

# **PRAIRIE CREEK SUB-BASIN LIFE CYCLE MONITORING PROJECT**

**California Cooperative Fish and Wildlife Research Unit  
Humboldt State University**

**Final Report for:  
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## EXECUTIVE SUMMARY

This report provides a synthesis of life cycle monitoring data collected for coho salmon in the Prairie Creek watershed of Humboldt County, California, during 1998-2011. Limited data for Chinook salmon, steelhead and coastal cutthroat trout are also presented in the body of the report and in appendices. The report is organized by habitat and life stages of coho salmon.

### ***Study Area***

Prairie Creek is a fourth-order tributary to Redwood Creek that drains a 102.5 km<sup>2</sup> sub-watershed. Prairie Creek is approximately 20 km long, but has 38 km of habitat available to anadromous fish. It is located in the Northern California coastal zone within Redwood National and State Parks, Humboldt County, California, in old growth redwood (*Sequoia sempervirens*) forest. Prairie Creek supports four species of salmonids, Chinook salmon, coho salmon, steelhead (*O. mykiss*), and coastal cutthroat trout (*O. clarkii clarkii*), as well as threespine stickleback (*Gasterosteus aculeatus*), Sacramento sucker (*Catostomus occidentalis*), prickly sculpin (*Cottus asper*), coast range sculpin (*C. aleuticus*), Pacific lamprey (*Lampetra tridentata*), and Pacific brook lamprey (*L. richardsoni*).

### ***Habitat***

In this study, habitat was measured each year to allocate fish sampling effort randomly among primary habitat types. The habitat data generally are coarse scale (pools, runs and riffles) represent summer conditions, although habitat surveys were conducted during one winter. The most common habitat in Prairie, Streelow and Lost Man creeks during all years was pool habitat. In Boyes Creek, riffles comprised the greatest area of habitat during all years. We found that maximum depth of pool habitats was greatest in Lost Man and Streelow creeks, it was intermediate in Prairie Creek and shallowest in Boyes Creek. We also found that average volume of pools in summer was greatest in Lost Man Creek and least in Boyes Creek, with volume in Boyes Creek being only 1/8<sup>th</sup> that in Lost Man Creek.

Daily average water temperatures were lowest during late December through February and increased to a maximum in July, but daily average maximum temperatures never exceeded

14 °C. Average monthly discharge in Prairie Creek was greatest and most variable during December and lowest and more constant during August.

### **Egg Survival**

Number of coho salmon fry emerging from natural redds sampled in three tributaries was variable. In Prairie Creek, all five redds trapped produced fry (average 908/redd). However, in Streeflow Creek only two of five redds trapped produced eggs (average 2,392/redd) and in Boyes Creek only 652 fry were produced from one redd, the other four producing nothing. Variation in the number of fry produced from redds in Prairie, Streeflow and Boyes creeks was explained primarily by the amount of fine sediment ( $< 3.33$  mm dia.) accumulating in these redds and the presence or absence of predaceous oligochaete worms.

Survival of coho salmon eggs in artificial redds averaged 70% at egg hatching and declined to 32% at fry emergence. However, excluding redds invaded by predaceous oligochaete worms, averaged 75% at egg hatching and declined to only 65% at fry emergence.

Coho salmon egg development and emergence from redds was related to accumulated water temperature. Fry were first recorded emerging from natural redds at 696 degree days and the peak of emergence occurred at 755 degree days. Ninety percent of fry captured had emerged from redds by 809 degree days. Degree days recorded correspond with an average date at first emergence of 26 February, at peak emergence of 4 April and 90% emergence of 12 April.

### **Juvenile Fish Abundance**

Abundance of juvenile coho salmon in Prairie Creek averaged 5,454 fish, while in Boyes Creek it averaged 2,352 and in Streeflow Creek 2,656 fish. Abundance did not differ statistically among most years.

Unlike abundance, density of fish species can be compared among watersheds. Density of juvenile coho salmon during summer in Boyes Creek ( $0.77 \text{ m}^2$ ) was statistically greater than in either Prairie Creek ( $0.33 \text{ m}^2$ ) or Streeflow Creek ( $0.38 \text{ m}^2$ ). Among all streams, density did not differ statistically among years, although the probability value was only slightly greater than alpha (0.05).

Survival of juvenile coho salmon between July and October ranged from 60% to 94% among all streams and years. Survival was greatest in Prairie Creek (mean = 92%), intermediate in Streeflow Creek (mean = 75%), and lowest in Boyes Creek (mean = 68%). Among years,

summer survival ranged from 72% in 2003 to 87% in 1999 and was not statistically different.

Fork length of juvenile coho salmon during July and August averaged 59.6 mm, while weight averaged 2.35 g. During 1999-2003, average fork length in October was 65.6 mm while average weight was 3.74 g and in May average fork length was 81.7 mm and weight 8.16 g. Size of juvenile coho salmon in the Prairie Creek watershed was negatively related to their density in pool and run habitats, though this relationship was not statistically significant.

Specific growth rates of juvenile coho salmon in the Prairie Creek watershed were greatest between May, at hatching, and July, and then declined during July – October and October - March. Absolute growth in both length and weight was greatest during October – March and lowest during July - October.

Diet of juvenile coho salmon was varied and contained organisms commonly found drifting in the water column as well as organisms associated with the benthos. The most important prey in stomachs during spring, summer and fall were larvae and adult Diptera and Oligocheata. Amphipoda also contributed substantially to the diet of juvenile coho salmon in Streelow Creek, but not in other streams.

### ***Downstream Migrant Trapping***

Average annual production of age 1+ coho salmon estimated from the lower Prairie Creek site was 9,078 smolts and in Streelow Creek it was 2,942 smolts. Average annual production of age 1+ coho salmon estimated from Boyes Creek was only 467 smolts and assumed to be reflected in the lower Prairie Creek trap, located downstream of the confluence with Boyes Creek. The low coho salmon smolt production from Boyes Creek is notable, being only 1/6<sup>th</sup> of the production from Streelow Creek despite being roughly the same length and having higher densities of juveniles than the other tributaries.

Annual coho salmon smolt migration in the Prairie Creek watershed began as early as calendar days 70 – 80, with around half the migration completed by day 100 – 120 and 95% of the migration by day 120 – 160. These dates correspond with the range of median dates of migrant Spence and Hall (2010) report for California streams. Diel timing of migration of coho salmon smolts in Prairie Creek occurred during most of the day. Ninety-three of 100 PIT tagged smolts were re-sighted at the lower Prairie Creek trap during a period beginning at 2100 hours and extending until 1000 hours the following day.

Eleven species of fish were collected in downstream migrant traps (DSMT). The most common species/age class collected were age 0+ coho salmon, with average annual catches ranging from 11,790 at the Boyes Creek site to 36,121 at the upper Prairie Creek site. Chinook salmon (age 0+) were also abundant at both Prairie Creek sites, with average annual catch at the lower site being 26,865 and at the upper site 44,136. Chinook salmon were, however, far less abundant at the Boyes Creek and Streelow Creek sites.

### ***Adult Salmonid Escapement***

Average escapement of coho salmon to Prairie Creek estimated using live fish AUC was 297 fish, using redd expansion methods it was 312 fish. Coho salmon escapement using redd expansion methods was positively related to escapement estimated using AUC methods. These average coho salmon escapements estimates for Prairie Creek relied on sampling about 16 km of habitat most years, providing an average spawner/km estimate of 18.5 to 19.5 fish. Escapement of Chinook salmon averaged 272 fish when estimated from live fish AUC. Escapement of steelhead and coastal cutthroat trout was much lower. Both coho salmon and Chinook salmon showed cyclical abundance.

Run timing of coho and Chinook salmon, measured as average daily catch at the weir, overlapped considerable. During five years of weir operation, average date of Chinook salmon arrival at the weir preceded coho by about one week. Run timing of coho salmon was, however, more extended than Chinook salmon.

### ***Survival***

Estimated rates of survival for coho salmon during freshwater within the ranges reported by others. Calculated survival during freshwater residency averaged 30.8% and ranged from 16.3% to 82.3%. Eliminating two years when freshwater survival was considered high (56.3% and 82.3%) resulted in a mean freshwater survival rate estimate of 23.1%.

Marine survival reported here is thought to be confounded by errors in either adult escapement or smolt production, or both. Calculated marine survival rates averaged 27.1% and ranged from 1.7% to 78.7%. Eliminating the two years when marine survival was highest (57.5% and 78.7%) reduced average survival to 16.9%.

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## 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 northern California's coastal river systems, both the California Coastal Chinook salmon (*O. tshawytscha*) and Southern Oregon/Northern California Coasts coho salmon (*O. kisutch*) ESUs 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, Solazzie 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. This plan describes a statistically valid approach to monitoring adult salmonid escapement at a regional spatial scale and an approach to monitoring multiple life stages of salmonids in selected watersheds, referred to as life cycle monitoring stations.

When data from life cycle monitoring stations monitoring multiple life stages are combined, they enable investigators to estimate survival in the ocean and in freshwater. When multiple life stages are monitored over long periods, inferences can be made about freshwater habitat, freshwater productivity and ocean conditions influencing survival.

In this report, estimates of adult salmonid escapement, juvenile salmonid abundance and abundance of downstream migrating salmonids are reported for Prairie Creek. The data reported cover more than a decade, beginning in 1998 and extending through 2011.

## STUDY AREA

The primary study area was the upper 13 km of Prairie Creek. Prairie Creek is a fourth-order tributary to Redwood Creek that drains a 102.5 km<sup>2</sup> watershed (Figure 1). Prairie Creek is approximately 20 km long, but has 38 km of habitat available to anadromous fish (Cannata et al. (2006). It is located in the Northern California coastal zone within Redwood National and State

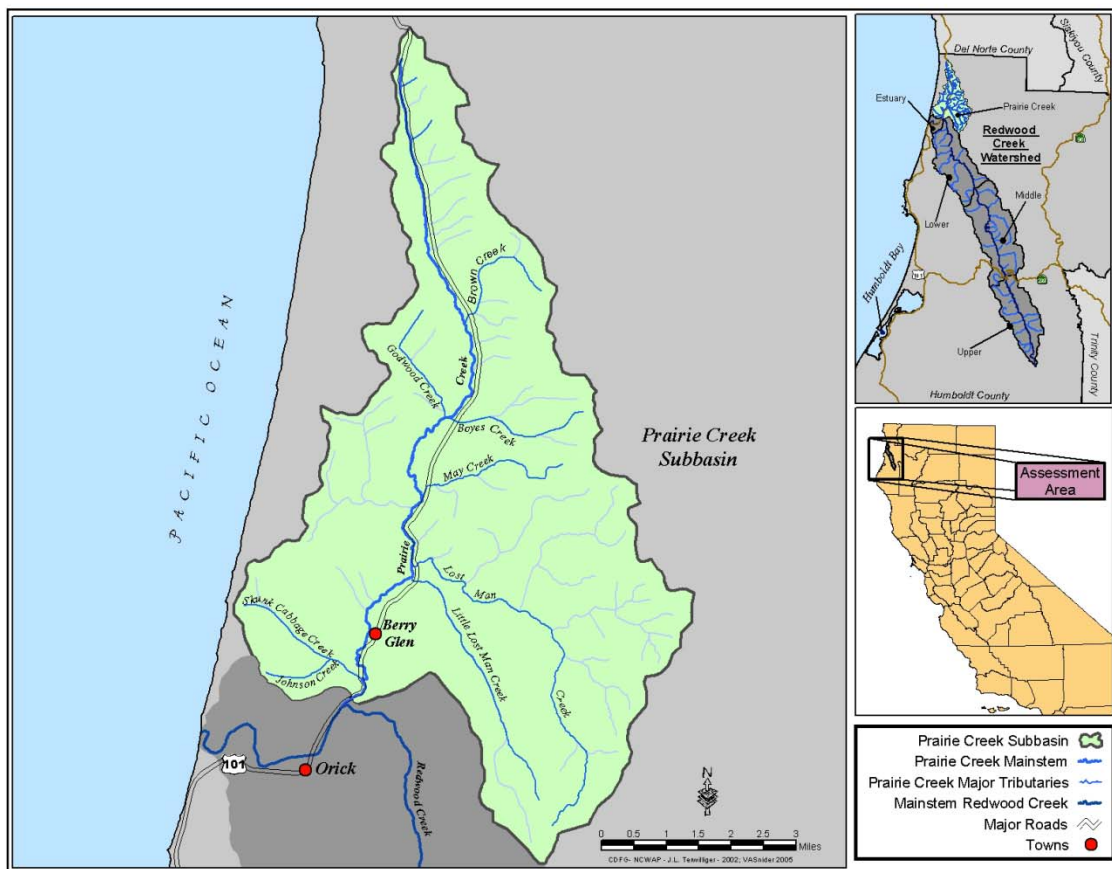


Figure 1. Map of Prairie Creek watershed showing its location in the Redwood Creek watershed (from Cannata et al. 2006).

Parks, Humboldt County, California, in old growth redwood (*Sequoia sempervirens*) forest. Prairie Creek supports four species of salmonids, Chinook salmon, coho salmon, steelhead (*O. mykiss*), and coastal cutthroat trout (*O. clarkii clarkii*), as well as threespine stickleback (*Gasterosteus aculeatus*), Sacramento sucker (*Catostomus occidentalis*), prickly sculpin (*Cottus asper*), coast range sculpin (*C. aleuticus*), Pacific lamprey (*Lampetra tridentata*), and Pacific brook lamprey (*L. richardsoni*).

Tributaries sampled during different periods of the study included Lost Man Creek, Boyes Creek and Streelow Creek. Lost Man Creek, the largest tributary to Prairie Creek drains a 51 km<sup>2</sup> watershed. Although the watershed contains some old growth redwood, portions of this watershed were logged heavily in the past. The vegetation in the lower portion of Lost Man Creek is dominated red alder (*Alnus rubra*), with second growth redwood, mixed with big leaf maple (*Acer macrophyllum*), California-laurel (*Umbellularia californica*). Second growth redwood predominates the vegetation of the upper portion of the watershed.

Boyes Creek, a tributary of Prairie Creek, located in Redwood National and State Parks, Humboldt County, California, is a third order creek that drains a 4.4 km<sup>2</sup> watershed. The study reach was a 2.3 km section beginning at the mouth of the creek. Although the watershed contains some old growth redwood, portions of this creek were clear-cut in the past. Boyes Creek is dominated with second growth redwood, mixed with big leaf maple, red alder, California-laurel, and western hemlock (*Tsuga heterophylla*) (Sparkman 2004). In addition to coho salmon, the study reach contained Chinook salmon, steelhead, coastal cutthroat trout, threespine stickleback, prickly sculpin, coast range sculpin and Pacific lamprey (Bell et al. 2001).

Streelow Creek is a third order stream and a tributary to Prairie Creek that drains a 5.7 km<sup>2</sup> watershed. The study reach was a 2.2 km section beginning at the mouth of the stream. This creek was extensively clear cut logged in the 1950 -1960's for old growth redwood, and is considered to be in a recovering state. The watershed is forested with second growth redwood, mixed primarily with red alder (Sparkman 2004).

## METHODS

### *Habitat*

Area of habitat available to fish was estimated each year in July or August. In Prairie Creek the area sampled extended from the confluence of Brown's Creek upstream six km, in Boyes Creek it extended from the confluence with Prairie Creek upstream two km, in Streelow Creek it extended from the confluence with Prairie Creek upstream two km and in Lost Man Creek it extended from the confluence with Prairie Creek upstream four km. Surveyed stream habitats were delineated into six habitat strata: pools, runs, riffles, and "other". Criteria detailed in Hawkins et al. (1993) and Bisson et al. (1982) were used to distinguish habitat types and geomorphic unit breaks. Small habitat units characterized by a length to average wetted width ratio of less than one, were included as part of the next upstream unit (Roper and Scarnecchia 1995). Habitat units classified as complex or "other" were considered unsuitable for estimation of fish abundance using diver observation or electrofishing removal methods. Complex habitat units were generally characterized by extreme physical habitat complexity due to extensive undercut banks and (or) abundant woody debris. "Other" habitat units were mostly minor side channel habitat of marginal width and depth. Physical measurements of thalweg length, wetted widths, and approximate maximum depth were recorded for all surveyed habitats. In pools, wetted width measurements were taken at the upstream, middle and lower portions of habitat units, whereas in runs and riffles width measurements were taken at the upstream and downstream portions of habitat units. Surveyed habitats were numbered sequentially allowing for subsequent identification of individual habitat units.

Water temperature was recorded continuously using temperature data recorders (Hobo Inc., Pocase, MA) in Prairie, Streelow and Boyes creeks during 1998 – 2001. Two to four data loggers programmed to record at 1 hr intervals were placed in each stream and data were reported as daily averages. During 2000 – 2011, daily average water temperature data were obtained from a gauge operated by the National Park Service in Prairie Creek near the confluence of May Creek. Discharge data were also obtained from this gauge for the same period.

## ***Egg Survival***

In 2000, artificial redds were constructed and planted with eyed coho salmon eggs to estimate survival at three important life history stages (hatching, alevin, and emergent fry), and to determine specific relations of average egg container survival with average abiotic and biotic (worms) redd variables. Five artificial redds were dug in each of Prairie, Boyes and Streelow creeks on 25 - 26 January, 2000 using a McLeod shovel. Redds were randomly located in likely coho salmon spawning areas. Two gravel inflow rate standpipes were placed in each redd, one 30 cm upstream of the first two egg containers and the other 30 cm downstream of the last two egg containers. The standpipes were set such that the holes ranged from 18 - 25 cm deep when covered with gravels.

Coho salmon eyed eggs from the California Department of Fish and Game Trinity River Hatchery were used in the experiment. Trinity River Hatchery coho salmon are within the same evolutionarily significant unit (ESU) as Prairie Creek stock and were certified as disease free. Six egg containers were placed in each red, at a depth of 25 cm, in three pairs placed 0.3 m apart along the midline of the redd. Fifty eyed eggs were placed in each egg container. Egg containers were made of styrene, which is similar to polyvinyl chloride (PVC), and were cylindrical in shape. Each egg container had 104 - 2.8 mm diameter holes drilled to ensure adequate water passage.

Two days prior to pulling the egg containers, inflow rates (ml/sec), dissolved oxygen concentration (mg/l), specific conductance ( $\mu\text{S}/\text{cm}$ ), and temperature ( $^{\circ}\text{C}$ ) for each redd were recorded from each stand pipe and averaged to give redd values.

Paired egg containers were randomly drawn without replacement for removal and counting of dead and surviving eggs, eleutheroembryos, alevins, and emergent fry at time intervals based upon egg ages of 55, 71, and 90 - 92 days. The time intervals corresponded to the hatching stage, the alevin stage, and the emergent fry stage, respectively. Each egg container was excavated and lifted from the redd substrate, and immediately placed in a 5 gallon bucket to prevent the escape of water and sediments. Egg container water and fine sediments  $< 2.8$  mm that intruded into egg containers were then placed in individual containers for further analysis.

Eggs were considered dead if eye pigments (black and gold) were missing, or if the egg appeared opaque. Eluetheroembryos, alevins, and emergent fry were considered dead if they

appeared opaque, not breathing, nor moving when placed in a small dish of water. The paired, egg container survival data were averaged to determine an average percentage of survival in egg containers. Predacious oligochaete worms (*H. ichthyophagous*) were also counted and collected if present.

Fine sediments that intruded into the egg containers were oven dried (oven model 17, Precision Scientific Co., Chicago, IL) at 60 - 80 °C for 8 - 10 hours, and weighed on an analytical balance (model A5200, Ohaus Inc., Pine Brook, NJ) to the nearest 0.0001 g. The amount of fine sediments in paired egg containers was then averaged for statistical analyses.

Multiple regression was used to identify significant relations of abiotic and biotic independent variables with egg survival. All possible subsets of independent variables were used in model selection. The number of regression models used in statistical analysis was limited to 15 to reduce the risk of overfitting statistical models to a relatively small number of observations. AIC<sub>c</sub> adjusted for small sample sizes, estimates of posterior relative probabilities for each model, and the probability that the best fitting model contained a particular independent variable were once again used for model evaluation (Burnham and Anderson 1998).

### ***Juvenile Abundance***

A modified two-stage sampling method was used to estimate juvenile coho salmon abundance in pools and runs (Hankin and Reeves 1988). This method consists of first estimating habitat available to fish, as described above, followed by two-stage fish sampling.

An adaptive sequential independent sampling scheme (ASIS) was used to select first phase sample units with expected inclusion probability equal to 0.5. First phase sample units were selected after habitat units (shallow pools or runs) were classified and measured. Shallow pool and run habitat units selected during the first phase were flagged by a habitat survey crew at the upper and lower habitat boundaries. Shortly thereafter, a two-person dive crew conducted single dive counts in flagged first phase units. Individual units were sampled by a single diver, with two divers working upstream while sampling alternating habitat units. Divers recorded numbers of juvenile coho salmon, steelhead and coastal cutthroat trout observed within habitat units. After a single dive count was made in a given first phase unit, ASIS was used to determine whether or not the sampled unit was selected at the second phase of sampling. Nominal ASIS

selection probabilities for the second phase of sampling were set at 0.25 for the shallow pool habitat strata and 0.33 for the run habitat strata. All deep pool units were flagged for sampling. For second phase units, the following decision rule was used to determine mode of calibration: a) if the count of juvenile coho salmon was less than or equal to 20, then the method of bounded counts (MBC) (Robson and Whitlock 1964; Routledge 1982) was used to calibrate the first phase dive count; or

b) if the count of juvenile coho salmon exceeded 20, then 3 to 5 pass depletion electrofishing was used to calibrate the first phase dive count. When the method of bounded counts was used for calibration of second phase units, three additional single-pass dive counts were immediately conducted. Abundance of juvenile coho salmon ( $\hat{Y}$ ) in units selected for MBC calibration were determined using the formula:

$$\hat{Y}_{MBC} = X_m + (X_m - X_{m-1})$$

where  $X_m$  is the highest count and  $X_{m-1}$  the second highest count.

All surveyed deep pool units were selected for abundance sampling. Four repeated dive counts were made in deep pool units. If densities of juvenile coho salmon were low, then valid MBC estimates of abundance could be estimated. When densities were high, however, the MBC assumptions (no double counting of fish) could not be met. Therefore, reliable estimation of abundance was not consistently possible for deep pools. Depletion electrofishing was used in selected second phase units where first phase dive counts exceeded 20 or more juvenile coho salmon. All second phase units selected for electrofishing calibration were sampled within one day of corresponding first phase dive counts. Units sampled using electrofishing methods were blocked with 6 mm mesh netting at the upstream and downstream unit breaks. Blocked units were sampled using two battery backpack electroshockers (Smith and Root Model 12) with multiple removal passes of timed equal effort. Number of juvenile coho salmon caught was recorded for each electrofishing pass within a sampled unit and fish abundance ( $\hat{y}_J$ ) determined using a jackknife estimator (Pollock and Otto 1983):

$$y_J = \sum_{i=1}^{m-1} C_i + mC_m$$

where  $C_i$  is the number of fish caught on pass  $i$ , and  $m$  is the number of passes.

We used a multistage design (Hankin 1984) to estimate abundance in riffles.

In the riffle stratum, an initial random start between 1 and 12 was selected, and then

every 12th riffle unit thereafter was flagged and subsequently sampled using 2 to 3 pass depletion electrofishing.

Total abundance of juvenile coho salmon in deep pool, run and shallow pool habitat was estimated using special cases of the general regression estimators presented in Sarndal et al. (1992). Second-phase “calibration” estimates of juvenile coho salmon abundance were treated as error free measurements of true unit abundance (Dolloff et al. 1993). During years (1999-2004) when total abundance was estimated in both summer and fall, summer survival rates of juvenile coho salmon was estimated as the difference in abundance between the summer and fall sample.

### ***Downstream Migrant Trapping***

During 1999 through 2003, four downstream migrant traps (DSMT) were operated. One on Prairie Creek above the confluence of Brown’s Creek, another on Prairie Creek above the confluence of Streelow Creek, one on Boyes near the mouth and one on Streelow Creeks near the mouth. During 2004 through 2010, a single DSMT was operated on Prairie Creek above the confluence of Streelow Creek. In 2011, a single screw type DSMT was operated at the mouth of Prairie Creek. The smolt trapping season typically began in mid-March and extended through mid-June, however in 2011 the DSMT was operated to August. Weather influenced DSMT operation and some years DSMT were installed as early as February and other years as late as April.

Until 2011, downstream migrant traps consisted of fyke nets installed facing upstream in the thalweg, with the cod-end attached to a 15.24 cm diameter PVC pipe that was 5-10 m long, depending on the trap location. The PVC pipe lead into a live box. In 2011, a five foot diameter screw type DSMT was used. Traps in all types of DSMT were checked daily and fish enumerated and traps cleared of debris.

Each week a random sample of up to 50 age 0+ and 1+ coho salmon, age 0+ Chinook salmon, age 0+ and 1+ steelhead and coastal cutthroat trout were selected for recording biometric data. These randomly selected fish were anesthetized with MS-222 in 4 L plastic containers before recording fork length (mm) and wet weight (0.1 g) on an Ohaus Scout digital balance. Coho salmon without an adipose fin were scanned with a handheld PIT tag pocket reader to record the PIT tag number. After length and weight were recorded, fish were placed in 19 L

buckets filled with cool stream water to recover. Age 0+ and age 1+ fish were placed in separate buckets. After recovering from anesthesia, 0+ fish were transported 100 m downstream of the trap site and released and older fish were transported 200 m downstream of the trap site and released.

The efficiency of DSMT in capturing fish is less than 100%, therefore catches in DSMT represent a portion of the total fish migrating downstream. We estimated trap efficiency of the DSMT and the number of age 1+ coho salmon migrating downstream weekly. Efficiency estimates consisted of marking a portion of age 1+ coho salmon captured in the trap live box and releasing them upstream 100-200 m. We then used Darroch Analysis with Rank-Reduction (DARR), a program for analyzing stratified mark-recapture data from small populations, to estimate weekly abundance of age 1+ coho salmon migrating downstream (Bjorkstedt 2000). All other species and age classes were enumerated and their raw catches reported.

