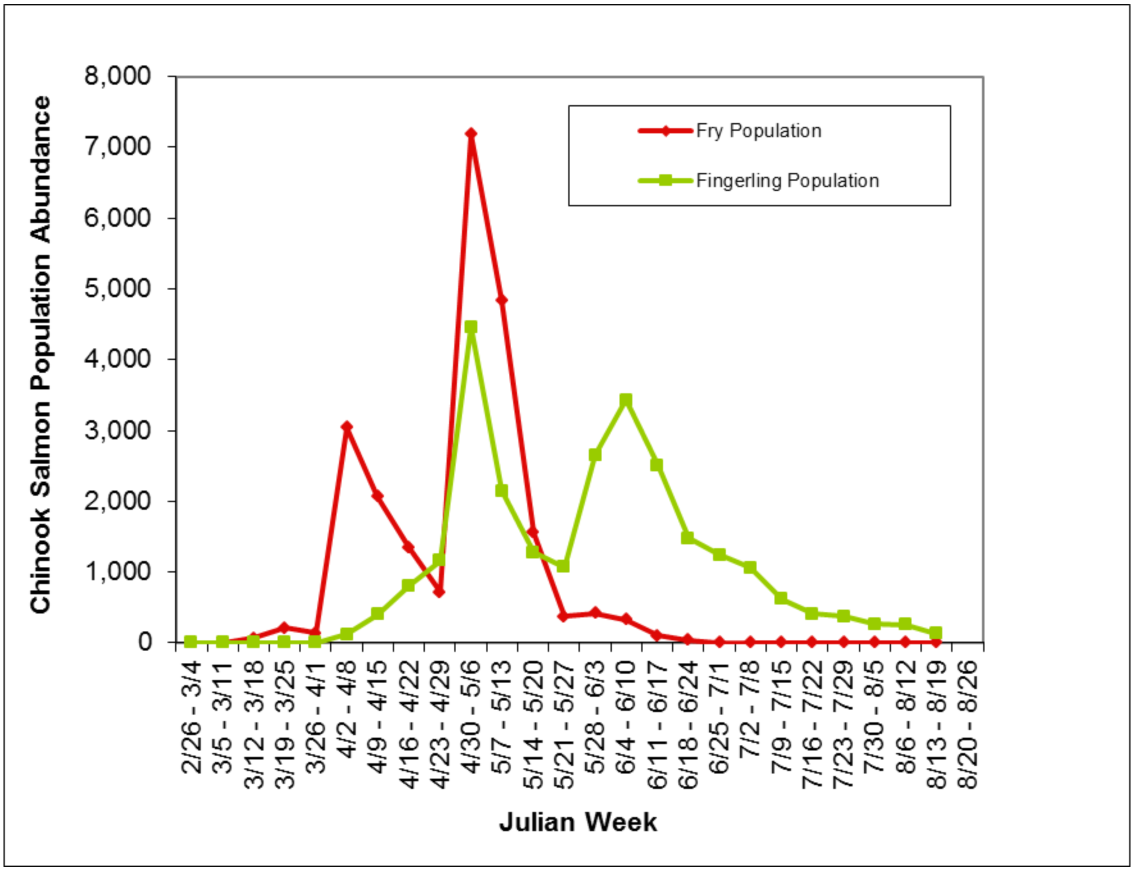

Figure 6. Average weekly Chinook salmon fry and fingerling migration over three study years, Prairie Creek, Humboldt County, CA.

1+ Steelhead trout

The population abundance (or production) of 1+ steelhead trout emigrating past the trap in lower Prairie Creek equaled 3,756 (± 21.2%) in YR 2011, 2,964 (± 23.0%) in YR 2012, and 6,735 (± 11.8%) in YR 2013 (Figure 7). Average population abundance over YRS 2011 – 2013 equaled 4,485 (SD = 1,988; SEM = 1,148).

Correlation of time (study year) on yearly population abundances indicated a non-significant, positive relationship (n = 3, p = 0.46, r = 0.75, power = 0.08) (Figure 7).

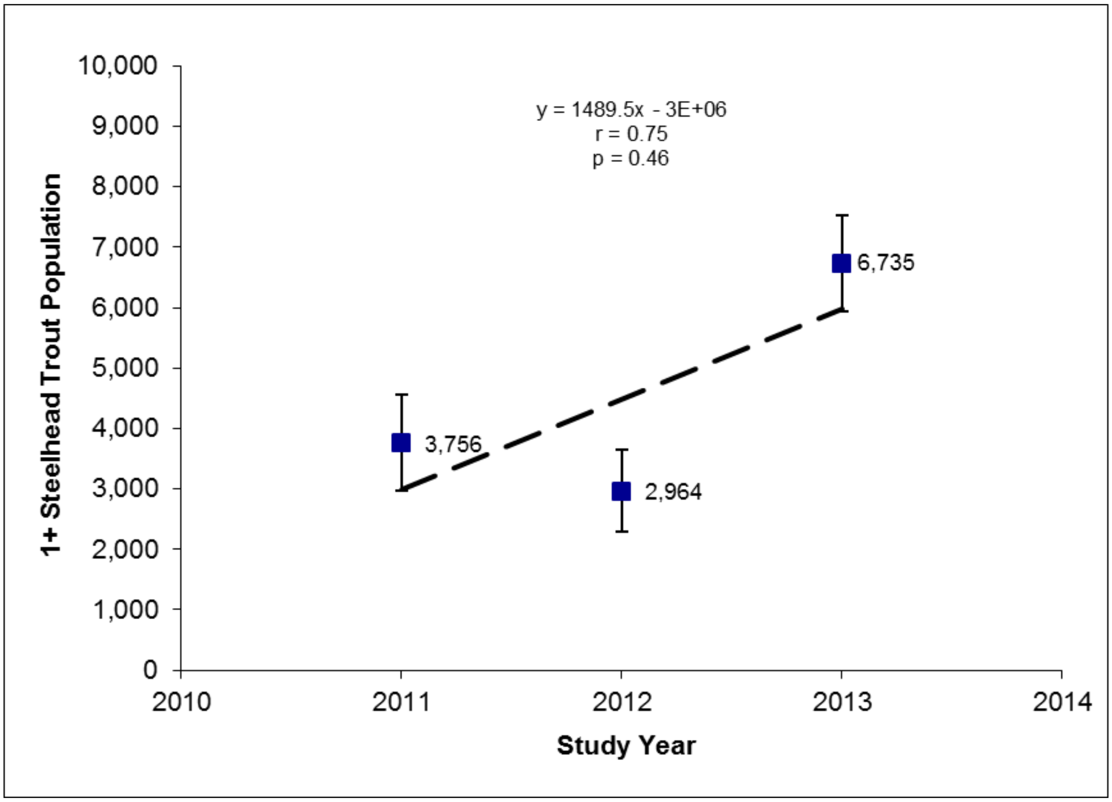

Figure 7. 1+ steelhead trout population abundance estimates (error bars are 95% confidence interval) in YRS 2011 – 2013. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

The pattern in monthly 1+ steelhead trout population abundances showed variation among study years, however the most important month each study year was May (Figure 8). May accounted for 53% of total migration in YR 2011, 36% in YR 2012, and 46% in YR 2013. The two most important months for population emigration were May/June (80% of total) in YR 2011, May/June (68% of total) in YR 2012, and April/May (76%) in YR 2013 (Figure 8).

The peaks in weekly population emigration in YRS 2011 – 2013 occurred in late April/early May (YR 2013), early to mid-May (YR 2011), and mid to late May (YR 2012) (Table 19).

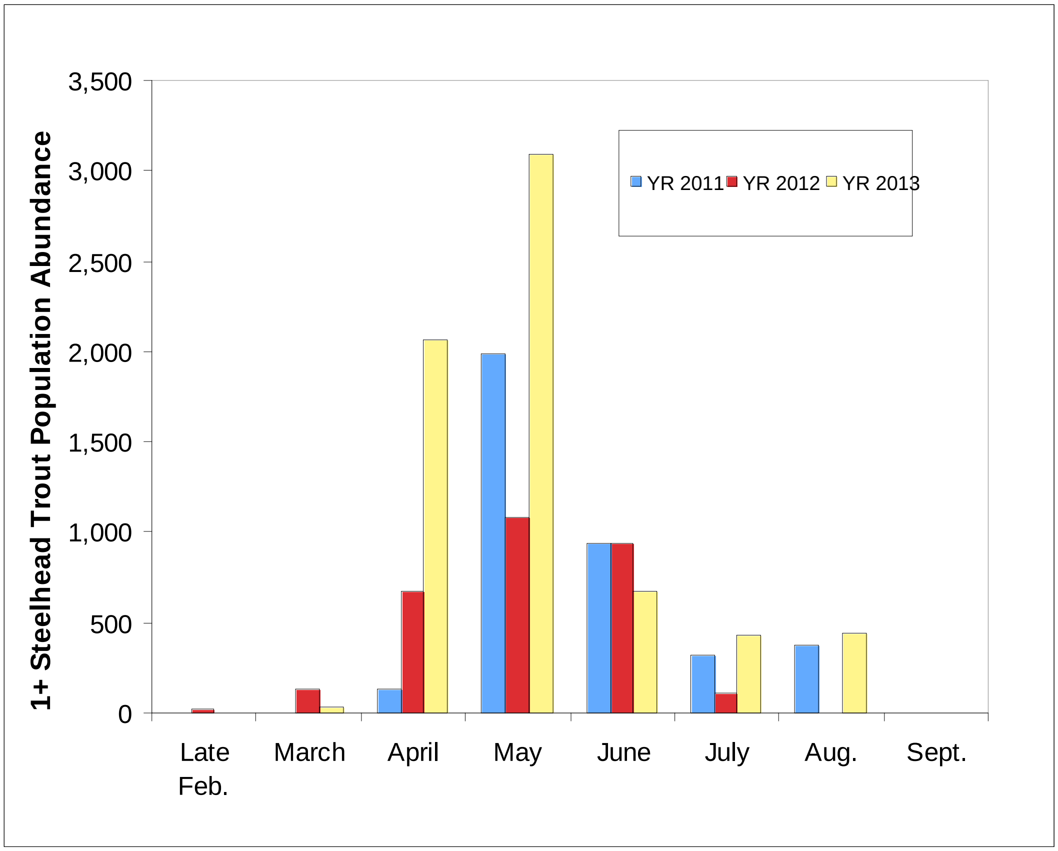

Figure 8. 1+ steelhead trout population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

Table 19. Date of peak weekly 1+ steelhead 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 (751)
2012	5/21 - 5/27 (388)
2013	4/30 - 5/06 (1,700)

2+ Steelhead trout

The population abundance (or production) of 2+ steelhead trout emigrating past the trap in lower Prairie Creek equaled 1,211 (± 30.1%) in YR 2011, 295 (± 44.4%) in YR 2012, and 4,020 (± 24.7%) in YR 2013 (Figure 9). Average population abundance over YRS 2011 – 2013 equaled 1,842 (SD = 1,941; SEM = 1,121).

