

ESCAPEMENT, MIGRATION TIMING, AND SPATIAL DISTRIBUTION OF
ADULT CHINOOK AND COHO SALMON IN PRAIRIE CREEK, CALIFORNIA

By

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A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

Of the Requirements for the Degree

Masters of Science

In Natural Resources: Fisheries

May 2011

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ABSTRACT

Escapement, migration timing, and spatial distribution of adult Chinook and coho salmon in Prairie Creek, California

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During the 2005/2006 and 2006/2007 spawning seasons I monitored escapement of adult Chinook and coho salmon in Prairie Creek, California, a small coastal stream (34.4 km² watershed) located within Redwood State and National Parks. I compared traditional stream survey escapement estimation methods with modern mark-recapture using a resistance-board weir as a sampling platform to tag salmon. Methods for estimating escapement included area-under-the-curve (AUC), redd count expansion, Chapman-Petersen live mark-carcass recapture, and Jolly-Seber carcass mark-recapture. Chinook salmon and coho salmon residence time in the survey area was estimated to improve accuracy of the AUC method. The four techniques provided estimates of Chinook salmon escapement ranging from 41 to 285 for the first study year and from 24 to 87 for the second year. Escapement estimates for coho salmon were 51 to 485 for the first year and 45 to 212 for the second year. Residence time in the survey area was estimated to be 12 days for Chinook salmon and 17 days for coho salmon.

Trends in species, sex, and size of salmon captured at the weir were analyzed over time. Sex and body size were found to be significant in relation to date of weir capture, but not for both species or over both years. The daily probabilities of upstream movement of coho salmon past the weir were fit with generalized additive models of observed environmental factors. The best-fitting model of the probability of movement

included the explanatory factors of mean daily discharge, mean daily stream temperature, and mean daily turbidity. Mean daily discharge and mean daily turbidity were identified as significant factors.

ACKNOWLEDGEMENTS

I would like to thank my major advisor, Dr. Walter G. Duffy, for the guidance he provided me throughout the writing of this thesis. I also extend my thanks to the other members of my committee, Drs. Eric P. Bjorkstedt and Peggy Wilzbach, for their advice and support. Kay Brisby deserves special recognition for the invaluable assistance she provides to graduate students supported by the USGS California Cooperative Fish and Wildlife Research Unit.

This work would not have been possible without the dedicated field assistance of California Cooperative Fish and Wildlife Research Unit technicians and fellow graduate students. Marty Reed and Lewis McCrigler provided excellent technical and logistic support. Thanks also to Michael Sparkman and Seth Ricker of the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program for their input and advice, as well as to Randy Klein of the National Park Service for providing stream discharge and turbidity data.

Funding for this project was provided by the California Department of Fish and Game, Fishery Restoration Grants Program. I am also grateful for generous scholarships provided by the Marin Rod and Gun Club, and the Rotary Club of Eureka Woolford Fellowship, and the Western Division of the American Fisheries Society.

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DEFINITIONS OF EQUATION VARIABLES

Variable	Definition
x_i	Population of Chinook or coho in the stream during stream survey at time i
fo	Number of Chinook or coho salmon observed by surveyors during stream survey
oe	Observer efficiency factor
AUC	Area under the population curve
t_i	Water year date of survey i , where the water year is defined as beginning on October 1, when $t=1$, and ending on September 30, when $t=365$
$\hat{E}_{auc}$	Escapement estimate calculated using the area under the curve method
rt	Residence time
Pr(OK)	The probability that an unknown redd was built by a coho salmon
t	Water year date, where the water year is defined as beginning on October 1, when $t=1$, and ending on September 30, when $t=365$
$\hat{E}_{redd}$	Escapement estimate calculated using the redd expansion method
R	Number of redds counted over the entire season in the survey reaches
M	Number of mature males captured at the weir
J	Number of jack males captured at the weir
F	Number of female captured at the weir
$\hat{E}_{CP}$	Escapement estimate calculated using Chapman-Petersen mark-recapture method
n_1	Number of Chinook or coho salmon captured and marked with PIT or radio-telemetry tags at the weir
n_2	Number of Chinook or coho salmon carcasses counted on walking surveys

DEFINITIONS OF EQUATION VARIABLES (CONTINUED)

m_2	Number of PIT or radio-telemetry tag marked Chinook or coho salmon carcasses counted on walking surveys
Φ	Apparent survival rate
p	Capture probability
$\hat{E}_{JS}$	Escapement estimate calculated using modified Jolly-Seber mark-recapture method
n_1	The number of carcasses sampled at the first sample time
R_1	The number of carcasses tagged and released at the first sample time
$\hat{N}_2$	The estimated population size at sample time two
$\hat{\Phi}_i$	The Program MARK estimate of the survival rate from i to $i+1$
$\hat{B}_i$	The joining number; the estimated number of carcasses still present at the sample time $i+1$
$\hat{D}_i$	$\hat{B}_i / \sqrt{\hat{\Phi}_i}$
$\hat{N}_i$	The estimated population size at sample time i
n_i	the number sampled at sample time i
R_i	The number of carcasses tagged and released at sample time i
Pr(Move)	Pr($X n$), or the estimated daily binomial probability of a staging coho salmon moving upstream to be captured at the weir
X	The number of coho salmon migrating upstream to be captured at the weir each day, t
n	The number of staging coho salmon available for upstream migration each day, t

INTRODUCTION

Population monitoring of Pacific salmon (*Oncorhynchus* spp.) is vital in California, where multiple species are listed within many Evolutionarily Significant Units (ESUs) 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 (United States Office of the Federal Register 1997, 1999). A lack of reliable monitoring makes it impossible to know the true extent of their decline (Brown et al. 1994, Korman et al. 2002).

Estimates of escapement, the number of adult salmon surviving marine and freshwater fisheries to return to their freshwater spawning grounds, are an essential metric used by fisheries managers to monitor current and future population abundances of Pacific salmon. The information provided by escapement estimates is used to set harvest regulations and to monitor populations for conservation. Estimates of escapement must be accurate, precise, and comparable to have value in monitoring population change (Ludwig and Walters 1981, Walters and Ludwig 1981, Symons and Waldichuk 1984, Botkin et al. 2000, Hill and Irvine 2001). These attributes are especially important if escapement is used to detect cause-and-effect relationships over time for validation monitoring (Korman and Higgins 1997, Botkin et al. 2000).

A greater understanding of the adult freshwater life history of anadromous Pacific salmon is also necessary for planning population recovery and conservation. The timing, in addition to magnitude, of a salmon population's return to freshwater is of great

importance in fisheries management. The time of year a salmon returns to its natal stream is a genetically heritable trait. It is shaped by natural selection to occur when stream-specific long-term average stream flow and temperature are favorable for spawning success and embryo incubation (Gharrett and Smoker 1993, Quinn and Adams 1996, Dahl et al. 2004). Annual environmental variables also play a role in stimulating the return migration of adult salmonids, although no clear consensus on their influence exists in the fisheries literature.

Changes in discharge are frequently cited as the dominant environmental stimulus to upstream movement (Banks 1969, Jonsson 1991). Multiple studies have found that salmon ascend streams as flows increase (Davidson et al. 1943, Hunter 1959, Banks 1969, Alabaster 1970, Jensen et al. 1986), and that the largest pulses of fish return as high flows are subsiding (Huntsman 1948, Trepanier et al. 1996). However, this is not always the case. Thorstad and Heggberget (1998) and Dahl et al. (2004) found no correlation between increased water flow and upstream migration of adult salmon.

Stream temperature is another potential cue to migration, given that migratory fishes are known to respond to small changes in temperature (Quinn and Adams 1996). Jensen et al. (1986) and Dahl et al. (2004) reported that increases in stream temperature were positively correlated with the number of returning salmon. On the contrary, studies by Davidson et al. (1943), Neave (1943), and Trepanier et al. (1996) found no association between stream temperature and the time adult salmon migrated upstream in rivers. These inconsistent results suggest that a complex interplay of genetic and environmental cues act to prompt upstream migration. Further examination of migration timing and its

correlation to the environmental factors of discharge and stream temperature, as well as to other possible cues such rainfall, turbidity, and light intensity, is needed.

The timing of return migration and arrival on the spawning grounds is also related to sex, body size, and age. Male Pacific salmon commonly arrive on the spawning grounds before females (Morbey 2000). The early arrival of males is hypothesized to increase male spawning success by increasing the chance of multiple pairings. Another trend observed in migration timing is that of older and larger salmon arriving before smaller salmon on the spawning grounds (Stewart et al. 2002, Molyneaux and Folletti 2005, Quinn 2005). Larger and older salmon may gain less benefit from remaining longer at sea feeding, since they would grow proportionally less than smaller and younger salmon in the same amount of time (Quinn 2005). The competitive edge larger salmon have over smaller salmon on the spawning grounds may also favor a later return date for the smaller salmon.

The spatial distribution of adult salmon on the spawning grounds may also be linked to their time of entry into freshwater. Salmon entering a river earlier often spawn in upstream tributaries while fish that arrive later spawn further downstream. This tributary-specific run timing has been well documented on large river systems (e.g. the Yukon River: Eiler et al. 2006). The phenomenon of early-arriving salmon spawning further upstream was also observed in coho salmon and steelhead (*O. mykiss*) in a small coastal drainage, although Chinook salmon did not exhibit this pattern (Briggs 1953).

Residence time, or the time a salmon remains alive in the stream while spawning, is another aspect of a returning salmon's life history warranting further study. An understanding of the factors influencing residence time could be used to improve

escapement estimation, since residence time is one of the principal parameters used in the area-under-the-curve (AUC) estimation method (Shardlow et al. 1987, English et al. 1992, Irvine et al. 1992, Jones et al. 1998, Shardlow 2004). Studies have found that residence time of Pacific salmon returning to a stream varies over the course of the spawning season. As the spawning season progresses, residence time of salmon entering the stream decreases (Neilson and Geen 1981, Hendry et al. 1999). Hendry et al. (1999) hypothesized that females entering the stream earlier remain longer to guard their redds from other females. Males that arrive earlier remain longer to increase reproductive success by spawning with as many females as possible. Body size may also affect the length of residence time. Larger salmon with greater energy stores would be expected to survive longer on the spawning grounds, as has been seen in coho salmon residence time (van den Berghe and Gross 1986). Another factor determining residence time may be the distance a salmon travels upstream before reaching its spawning site. Salmon traveling further upstream before spawning expend more energy in travel, and so should have shorter residence times than salmon spawning closer to the stream mouth.

I studied populations of adult Chinook and coho salmon returning to spawn in Prairie Creek, a small coastal stream in northern California. Although many attempts have been made to identify the stimulus for the onset of adult salmon freshwater migration, no agreement has been reached on the influence of environmental cues. To evaluate relationships between return timing and environmental stimuli, I compared the movements of adult coho salmon past a weir located 6.8 km upstream of the mouth of Prairie Creek with the potential environmental cues of discharge, stream temperature, turbidity, rainfall, and light intensity. In addition, I investigated temporal patterns in sex

and size distributions of upstream migrating adult salmon to determine if the trends observed in other returning salmonid populations also occur on Prairie Creek. I also investigated the spatial distribution of spawning salmon and redds built by each species in terms of observation date and distance located upstream.

The main objective of this study was to improve escapement estimation methods for adult Chinook salmon and coho salmon on Prairie Creek. These populations have been monitored since 1998 using traditional methods based upon live salmon counts, redd counts, and carcass mark-recapture. I installed and operated a resistance-board weir to see if it would improve escapement estimates. Weirs are considered the most accurate and precise form of escapement estimation when they operate at 100% efficiency, since they allow a count of all salmon entering the system (Cousens et al. 1982, Shardlow et al. 1986, Schwarz et al. 1993, Miyakoshi and Kudo 1999). I tagged all adult salmon caught at the weir and estimated escapement from live mark-carcass recapture based on the ratio of tagged to untagged salmon found as carcasses on the spawning grounds. I evaluated the accuracy and variation of traditional escapement estimation methods by comparing them with the more accurate weir-based escapement estimation methods.

To improve accuracy of the AUC method, I estimated residence time of adult Chinook and coho salmon in Prairie Creek. Most calculations of AUC escapement rely upon constant values for residence time that are borrowed from other studies (Shardlow 2004). Since residence time varies among streams, this introduces bias into the AUC escapement estimate (Perrin and Irvine 1990, Bue et al. 1998), and residence times should therefore be calculated specifically for each system studied. Although Perrin and Irvine (1990) suggested that residence times should not be extrapolated between years,

Parken et al. (2003) found that residence time remained fairly constant over the course of a four-year study. Assuming slight interannual variation in residence time, estimating a stream-specific residence time of adult salmon in Prairie Creek will be useful for past as well as future years" AUC estimates. Since residence time varies not only between streams, but also within a stream over the course of the spawning season, I tested for differences between early and late arriving salmon of both species. I also evaluated the relationship of residence time to body size, sex, and distance traveled upstream.

Hypotheses

H₁ The daily probability of Chinook and coho salmon moving upstream past the installed weir can be modeled with the factors of discharge, stream temperature, and turbidity.

H₂ Temporal patterns in sex and size exist in run-timing of spawning Chinook and coho salmon on Prairie Creek.

- Male Chinook and coho salmon arrive at the spawning grounds earlier than female Chinook and coho salmon.
- Larger Chinook and coho salmon arrive at the spawning grounds earlier than smaller Chinook and coho salmon.

H₃ Early-arriving Chinook and coho salmon spawn further upstream than later-arriving Chinook and coho salmon.

H₄ Residence times of Pacific salmon decrease as the spawning season progresses.

- Early-arriving Chinook and coho salmon remain alive in the stream longer than later-arriving Chinook and coho salmon.

MATERIALS AND METHODS

Site Description

Prairie Creek is a fourth-order tributary to Redwood Creek which drains a 34.4 km² watershed (Figure 1). Prairie Creek is approximately 20 km long. 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, and coastal cutthroat trout (*O. clarki clarki*), 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*).

Study areas were based upon survey reaches previously established by the USGS California Cooperative Fish and Wildlife Research Unit. These began 50 m below the confluence of Prairie Creek and Streelow Creek, which is 6.75 km upstream of the mouth of Prairie Creek, and continued upstream for 13.27 km (Figure 1, Table 1). Population estimation and monitoring of juvenile and adult Pacific salmon on these reaches have been conducted since 1998 (Brakensiek 2002, Sparkman 2003, Feola 2007, Duffy and Bjorkstedt 2008, Gough 2010, Duffy et al. in press, California Cooperative Fish and Wildlife Research Unit unpublished).

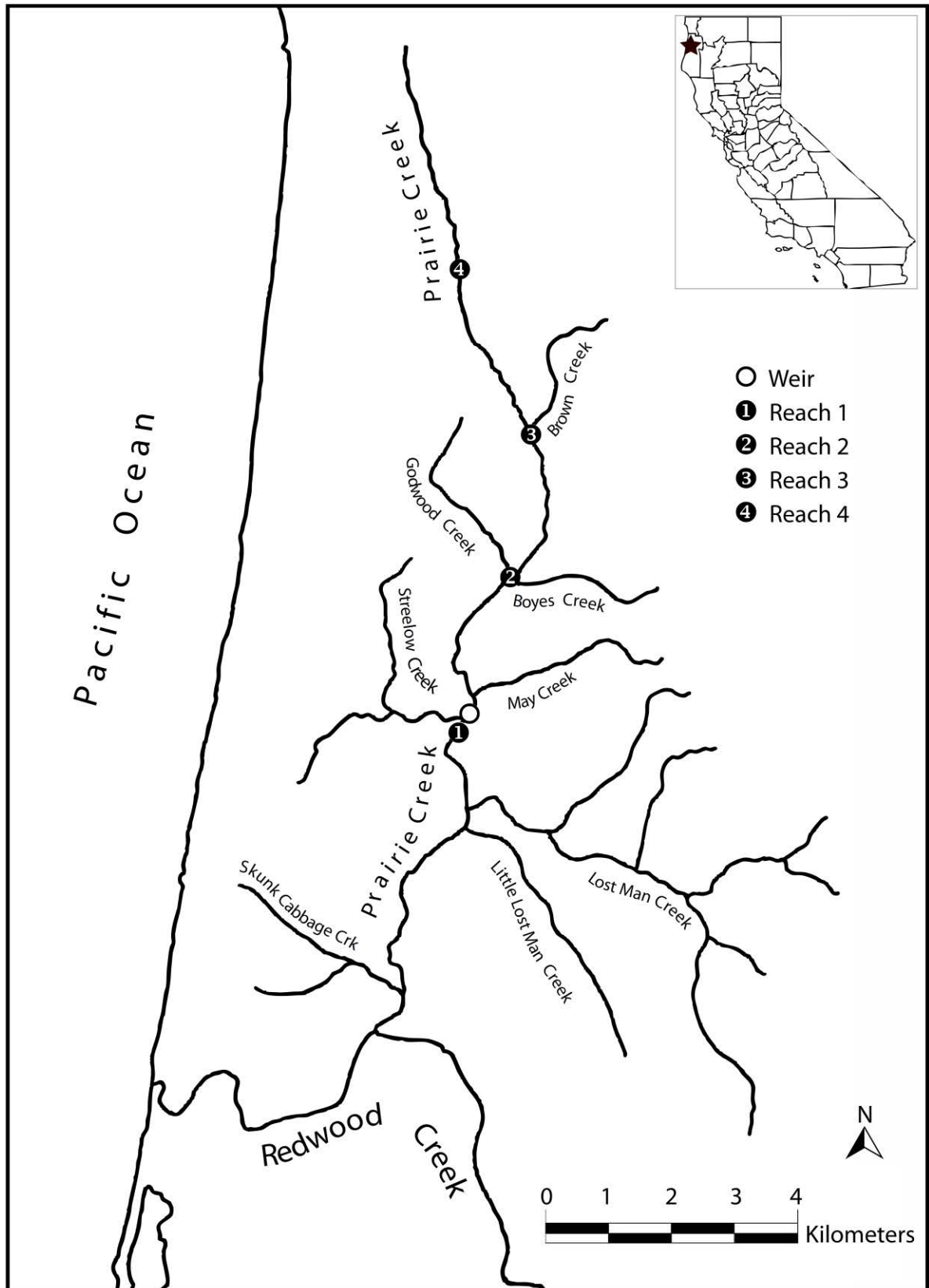


Figure 1. Map of Prairie Creek study area showing weir placement and the beginning locations of survey reaches, Humboldt County, California, 2005-2007.