## ***Adult Escapement***

### *Stream Surveys*

Walking surveys were conducted each year over the spawning period, beginning when the bar on Redwood Creek breached and continuing through to mid-March or early April. To accomplish surveys, four reaches were established on Prairie Creek, one on Boyes Creek, one on Streelow Creek and two on Lost Man Creek (Table 1). Each reach was surveyed at 10-14 day intervals, unless stream flow was so high as to be unsafe or heavy rain limited visibility below the water surface. Surveys were conducted by two trained surveyors walking upstream and

Table 1. Location and length of study site reaches on Prairie, Boyes, Streelow and Lost Man creeks.

| Reach No. | Start and end locations                                     | Location (m)    | Reach length (m) |
|-----------|-------------------------------------------------------------|-----------------|------------------|
| 1         | Streelow Creek to Boyes Creek                               | 0 - 4,175       | 4,175            |
| 2         | Boyes Creek to Browns Creek                                 | 4,175 - 7,550   | 3,375            |
| 3         | Browns Creek to Zig Zag #2 trail bridge                     | 7,550 - 11,070  | 3,520            |
| 4         | Zig Zag #2 trail bridge to end of study area                | 11,070 - 13,270 | 2,200            |
| 5         | Boyes Creek                                                 | 0-2,000         | 2,000            |
| 6         | Streelow Creek                                              | 0-2,200         | 2,200            |
| 7         | Lost Man Creek, confluence to 1 <sup>st</sup> bridge        | 0-1,800         | 1,800            |
| 8         | Lost Man Creek, 1 <sup>st</sup> bridge to end of study area | 1,800-4,200     | 2,400            |

recording observations of live fish, redds, and carcasses. Stream reaches were flagged with 50 m markers to allow surveyors to record approximate stream location of observed live fish, redds, and carcasses. Surveyors recorded species, sex, estimated total length, and distance upstream of each live fish observed. Redds built since the previous survey were measured to record length and width. Measured redds were identified, by placing surveyors flagging on riparian vegetation near the downstream end, to avoid double counting. Surveyors recorded the stream location of each redd. Carcasses were identified to species and sex, total length, and location was recorded. Carcass condition was recorded as fresh (eyes clear and flesh firm), decayed minus (eyes cloudy and flesh firm), decayed plus (eyes cloudy and flesh very soft), or skeleton (flesh falling off). All carcasses were scanned with a PIT tag reader to identify recaptured fish previously tagged and fish were also checked for the presence of a secondary mark, an operculum punch, in case of PIT tag loss. On initial sighting, carcasses were tagged with a uniquely numbered metal tag on the lower jaw before being placed back in the stream.

To investigate variation between sets of surveyors, double-blind surveys were conducted during two year of the study. On double-blind surveys one pair of observers first surveyed the stream reach, recording the distances upstream of all live fish, redds, and carcasses (but without flagging the observed redds). Two hours after the first pair of observers began their survey, another pair of observers surveyed the same stream reach, recorded the same information and also flagged redds. Observations of live fish, redds, and carcasses were compared.

### *Escapement Estimation*

#### *Area-Under-the-Curve*

Live fish counts made on spawning surveys were used to estimate escapement using the trapezoidal AUC method (Bue et al. 1998, English et al. 1992). Fish that were not identified to species by stream surveyors were classified as unknown. These fish were later assigned as Chinook salmon, coho salmon or steelhead based on logistic regression incorporating date and distance upstream.

Escapement of Chinook salmon, coho salmon and steelhead as calculated using a spreadsheet model incorporating elements of a AUC software package (Irvine et al. 1993). The model calculated daily stream population estimates, the area under the population curve, and the

AUC escapement. The daily population of fish in the stream ( $x_i$ ) was estimated by dividing the number of fish observed ( $fo$ ) by the observer efficiency factor ( $oe$ ):

$$x_i = \frac{fo}{oe}$$

An observer efficiency of 35% was used to expand the observed number of fish to an estimate of the actual number of fish present during each sampling period. This expansion value was based on a study of observer efficiency in Prairie Creek (Poxon 2012).

Each of the study reaches were surveyed on separate days, the data from each of these surveys was then summed for each stream to calculate the total number of fish observed during each sampling period. For Prairie Creek, the mean date of the four surveys was recorded as the survey date. The sampling period population estimates were plotted against time and the area under the population curve ( $auc$ ) was estimated by summing the rectangular areas that approximate the area under the escapement curve:

$$auc = \sum_{i=2}^n (t_i - t_{i-1}) \cdot \frac{(x_i + x_{i-1})}{2}$$

where  $t_i$  is the water year day of the  $i^{th}$  survey day where the water year is defined as beginning on October 1, when  $t=1$ , and ending on September 30, when  $t=365$ .

Escapement ( $\hat{E}_{auc}$ ) was then estimated by dividing the  $auc$  by the fish species' residence time ( $rt$ ):

$$\hat{E}_{auc} = \frac{auc}{rt}$$

Residence times were estimated to be 12 days for Chinook salmon and 17 days for coho salmon and were calculated for the Prairie Creek survey area through the recovery of carcasses of fish that had been tagged as live fish at a weir (Wright 2011). Residence time was estimated

as the number of days between a fishes initial capture at the weir and its recaptured as a carcass. Only carcasses found in a fresh condition (i.e. exhibiting recent death) were used to calculate residence time.

### *Redd Count Expansion*

Counts of redds was also used to estimate escapement of each species. Surveyors counted redds present in each stream and the species of fish present on the redd. If no fish were seen at the redd site, the redd was classified as being built by an unknown species.

Species were assigned to unidentified redds using a logistic regression equation created for this purpose using Prairie Creek data (Gough 2010). In analyzing survey data collected on Prairie Creek from 1998-2004, Gough (2010) found that the probability that an unknown redd was built by a coho salmon ( $\text{Pr}(\text{OK})$ ) was strongly related to the water year date ( $t$ ) on which the redd was first seen on a survey. The model he used was:

$$\text{Pr}(\text{OK}) = 1 / (1 + e^{-(-14.0304 + 0.1531 * t)})$$

If  $\text{Pr}(\text{OK})$  was equal to or greater than 0.50, the unidentified redd was determined to have been built by a coho salmon. If  $\text{Pr}(\text{OK})$  was less than 0.50, the unidentified redd was classified as a Chinook salmon redd. A similar logistic regression model was used to separate steelhead from salmon.

Redd count totals were then expanded by each species' sex ratio as observed at the weir to estimate escapement ( $\hat{E}_{redd}$ ) using the following equation:

$$\hat{E}_{redd} = R + \left( \frac{M + J}{F} \times R \right)$$

where  $R$  is the number of redds counted,  $M$  is the number of males captured at a weir,  $J$  is the number of jacks captured at the weir, and  $F$  is the number of females captured at the weir. During years, or on tributaries, a weir was not operated, the variables  $M$ ,  $F$  and  $J$  were based on visual observations.

### *Weir Operation*

A resistance-board weir was installed on Prairie Creek and operated from the 2005/2006 through the 2009/2010 season. A second weir was built on Lost Man Creek during the 2008/2009 season and operated through the 2009/2010 season. Resistance-board weirs consist of a series of connected panels installed across the stream to block fish passage. Weir panels, made of PVC pipes with resistance boards fastened on the downstream end, are attached to a cable stretched across the stream bottom. The flotation of the closed PVC pipes and the force of water pushing against the resistance boards cause panels to float and maintain position at the top of the water column. Instead of becoming clogged with large woody debris and blowing out, these weirs are designed to briefly submerge and allow debris to float downstream. When floating in the water column the weir will effectively block all salmon from moving upstream.

The resistance-board weir on Prairie Creek was installed at the downstream end of study reach 1 (Table 1) while the weir on Lost Man Creek was installed at the downstream end of study reach 7 (Figure 1). Both weirs were used to capture Chinook and coho salmon migrating upstream to their spawning grounds. A passage chute was installed in the weir at the thalweg to funnel fish trapped by the weir upstream into a live box. The live box was checked two or more times daily for trapped fish, depending on the frequency of fish capture.

Captured fish were tagged with 32 mm passive integrated transponder (PIT) tags directly below the dorsal fin on the left side of the body. PIT tagging allowed fish to be individually recognized when carcasses were scanned with handheld PIT tag readers on stream surveys. Fish also received an operculum punch as a secondary mark in case of tag loss. Some fish were tagged with Lotek radio transmitters instead of PIT tags and received a secondary mark of a yellow hog-ring tag. All fish were identified to species and, sex, total length and condition were recorded. Fish condition was recorded as: 1) fresh, brightly colored with clear eyes; 2) dark coloration with milt or eggs being released; or 3) the fish had completed spawning. After handling, the fish were placed in a recovery basin for half an hour before being released upstream of the weir.

### ***Survival***

Survival of coho salmon  $S_{FW}$  was calculated for the both period of freshwater residency and for the period of ocean occupancy. Survival during freshwater residency was calculated as the difference between juvenile abundance.

$$S_{FW} = \frac{N_{SM(t)}}{N_{J(t-1)}}$$

where  $N_{SM}$  = smolt production,  $N_J$  = juvenile abundance and  $t$  = time (year). Similarly, survival during ocean residency was calculated as:

$$S_M = \frac{N_{A(t-2)}}{N_{SM(t)}}$$

where  $N_A$  = adult escapement.

## RESULTS

### *Habitat*

Habitat available to juvenile fish was surveyed annually in Prairie Creek during 1998-2011, in Boyes, Streelow creeks during 1998-2006 and in Lost Man Creek during 2005-2011. Amount of habitat surveyed each year averaged 25,919 m<sup>2</sup> in Prairie Creek, 6,048 m<sup>2</sup> in Boyes Creek, 8,102 m<sup>2</sup> in Streelow Creek and 21,675 m<sup>2</sup> in Lost Man Creek (Tables 2, 3, 4, 5). However, average area surveyed in each stream was much greater in some years than other years (Table 4).

The most common habitat type in three of the four streams during all years was pool habitat, representing 30.9-51.5% of the area in Prairie Creek, 39.4-64.5% in Streelow Creek, 23.8-46.5% in Lost Man Creek, but only 15.9-38.1% in Boyes Creek (Tables 2, 3, 4, 5). Run habitats were the second most common habitat in all but Lost Man Creek, but low area of run habitats may have been influenced by observers in 2010 (Table 5). Riffle habitat comprised the greatest area of habitat in Boyes Creek (23.6-50.2%) during all years and represented the second most area in Lost Man Creek (Tables 3, 5).

Maximum depth of pool habitats varied among streams (two-way ANOVA,  $df = 3$ ,  $F = 60.89$ ,  $p < 0.001$ ) and among years ( $df = 13$ ,  $F = 13.85$ ,  $p < 0.001$ ). Average maximum pool depth in Lost Man Creek (0.80 m) and Streelow Creek (0.77 m) did not differ ( $p = 0.383$ ), but did differ from the average maximum pool depth in Prairie Creek (0.70 m) and Boyes Creek (0.54 m) ( $p < 0.001$  in all comparisons). Average volume of pools in summer varied from 88.4 m<sup>3</sup> in Lost Man Creek to 46.5 m<sup>3</sup> in Prairie Creek, 37.0 m<sup>3</sup> in Streelow Creek and 12.7 m<sup>3</sup> in Boyes Creek. Volume of pool habitats in summer was greater than any other habitat and two to three times the volume of run habitats.

During limited winter surveys, volume of pool habitats in Prairie Creek (60.8 m<sup>3</sup>) and Streelow Creek (42.1 m<sup>3</sup>) were qualitatively greater than during summer and volume of run habitats was only slightly less than pools. In Boyes Creek, however, volume of pool habitats in winter (11.6 m<sup>3</sup>) was less than in summer and less than winter run habitats (15.9 m<sup>3</sup>).

Table 2. Percentage of habitat area in four habitat types and total area of habitat surveyed in Prairie Creek 1998 -2011.

| Year | Percentage of Total |        |           |         | Total (m <sup>2</sup> ) |
|------|---------------------|--------|-----------|---------|-------------------------|
|      | % Pools             | % Runs | % Riffles | % Other |                         |
| 1998 | 51.5                | 23.4   | 24.3      | 0.8     | 25,740                  |
| 1999 | 32.2                | 28.0   | 23.6      | 16.3    | 25,184                  |
| 2000 | 37.9                | 25.7   | 29.1      | 7.2     | 26,672                  |
| 2001 | 41.6                | 32.5   | 25.9      | 0.0     | 24,393                  |
| 2002 | 46.1                | 27.4   | 25.8      | 0.7     | 26,773                  |
| 2003 | 48.6                | 28.6   | 22.1      | 0.6     | 26,575                  |
| 2004 | 45.3                | 25.8   | 28.9      | 0.0     | 24,939                  |
| 2005 | 41.2                | 37.0   | 21.8      | 0.0     | 23,905                  |
| 2006 | 37.2                | 35.0   | 26.7      | 1.1     | 22,446                  |
| 2007 | 41.2                | 38.9   | 18.0      | 1.9     | 22,644                  |
| 2008 | 48.0                | 27.1   | 23.9      | 1.0     | 22,439                  |
| 2009 | 43.2                | 30.8   | 24.0      | 2.0     | 43,047                  |
| 2010 | 35.7                | 31.0   | 32.1      | 1.2     | 26,124                  |
| 2011 | 30.9                | 29.8   | 27.9      | 11.4    | 24,273                  |

Table 3. Percentage of habitat area in four habitat types and total area of habitat surveyed in Boyes Creek 1998 -2006.

| Year | Percentage of Total |        |           |         | Total (m <sup>2</sup> ) |
|------|---------------------|--------|-----------|---------|-------------------------|
|      | % Pools             | % Runs | % Riffles | % Other |                         |
| 1998 | 38.1                | 22.9   | 38.2      | 0.8     | 6,111                   |
| 1999 | 33.1                | 42.6   | 23.6      | 0.6     | 5,854                   |
| 2000 | 27.9                | 35.3   | 36.8      | 0.0     | 6,852                   |
| 2001 | 31.9                | 24.2   | 43.3      | 0.6     | 6,133                   |
| 2002 | 26.7                | 19.6   | 45.7      | 8.1     | 5,757                   |
| 2003 | 15.9                | 33.9   | 50.2      | 0.0     | 5,751                   |
| 2004 | 35.3                | 21.7   | 42.6      | 0.4     | 5,024                   |
| 2005 | 22.0                | 38.6   | 39.4      | 0.0     | 12,132                  |
| 2006 | 27.0                | 27.6   | 45.4      | 0.0     | 4,673                   |

Table 4. Percentage of habitat area in four habitat types and total area of habitat surveyed in Streeflow Creek 1998 -2006.

| Year | Percentage of Total |        |           |         | Total (m <sup>2</sup> ) |
|------|---------------------|--------|-----------|---------|-------------------------|
|      | % Pools             | % Runs | % Riffles | % Other |                         |
| 1998 | 64.7                | 24.9   | 7.3       | 3.1     | 12,226                  |
| 1999 | 55.1                | 30.8   | 13.8      | 0.4     | 8,684                   |
| 2000 | 53.6                | 27.4   | 19.0      | 0.0     | 8,419                   |
| 2001 | 39.4                | 40.6   | 18.9      | 1.1     | 7,238                   |
| 2002 | 46.4                | 33.5   | 19.9      | 0.2     | 8,184                   |
| 2003 | 60.9                | 27.6   | 10.8      | 0.8     | 7,570                   |
| 2004 | 43.3                | 33.3   | 21.1      | 2.3     | 5,012                   |
| 2005 | 54.0                | 35.3   | 9.1       | 1.6     | 5,275                   |
| 2006 | 47.5                | 32.9   | 18.9      | 0.6     | 5,686                   |

Table 5. Percentage of habitat area in six habitat types and total area of habitat surveyed in Lost Man Creek 2005 -2011.

| Year | Percentage of Total |        |           |         | Total  |
|------|---------------------|--------|-----------|---------|--------|
|      | % Pools             | % Runs | % Riffles | % Other |        |
| 2005 | 46.5                | 28.0   | 25.6      | 0.0     | 5,159  |
| 2006 | 23.8                | 13.0   | 63.1      | 0.0     | 4,007  |
| 2007 | 48.8                | 4.1    | 47.0      | 0.0     | 2,842  |
| 2008 | 55.8                | 9.6    | 34.6      | 0.0     | 3,892  |
| 2009 | 33.4                | 23.3   | 34.9      | 8.3     | 29,939 |
| 2010 | 35.3                | 29.0   | 35.1      | 0.6     | 36,886 |
| 2011 | 36.2                | 22.9   | 37.9      | 3.0     | 39,805 |

Daily average water temperatures were lowest during late December through February, then gradually increasing through July (Table 6, Figure 2). Daily average low temperatures ranged from 3.9 – 6.3 °C during 1998 – 2001, while daily average maximum temperatures never exceeded 13.6 °C (Table 6.). Summer water temperature, reported hourly lower in the watershed during 2001 – 2011, peaked in July (Figure 2). In some years, such as 2005, water temperature increased somewhat steadily through July, then began to decline steadily in August. In other years, hourly water temperatures rose to a peak in July, but then were variable, presumably showing the influence of marine fog (Appendix C). Hourly maximum temperatures varied between about 15.0 °C and 16.5 °C annually.

Table 6. Average, maximum and minimum of daily water temperatures in Prairie, StreeLOW and Boyes creeks during 1998 – 2001.

| Year | Prairie Cr. |            |            | StreeLOW Cr. |            |            | Boyes Cr.  |            |            |
|------|-------------|------------|------------|--------------|------------|------------|------------|------------|------------|
|      | <u>Avg</u>  | <u>Max</u> | <u>Min</u> | <u>Avg</u>   | <u>Max</u> | <u>Min</u> | <u>Avg</u> | <u>Max</u> | <u>Min</u> |
| 1998 | 7.7         | 9.8        | 4.2        | 8.9          | 10.8       | 4.8        | 9.0        | 11.0       | 3.9        |
| 1999 | 8.6         | 11.7       | 6.0        | 8.3          | 10.9       | 5.9        | 8.1        | 10.0       | 5.4        |
| 2000 | 10.2        | 13.6       | 6.3        | 8.7          | 10.2       | 5.9        | 8.4        | 10.3       | 6.3        |
| 2001 | 7.4         | 9.7        | 5.0        | 7.4          | 9.2        | 5.2        | 7.6        | 10.0       | 4.9        |

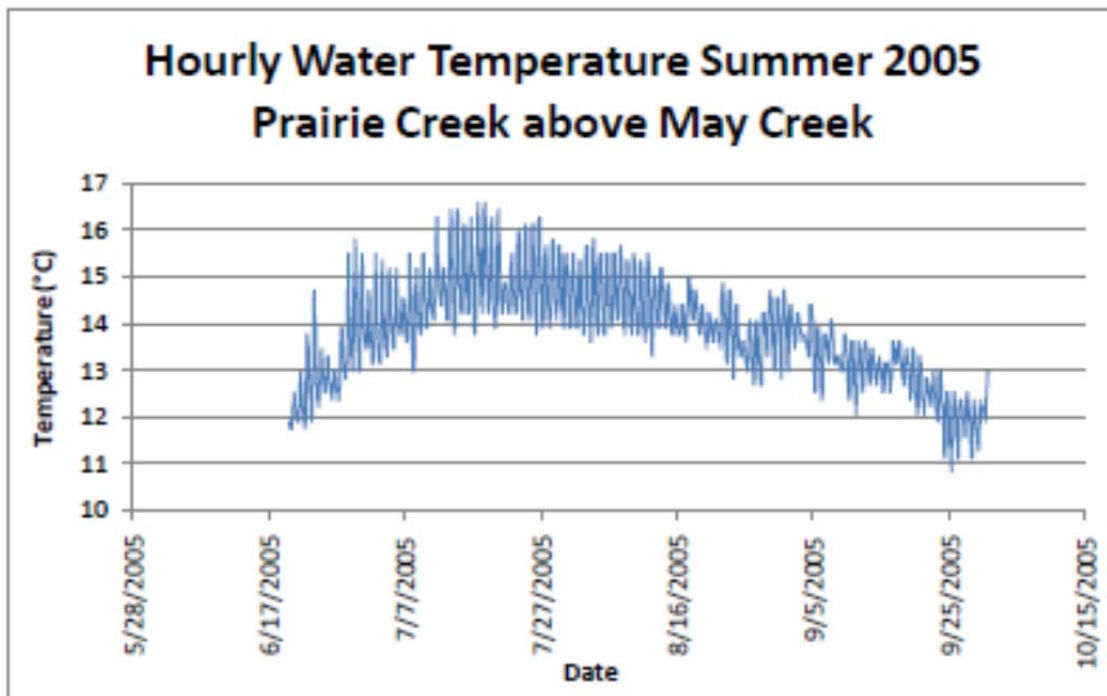


Figure 2. Hourly water temperature recorded in Prairie Creek above the confluence of May Creek during June – September, 2005.

Average monthly discharge in Prairie Creek above the confluence of May Creek during water years 1998-2008 was greatest and most variable during December ( $3.73 \text{ m}^3/\text{s}$ ,  $\text{SD} = 3.30 \text{ m}^3/\text{s}$ ) (Figure 3). Discharge remained relatively high through February, then declined. Minimum average monthly discharge during the period occurred during August and was  $0.29 \text{ m}^3/\text{s}$  ( $\text{SD} = 0.22 \text{ m}^3/\text{s}$ ).

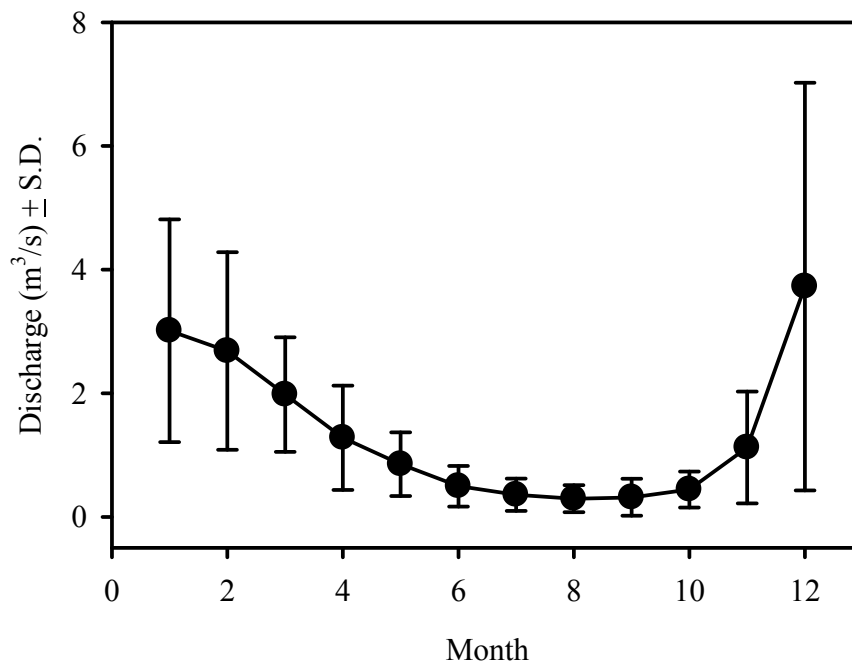


Figure 3. Monthly average discharge ( $\text{m}^3/\text{s}$ )  $\pm$  standard deviation in Prairie Creek above the confluence of May Creek during water years 1998 - 2008.

### ***Egg Survival***

Number of coho salmon fry emerging from natural redds located in Prairie, Streelow and Boyes creeks ranged from 0 to 2,671 and averaged 666 fry/redd ( $\text{SD} = 868$ ). Among streams, average number of coho samon fry emerging from redds ranged from 959 ( $\text{SD} = 1,322$ ) in Streelow Creek to 908 ( $\text{SD} = 517$ ) in Prairie Creek and 130 ( $\text{SD} = 292$ ) in Boyes Creek. However, four of five redds in Boyes Creek produced no coho salmon fry, while two of five

redds in Streelow Creek produced no fry. Number of coho salmon fry emerging from redds in Prairie Creek ranged from 498 - 1,772.

Fry were first recorded emerging from natural redds at 696 degree days (SD = 51 degree days) and the peak of emergence occurred at 755 degree days (SD = 55 degree days, Figure 4). Ninety percent of fry captured had emerged from redds by 809 degree days (SD = 45 degree days). Degree days recorded from first emergence correspond with an average calendar date of 26 February, peak emergence with 4 April and 90% emergence with 12 April.

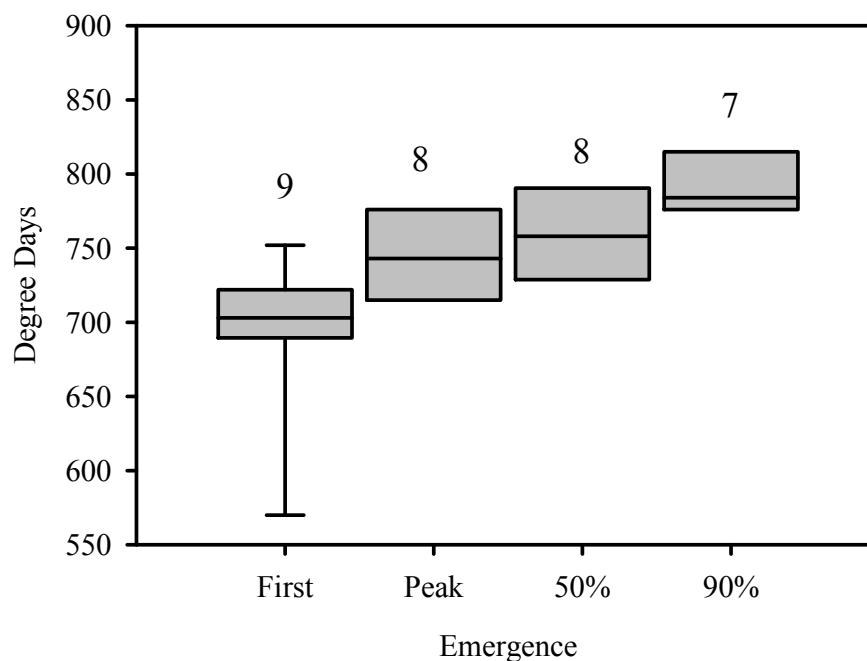


Figure 4. Box plot of emergence of coho salmon alevins from redds in Prairie Creek as a function of cumulative degree days since deposition. Numbers above boxes are sample sizes.