Correlation of time (study year) on yearly population abundances indicated a non-significant, positive relationship (n = 3, p = 0.48, r = 0.72, power = 0.08) (Figure 9).

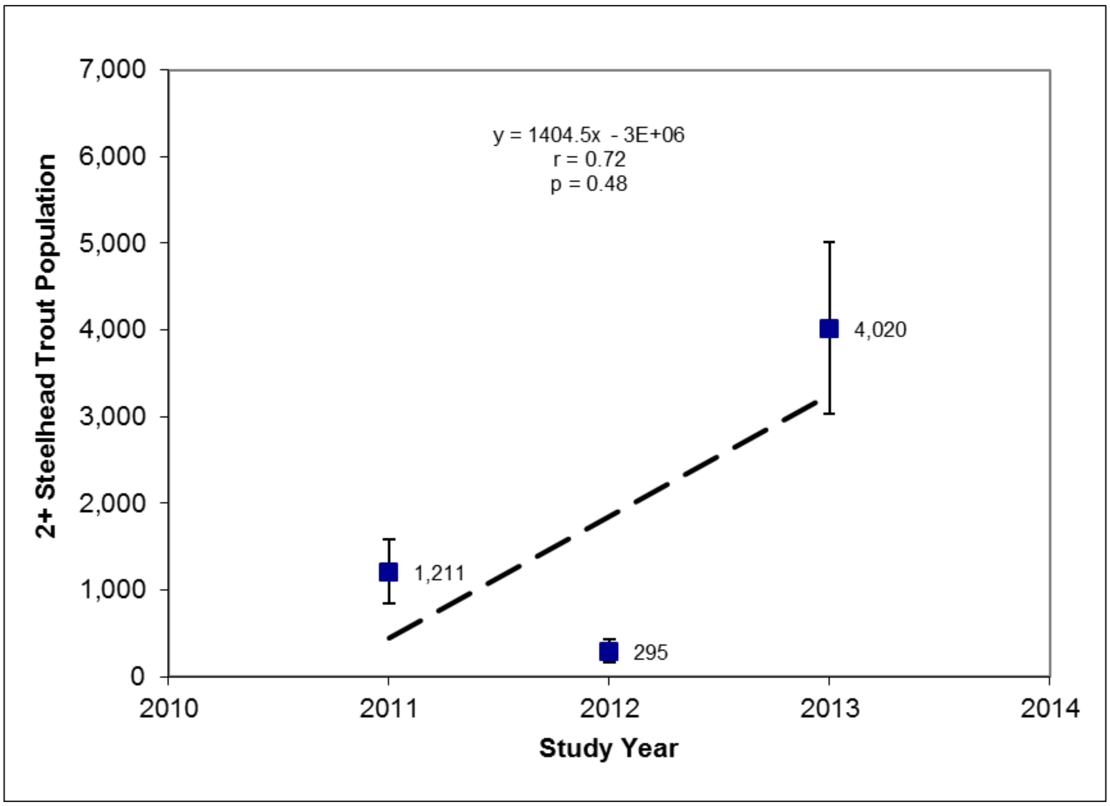

Figure 9. 2+ steelhead trout population abundance estimates (error bars are 95% confidence interval) in YRS 2011 – 2013. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

The pattern in monthly population abundances varied over study years (Figure 10). The most important month for emigration was May (59% of total) in YR 2011, March (30% of total) in YR 2012, and May (59% of total) in YR 2013 (Figure 10). The two most important months for 2+ steelhead trout population emigration were May/July (74% of total) in YR 2011, March/April (52% of total) in YR 2012, and April/May (85%) in YR 2013 (Figure 10).

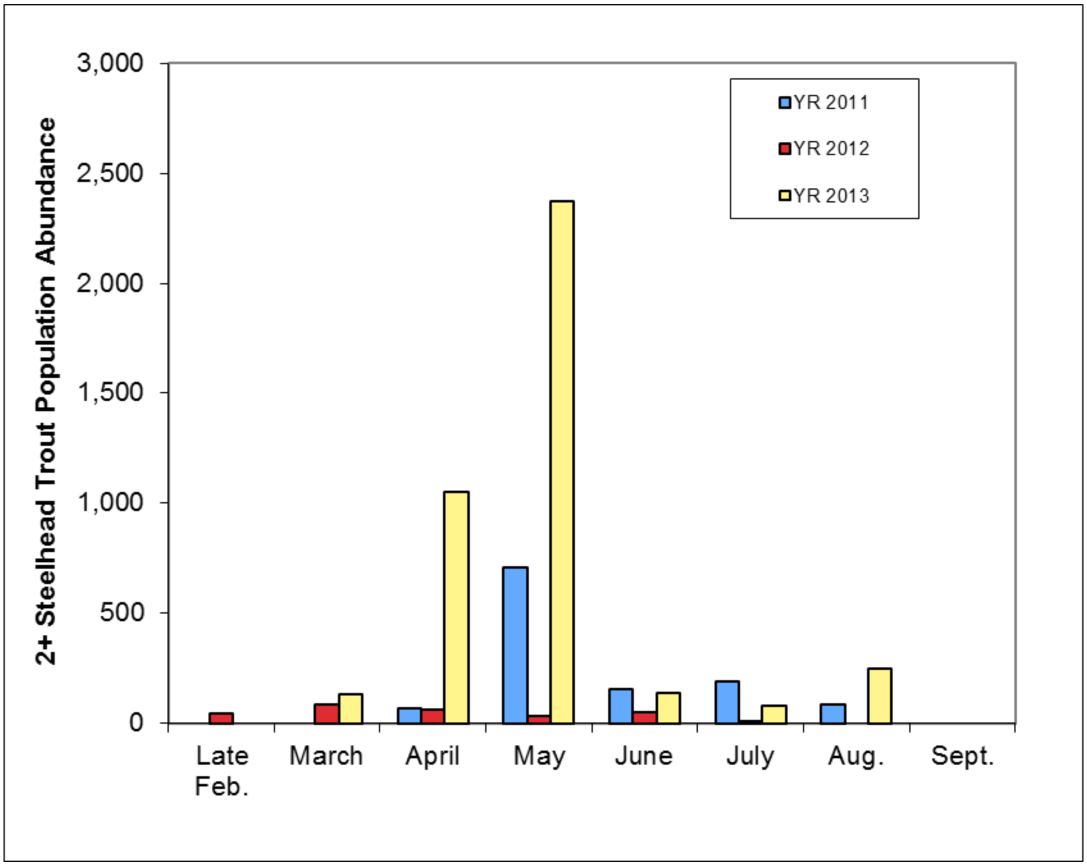

Figure 10. 2+ steelhead trout population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

The peaks in weekly population emigration in YRS 2011 – 2013 occurred in May (YR 2011), late February/early March (YR 2012), and late April/early May (YR 2013) (Table 20).

Table 20. Date of peak weekly 2+ steelhead 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 (299)
2012	2/26 - 3/04 (112)
2013	4/30 - 5/06 (1,170)

0+ Coho Salmon

The population abundance (or production) of 0+ coho salmon emigrating past the trap in lower Prairie Creek equaled 726 (± 33.3%) in YR 2011, 8,403 (± 21.5%) in YR 2012, and 3,281 (± 48.6%) in YR 2013 (Figure 11). Average population abundance over YRS 2011 – 2013 equaled 4,137 (SD = 3,909; SEM = 2,257).

Correlation of time (study year) on yearly population abundances indicated a non-significant, positive relationship (n = 3, p = 0.79, r = 0.33, power = 0.05) (Figure 11).

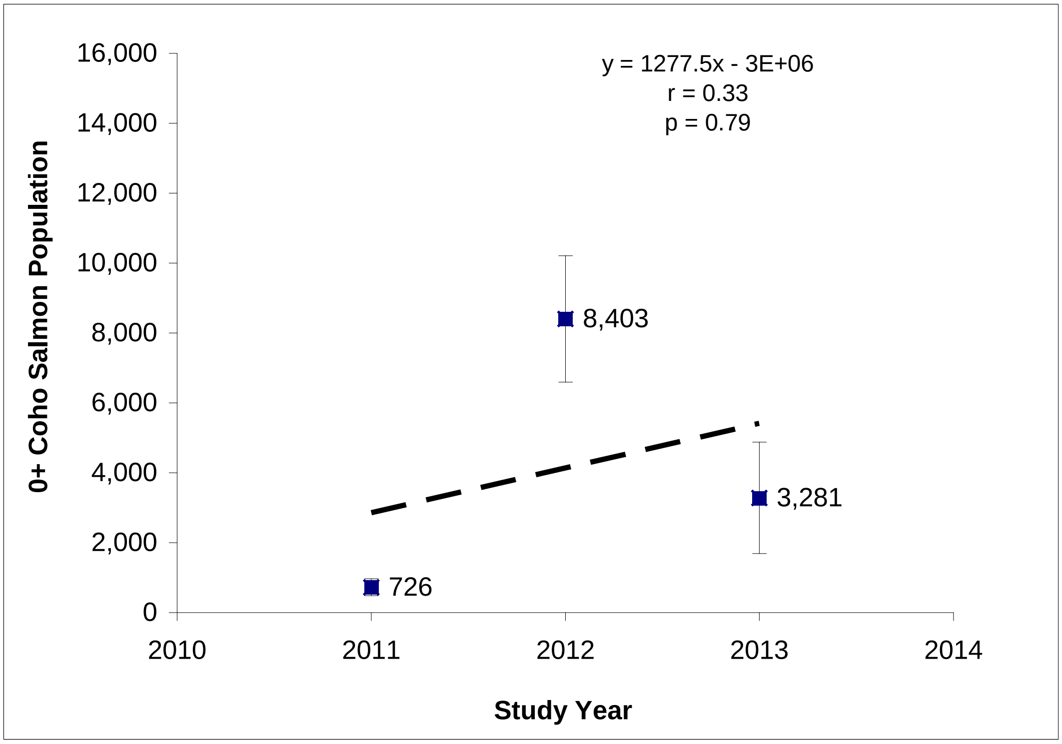

Figure 11. 0+ coho salmon population abundance estimates (error bars are 95% confidence intervals) in YRS 2011 - 2013. Lack of error bars in YR 2011 is due to scale of Y axis. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

The pattern in monthly population abundances was similar each study year (Figure 12). The month of April was the most important month, and accounted for 37% of total migration in YR 2011, 40% in YR 2012, and 87% in YR 2013. The two most important months for population emigration were April/May (67% of total) in YR 2011, April/May (72% of total) in YR 2012, and April/May (96%) in YR 2013 (Figure 12).