Table 1. Length and location of study site reaches along Prairie Creek, Humboldt County, California, 2005-2007.

Reach	Start and end locations	Meter location	Total length (m)
1	Streelow Creek to Boyes Creek	0 - 4,175 m	4,175
2	Boyes Creek to Brown Creek	4,175 - 7,550 m	3,375
3	Brown Creek to Zig Zag #2 trail bridge	7,550 - 11,070 m	3,520
4	Zig Zag #2 trail bridge to end of study area	11,070 - 13,270 m	2,200

Review of Methods for Estimating Escapement

Several methods have been used to estimate escapement of adult salmon into a river or stream. These include counts of live salmon, counts of redds (nest sites) built by spawning salmon, counts of salmon passing weirs or fences, tagging live salmon and recapturing marked carcasses, tagging and recapturing carcasses, hydroacoustic or video camera counts of salmon, and counts of juvenile recruitment (Cousens et al. 1982, Shardlow et al. 1986, Beland 1996).

The most common escapement estimation method involves periodic counts of live salmon in a stream. Counts of salmon, repeated at regular intervals, are obtained from walking surveys, observation towers, aerial surveys, or photographic methods (Cousens et al. 1982). An area-under-the-curve (AUC) analysis is then used to calculate an estimate of spawning escapement based on live salmon counts. The AUC analysis is sensitive to the ability of surveyors to see salmon (observer efficiency) and the time salmon remain in the stream to be observed (residence time). Salmon counted on surveys are expanded by observer efficiency to estimate the actual number present at the time of each survey. These values are plotted against time to generate an escapement curve, and the area under this curve represents the total number of salmon-days for the season. When the area-under-the-curve is divided by residence time an estimate of total number of salmon in the stream over the course of the spawning season (escapement) is obtained. The AUC estimate of escapement increases in accuracy with more frequent surveys of the spawning area (Bue et al. 1998, Hill 1997). The accuracy of an AUC escapement estimate also increases as observer efficiency increases and with accuracy of estimated

residence time (Shardlow et al. 1987, English et al. 1992, Irvine et al. 1992, Jones et al. 1998, Shardlow 2004).

Escapement can also be estimated by counting the number of redds built by adult female salmon. By looking for disturbed gravel and nesting structures, survey crews can visually identify redds on the spawning grounds. Redd counts have been used historically as an index of adult escapement and to monitor long-term trends in populations (Rieman and Myers 1997). They can be expanded to an estimate of adult escapement when multiplied by the average number of spawners per redd (obtained from an independent estimate of adult escapement, such as weir counts of redd-surveyed streams; Al-Chokhachy et al. 2005). Measurement of total redd-area in a stream has also been used to estimate escapement (Gallagher and Gallagher 2005). Redd surveys are a cost and time effective method, because they require fewer surveys than the AUC method (Al-Chokhachy et al. 2005). However, identification of redds is subjective and observer variability reduces accuracy (Dunham et al. 2001). Test digs, multiple redds built by a single female, redd superimposition, and the inability to distinguish between redds of different species all contribute to uncertainty of escapement estimates from redd counts (Cousens et al. 1982, Al-Chokhachy et al. 2005, Gallagher and Gallagher 2005).

Weirs and fence counts generally provide the most accurate and precise estimates of escapement (Cousens et al. 1982, Shardlow et al. 1986, Schwarz et al. 1993, Miyakoshi and Kudo 1999). All adult salmon are counted as they enter the system, giving an absolute count of escapement. Weir counts thus provide a measure of escapement that can be used to test the accuracy of other methods and to calibrate methods of escapement estimation. Weirs are expensive to build and run, and to be most

effective must remain in operation for the entire upstream migration (Miyakoshi and Kudo 1999).

Since it is difficult to maintain a weir for the entire spawning season, mark and recapture is often used as an additional form of escapement estimation (Schwarz and Taylor 1998, Miyakoshi and Kudo 1999). Salmon are marked upon entering the system at the weir and recaptured upstream as carcasses (Maselko et al. 2003, Miyakoshi et al. 2003). This method assumes that all marked salmon will remain in the study area and will mix evenly with unmarked salmon throughout the spawning area. If these assumptions are valid, the ratio of marked to unmarked salmon that are recaptured can be used to estimate escapement.

The carcasses of salmon that have died after spawning can also be marked and recaptured to estimate escapement. By tagging carcasses and releasing them for subsequent recapture, Boydstun (1994) was able to estimate the number of spawning fall Chinook salmon in Bogus Creek, a tributary to the Klamath River, California. This method and the previous both rely on carcass retention in the stream. Cederholm et al. (1989) found that coho salmon carcasses were retained in spawning areas in small streams, and the capacity of a stream to retain carcasses increased with the presence of organic debris. However, high flows flush carcasses downstream and carnivores remove carcasses from the system (Cederholm et al. 1989). The differences in spawning behavior between male and female salmon may also affect carcass recapture (Miyakoshi et al. 2003), as females are more likely to be recaptured as carcasses since they remain in shallow water near their redds until death (Shardlow et al. 1986).

Fish Capture and Tagging

A resistance-board weir was installed 6.8 km upstream of the mouth of Prairie Creek, about 150 m upstream of its confluence with Streelow Creek, 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 salmon trapped by the weir upstream into a live box. The live box was checked two or more times daily for trapped salmon, depending on the capture frequency.

Resistance-board weirs consist of a series of connected panels installed across the stream to block fish passage (Tobin 1994, Stewart 2002). This style of weir was developed in Japan in the 1980s and is now used in Alaska and the Pacific Northwest to census adult salmon, steelhead, and Dolly Varden (Schroeder 1996). 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. These weirs are designed to briefly submerge and allow debris to float downstream, instead of becoming clogged with large woody debris and blowing out. When floating in the water column the weir will effectively block all adult salmon from moving upstream.

Captured salmon 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 salmon to be individually recognized when carcasses were scanned with handheld PIT tag readers on stream surveys. Tagged salmon also received an operculum punch as a secondary mark in case of tag loss. Some salmon were esophageal-tagged with radio

transmitters instead of PIT tags and received a secondary mark of a yellow hog-ring tag. Species, sex, total length and condition of all captured salmon were recorded. Condition was recorded as: 1) fresh, bright coloration with clear eyes; 2) dark coloration with milt or eggs being released; or 3) the fish had completed spawning. After handling, salmon were placed in a 1.5 m³ recovery basin for half an hour before being released upstream of the weir. The Institutional Animal Care and Use Protocol (Issue Date: 12/2/2005, Protocol No.: 05/06.F.32.A) was followed throughout the course of the study.

Stream Surveys

Walking surveys were conducted frequently over the course of the spawning period. Each reach was surveyed weekly unless stream flow was so high as to be unsafe or heavy rain and (or) turbidity limited visibility below the water surface. Surveys were conducted by two trained surveyors walking upstream and recording observations of live salmon, redds, and carcasses. Stream reaches were flagged with meter markers every 50 m to allow surveyors to record approximate stream location of all observations. Surveyors recorded species, sex, estimated fish total length, and location. Redds built since the previous survey were measured to record length and width. To avoid double counting, measured redds were identified by placing labeled surveyors flagging on riparian vegetation near the downstream end. Surveyors recorded the location of each redd in meters upstream from the beginning of the survey reach, as well as the redd's horizontal or lateral position across the streambed. Lateral stream position of a redd was recorded on a 1 to 5 integer scale, where 1 was adjacent to the left stream bank and 5 was adjacent to the right stream bank. Carcasses were identified to species and sex, measured

for total length, and stream location was recorded. Carcass condition was recorded as: 1) fresh (eyes clear and flesh firm), 2) decayed minus (eyes cloudy and flesh firm), 3) decayed plus (eyes cloudy and flesh very soft), or 4) skeleton (flesh falling off) as in Sykes and Botsford (1986). All carcasses were scanned with a PIT tag reader to identify recaptured individuals and 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 three times over this two-year study. On double-blind surveys one pair of observers first surveyed the stream reach, recording the location of all live salmon, 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 salmon, 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 (modified from English et al. 1992, Bue et al. 1998, Hilborn et al. 1999, Parken et al. 2003). Escapement was calculated for Chinook and coho salmon using the AUC software package designed by Irvine et al. (1993). This program calculates stream population estimates at each survey time, the area under the population curve, and the AUC escapement. The population of Chinook and coho

salmon in the survey reach on the day of each survey (x_i) was estimated by dividing the number of each species observed (fo) by the observer efficiency factor (oe):

$$x_i = \frac{fo}{oe} \quad \text{Equation 1}$$

An observer efficiency of 76% was used to expand the observed number of salmon to an estimate of the actual number of salmon present during each sampling period. This expansion value was based on a study of observer efficiency in 30 Oregon coastal streams, where the authors found that surveyors observed 75.5% of the adult coho salmon and 76.1% of the adult Chinook salmon (Solazzi 1984).

Each of the four reaches on Prairie Creek were surveyed on separate days, and the data from each of these surveys was then summed to calculate the total number of each species observed during each sampling period. I assumed that live fish did not move between reaches during each sampling period. 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:

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

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 species" residence time (rt):

$$\hat{E}_{auc} = \frac{AUC}{rt} \quad \text{Equation 3}$$

Residence time estimates were calculated for the Prairie Creek survey area through the recovery of carcasses of salmon that had been tagged upon live capture at the weir. Residence time was estimated as the number of days between a salmon's initial capture at the weir and its recapture as a carcass. Only carcasses found in a fresh condition (i.e. carcass condition of 1: fresh (eyes clear and flesh firm)) were used to calculate residence time.

Redd Count Expansion

Another method of escapement estimation involved counting redds built by each species over the spawning season. Surveyors counted redds present in the creek and the species of salmon present on the redd. If no salmon were seen at the redd site, the redd was classified as being built by an unknown species.

A logistic regression model was used to distinguish Chinook salmon from coho salmon redds for those redds which did not have a known associated species when observed. Gough (2010) developed this model to assign species to unknown redds using Prairie Creek adult salmonid redd data spanning the 1998/1999 through 2003/2004 spawning seasons. One model which included time (water year day) as the only parameter predicted species with 93.3% concordance with the data set. This model was used to distinguish Chinook salmon from coho salmon redds:

$$\Pr(OK) = 1 / (1 + e^{-(14.0304 + 0.153 * t)}) \quad \text{Equation 4}$$

where $\Pr(OK)$ is the probability that an unknown redd was built by a coho salmon, and t is water year day. If $\Pr(OK)$ was greater or equal to 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.

To develop estimates of escapement based on redd counts ($\hat{E}_{redd}$), the redd count totals were then expanded by each species' sex ratio as observed at the weir using the following equation:

$$\hat{E}_{redd} = \left(\frac{F + M + J}{F} \right) \times R = \left(1 + \frac{M + J}{F} \right) \times R \quad \text{Equation 5}$$

where R is the number of redds counted, M is the number of males captured at the weir, J is the number of jacks captured at the weir, F is the number of females captured at the weir, and it is assumed that each female builds one redd.

Mark-Recapture

Live salmon captured and tagged with 32 mm PIT tags or radio-telemetry tags at the weir were recaptured as carcasses by survey crews. All carcasses found on surveys, whether marked with previous tags from handling at the weir or not, were tagged with uniquely-numbered circular metal tags through the lower jaw for identification if recaptured on subsequent surveys. Both of these tagging methods were used to estimate adult escapement with mark and recapture.

Live-Mark Carcass-Recapture. I used Chapman's modified version of the simple Petersen abundance estimator to estimate escapement from salmon tagged at the weir and recaptured as carcasses ($\hat{E}_{CP}$). This estimator has been found to give an unbiased estimate in most situations (Ricker 1975):

$$\hat{E}_{CP} = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} \quad \text{Equation 6}$$

where n_1 is the number of salmon captured and marked with PIT or radio-telemetry tags at the weir, n_2 is the number of salmon carcasses counted on walking surveys, and m_2 is the number of PIT or radio-telemetry tag marked salmon carcasses that were recaptured.

Jolly-Seber Carcass Mark-Recapture. A modified Jolly-Seber method was used to estimate escapement from marking carcasses and recovering carcasses (Sykes and Botsford 1986, Boydstun 1994). The individual encounter histories of tagged carcasses were used to estimate apparent survival rate parameters (Φ) and capture probability parameters (p) in Program MARK (White and Burnham 1999). Program MARK was used to compare four models with these estimated parameters (Table 2). These models differ in their treatment of apparent survival and capture probability as time independent or dependent.

After selecting the best models using Akaike Information Criterion corrected for small sample size (AICc), escapements were calculated using a modified version of the Jolly-Seber estimator as described by Sykes and Botsford (1986):

$$\hat{E}_{JS} = n_1 + \frac{\hat{N}_2 - R_1 \hat{\Phi}_1}{\sqrt{\hat{\Phi}_1}} + \hat{D}_2 + \hat{D}_3 + \dots + \hat{D}_{finalsampletime} \quad \text{Equation 7}$$

where n_1 is the number sampled at the first sample time, R_1 is the number tagged and released at the first sample time, $\hat{N}_2$ is the estimated population size at sample time two, $\hat{D}_i = \hat{B}_i / \sqrt{\hat{\Phi}_i}$, $\hat{\Phi}_i$ is the Program MARK estimate of the survival rate from i to $i+1$, and

Table 2. Summary of Jolly-Seber models developed in Program MARK for analysis of adult Chinook and coho salmon carcass mark-carcass recapture data, Prairie Creek study area, Humboldt County, California, 2005-2007. The parameters being tested are apparent survival rate (Φ) and capture probability (p) of carcasses on stream surveys. A (t) following the parameter means that the parameter is time dependent, therefore not constant over all surveys; a (.) following the parameter means that the parameter is not time dependent, therefore constant over all surveys.

Model	Parameters	Explanation
1	$\Phi(t)p(t)$	Both survival rate and capture rate are time dependent
2	$\Phi(.)p(t)$	Survival rate is constant and capture rate is time dependent
3	$\Phi(t)p(.)$	Survival rate is time dependent and capture rate is constant
4	$\Phi(.)p(.)$	Both survival rate and capture rate are constant

$\hat{B}_i$ = the number joining, and is the estimated number of carcasses still present at the sample time $i+1$ which immigrated between i and $i+1$.

The estimated population size at sample time i is:

$$\hat{N}_i = \frac{n_i}{p_i} \quad \text{Equation 8}$$

where p_i is the Program MARK estimate of capture probability at sample time i .