Survival of coho salmon eggs placed in artificial redds was generally high through hatching, but became more variable by the time eggs developed to alevins and emergent fry (Table 6). Average survival to hatching among all streams declined from 70% at hatching to 32% at fry emergence. Excluding redds invaded by predaceous oligochaete worms, however, average survival to hatching among all streams was 75% at hatching and declined to only 65% at fry emergence. Among redds not infected with predaceous oligochaete worms, survival was lower in Boyes Creek than in Prairie or Streelow creeks.

Table 7. Average survival of coho salmon eggs placed in individual artificial redds in Prairie, Boyes, and Streelow creeks, Humboldt County, California, 2000. Averages were calculated from <sup>1</sup>confidence intervals).

| Stream      | Redd No. | Percent survival to  |                        |                        |
|-------------|----------|----------------------|------------------------|------------------------|
|             |          | Hatching             | Alevin                 | Emergent Fry           |
| Prairie Cr  | 1        | 67 (1.2)             | 35 (1.6)               | 29 (16.1)              |
| Prairie Cr  | 2        | 96 (5.0)             | 87 (8.3)               | 84 (2.2)               |
| Prairie Cr  | 3        | 84 (2.5)             | 72 (8.3)               | 80 (7.5)               |
| Prairie Cr  | 4        | 95 (1.2)             | 83 (10.6)              | 45 (2.1)               |
| Prairie Cr  | 5        | 96 (0.0)             | 95 (1.2)               | 94 (1.2)               |
| Boyes Cr    | 1        | 54 (22.4)            | 29 (26.1)              | 47 (3.3)               |
| Boyes Cr    | 2        | 53 (16.1)            | 44 (5.9)               | 0 (0.0) <sup>1</sup>   |
| Boyes Cr    | 3        | 43 (6.2)             | 9 (1.1) <sup>1</sup>   | 4 (4.1) <sup>1</sup>   |
| Boyes Cr    | 4        | 42 (0.0)             | 30 (0.0)               | 29 (10.7) <sup>1</sup> |
| Boyes Cr    | 5        | 65 (6.2)             | 54 (2.4)               | 56 (29.8)              |
| Streelow Cr | 1        | 94 (2.5)             | 77 (16.3)              | 74 (4.1)               |
| Streelow Cr | 2        | 69 (33.5)            | 11 (13.7) <sup>1</sup> | 0 (0.0) <sup>1</sup>   |
| Streelow Cr | 3        | 0 (0.0) <sup>1</sup> | 0 (0.0) <sup>1</sup>   | 0 (0.0) <sup>1</sup>   |
| Streelow Cr | 4        | 93 (1.2)             | 83 (1.1)               | 75 (6.6)               |
| Streelow Cr | 5        | 94 (5.0)             | 0 (0.0) <sup>1</sup>   | 0 (0.0) <sup>1</sup>   |
| Average:    |          | 70 (24.4)            | 43 (21.5)              | 32 (20.9)              |

<sup>1</sup>Oligochaete worm *Haplotaxis ichthyophagous* present in redd.

### ***Juvenile Fish Abundance***

Abundance of juvenile fish was estimated in Prairie Creek and two tributaries, Boyes Creek and Streelow Creek. Abundance estimates for Prairie Creek began in October 1998 and continued through August 2010. Prairie Creek abundance estimates for 2009 and 2010 include sampling in Lost Man Creek. Abundance estimates for Boyes Creek and Streelow Creek covered the period October 1998 through July 2004. Estimates were made during both summer and fall for period 1998 through 2003, in 2004 and later abundance was estimated only during late summer. Abundance of juvenile coho salmon, the most common species encountered, are reported here. Abundance of other species, not presented here, is archived and available upon request.

Abundance of juvenile coho salmon during summer was greater in Prairie Creek (mean abundance 5,454 fish) than in either Boyes Creek (mean 2,352) or Streelow Creek (mean 2,656) (two-way ANOVA  $df = 2$ ,  $F = 20.98$ ,  $p < 0.001$ ) (Tables 7, 8, 9). During six fall sampling years, average abundance of juvenile coho salmon among all habitats in Prairie Creek was 5,803, while in Boyes Creek it was 2,290 and in Streelow Creek it was 2,588. Total abundance differed in only 2000 and 2002, all other years being not significantly different (two-way ANOVA  $df = 8$ ,  $F = 3.99$ ,  $p = 0.014$ ). Abundance of juvenile coho salmon was greatest in pool habitats of all streams (Tables 6, 7, 8), followed by run habitats and riffles. However, total abundance was influenced by different areas of habitat sampled in each stream.

Table 8. Estimated abundance (No.) of juvenile coho salmon in Prairie Creek during 1998-2011.

| Year              | Month | Pools |        | Runs  |        | Riffles |        | Total |        |
|-------------------|-------|-------|--------|-------|--------|---------|--------|-------|--------|
|                   |       | No.   | 95% CI | No.   | 95% CI | No.     | 95% CI | No.   | 95% CI |
| 1998              | Oct   | 5,080 | 75     | 1,047 | 11     | 0       | 0      | 6,127 | 67     |
| 1999              | Aug   | 4,256 | 63     | 1,645 | 23     | 1,229   | 240    | 7,130 | 303    |
| 1999              | Oct   | 5,123 | 949    | 1,703 | 27     | 537     | 95     | 7,363 | 850    |
| 2000              | Aug   | 2,741 | 138    | 1,733 | 17     | 20      | 0      | 4,494 | 109    |
| 2000              | Oct   | 2,622 | 432    | 1,443 | 21     | 22      | 0      | 4,086 | 324    |
| 2001              | Aug   | 1,875 | 56     | 728   | 4      | 14      | 0      | 2,617 | 40     |
| 2001              | Oct   | 1,588 | 83     | 805   | 8      | 0       | 0      | 2,393 | 62     |
| 2002              | Aug   | 4,243 | 886    | 2,919 | 17     | 1,025   | 50     | 8,187 | 657    |
| 2002              | Oct   | 4,500 | 2,519  | 2,764 | 32     | 465     | 63     | 7,729 | 1,826  |
| 2003              | Aug   | 4,481 | 435    | 2,484 | 24     | 1,699   | 801    | 8,664 | 1,126  |
| 2003              | Oct   | 3,709 | 81     | 2,722 | 24     | 686     | 70     | 7,117 | 144    |
| 2004              | Aug   | 3,134 | 260    | 1,972 | 24     | 261     | 12     | 5,367 | 231    |
| 2005              | Aug   | 1,460 | 93     | 1,391 | 39     | 303     | 30     | 3,154 | 122    |
| 2006              | Aug   | 3,870 | 84     | 2,176 | 675    | 701     | 27     | 6,747 | 578    |
| 2007              | Aug   | 2,950 | 77     | 1,627 | 72     | 64      | 2      | 4,641 | 107    |
| 2008              | Aug   | 3,276 | 217    | 1,698 | 117    | 61      | 1      | 5,035 | 242    |
| 2009 <sup>1</sup> | Aug   | 2,465 | 80     | 1,011 | 15     | 565     | 79     | 4,041 | 148    |
| 2010 <sup>1</sup> | Aug   | 3,102 | 112    | 1,466 | 17     | 549     | 60     | 5,117 | 153    |
| 2011 <sup>1</sup> | Aug   | 2,278 | 90     | 2,324 | 78     | 437     | 195    | 5,039 | 313    |

<sup>1</sup>2009 - 2011 abundance estimates include Lost Man Creek.

Table 9. Estimated abundance (No.) of juvenile coho salmon in Boyes Creek during 1998-2006.

| Year | Month | Pool  |          | Run   |          | Riffle |          | Total |          |
|------|-------|-------|----------|-------|----------|--------|----------|-------|----------|
|      |       | No.   | 95% C.I. | No.   | 95% C.I. | No.    | 95% C.I. | No.   | 95% C.I. |
| 1998 | Oct   |       |          |       |          |        |          |       |          |
| 1999 | Jul   | 1,035 | 118      | 1,027 | 114      | 167    | 23       | 2,229 | 151      |
| 1999 | Oct   | 824   | 97       | 981   | 98       | 59     | 9        | 1,864 | 118      |
| 2000 | Jul   | 0     | 0        | 227   | 46       | 0      | 0        | 227   | 46       |
| 2000 | Oct   | 434   | 78       | 269   | 27       | 189    | 7        | 723   | 57       |
| 2001 | Jul   | 1,954 | 378      | 1,111 | 191      | 443    | 159      | 3,508 | 399      |
| 2001 | Oct   | 1,533 | 198      | 881   | 146      | 7      | 4        | 2,422 | 175      |
| 2002 | Jul   | 2,193 | 234      | 1,694 | 108      | 1,125  | 100      | 5,011 | 241      |
| 2002 | Oct   | 1,516 | 120      | 1,019 | 89       | 452    | 33       | 2,987 | 128      |
| 2003 | Jul   | 779   | 73       | 1,366 | 83       | 344    | 30       | 2,488 | 100      |
| 2003 | Oct   | 464   | 98       | 935   | 64       | 97     | 12       | 1,496 | 85       |
| 2004 | Jul   | 1,148 | 89       | 641   | 87       | 447    | 136      | 2,236 | 179      |
| 2005 | Jul   | 1,236 | 84       | 475   | 66       | 0      | 0        | 1,710 | 104      |
| 2006 | Aug   | 807   | 64       | 506   | 50       | 93     | 16       | 1,406 | 81       |

Table 10. Estimated abundance (No.) of juvenile coho salmon in Streelow Creek during 1998-2004.

| Year | Month | Pool  |          | Run   |          | Riffle |          | Total |          |
|------|-------|-------|----------|-------|----------|--------|----------|-------|----------|
|      |       | No.   | 95% C.I. | No.   | 95% C.I. | No.    | 95% C.I. | No.   | 95% C.I. |
| 1998 | Oct   | 1,167 | 223      | 996   | 131      | 69     | 86       | 2,232 | 270      |
| 1999 | Jul   | 406   | 241      | 1,273 | 190      | 539    | 135      | 2,218 | 331      |
| 1999 | Oct   | 435   | 186      | 964   | 200      | 246    | 71       | 1,645 | 273      |
| 2000 | Jul   | 250   | 240      | 327   | 91       | 24     | 13       | 601   | 206      |
| 2000 | Oct   | 1,597 | 219      | 417   | 57       | 34     | 10       | 2,048 | 165      |
| 2001 | Jul   | 995   | 105      | 895   | 54       | 33     | 12       | 1,922 | 89       |
| 2001 | Oct   | 931   | 93       | 714   | 70       | 0      | 0        | 1,645 | 163      |
| 2002 | Jul   | 3,259 | 343      | 2,131 | 159      | 467    | 36       | 5,857 | 273      |
| 2002 | Oct   | 2,293 | 309      | 1,455 | 123      | 100    | 14       | 3,848 | 222      |
| 2003 | Jul   | 3,134 | 204      | 1,090 | 94       | 162    | 56       | 4,385 | 213      |
| 2003 | Oct   | 2,729 | 181      | 494   | 47       | 49     | 21       | 3,272 | 154      |
| 2004 | Jul   | 718   | 57       | 596   | 57       | 63     | 51       | 1,377 | 95       |

Abundance of juvenile coho salmon in pool and run habitats of Prairie Creek was not correlated with habitat available to them ( $r^2 = 0.000$ , Figure 5). In 11 of 14 years, summer abundance estimates ranged from the lowest to highest recorded when habitat area varied little. Sampling a greater amount of habitat during three years did not result in greater estimated abundance.

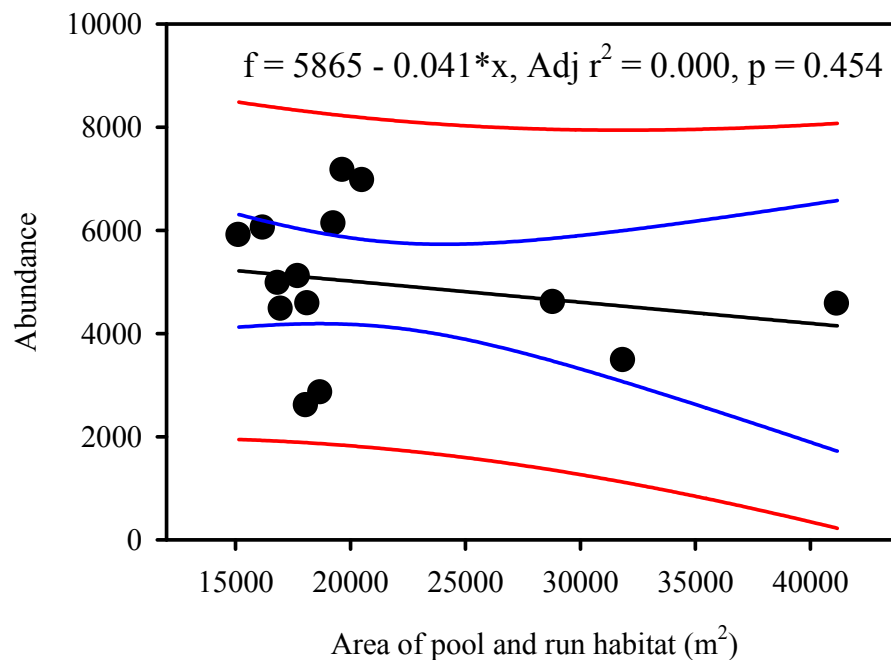


Figure 5. Regression of juvenile coho salmon abundance in pool and run habitats of Prairie Creek during August with area of those habitats available to fish each year.

Density of juvenile coho salmon differed from abundance, due in part to differences in the area sampled among streams. In contrast to abundance, summer density of juvenile coho salmon in pool and run habitats was actually lowest Prairie Creek ( $0.325 \text{ fish/m}^2$ ), greatest in Boyes Creek ( $0.767 \text{ fish/m}^2$ ) and intermediate in Streelow Creek ( $0.384 \text{ fish/m}^2$ ) (Figure 6). Density of juvenile coho salmon during summer in Boyes Creek was statistically greater than in either Prairie or Boyes creeks (two-way ANOVA,  $df = 2$ ,  $F = 5.76$ ,  $p = 0.16$ ). Among all streams, density did not differ among years ( $df = 8$ ,  $F = 2.48$ ,  $p = 0.07$ ), although the probability

value was only slightly greater than alpha (0.05). Among years, density ranged from 0.135 fish/m<sup>2</sup> in 2000 to 1.064 fish/m<sup>2</sup> in 2002.

Survival of juvenile coho salmon between July and October ranged from 60% to 94% among all streams and years. Survival was greatest in Prairie Creek (mean = 92%) and lowest in Boyes Creek (mean = 68%) (two-way ANOVA,  $df = 2$ ,  $F = 11.11$ ,  $p = 0.010$ ). Summer survival in Streelow Creek was intermediate (mean = 75%). Summer survival for all streams, among years ranged from 72% in 2003 to 87% in 1999 and was not statistically different ( $df = 4$ ,  $F = 1.95$ ,  $p = 0.222$ ).

Size of juvenile coho salmon varied among seasons. Average fork length and weight was most often greatest in May and/or June when smolting individuals were present in samples and was least in July (Appendix D). In Prairie, Boyes and Streelow creeks during July and August, juvenile coho salmon fork length averaged 59.6 mm (Figure 7) and weight averaged 2.35 g. These three streams were also sampled in October during 1999 – 2003 and average fork length increased 13.0 mm during this summer/fall period while average weight increased 1.63 g (Appendix D). Between October and May, average fork length increased another 19.1 mm and weight increased 5.1 g. In all three streams, specific growth rates were greatest between hatching in May and sampling in July (Table 10). Absolute growth in both length and weight was greatest between October and March.

Size of juvenile coho salmon was negatively related to their density in pool and run habitats. However, neither the relationship between fork length and density nor the relationship between weight and density was statistically significant (Figures 8 and 9).

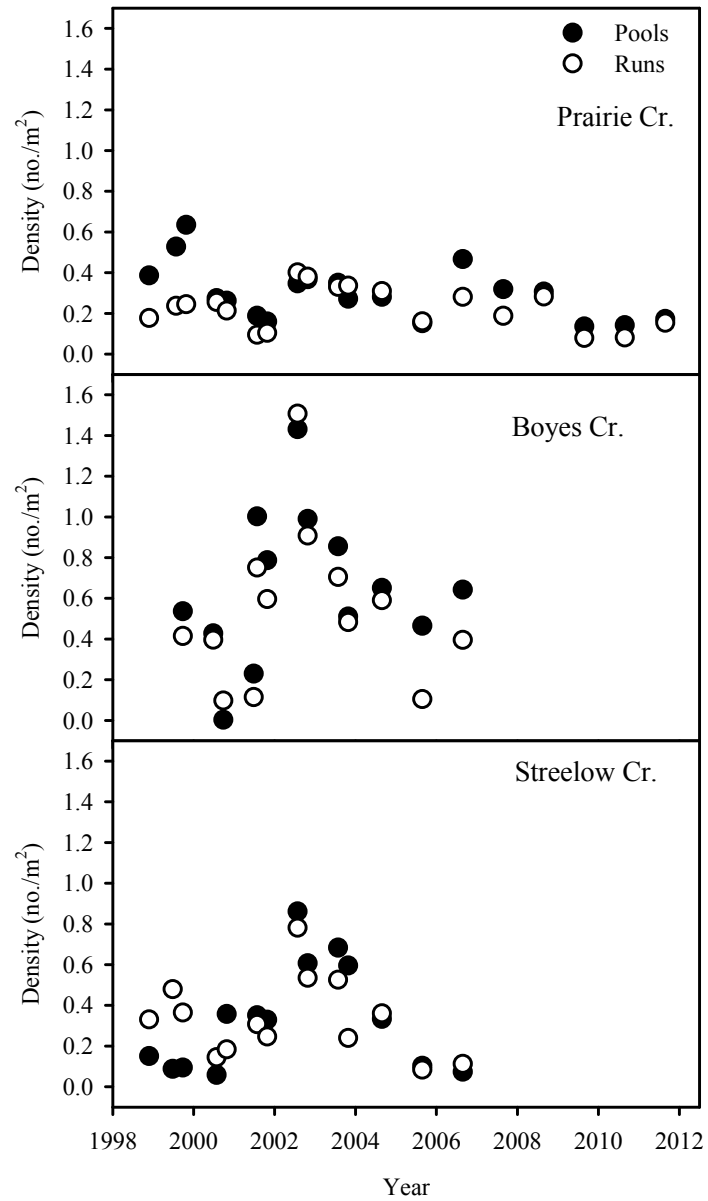


Figure 6. Average density (no./m<sup>2</sup>) of juvenile coho salmon in pool and run habitats of Prairie Creek (top), Boyes Creek (middle) and Streeflow Creek (bottom) during 1998-2011.

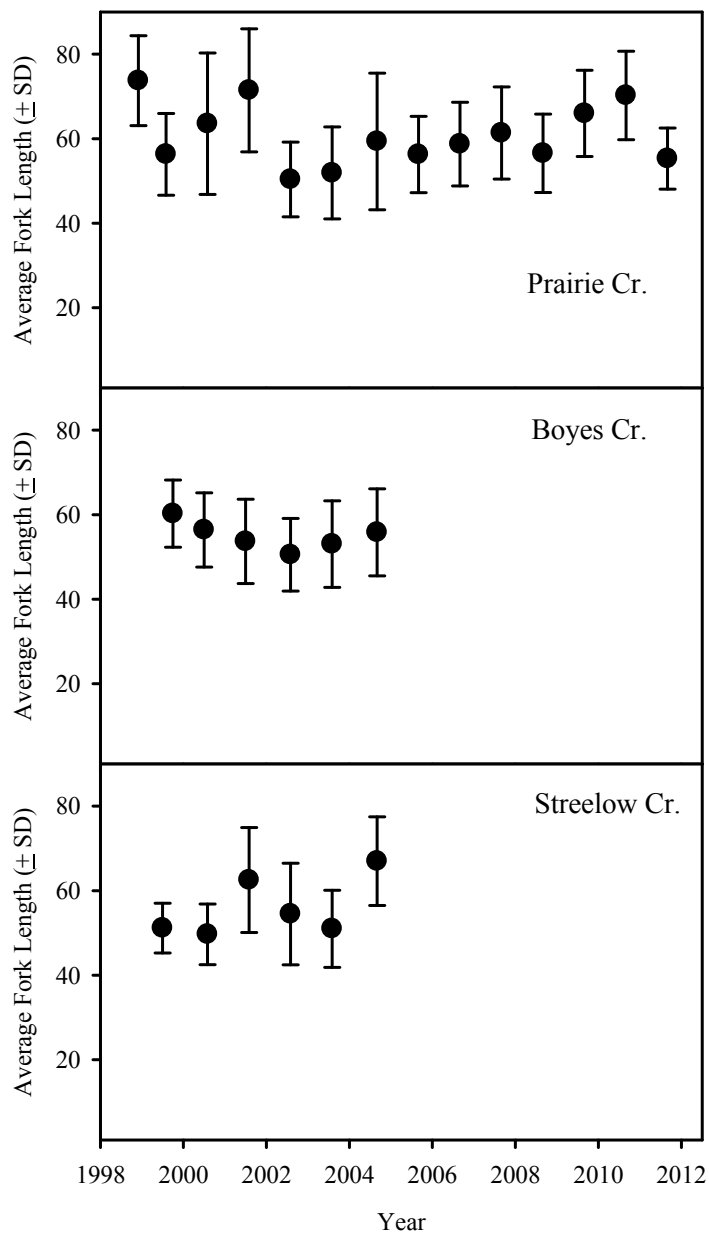


Figure 7. Average fork length (mm  $\pm$  1 SD) of juvenile coho salmon collected using electrofishing in Prairie Creek (top), Boyes Creek (middle) and Streeflow Creek (Bottom) during summer in 1999 – 2011. In 1998, data for Prairie Creek were collected in November.

Table 11. Mean specific growth rate (SGR,  $\text{g} \cdot \text{g}^{-1} \cdot \text{d}^{-1}$ ) and absolute growth in mass ( $\text{AG}_{\text{WT}}$ , g) and fork length ( $\text{AG}_{\text{LT}}$ , mm) for juvenile coho salmon captured in stream study reaches during July and October 2002 and March 2003. Standard errors of means are presented in parentheses.

|                         | Boyce Creek |      |      | Prairie Creek |      |      | Steelelow Creek |      |      |
|-------------------------|-------------|------|------|---------------|------|------|-----------------|------|------|
|                         | Jul         | Oct  | Mar  | Jul           | Oct  | Mar  | Jul             | Oct  | Mar  |
| n                       | 288         | 361  | 48   | 569           | 759  | 91   | 364             | 402  | 111  |
| SGR                     | 1.33        | 0.33 | 0.57 | 1.43          | 0.45 | 0.43 | 1.55            | 0.62 | 0.35 |
| $\text{AG}_{\text{WT}}$ | 1.18        | 0.51 | 3.16 | 1.18          | 0.77 | 2.63 | 1.51            | 1.32 | 2.66 |
| $\text{AG}_{\text{LT}}$ | 12.9        | 5.8  | 18.8 | 12.8          | 7    | 18.1 | 15.5            | 10.7 | 15.5 |

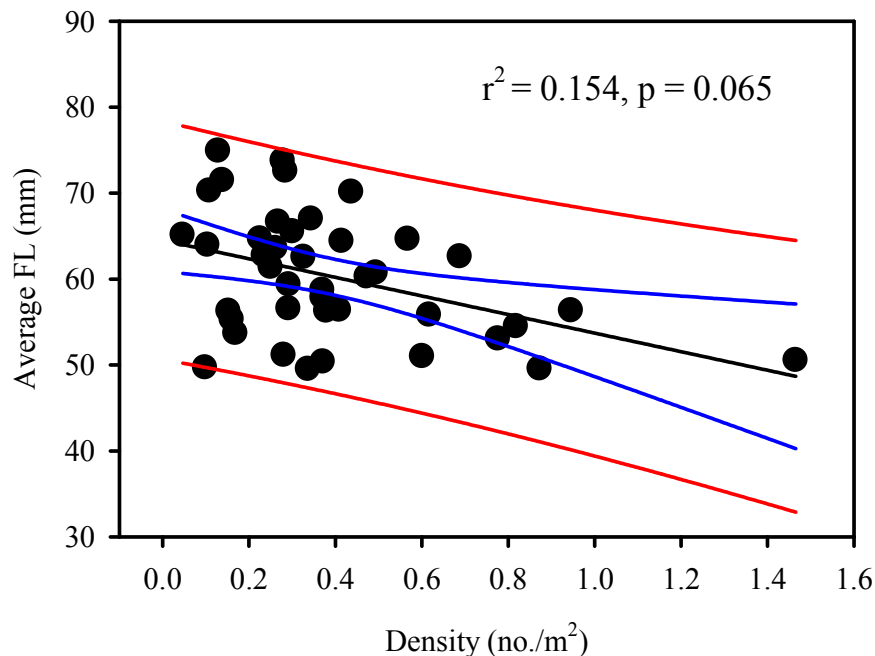


Figure 8. Relationship between juvenile coho salmon fork length (mm) and density ( $\text{no./m}^2$ ) in the Prairie Creek watershed 1998 – 2011. Outer bands = prediction intervals, inner bands = 95% CI.