The peaks in weekly population emigration occurred in late April/early May in YR 2011, April in YR 2011, and April in YR 2013 (Table 21).

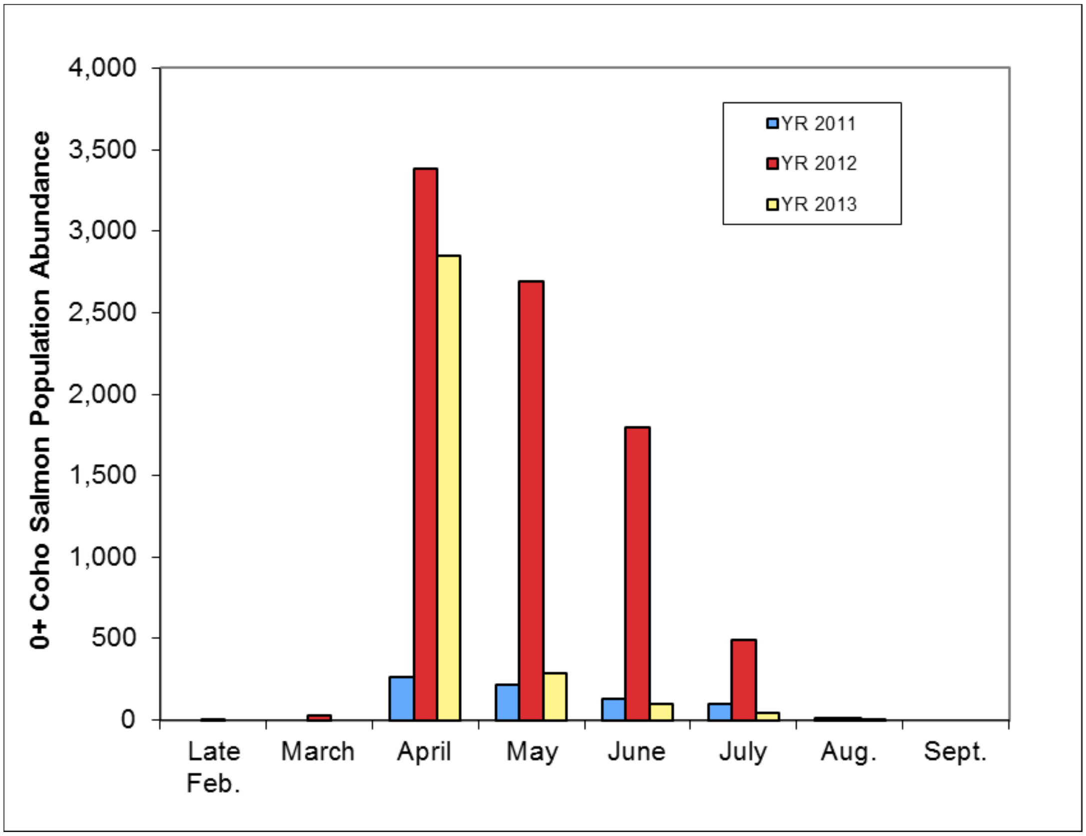

Figure 12. 0+ coho salmon population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

Table 21. 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)

1+ Coho Salmon

The population abundance (or production) of 1+ coho salmon emigrating past the trap in lower Prairie Creek equaled 8,446 (± 15.1%) in YR 2011, 20,141 (± 15.9%) in YR 2012, and 23,580 (± 10.3%) in YR 2013 (Figure 13). Average population abundance over YRS 2011 – 2013 equaled 17,389 (SD = 7,933; SEM = 4,580). Correlation of time (study year) on yearly population abundances indicated a non-significant, positive relationship (n = 3, p = 0.19, r = 0.95, power = 0.20) (Figure 13).

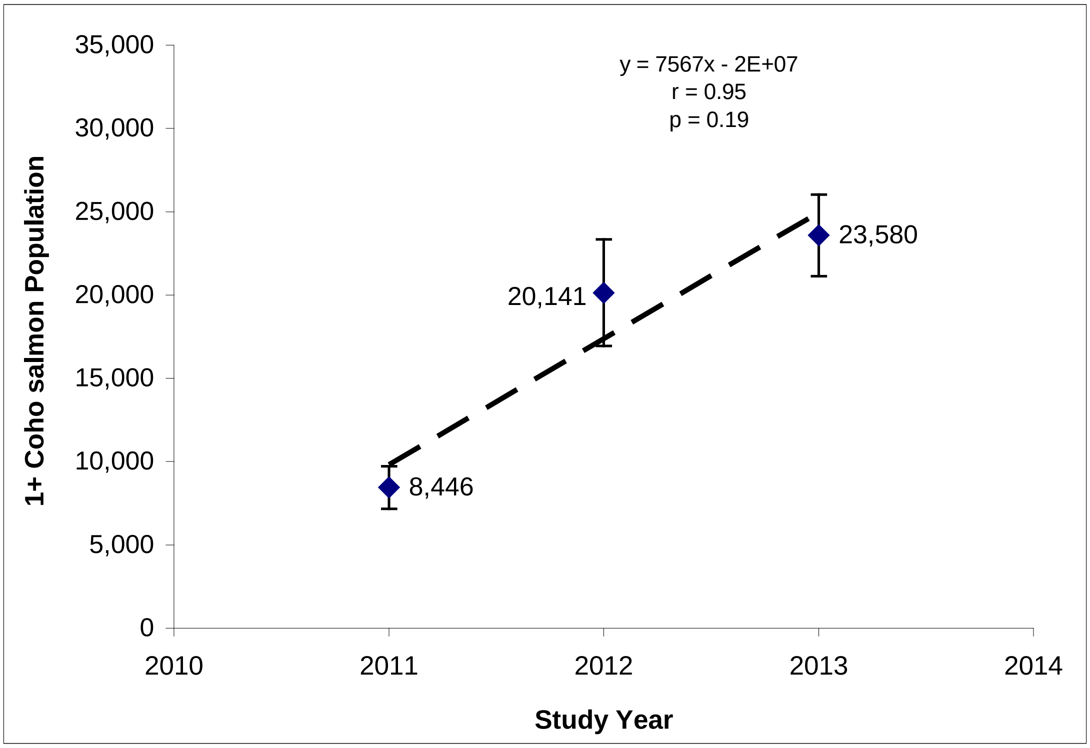

Figure 13. 1+ coho salmon population abundance estimates (error bars are 95% confidence interval) in YRS 2011 – 2013. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

Monthly population abundances varied over study years (Figure 14). The most important month for emigration was May (78% of total) in YR 2011, May (45% of total) in YR 2012, and April (43% of total) in YR 2013 (Figure 14). The two most important months for 1+ coho salmon population emigration were May and June (94% of total) in YR 2011, April and May (71% of total) in YR 2012, and April and May (79%) in YR 2013 (Figure 14).

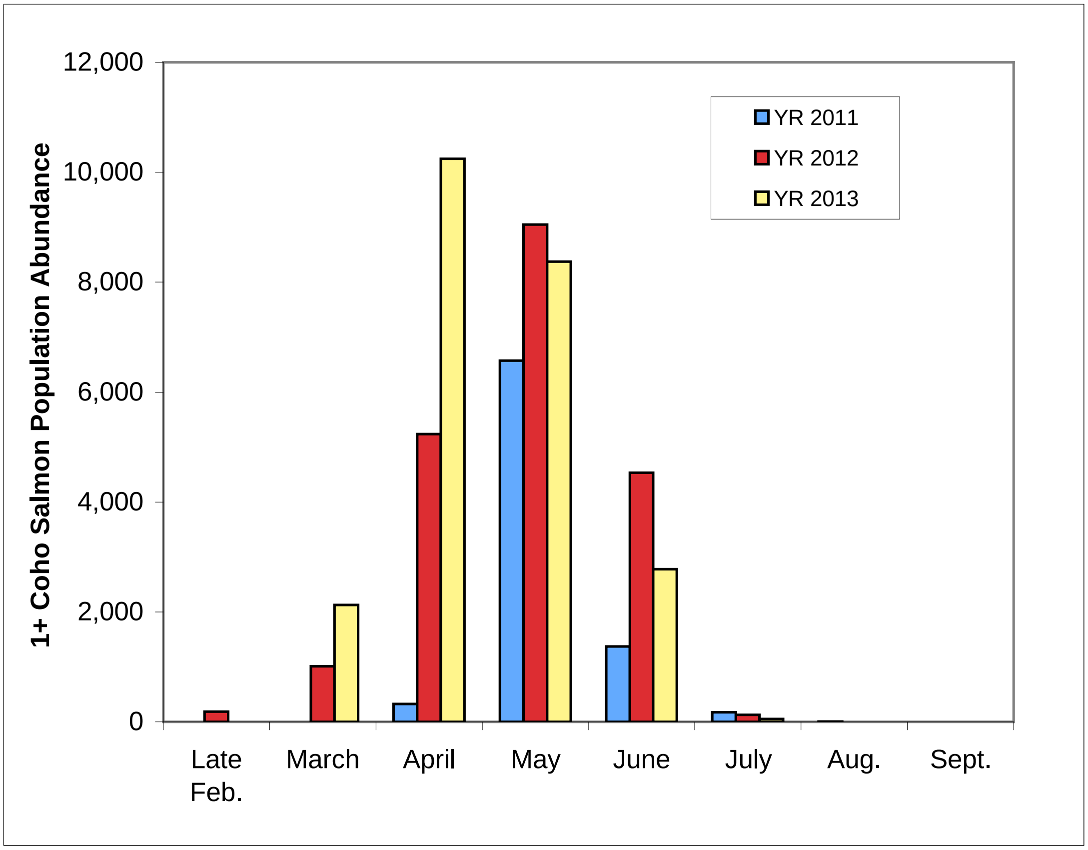

Figure 14. 1+ coho salmon population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

The peaks in weekly population emigration occurred in May in YR 2011, May in YR 2012, and April in YR 2013 (Table 22).

Table 22. 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)

Cutthroat Trout

The population abundance (or production) of cutthroat trout emigrating past the trap in lower Prairie Creek equaled 5,224 (± 19.0%) in YR 2011, 5,488 (± 27.6%) in YR 2012, and 5,043 (± 15.7%) in YR 2013 (Figure 15). Average population abundance over YRS 2011 – 2013 equaled 5,252 (SD = 224; SEM = 129).