And the number joining, $\hat{B}_i$, is calculated as:

$$\hat{B}_i = \hat{N}_{i+1} - \hat{\Phi}_i (\hat{N}_i - n_i + R_i) \quad \text{Equation 9}$$

Redd Site Location

Boxplots and linear regression were used to compare positively identified observations of Chinook and coho salmon redds recorded on stream surveys in space (distance upstream from beginning of survey area) and time (date of observation). The boxplots illustrated differences between the two species in median and range of both location and date of redd observation. Linear regressions were used to examine the extent of a linear relationship between each species and the two independent variables of redd location and date of redd observation.

Movement Analysis

A two-stage model was developed to investigate the influence of environmental variables on the upstream movement of adult coho salmon past the Prairie Creek weir. The first stage of the model predicted the date salmon entered the Redwood Creek estuary, and therefore the number of available fish within range of sensing local

environmental cues that might stimulate further upstream migration. No information was available for numbers of salmon pooling in Redwood Creek estuary. A model of coho salmon arrival was built assuming arrival followed a smooth distribution where more fish were available to migrate upstream past the Prairie Creek weir than actually migrated on any given day. I assumed that the distribution of captured individuals was similar to the true arrival distribution. The number of coho salmon staging in Redwood Creek estuary was modeled by fitting a gamma distribution to the upstream weir passage data and adding a time lag to account for travel time between the estuary and the weir.

This pool of staging coho salmon was the available number of salmon that could choose to migrate upstream to the weir and be captured on a given day. I predicted daily binomial movement probabilities ($\text{Pr}(\text{Move})$) under the assumption that pooling fish had equal probability of upstream movement regardless of their waiting time.

$$\text{Pr}(\text{Move}) = \text{Pr}(X|n) = \frac{X}{n} \quad \text{Equation 11}$$

where X = observed daily number of coho salmon captured at weir, and n = modeled daily number of available coho salmon staging downstream.

I evaluated the effect of environmental variables on the upstream movement of coho salmon past the Prairie Creek weir by fitting generalized additive models relating daily movement probabilities to five variables: (1) daily discharge, (2) mean daily turbidity, (3) mean daily stream temperature, (4) cumulative daily precipitation, and (5) mean daily light intensity (Table 3). Discharge and turbidity measurements were collected by the National Park Service at their Prairie Creek (near May Creek) gauge (approximately 400 m above weir site). Stream temperature was recorded using a HOBO Water Temp Pro v2 Data Logger (HOBO Inc., Pocasset, Massachusetts) located at the

Table 3. Description of environmental variables collected and used to fit a generalized additive model of the probability of coho salmon upstream movement past the Prairie Creek weir, Humboldt County, California, 2006/2007.

Variable	Notation	Units	Description
Discharge	Q	cfs	Mean daily stream discharge recorded at the May Creek bridge
Turbidity	T	FBU	Mean daily turbidity recorded at the May Creek bridge
Stream temperature	S	°C	Mean daily stream temperature recorded at the weir site
Precipitation	P	mm	Sum of daily precipitation recorded at the May Creek bridge weather station
Light intensity	L	L/m ²	Average daily light intensity recorded at the May Creek bridge weather station

weir site. Precipitation, and light intensity measurements were collected at a remote weather station located near the confluence of Prairie Creek and May Creek (HOBO Event Logger attached to a HOBO Tipping Bucket Rain Gauge; HOBO Light Intensity Data Logger).

Data from January 18, 2007, was omitted because measurements of all environmental variables were not available. Dates when the weir was non-functional and zero coho salmon were captured were excluded ($n=3$). The data collected for light intensities from January 18 onward was compromised, and so was eliminated from model testing. Generalized additive models were tested on two data sets: (1) omitting light intensity as a variable, and (2) including all variables but truncating data at January 17, 2007.

I used stiff smoothing functions to fit the generalized additive models to limit the resulting model fits (i.e., I allowed only 4 “knots” demarcating regions of different curvature in the fitted cubic splines; Wood 2006). This was done to focus on general patterns more consistent with ecological mechanisms and to avoid over-fitting the data. I weighted the models using the standard errors of the binomial movement probability estimates to account for their uncertainty. Model selection criteria of analysis of deviance, Akaike’s information criterion (AIC), and generalized cross-validation scores (GCV) were used to evaluate a suite of models spanning all combinations of one to five of the continuous explanatory variables identified above. Analysis was performed in the R package *mgcv* version 1.6 (Wood 2006).

RESULTS

Fish Capture and Tagging

In the first study year, the Prairie Creek weir was installed on December 9, 2005, and operated for 86 days before it was removed on March 24, 2006. Although adult Chinook and coho salmon were seen by surveyors in the spawning areas above the weir before this date, the weir was in place before the peak of the adult coho salmon upstream migration. High stream flows overtopped the weir for nine days (from December 28-January 4 and January 11-12). The weir was also removed for repairs for 19 days in February. During the second year of study, the weir was installed in Prairie Creek on November 8, 2006, and operated for 146 days until April 2, 2007. It was overtopped by high flows on 13 days, but captured salmon on 10 of these dates.

During the 2005/2006 trapping season 10 Chinook salmon, 58 coho salmon, 14 steelhead, and one chum salmon were captured at the weir (Figure 2, Appendix A). PIT tags were implanted in eight Chinook salmon and 36 coho salmon. Radio-telemetry tags were attached to 15 coho salmon. One coho salmon was double-marked with both PIT and radio-telemetry tags. All Chinook and coho salmon in condition 1 (fresh) and 2 (dark, milt or eggs being released) were tagged, with the exception of salmon that escaped from the sampling basin before tagging.

During the 2006/2007 season 12 Chinook salmon, 99 coho salmon, 77 steelhead, 2 chum salmon, and 7 coastal cutthroat trout were captured at the weir (Figure 3, Appendix B). Five Chinook salmon were marked with PIT tags and three were marked with radio-telemetry tags. Eighty coho salmon were marked with PIT tags and 12 were

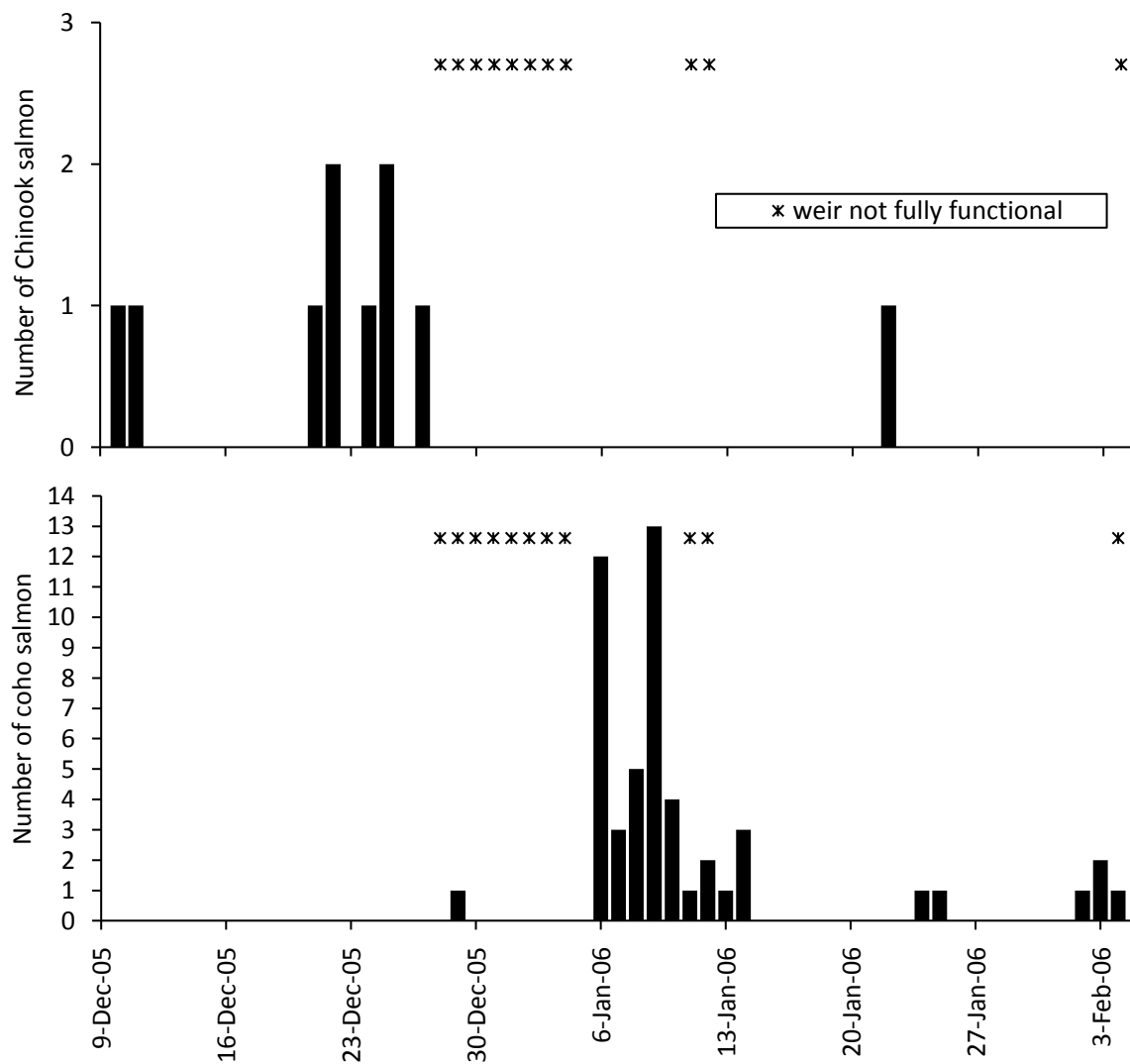


Figure 2. Daily numbers of Chinook salmon (top) and coho salmon (bottom) captured at the Prairie Creek weir, Humboldt County, California, during the 2005/2006 study year. Please note differences in scale of y-axes. Asterisks indicate dates the weir was overtopped by high flows and not 100% efficient at trapping fish.

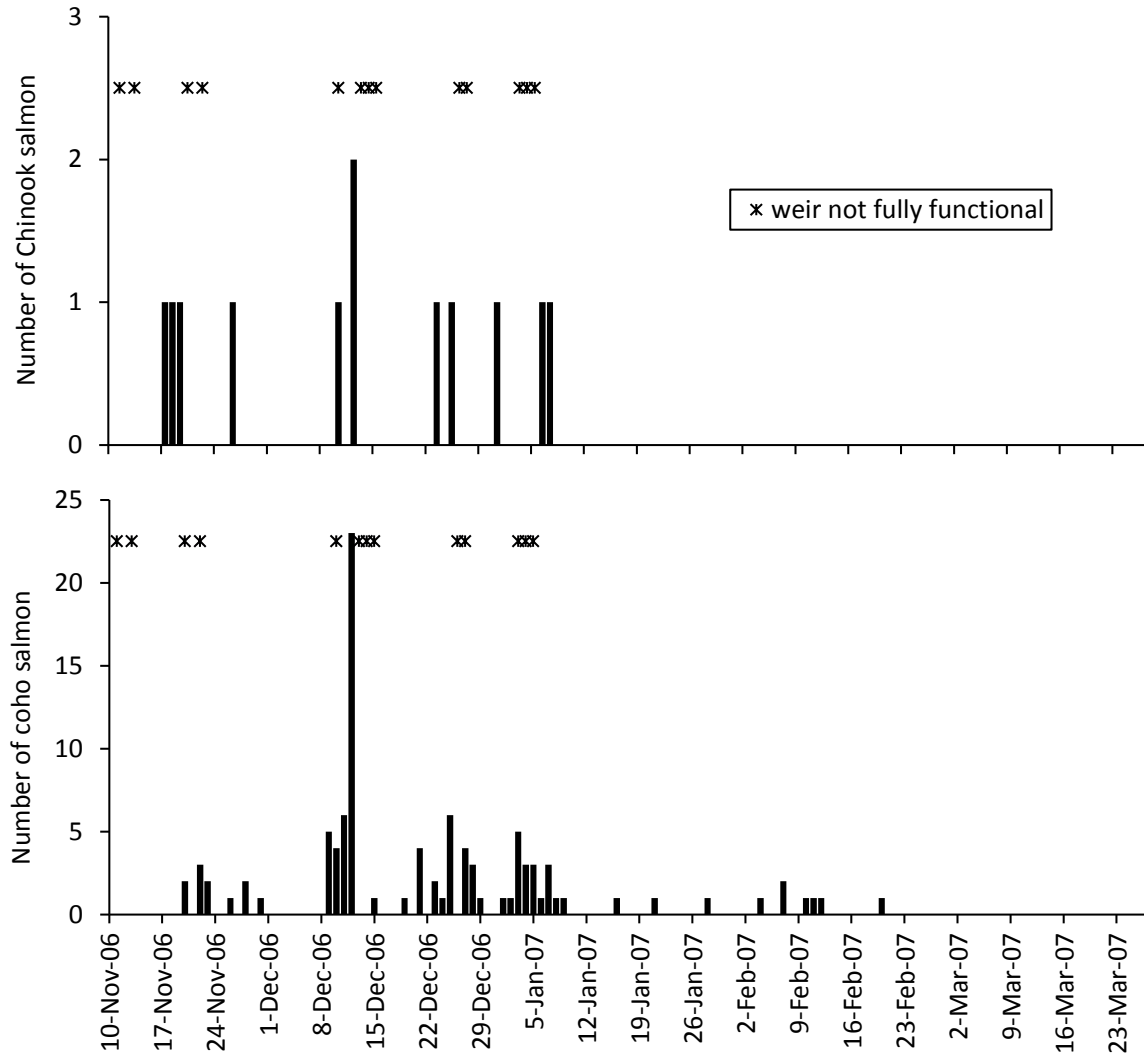


Figure 3. Daily numbers of Chinook salmon (top) and coho salmon (bottom) captured at the Prairie Creek weir, Humboldt County, California, during the 2006/2007 study year. Please note differences in scale of y-axes. Asterisks indicate dates the weir was overtopped by high flows and not 100% efficient at trapping fish.

marked with radio-telemetry tags. Two of these coho salmon were double-marked with both PIT and radio-telemetry tags.

In both years Chinook salmon were not abundant enough to identify a peak in their arrival (Figure 2, 3). In 2005/2006 all but one Chinook arrived by late December, and in 2006/2007 all Chinook arrived by early January. The peak arrival of coho salmon was early January in 2006/2006, but mid-December through early January in 2006/2007 (Figure 2, 3). Coho salmon continued to enter the study area through early February in 2005/2006 and late February in 2006/2007.

Neither body size nor sex were consistently related to the date salmon were captured at the weir (all $p > 0.05$, except for body size of coho salmon in 2006/2007). In 2006/2007, larger coho salmon returned earlier than smaller ones ($p = 0.023$, $n = 96$). In 2005/2006, body size was not significantly related to date of weir capture in either Chinook or coho salmon and male and female salmon arrived at the weir with statistically similar timing. Males were more common than females during both years (Table 4). However, for coho salmon the sex ratio was influenced by jacks and the number of females was only slightly less than adult males during both years.

Average fork lengths for Chinook and coho salmon varied little between the two study years (Table 4, Figure 4). When jacks were separated from mature adult salmon, the fork lengths of adult Chinook and coho salmon measured at the weir were significantly different ($p < 0.0001$). Length frequency histograms of all species illustrate the differences in fork length between age classes and sexes (Figure 4).

Table 4. Mean fork lengths of adult Chinook salmon and coho salmon captured at the weir during trapping operations on Prairie Creek, Humboldt County, California, 2005-2007.