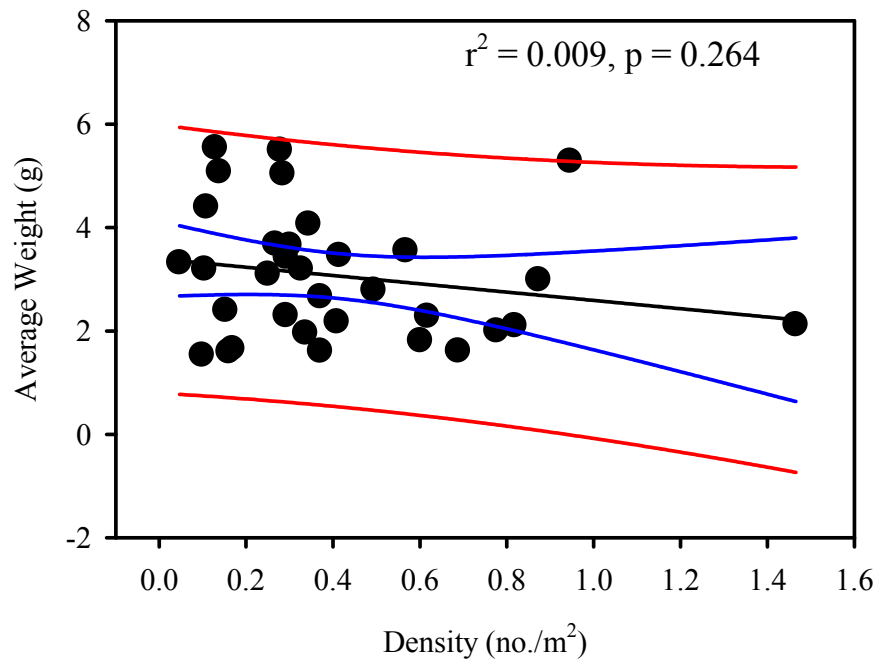


Figure 9. Relationship between juvenile coho salmon weight (g) and density (no./m<sup>2</sup>) in the Prairie Creek watershed 1998 – 2011. Outer bands = prediction intervals, inner bands = 95% CI.

Diet of juvenile coho salmon was varied and contained organisms commonly found drifting in the water column as well as organisms associated with the benthos (Table 11). The most important prey in stomachs of fish from Prairie, Boyes and Strelow creeks during spring, summer and fall were larvae and adult Diptera and Oligocheata. Amphipoda also contributed substantially to the diet of juvenile coho salmon in Strelow Creek, but not in other streams.

Table 12. Mean percentage biomass of juvenile coho coho salmon diet collected in July and October 2002, and March 2003 from the three northern California streams.

| Taxa          | Boyces Creek |      |      | Prairie Creek |      |      | Streelow Creek |      |      |
|---------------|--------------|------|------|---------------|------|------|----------------|------|------|
|               | Jul          | Oct  | Mar  | Jul           | Oct  | Mar  | Jul            | Oct  | Mar  |
| Amphipoda     | 0.0          | 0.0  | 6.0  | 1.3           | 0.9  | 2.2  | 23.2           | 17.2 | 23.7 |
| Aranea        | 6.5          | 3.6  | 7.3  | 9.8           | 4.5  | 1.5  | 8.9            | 5.0  | 5.8  |
| Coleoptera    | 12.4         | 9.0  | 18.5 | 13.1          | 2.9  | 8.3  | 3.6            | 8.7  | 9.4  |
| Collembolla   | 0.6          | 1.0  | 0.5  | 1.1           | 11.8 | 1.9  | 0.8            | 0.7  | 0.4  |
| Diplopoda     | 3.8          | 3.9  | 2.3  | 0.5           | 3.7  | 1.7  | 4.9            | 7.5  | 0.0  |
| Diptera       | 32.4         | 47.3 | 13.6 | 16.7          | 24.2 | 8.3  | 18.8           | 23.9 | 9.5  |
| Ephemeroptera | 5.5          | 7.5  | 6.0  | 12.9          | 7.9  | 11.5 | 2.0            | 4.6  | 3.3  |
| Homoptera1    | 0.6          | 3.1  | 1.3  | 0.7           | 1.8  | 0.9  | 0.8            | 2.3  | 0.5  |
| Hymenoptera   | 1.4          | 2.8  | 0.4  | 4.3           | 0.8  | 0.3  | 0.6            | 4.4  | 0.9  |
| Isopoda       | 2.3          | 0.0  | 2.1  | 4.6           | 0.0  | 1.4  | 4.5            | 1.4  | 4.5  |
| Lepidoptera   | 4.2          | 2.5  | 1.2  | 2.2           | 5.7  | 1.3  | 3.0            | 4.6  | 1.8  |
| Oligochaeta   | 19.7         | 3.0  | 20.9 | 13.1          | 6.4  | 24.6 | 16.6           | 10.4 | 18.5 |
| Plecoptera    | 2.0          | 1.1  | 6.0  | 2.9           | 4.6  | 9.3  | 4.6            | 2.5  | 8.7  |
| Trichoptera   | 5.9          | 10.3 | 6.6  | 11.2          | 18.4 | 23.9 | 5.6            | 5.0  | 9.5  |
| Other         | 2.8          | 4.9  | 7.4  | 5.6           | 6.4  | 2.9  | 2.0            | 1.9  | 3.5  |
|               | 100          | 100  | 100  | 100           | 100  | 100  | 100            | 100  | 100  |
| Sample Size   | 54           | 55   | 29   | 61            | 76   | 46   | 55             | 81   | 39   |

### ***Downstream Migrant Trapping***

Downstream migrant trapping was conducted on Prairie Creek above the confluence of Streelow Creek (lower Prairie Creek) from 1999-2008. Trapping at the lower Prairie Creek site was suspended in 2009 due to the state withdrawing bond funding. It was restarted in 2010, but repeated storms damaged the trap and reliable data were never gathered. In 2011, the lower trap site was re-located at the mouth of Prairie Creek and a screw trap was deployed to replace fyke net traps. During 1999 – 2004, downstream migrant trapping was also conducted on Prairie Creek above the confluence of Browns Creek (upper Prairie Creek), on Boyces Creek and on Streelow Creek.

Production of age 1+ coho salmon migrating downstream was greatest in the lower Prairie Creek trap, followed by the traps on upper Prairie Creek, Streelow Creek and Boyces

Creek. Average annual production of age 1+ coho salmon migrating past the lower Prairie Creek site was 9,078 and was 112,926 during the six year period 1999-2004. Average annual number of age 1+ coho salmon migrating past the lower Prairie Creek site was 3,962, while at Streelow Creek it was 2,942 and at Boyes Creek it was 467 (Tables 12, 13, 14, 15).

The most common species/age class collected at most DMST sites were age 0+ coho salmon, with average annual catches ranging from 11,790 at the Boyes Creek site to 36,121 at the upper Prairie Creek site. Chinook salmon (age 0+) were also abundant at both Prairie Creek sites, with average annual catch at the lower site being 26,865 and at the upper site 44,136 (Tables 12, 13). Chinook salmon were, however, far less abundant at the Boyes Creek and Streelow Creek sites (Tables 14, 15). Other species common in DMST catches included steelhead, coastal cutthroat trout and trout that could not be classified as either steelhead or cutthroat.

Downstream movement of PIT tagged coho salmon smolts revealed both general and specific patterns. In general, most (48 of 55) coho salmon smolts recorded were captured in the trap during a period beginning at 2100 hours and extending until 1000 hours the following day (Figure 10). The remaining seven fish were recorded during 1100 hours through 2000 hours and movement during this period was not consistent.

Table 13. Coho salmon smolt production estimates (+ S.D.) and raw catch data for all species in a DMST operated in Prairie Creek. During 1999-2008 the DMST was located above the confluence of Streelow Creek, in 2011 it was located at the mouth of Prairie Creek.

| Species                | Year     |         |         |         |        |        |       |       |         |       |       |
|------------------------|----------|---------|---------|---------|--------|--------|-------|-------|---------|-------|-------|
|                        | 1999     | 2000    | 2001    | 2002    | 2003   | 2004   | 2005  | 2006  | 2007    | 2008  | 2011  |
| Coho salmon 1+         | 29,606   | 5,616   | 23,398  | 13,962  | 3,590  | 1,381  | 2,114 | 4,255 | 4,352   | 2,503 | 8,446 |
| Prod Est $\pm$ S.D.    | (6,638)  | (1,516) | (3,506) | (1,622) | (646)  | (540)  | (423) | (851) | (1,175) | (676) | (650) |
|                        | Raw Data |         |         |         |        |        |       |       |         |       |       |
| Coho salmon 0+         | 2,702    | 2,690   | 1,677   | 230,745 | 17,648 | 15,765 | 9,410 | 4,282 | 408     | 2,209 | 778   |
| Chinook salmon         | 56,615   | 22,409  | 18,026  | 110,148 | 11,038 | 45,358 | 2,772 | 1,401 | 598     | 288   | 7,743 |
| Steelhead trout        | 218      | 284     | 505     | 172     | 68     | 8      | 57    | 160   | 216     | 188   | 2,289 |
| Cutthroat trout        | 462      | 394     | 1,316   | 477     | 36     | 49     | 233   | 479   | 458     | 299   | 1,219 |
| Unidentified trout     | 1,350    | 1,788   | 3,482   | 1,504   | 4,677  | 2,442  | 169   | 103   | 399     | 13    | --    |
| Pacific lamprey        | 56       | 30      | 25      | 113     | 20     | 0      | 9     | 18    | 46      | 40    | 43    |
| Western brook lamprey  | 159      | 1       | 219     | 9       | 51     | 1      | 80    | 58    | 58      | 13    | 73    |
| Lamprey ammocete       | 152      | 18      | 189     | 246     | 79     | 79     | 0     | 0     | 0       | 0     | 1,335 |
| Coastrange sculpin     | 95       | 24      | 154     | 71      | 80     | 0      | 18    | 28    | 13      | 12    | 1,498 |
| Prickly sculpin        | 124      | 147     | 344     | 97      | 18     | 3      | 248   | 382   | 134     | 146   | 1,693 |
| Threespine stickleback | 41       | 13      | 103     | 78      | 46     | 6      | 62    | 117   | 60      | 66    | 1,011 |
| Sacramento sucker      | 13       | 0       | 6       | 3       | 1      | 0      | 0     | 6     | 2       | 4     | 120   |

Table 14. Coho salmon smolt production estimates (+ S.D.) and raw catch data for all species in a DMST operated in Prairie Creek above the confluence of Browns Creek, 1999-2004.

| Species                | Year     |         |       |         |        |        |
|------------------------|----------|---------|-------|---------|--------|--------|
|                        | 1999     | 2000    | 2001  | 2002    | 2003   | 2004   |
| Coho salmon 1+         | 2,188    | 10,665  | 2,772 | 2,319   | 3,402  | 803    |
| Prod Est $\pm$ S.D.    | (427)    | (1,600) | (277) | (186)   | (710)  | (120)  |
|                        | Raw Data |         |       |         |        |        |
| Coho salmon 0+         | 8,733    | 2,210   | 1,292 | 137,844 | 50,882 | 15,765 |
| Chinook salmon         | 97,005   | 11,520  | 493   | 62,948  | 47,492 | 45,358 |
| Steelhead trout        | 23       | 7       | 37    | 29      | 8      | 8      |
| Cutthroat trout        | 506      | 593     | 765   | 610     | 39     | 49     |
| Unidentified trout     | 390      | 479     | 302   | 568     | 1,988  | 2,442  |
| Pacific lamprey        | 15       | 37      | 30    | 26      | 4      | 0      |
| Western brook lamprey  | 126      | 56      | 99    | 1       | 1      | 1      |
| Lamprey ammocete       | 87       | 94      | 239   | 114     | 80     | 79     |
| Coastrange sculpin     | 9        | 9       | 4     | 1       | 0      | 0      |
| Prickly sculpin        | 26       | 42      | 67    | 13      | 2      | 3      |
| Threespine stickleback | 1        | 9       | 36    | 6       | 7      | 6      |
| Sacramento sucker      | 0        | 0       | 0     | 0       | 0      | 0      |

Table 15. Coho salmon smolt production estimates (+ S.D.) and raw catch data for all species in a DMST operated in Stree low Creek, 1999-2004.

| Species                | Year     |        |        |       |       |       |
|------------------------|----------|--------|--------|-------|-------|-------|
|                        | 1999     | 2000   | 2001   | 2002  | 2003  | 2004  |
| Coho salmon 1+         | 584      | 4,329  | 9,074  | 2369  | 743   | 552   |
| Prod Est $\pm$ S.D.    | (234)    | (1732) | (4174) | (233) | (437) | (232) |
|                        | Raw Data |        |        |       |       |       |
| Coho salmon 0+         | 3481     | 10648  | 269    | 43625 | 13848 | 496   |
| Chinook salmon         | 431      | 7      | 5      | 22    | 1490  | 1502  |
| Steelhead trout        | 0        | 4      | 52     | 220   | 10    | 6     |
| Cutthroat trout        | 13       | 237    | 351    | 310   | 10    | 5     |
| Unidentified trout     | 80       | 112    | 269    | 57    | 128   | 28    |
| Pacific lamprey        | 1        | 7      | 4      | 4     | 0     | 4     |
| Western brook lamprey  | 2        | 3      | 6      | 7     | 4     | 2     |
| Lamprey ammocete       | 12       | 36     | 516    | 274   | 101   | 24    |
| Coastrange sculpin     | 0        | 1      | 17     | 0     | 8     | 1     |
| Prickly sculpin        | 14       | 300    | 191    | 44    | 8     | 5     |
| Threespine stickleback | 5        | 41     | 130    | 95    | 25    | 34    |
| Sacramento sucker      | 1        | 8      | 1      | 1     | 0     | 0     |

Table 16. Coho salmon smolt production estimates (+ S.D.) and raw catch data for all species in a DMST operated in Boyes Creek, 1999-2004.

| Species                | Year     |       |       |        |        |       |
|------------------------|----------|-------|-------|--------|--------|-------|
|                        | 1999     | 2000  | 2001  | 2002   | 2003   | 2004  |
| Coho salmon 1+         | 302      | 784   | 769   | 427    | 49     | 471   |
| Prod Est $\pm$ S.D.    | (106)    | (274) | (300) | (43)   | (29)   | (120) |
| Species                | Raw Data |       |       |        |        |       |
|                        | 1999     | 2000  | 2001  | 2002   | 2003   | 2004  |
| Coho salmon 0+         | 70       | 219   | 976   | 52,077 | 10,794 | 6,606 |
| Chinook salmon         | 0        | 55    | 0     | 9      | 95     | 0     |
| Steelhead trout        | 5        | 1     | 1     | 50     | 1      | 33    |
| Cutthroat trout        | 17       | 87    | 148   | 228    | 10     | 41    |
| Unidentified trout     | 48       | 1,312 | 74    | 25     | 182    | 236   |
| Pacific lamprey        | 9        | 5     | 0     | 5      | 0      | 0     |
| Western brook lamprey  | 8        | 1     | 0     | 1      | 3      | 2     |
| Lamprey ammocete       | 7        | 19    | 0     | 84     | 6      | 3     |
| Coastrange sculpin     | 5        | 1     | 0     | 3      | 6      | 3     |
| Prickly sculpin        | 7        | 9     | 0     | 10     | 2      | 45    |
| Threespine stickleback | 14       | 10    | 0     | 21     | 3      | 67    |
| Sacramento sucker      | 5        | 0     | 0     | 1      | 0      | 0     |

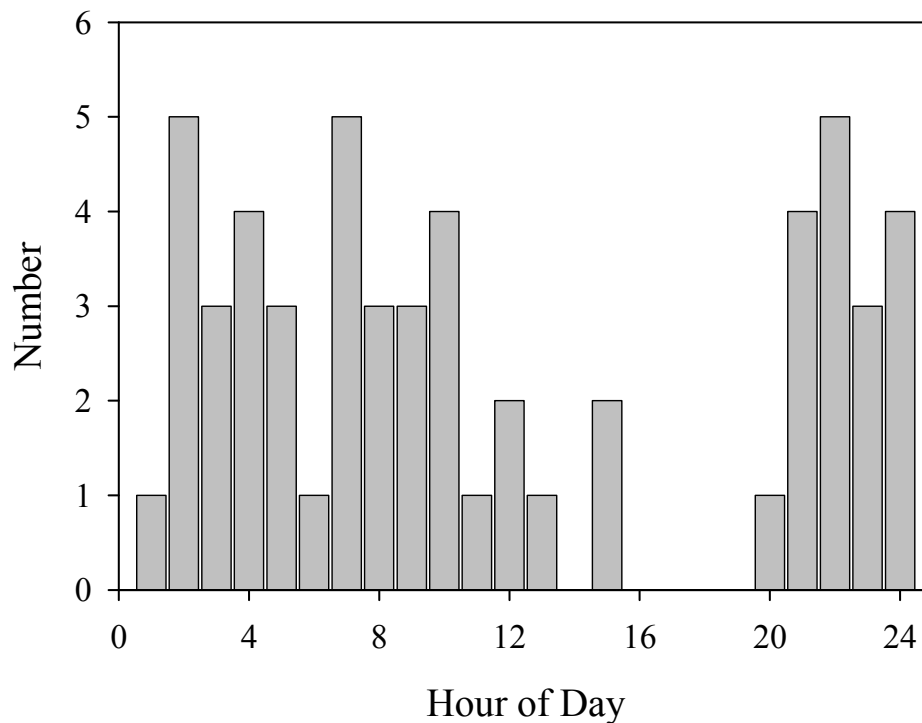


Figure 10. Time of day PIT tagged coho salmon smolts were captured at a downstream migrant trap in Prairie Creek in 2003.

## ***Adult Salmonid Escapement***

Adult escapement was estimated using multiple techniques. The area-under-the-curve (AUC) method for live fish appeared to provide the most reliable estimates of escapement and are reported here. We also estimated escapement using the redd expansion method. We also estimated escapement using carcass mark-recapture data from three seasons. In addition to these three methods for estimating escapement, we present data on the number of each species of adult salmonids intercepted at weirs operated on Prairie and Lost Man creeks during five winters.

Comparison of escapement estimates calculated from carcass mark-recapture, redd expansion and AUC data suggested that the latter two methods provided comparable estimates, but carcass mark-recapture did not. In two of three years, redd expansion and AUC derived escapement estimates deviated by 3% and 23% respectively (Table 16). Estimates generated from carcass mark-recapture data during two of the three years were 55% and 57% less than estimates relying on AUC data.

Most abundant species spawning in Prairie Creek were coho salmon and Chinook salmon. Averaging estimated escapement of coho salmon during 1998/99 through 2011/12 was 297 fish, while escapement of Chinook salmon averaged 272 fish during the same period (Table 17). Escapement of steelhead and coastal cutthroat trout was much lower. Both coho salmon and Chinook salmon showed cyclical abundance. The initial estimate of adult coho salmon escapement to Prairie Creek was relatively low, 56 fish in 1998-99, then increased to a peak of 680 fish in 2001/02, remaining relatively high for six years, before declining to a low of 28 fish in 2009/10 and again increasing after (Table 17).

Coho salmon escapement estimates derived using the redd expansion method generally reflected estimates derived from AUC methods. During the 14 year period, annual escapement of coho salmon estimated from redd expansion data was 312 fish as compared with 297 fish using the AUC technique (Tables 17, 18). Coho salmon escapement using redd expansion methods was positively related to escapement estimated using AUC methods (Adjusted  $r^2 = 0.477$ ,  $p = 0.0037$ ) (Figure 11). Within individual years there was less agreement, although estimates using the two methods differed by 30% or less on seven of 14 years.

Table 17. Escapement of adult coho salmon to Prairie Creek during 2001/2002 through 2003/2004 estimated using three separate techniques.

| Season  | Carcass Peterson<br>Mark/Recapture | Redd Expansion | Live Fish AUC |
|---------|------------------------------------|----------------|---------------|
| 2001/02 | 359                                | 680            | 658           |
| 2002/03 | 250                                | 542            | 439           |
| 2003/04 | 181                                | 268            | 163           |

Table 18. Escapement of adult coho and Chinook salmon, steelhead and coastal cutthroat trout to Prairie Creek estimated from live fish observations using area-under-the-curve analysis.

| Year    | Coho |        | Chinook |        | Steelhead |        | Cutthroat |        |
|---------|------|--------|---------|--------|-----------|--------|-----------|--------|
|         | Est. | 95% CI | Est.    | 95% CI | Est.      | 95% CI | Est.      | 95% CI |
| 1998/99 | 56   | 3.4    | 541     | 38.9   | 10        | 0.6    | 2         | 0.2    |
| 1999/00 | 84   | 6.7    | 353     | 19.9   | 4         | 2.2    | 22        | 1.3    |
| 2000/01 | 212  | 6.0    | 321     | 16.4   | 9         | 1.9    | 4         | 0.5    |
| 2001/02 | 680  | 19.4   | 710     | 34.1   | 9         | 1.6    | 1         | 0.4    |
| 2002/03 | 542  | 46.1   | 183     | 17.6   | 28        | 2.4    | 0         | 0.0    |
| 2003/04 | 268  | 12.4   | 654     | 48.6   | 24        | 6.3    | 21        | 1.3    |
| 2004/05 | 643  | 40.6   | 200     | 22.0   | 70        | 9.7    | 28        | 2.3    |
| 2005/06 | 349  | 27.6   | 121     | 13.0   | 142       | 9.8    | 22        | 3.8    |
| 2006/07 | 165  | 8.5    | 115     | 9.2    | 70        | 5.9    | 15        | 3.2    |
| 2007/08 | 466  | 44.5   | 38      | 4.1    | 136       | 9.0    | 27        | 2.8    |
| 2008/09 | 127  | 25.8   | 73      | 18.4   | 12        | 1.9    | 0         | 0.0    |
| 2009/10 | 28   | 4.1    | 46      | 7.5    | 4         | 0.0    | 3         | 0.6    |
| 2010/11 | 218  | 22.0   | 144     | 14.8   | 4         | 0.4    | 27        | 3.2    |
| 2011/12 | 323  | 49.9   | 311     | 48.4   | 36        | 5.8    | 64        | 12.8   |

Table 19. Escapement of adult coho and Chinook salmon and steelhead to Prairie Creek estimated from redd observations.

| Year    | Coho | Chinook | Steelhead |
|---------|------|---------|-----------|
| 1998/99 | 106  | 672     | 0         |
| 1999/00 | 81   | 558     | 4         |
| 2000/01 | 396  | 620     | 55        |
| 2001/02 | 1198 | 595     | 24        |
| 2002/03 | 447  | 59      | 2         |
| 2003/04 | 352  | 657     | 13        |
| 2004/05 | 488  | 426     | 0         |
| 2005/06 | 385  | 217     | 24        |
| 2006/07 | 165  | 95      | 2         |
| 2007/08 | 41   | 7       | 55        |
| 2008/09 | 198  | 15      | 33        |
| 2009/10 | 98   | 147     | 0         |
| 2010/11 | 43   | 187     | 0         |
| 2011/12 | 366  | 903     | 11        |

(Male + jack)/female ratio for fish captured at the weir during all years is: coho = 1.71, Chinook 2.67, steelhead 1.19 and cutthroat 1.18.

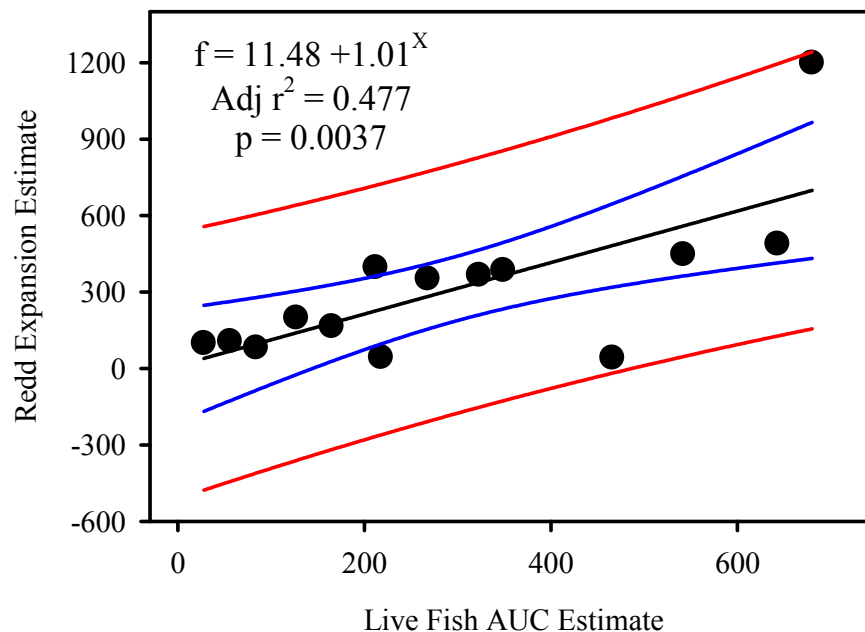


Figure 11. Relationship between coho salmon escapement in Prairie Creek estimated using area-under-the-curve analysis of data for live fish observed and expansion from observed redds using female:male + jack ratios observed at a weir.

Fewer fish were captured at the weirs than were estimated using AUC or redd expansion. However, trends in weir catches generally reflected escapement estimates over comparable periods, excepting 2005/06 when the weir was damaged by storms for an extended period (Table 19).

Run timing of coho and Chinook salmon, measured as average daily catch at the weir, overlapped considerable (Figure 12). During five years of weir operation, coho salmon were captured as early as 10 November and as late as 3 March. Average date of arrival at the weir for coho salmon over the five year period was December 26 (SD = 17 days) and annually ranged from December 20 to December 30. Peak abundance of coho salmon was recorded during 18 – 23 December, with secondary peaks occurring in mid-November and early and late December. Chinook salmon were captured at weir as early as 18 November and as late as 27 January. Average date of arrival at the weir for Chinook salmon over the five year period was December 19 (SD = 13 days) and annually ranged from December 11 to December 26. Peak abundance of Chinook salmon was recorded during 23 - 24 December and 6 January. Steelhead were captured at weir as early as 17 November and as late as 2 April. Peak abundance of steelhead occurred during 31 - 17 March. Coastal cutthroat trout were captured at the weir as early as 9 November and as late as 27 February. Pulses in catch of coastal cutthroat trout occurred in mid-November, mid-December and early February (Figure 12).