Correlation of time (study year) on yearly population abundances indicated a non-significant, negative relationship (n = 3, p = 0.73, r = 0.40, power = 0.05) (Figure 15).

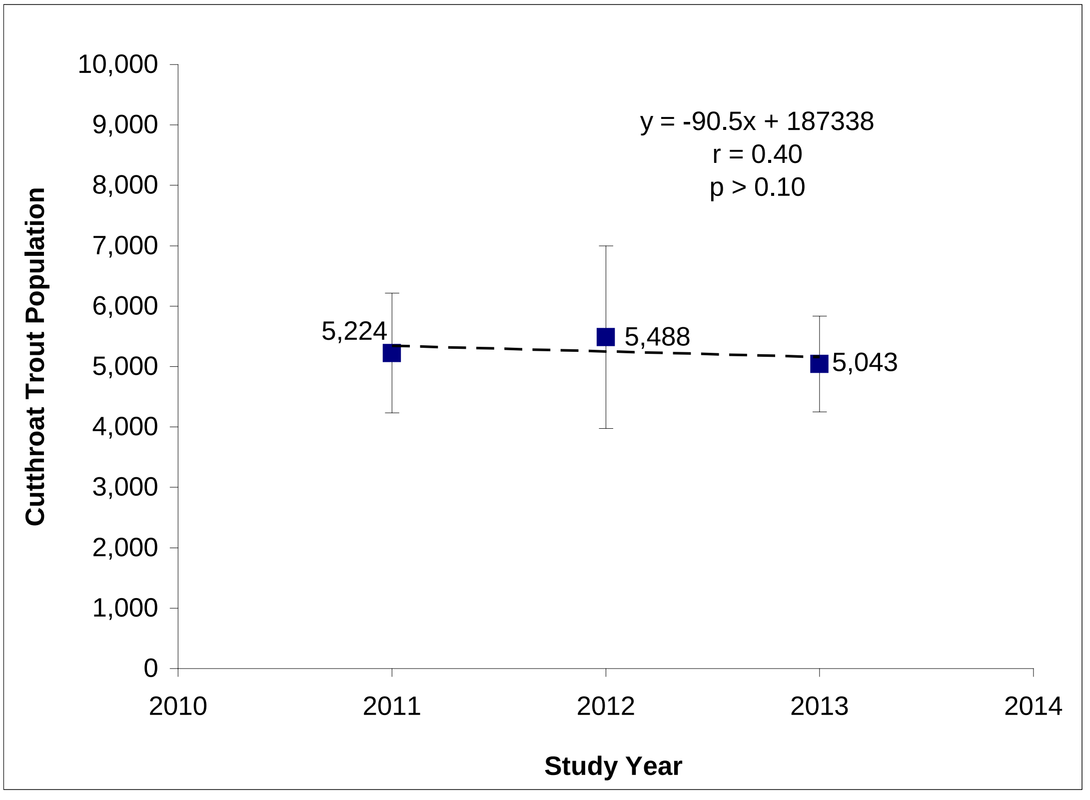

Figure 15. Coastal cutthroat trout population abundance estimates (error bars are 95% confidence interval) in YRS 2011 – 2013. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, Prairie Creek, Humboldt County, CA.

Monthly population abundances varied over study years (Figure 16). The most important month for emigration was May (78% of total) in YR 2011, May (45% of total) in YR 2012, and April (42% of total) in YR 2013 (Figure 16). The two most important months for cutthroat trout population emigration were May and June (89% of total) in YR 2011, April and May (85% of total) in YR 2012, and April and May (81%) in YR 2013 (Figure 16).

The peaks in weekly population emigration occurred in May in YR 2011, May in 2012, and late April/early May in YR 2013 (Table 23).

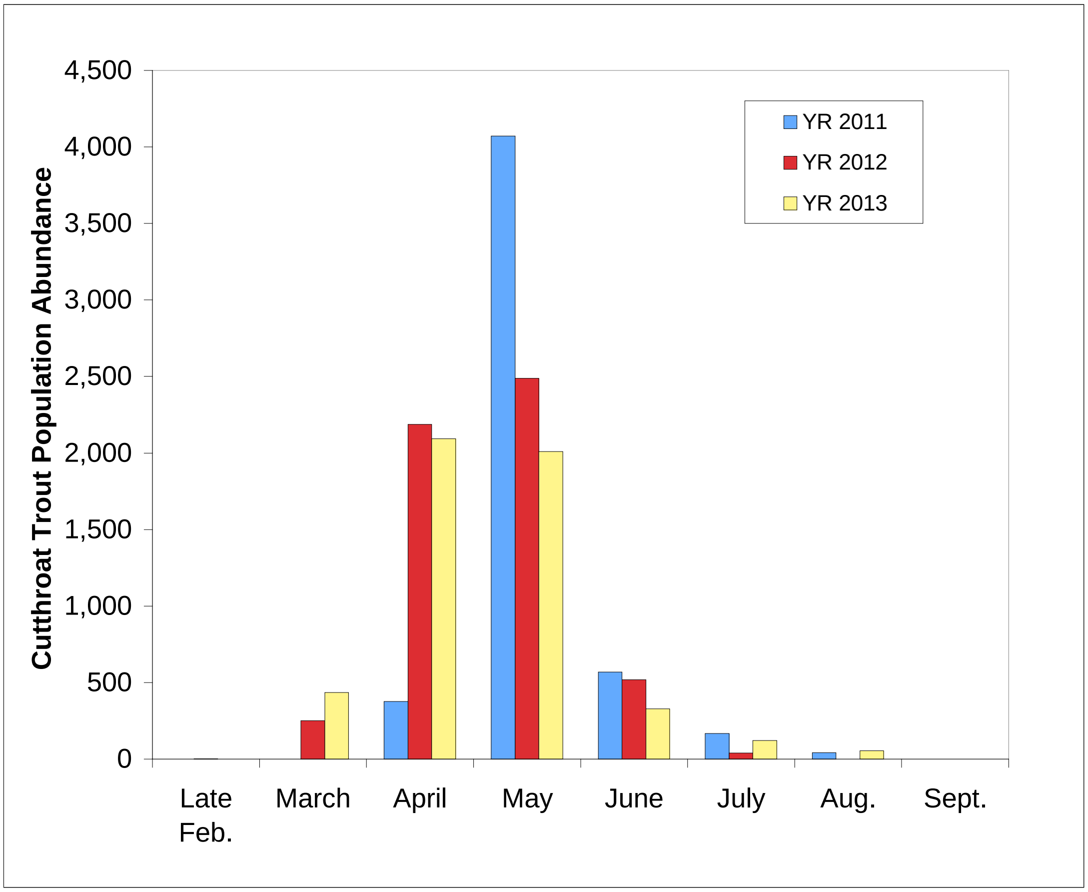

Figure 16. Coastal cutthroat trout population abundances by month in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

Table 23. 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)

Age Composition of Juvenile Steelhead Trout

Far more 1+ steelhead trout migrated downstream than 2+ steelhead trout in any given year (Table 24). On average, 1+ steelhead trout comprised 76% and 2+ steelhead trout comprised 24% of the total age-1 and older steelhead trout population (Table 24).

The ratio of 1+ steelhead trout to 2+ steelhead trout equaled 3:1 in YR 2011, 10:1 in YR 2012, and 1.7:1 in YR 2013.

Table 24. Comparison 1+ steelhead trout and 2+ steelhead trout population abundances in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

	Percent Composition Age-1 and older juvenile Steelhead trout	
Study Year	1+ Steelhead	2+ Steelhead
2011	75.6	24.4
2012	90.9	9.1
2013	62.6	37.4
Average	76.4	23.6
All Years Pooled	70.9	29.1

Fork Lengths and Weights

0+ Chinook Salmon

The number of FL (mm) measurements ranged from 2,652 to 4,038, and for Wt (g) ranged from 1,443 to 2,486 over study years 2011 – 2013 (Table 25). Average FL (mm) ranged from 52.7 to 65.1 mm, and average Wt (g) ranged from 1.83 to 4.09 over the three current study years (Table 25). Average FL over three study years equaled 58.1 mm (SD = 6.4 mm; SEM = 3.7 mm), and for Wt equaled 2.74 g (SD = 1.19 g; SEM = 0.69 g).

Table 25. 0+ Chinook salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			58.1			2.74	

1+ Chinook Salmon

Average FL (mm) equaled 122 mm (n = 2) in YR 2011, and average FL (mm) and Wt (g) equaled 100.6 mm (n = 5) and 17.5 g (n = 3) in YR 2012. One 1+ Chinook salmon was captured in YR 2013, with a FL of 108 mm, and a Wt of 11.5 g.

0+ Steelhead Trout

The number of FL (mm) measurements ranged from 816 to 1,474, and the average FL (mm) ranged from 32.5 to 44.3 mm over the three current study years (Table 26). Average FL over three study years equaled 40.1 mm (SD = 6.6 mm; SEM = 3.8 mm).

Table 26. 0+ trout average and median fork lengths in YRS 2011 - 2013, 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	-	-	-
Avg.			40.1		-	-	-

* Includes an unknown number of 0+ cutthroat trout.

1+ Steelhead Trout

The number of FL (mm) measurements ranged from 463 to 1,350 and for Wt (g) ranged from 297 to 1,056 over study years 2011 – 2013 (Table 27). Average FL (mm) ranged from 92.2 to 98.9 mm, and average Wt (g) ranged from 9.21 to 10.75 over the three current study years (Table 27). Average FL over three study years equaled 96.1 mm (SD = 3.5 mm; SEM = 2.0 mm), and for Wt equaled 10.16 g (SD = 0.83; SEM = 0.48 g).

2+ Steelhead Trout

The number of FL (mm) measurements ranged from 79 to 708 and for Wt (g) ranged from 56 to 691 over study years 2011 – 2013 (Table 28). Average FL (mm) ranged from 145.6 to 157.9 mm, and average Wt (g) ranged from 33.21 to 37.00 over the three current study years (Table 28). Average FL over three study years equaled 150.8 mm (SD = 6.4 mm; SEM = 3.7 mm), and for Wt equaled 35.70 g (SD = 2.16 g; SEM = 1.25 g).

Table 27. 1+ steelhead trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			96.1			10.16	

Table 28. 2+ steelhead trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			150.8			35.70	

0+ Coho Salmon

The number of FL (mm) measurements ranged from 197 to 1,221 and for Wt (g) ranged from 86 to 1,099 over study years 2011 – 2013 (Table 29). Average FL (mm) ranged from 38.4 to 49.2 mm, and average Wt (g) ranged from 0.62 to 2.11 g over the three current study years (Table 29). Average FL over three study years equaled 42.5 mm (SD = 5.9 mm; SEM = 3.4 mm), and for Wt equaled 1.13 g (SD = 0.85 g; SEM = 0.49 g).