2005/2006	Chinook salmon			coho salmon		
	n	FL (cm)	SD	n	FL (cm)	SD
Female	2	98	17	24	66	3.2
Male	8	82	14	30	69	4.8
Jack	0	--	--	4	39	9.0
Combined	10	85	15	58	66	8.6
2006/2007						
Female	4	84	9.1	37	69	4.3
Male	4	78	9.2	43	69	6.3
Jack	4	47	3.1	18	42	2.7
Combined	12	70	19	98	64	12

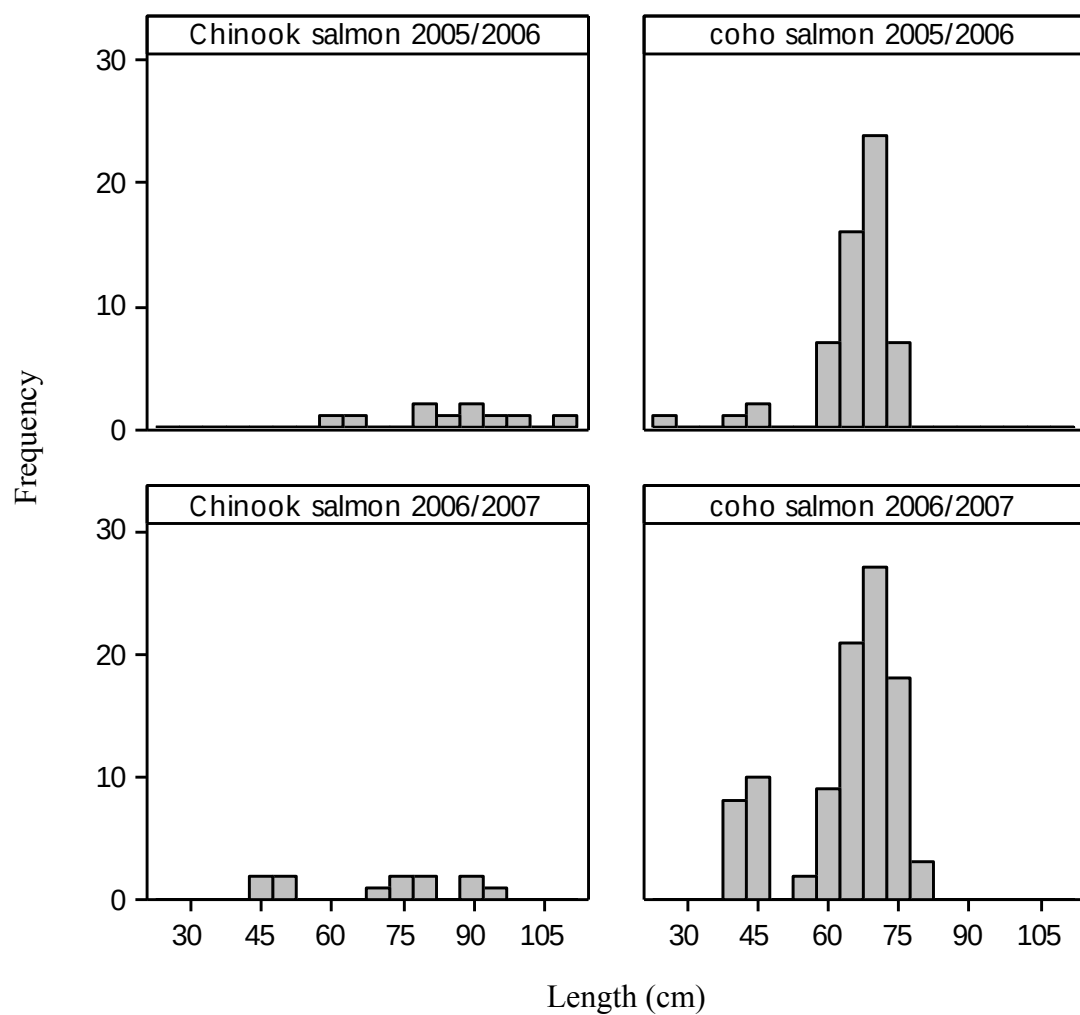


Figure 4. Length-frequency histograms of Chinook salmon and coho salmon captured at the Prairie Creek weir, Humboldt County, California, during 2005/2006 (top row) and 2006/2007 (bottom row).

Stream Surveys

In the first year of this study, surveys of Prairie Creek began on November 18, 2005. Three adult Chinook salmon were seen in the first set of stream surveys. Surveys were continued until April 7, 2006, over a month after the last live adult coho salmon had been seen on February 22, 2006. In the second year of this study, surveys began on November 6, 2006, and adult salmon were not seen until the second set of surveys on November 19, 2006. Surveys were continued until March 18, 2007, a month after the last live adult coho salmon was seen on February 19, 2007.

Double-blind surveys were performed three times during this study to investigate variation between observers (February 7 and 18, 2006, January 8, 2007 (Figure 5)). Each survey pair had one experienced observer (1-5 years previous experience) and one newly trained observer (0 years previous experience). On each double-blind survey, the two survey crews varied greatly in the number and stream location of redds, live fish, and carcasses observed. The greatest discrepancies were in the first double-blind surveys redd counts, when the first survey crew observed 12 redds and the second survey crew observed 8 redds. Of these observed redds, only 4 were in matching locations and thus shared observations.

Escapement Estimation

Area-Under-the-Curve

Live adult salmon observations recorded during stream surveys were used to calculate AUC escapement estimates (Appendices C, D). Live counts of Chinook and coho salmon per sampling period (set of four reach surveys) are summarized in Table 5.

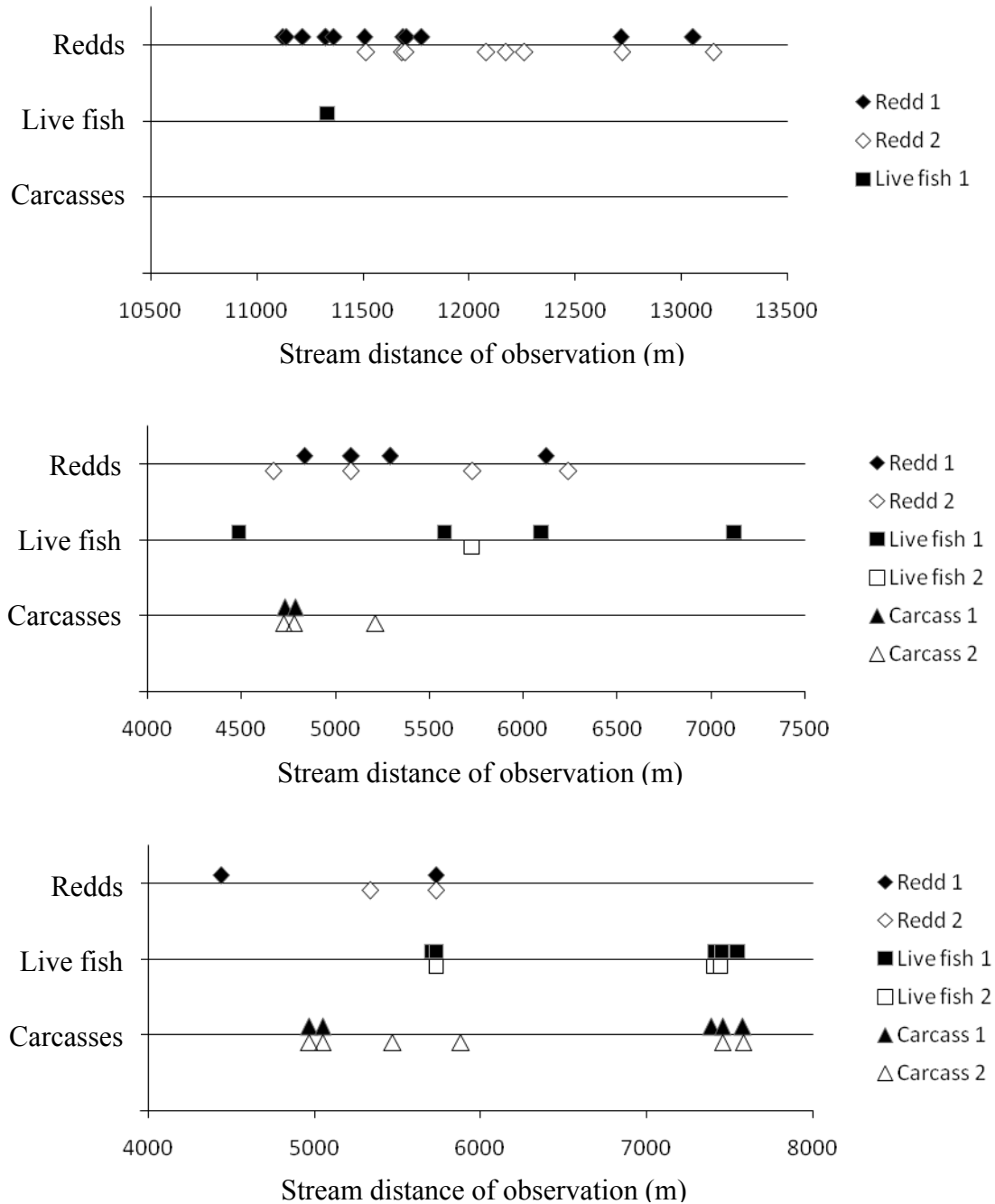


Figure 5. Location of live fish, redds, and carcasses observed by two pairs of surveyors during double-blind surveys conducted on 7 Feb 2006 (top), 18 Feb 2006 (middle), and 8 Jan 2007 (bottom) in Prairie Creek, Humboldt County, California. Redd 1, Live fish 1, and Carcass 1 are redds, live fish, and carcasses observed by the first survey crew walking through the surveyed reach. Redd 2, Live fish 2, and Carcass 2 are redds, live fish, and carcasses observed by the second survey crew walking through the survey reach.

Table 5. Counts of live Chinook and coho salmon recorded during stream surveys of Prairie Creek, Humboldt County, California, and used to calculate estimates of escapement with the AUC method, 2005-2007. The first two columns include only salmon positively identified to species, the third and fourth columns include counts expanded to assign species based upon fork length.

Year	Sampling period	Date	Stream survey counts			
			Positively identified		Including unknowns ¹	
			Chinook	Coho	Chinook	Coho
2005/2006	1	19-Nov-05	1	0	1	4
	2	5-Dec-05	6	19	6	29
	3	12-Dec-05	28	33	28	43
	4	22-Dec-05	19	30	19	32
	5	23-Jan-06	2	15	2	20
	6	8-Feb-06	1	5	1	10
	7	16-Feb-06	0	5	0	6
	8	22-Feb-06	0	2	0	3
	9	30-Mar-06	0	0	0	0
	Total		57	109	57	147
2006/2007	1	7-Nov-06	0	0	0	0
	2	21-Nov-06	2	4	2	5
	3	26-Nov-06	4	1	4	11
	4	30-Nov-06	4	10	4	15
	5	4-Dec-06	2	10	2	12
	6	8-Dec-06	3	5	3	7
	7	19-Dec-06	27	44	27	55
	8	2-Jan-07	16	30	16	37
	9	9-Jan-07	3	16	3	19
	10	15-Jan-07	0	8	1	10
	11	22-Jan-07	0	2	0	3
	12	29-Jan-07	0	2	0	4
	13	5-Feb-07	0	1	0	2
	14	19-Feb-07	0	5	0	5
	15	9-Mar-07	0	0	0	0
	16	15-Mar-07	0	0	0	0
	Total		61	138	62	185

¹Unknowns assigned as Chinook or coho salmon based on size: length >70 cm classified as Chinook salmon; length ≤70 cm classified as coho salmon.

Observers recorded 14.6% (2005/2006) and 18.7% (2006/2007), of the live salmon seen on surveys as unknown species. Since the body lengths of mature adult Chinook salmon (mean FL=84cm, SD=13) and coho salmon (mean FL=68cm, SD=6.1) were significantly different ($p<0.0001$), species designations were assigned to the unknowns based upon their estimated fork lengths. Unknown salmon with a fork length greater than 70cm were classified as Chinook salmon while unknown salmon less or equal to 70cm long were classified as coho salmon (Table 5). Escapement estimates calculated using the AUC method were 65 Chinook and 145 coho salmon in 2005/2006, and 65 Chinook and 126 coho salmon in 2006/2007 (Table 6).

It was not possible to estimate residence times during the 2005/2006 spawning season. No salmon PIT-tagged at the weir were recovered as carcasses in a fresh condition on stream surveys. In 2006/2007, five Chinook salmon and 24 coho salmon that were tagged at the weir were recovered as carcasses in a fresh condition. Estimated residence time within the Prairie Creek survey area was 12 days for Chinook salmon and 17 days for coho salmon (Table 7).

The larger sample size of coho salmon carcasses observed in a fresh condition ($n=24$) allowed me to compare residence time with sex, arrival date, body size, and condition upon entry into the survey reaches. Although average residence time of male coho salmon (14 days) was less than that of females (18 days), there was no significant relationship between residence time and sex. There was also no evidence of a relationship between residence time and the date of entry into survey reaches. However, residence time was positively related to body size, as larger salmon tended to have longer

Table 6. Escapement estimates of Chinook and coho salmon calculated using the methods of AUC, redd count expansion, Chapman-Petersen live-mark carcass-recapture, and Jolly-Seber carcass-mark carcass-recapture, Prairie Creek study area, Humboldt County, California, 2005/2006 and 2006/2007.

Method	Chinook salmon		Coho salmon	
	2005/2006	2006/2007	2005/2006	2006/2007
Weir passage count	10	12	58	99
AUC	65	65	145	126
Redd count expansion	285	87	366	155
Chapman-Petersen M-R	41	38	485	212
Jolly-Seber M-R	--	24	51	45

Table 7. Estimated residence times (rt) of Chinook and coho salmon in Prairie Creek study area, Humboldt County, California, 2006/2007.

Sex	Chinook salmon			coho salmon		
	n	rt	SD	n	rt	SD
Female	3	15	2.3	15	18	9.8
Male	2	9	2.8	9	14	8.5
Total	5	12	3.8	24	17	9.3

residence times (linear regression, $p=0.029$, $R^2=0.20$). Residence time was also related to the condition of coho salmon when they were first captured at the weir. Coho salmon with a fresh and bright condition (weir condition = 1) when they arrived at the weir had longer residence times than those arriving with breeding coloration (weir condition = 2; $p=0.016$).

Redd Count Expansion

Redd counts made by stream surveyors (Appendices E, F) were expanded to estimate escapement. In 2005/2006, 85.9% of redds observed did not have salmon present on them while in 2006/2007, 45.5% did not have salmon associated with them (Table 8). These redds were classified as having been built by an unknown species, and were assigned a species based on a logistic regression equation (Gough 2010). Redds observed after the date the last coho salmon was seen alive on a survey were assumed to have been built by steelhead and were not assigned as Chinook or coho salmon redds.

Using the redd count expansion method, I estimated that 285 Chinook salmon and 366 coho salmon spawned in the Prairie Creek study area in 2005/2006 (Table 6). In 2006/2007, I estimated 87 Chinook salmon and 155 coho salmon spawned in the study area (Table 6).

Mark-Recapture

Live-Mark Carcass-Recapture. Numbers of Chinook and coho salmon marked at the weir, numbers of Chinook and coho salmon carcasses sampled on stream surveys, and

Table 8. Number of Chinook and coho salmon redds observed during stream surveys of Prairie Creek, Humboldt County, California, 2005-2007. The first two columns are number of redds positively associated with a species; the third and fourth columns include positively identified redds and redds assigned a species based upon a logistic regression equation developed by Gough (2010).

Year	Sampling period	Date	Redd counts			
			Positively identified		Including unknowns	
			Chinook	Coho	Chinook	Coho
2005/ 2006	1	19-Nov-05	0	0	4	0
	2	5-Dec-05	2	5	6	5
	3	12-Dec-05	4	3	28	3
	4	22-Dec-05	0	2	18	13
	5	23-Jan-06	1	8	1	67
	6	8-Feb-06	0	2	0	38
	7	16-Feb-06	0	2	0	20
	8	22-Feb-06	0	0	0	7
	9	30-Mar-06	0	0	0	7
	Total		7	22	57	149
2006/ 2007	1	7-Nov-06	0	0	0	0
	2	21-Nov-06	1	1	3	1
	3	26-Nov-06	2	1	9	1
	4	30-Nov-06	0	3	2	3
	5	4-Dec-06	0	1	0	1
	6	8-Dec-06	0	0	0	0
	7	19-Dec-06	7	18	14	18
	8	2-Jan-07	1	7	1	12
	9	9-Jan-07	0	3	0	8
	10	15-Jan-07	0	0	0	5
	11	22-Jan-07	0	0	0	0
	12	29-Jan-07	0	1	0	4
	13	5-Feb-07	0	0	0	2
	14	19-Feb-07	0	2	0	4
	15	9-Mar-07	0	0	0	13
	16	15-Mar-07	0	0	0	17
	Total		11	37	29	89

numbers of those carcasses found to be recaptured-tagged carcasses were low during the 2005/2006, but increased during 2006/2007 (Table 9). Escapements estimated using the Chapman-Petersen estimator were 41 Chinook salmon and 485 coho salmon in 2005/2006, and 38 Chinook salmon and 212 coho salmon in 2006/2007 (Table 6, 9). Variances of escapement estimates were large in 2005/2006, but smaller in 2006/2007 due to higher recapture rates of tagged individuals (Table 9).