The three cohorts of coho salmon differ in abundance, but not greatly (Figure 13). When peak abundances are examined, there appears to be one strongest cohort, one intermediate and one weaker cohort. However, when periods of low abundance are examined differences in abundance among the three cohorts is much less obvious (Figure 13).

Table 20. Number of four species captured at Prairie Creek sub-basin weirs, 2005/2006 - 2009/2010.

| Season  | Coho |     |       | Chinook |    |       | Steelhead |    |       | Cutthroat |   |       | Total fish |
|---------|------|-----|-------|---------|----|-------|-----------|----|-------|-----------|---|-------|------------|
|         | ♀    | ♂   | ♀ + ♂ | ♀       | ♂  | ♀ + ♂ | ♀         | ♂  | ♀ + ♂ | ♀         | ♂ | ♀ + ♂ |            |
| 2005/06 | 24   | 35  | 59    | 2       | 8  | 10    | 4         | 10 | 14    | 0         | 0 | 0     | 83         |
| 2006/07 | 39   | 61  | 100   | 4       | 8  | 12    | 39        | 42 | 81    | 3         | 2 | 5     | 198        |
| 2007/08 | 66   | 110 | 176   | 3       | 12 | 15    | 1         | 3  | 4     | 11        | 9 | 20    | 215        |
| 2008/09 | 36   | 56  | 94    | 31      | 53 | 84    | 3         | 3  | 6     | 5         | 5 | 10    | 194        |
| 2009/10 | 13   | 28  | 41    | 18      | 36 | 54    | 24        | 29 | 53    | 5         | 4 | 9     | 157        |

Table 21. Average size (fork length (mm) and standard deviation) of five species of adult salmonids captured at a weir on Prairie Creek during 2005/2006 through 2009/2010.

| Species         | Female |      |     | Male |      |      |
|-----------------|--------|------|-----|------|------|------|
|                 | n      | Avg  | SD  | n    | Avg  | SD   |
| Coho salmon     | 195    | 66.5 | 5.6 | 324  | 63.6 | 12   |
| Chinook salmon  | 52     | 86.4 | 8.7 | 117  | 79.9 | 18.8 |
| Chum salmon     | 2      | 62.5 | 3.5 | 3    | 72.7 | 12.5 |
| Steelhead       | 86     | 67.1 | 6.4 | 101  | 64.4 | 8.7  |
| Cutthroat trout | 25     | 38.9 | 6.7 | 35   | 34.4 | 5.0  |

### ***Survival***

Estimated rates of survival for coho salmon were high for both the freshwater and marine residency. Calculated survival during freshwater residency averaged 30.8% and ranged from 16.3% to 82.3% (Table 20). Eliminating two years when freshwater survival was unrealistically high (56.3% and 82.3%) resulted in a mean freshwater survival rate estimate of 23.1%. Calculated marine survival rates averaged 27.1% and ranged from 1.7% to 78.7%. Eliminating the two years when marine survival was highest (57.5% and 78.7%) reduced average survival to 16.9%, but still unrealistically high.

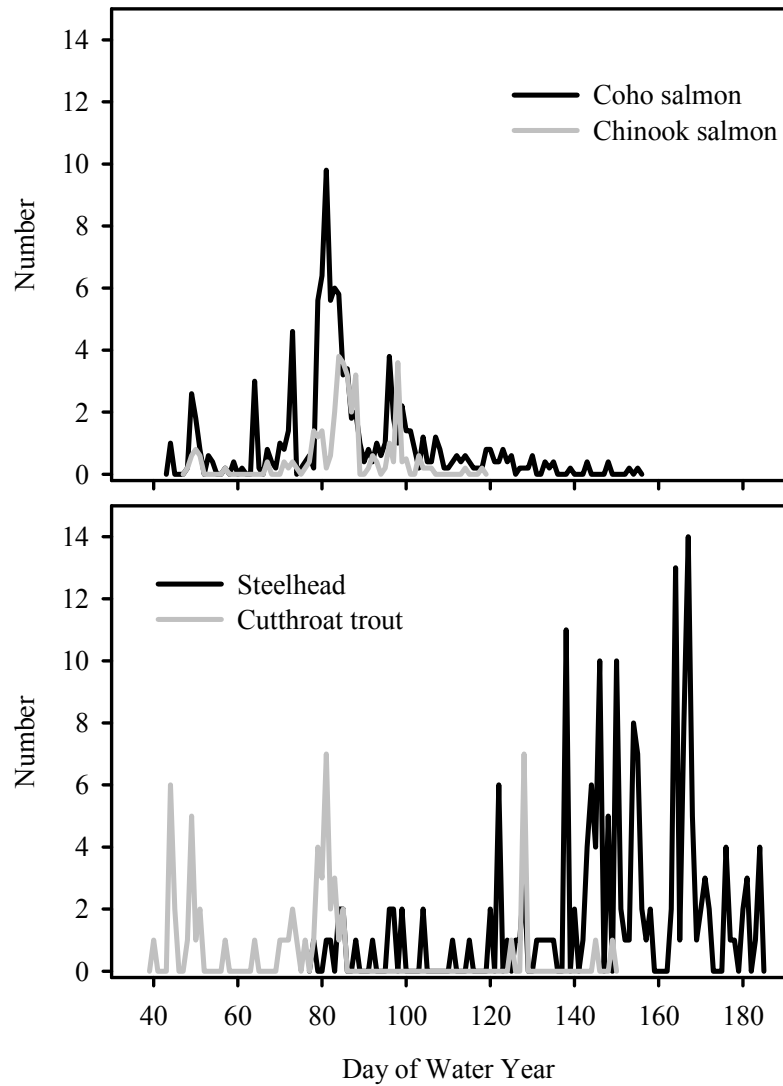


Figure 12. Daily average number of coho salmon, Chinook salmon and steelhead captured at the weir on Prairie Creek during five winters. Peak is December 20.

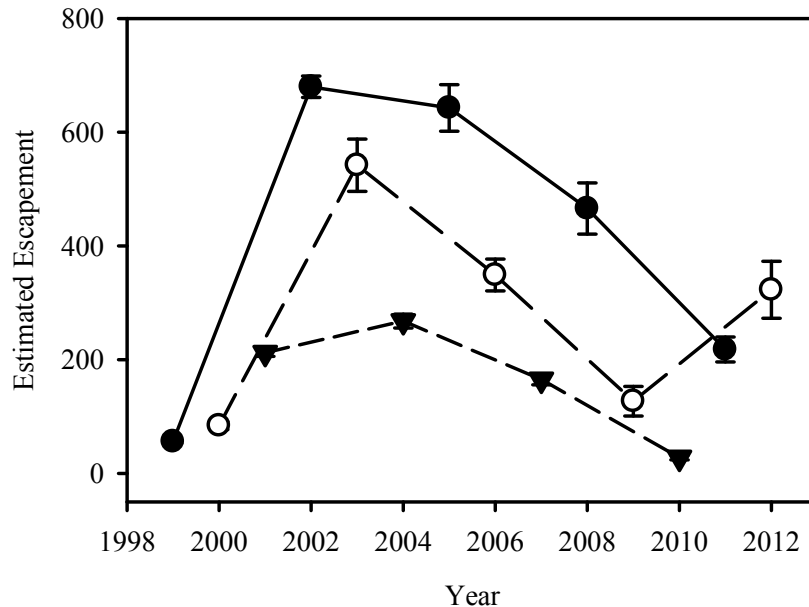


Figure 13. Estimated escapement of three cohorts of coho salmon to Prairie Creek.

Table 22. Estimated annual abundance of coho salmon in Prairie Creek and their rates of survival in freshwater and marine habitat. Year for adult escapement data is listed as second half of season (e.g. year 2000 = 1999/2000 spawning season).

| Year | Estimated Abundance |       |         | % Survival |        |
|------|---------------------|-------|---------|------------|--------|
|      | Juvenile            | Smolt | Adult   | Freshwater | Marine |
| 1998 | 6,127               |       |         |            |        |
| 1999 | 7,130               | 1,876 | 56      | 30.6       |        |
| 2000 | 4,494               | 1,182 | 84      | 16.6       |        |
| 2001 | 2,617               | 689   | 212     | 15.3       | 11.3   |
| 2002 | 8,187               | 2,154 | 680     | 82.3       | 57.5   |
| 2003 | 8,664               | 2,280 | 542     | 27.8       | 78.7   |
| 2004 | 5,367               | 1,412 | 268     | 16.3       | 12.4   |
| 2005 | 3,154               | 830   | 643     | 15.5       | 28.2   |
| 2006 | 6,747               | 1,775 | 349     | 56.3       | 24.7   |
| 2007 | 4,641               | 1,221 | 165     | 18.1       | 19.9   |
| 2008 | 5,035               | 1,694 | 466     | 36.5       | 26.3   |
| 2009 | 4,041               | 1,063 | 127     | 21.1       | 10.4   |
| 2010 | 5,117               | 1,346 | 28      | 33.3       | 1.7    |
| 2011 | 5,039               | 8,446 | 218     |            | 20.5   |
| 2012 |                     |       | 323     |            | 24.0   |
|      |                     |       | Average | 30.8       | 26.5   |

## DISCUSSION

### *Habitat*

In this study, habitat was measured each year to allocate fish sampling effort randomly among primary habitat types. The habitat data generally are coarse scale (pools, runs and riffles) represent summer conditions, although habitat surveys were conducted during one winter. The most common habitat in Prairie, Streeflow and Lost Man creeks during all years was pool habitat. In Boyes Creek, riffles comprised the greatest area of habitat during all years. Prairie Creek and all tributaries sampled are low gradient ( $< 3.0\%$ ) in reaches studied. However, Boyes Creek differed from other streams sampled in land use history, having been impacted by a mass wasting event during the 1980's. Sediment from this event may still be migrating through the sub-watershed and influencing habitats there.

We analyzed pool habitats because of their importance to juvenile coho salmon. Pool area was correlated strongly with coho salmon smolt abundance in Washington streams, suggesting summer pool area may be a limiting factor for smolt production (Sharma and Hilborn 2001). Nickelson et al. (1992) reported that highest density of juvenile coho salmon during summer in coastal Oregon streams occurred in pools. Similarly, Hampton (1988) and Beecher et al. (2002) reported that juvenile coho salmon preferred water depths of roughly 0.5 – 1.2 m having current velocities of 15 cm/s or less. We found that maximum depth of pool habitats was greatest in Lost Man and Streeflow creeks, it was intermediate in Prairie Creek and shallowest in Boyes Creek. We also found that average volume of pools in summer was greatest in Lost Man Creek and least in Boyes Creek, with volume in Boyes Creek being only  $1/8^{\text{th}}$  that in Lost Man Creek. Volume of pool habitat in Prairie Creek and Streeflow Creek increased during winter, but decreased in Boyes Creek. Maximum pool depth during winter has been positively correlated with density of juvenile coho salmon (Nickelson et al. 1992). Evidence suggests that habitat quality for juvenile coho salmon is lower in Boyes Creek than in other streams sampled. This evidence includes a smaller proportion of habitat area in pools and pool habitats having reduced depth and volume relative to other streams.

Daily average water temperatures were lowest during late December through February and increased to a maximum in July, but daily maximum temperatures never exceeded  $14^{\circ}\text{C}$ . When measured hourly, maximum temperatures in Prairie Creek typically exceeded  $16^{\circ}\text{C}$  for several hours each day during July and sometimes August. Thus, daily maximum temperatures

were within the 11.8 – 14.6 °C range considered optimal for rearing by juvenile coho salmon (ODEQ 1995) and hourly maximum temperatures exceeded this range only briefly. In some years, water temperature increased somewhat steadily through July before declining in August through winter. In other years, hourly water temperatures rose to a peak in July, but then were variable, presumably showing the influence of marine fog. Average monthly discharge in Prairie Creek was greatest and most variable during December and lowest and more constant during August.

### **Egg Survival**

Number of coho salmon fry emerging from natural redds sampled in three tributaries was variable. In Prairie Creek, all five redds trapped produced fry (average 908/redd). However, in Streelaw Creek only two of five redds trapped produced eggs (average 2,392/redd) and in Boyes Creek only 652 fry were produced from one redd, the other four producing nothing. Sparkman (2004) found that 41% of the variation in the number of fry produced from redds in Prairie, Streelaw and Boyes creeks was explained by the amount of fine sediment (< 3.33 mm dia.) accumulating in these redds and the presence or absence of predaceous oligochaete worms. Fine sediment in redds was also identified as the probable variable contributing to coho salmon egg mortality in Prairie Creek (Coey 1998), although in that study a quantitative relationship was not established. Sparkman stated that he thought the failure of coho salmon redds to produce fry could be attributed more to fine sediment in redds than the presence of oligochaete worms. He noted four of the five coho salmon redds trapped in Boyes Creek produced no fry and that these redds had elevated levels of fine sediment levels, but no oligochaete worms were not found in these redds. However, Sparkman (2004) acknowledge that methods he used may not have detected all oligochaete worms that can be fairly mobile (Williams 1996, Meyer 2003). This finding is consistent with previous findings that fine sediments accumulating in coho salmon redds negatively affect the survival to emergence of eggs, embryos and alvins (Koski 1966, Tagart 1984).

Survival of coho salmon eggs in artificial redds averaged 70% at egg hatching and declined to 32% at fry emergence. However, excluding redds invaded by predaceous oligochaete worms, averaged 75% at egg hatching and declined to only 65% at fry emergence. These survival estimates, both including oligochaete worms and excluding worms, are generally consistent with previous findings. Coey (1998) reported coho salmon egg survival in Prairie

averaged 32.8% in a sediment affected reach and 23.8% in a control reach. Briggs (1953) estimated that coho salmon egg to fry survival in Prairie Creek was 74%. Briggs' estimates exclude redds invaded by oligochaete worms and were based on excavating redds, then counting live and dead eggs. Other estimates of coho salmon egg to emergence survival range from 16.2% in experimental hatchery troughs (Shapovalov and Taft 1954), 29.8% in a stream impacted by logging (Tagart 1984) to 82% in the Alsea, Oregon, watershed under good conditions (Moring and Lantz 1975). Quinn (2005) suggested that, under optimal conditions, salmon egg to fry survival may be as high as 80%.

We found that coho salmon egg development and emergence from redds was related to accumulated water temperature. Fry were first recorded emerging from natural redds at 696 degree days and the peak of emergence occurred at 755 degree days. Ninety percent of fry captured had emerged from redds by 809 degree days. Degree days recorded correspond with an average date at first emergence of 26 February, at peak emergence of 4 April and 90% emergence of 12 April.

### ***Juvenile Fish Abundance***

Abundance of juvenile coho salmon was estimated during summer each year and again in October during 1998 – 2003. These data provide information on abundance trends over time and the relative contribution of tributaries to the juvenile coho salmon population in the Prairie Creek sub-watershed. Due to the influence of sampling area, abundance estimates typically cannot be directly compared with those from other watersheds.

Abundance of juvenile coho salmon in Prairie Creek averaged 5,454 fish, while in Boyes Creek it averaged 2,352 and in Streelaw Creek 2,656 fish. Abundance did not differ statistically among most years. However, in 2000 abundance was statistically lower than other years and influenced by particularly low abundance in Streelaw and Prairie creek. Low abundance during 2000 may have been the result of low discharge as discharge during August that year was lower than during any other years sampled. Abundance in 2002 was greater than other years, but environmental variables such as flow and water temperature do not suggest more favorable habitat conditions during that year.

Unlike abundance, density of fish species can be compared among watersheds. Density of juvenile coho salmon during summer in Boyes Creek ( $0.77 \text{ m}^2$ ) was statistically greater than

in either Prairie Creek ( $0.33 \text{ m}^2$ ) or Boyes Creek ( $0.38 \text{ m}^2$ ). These findings seem counterintuitive upon initial examination, since Boyes Creek is smaller than other tributaries sampled and had the lowest quality habitat (shallowest pools, lowest volume pools). However, previous investigations have reported that the highest densities of juvenile coho salmon during summer are usually found in the smallest streams (Rosenfeld et al. 2000). Among all streams, density did not differ statistically among years, although the probability value was only slightly greater than alpha (0.05). Densities reported here for the Prairie Creek watershed are within the range reported from coastal streams in Oregon. Jepsen and Rodgers (2004) reported that mean densities of juvenile coho salmon in 1<sup>st</sup> – 3<sup>rd</sup> order streams in five coastal regions ranged from  $0.29 - 1.19 \text{ fish/m}^2$  and only  $0.00 - 0.23$  in 4<sup>th</sup> – 5<sup>th</sup> order streams. Prairie Creek is a 4<sup>th</sup> order stream, although it is a 3<sup>rd</sup> order stream in the portion we sampled for juvenile fish. Both Streelow and Boyes creeks are 2<sup>nd</sup> order streams.

Survival of juvenile coho salmon between July and October ranged from 60% to 94% among all streams and years. Survival was greatest in Prairie Creek (mean = 92%), intermediate in Streelow Creek (mean = 75%), and lowest in Boyes Creek (mean = 68%). Among years, summer survival ranged from 72% in 2003 to 87% in 1999 and was not statistically different. Survival of juvenile coho salmon during the summer to fall period has been demonstrated to be density dependent, and most strongly expressed in small streams where habitat volume shrinks more dramatically with declining summer flow that also delivers less drifting prey (Au 1972, Quinn 2005). Although we did not test for density dependence in summer to fall survival, our finding that survival was lowest in the smallest tributary we sample, Boyes Creek, is consistent with those previous interpretations. Lestelle (2007) re-analyzed data presented by Au (1972) and found that when the influence of density was removed, survival during June to October should be about 86%. The survival rate absent density effects Lestelle (2007) reports suggests that habitat in Prairie Creek, and probably Streelow Creek, is adequate to minimize any density effects on summer to fall survival of juvenile coho salmon.

Fork length of juvenile coho salmon during July and August averaged 59.6 mm, while weight averaged 2.35 g. During 1999-2003, average fork length in October was 65.6 mm while average weight was 3.74 g and in May average fork length was 81.7 mm and weight 8.16 g. Size of juvenile coho salmon in the Prairie Creek watershed reported here are generally comparable with sizes reported from California (Shapovalov and Taft 1954), Oregon (Ebersole

et al. 2009) and Washington (Nielsen 1992). Size of juvenile coho salmon in the Prairie Creek watershed was negatively related to their density in pool and run habitats, though this relationship was not statistically significant. Ebersole et al. (2009) also report juvenile coho salmon in headwaters of the Smith River, Oregon, were limited by density within habitats and minimum summer discharge. Nielsen (1992) separated juvenile coho salmon in Huckleberry Creek Washington into three behavioral categories, based on size. However, when size data reported by Nielsen (1992) for August are combined they yield an average fork length of 59.6 mm, the same as in Prairie Creek.

Specific growth rates of juvenile coho salmon in the Prairie Creek watershed were greatest between May, at hatching, and July, then declined during July – October and October - March. Absolute growth in both length and weight was greatest during October – March and lowest during July - October. This pattern in growth is consistent with the seasonal growth of juvenile coho salmon reported from the Pacific Northwest (Quinn 2005). Growth is normally rapid as fry are developing to parr during spring when flow remains relatively high and water temperatures increase from winter lows. During summer, growth declines as flow declines and biomass density increases, resulting in greater competition. Finally, growth during winter is limited by cool water temperatures.

Diet of juvenile coho salmon was varied and contained organisms commonly found drifting in the water column as well as organisms associated with the benthos. The most important prey in stomachs during spring, summer and fall were larvae and adult Diptera and Oligocheata. Amphipoda also contributed substantially to the diet of juvenile coho salmon in Streelow Creek, but not in other streams. These findings differ somewhat from previously published findings and offer some insight to the role of habitat in the ecology of juvenile coho salmon. Most published accounts of the diet of juvenile coho salmon identify drifting larvae and adults of aquatic insects as making up the majority of prey consumed, with Diptera often the most important insect (reviewed by Sandercock 1991). Gonzales (2006) found that aquatic oligocheates, as a proportion of biomass in stomachs and as energy consumed, were also an important prey throughout the Prairie Creek watershed. He also found that amphipods were an important prey in Streelow Creek, but not in other tributaries. The occurrence of oligocheates in the diet of coho salmon in Prairie Creek suggest that these fish employ a more divers foraging strategy than has been previously reported. The occurrence of Diplopoda larvae, a larvae

associated with leaf packs, in the diet reinforces this interpretation that juvenile coho salmon were foraging on the bottom as well as in the water column. The importance of amphipods in the diet of fish from Streeflow Creek reflects riparian condition. Streeflow Creek was logged in the 1960's and today the riparian is dominated by alder, which decompose quickly and favor amphipods, while the riparian in other tributaries is a mixture of redwood, big leaf maple and alder.

### ***Downstream Migrant Trapping***

Average annual production of age 1+ coho salmon estimated from the lower Prairie Creek site was 9,078 smolts and in Streeflow Creek it was 2,942 smolts. Average annual production of age 1+ coho salmon estimated from Boyes Creek was only 467 smolts and assumed to be reflected in the lower Prairie Creek trap, located downstream of the confluence with Boyes Creek. Bradford et al. (1997) reported that coho salmon smolt production was linearly related to stream length and production estimates from Prairie Creek fall within a cluster of points reported by them for streams of similar size. The low coho salmon smolt production from Boyes Creek is notable, being only 1/6<sup>th</sup> of the production from Streeflow Creek despite being roughly the same length and having higher densities of juveniles than the other tributaries. This may be the result of Boyes Creek being impacted by sediment mass wasting during road construction in the 1980's, which continues to be reflected by habitat quality and, as shown here, contributing to low overwinter survival.

Annual timing of coho salmon smolt migration has been documented to be correlated with latitude, with southern populations in California and Oregon migrating earlier than more northerly populations. Feola (2007) found that smolt migration in the Prairie Creek watershed began as early as calendar days 70 – 80, with around half the migration completed by day 100 – 120 and 95% of the migration by day 120 – 160. These dates correspond with the range of median dates of migrant Spence and Hall (2010) report for California streams.

Diel timing of migration of coho salmon smolts in Prairie Creek occurred during most of the day. Ninety-three of 100 PIT tagged smolts were re-sighted at the lower Prairie Creek trap during a period beginning at 2100 hours and extending until 1000 hours the following day. The remaining seven fish were recorded during 1100 hours through 2000 hours and movement during this period was not consistent. No single environmental variable explained a substantial amount of

the variation in daily migration, but models including or related to date, water temperature, discharge and lunar cycle performed roughly equally (Feola 2007).

Eleven species of fish were collected in downstream migrant traps (DSMT). The most common species/age class collected were age 0+ coho salmon, with average annual catches ranging from 11,790 at the Boyes Creek site to 36,121 at the upper Prairie Creek site. Chinook salmon (age 0+) were also abundant at both Prairie Creek sites, with average annual catch at the lower site being 26,865 and at the upper site 44,136. Chinook salmon were, however, far less abundant at the Boyes Creek and Streelow Creek sites. These two tributaries are 2<sup>nd</sup> order streams and adult Chinook salmon were rarely observed in either stream. Other species common in DSMT catches included steelhead, coastal cutthroat trout and trout that could not be classified as either steelhead or cutthroat. Duffy et al. (2011) found that predators in DSMT (primarily coastal cutthroat trout) consumed up to 25% of the available salmonid fry in traps on specific dates. Over the course of the study, they consumed 2.5% of all salmonid fry captured in traps, but this fraction ranged from less than 1% to more than 10% in any given year.

### ***Adult Salmonid Escapement***

Average escapement of coho salmon to Prairie Creek estimated using live fish AUC was 297 fish, using redd expansion methods it was 312 fish. Coho salmon escapement using redd expansion methods was positively related to escapement estimated using AUC methods. Escapement of Chinook salmon averaged 272 fish when estimated from live fish AUC. Escapement of steelhead and coastal cutthroat trout was much lower. Both coho salmon and Chinook salmon showed cyclical abundance. Trends in weir catches generally reflected escapement estimates over comparable periods. Gallagher et al. (2010) compared three methods of estimating escapement of coho salmon and steelhead in three California streams. They used a live fish capture-recapture method as a standard and compared it with estimates derived from carcass capture-recapture, live fish AUC and redd expansion methods. Gallagher et al. (2010) found that carcass capture-recapture methods were unreliable in the Mendocino County streams they studied, but that redd expansion and live fish AUC methods provided results comparable live fish capture-recapture methods. They recommended the use of redd expansion methods to estimate escapement in California streams primarily due to the sensitivity of some parameters (stream residence time and observer efficiency) in the live fish AUC method. While it is true

that the live fish AUC is sensitive to these model parameters, results of the live fish AUC method has the advantage of being based on positive observations of species whereas many of the redds in the redd expansion method are of unknown species. Thus, it seems that in streams like Prairie Creek with both coho salmon and Chinook salmon having overlapping run timing there is validity in using both techniques.

Most monitored populations of coho salmon exhibited declining escapement during 2004 – 2010 (<https://nrm.dfg.ca.gov/Documents/ContextDocs.aspx?cat=Fisheries--CohoSalmon> ).

The decline in escapement to some of these streams, such as the Shasta and Mattole rivers, was been dramatic, declining from 100's to 10's of fish during this period. However, a seven year data set is not exceptionally long and this regional decline may, in most streams, be part of an oscillation in abundance brought about by natural phenomenon. Furthermore, when individual cohorts are examined independently it quickly becomes clear that any seven year period is inadequate to judge population status. Escapement estimates provide valuable information about trends in population size, but do not allow for comparisons among streams due the wide variation in stream length or area within streams suitable for spawning.