1+ Coho Salmon

The number of FL (mm) measurements ranged from 1,401 to 2,793 and for Wt (g) ranged from 553 to 1,915 over study years 2011 – 2013 (Table 30). Average FL (mm) ranged from 101.2 to 108.8 mm, and average Wt (g) ranged from 11.01 to 13.47 over the three current study years (Table 30). Average FL over three study years equaled 104.1 mm (SD = 4.1 mm; SEM = 2.4 mm), and for Wt equaled 12.18 g (SD = 1.23 g; SEM = 0.71 g).

Table 29. 0+ coho salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			42.5			1.13	

Table 30. 1+ coho salmon average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			104.1			12.18	

Cutthroat Trout

The number of FL (mm) measurements ranged from 547 to 1,323 and for Wt (g) ranged from 390 to 1,055 over study years 2011 – 2013 (Table 31). Average FL (mm) ranged from 142.2 to 148.5 mm, and average Wt (g) ranged from 32.70 to 39.49 over the three current study years (Table 31). Average FL over three study years equaled 144.5 mm (SD = 3.5 mm; SEM = 2.0 mm), and for Wt equaled 35.13 g (SD = 3.79 g; SEM = 2.19 g).

Table 31. Cutthroat trout average and median fork lengths (mm) and weights (g) in YRS 2011 - 2013, 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
Avg.			144.5			35.13	

Developmental Stages

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 32). 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 - 2013 for 1+ steelhead trout was nearly 100%, and for 2+ steelhead trout equaled 100% (Table 32).

1+ Chinook Salmon

All 1+ Chinook salmon captured in YRS 2011 - 2013 were in a smolt stage.

Table 32. Developmental stages of captured 1+ and 2+ steelhead trout in YRS 2011 - 2013, 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
Avg.	1.6	73.7	24.7	0.0	19.5	80.5

1+ Coho Salmon, and 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 33). The majority of 1+ coho salmon were classified as smolts, and for cutthroat trout, the majority were classified as smolts in YRS 2011 and 2013 (Table 33).

Table 33. Developmental stages of captured 1+ coho salmon and cutthroat trout in YRS 2011 - 2013, 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
Avg.	0.0	14.4	85.6	0.1	47.7	52.2

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 over the three study years ranged from 0.00 – 1.4%, and using all data (pooling) equaled 0.4% of the total captured and handled (Table 34). 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 34. Total rotary screw trap trapping mortality in YRS 2011 - 2013, Prairie Creek, Humboldt County, CA.

	Trapping Mortality in YRS 2011 - 2013		
Age/Species	Total Catch*	No. of Mortalities	Percent Mortality
0+ Chinook	57,107	239	0.4
1+ Chinook	8	0	0.0
0+ Trout	7,252	99	1.4
1+ Steelhead	3,047	0	0.0
2+ Steelhead	1,101	0	0.0
Cutthroat	3,530	0	0.0
Adult CT	47	0	0.0
0+ Coho	1,940	24	1.2
1+ Coho	15,296	11	0.1
0+ Pink	9	0	0.0
Total:	89,337	373	0.4

*Catches are not expanded for missed days of trapping.

Stream Temperatures

Average daily (24 hr period) stream temperatures at the trapping site during trap deployment ranged from 10.8 – 12.0 ^{o}C (Table 35). Average daily stream temperatures during the trapping periods in YRS 2011 – 2013 were similar, with the largest difference among years equaling 1.2 ^{o}C. Minimum stream temperatures ranged from 6.4 to 7.9 ^{o}C, and maximum stream temperatures ranged from 14.6 to 15.9 ^{o}C (Table 35). Average daily stream temperatures (truncated for equal comparisons) were also similar among study years (Table 36).

Average daily stream temperatures (^{o}C) increased over study periods each year (Figure 17).

Table 35. 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 – 2013, 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
Avg.	11.6 (0.4)			52.8 (0.7)		

Table 36. Average daily stream temperature (^{o}C) (truncated) at the trap site in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

	Average Daily Stream Temperature (Truncated 4/13 – 8/05)	
Study Year	(^{o}C)	(^{o}F)
2011	11.7	53.1
2012	11.8	53.3
2013	12.6	54.7

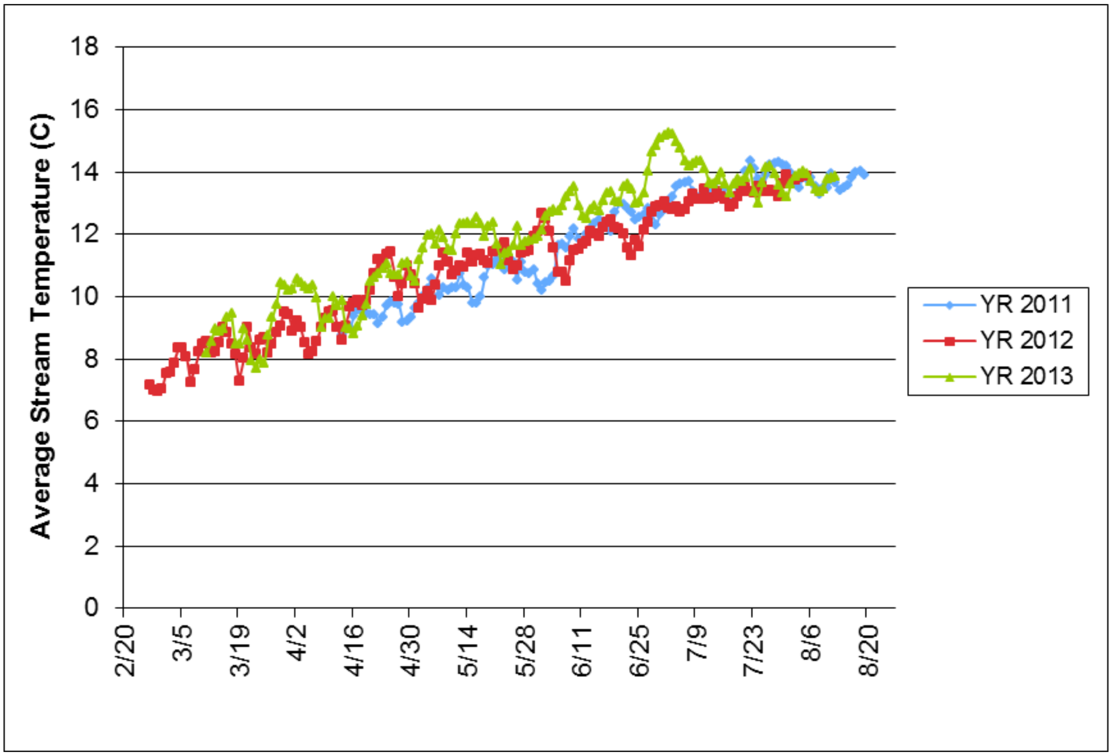

Figure 17. Average daily stream temperatures (°C) in YRS 2011 – 2013, Prairie Creek, Humboldt County, CA.

The MWAT's during the trapping periods in YRS 2011 – 2013 ranged from 13.8 - 15.0 °C, and occurred in early July, late July, and early August (Table 37). MWMT's ranged from 14.4 – 15.7 °C, and also occurred in early July, late July, and early August (Table 37).

Table 37. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site in Prairie Creek, Humboldt County, CA., study years 2011 – 2013.

	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)

DISCUSSION

Redd Surveys

The objective of spawning surveys in the Coastal Monitoring Program is to estimate annual abundance and, through time, population trajectory or trend in abundance. This monitoring program relies on spawning ground surveys and uses the number of redds as the population metric from which adult abundance is estimated (Adams et al. 2011). Redd counts however, represent only a fraction of the true number of redds. Accuracy of redd counts relative to true number of redds is influenced by the frequency and magnitude of annual stream discharge which governs both the recruitment of new fish and subsequent redd building (Goin 2010), the redd survival process (Jones 2012), experience of surveyors, frequency of surveys, and any interactions of above mentioned variables. The relatively stable hydrology of Prairie Creek allows for more frequent surveys than many northern California steams, which is thought to minimize these sources of error; however, in 2011/2012 the average time between surveys on individual reaches was 17 days (range of 15 – 22 days), and in 2012/2013 the average time between surveys was 12 days (range of 11 -14 days). Although Prairie Creek is more suitable for redd surveys compared to Redwood Creek, the high average time between surveys may limit inference on population abundances without an independent study on population abundances.

Number of redds constructed by coho salmon in Prairie Creek during 2011/2012 and 2012/2013 was 379 and 363, respectively. Thought not directly comparable, these numbers are probably within the range of abundance estimates by Duffy (2013) derived from observations of live fish during the 1998/19999 through 2011/2012 seasons. Table 38 from Duffy (2013), reproduced below, reveals that estimated abundance ranged from a low of 28 fish in 2009/2010 to a high of 680 in 2001/2002. Estimated abundance figures were derived from a less complete census than that of CDFW surveys in 2011/2012 and 2012/2013, but still reflected the bulk of coho salmon spawning habitats in Prairie Creek. Although the recent redd surveys within the Prairie Creek sub-basin cover more area, there are still sections where adult coho have been observed that were not surveyed, such as: North and South Fork Browns Creek, upper Godwood Creek, upper Streelow Creek and upper North Fork Streelow Creek, and Ten-Taypo Creek, among other areas.

Table 38. Escapement of adult coho salmon to Prairie Creek estimated from live fish observations using area-under-the-curve analysis.

Spawning Season	Estimated Abundance	95% CI
1998/99	56	3.4
1999/00	84	6.7
2000/01	212	6.0
2001/02	680	19.4
2002/03	542	46.1
2003/04	268	12.4
2004/05	643	40.6
2005/06	349	27.6
2006/07	165	8.5
2007/08	466	44.5
2008/09	127	25.8
2009/10	28	4.1
2010/11	218	22.0
2011/12	323	49.9

It should be noted that redd abundance estimates reported here are not expanded. Duffy (2013) recorded the proportion of male and female coho salmon arriving at a weir on Prairie Creek over a 5 year period and found that females represented only 38% of all adults. When these data were used to expand redd counts, the expanded redd counts were comparable to estimates derived from live fish observation.

Summer Juvenile Distribution and Marking

In northern California, coho salmon are listed as threatened and are continuing to experience populations 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). We found that juveniles in Prairie Creek that were larger in fall were generally move likely to survive the winter, a phenomenon previously observed in Prairie Creek (Brakensiek and Hankin 2007) and other watersheds (Quinn and Peterson 1996; Ebersole et al. 2006; Pess et al. 2011). However, all fish that did not migrate before the summer of 2013 would be considered mortalities by our model, meaning estimated survival may be biased low for small individuals due to their higher probability of spending a second year in freshwater (Bell and Duffy 2007).