Jolly-Seber Carcass Mark-Recapture. I used Program MARK to rank models of apparent survival (Φ) and capture probability (p) rates with Akaike's Information Criterion scores, corrected for small samples (AICc). After choosing the model with the lowest AICc for each species for each year (Table 10), I used the estimated parameters of apparent survival and capture probability to calculate Jolly-Seber estimates. With this method, I estimated 51 coho salmon adults returned in 2005/2006, and in 2006/2007 24 Chinook salmon and 45 coho salmon returned to spawn in the Prairie Creek study area (Table 6). An estimate of Chinook salmon escapement could not be determined in the first study year. An examination of the encounter history shows extremely low recapture of tagged carcasses, leading to estimates of zero capture probability for all but two of the eight sampling periods. Encounter histories for Chinook and coho salmon carcasses sampled in the Prairie Creek stream surveys are included in Appendices G-J.

Redd Site Location

Locations of redds positively associated with a single species were analyzed graphically with boxplots (Figure 6) and using linear regression to identify trends in

Table 9. Number of Chinook and coho salmon marked with PIT or radio-telemetry tags at weir (n_1), number of carcasses sampled on stream surveys (n_2), number of PIT or radio-telemetry tagged fish recaptured as carcasses on stream surveys (m_2), escapement estimates ($\hat{E}_{CP}$), and their variance estimates ($\tilde{V}$) in Prairie Creek, Humboldt County, California, 2005-2007.

Measure	Chinook salmon		coho salmon	
	2005/2006	2006/2007	2005/2006	2006/2007
n_1	8	8	51	80
n_2	8	24	27	62
m_2	1	5	2	26
$\hat{E}_{CP}$	41	38	485	212
$\tilde{V}$	3,800	9	841,000	169

Table 10. Ranking of estimated apparent survival rate (Φ) and capture probability (p) parameter models of Chinook and coho salmon Jolly-Seber carcass mark-recapture escapement estimation, Prairie Creek, Humboldt County, California, 2005-2007. Akaike's Information Criterion scores corrected for small samples (AICc) are listed in order of best fit each model. A (t) following the parameter means that the parameter is time dependent, therefore not constant over all surveys; a (.) following the parameter means that the parameter is not time dependent, therefore constant over all surveys.

Model	coho salmon				Chinook salmon			
	2005/2006		2006/2007		2005/2006		2006/2007	
	AICc	Δ AICc	AICc	Δ AICc	AICc	Δ AICc	AICc	Δ AICc
$\Phi(t)p(.)$	40.5	0.00	253.2	9.7	24.5	181.6	141.3	13.7
$\Phi(t)p(t)$	43.3	2.76	264.1	20.6	56.8	213.9	156.0	28.4
$\Phi(.)p(.)$	44.3	3.83	243.5	0.0	16.3	173.4	127.6	0.0
$\Phi(.)p(t)$	49.4	8.91	255.8	12.3	-157	0.0	139.2	11.7

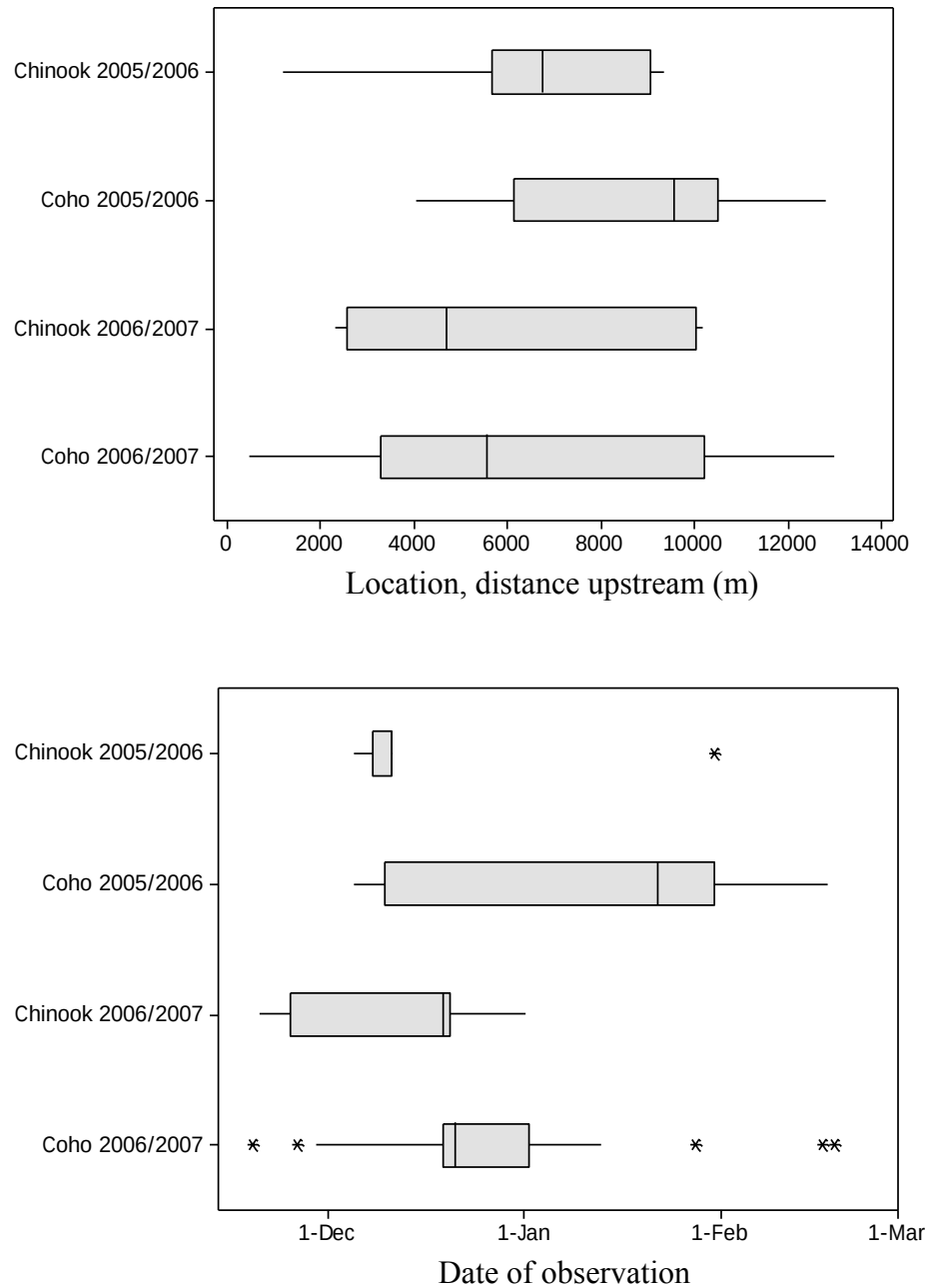


Figure 6. Boxplots describing location (top) and date (bottom) of Chinook and coho salmon redd observations in Prairie Creek, Humboldt County, California, 2005-2007. Redd locations are given in distance (m) from the beginning of survey area. The boxes represent the interquartile ranges of each data set. The left edge of the box represents the first quartile, while the right edge represents the third quartile. Thus the box portion on the plot represents the interquartile range, or the middle 50% of observations. The vertical line drawn through the box represents the median of the data. The horizontal lines, or whiskers, extending from the box indicate the lowest and highest values in the data set (excluding outliers). Outliers are represented by asterisks. These values are greater than 1.5 times the interquartile range.

distance upstream or date between Chinook and coho salmon species. In 2005/2006, seven Chinook and 22 coho salmon redds were positively identified. In 2006/2007, 11 Chinook and 37 coho salmon redds were positively identified. Coho salmon redds were observed over a longer period and further upstream as compared to Chinook salmon redds. The slope of the regression line for each species did not differ significantly from zero in either year. This suggests the absence of relationships between date of redd formation and location.

Movement Analysis

A two-stage model was developed to investigate the influence of environmental cues on movement of adult coho salmon upstream in the Prairie Creek watershed. In the first stage of this model, the number of adult coho salmon returning from the ocean to stage in the Redwood Creek estuary was modeled with a smooth-fitting gamma distribution curve (Figure 7A). This curve was fit to passage counts of coho salmon passing Prairie Creek weir and adjusted to account for travel time between the staging area and weir location, as well as to ensure non-negative numbers of fish were available to pass the weir. Daily upstream passage counts at the weir and model predictions of staging coho salmon are shown in Figure 7B. Model predictions of staging coho salmon were discretized for use in estimating the daily binomial probability that individual coho salmon moved past the weir during the 2006/2007 spawning season (Figure 7C). This process assumes that each salmon is independent and makes a new independent „decision“ regarding whether to move each day.

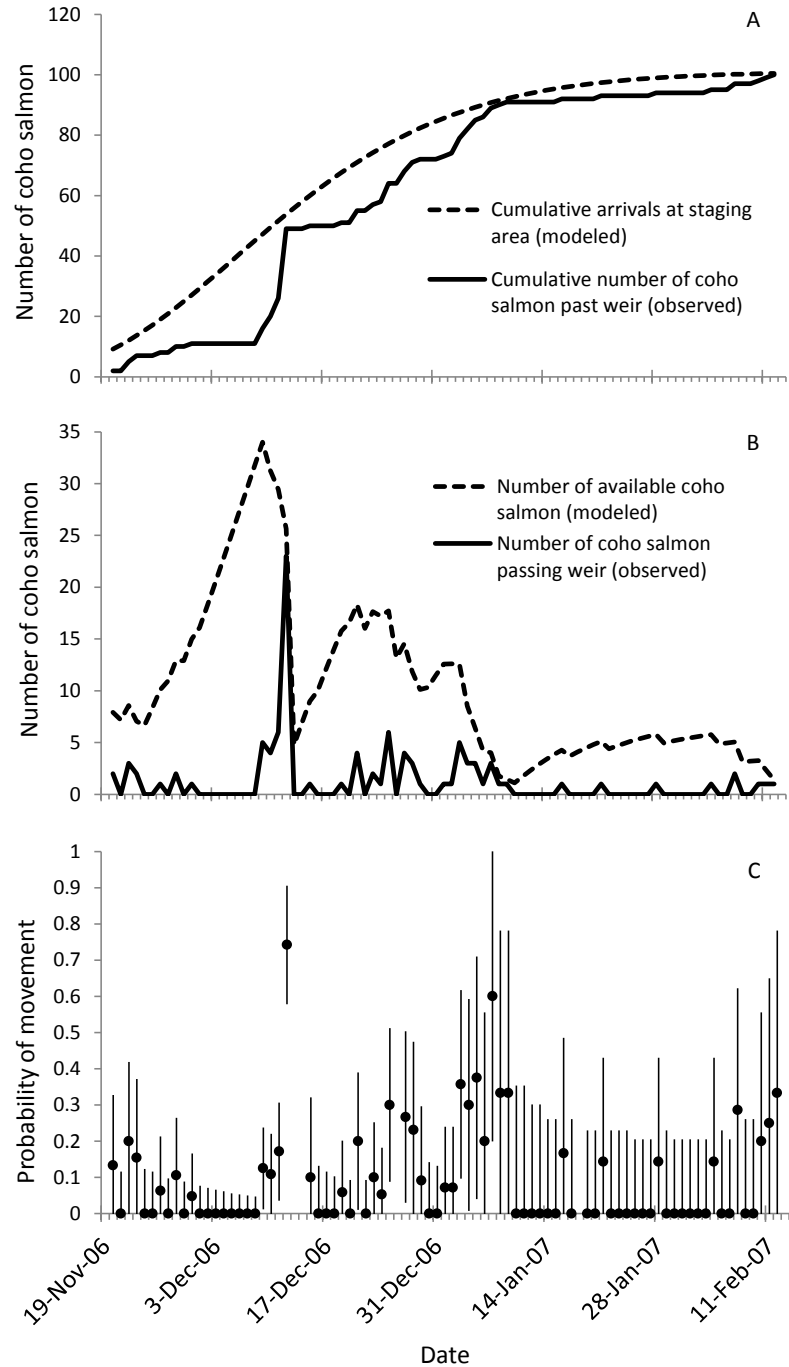


Figure 7. (A) Cumulative number of modeled coho salmon arriving at staging area (dashed line) and cumulative number of observed coho salmon passing Prairie Creek weir (solid line), Humboldt County, California, 2006/2007. (B) Daily number of modeled staging coho salmon available to move upstream (dashed line) and daily number of coho salmon observed passing Prairie Creek weir (solid line), Humboldt County, California, 2006/2007. (C) Estimated daily binomial movement probabilities of coho salmon past Prairie Creek weir with standard error bars, Humboldt County, California, 2006/2007.

I then assessed environmental factors affecting the estimated daily movement probabilities using generalized additive models (Figure 8, environmental variable data set from November 20, 2006, to February 12, 2007). This analysis spanned the period during which 98% of coho salmon were captured at the weir.

Interpretation of the significance of environmental variables was complicated by their multicollinearity (Figure 9). Mean daily discharge and turbidity measurements were strongly related ($R^2=0.652$). Daily change in mean daily discharge and daily change in mean daily turbidity were also related ($R^2=0.5779$). Less significant relationships existed between other measured environmental variables.

Cumulative daily precipitation and mean daily light intensity had weak and inconsistent effects on the probability of movement of coho salmon past the Prairie Creek weir. These two environmental variables were therefore dropped from further consideration. The remaining models spanned all combinations of one to three of the remaining continuous explanatory variables (mean daily discharge, mean daily turbidity, and mean daily stream temperatures) over the full time period. I ranked the models using model selection criteria of analysis of deviance, AIC, and GCV scores (Table 11). Top models exhibited high adjusted R-squared values, low AIC values, and low GCV scores. The full model ($\text{Pr}(\text{Move}) \sim \text{Q}+\text{T}+\text{S}$) was slightly superior to the second-ranking model ($\text{Pr}(\text{Move}) \sim \text{Q}+\text{S}$; $\Delta\text{AIC}=1.3$, Table 11).

Mean daily discharge ($p=0.017$) and mean daily stream temperature ($p=0.0053$) were the most significant and strongest predictors of probability of movement in the best-ranked model. Mean daily turbidity ($p=0.22$) was not a significant term in this model,

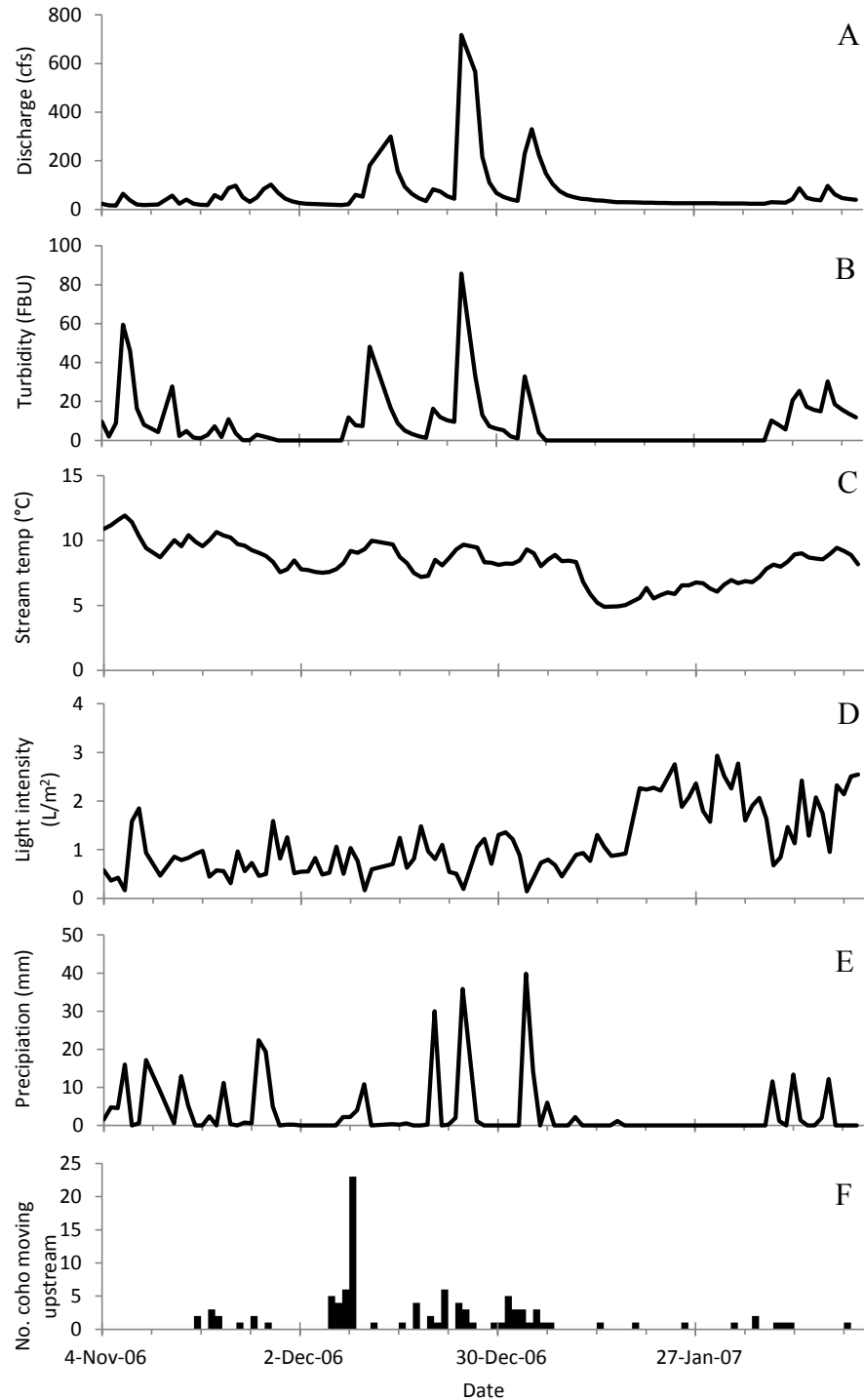


Figure 8. The top five panels of this vertically stacked time-series plot display (A) mean daily stream discharge (cfs), (B) mean daily turbidity (FBU), (C) mean daily stream temperature (°C), (D) mean daily light intensity (L/sf), and (E) cumulative daily precipitation (mm) measured at Prairie Creek study site, Humboldt County, California, 2006/2007. The bottom panel (F) displays daily counts of coho salmon captured at the Prairie Creek weir, Humboldt County, 2006/2007.