Coho salmon escaping to Redwood Creek spawn primarily in the Prairie Creek watershed. Escapements estimates for Prairie Creek relied on sampling about 16 km of habitat most years, providing an average spawner/km estimate of 18.5 to 19.5 fish. This density of spawners is about half the 19 females/km Bradford et al. (2000) suggested was necessary to “fully seed” a watershed with juveniles. NOAA-NMFS (2012) recommended that Redwood Creek watershed would need 4,900 coho salmon spawners to meet population viability. This number is taken from Williams et al. (2008) estimate of a relationship between kilometers of habitat in a watershed with Intrinsic Potential (IP km) to support rearing coho salmon and the number of spawners/IP km. However, NOAA-NMFS (2012) notes there is little evidence of coho salmon historically spawning in much of Redwood Creek outside the Prairie Creek sub-basin and that the primary high IP km areas in the watershed are located in Prairie Creek.

Run timing of coho and Chinook salmon, measured as average daily catch at the weir, overlapped considerable. During five years of weir operation, average date of Chinook salmon arrival at the weir preceded coho by about one week. Run timing of coho salmon was, however, more extended than Chinook salmon. Coho salmon arrived at the weir as early as 10 November and as late as 3 March while Chinook salmon were captured at weir as early as 18 November and

as late as 27 January. Steelhead were captured at weir as early as 17 November and as late as 2 April. Peak abundance of steelhead occurred during 31 - 17 March. Coastal cutthroat trout were captured at the weir as early as 9 November and as late as 27 February. Pulses in catch of coastal cutthroat trout occurred in mid-November, mid-December and early February (Figure 12).

Timing of escapement in coho salmon has recently be found to have important implications for fitness or reproductive success (Anderson et al. 2010, Kodama et al. 2012). Using genetic techniques to associate offspring with parents, both studies found that relatively few adults had high reproductive success (e.g. their progeny returned to spawn) while most adults did not contribute to future generations. Furthermore, both studies found that adults spawning early in the season or near the peak of the spawning season, were more likely to have high reproductive success while those spawning late in the season had low reproductive success. In addition, Anderson et al. (2010) found that size of juvenile coho salmon in summer was strongly correlated with the date their parents spawned, with early spawners producing larger juveniles and late spawners producing smaller juvenile. In Prairie Creek, adult coho salmon arrived at the weir in pulses most often associated with higher discharge during storms in December (Wright 2011). Findings of Anderson et al. (2010) and Kodama et al. (2012) suggest that these fish likely contribute to future coho salmon populations in Prairie Creek, while those adults arriving in late January through February may contribute little.

## ***Survival***

Estimated rates of survival for coho salmon during freshwater within the ranges reported by others. Calculated survival during freshwater residency averaged 30.8% and ranged from 16.3% to 82.3%. Eliminating two years when freshwater survival was considered high (56.3% and 82.3%) resulted in a mean freshwater survival rate estimate of 23.1%. Brakensiek (2002) reported that survival of coho salmon in Prairie Creek during summer was higher in run habitats (86.6%) and pools (74.2%) than in riffles (32.5%) and that winter survival was 45.5%. For fish in pools, this translates to a survival rate during freshwater residency of 33.8%, similar to the 30.8% reported here. Wright et al. (2011) reported that overwinter survival of coho salmon in Pudding Creek, Mendocino County, California, ranged from 17% to 80% over four years. Other studies considering longer periods report lower survival. For example; survival from egg to

smolt stage was reported to be 1% - 2% and from fry to smolt stage it was 0.7% - 9.6% (Sandercock 1991).

Marine survival reported here is confounded by errors in either adult escapement or smolt production, or both. Calculated marine survival rates averaged 27.1% and ranged from 1.7% to 78.7%. Eliminating the two years when marine survival was highest (57.5% and 78.7%) reduced average survival to 16.9%, but this estimate is still higher than would be expected based on the literature. Shapovalov and Taft reported that marine survival of coho salmon in central California ranged from 0.98% – 77.2% and averaged 4.95%. Studies from British Columbia and Washington generally report marine survival rates in coho salmon of less than 10%, although a few exceed 15% and at least one experimental study of hatchery releases demonstrated survival of more than 40% under optimal conditions (Sandercock 1991).

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**Appendix A. Number (n) and area (m<sup>2</sup>) of pool, run, riffle and other habitat types in tributaries sampled each year.**

Appendix A1. Number (n) and area (m<sup>2</sup>) of pool, run, riffle and other habitat types and total area of habitat surveyed in Prairie Creek 1998 -2011.

| Year | Pools |                        | Runs |                        | Riffles |                        | Other |                        | Total |                        |
|------|-------|------------------------|------|------------------------|---------|------------------------|-------|------------------------|-------|------------------------|
|      | n     | Area (m <sup>2</sup> ) | n    | Area (m <sup>2</sup> ) | n       | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) |
| 1998 | 185   | 13,244                 | 100  | 6,028                  | 151     | 6,249                  | 5     | 218                    | 441   | 25,740                 |
| 1999 | 142   | 8,109                  | 93   | 7,041                  | 154     | 5,938                  | 51    | 4,096                  | 440   | 25,184                 |
| 2000 | 117   | 10,114                 | 112  | 6,868                  | 170     | 7,769                  | 30    | 1,922                  | 429   | 26,672                 |
| 2001 | 133   | 10,140                 | 164  | 7,936                  | 183     | 6,316                  | 0     | 0                      | 480   | 24,393                 |
| 2002 | 116   | 12,335                 | 126  | 7,336                  | 137     | 6,918                  | 4     | 183                    | 383   | 26,773                 |
| 2003 | 141   | 12,927                 | 141  | 7,599                  | 139     | 5,878                  | 3     | 171                    | 424   | 26,575                 |
| 2004 | 147   | 11,289                 | 93   | 6,433                  | 140     | 7,218                  | 0     | 0                      | 380   | 24,939                 |
| 2005 | 116   | 9,850                  | 133  | 8,851                  | 112     | 5,203                  | 0     | 0                      | 361   | 23,905                 |
| 2006 | 123   | 8,358                  | 144  | 7,845                  | 126     | 5,997                  | 7     | 246                    | 400   | 22,446                 |
| 2007 | 112   | 9,331                  | 133  | 8,807                  | 102     | 4,083                  | 6     | 423                    | 353   | 22,644                 |
| 2008 | 133   | 10,780                 | 109  | 6,073                  | 133     | 5,358                  | 7     | 228                    | 382   | 22,439                 |
| 2009 | 154   | 18,605                 | 119  | 13,263                 | 109     | 10,310                 | 6     | 869                    | 388   | 43,047                 |
| 2010 | 131   | 9,326                  | 120  | 8,104                  | 164     | 8,385                  | 4     | 310                    | 419   | 26,124                 |
| 2011 | 60    | 4,789                  | 86   | 6,801                  | 112     | 7,256                  | 58    | 5,428                  | 316   | 24,273                 |

Appendix A2. Number (n) and area (m<sup>2</sup>) of pool, run, riffle and other habitat types and total area of habitat surveyed in Boyes Creek 1998 -2006.

| Year | Pools |                        | Runs |                        | Riffles |                        | Other |                        | Total |                        |
|------|-------|------------------------|------|------------------------|---------|------------------------|-------|------------------------|-------|------------------------|
|      | n     | Area (m <sup>2</sup> ) | n    | Area (m <sup>2</sup> ) | n       | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) |
| 1998 | 138   | 2,328                  | 75   | 1,397                  | 122     | 2,337                  | 5     | 48                     | 340   | 6,111                  |
| 1999 | 80    | 1,940                  | 67   | 2,495                  | 55      | 1,382                  | 3     | 37                     | 205   | 5,854                  |
| 2000 | 69    | 1,915                  | 85   | 2,417                  | 94      | 2,520                  | 0     | 0                      | 248   | 6,852                  |
| 2001 | 76    | 1,956                  | 64   | 1,486                  | 118     | 2,654                  | 7     | 37                     | 265   | 6,133                  |
| 2002 | 62    | 1,537                  | 57   | 1,126                  | 95      | 2,628                  | 21    | 466                    | 235   | 5,757                  |
| 2003 | 41    | 914                    | 81   | 1,947                  | 85      | 2,889                  | 0     | 0                      | 207   | 5,751                  |
| 2004 | 66    | 1,773                  | 46   | 1,092                  | 65      | 2,138                  | 1     | 20                     | 178   | 5,024                  |
| 2005 | 48    | 2,674                  | 65   | 4,680                  | 85      | 4,777                  | 12    | 0                      | 210   | 12,132                 |
| 2006 | 56    | 1,262                  | 67   | 1,290                  | 85      | 2,121                  | 28    | 0                      | 236   | 4,673                  |

Appendix A3. Number (n) and area (m<sup>2</sup>) of pool, run, riffle and other habitat types and total area of habitat surveyed in Streeflow Creek 1998 -2006.

| Year | Pools |                        | Runs |                        | Riffles |                        | Other |                        | Total |                        |
|------|-------|------------------------|------|------------------------|---------|------------------------|-------|------------------------|-------|------------------------|
|      | n     | Area (m <sup>2</sup> ) | n    | Area (m <sup>2</sup> ) | n       | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) |
| 1998 | 103   | 7,914                  | 56   | 3,041                  | 27      | 897                    | 6     | 373                    | 192   | 12,226                 |
| 1999 | 91    | 4,784                  | 57   | 2,671                  | 25      | 1,199                  | 3     | 31                     | 176   | 8,684                  |
| 2000 | 101   | 4,512                  | 56   | 2,307                  | 48      | 1,600                  | 0     | 0                      | 205   | 8,419                  |
| 2001 | 68    | 2,855                  | 81   | 2,941                  | 59      | 1,365                  | 5     | 77                     | 213   | 7,238                  |
| 2002 | 69    | 3,800                  | 54   | 2,738                  | 59      | 1,631                  | 2     | 16                     | 184   | 8,184                  |
| 2003 | 104   | 4,610                  | 63   | 2,086                  | 39      | 816                    | 6     | 59                     | 212   | 7,570                  |
| 2004 | 65    | 2,172                  | 49   | 1,668                  | 54      | 1,056                  | 3     | 116                    | 171   | 5,012                  |
| 2005 | 60    | 2,851                  | 52   | 1,861                  | 26      | 478                    | 25    | 85                     | 163   | 5,275                  |
| 2006 | 56    | 2,701                  | 48   | 1,873                  | 32      | 1,076                  | 27    | 36                     | 163   | 5,686                  |

Appendix A4. Number (n) and area (m<sup>2</sup>) of pool, run, riffle and other habitat types and total area of habitat surveyed in Lost Man Creek 1998 -2006.

| Year | Pools |                        | Runs |                        | Riffles |                        | Other |                        | Total |                        |
|------|-------|------------------------|------|------------------------|---------|------------------------|-------|------------------------|-------|------------------------|
|      | n     | Area (m <sup>2</sup> ) | n    | Area (m <sup>2</sup> ) | n       | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) | n     | Area (m <sup>2</sup> ) |
| 2005 | 22    | 2,398                  | 19   | 1,443                  | 25      | 1,319                  | 0     | 0                      | 66    | 5,159                  |
| 2006 | 14    | 955                    | 12   | 522                    | 34      | 2,529                  | 0     | 0                      | 60    | 4,007                  |
| 2007 | 23    | 1,388                  | 5    | 118                    | 33      | 1,337                  | 0     | 0                      | 61    | 2,842                  |
| 2008 | 27    | 2,171                  | 6    | 375                    | 29      | 1,345                  | 0     | 0                      | 62    | 3,892                  |
| 2009 | 51    | 10,011                 | 38   | 6,975                  | 68      | 10,461                 | 15    | 2,492                  | 172   | 29,939                 |
| 2010 | 73    | 13,039                 | 70   | 10,699                 | 102     | 12,938                 | 1     | 210                    | 246   | 36,886                 |
| 2011 | 56    | 8,617                  | 62   | 8,609                  | 123     | 16,327                 | 28    | 6,252                  | 269   | 39,805                 |

**Appendix B. Estimated population density (no/ha) of coastal cutthroat trout, age 0+ trout and other fish species sampled in the Prairie Creek watershed each year.**

Appendix B1. Estimated population density (no ha) of coastal cutthroat trout in three types of habitat and total density within Prairie Creek.

| Year | Month | Pool | C.I. | Run | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|-----|------|--------|------|-------|------|
| 2000 | July  | 284  |      | 258 | 6    | 201    | 89   | 743   | 101  |
| 2000 | Oct.  | 113  | 3    | 105 | 2    | 240    | 94   | 458   | 99   |
| 2001 | July  | 208  | 8    | 463 | 7    | 520    | 165  | 1191  | 180  |
| 2001 | Oct.  | 107  | 4    | 56  | 1    | 39     | 23   | 202   | 28   |
| 2002 | July  | 91   | 6    | 70  | 2    | 319    | 142  | 480   | 150  |
| 2002 | Oct.  | 378  | 24   | 112 | 4    | 98     | 66   | 588   | 94   |
| 2003 | July  | 77   | 11   | 112 | 2    | 566    | 229  | 755   | 242  |
| 2003 | Oct.  | 155  | 6    | 155 | 3    | 64     | 50   | 374   | 59   |
| 2004 | July  | 455  | 13   | 286 | 14   | 87     | 48   | 828   | 75   |
| 2005 | Aug   | 299  | 10   | 388 | 4    | 99     | 3    | 786   | 17   |
| 2006 | Aug   | 332  | 19   | 92  | 7    | 219    | 10   | 643   | 36   |
| 2007 | Aug   | 452  | 10   | 255 | 6    | 142    | 2    | 849   | 18   |
| 2008 | Aug   | 520  | 7    | 145 | 6    | 140    | 4    | 805   | 17   |
| 2009 | Aug   | 139  | 10   | 171 | 18   | 419    | 13   | 729   | 41   |
| 2010 | Aug   | 669  | 13   | 580 | 6    | 301    | 5    | 1550  | 24   |
| 2011 | Aug   | 487  | 15   | 362 | 7    | 378    | 13   | 1227  | 35   |

Appendix B2. Estimated population density (no ha) of coastal cutthroat trout in three types of habitat and total density within Boyes Creek.

| Year | Month | Pool | C.I. | Run | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|-----|------|--------|------|-------|------|
| 2000 | July  | 678  | 202  | 312 | 65   | 213    | 75   | 565   | 88   |
|      | Oct.  | 652  | 224  | 359 | 67   | 193    | 53   | 598   | 91   |
| 2001 | July  | 1279 | 402  | 208 | 54   | 81     | 57   | 653   | 142  |
|      | Oct.  | 781  | 320  | 152 | 47   | 14     | 19   | 409   | 113  |
| 2002 | July  | 1488 | 202  | 148 | 30   | 563    | 13   | 714   | 66   |
|      | Oct.  | 1212 | 238  | 159 | 38   | 196    | 70   | 527   | 86   |
| 2003 | July  | 996  | 272  | 172 | 23   | 118    | 28   | 378   | 48   |
|      | Oct.  | 1213 | 415  | 182 | 44   | 39     | 19   | 379   | 76   |
| 2004 | Aug   | 651  | 309  | 296 | 53   | 46     | 34   | 529   | 114  |
| 2005 | Aug   | 105  | 20   | 115 | 11   | 0      | 0    | 220   | 31   |
| 2006 | Aug   | 49   | 16   | 22  | 9    | 0      | 0    | 71    | 25   |

Appendix B3. Estimated population density (no ha) of coastal cutthroat trout in three types of habitat and total density within Streeflow Creek.

| Year | Month | Pool | C.I. | Run | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|-----|------|--------|------|-------|------|
| 2000 | Oct.  | 760  | 219  | 332 | 30   | 267    | 72   | 789   | 122  |
|      | July  | 792  | 210  | 286 | 51   | 762    | 133  | 855   | 126  |
| 2001 | Oct.  | 1020 | 571  | 488 | 71   | 466    | 233  | 984   | 242  |
|      | July  | 697  | 427  | 633 | 119  | 221    | 114  | 953   | 209  |
| 2002 | Oct.  | 1063 | 193  | 211 | 45   | 394    | 122  | 774   | 102  |
|      | July  | 783  | 217  | 250 | 63   | 258    | 86   | 658   | 118  |
| 2003 | Oct.  | 537  | 133  | 139 | 29   | 445    | 121  | 522   | 88   |
|      | July  | 403  | 92   | 72  | 29   | 90     | 82   | 332   | 65   |
| 2004 | Aug   | 620  | 138  | 218 | 50   | 524    | 364  | 708   | 102  |
| 2005 | Aug   | 285  | 15   | 149 | 6    | 0      | 0    | 434   | 21   |
| 2006 | Aug   | 20   | 5    | 251 | 71   | 1      | 0    | 272   | 76   |

Appendix B4. Estimated population density (no ha) of age 0+ trout in three types of habitat and total density within Prairie Creek.

| Year | Month | Pool | C.I. | Run  | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|------|------|--------|------|-------|------|
| 1998 | Oct.  | 572  | 4    | 155  | 4    | 320    | 7    | 1047  | 15   |
| 1999 | July  |      |      |      |      | 1839   | 93   | 1839  | 93   |
| 1999 | Oct.  |      |      |      |      | 1709   | 165  | 1709  | 165  |
| 2000 | July  | 250  | 12   | 183  | 8    | 706    | 27   | 1139  | 47   |
| 2000 | Oct.  | 424  | 16   | 362  | 7    | 496    | 44   | 1282  | 67   |
| 2001 | July  | 578  | 19   | 719  | 3    | 627    | 33   | 1924  | 55   |
| 2001 | Oct.  | 612  | 14   | 391  | 5    | 214    | 43   | 1217  | 62   |
| 2002 | July  | 359  | 8    | 373  | 5    | 863    | 15   | 1595  | 28   |
| 2002 | Oct.  | 530  | 11   | 435  | 5    | 664    | 41   | 1629  | 57   |
| 2003 | July  | 542  | 14   | 403  | 15   | 1376   | 206  | 2321  | 235  |
| 2003 | Oct.  | 505  | 8    | 296  | 5    | 787    | 44   | 1588  | 57   |
| 2004 | July  | 592  | 13   | 158  | 11   | 1215   | 35   | 1965  | 59   |
| 2005 | Aug   | 173  | 14   | 320  | 12   | 548    | 21   | 1041  | 47   |
| 2006 | Aug   | 398  | 36   | 262  | 14   | 727    | 15   | 1387  | 65   |
| 2007 | Aug   | 829  | 40   | 1012 | 34   | 601    | 49   | 2442  | 123  |
| 2008 | Aug   | 571  | 22   | 478  | 7    | 316    | 10   | 1365  | 39   |
| 2009 | Aug   | 1245 | 14   | 397  | 8    | 2343   | 111  | 3985  | 133  |
| 2010 | Aug   | 3533 | 47   | 2715 | 51   | 1252   | 62   | 7500  | 160  |
| 2011 | Aug   | 1786 | 15   | 2061 | 82   | 2352   | 99   | 6199  | 196  |

Appendix B5. Estimated population density (no ha) of age 0+ trout in three types of habitat and total density within Boyes Creek.

| Year | Month | Pool | C.I. | Run  | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|------|------|--------|------|-------|------|
| 2000 | July  | 244  | 94   | 212  | 40   | 473    | 66   | 929   | 200  |
|      | Oct.  | 106  | 44   | 144  | 31   | 81     | 11   | 331   | 86   |
| 2001 | July  | 210  | 14   | 288  | 13   | 216    | 30   | 714   | 57   |
|      | Oct.  | 744  | 225  | 2784 | 138  | 347    | 101  | 3875  | 464  |
| 2002 | July  | 285  | 102  | 111  | 8    | 171    | 23   | 567   | 133  |
|      | Oct.  | 147  | 10   | 83   | 6    | 145    | 15   | 375   | 31   |
| 2003 | July  | 275  | 22   | 391  | 9    | 896    | 54   | 1562  | 85   |
|      | Oct.  | 119  | 15   | 248  | 8    | 381    | 9    | 748   | 32   |
| 2004 | Aug   | 470  | 14   | 362  | 15   | 709    | 20   | 1541  | 49   |
| 2005 | Aug   | 170  | 34   | 915  | 108  | 262    | 153  | 1347  | 295  |
| 2006 | Aug   | 62   | 22   | 138  | 45   | 434    | 164  | 634   | 231  |

Appendix B6. Estimated population density (no ha) of age 0+ trout in three types of habitat and total density within Streeflow Creek.

| Year | Month | Pool | C.I. | Run  | C.I. | Riffle | C.I. | Total | C.I. |
|------|-------|------|------|------|------|--------|------|-------|------|
| 1998 | Oct.  | 829  | 147  | 863  | 110  | 126    | 130  | 1818  | 387  |
| 1999 | July  | 720  | 520  | 2442 | 491  | 877    | 225  | 4039  | 1236 |
| 1999 | Oct.  | 57   | 62   | 268  | 53   | 232    | 49   | 557   | 164  |
| 2000 | Oct.  | 84   | 31   | 54   | 8    | 91     | 17   | 229   | 56   |
| 2000 | July  | 149  | 51   | 437  | 36   | 290    | 47   | 876   | 134  |
| 2001 | Oct.  | 241  | 45   | 641  | 77   | 222    | 49   | 1104  | 171  |
| 2001 | July  | 190  | 46   | 518  | 81   | 297    | 52   | 1005  | 179  |
| 2002 | Oct.  | 70   | 52   | 249  | 55   | 340    | 57   | 659   | 164  |
| 2002 | July  | 215  | 42   | 199  | 45   | 265    | 37   | 679   | 124  |
| 2003 | Oct.  | 321  | 28   | 262  | 23   | 59     | 6    | 642   | 57   |
| 2003 | July  | 227  | 36   | 288  | 41   | 143    | 28   | 658   | 105  |
| 2004 | Aug   | 353  | 41   | 382  | 36   | 182    | 148  | 917   | 225  |
| 2005 | Aug   | 214  | 55   | 149  | 19   | 0      | 0    | 363   | 74   |
| 2006 | Aug   | 145  | 17   | 172  | 22   | 59     | 8    | 376   | 47   |

Appendix B7. Estimated abundance of seven species of fish in Prairie Creek, 1998-2011.

| Year | Month | Lamprey<br>Ammocete | Sculpin <sup>1</sup> | Stickleback | Western Brook<br>Lamprey | Steelhead | Chinook | Sucker |
|------|-------|---------------------|----------------------|-------------|--------------------------|-----------|---------|--------|
| 1998 | Oct.  |                     | 1                    | 8           | 14                       |           |         |        |
| 1999 | July  | 101                 | 11                   | 34          | 22                       |           |         |        |
| 1999 | Oct.  | 24                  | 4                    | 25          |                          | 0         |         |        |
| 2000 | July  | 25                  | 5                    | 28          |                          | 2         | 1       |        |
| 2000 | Oct.  | 60                  | 14                   | 62          | 6                        | 74        |         |        |
| 2001 | July  | 0                   |                      |             |                          | 76        |         |        |
| 2001 | Oct.  | 118                 | 8                    | 64          | 18                       | 56        |         |        |
| 2002 | July  | 136                 |                      | 90          | 2                        | 38        |         |        |
| 2002 | Oct.  | 15                  | 1                    | 30          | 82                       | 1         |         |        |
| 2003 | July  | 98                  | 1                    | 33          | 6                        | 10        | 1       |        |
| 2003 | Oct.  | 44                  | 1                    | 18          |                          | 3         |         |        |
| 2004 | July  | 24                  | 5                    | 16          |                          | 5         | 2       |        |
| 2005 | Aug   | 11                  | 3                    |             |                          | 8         |         |        |
| 2006 | Aug   | 5                   | 1                    | 5           | 2                        | 9         |         |        |
| 2007 | Aug   | 6                   | 2                    | 8           |                          | 12        | 1       |        |
| 2008 | Aug   | 0                   | 3                    | 124         | 17                       | 9         |         |        |
| 2009 | Aug   | 0                   | 43                   | 27          |                          | 79        |         | 3      |
| 2010 | Aug   | 1                   | 34                   | 13          |                          | 21        |         |        |
| 2011 | Aug   | 24                  | 53                   | 5           | 4                        | 70        |         |        |

<sup>1</sup>Sculpin includes prickly and coast range sculpin.

Appendix B8. Estimated abundance of six species of fish in Boyes Creek, 1998-2006.

| Year | Month | Lamprey<br>Ammocete | Sculpin | Stickleback | Western Brook<br>Lamprey | Steelhead | Chinook |
|------|-------|---------------------|---------|-------------|--------------------------|-----------|---------|
| 1998 | Oct.  |                     |         |             |                          |           |         |
| 1999 | July  |                     |         |             |                          |           |         |
| 1999 | Oct.  |                     |         |             |                          |           |         |
| 2000 | July  |                     |         |             |                          |           |         |
| 2000 | Oct.  |                     |         |             |                          |           |         |
| 2001 | July  |                     |         | 0           | 14                       | 9         |         |
| 2001 | Oct.  |                     |         | 82          |                          | 12        |         |
| 2002 | July  |                     |         | 23          | 1                        | 2.0       |         |
| 2002 | Oct.  |                     |         | 42          | 6                        | 0         |         |
| 2003 | July  | 6                   |         | 25          | 20                       | 2         | 1       |
| 2003 | Oct.  | 11                  |         | 59          | 2                        | 2         |         |
| 2004 | July  | 10                  | 3       | 55          |                          | 11        |         |
| 2005 | Aug   | 7                   | 10      | 48          | 1                        | 10        |         |
| 2006 | Aug   | 1                   | 5       | 14          | 1                        | 6         |         |

<sup>1</sup>Sculpin includes prickly and coast range sculpin.