Juveniles that were tagged lower in the watershed in fall of 2012 had elevated apparent overwinter survival to spring of 2013 relative to fish tagged higher in the watershed, which is consistent with the results reported by Roni et al. (2012), but in contrast with other studies that have documented increased survival by juveniles higher in the watershed (Quinn and Peterson 1996; Ebersole et al. 2009). The exception to this observation was large juveniles tagged near the confluence, which appeared to have very poor survival. However, large fish in other watersheds have been documented migrating to sea earlier than the rest of the cohort (Irvine and Ward 1989; Giannico and Hinch 2007), meaning the low survival of large fish near the confluence may actually reflect a pattern of early emigration by the most mature fish. March 4th was considered to be the start date of spring migration since this was the first day that a fish was detected at the antennas since February, and several more individuals were encountered in the days that followed. However, migration could have occurred before this date but been undetected by the antennas. Additional migrants may have been missed on March 8^{th} and 9^{th}, days when neither the confluence antennas nor the trap were in operation.

Alternatively, the individuals that experienced poor apparent survival near the confluence may represent fall emigrants, a life history recently documented in other streams. Although only two potential fall migrants were encountered in Prairie Creek (fish that were last encountered at the confluence antennas in fall and were swimming in a downstream direction), more may have emigrated when high flow events rendered the confluence antennas inoperable for a total of 25 days in November and December. In nearby Freshwater Creek, Hauer (2013) reported that up to 27% of juvenile coho salmon emigrated from the stream in fall and overwintered in a tidally influenced marsh. 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 both of these studies, juveniles that were lower in the watershed had a higher probability of migrating in fall. Juveniles migrating from Prairie Creek in fall might overwinter in the Redwood Creek estuary and its tributaries, although the amount of habitat in this area has been greatly reduced from its historical state by an Army Corps of Engineers flood control project. Since the completion of these flood levees in 1968, 50 percent of the estuary has filled with ocean derived sediments or become isolated from the embayment (Janda et al. 1975; Ricks 1995). However, small numbers of coho salmon juveniles have recently been documented year round in Strawberry Creek, a tributary of the south slough of the Redwood Creek estuary (David Anderson, Redwood National and State Parks, 121200 Highway 101, P.O. Box 7, Orick, California 95555, personal communication) indicating this area may still have some viable rearing habitat.

The maximum depth measurement of habitat units had no effect on apparent overwinter survival. This is consistent with the results of Quinn and Peterson (1996), who found that overwinter survival in Big Beef Creek was not influenced by residual pool depth of the habitat unit. Volume of large woody debris in the habitat unit also had no impact on overwinter survival, although this may be a reflection of the limitations of the sampling methodology. Future habitat surveys in Prairie Creek may be improved by utilizing a more precise method of quantifying large woody debris or by recording the amount of large wood debris in the bankfull channel rather than amount at summer base flow, which may not be an accurate reflection of available cover during winter conditions. Alternatively, characteristics of a juvenile's summer habitat unit may always be a poor predictor of survival because juveniles in Prairie Creek are unlikely to remain in the same habitat unit during winter; Bell et al. (2001) found that juveniles in upper Prairie Creek had low habitat unit fidelity over winter - a mean of 16% in both years surveyed.

The apparent overwinter survival rate for juvenile coho salmon in Prairie Creek during 2012/2013 was estimated at 39.4% (SE = 4.1%), and is close to the survival rate reported by Brakensiek and Hankin (2007) for the winter of 1999-2000 (45.5% survival). This estimate is well within the broad range of overwinter survival rates (5 - 74%) published from other studies from 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). Unlike Brakensiek and Hankin (2007), I did not find evidence of PIT tag induced mortality, although this may be partially attributed to the fact Brakensiek and Hankin tagged juveniles as small as 55 mm (compared to 60 mm in this study). Our results are consistent with those of Peterson et al. (1994), who found no differences in overwinter growth or survival between juvenile coho salmon marked with coded wire tags and those injected with PIT tags. Overwinter tag loss rate in this study was relatively high (13.3%), however, this estimate was derived from a small sample size (30 fish captured at the rotary screw trap), and so it should be interpreted with this limitation in mind. Although most PIT tag studies of juvenile salmonids have reported a tag shed rate of less than 5% (Ombredane et al. 1998; Bell et al. 2001; Gries and Letcher 2002; Brakensiek and Hankin 2007; Sloat et al. 2011), Acolas et al. (2007) found up to 20% of juvenile brown trout between 57 and 63 mm rejected their PIT tag one month after implantation, and smaller fish were more likely to lose their tag than larger fish. Since juveniles that shed their tag were not detected at the antennas, they were considered to be mortalities by our model. All juveniles that did not migrate to the ocean in the spring of 2013 were also considered mortalities, including one fish that was encountered the following fall. When adjusted for this known two year old resident and pit tag loss, apparent overwinter survival rate increases to 44.9%. Some caution should be used when interpreting the estimates produced by our overwinter survival analysis since we were limited to tagging juveniles 60 mm FL or larger. Approximately two thirds of the fish we sampled in August were smaller than 60 mm FL, meaning results reported here are only applicable to the largest individuals, which likely had higher survival than the rest of the population.

Although a previous study reported a pulse of downstream movement by juvenile coho salmon from upper Prairie Creek in November (Brakensiek and Hankin 2007), we did not observe any evidence of fall redistribution. However, this may be due to the fact that the fyke trap used by Brakensiek and Hankin to monitor fall migrants was much farther upstream than our upper antennas (approximately 7.3 km farther from the confluence). Fall redistribution may be more common in this upstream region, which would explain the lack of overwinter encounters at the upstream antennas. Downstream movement in fall may have occurred, but been missed by the upper antennas during high flow events, although it seems unlikely that substantial migration could have been missed in limited period the upper antennas were inoperable (a total of 13 days in November and December). In order to assess this possibility, a capture efficiency rate for the upper antennas was calculated using the 66 individuals encountered during spring migration. By considering the two antenna loops to be separate encounter occasions, the probability of being detected by at least one antenna in spring was estimated to be 92.6%. This figure is significantly higher than the efficiency estimate produced by the full overwinter survival model for fish tagged above the upstream antennas (68.9%), indicating a possible violation of the survival model's assumption that no fish migrated from upper Prairie Creek prior to March. However, the treatment of the antenna loops as separate occasions relies on the assumption that they are independent encounters, which may not be the case. Although the antenna loops collected data separately, they still transmitted data to the same readers system and received power from the same battery source, meaning if one loop was not functional the other was most likely not operating either. Nevertheless, the disparity between the efficiency estimations indicates the need for more research into how juveniles in Prairie Creek redistribute during and after peak flow events.

The proportion of two year old residents in the Prairie Creek watershed was estimated to be 1.4% in the fall of 2012. This estimate is slightly lower than the range reported by Ransom (2007), who found that the proportion of age 1+ individuals from the 2000-2002 cohorts varied from 1.9% to 29.5% in mainstem Prairie Creek, 3.6% to 15.3% in Streelow Creek, and 1.6% to 8.9% in Boyes Creek. In his study of these streams and three others in northern California, Ransom (2007) observed that the number of juveniles residing in freshwater for a second year did not appear to be related to initial class year strength (as measured by density) or mean size of juveniles in that cohort. The highest summer proportion of 1+ individuals was observed after a winter with very low stream flow, suggesting milder conditions allow a greater number of small individuals (future two year freshwater residents) to survive the winter. High discharge rates during the spring proceeding our sampling may have displaced smaller individuals downstream, ultimately leading to a reduced proportion of two year residents during the fall 2012 sampling.

Specific growth rate over winter (0.35% in weight/day) was within the range of growth rates reported by Justice (2007) for another northern California stream, East Fork Mill Creek (0.35 to 0.45% in weight/day) and the Giannico and Hinch (2003) for artificial side channels in the Cheakamus and Mamquam Rivers (0.23 to 0.66% in weight/day). Mean overwinter growth rate for Prairie Creek was higher than the rate observed by Bratty (1999) in Lemieux and Mann Creeks, British Columbia, (0.08% in weight/day) but lower than the rate reported by Ebersole et al. (2006) in West Fork Smith River, Oregon (0.58% in weight/day). A linear regression of the relationship between size in fall and overwinter growth revealed that juveniles that were smaller at the time of tagging experienced the highest growth rates. This trend is consistent with the von Bertalanffy growth function, which assumes growth rate slows as a fish becomes larger. The tendency for smaller juvenile coho salmon to experience higher growth rates was previously noted by Ransom (2007) in Boyes, Streelow, and Prairie Creek; and Hauer (2013) and Roni et al. (2012) in other watersheds. Contrary to studies in other areas (Swales et al. 1988; Quinn and Peterson 1996; Ebersole 2006) we did not find that location in the watershed influenced growth rate, meaning juveniles near headwaters and juveniles near the confluence likely experienced similar growth. Alternatively, distance from confluence alone may not accurately describe the complex relationship between fall location and growth rate, especially if juveniles did not remain in their original tagging location over winter.

This study demonstrates the advantages of PIT tags, which allowed us to examine how size and habitat characteristics affected survival, growth, and migration timing of juvenile coho salmon. However, the caveats of this technology, including PIT tag induced mortality and tag loss, must be considered since the accuracy of a survival model depends on individuals surviving the tagging process and retaining their tags throughout the study. To reduce loss of PIT tags, we recommend making the smallest incision necessary to implant the tag and incorporating the use of a veterinary tissue adhesive to close incisions. Furthermore, studies that estimate freshwater survival of juvenile coho salmon often do not account for individuals that migrate to sea prior to spring migrant trapping (Roni et al. 2012), or during antenna downtime. Our results indicate the practice of treating these individuals as mortalities may lead to overwinter survival rates that are biased low for the certain migrants. We also recommend future studies of Prairie Creek examine factors that influence spring migration timing using a modeling approach that accounts for both individual characteristics and environmental factors. These results indicated both may play a role in migration timing, but the linear models used were too simple to address the myriad of interacting factors that influence when a juvenile salmon migrates to the ocean. The relationship between fish size, rearing location, flow, water temperature, and other factors could best be addressed by a project fully dedicated to examining this complex issue, such as the study by Feola (2007), which examined how environmental variables affect spring migration timing in Prairie Creek and Boyes Creek. Finally, this study highlights the need to consider alternatives to pass through antennas when examining fall redistribution, especially in streams that are prone to high flow events. Utilizing an antenna design that is less susceptible to storm damage or sampling in areas where juveniles may potentially be migrating may help illuminate overwinter movement patterns in watersheds where pass through antennas are difficult to maintain. For example, in lower Prairie Creek, a seine or a handheld pit tag reader with a wand could be used to search for migrants from the upper part of the watershed.