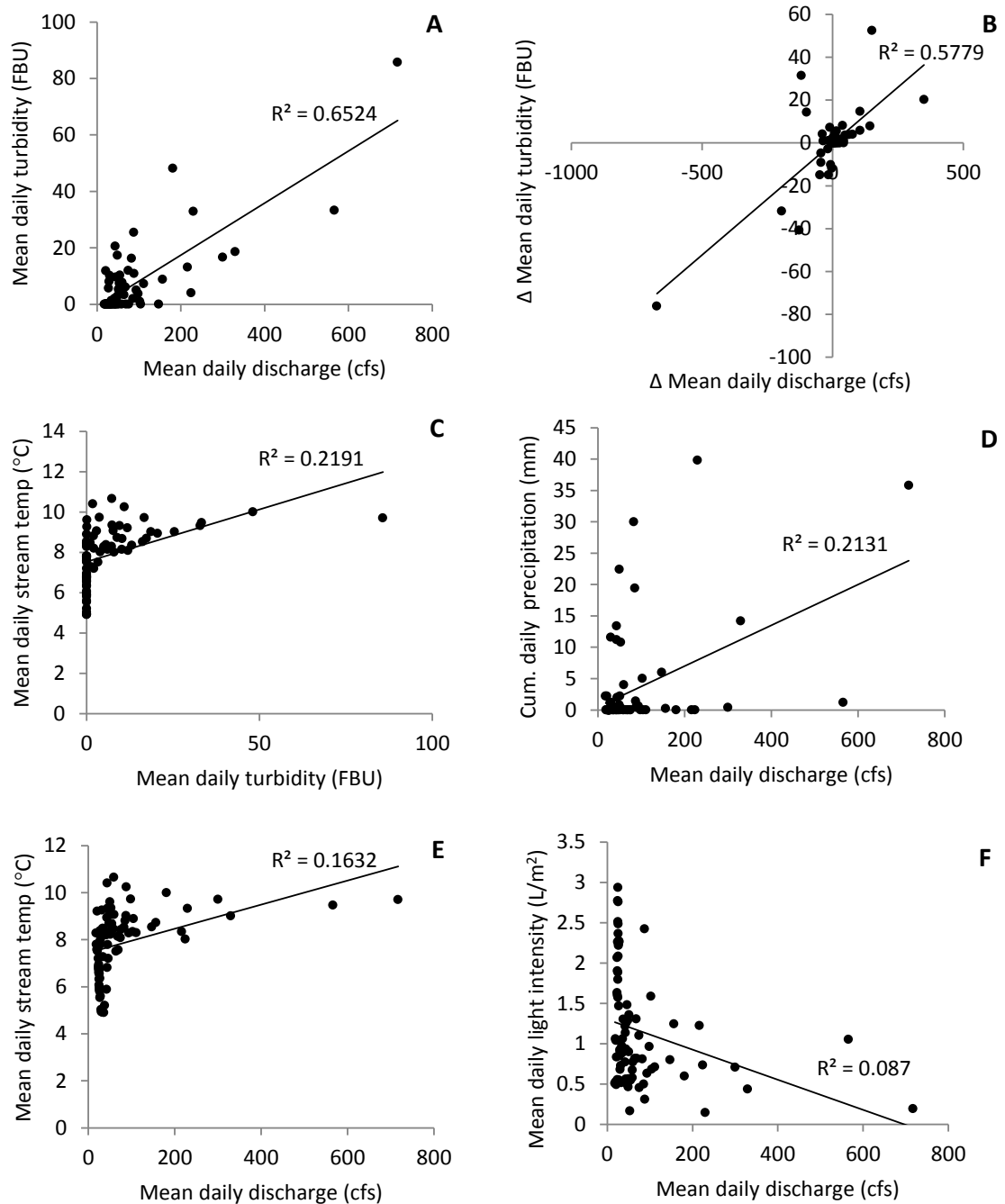


Figure 9. Correlation between (A) mean daily turbidity (FBU) vs. mean daily discharge (cfs), (B) daily change in mean daily turbidity (FBU) vs. daily change in mean daily discharge (cfs), (C) mean daily stream temperature ($^{\circ}\text{C}$) vs. mean daily turbidity (FBU), (D) cumulative daily precipitation (mm) vs. mean daily discharge (cfs), (E) mean daily stream temperature ($^{\circ}\text{C}$) vs. mean daily discharge (cfs), and (F) mean daily light intensity (L/sf) vs. mean daily discharge (cfs) measured at the Prairie Creek study area, Humboldt County, California, November 20, 2006 to February 12, 2007.

Table 11. Results of fitting generalized additive models of environmental cues to describe the probability of the movement of coho salmon past Prairie Creek weir, Humboldt County, California, 2006/2007. The models have been ranked according to model selection criteria, with top models exhibiting high adjusted R-squared values, low AIC values, and low GCV scores. Notation: Q = mean daily discharge, T = mean daily turbidity, and S = mean daily stream temperature.

Rank	Variables	R-Sq (adj)	AIC	Δ AIC	GCV
1	Q + T + S	0.356	292.7	0.0	0.776
2	Q + S	0.358	294.0	1.3	0.788
3	Q + T	0.273	296.0	3.3	0.807
4	T + S	0.325	297.5	4.8	0.822
5	S	0.330	300.1	7.4	0.848
6	Q	0.225	302.7	10.0	0.876
7	T	0.064	310.5	17.8	0.963

although it was significant in all other models. Figure 10 illustrates the effects of these explanatory variables on the probability of movement of coho salmon past the weir. The probability of movement increased with discharge up to approximately 320 cfs but appeared to decline with higher discharge events (Figure 10A). The probability of movement increased with increasing turbidity over the entire range of measured turbidities (Figure 10B). The probability of movement was low when stream temperatures were below 7.5 C°, but increased with increasing stream temperature from 7.5 to 9.5 C° (Figure 10C).

Due to the strong correlation between discharge and turbidity, there was a complex relationship between probability of movement, discharge, and turbidity (Figure 11). As turbidity increased, discharge had a heightened effect on the probability of movement. This illustrates the combined effect of the two environmental variables, and indicates that turbidity and discharge have a positive interaction.

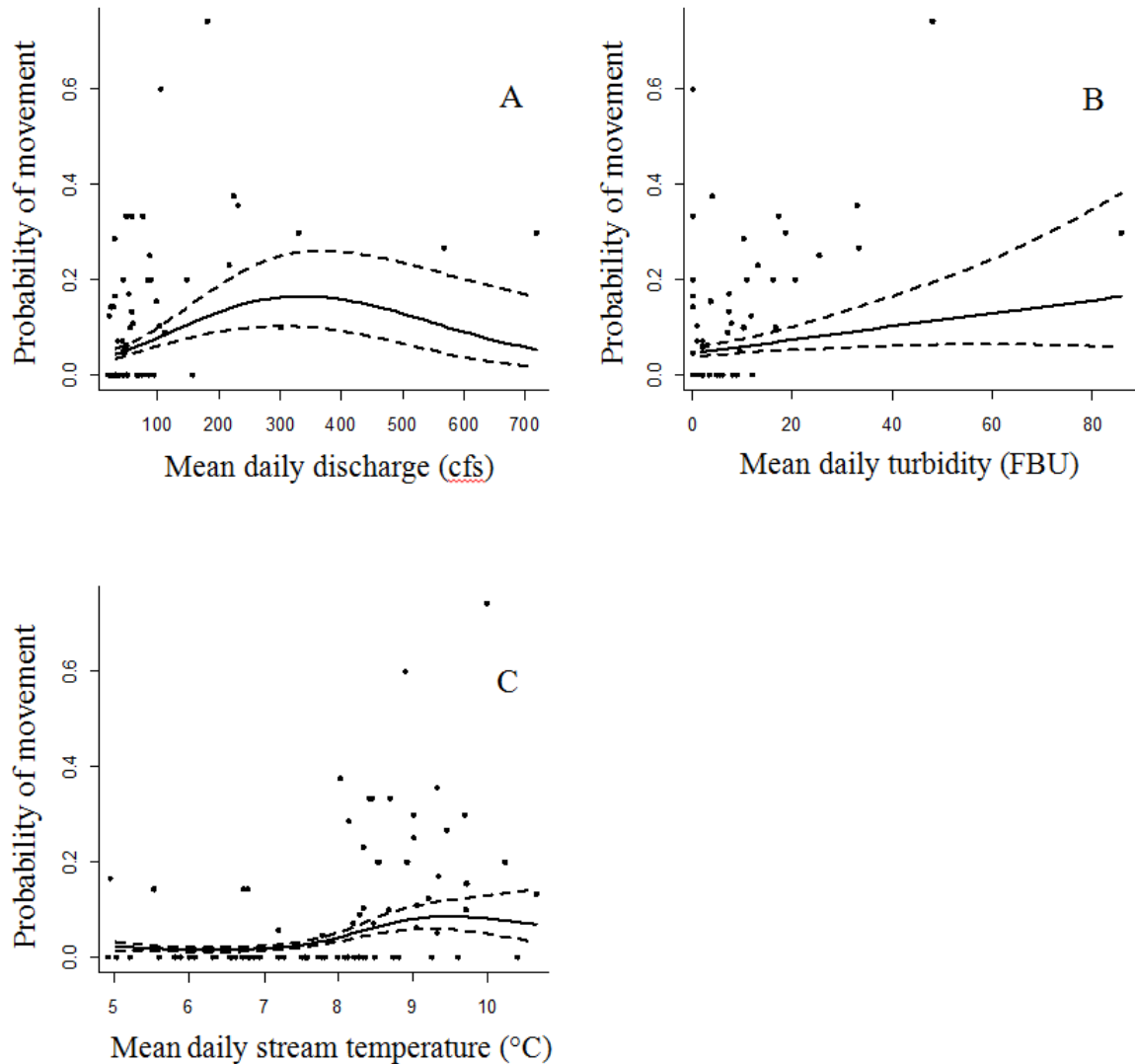


Figure 10. Illustrative relationships (derived from generalized additive models) between the probability of movement of coho salmon upstream past the Prairie Creek weir and (A) mean daily discharge, (B) mean daily turbidity, and (C) mean daily stream temperature measured at the Prairie Creek study site, Humboldt County, California, 2006/2007. For each panel, the fitted line was calculated over the range of the indicated variable by using the median values for the other two variables and was weighted by the standard error of the probability of movement estimates. The solid line is the fitted line and the dashed lines are upper and lower standard errors. The dots are the observed mean daily measurements of the variable fit in each panel.

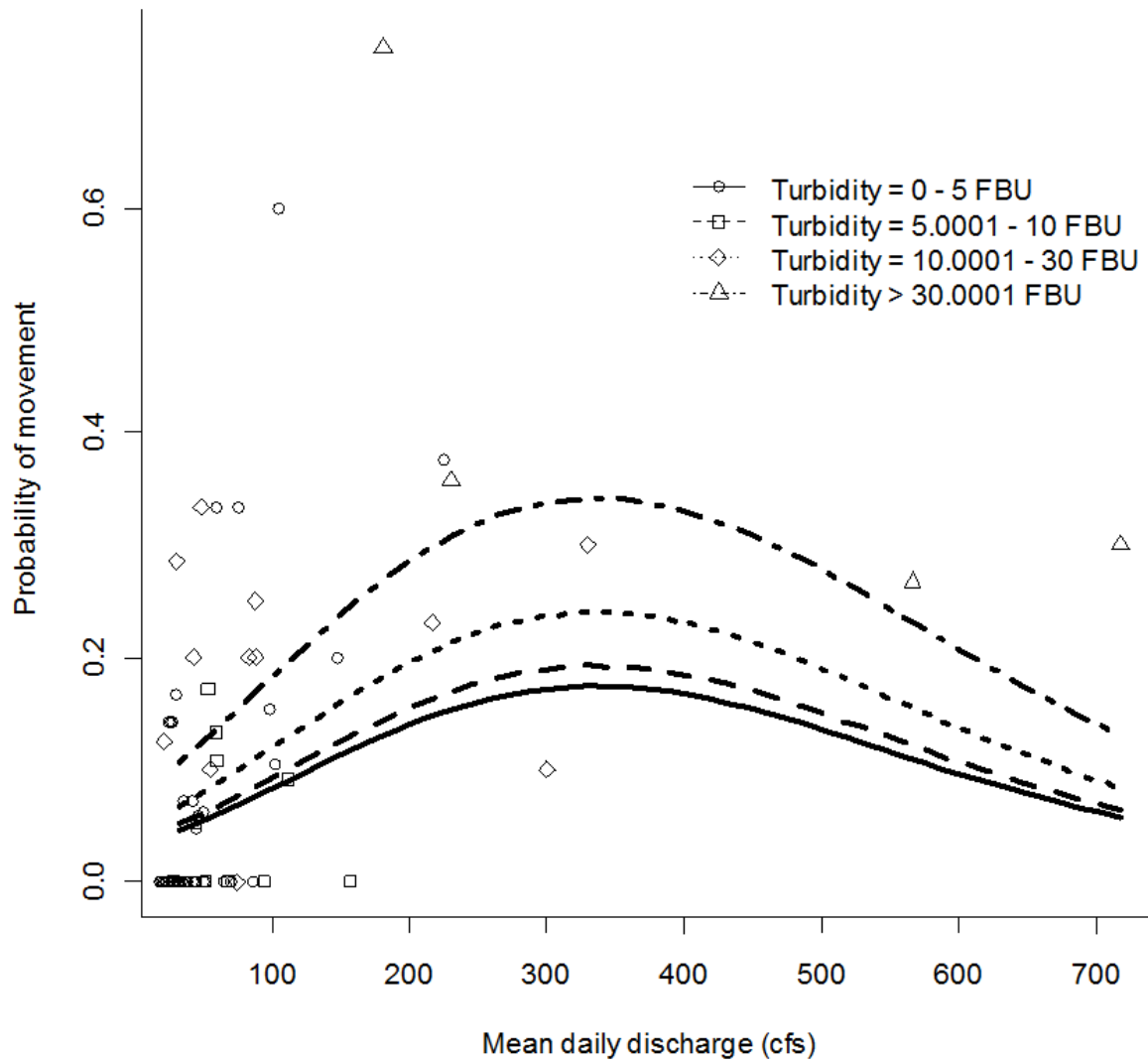


Figure 11. Illustrative relationship (derived from generalized additive models) between the probability of movement of coho salmon upstream past the Prairie Creek weir, mean daily discharge, and mean daily turbidity measured at the Prairie Creek study site, Humboldt County, California, 2006/2007. For this graph, the fitted lines were calculated over the range of discharge for four incremental ranges of observed mean daily turbidity [0-5 FBU (solid line), 5.0001-10 FBU (dashed line), 10.0001-30 FBU (dotted line), and >30.0001 FBU (dotted-dashed line)], using the median observed value for daily mean stream temperature, and weighted by the standard errors of the probability of movement estimates. The plotted points are the observed mean daily discharge data divided into four incremental ranges by associated observed mean daily turbidity data [0-5 FBU (circle), 5.0001-10 FBU (square), 10.0001-30 FBU (diamond), and >30.0001 FBU (triangle)].