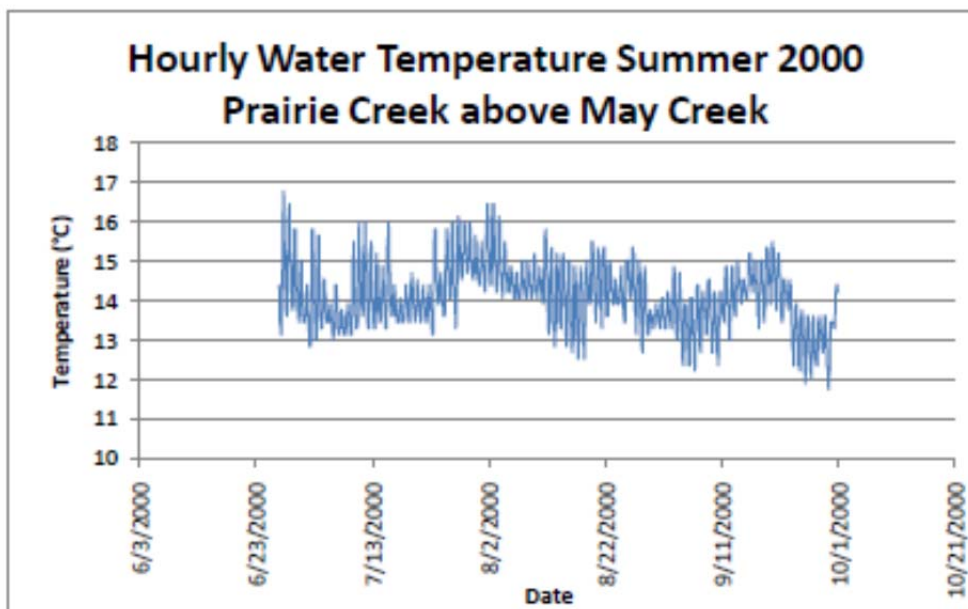
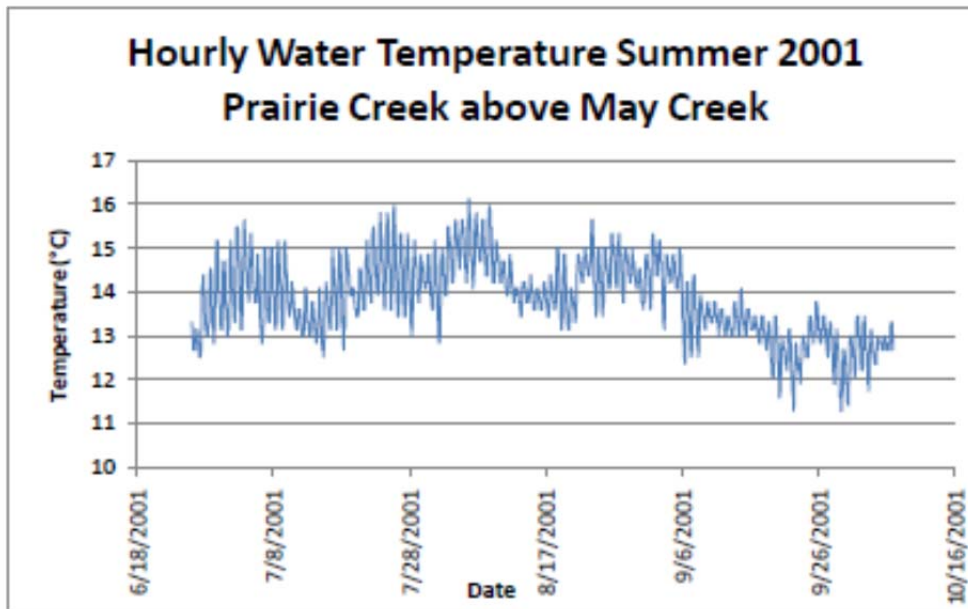
Appendix B9. Estimated abundance of seven species of fish in Streeflow Creek, 1998-2006.

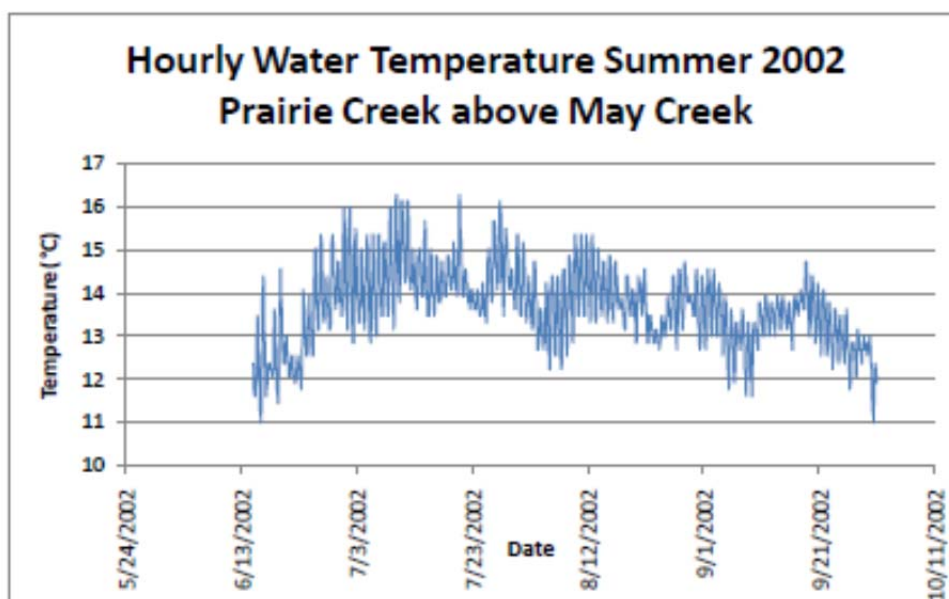
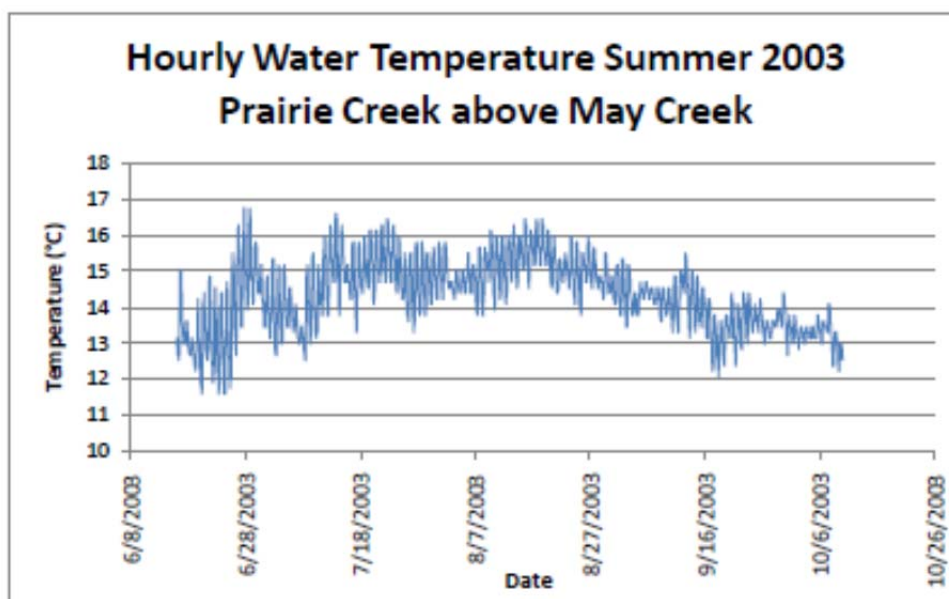
| Year | Month | Lamprey<br>Ammocete | Sculpin | Stickleback | Western Brook<br>Lamprey | Steelhead | Chinook | Sucker |
|------|-------|---------------------|---------|-------------|--------------------------|-----------|---------|--------|
| 1998 | Oct.  |                     |         | 1           |                          |           |         |        |
| 1999 | July  |                     |         | 6           |                          |           | 12      |        |
| 1999 | Oct.  |                     | 1       | 6           | 1                        |           |         |        |
| 2000 | July  |                     |         | 18          | 6                        |           | 1       |        |
| 2000 | Oct.  |                     |         | 67          |                          | 1         |         |        |
| 2001 | July  |                     | 2       |             | 27                       | 8         |         |        |
| 2001 | Oct.  |                     |         | 52          | 2                        | 55        |         |        |
| 2002 | July  |                     |         | 15          | 32                       | 7         |         |        |
| 2002 | Oct.  |                     |         | 11          | 7                        |           |         |        |
| 2003 | July  | 6                   | 1       | 19          |                          | 1         |         |        |
| 2003 | Oct.  | 11                  |         | 15          | 38                       | 12        |         |        |
| 2004 | July  | 10                  | 1       | 27          |                          | 17        | 8       | 3      |
| 2005 | Aug   | 7                   | 1       | 7           | 14                       | 4         |         |        |
| 2006 | Aug   | 1                   |         | 3           | 8                        | 22        |         |        |

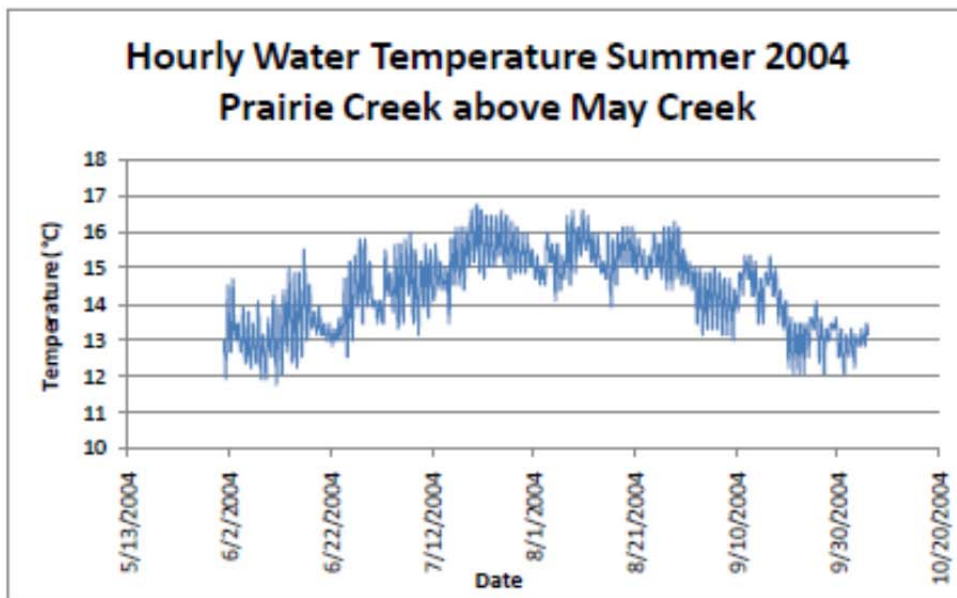
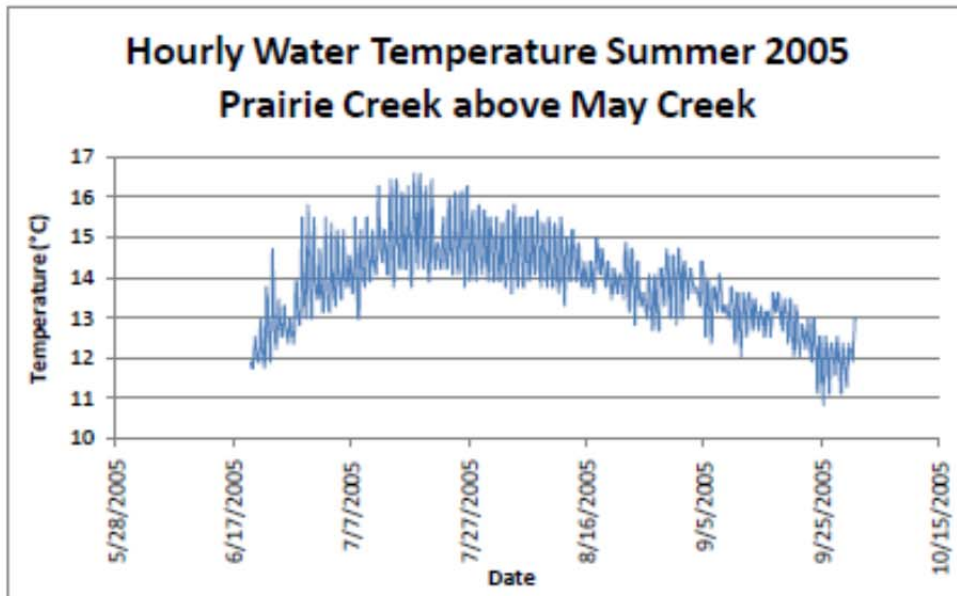
<sup>1</sup>Sculpin includes prickly and coast range sculpin.

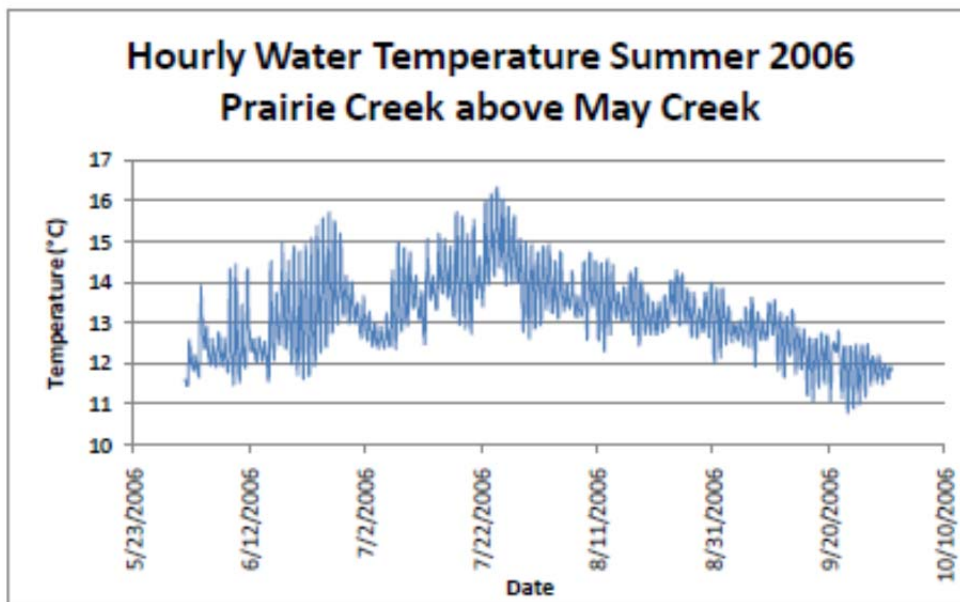
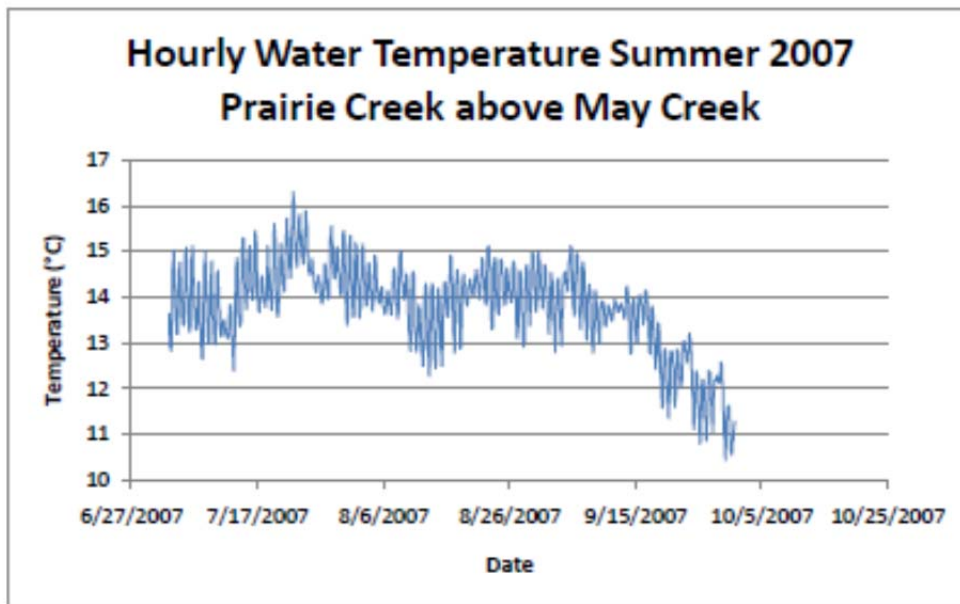
**Appendix C. Hourly summer water temperature recorded in Prairie Creek above the confluence of May Creek during 2000 - 2011.**

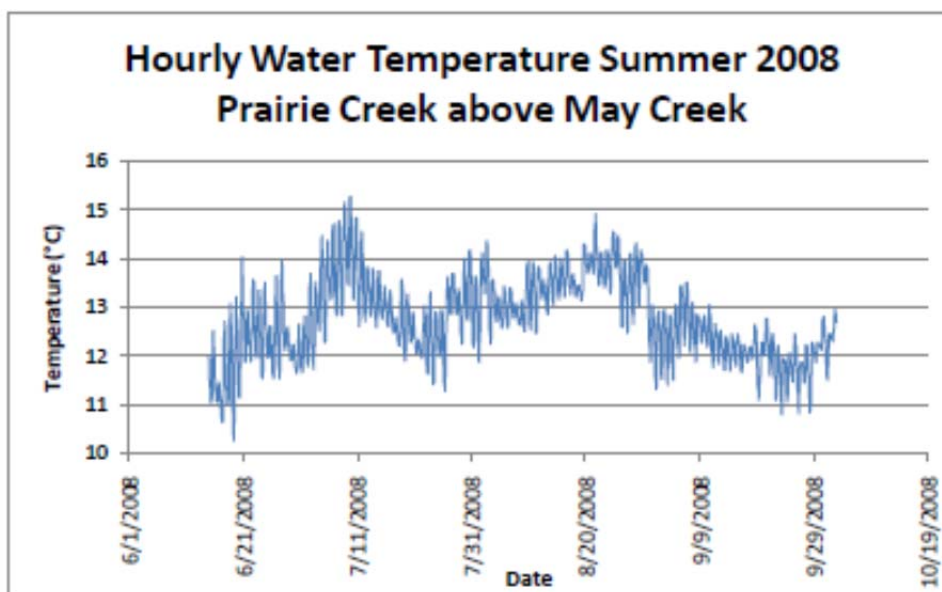
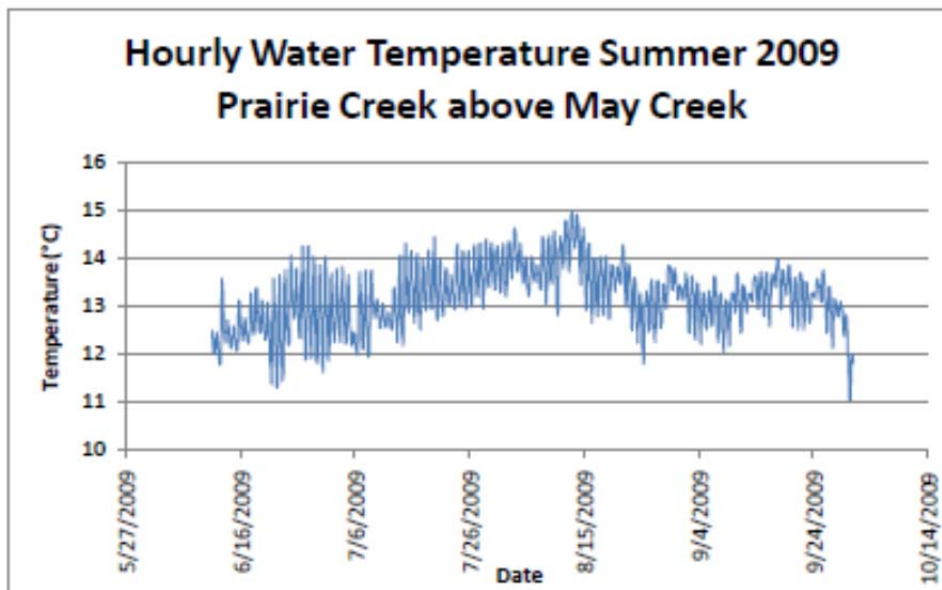
Appendix C1. Hourly summer water temperature in Prairie Creek above the confluence of May Creek during 2000 - 2011.

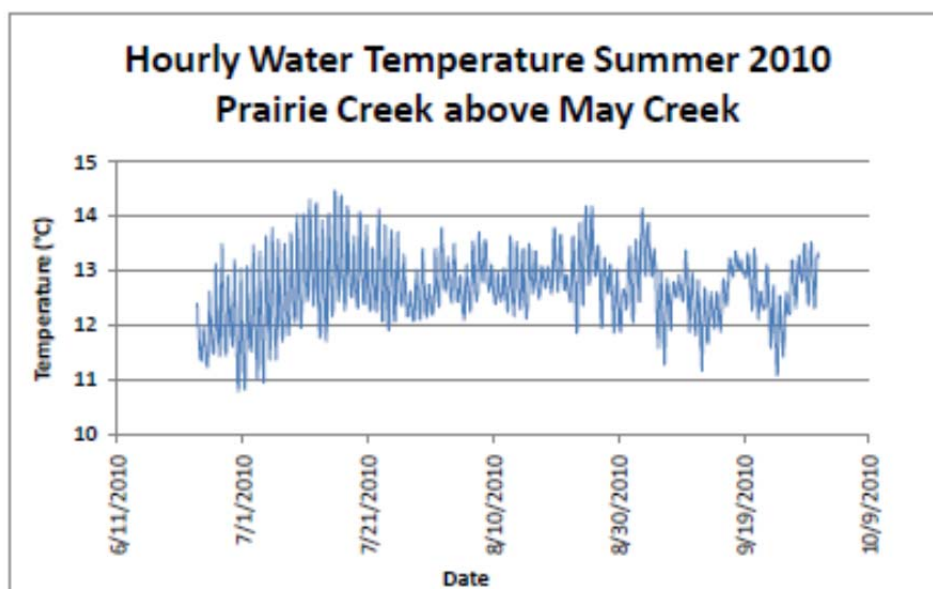
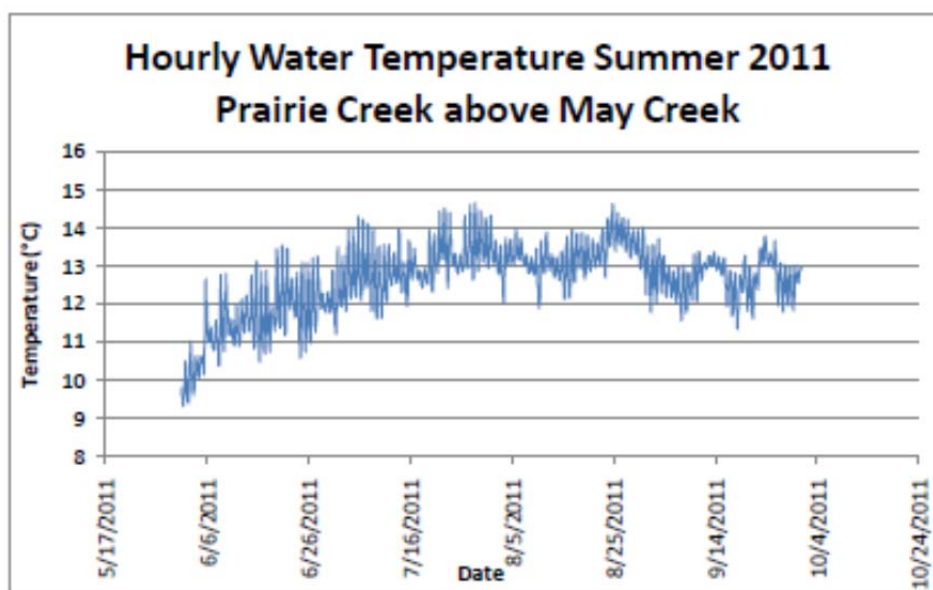












**Appendix D. Average fork length (FL) and weight (g),  $\pm$  1 standard deviation salmonids collected in Prairie Creek during summer 1998-2011.**

Appendix D1. Average fork length (FL) and weight (g),  $\pm$  1 standard deviation, of juvenile coho salmon in the Prairie Creek watershed, 1998-2011.

| Year | Month | n    | Avg FL (mm) | S.D. | Avg Wt (g) | S.D. |
|------|-------|------|-------------|------|------------|------|
| 1998 | 12    | 121  | 74          | 11.7 | 5.6        | 2.7  |
| 1999 | 1     | 4    | 75          | 9.4  | 5.3        | 1.9  |
| 1999 | 2     | 408  | 74          | 9.0  | 5.1        | 4.7  |
| 1999 | 3     | 997  | 70          | 22.2 | 5.0        | 3.5  |
| 1999 | 4     | 605  | 82          | 16.3 | 7.3        | 3.6  |
| 1999 | 5     | 1286 | 85          | 26.3 | 8.9        | 5.9  |
| 1999 | 6     | 329  | 80          | 26.0 | 9.6        | 4.4  |
| 1999 | 7     | 317  | 55          | 9.4  | 1.7        | 0.7  |
| 1999 | 8     | 14   | 53          | 4.7  |            |      |
| 1999 | 9     | 510  | 63          | 8.8  |            |      |
| 1999 | 10    | 851  | 70          | 9.8  | 4.3        | 2.0  |
| 1999 | 11    | 348  | 66          | 11.9 | 5.0        | 2.9  |
| 1999 | 12    | 19   | 65          | 8.5  | 4.6        | 0.8  |
| 2000 | 1     | 45   | 67          | 8.6  | 4.1        | 1.3  |
| 2000 | 2     | 357  | 72          | 10.3 | 4.7        | 1.8  |
| 2000 | 3     | 1087 | 70          | 22.6 | 5.0        | 3.6  |
| 2000 | 4     | 652  | 82          | 17.4 | 7.2        | 4.1  |
| 2000 | 5     | 1251 | 84          | 26.3 | 8.9        | 5.9  |
| 2000 | 6     | 252  | 89          | 23.0 | 9.2        | 4.5  |
| 2000 | 7     | 145  | 52          | 10.7 | 2.4        | 2.2  |
| 2000 | 8     | 12   | 52          | 4.5  |            |      |
| 2000 | 9     | 65   | 65          | 7.2  | 3.3        | 1.1  |
| 2000 | 10    | 360  | 64          | 10.5 | 3.5        | 1.9  |
| 2000 | 11    | 247  | 61          | 8.1  | 3.2        | 1.4  |
| 2000 | 12    | 59   | 64          | 8.0  | 3.6        | 1.7  |
| 2001 | 2     | 20   | 83          | 16.6 | 6.8        | 5.1  |
| 2001 | 3     | 1568 | 85          | 13.1 | 7.2        | 4.5  |
| 2001 | 4     | 720  | 92          | 18.0 | 9.2        | 5.2  |
| 2001 | 5     | 2640 | 100         | 16.6 | 11.5       | 4.8  |
| 2001 | 6     | 351  | 79          | 28.9 | 7.0        | 5.8  |
| 2001 | 7     | 375  | 60          | 15.1 | 3.4        | 1.6  |
| 2001 | 10    | 326  | 71          | 11.9 | 4.7        | 2.5  |
| 2002 | 3     | 1030 | 76          | 24.3 | 6.0        | 4.7  |
| 2002 | 4     | 1490 | 79          | 28.1 | 7.4        | 5.8  |
| 2002 | 5     | 1900 | 93          | 30.7 | 11.2       | 6.8  |
| 2002 | 6     | 335  | 92          | 30.3 | 10.3       | 7.2  |