Smolt Abundances

The main goal of our downstream migration 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 majority of 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. 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 Redwood Creek to provide a basin wide estimate for smolt production in Redwood Creek on an annual basis (Sparkman, In progress$_a$). Adult escapement to the Redwood Creek 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 very useful for critically evaluating freshwater population dynamics in light of habitat quality. The DIDSON sonar unit can also be used to calibrate or assess accuracy of redd counts. 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 three consecutive years of trapping in lower Prairie Creek occurred under varying environmental conditions (eg streamflow), as evidenced by variation in the number of missed trapping days each year. YR 2012 was the most difficult year to trap in because of high streamflows and high debris loading within the livebox and on the trap. The number of missed days during trap deployment ranged from 1 – 22 days, and the average across all years equaled 9 or 5.8% of total possible days for trapping. The estimates for catch and subsequent expansions to the population level, based on the missed trapping day, were negligible for each most species at age; the greatest impact on a population estimate was estimated at 20%, and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point estimate. The number of fish missed when the trap was inoperable would not have greatly impacted population estimates. Thus, smolt trapping in lower Prairie Creek resulted in very good estimates of wild coho salmon, Chinook salmon, steelhead trout, and cutthroat trout smolt abundances from areas upstream of the trapping site.

<u>0+ Chinook Salmon</u>

Ocean-type type juvenile Chinook salmon were the most numerous downstream migrant captured each study year, and were also the most numerous migrant at the population level. The population abundance of 0+ Chinook salmon increased over three study years, such that abundance in YR 2012 was two times greater than abundance in YR 2011, and abundance in YR 2013 was nearly three times greater than abundance in YR 2012. Population abundances over three study years totaled 144,805 individuals, ranged from 15,148 to 96,817, and averaged 48,268 individuals. In comparison, 0+ Chinook salmon population abundances in upper Redwood Creek ranged from 30,100 to 680,747, and averaged 299,429 over YRS 2011 – 2013 (Sparkman, In progress$_a$). 0+ Chinook salmon population abundances through lower Redwood Creek ranged from 147,719 to 566,859 and averaged 308,316 over YRS 2011 – 2013 (Sparkman, In progress$_a$). For each trap location, the highest abundance occurred in YR 2013.

The trend in abundance over three consecutive study years was positive; however, statistical significance was not detected ($p > 0.10$) even though the r value for the correlation test equaled 0.95. The lack of a significant trend was likely due to low sample size ($n = 3$). 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, the data clearly showed there were consistently more Chinook salmon fry/smolts over the three study years. Based upon data collected in upper Redwood Creek, it may take nine plus years to determine a significant trend in 0+ Chinook salmon population abundance (Sparkman 2013).

0+ Chinook salmon population abundances by month in Prairie Creek ranged from 13 (March 2012) to 42,528 (May 2013). Population abundances peaked in June (N = 5,703) in YR 2011, May (N = 21,848) in YR 2012, and May (N = 42,528) in YR 2013. The two most important months were May/June (68% of total) in YR 2011, May/June (88% of total) in YR 2012, and April/May (76% of total) in YR 2013. The two most important months for emigration from upper Redwood Creek were April/May in YR 2011, April/June in YR 2012, and May/June in YR 2013, and for lower Redwood Creek the two most important months were June/July in YRS 2011-2012, and May/June in YR 2013 (Sparkman, In progress$_a$).On a weekly basis, populations peaked during 6/18 – 6/24 (N = 1,608) in YR 2011, 5/07 – 5/13 (N = 10,057) in YR 2012, and 4/30 – 5/06 (N = 26,769) in YR 2013.

Each study year 0+ Chinook salmon (ocean-type) emigrating from Prairie Creek (and Redwood Creek, Sparkman In progress$_a$) exhibited two different juvenile life histories (fry and fingerling) based on size and time of downstream migration. The fry (Avg. FL = 41 mm over three years) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (or smolts) (Avg. FL = 63 mm over three years) which have reared in the stream for a longer period of time prior to passing the trap site. Although there was overlap in the timing of fry (FL < 45 mm) and fingerling (FL > 44 mm) downstream migration, temporal differences were evident. Fry migration peaked 4/30 – 5/06 (n = 408) in YR 2011, 5/07 – 5/13 (n = 9,339) in YR 2012, and 4/30 – 5/06 (n = 14,532) in YR 2013. In contrast, fingerling migration peaked 6/18 – 6/24 (n = 1,608) in YR 2011, 6/04 – 6/10 2,378 in YR 2012, and 4/30 – 5/06 (n = 12,237) in YR 2013. 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

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 46% of the population migrating through lower Prairie Creek over three study years, and totaled 67,233 individuals. This contrasted 0+ Chinook salmon migration through lower Redwood Creek in YRS 2011 – 2013 where 17% (N = 160,438) of the migrants were estimated as fry (Sparkman, In progress$_a$). The fry migrating from Prairie Creek must continue to migrate and rear in lower Redwood Creek 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 Redwood Creek and estuary can impact survival and growth of 0+ Chinook salmon, which in turn can negatively influence the abundance of adult Chinook salmon returns to Prairie Creek.

The average size of Prairie Creek 0+ Chinook salmon migrants ranged from 53 – 65 mm FL, and across all years averaged 58 mm FL. The relatively small size of Chinook migrants emigrating from Prairie Creek suggests they need to continue rearing in lower Redwood Creek and estuary in order to attain a size that increases marine survival. In comparison, 0+ Chinook salmon emigrating from upper Redwood Creek ranged from 51 – 56 mm FL (Avg. FL = 52mm) in YRS 2011 – 2013; and 0+ Chinook salmon migrants passing through lower Redwood Creek ranged from 61 – 71 mm FL (Avg. FL = 65 mm) in YRS 2011 - 2013 (Sparkman, In progress$_a$). The small, average size of 0+ Chinook salmon in both Redwood Creek and Prairie Creek provides evidence that lower Redwood Creek and estuary are important areas where juvenile Chinook salmon need to increase growth to increase survival. Unfortunately, lower Redwood Creek 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. Our data in comparison with lower Redwood Creek, suggests that Prairie Creek 0+ Chinook salmon need to increase size in the estuary more so than Chinook salmon passing through lower Redwood Creek.

<u>1+ Chinook Salmon</u>

One year old juvenile Chinook salmon (stream-type) in Prairie Creek represent the third juvenile Chinook salmon life history. Stream-type juvenile Chinook salmon are easily differentiated from ocean-type 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 eight individuals over three consecutive study years. 1+ Chinook salmon were captured in June and July in YR 2011, February, May, and June in YR 2012, and May in YR 2013.

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. The low streamflows 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. 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).

0+ Trout

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. 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 out-migrate soon after emergence from redds to occupy other rearing areas (we observe this as well in both upper and lower Redwood Creek). Passive downstream migration can also occur when stream discharge increases. 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 (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 affect on migration is that it often fails to explain why juvenile salmonids (e.g. 0+ TR, 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 2013). Based upon experiments conducted in upper Redwood Creek, Sparkman (2013) reported that marked 0+ steelhead trout released in upper Redwood Creek were recaptured in lower Redwood Creek in four 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 ranged from 1,228 – 4,522 with most catches occurring in May (YR 2011) and June (YRS 2012 and 2013). Relatively high catches of young-of-year trout by downstream migrant traps in small and large streams is not uncommon (Sparkman 2013). For example, 0+ steelhead trout catches in upper Redwood Creek from YRS 2000 – 2013 ranged from 32,585 - 128,885 and averaged 67,237 per year (Sparkman, In progress$_a$). In YR 2013, a total of 67,796 0+ steelhead trout were captured moving downstream in upper Redwood Creek (Sparkman, In progress$_a$).

The 0+ trout captured by the trap in lower Prairie Creek indicate these fish are going to rear for some time period in lower Redwood Creek (including the estuary), before possibly migrating back upstream into Prairie Creek. Dave Anderson (pers. comm. 2012), for example, routinely captures young-of-year steelhead trout (and coho salmon) in the estuary during summer and early fall sampling. Although relatively few 0+ trout migrated downstream past the trap site in any given study year, the condition of lower Redwood Creek and estuary can impact the survival and growth of 0+ trout, which in turn could influence the number of older, juvenile steelhead trout and cutthroat trout in following years.

1+ Steelhead Trout

One-year-old steelhead trout smolts were the most numerous juvenile steelhead trout aged-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) ranged from 1.7:1 to 10:1, and averaged 5:1 over three study years. On a percentage basis, 1+ steelhead trout comprised 63 – 91% of the total juvenile steelhead trout age-1 and older population abundance each study year.

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 observed 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. 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 Redwood Creek indicate that 1+ steelhead trout are entering the estuary and ocean, and successfully returning to spawn as adults (Sparkman, In progress$_b$). 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 ranged from 2,964 to 6,735 and averaged 4,485 individuals over study YRS 2011 – 2013. In comparison 27,000 to 37,000 (Avg. 32,000) 1+ steelhead trout emigrated from upper Redwood Creek, and 20,500 to 35,000 (Avg. 26,087) emigrated through lower Redwood Creek (upstream of confluence with Prairie Creek) over the same study years (Sparkman, In progress$_a$). Population abundances by month in Prairie Creek ranged from 2 (August 2012) to 3,089 (May 2013), and peaked in May each study year. The two most important months for emigration were May/June in YRS 2011 and 2012, and April/May in YR 2013. Population migration during these time periods accounted for 78% (YR 2011), 68% (YR 2012), and 76% (YR 2013) of total migration. The two most important months for emigration from upper Redwood Creek were April/June in YRS 2011 - 2012, and April/May in YR 2013, and for lower Redwood Creek the two most important months were June/July each study year (Sparkman, In progress$_a$). Compared to lower Redwood Creek populations, Prairie Creek 1+ steelhead trout smolts entered the lower river and estuary before most of the smolts from Redwood Creek emigrated through lower Redwood Creek.

The average size of 1+ steelhead trout migrants in Prairie Creek ranged from 92 – 99 mm (FL), and 9.2 – 10.8 g (Wt) over three study years, and averaged 96 mm (FL) and 10.2 g (Wt). The average size of Prairie Creek migrants was greater than the average size of 1+ steelhead trout in upper Redwood Creek (Avg. 87 mm FL; 7.9 g Wt), and lower Redwood Creek (Avg. 94 mm FL; 10.0g Wt) over these same time periods (Sparkman, In progress$_a$).