DISCUSSION

Time of Arrival

Morbey (2000) found that male Pacific salmon almost always arrived at the spawning grounds earlier on average than females. This was true in 90% of all years in an analysis that included 105 years of sex-specific arrival timing data from 7 streams in Alaska, British Columbia, Washington, and New Zealand. Given these findings, I expected male salmon to arrive earlier in the season than females, increasing males' chances to have multiple pairings and greater spawning success, but male and female salmon did not differ in arrival date. Perhaps this was due to the nearly equal sex ratio observed in Prairie Creek or its nearness to the ocean.

In 2006/2007, larger coho salmon arrived at the weir earlier than smaller ones. This result is consistent with the findings of previous studies (Stewart et al. 2002, Molyneaux and Folletti 2005). There are many hypotheses to support this trend: larger salmon may migrate faster and so arrive earlier due to swimming ability. They may have less to gain by remaining at sea to feed. Or they may have different reproductive strategies than smaller salmon (i.e. prior residency to guard mating territory as compared to sneaker behavior, Quinn 2005). Smaller sample size and low sampling efficiency at high stream discharge may have hindered my ability to detect relationships between body size and time of arrival of Chinook salmon in 2006/2007 and of both species in 2005/2006.

Movement Analysis

While genetic inheritance controls adult salmon migration timing at the broadest evolutionarily scale (Gharrett and Smoker 1993, Quinn and Adams 1996, Dahl et al. 2004), in-river environmental conditions also affect the timing of a salmon's upstream movement. An understanding of the influence of environmental cues on the timing of a salmon's upstream migration can be used for in-season management of fisheries (Keefer et al. 2011). My hypothesis that the strongest in-river environmental factors stimulating upstream migration would be increased discharge, stream temperature, and turbidity was validated by my study's findings.

These findings are well corroborated by the literature. Increased discharge and its descending limb are commonly cited as the dominant environmental stimulus to upstream movement of salmonids (Banks 1969, Alabaster 1970, Jensen et al. 1986, Jonsson 1991, Trepanier et al. 1996, Keefer et al. 2011). Change in stream temperature is another environmental cue used by salmon (Quinn and Adams 1996). Temperature change has also been correlated with the return migration of salmon (Jensen et al. 1986, Dahl et al. 2004, Keefer et al. 2011). Increased discharge and corresponding changes in stream temperatures occur seasonally with fall and winter storms, and salmon may have evolved to sense and react to these cues based upon the success of spawning migrations. Turbidity has been linked to downstream migration of juvenile salmonids as a predator-avoidance strategy (Gregory and Levings 1998). The same reasoning may apply to adults migrating upstream.

The difficulty in testing the significance of these cues on movement probability is their inter-relatedness (Figure 9). The results of the generalized additive model analysis

allow us to interpret the environmental variables'' solitary and combined effects on the daily probability of movement in Prairie Creek (Figures 10, 11).

Precipitation and light intensity were dropped from analysis due to their weak and insignificant effects, and also because of their lack of biological value as predictor variables. Precipitation is linked to discharge, and so was redundant in the model. The resolution of mean daily light intensity was not valid for this analysis. The variation in light intensity throughout the day was not accounted for in a single mean daily value, and this resolution was not useful in predicting whether or not a fish would move upstream.

In modeling the pool of coho salmon available for upstream movement (Figure 7), I assumed that arrival of coho salmon to the staging area was similar to the arrival of coho salmon captured at the weir. Since the weir was not efficient in capturing fish at all flows, the arrival distribution of captured coho salmon may have been different from the true arrival distribution of coho salmon to that site. I also assumed that each salmon was independent and made an independent decision regarding upstream movement. This model did not take into consideration the schooling behavior salmon may exhibit during migration.

Escapement Methods

While Sykes and Botsford (1986) and Boydstun (1994) found the Jolly-Seber carcass mark-recapture method reliable in Bogus Creek, a productive tributary to the Klamath River, it may not be effective in small coastal streams like Prairie Creek (Gallager et al. 2010, Gough 2010). The Jolly-Seber carcass mark-recapture estimator under-estimated the number of salmon returning to the Prairie Creek study area. This

was probably due to small sample size, the high removal rate of carcasses from the survey area by flashy flows and predators, and the high recapture probabilities of marked carcasses that did remain in survey area. Surveyors had low initial recovery rates of carcasses, but high recapture rates of sedentary carcasses (such as those submerged in deep pools or dragged out of water onto the bank by scavengers).

Methods using weirs and associated live mark-recapture estimates are generally regarded as the most accurate and precise estimates of escapement (Cousens et al. 1982, Shardlow et al. 1986, Schwarz et al. 1993, Miyakoshi and Kudo 1999). However, accuracy of mark-recapture estimates depends on the proportion of the population that is marked and the proportion of those marked individuals that are recovered. Increasing recapture rate of tagged individuals improves the precision of mark-recapture results (Robson and Regier 1964). For instance, with a population size of 100 individuals, Robson and Regier (1964) recommended capturing and marking 90% of the population at the weir and sampling 35% of the population as carcasses on the spawning grounds to have an accuracy of $\pm 10\%$ (Boydston and McDonald 2005). This is a tagged carcass recapture rate of 31.5%.

In 2005/2006 rates of recapture of tagged individuals were one tagged carcass per eight sampled carcasses (12.5%) for Chinook salmon, and two tagged carcasses per 27 sampled carcasses (7.4%) for coho salmon. In 2006/2007 these rates were much higher at five tagged carcasses per 24 sampled carcasses (20.8%) for Chinook salmon, and 26 tagged carcasses per 62 sampled carcasses (41.9%) for coho salmon. Therefore these estimates of coho escapement should be more accurate than those from the previous year. In order to improve live mark-carcass recapture estimates, weirs must be successfully

operated at higher flows so that greater proportions of the populations are marked, or stream surveys must be frequent enough to sample carcasses before they are removed from the survey area.

The accuracy of AUC is also improved by increasing the frequency of stream surveys (Hill 1997, Bue et al. 1998), as well as by using accurate estimates of residence time and observer efficiency (Shardlow et al. 1987, English et al. 1992, Irvine et al. 1992, Jones et al. 1998, Shardlow 2004). If surveys are performed frequently the opportunity to observe salmon building redds increases. When salmon are observed on redds, those redds can be identified to species, improving the accuracy of redd count expansions. When comparing the 2005/2006 data with the 2006/2007 data, it is apparent that with less frequent surveys in the first year due to a month of continuous rain storms late-December through January, more redds were classified as being built by an unknown species.

I improved the accuracy of AUC escapement estimates by calculating stream-specific estimates of residence time for Chinook and coho salmon in Prairie Creek. It is common practice to „borrow“ values from the literature for residence time and observer efficiency when calculating AUC estimates of escapement. However, results are improved when these values are specifically estimated for the population in question. The Chinook salmon residence time estimated in this study was similar to those found in other studies (Table 12). Residence time estimates of coho salmon in the Pacific Northwest show much greater variation and range from 9 days (Washington, van den Berge and Gross 1986) to 26 days (California, Gallagher et al. 2010, Table 12). The estimate of coho salmon residence time in Prairie Creek was in between these values. The large variation in coho salmon residence times indicates that using a value

Table 12. Average residence times (rt) for coho and Chinook salmon found in the literature.

Source	Watershed	Species	Type of rt	rt
van den Berge and Gross (1986)	Dear Creek, WA	Coho	Stream life	9 days
Moring and Lantz (1975)	Alsea watershed, OR	Coho	Stream life	Mostly females: 10.8 days
Willis (1954)	Spring Crk, OR	Coho	Stream life	Females: 11 days Males: 12 days
Gallagher et al. (2010)	Coastal streams, Mendocino County, CA	Coho	Residence time	26 days
Perrin and Irvine (1990)	Review of 52 references	Coho Chinook	Survey life Survey life	11.4 days 12.1 days
Hill and Irvine (2001)	Nechako Rv, BC	Chinook	Redd residence time	11.2 d (avg 1980,1988-1998)
Neilson and Geen (1981)	Morice Rv, BC	Chinook	Redd residence time	Females: early arr. 13.1 d; late arr. 7.7 d

calculated in another region may add significant error to escapement estimates.

Observer efficiency was not estimated in this study. A value of 76% efficiency was used to expand the observed number of live fish on surveys to an estimate of the actual number of fish present, based upon an estimate of observer efficiency in Oregon coastal streams (Solazzi 1984). Research began in 2007 to estimate observer efficiency of adult salmonids by stream surveyors on Prairie Creek. Preliminary analysis indicates much lower observer efficiency of adult salmonids in Prairie Creek than reported by Solazzi (1984, Poxon 2011, personal communication).

Estimates of observer efficiency for redd observation on stream surveys have not been reported in the literature. We ran three double-blind surveys during the two seasons of this study and the teams of observers had strikingly different observations. Research has suggested that false positives and omissions made by surveyors are often canceled out, resulting in generally correct survey counts (McGrath and Thurow 2007).

Another source of error in escapement expansion from redd counts is the assumption that each female salmon digs only one redd. Briggs (1953) found that at least half of the spent female coho salmon on Prairie Creek dug post-spawning redds, in areas well-separated from the place of egg deposition. In 2005/2006, one of the nine female coho salmon radio-tagged at the weir built two redds (Sparkman 2010, personal communication). In 2006/2007, none of the nine female radio-tagged coho salmon built more than one redd. More importantly, females may dig several test redds which do not contain eggs but can be mistakenly counted as true redds by observers. This behavior was observed in 27% of radio-tagged female coho salmon in Prairie Creek in 2007/2008. Both scenarios result in over-estimation of escapement when using the redd count

expansion method. Redd counts under-estimate escapement when scouring, bedload movement, poor visibility, or superimposition render them unobservable to surveyors.

I recommend continuing historic stream surveys and using the AUC estimation method for future Prairie Creek adult Chinook and coho salmon escapement estimates. Stream surveys are cost effective and less invasive than a weir. The weir has provided a platform for research opportunities: stream-specific estimates of survey residence time and observation efficiency for Prairie Creek that will increase the accuracy of future AUC estimation. In future studies, measurements of uncertainty could be applied to AUC estimates in the form of a maximum likelihood model (Hilborn et al. 1999) or bootstrap sampling of replicate survey data (Parken et al. 2003) if the survey data is structured appropriately. Recording redd counts along with live fish counts during future stream surveys will add to the historic data set that has been collected on Prairie Creek since 1998.

LITERATURE CITED

- Alabaster, J. S. 1970. River flow and upstream movement and catch of migratory salmonids. *Journal of Fish Biology* 2: 1-13.
- Al-Chokhachy, R., P. Budy, and H. Schaller. 2005. Understanding the significance of redd counts: a comparison between two methods for estimating the abundance of and monitoring bull trout populations. *North American Journal of Fisheries Management* 25: 1505-1512.
- Banks, J. W. 1969. A review of the literature on the upstream migration of adult salmonids. *Journal of Fish Biology* 1: 85-136.
- Beland, K. F. 1996. The relation between redd counts and Atlantic salmon (*Salmo salar*) parr populations in the Dennys River, Maine. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 513-519.
- Botkin, D. B., D. L. Peterson, and J. M. Calhoun. 2000. The scientific basis for validation monitoring of salmon for conservation and restoration plans. Olympic Natural Resources Technical Report. University of Washington and Olympic Natural Resources Center, Forks, Washington.
- Boydston, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall Chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. *California Fish and Game* 80: 1-13.
- Boydston, L. and T. McDonald. 2005. Action plan for monitoring California's coastal anadromous salmonids: a joint planning effort of the California Department of Fish and Game and NOAA Fisheries. Unpublished report available from National Oceanographic and Atmospheric Administration Fisheries, Southwest Fisheries Science Center, Santa Cruz, California.
- Brakensiek, K. E. 2002. Abundance and survival rates of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, Redwood National Park. Master's thesis. Department of Fisheries, Humboldt State University, Arcata, California.
- Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. *California Fish and Game, Fish Bulletin* 94, Stanford University, California.
- Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. *North American Journal of Fisheries Management* 14: 237-261.
- Bue, B. G., S. M. Fried, S. Sharr, D. G. Sharp, J. A. Wilcock, and H. J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: the Prince William Sound pink salmon example. *North Pacific Anadromous Fish Commission Bulletin* No. 1: 240-250.

- California Cooperative Fish and Wildlife Research Unit. 2011. Population estimates of juvenile and adult salmonids in Prairie Creek, California: 10-year report. Unpublished report. California Cooperative Fish and Wildlife Research Unit, Arcata, California.
- Cederholm, C. J., D. B. Houston, D. L. Cole, and W. J. Scarlett. 1989. Fate of coho salmon (*Oncorhynchus kisutch*) carcasses in spawning streams. *Canadian Journal of Aquatic and Fisheries Science* 46: 1347-1355.
- Cousens, N. B. F., G. A. Thomas, C. G. Swann, and M. C. Healey. 1982. A review of salmon escapement estimation techniques, Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1108, Nanaimo, British Columbia.
- Dahl, J., J. Dannewitz, L. Karlsson, E. Petersson, A. Löf, and B. Ragnarsson. 2004. The timing of spawning migration: implications of environmental variation, life history, and sex. *Canadian Journal of Zoology* 82: 1864-1870.
- Davidson, F. A., E. Vaughan, and S. J. Hutchinson. 1943. Factors influencing the upstream migration of the pink salmon (*Oncorhynchus gorbuscha*). *Ecology* 24: 149-168.
- Duffy, W. D. and E. P. Bjorkstedt. 2008. Demographics of coastal cutthroat trout *Oncorhynchus clarkii clarkii* in Prairie Creek, California. Pages 100-106 in P. J. Connolly, T. H. Williams, and R. E. Gresswell, editors. The 2005 coastal cutthroat trout symposium: status, management, biology, and conservation. Oregon Chapter, American Fisheries Society, Portland, Oregon.
- Duffy, W. D., E. P. Bjorkstedt, and C. S. Ellings. In press. Predation on juvenile Pacific salmon *Oncorhynchus* spp. in downstream migrant traps in Prairie Creek, California. *North American Journal of Fisheries Management*.
- Dunham, J., B. Rieman, and K. Davis. 2001. Sources and magnitude of sampling error in redd counts for bull trout. *North American Journal of Fisheries Management* 21: 343-352.
- Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2003. United States Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-AFSC-163, Seattle, Washington.
- English, K. K., R. C. Bocking, and J. R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 1982-1989.
- Feola, J. E. 2007. Environmental variables influencing downstream migration of juvenile coho salmon (*Oncorhynchus kisutch*) in three Northern California streams. Master's thesis. Department of Fisheries, Humboldt State University, Arcata, California.

- Gallagher, S. P., P. B. Adams, D. W. Wright, and B. W. Collins. 2010. Performance of spawner survey techniques at low abundance levels. *North American Journal of Fisheries Management* 30: 1086-1097.
- Gallagher, S. P. and C. M. Gallagher. 2005. Discrimination of Chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in Northern California. *North American Journal of Fisheries Management* 25: 284-300.
- Gharrett, A. J. and W. W. Smoker. 1993. Genetic components in life history traits contribute to population structure. Pages 197–202 in J. G. Cloud, editor. *Genetic conservation of salmonids*. Plenum Publishing Company, New York, New York.
- Gough, S. 2010. A comparison of escapement estimate methods plus escapement-recruitment relationships for Chinook salmon and coho salmon in a coastal stream. Master of Science Thesis. Department of Fisheries, Humboldt State University, Arcata, California.
- Gregory, R. S. and C. D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. *Transactions of the American Fisheries Society* 127: 275-285.
- Hendry, A. P., O. K. Berg, and T. P. Quinn. 1999. Condition dependence and adaptation-by-time: breeding date, life history, and energy allocation within a population of salmon. *Oikos* 85: 499-514.
- Hilborn, R., B. G. Bue, and S. Sharr. 1999. Estimating spawning escapements from periodic counts: a comparison of methods. *Canadian Journal of Fisheries and Aquatic Sciences* 56: 888-896.
- Hill, R. A. 1997. Optimizing aerial count frequency for the area-under-the-curve method of estimating escapement. *North American Journal of Fisheries Management* 17: 461-466.
- Hill, R. A. and J. R. Irvine. 2001. Standardizing spawner escapement data: a case study of the Nechako River Chinook salmon. *North American Journal of Fisheries Management* 21: 651-655.
- Hunter, J. G. 1959. Survival and production of pink and chum salmon in a coastal stream. *Journal of Fisheries Research Board of Canada* 16: 835-886.
- Huntsman, A. G. 1948. Freshets and fish. *Transactions of the American Fisheries Society* 75: 257-266.
- Irvine, J. R., R. C. Bocking, K. K. English, and M. Labelle. 1992. Estimating coho salmon (*Oncorhynchus kisutch*) spawning escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 1972-1981.
- Irvine, J. R., J. F. T. Morris, and L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1932, Nanaimo, British Columbia.