Continued

Appendix D1. Completed.

| Year | Month | n    | Avg FL (mm) | S.D. | Avg Wt (g) | S.D. |
|------|-------|------|-------------|------|------------|------|
| 2002 | 7     | 1230 | 52          | 10.0 | 1.8        | 1.2  |
| 2002 | 10    | 1544 | 59          | 11.5 | 2.8        | 3.7  |
| 2003 | 2     | 68   | 70          | 7.1  | 3.7        | 1.2  |
| 2003 | 3     | 756  | 72          | 13.2 | 4.6        | 2.2  |
| 2003 | 4     | 623  | 65          | 23.5 | 4.4        | 5.0  |
| 2003 | 5     | 402  | 61          | 28.4 | 4.3        | 5.8  |
| 2003 | 6     | 153  | 50          | 15.3 | 1.9        | 2.4  |
| 2003 | 7     | 1134 | 52          | 10.1 | 1.9        | 1.6  |
| 2003 | 10    | 1008 | 64          | 13.5 | 3.4        | 2.2  |
| 2004 | 3     | 80   | 54          | 19.6 | 2.4        | 2.3  |
| 2004 | 4     | 338  | 57          | 25.1 | 3.3        | 4.7  |
| 2004 | 5     | 232  | 60          | 28.0 | 3.9        | 4.8  |
| 2004 | 8     | 702  | 60          | 12.2 | 2.9        | 2.0  |
| 2005 | 3     | 67   | 76          | 18.7 | 5.4        | 3.0  |
| 2005 | 4     | 209  | 84          | 26.0 | 7.9        | 4.9  |
| 2005 | 5     | 221  | 83          | 27.7 | 7.8        | 5.2  |
| 2005 | 8     | 71   | 56          | 9.0  | 2.4        | 1.3  |
| 2006 | 2     | 7    | 80          | 9.3  | 5.4        | 2.0  |
| 2006 | 3     | 143  | 67          | 23.0 | 6.6        | 28.5 |
| 2006 | 4     | 273  | 75          | 25.4 | 5.9        | 4.3  |
| 2006 | 5     | 527  | 91          | 24.2 | 9.5        | 4.9  |
| 2006 | 6     | 5    | 99          | 8.3  | 10.6       | 2.8  |
| 2006 | 8     | 133  | 59          | 9.9  | 2.2        | 1.1  |
| 2007 | 4     | 193  | 86          | 18.0 | 7.6        | 3.5  |
| 2007 | 5     | 852  | 98          | 11.3 | 10.2       | 5.4  |
| 2007 | 6     | 46   | 94          | 24.9 | 10.4       | 6.8  |
| 2007 | 8     | 59   | 61          | 10.9 | 3.1        | 2.0  |
| 2008 | 4     | 707  | 69          | 31.2 | 5.7        | 5.9  |
| 2008 | 8     | 288  | 57          | 9.3  | 2.3        | 1.3  |
| 2009 | 8     | 106  | 64          | 8.5  | 3.2        | 1.3  |
| 2009 | 9     | 240  | 66          | 10.2 | 3.5        | 1.8  |
| 2010 | 8     | 57   | 70          | 10.5 | 4.4        | 2.3  |
| 2010 | 9     | 28   | 71          | 8.4  | 4.4        | 1.6  |
| 2011 | 4     | 53   | 78          | 34.1 | 7.4        | 6.7  |
| 2011 | 5     | 310  | 105         | 18.6 | 12.8       | 4.7  |
| 2011 | 6     | 188  | 105         | 18.1 | 13.2       | 4.6  |
| 2011 | 7     | 79   | 89          | 21.2 | 9.0        | 6.8  |
| 2011 | 8     | 133  | 72          | 14.5 | 4.6        | 3.0  |

Appendix D2. Average fork length (FL) and weight (g),  $\pm$  1 standard deviation, of juvenile Chinook salmon in the Prairie Creek watershed, 1998-2011.

| Year | Month | n   | Avg FL (mm) | S.D. | Avg Wt (g) | S.D. |
|------|-------|-----|-------------|------|------------|------|
| 1999 | 3     | 31  | 37          | 2.2  | 0.5        | 0.1  |
| 1999 | 4     | 60  | 40          | 4.0  | 8.9        | 18.0 |
| 1999 | 5     | 3   | 55          |      |            |      |
| 1999 | 6     | 17  | 66          | 17.9 |            |      |
| 1999 | 7     | 12  | 53          | 6.2  |            |      |
| 2000 | 3     | 31  | 37          | 2.2  | 0.5        | 0.1  |
| 2000 | 4     | 87  | 41          | 3.5  | 6.1        | 15.1 |
| 2000 | 6     | 13  | 56          | 17.0 |            |      |
| 2000 | 7     | 12  | 53          | 6.2  |            |      |
| 2000 | 8     | 5   | 48          | 2.1  |            |      |
| 2001 | 3     | 48  | 39          | 1.6  | 0.5        | 0.0  |
| 2001 | 4     | 14  | 39          | 1.6  | 0.5        | 0.1  |
| 2001 | 5     | 99  | 44          | 4.2  | 3.2        | 14.7 |
| 2001 | 6     | 11  | 49          | 4.8  | 1.3        | 0.4  |
| 2002 | 3     | 97  | 39          | 1.9  | 0.5        | 0.1  |
| 2002 | 4     | 172 | 41          | 2.3  | 0.6        | 0.1  |
| 2002 | 5     | 113 | 46          | 7.8  | 1.1        | 0.7  |
| 2002 | 6     | 33  | 55          | 10.2 | 2.3        | 2.3  |
| 2003 | 3     | 10  | 35          | 2.9  | 0.2        | 0.0  |
| 2003 | 4     | 162 | 40          | 1.5  | 0.5        | 0.1  |
| 2003 | 5     | 112 | 48          | 5.4  | 1.1        | 0.4  |
| 2003 | 6     | 29  | 53          | 5.8  | 1.7        | 0.6  |
| 2004 | 3     | 11  | 38          | 0.7  | 0.5        | 0.0  |
| 2004 | 4     | 122 | 40          | 1.6  | 1.1        | 5.7  |
| 2004 | 5     | 100 | 43          | 3.2  | 1.8        | 9.6  |
| 2005 | 4     | 45  | 41          | 1.6  | 0.7        | 0.1  |
| 2005 | 5     | 42  | 48          | 6.2  | 1.1        | 0.6  |
| 2006 | 3     | 28  | 39          | 0.9  | 0.5        | 0.1  |
| 2006 | 4     | 52  | 42          | 3.5  | 0.7        | 0.2  |
| 2006 | 5     | 112 | 52          | 7.7  | 1.6        | 0.7  |
| 2007 | 4     | 5   | 42          | 4.1  | 0.7        | 0.3  |
| 2007 | 5     | 87  | 49          | 6.4  | 1.2        | 0.5  |
| 2007 | 6     | 35  | 56          | 7.3  | 1.9        | 0.7  |
| 2008 | 4     | 122 | 43          | 4.1  | 0.7        | 0.3  |
| 2011 | 4     | 66  | 45          | 5.6  | 0.8        | 0.4  |
| 2011 | 5     | 307 | 51          | 6.2  | 1.4        | 0.6  |
| 2011 | 6     | 270 | 59          | 7.7  | 2.4        | 1.0  |
| 2011 | 7     | 453 | 75          | 9.8  | 5.0        | 2.2  |
| 2011 | 8     | 350 | 85          | 7.3  | 7.2        | 1.8  |

Appendix D3. Average fork length (FL) and weight (g),  $\pm$  1 standard deviation, of steelhead in the Prairie Creek watershed, 1998-2011.

| Year | Month | n   | Avg FL (mm) | S.D. | Avg Wt (g) | S.D.  |
|------|-------|-----|-------------|------|------------|-------|
| 1999 | 2     | 72  | 148         | 25.3 | 35.0       | 14.7  |
| 1999 | 3     | 105 | 162         | 48.5 | 41.7       | 13.7  |
| 1999 | 4     | 43  | 159         | 14.4 | 44.8       | 10.2  |
| 1999 | 5     | 20  | 150         | 16.8 | 41.6       | 13.5  |
| 1999 | 6     | 3   | 127         | 14.6 | 23.8       | 7.0   |
| 2000 | 2     | 72  | 148         | 25.3 | 35.0       | 14.7  |
| 2000 | 3     | 101 | 168         | 64.8 | 41.7       | 13.8  |
| 2000 | 4     | 44  | 160         | 14.9 | 44.8       | 10.2  |
| 2000 | 5     | 20  | 150         | 16.8 | 41.6       | 13.5  |
| 2000 | 6     | 3   | 127         | 14.6 | 23.8       | 7.0   |
| 2000 | 7     | 2   | 107         | 28.3 | 15.3       | 11.4  |
| 2000 | 9     | 25  | 73          | 13.9 |            |       |
| 2000 | 10    | 11  | 101         | 18.7 | 12.5       | 5.7   |
| 2000 | 12    | 1   |             |      | 1.3        |       |
| 2001 | 2     | 7   | 195         | 5.0  | 67.9       | 6.4   |
| 2001 | 3     | 360 | 195         | 77.9 | 62.1       | 17.1  |
| 2001 | 4     | 39  | 170         | 19.9 | 46.2       | 11.4  |
| 2001 | 5     | 27  | 121         | 35.7 | 19.8       | 15.1  |
| 2001 | 6     | 5   | 128         | 11.3 | 24.4       | 7.3   |
| 2001 | 7     | 31  | 110         | 18.6 | 17.8       | 9.0   |
| 2001 | 10    | 99  | 83          | 22.4 | 52.4       | 437.2 |
| 2002 | 3     | 119 | 106         | 31.4 | 16.2       | 18.4  |
| 2002 | 4     | 200 | 103         | 39.0 | 13.0       | 11.3  |
| 2002 | 5     | 142 | 111         | 18.3 | 16.5       | 10.0  |
| 2002 | 6     | 7   | 114         | 17.4 | 17.2       | 7.4   |
| 2002 | 7     | 11  | 111         | 41.2 | 19.2       | 17.5  |
| 2002 | 10    | 1   | 73          |      | 5.2        |       |
| 2003 | 2     | 1   | 158         |      | 41.0       |       |
| 2003 | 3     | 15  | 104         | 26.9 | 14.5       | 11.6  |
| 2003 | 4     | 37  | 89          | 9.9  | 8.6        | 3.8   |
| 2003 | 5     | 27  | 86          | 8.2  | 7.2        | 2.2   |
| 2003 | 6     | 2   | 86          | 11.3 | 7.2        | 2.6   |
| 2003 | 7     | 8   | 101         | 26.6 | 14.6       | 14.7  |
| 2003 | 10    | 40  | 80          | 27.0 | 7.1        | 6.9   |
| 2004 | 4     | 34  | 98          | 17.8 | 11.9       | 7.1   |
| 2004 | 5     | 14  | 97          | 16.3 | 10.8       | 5.2   |
| 2004 | 8     | 32  | 106         | 29.2 | 14.2       | 7.5   |
| 2005 | 3     | 30  | 118         | 38.9 | 21.3       | 18.0  |

Continued

Appendix D3. Completed.

| Year | Month | n   | Avg FL (mm) | S.D. | Avg Wt (g) | S.D. |
|------|-------|-----|-------------|------|------------|------|
| 2005 | 4     | 18  | 116         | 25.5 | 18.3       | 13.6 |
| 2005 | 5     | 9   | 99          | 28.0 | 11.9       | 9.3  |
| 2005 | 8     | 1   | 109         |      | 15.0       |      |
| 2006 | 2     | 1   | 97          |      | 10.0       |      |
| 2006 | 3     | 2   | 84          | 8.5  | 7.1        | 2.4  |
| 2006 | 4     | 48  | 89          | 18.5 | 8.9        | 8.3  |
| 2006 | 5     | 105 | 96          | 18.4 | 10.7       | 7.3  |
| 2006 | 6     | 1   | 82          |      | 6.9        |      |
| 2006 | 8     | 9   | 114         | 25.0 | 3.4        | 1.6  |
| 2007 | 4     | 58  | 92          | 12.1 | 9.0        | 3.9  |
| 2007 | 5     | 150 | 96          | 15.6 | 10.1       | 6.0  |
| 2007 | 6     | 8   | 100         | 14.6 | 11.7       | 5.1  |
| 2007 | 8     | 11  | 95          | 18.1 | 11.2       | 6.0  |
| 2008 | 4     | 132 | 85          | 31.5 | 9.1        | 7.2  |
| 2009 | 8     | 12  | 91          | 17.2 | 9.4        | 3.6  |
| 2009 | 9     | 48  | 87          | 21.1 | 9.3        | 12.1 |
| 2010 | 8     | 5   | 130         | 28.7 | 25.6       | 14.2 |
| 2010 | 9     | 14  | 98          | 22.4 | 12.9       | 9.5  |
| 2011 | 4     | 27  | 117         | 33.3 | 20.2       | 15.3 |
| 2011 | 5     | 166 | 111         | 23.0 | 15.6       | 9.4  |
| 2011 | 6     | 76  | 110         | 17.9 | 15.3       | 7.6  |
| 2011 | 7     | 77  | 126         | 37.9 | 27.6       | 24.0 |
| 2011 | 8     | 80  | 107         | 33.7 | 17.9       | 18.4 |

Appendix D4. Average fork length (FL) and weight (g),  $\pm$  1 standard deviation, of coastal cutthroat trout in the Prairie Creek watershed, 1998-2011.

| Year | Month | n   | Avg FL (mm) | S.D. | Avg Wt (g) | S.D.  |
|------|-------|-----|-------------|------|------------|-------|
| 1999 | 2     | 39  | 121         | 41.3 | 20.6       | 31.7  |
| 1999 | 3     | 230 | 135         | 39.1 | 31.4       | 31.7  |
| 1999 | 4     | 296 | 139         | 34.0 | 33.6       | 18.7  |
| 1999 | 5     | 351 | 142         | 21.8 | 51.9       | 317.5 |
| 1999 | 6     | 65  | 145         | 25.2 | 40.2       | 25.3  |
| 1999 | 7     | 3   | 127         | 16.2 | 25.8       | 9.6   |
| 1999 | 8     | 5   | 128         | 59.6 | 86.3       |       |
| 1999 | 9     | 110 | 104         | 27.1 |            |       |
| 1999 | 10    | 4   | 124         | 18.4 |            |       |
| 1999 | 11    | 6   | 130         | 47.7 | 28.1       | 4.1   |
| 2000 | 1     | 14  | 101         | 28.7 | 7.8        | 6.3   |
| 2000 | 2     | 89  | 110         | 48.7 | 24.9       | 45.1  |
| 2000 | 3     | 249 | 135         | 39.4 | 32.8       | 37.8  |
| 2000 | 4     | 317 | 140         | 34.2 | 33.5       | 18.5  |
| 2000 | 5     | 350 | 141         | 21.2 | 51.7       | 317.5 |
| 2000 | 6     | 71  | 142         | 27.3 | 38.1       | 25.4  |
| 2000 | 7     | 36  | 114         | 23.1 | 19.6       | 12.9  |
| 2000 | 8     | 5   | 128         | 59.6 | 86.3       |       |
| 2000 | 9     | 38  | 97          | 33.6 | 12.5       | 12.9  |
| 2000 | 10    | 120 | 103         | 38.4 | 23.8       | 94.1  |
| 2000 | 11    | 7   | 124         | 46.8 | 28.1       | 4.1   |
| 2000 | 12    | 8   | 93          | 33.9 | 11.4       | 16.1  |
| 2001 | 2     | 10  | 169         | 68.4 | 22.0       | 10.1  |
| 2001 | 3     | 493 | 141         | 64.0 | 25.4       | 24.8  |
| 2001 | 4     | 272 | 144         | 36.5 | 30.4       | 18.6  |
| 2001 | 5     | 565 | 143         | 32.0 | 30.2       | 14.1  |
| 2001 | 6     | 43  | 125         | 43.4 | 19.9       | 15.8  |
| 2001 | 7     | 136 | 111         | 26.9 | 18.3       | 14.9  |
| 2001 | 10    | 168 | 105         | 56.3 | 15.0       | 15.8  |
| 2002 | 3     | 313 | 131         | 43.8 | 26.7       | 23.2  |
| 2002 | 4     | 475 | 146         | 29.7 | 41.0       | 20.5  |
| 2002 | 5     | 779 | 149         | 22.8 | 38.2       | 16.6  |
| 2002 | 6     | 50  | 138         | 22.9 | 31.6       | 14.9  |
| 2002 | 7     | 115 | 118         | 32.7 | 20.3       | 18.1  |
| 2002 | 10    | 201 | 109         | 26.5 | 15.6       | 13.1  |
| 2003 | 3     | 62  | 120         | 33.3 | 23.7       | 17.4  |
| 2003 | 4     | 22  | 122         | 28.5 | 26.2       | 17.0  |
| 2003 | 5     | 28  | 128         | 21.7 | 26.3       | 12.9  |

Continued

Appendix D4. Completed.

| Year | Month | n   | Avg FL (mm) | S.D. | Avg Wt (g) | S.D. |
|------|-------|-----|-------------|------|------------|------|
| 2003 | 6     | 20  | 125         | 33.4 | 22.5       | 15.5 |
| 2003 | 7     | 119 | 112         | 31.5 | 19.3       | 21.2 |
| 2003 | 10    | 146 | 117         | 31.6 | 16.0       | 10.8 |
| 2004 | 3     | 9   | 125         | 43.8 | 15.7       | 7.0  |
| 2004 | 4     | 59  | 135         | 35.4 | 24.7       | 10.7 |
| 2004 | 5     | 25  | 120         | 17.1 | 19.5       | 8.8  |
| 2004 | 8     | 130 | 112         | 30.6 | 16.3       | 10.9 |
| 2005 | 3     | 25  | 150         | 52.4 | 27.7       | 23.3 |
| 2005 | 4     | 115 | 140         | 17.3 | 31.9       | 12.1 |
| 2005 | 5     | 90  | 143         | 18.8 | 33.7       | 14.5 |
| 2005 | 8     | 12  | 102         | 24.1 | 10.5       | 8.7  |
| 2006 | 2     | 4   | 116         | 31.8 | 16.1       | 14.0 |
| 2006 | 3     | 14  | 137         | 35.7 | 33.7       | 28.4 |
| 2006 | 4     | 167 | 139         | 25.8 | 29.2       | 14.2 |
| 2006 | 5     | 296 | 142         | 14.6 | 30.1       | 10.5 |
| 2006 | 6     | 3   | 133         | 5.1  | 26.6       | 2.1  |
| 2006 | 8     | 19  | 100         | 19.5 | 2.9        | 2.7  |
| 2007 | 4     | 138 | 137         | 20.7 | 28.0       | 15.2 |
| 2007 | 5     | 305 | 139         | 20.9 | 26.9       | 10.7 |
| 2007 | 6     | 14  | 145         | 28.1 | 34.8       | 27.6 |
| 2007 | 8     | 8   | 96          | 26.8 | 11.7       | 11.2 |
| 2008 | 4     | 299 | 134         | 15.7 | 27.2       | 9.7  |
| 2008 | 8     | 2   | 178         | 10.6 | 62.5       | 15.7 |
| 2009 | 8     | 37  | 100         | 26.5 | 12.7       | 9.7  |
| 2009 | 9     | 13  | 140         | 65.8 | 55.6       | 66.9 |
| 2010 | 8     | 41  | 92          | 27.2 | 12.4       | 26.0 |
| 2010 | 9     | 37  | 81          | 17.5 | 6.6        | 4.8  |
| 2011 | 4     | 48  | 143         | 19.0 | 31.1       | 12.9 |
| 2011 | 5     | 223 | 141         | 26.9 | 28.6       | 15.8 |
| 2011 | 6     | 70  | 143         | 39.1 | 30.7       | 16.7 |
| 2011 | 7     | 40  | 169         | 43.0 | 59.5       | 49.5 |
| 2011 | 8     | 40  | 136         | 51.2 | 36.1       | 35.8 |

## Appendix E. California Cooperative Fish Research Unit Publications Related to Prairie Creek

Theses available at: <http://www.humboldt.edu/cuca/documents.html>

- Beesley, S. B. 2006. Secondary production of Paraleptophlebia (Ephemeroptera) within three northern California coastal streams. M.S. Thesis, Humboldt State University, Arcata , CA . 59 pp.
- Bell , E. 2001. Survival, growth and movement of juvenile coho salmon (*Oncorhynchus kisutch*) over-wintering in alcoves, backwaters, and main channel pools in Prairie Creek , California . M.S. Thesis, Humboldt State University, Arcata , CA . 75 pp.
- Bell, E., W.G. Duffy and T.D. Roelofs. 2001. Fidelity and survival of juvenile coho salmon in response to a flood. Transactions of the American Fisheries Society 130:450-458.
- Bell, E., and W.G. Duffy. 2007. Previously undocumented two-year freshwater residency of juvenile coho salmon in Prairie Creek, California. Transactions of the American Fisheries Society. 136:966-970.
- Brakensiek, K. E. 2002. Abundance and survival of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, Redwood National Park. M.S. Thesis, Humboldt State University, Arcata, CA. 110 pp.
- Coey, R. M. 1998. Effects of sedimentation on incubating coho salmon, (*Oncorhynchus kisutch*) in Prairie Creek, California. M. S. Thesis, Humboldt State University, Arcata, CA. 134 pp.
- Duffy, W.G., and E.P. Bjorkstedt. 2008. Demographics of coastal cutthroat trout, *Oncorhynchus clarki clarki*, in Prairie Creek, California. Pages 100 – 106 In: P.J. Connolly, T.H. Williams and R.E. Greswell editors. The 2005 coastal cutthroat trout symposium: biology, status, management and conservation. Oregon Chapter, American Fisheries Society, Portland.
- Duffy, W.G. , Bjorkstedt, E.P. and Ellings, C.S. 2011. Predation on juvenile Pacificsalmon *Oncorhynchus* spp. in downstream migrant traps in Prairie Creek, California', North American Journal of Fisheries Management, 31: 1, 151 — 164.
- Feola, J. E. 2007. Environmental variables influencing downstream migration of juvenile coho salmon (*Oncorhynchus kisutch*) in three northern California streams. M.S. Thesis, Humboldt State University, Arcata , CA . 82 pp. PDF
- Gonzales, E. J. 2006. Diet and prey consumption of juvenile coho salmon (*oncorhynchus kisutch*) in three northern California streams. M.S. Thesis, Humboldt State University, Arcata , CA . 66 pp.

- Gough, S.A. 2010. A comparison of escapement estimate methods plus escapement-recruitment relationships for coho salmon and Chinook salmon in Prairie Creek, California. M. S. Thesis, Humboldt State University, Arcata , CA.
- Metheny, M.D. 2012. Use of Dual Frequency Identification SONAR to estimate salmonid escapement to Redwood Creek, Humboldt County, California. M. S. Thesis, Humboldt State University, Arcata , CA.
- Moore, J.W., S.A. Hayes, W.G. Duffy, S. Gallagher, C.J. Michel, and D. Wright. 2011. Nutrient fluxes and the recent collapse of coastal California salmon populations. Canadian Journal of Fisheries and Aquatic Sciences 68:1161-1170.
- Moore, T. Redistribution, growth and survival of juvenile coho salmon (*Oncorhynchus kisutch*) during winter in Prairie Creek , California . M.S. Thesis, Humboldt State University, Arcata, CA. In preparation.
- Ransom, B. O. 2007. Extended freshwater rearing of juvenile coho salmon (*Oncorhynchus kisutch*) in northern California streams. M.S. Thesis, Humboldt State University, Arcata, CA. 72 pp.
- Sparkman, M. D. 2003. Negative influences of predacious egg-eating worms, *Haplotaxis* ichthyophagous, and fine sediments on coho salmon, *Oncorhynchus kisutch*, in natural and artificial redds. M. S. Thesis, Humboldt State Univ., Arcata , CA . 64 pp.
- Spence, B.C., and J.D. Hall. 2010. Spatiotemporal patterns in migration timing of coho salmon (*Oncorhynchus kisutch*) smolts in North America. Canadian Journal of Fisheries and Aquatic Sciences 37:1316-1334.
- Tussing, S. P. 2006. Influence of growth, habitat, and density on emigration of coastal cutthroat trout (*Oncorhynchus clarki clarki*) from small streams. M. S. Thesis, Humboldt State University, Arcata, CA . 64 pp.
- Willey, W. S. 2004. Energetic response of juvenile coho salmon (*Oncorhynchus kisutch*) to varying water temperature regimes in northern California streams. M. S. Thesis, Humboldt State University, Arcata , CA . 82 pp.
- Williams, M.C. 1996. A study of *Haplotaxis* ichthyophagous, an aquatic oligochaete. Masters thesis, Humboldt State University, Arcata, CA.
- Wright, K. Escapement estimation, migration timing, and spatial distribution of adult Chinook and coho salmon on Prairie C Creek, California. M. S. Thesis, Humboldt State University, Arcata, CA