2+ Steelhead Trout

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 YR 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 Redwood Creek) is that they were far less abundant (by about 40 - 90%) than 1+ steelhead trout smolts in any given study year. With respect to the combined population of 1+ and 2+ steelhead trout smolts each year, 2+ steelhead trout comprised 9 – 37% of the population. The ratio of 2+SH:1+ SH equaled 0.3:1 in YR 2011, 0.1:1 in YR 2012, and 0.6:1 in YR 2013.

The population abundance of 2+ steelhead trout emigrating from Prairie Creek ranged from 295 – 4,020 individuals, and averaged 1,842 over study years 2011 - 2013. In comparison 1,225 to 3,487 (Avg. 2,211) 2+ steelhead trout smolts emigrated from upper Redwood Creek, and 3,748 to 6,033 (Avg. 4,576) emigrated through lower Redwood Creek (upstream of confluence with Prairie Creek) over the same study periods (Sparkman, In progress$_a$). The largest population abundance in Prairie Creek occurred in YR 2013 (N = 4,020), which was greater than abundance in upper Redwood Creek in YR 2013 (N = 3,487) (Sparkman, In progress$_a$). The low abundance in YR 2012 (N = 295) in Prairie Creek can be considered a weak cohort, however, there is the chance that returning adult steelhead trout that only spent one year in freshwater will make up for the low adult return rate expected from this 2+ steelhead trout cohort. Similar to 0+ Chinook salmon and 1+ steelhead trout in Prairie Creek, the trend in 2+ steelhead trout over the three years was non-significantly positive, even though the r value for the correlation test was high (r = 0.75). 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 ranged from 0 (August 2012) to 2,373 (May 2013), and peaked in March (YR 2012) and May (YRS 2011, 2013). The two most important months for emigration were May/July in YR 2011, March/April in YR 2012, and April/May in YR 2013. Population migration during these time periods accounted for 74% (YR 2011), 52% (YR 2012), and 85% (YR 2013) of total migration. The two most important months for emigration from upper Redwood Creek were April/July in YR 2011, April/June in YR 2012, and April/May in YR 2013; and for lower Redwood Creek the two most important months were June/July in YRS 2011 - 2013 (Sparkman, In progress$_a$). Compared to lower Redwood Creek populations, Prairie Creek 2+ steelhead trout smolts enter the lower river and estuary before most of the smolts that emigrate through lower Redwood Creek.

The average size of 2+ steelhead trout migrants in Prairie Creek ranged from 146 – 158 mm (FL), and 33.2 – 37.0 g (Wt) by study year, and averaged 151 mm (FL) and 35.7 g (Wt) across three years. The average size of Prairie Creek migrants was close in value to 2+ steelhead trout collected in upper Redwood Creek (Avg. = 146 mm FL; 35.6 g Wt) and greater in value compared to lower Redwood Creek (Avg. = 144 FL; 32.7 g Wt) over these same time periods. The percentage of 2+ steelhead trout showing parr characteristics was zero each study year, and indicated 2+ steelhead trout do not emigrate through lower Prairie Creek in a parr stage (stream resident form). Rather, most of the 2+ steelhead trout were emigrating in a smolt form.

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. We were also unable to determine smolt to adult female steelhead trout from the steelhead redd counts conducted in Prairie Creek because the spawning surveys end (typically in late March) before steelhead trout spawning is over (May or June, depending upon various factors). In addition, we do not know the sex ratio of returning adult steelhead trout in Prairie Creek during the study periods. However, the belief that the number of 2+ smolts relate 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 or un-attainable. 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. 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.

Cutthroat Trout

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 – 1,793 individuals, and averaged 1,220. Few of the captured cutthroat trout were classified as parr (Avg. = 0.1%), and nearly equal numbers were classified as pre-smolts (Avg 47.7%) or smolts (Avg. 52.2%).

The spring/summer population abundance of coastal cutthroat trout emigrating from Prairie Creek ranged from 5,043 – 5,488 individuals, and averaged 5,252 over study years 2011 - 2013. In comparison, a total of 11 individuals were captured in the smolt trap in upper Redwood Creek (Rm 33) over YRS 2011 – 2013, and at the population level, 295 smolts migrated past the trap site in lower Redwood Cr (Rm 4) over YRS 2011 - 2013 (Sparkman, In progress$_a$). Clearly, Prairie Creek is a stronghold for coastal cutthroat trout within the Redwood Creek basin. The short term trend in population abundances in Prairie Creek approximated a straight line, and demonstrated population stability.

Population abundances by month in Prairie Creek ranged from 3 (late February 2012) to 4,071 (May 2011), and peaked in May (YRS 2011, 2012) and April (YR 2013). The two most important months for emigration were May/June (89% of total) in YR 2011, April/May (85% of total) in YR 2012, and April/May (81% of total) in YR 2013. The two most important months for emigration through lower Redwood Creek were July/August (79% of total) in YR 2011, June/July (65% of total) in YR 2012, and June/July (83% of total) in YR 2013 (Sparkman, In progress$_a$). Compared to lower Redwood Creek populations, Prairie Creek cutthroat trout smolts enter the lower river and estuary before most of the cutthroat trout smolts migrating through lower Redwood Creek.

The average size of cutthroat trout migrants in Prairie Creek ranged from 142 – 149 mm (FL), and 32.7 – 39.5 g (Wt) by study year, and averaged 145 mm (FL) and 35.1 g (Wt) across all years. The average size of Prairie Creek migrants was less than the average size of cutthroat trout captured in lower Redwood Creek (186 mm FL; 73.6 g Wt) over these same study years (Sparkman, In progress$_a$).

We used three characteristics to identify 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. Hybrid juveniles, the product of mating between 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, 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.

Few 0+ coho salmon were captured by the trap in lower Prairie Creek in three consecutive study years (total catch = 2,037 individuals). The low catches of 0+ coho salmon in lower Prairie Creek was contrasted by 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.

The population abundance of 0+ coho salmon passing through lower Prairie Creek ranged from 726 – 8,403, and averaged 4,137 individuals. The largest abundance occurred in YR 2012 (N = 8,403) and may reflect higher adult numbers, passive migration during high flow events, greater percentage of juveniles actively migrating downstream, or a combination of the three factors. The two most important months for downstream migration were April and May each study year, which accounted for 67 – 96% of the total population for a given study year. The migration of 0+ coho salmon through lower Prairie Creek indicated that these fish were moving downstream to rear, or possibly to enter the ocean at age-0. Thus, lower Redwood Creek and the estuary may serve as important places for young-of-year coho salmon to rear.

1+ Coho Salmon

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 – 10,447 individuals, and averaged 5,174. The majority of 1+ coho salmon were classified as smolts (78 – 96%), and zero were observed as being in a parr stage. The greatest catches occurred in YR 2013, which also had the highest population abundance.

Population abundances ranged from 8,446 – 23,580, averaged 17,389, and steadily increased each study year. The trend in abundance over three consecutive study years was positive; however, statistical significance was not detected ($p > 0.10$) even though the r value for the correlation test equaled 0.95. Similar to other species at age during YRS 2011 – 2013, the lack of a significant trend was likely due to low sample size ($n = 3$ 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 consistently more 1+ coho salmon smolts over the three study years. The abundance in Prairie Creek was considerably higher than 1+ coho salmon emigration through lower Redwood Creek over the same study periods. 1+ coho salmon abundance through lower Redwood Creek ranged from 113 - 48 and averaged 231 individuals (Sparkman, In progress$_a$). Clearly, Prairie Creek is a stronghold for 1+ coho salmon smolt abundances within the Redwood Creek basin.

1+ coho salmon population abundances by month in Prairie Creek ranged from 5 (August 2011) to 10,246 (April 2013), and peaked in May (YRS 2011, 2012) and April (YR 2013). The two most important months for emigration were May/June (94% of total) in YR 2011, April/May (71% of total) in YR 2012, and April/May (79% of total) in YR 2013. Migration in August was low each study year, and ranged from 0 – 5 individuals. The two most important months for emigration through lower Redwood Creek were April/May (96% of total) in YR 2011, May/June (75% of total) in YR 2012, and

May/June (96% of total) in YR 2013 (Sparkman, In progress$_a$). The migration period of 1+ coho salmon smolts passing through lower Prairie Creek was much more protracted compared to the smolt migration through lower Redwood Creek. The last 1+ coho salmon captured in lower Redwood Creek occurred on 6/21 in YR 2011, 6/26 in YR 2012, and 6/10 in YR 2013, compared to 8/9 in YR 2011, 7/15 in YR 2012, and 7/24 in YR 2013 for Prairie Creek populations.

The average size of 1+ coho salmon smolts in Prairie Creek ranged from 101 – 109 mm (FL), and 11.0 – 13.5 g (Wt) by study year, and averaged 104 mm (FL) and 12.2 g (Wt) across all years. The average size of 1+ coho salmon in Prairie Creek was slightly less than the average size for populations passing through lower Redwood Creek (106 mm FL; 12.9 g Wt) over these same study years (Sparkman, In progress$_a$). When comparing the size of 1+ coho salmon 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 cutthroat trout, which may compete for food resources with 1+ coho salmon in Prairie Creek.

<u>0+ Pink Salmon</u>

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 Redwood Creek 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 Redwood Creek during the fall of YR 2010 (D. Anderson, pers. com. 2012). Juvenile pink salmon have been captured with the smolt trap in upper Redwood Creek in YRS 2000, 2002, 2004, 2005, 2008, 2011, and 2013, and in lower Redwood Creek in YRS 2005 and 2013 (Sparkman, In progress$_a$).

0+ pink salmon were captured passing through lower Prairie Creek in YRS 2012 and 2013, with total catches equaling nine individuals. Thus, the parents were present in even and odd spawning years. It is hard to say if the parents of the juvenile pink salmon were strays or remnants of a historic run 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). 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 Redwood Creek (Sparkman, In progress$_{a}$), pink salmon are present and reproducing, albeit in low numbers.

ACKNOWLEDGEMENTS

We thank the Fisheries Restoration Grants Program (Project Numbers P1010302), and CDFW Steelhead Report Restoration Card Program, CDFW AFRAMP, and USGS California Cooperative Fish and Wildlife Research Unit for funding this study. We would also like to thank Leslie Farrar (USGS California Cooperative Fish and Wildlife Research Unit), Humboldt State University Sponsored Programs Foundation, CDFW Mary Kuehner, and CDFW (Scott Monday) for their assistance in managing the grant contract. Lastly, and by no means in the least, we thank the dedicated field crew (Melissa Gilbert, Michael Griffin, Charles Boone, Duane Linander, Dominic Vitali, Laurel Osborn, Jasper Amir, Matt Settlemayer, and David Kissinger, among others) for their hard work, attention to details, and positive attitudes.

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