- Jensen, A. J., T. G. Heggberget, and B. O. Johnsen. 1986. Upstream migration of adult Atlantic salmon, *Salmo salar* L., in the River Vefsna, northern Norway. *Journal of Fish Biology* 29: 459-465.
- Jones, E. L. III, T. J. Quinn II, and B. W. Van Alen. 1998. Observer accuracy and precision in aerial and foot counts of pink salmon in a southeast Alaska stream. *North American Journal of Fisheries Management* 18: 832-846.
- Jonsson, N. 1991. Influence of water flow, water temperature and light on fish migrations in rivers. *Nordic Journal of Freshwater Research* 66: 20-35.
- Keefer, M. L., C. A. Peery, and C. C. Caudhill. 2011. Migration timing of Columbia River Spring Chinook salmon: effects of temperature, river discharge, and ocean environment. *Transactions of the American Fisheries Society* 137: 1120-1133.
- Korman, J., R. N. M. Ahrens, P. S. Higgins, and C. J. Walters. 2002. Effects of observer efficiency, arrival timing, and survey life on estimates of escapement for steelhead trout (*Oncorhynchus mykiss*) derived from repeat mark-recapture experiments. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1116-1131.
- Korman, J. and P. S. Higgins. 1997. Utility of escapement time series data for monitoring the response of salmon populations to habitat alteration. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 2058-2067.
- Ludwig, D. and C. J. Walters. 1981. Measurement errors and uncertainty in parameter estimates for stock and recruitment. *Canadian Journal of Fisheries and Aquatic Sciences* 38: 711-720.
- Maselko, J. M., A. C. Wertheimer, and J. F. Thedinga. 2003. Selection and application of a mark-recapture technique for estimating pink salmon escapements. United States Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-AFSC-137, Seattle, Washington.
- McGrath, C. and R. Thurow. 2007. Bias and precision of Chinook salmon redd counts. Presentation at 2007 American Fisheries Society Annual Meeting, San Francisco, California. September 5, 2007.
- Miyakoshi, Y. and S. Kudo. 1999. Mark-recapture estimation of escapement of masu salmon *Oncorhynchus masou* with a comparison to a fence count. *North American Journal of Fisheries Management* 19: 1108-1111.
- Miyakoshi, Y., T. Takami, K. Takeuchi, H. Omori, M. Nagata, and J. R. Irvine. 2003. Sampling of masu salmon, *Oncorhynchus masou*, spawners on the spawning grounds: is carcass sampling effective as a mark-recovery method? *Fisheries Management and Ecology* 10: 273-275.
- Molyneaux, D.B. and D.L. Folletti. 2005. Salmon age, sex, and length catalog for the Kuskokwim Area, 2004. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A05-03, Anchorage, Alaska.
- Morbey, Y. 2000. Protandry in Pacific salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 57: 1252-1257.

- Moring, J. R. and R. L. Lantz. 1975. The Alsea watershed study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Fisheries Research Report, Oregon Department of Fish and Wildlife 9, Corvallis, Oregon.
- Neave, F. 1943. Diurnal fluctuations in the upstream migration of coho and spring salmon. Journal of Fisheries Research Board of Canada 6: 158-163.
- Neilson, J. D. and G. H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. Transactions of the American Fisheries Society 110: 554-556.
- Parken, C. K., R. E. Bailey, and J. R. Irvine. 2003. Incorporating uncertainty into area-under-the-curve and peak salmon escapement estimation. North American Journal of Fisheries Management 23: 78-90.
- Perrin, C. J. and J. R. Irvine. 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of Pacific salmon. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1733, Nanaimo, British Columbia.
- Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle, Washington.
- Quinn T. P. and D. J. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. Ecology 77: 1151-1162.
- Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191, Nanaimo, British Columbia.
- Rieman, B. E. and D. L. Myers. 1997. Use of redd counts to detect trends in bull trout (*Salvelinus confluentus*) populations. Conservation Biology 11: 1015-1018.
- Robson, D.S. and H.A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93: 215-226.
- Schroeder, R. K. 1996. A review of capture techniques for adult anadromous salmonids. Oregon Department of Fish and Wildlife, Fish Division Information Report Number 96-5, Portland, Oregon.
- Schwarz, C. J., R. E. Bailey, J. R. Irvine, and F. C. Dalziel. 1993. Estimating salmon spawning escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50: 1181-1197.
- Schwarz, C. J. and C. G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55: 281-296.
- Shardlow, T. 2004. Using time-lapse video to estimate survey life for area-under-the-curve methods of escapement estimation. North American Journal of Fisheries Management 24: 1413-1420.

- Shardlow T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 44: 1031-1037.
- Shardlow, T. F., T. M. Webb, and D. T. Lightly. 1986. Chinook salmon escapement estimation on the Campbell and Quinsam Rivers in 1984: accuracy and precision of mark/recapture techniques using tagged salmon carcasses. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1507, Vancouver, British Columbia.
- Solazzi, M.F. 1984. Relationships between visual counts of coho, Chinook, and chum salmon from spawning fish surveys and the actual number of fish present. Information Reports Number 84-7. Oregon Department of Fish and Wildlife, Research and Development Section, Corvallis, Oregon.
- 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. Master of Science Thesis. Department of Fisheries, Humboldt State University, Arcata, California.
- Stewart, D. C., G. W. Smith, and A. F. Youngson. 2002. Tributary-specific variation in timing of return of adult Atlantic salmon (*Salmo salar*) to fresh water has a genetic component. Canadian Journal of Fisheries and Aquatic Sciences 59: 276-281.
- Stewart, R. 2002. Resistance board weir panel construction manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A02-21, Anchorage, Alaska.
- Sykes, S. D. and L. W. Botsford. 1986. Chinook salmon, *Oncorhynchus tshawytscha*, spawning escapement based on multiple mark-recapture of carcasses. Fishery Bulletin 84(2): 261-270.
- Symons, P. E. K. and M. Waldichuk. 1984. Proceedings of the workshop on stream indexing for salmon escapement estimation. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1326, Vancouver, British Columbia.
- Tobin, J. H. 1994. Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers. United States Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report Number 22, Kenai, Alaska.
- Thorstad, E. B. and T. G. Heggberget. 1998. Migration of adult Atlantic salmon (*Salmo salar*); the effects of artificial freshets. Hydrobiologia 371/372: 339-346.
- Trepanier, S., M. A. Rodriguez, and P. Magnan. 1996. Spawning migrations in landlocked Atlantic salmon: time series modeling of river discharge and water temperature effects. Journal of Fish Biology 48: 925-936.
- United States Office of the Federal Register. 1997. Endangered and threatened species: threatened status for Southern Oregon/Northern California coast evolutionarily significant unit (ESU) of coho salmon. Federal Register 62: 24588-24609.

- United States Office of the Federal Register. 1999. Endangered and threatened species: threatened status for two Chinook salmon evolutionarily significant units (ESUs) in California; final rule. Federal Register 64: 50393-50415.
- van den Berghe, E. P. and M. R. Gross. 1986. Length of breeding life of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Zoology 64: 1482-1486.
- Walters, C. J. and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Canadian Journal of Fisheries and Aquatic Sciences 38: 704-710.
- White, G. C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 (Supplement): 120-138.
- Willis, R. A. 1954. The length of time that silver salmon spent before death on spawning grounds at Spring Creek, Wilson River in 1951-52. Fish Commission of Oregon Research Briefs 5, Clackamas, Oregon.
- Wood, S. N. 2006. Generalized additive models: an introduction with R. CRC Press, Boca Raton, Florida.

PERSONAL COMMUNICATIONS

- Poxon, B. 2011. Assistant Project Leader, Fifteenmile Creek Steelhead Production Study, Oregon Department of Fish and Wildlife, Mid Columbia District, 3701 W. 13th Street, The Dalles, Oregon 97058.
- Sparkman, M. 2010. Fish Biologist, Anadromous Fisheries Resource Assessment and Monitoring Program, California Department of Fish and Game, 50 Ericson Court, Arcata, California 95521.

APPENDICES

Appendix A. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, December 2005 to February 2006. Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
10-Dec-05	OT	F	110	U	N
11-Dec-05	OT	M	89	U	N
11-Dec-05	OK	M	60	U	PIT
17-Dec-05	OKE	F	63	1	PIT
19-Dec-05	OK	F	69	1	RT
19-Dec-05	OK	M	72	1	PIT
19-Dec-05	OK	F	59	1	RT
19-Dec-05	OK	M	64	1	PIT
19-Dec-05	OK	M	41	1	PIT
19-Dec-05	OK	F	70	1	RT
19-Dec-05	OK	M	70	1	PIT
19-Dec-05	OK	M	75	1	PIT
19-Dec-05	OK	F	70	1	RT
19-Dec-05	OK	F	62	1	RT
19-Dec-05	OK	M	59	1	PIT
19-Dec-05	OK	F	68	1	RT
20-Dec-05	OK	F	69	3	RT
20-Dec-05	OK	M	75	1	PIT
20-Dec-05	OK	F	65	1	RT
21-Dec-05	OK	M	65	1	PIT
21-Dec-05	OT	M	97	3	PIT
21-Dec-05	OK	F	65	1	PIT
21-Dec-05	OK	F	62	2	PIT
21-Dec-05	OK	M	63	1	PIT
21-Dec-05	OK	M	64	1	PIT
22-Dec-05	OK	M	71	1	PIT
22-Dec-05	OT	M	79	1	PIT
22-Dec-05	OK	M		2	PIT
22-Dec-05	OK	M	67	2	PIT
22-Dec-05	OT	M	63	1	PIT
22-Dec-05	OK	M	70	U	N
22-Dec-05	OK	F	64	1	RT
22-Dec-05	OK	F	64	1	RT
22-Dec-05	OK	F	68	1	RT
22-Dec-05	OK	F	68	1	RT
22-Dec-05	OK	F	70	1	RT
22-Dec-05	OK	M	72	1	PIT

Appendix A. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, December 2005 to February 2006 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
22-Dec-05	OK	M	71	1	PIT
22-Dec-05	OK	M	70	1	N
22-Dec-05	OK	M	75	1	PIT
23-Dec-05	OK	F	65	1	RT
23-Dec-05	OK	F	68	1	PIT
23-Dec-05	OK	M	70	2	N
23-Dec-05	OK	M	67	2	PIT
24-Dec-05	OK	M	61	1	PIT
24-Dec-05	OM	M	65	1	N
24-Dec-05	OT	F	86	3	PIT
25-Dec-05	OT	M	60	2	PIT
25-Dec-05	OK	M	68	1	PIT
25-Dec-05	OK	M	73	1	PIT
25-Dec-05	OT	M	81	2	PIT
26-Dec-05	OK	F	65	1	PIT and RT
27-Dec-05	OK	M	73	1	N
27-Dec-05	OT	M	90	2	PIT
27-Dec-05	OK	M	63	2	PIT
27-Dec-05	OK	M	72	1	PIT
6-Jan-06	OK	M	75	2	PIT
7-Jan-06	OK	F	67	1	PIT
14-Jan-06	OM	M		U	N
15-Jan-06	OK	M	26	2	PIT
16-Jan-06	OK	F	68	3	N
16-Jan-06	OK	M	45	U	PIT
17-Jan-06	OK	M	69	1	PIT
19-Jan-06	OM	F	77	1	N
22-Jan-06	OT	M	98	2	PIT
22-Jan-06	OK	M	45	3	N
23-Jan-06	OK	M	64	3	N
27-Jan-06	OK	F	69	2	PIT
28-Jan-06	OK	F	68.5	1	PIT
28-Jan-06	OM	M	66.5	1	N
28-Jan-06	OM	M	62	1	N
29-Jan-06	OM	M	47	1	N
29-Jan-06	OM	M	65	1	N
29-Jan-06	OM	M	61	1	N

Appendix A. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, December 2005 to February 2006 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
29-Jan-06	OM	M	52	1	N
29-Jan-06	OK	M	70	2	N
30-Jan-06	OM	F	77	1	N
30-Jan-06	OM	M	48.5	1	N
30-Jan-06	OK	F	67	1	PIT
31-Jan-06	OK	M	75	2	PIT
1-Feb-06	OM	M	60	1	N
2-Feb-06	OK	F	60	1	N
3-Feb-06	OM	F	84	U	N
4-Feb-06	OM	F	69	1	N

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007. Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
15-Nov-06	OKE	F	65.0	2	N
17-Nov-06	OT	F	79.0	1	RT
18-Nov-06	OT	F	95.0	1	PIT
19-Nov-06	OT	F	88.5	1	N
20-Nov-06	OK	F	60	2	N
20-Nov-06	OK	M	70	2	N
22-Nov-06	OK	M	62.0	1	PIT
22-Nov-06	OK	F	68.0	1	PIT
22-Nov-06	OK	M	72.0	1	PIT
23-Nov-06	OK	M	65.0	1	PIT
23-Nov-06	OK	M	63.5	1	PIT
26-Nov-06	OK	F	71.0	1	PIT
26-Nov-06	OT	M	50.0	1	PIT
26-Nov-06	OC	M	41.0	1	N
28-Nov-06	OK	M	80.0	1	PIT
28-Nov-06	OK	F	75.0	1	PIT
30-Nov-06	OK	F	74.0	2.5/3	N
9-Dec-06	OK	F	74.5	2	PIT
9-Dec-06	OK	M	60.0	2	PIT
9-Dec-06	OK	F	70.5	2	PIT
9-Dec-06	OK	M	70.0	2	PIT
9-Dec-06	OK	M	68.0	2	PIT
10-Dec-06	OK	M	59.5	1	PIT
10-Dec-06	OK	M	45.5	1	PIT
10-Dec-06	OK	M	76.0	3	PIT
10-Dec-06	OK	M	71.0	2	PIT
10-Dec-06	OT	M	48.5	2	PIT
10-Dec-06	OC	F	47.5	1	N
11-Dec-06	OK	M	75.5	2	PIT
11-Dec-06	OK	M	45.5	1	PIT
11-Dec-06	OC	F	40.0	1	N
11-Dec-06	OK	M	61.5	1	PIT
11-Dec-06	OK	M	66.0	1	PIT
11-Dec-06	OK	F	70.0	1	PIT
11-Dec-06	OK	F	68.5	2	PIT
12-Dec-06	OK	M	72.0	1	PIT
12-Dec-06	OK	F	68.0	1	PIT

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
12-Dec-06	OC	F	38.5	1	N
12-Dec-06	OK	F	71.5	1	PIT
12-Dec-06	OK	F	71.0	1	PIT
12-Dec-06	OT	M	43.0	1	PIT
12-Dec-06	OK	M	72.5	1	PIT
12-Dec-06	OK	F	64.5	1	PIT
12-Dec-06	OK	M	38.5	1	PIT
12-Dec-06	OK	M	70.0	1	PIT
12-Dec-06	OC	F	46.5	1	N
12-Dec-06	OK	M	82.0	1	PIT
12-Dec-06	OK	F	72.0	1	PIT
12-Dec-06	OK	M	66.0	1	PIT
12-Dec-06	OK	F	68.0	1	PIT
12-Dec-06	OK	M	75.0	1	PIT
12-Dec-06	OK	M	75.0	1	PIT
12-Dec-06	OT	M	70.0	1	RT
12-Dec-06	OK	F	70.0	1	RT
12-Dec-06	OK	F	66.0	1	PIT and RT
12-Dec-06	OK	F	69.0	1	PIT and RT
12-Dec-06	OK	F	66.0	1	PIT
12-Dec-06	OK	F	70.0	1	PIT
12-Dec-06	OK	M	42.0	1	PIT
12-Dec-06	OK	M	74.0	1	PIT
12-Dec-06	OK	F	67.0	1	PIT
12-Dec-06	OC	M	30.0	1	N
12-Dec-06	OK	F	67.0	1	PIT
15-Dec-06	OK	F	64.0	1	PIT
19-Dec-06	OK	M	40.0	2	PIT
21-Dec-06	OK	F	61.5	1	PIT
21-Dec-06	OK	M	75.0	2	PIT
21-Dec-06	OK	M	70.5	2	PIT
21-Dec-06	OK	M	61.5	2	PIT
23-Dec-06	OK	M	59.0	2	PIT
23-Dec-06	OT	M	91.0	3	N
23-Dec-06	OKE	F	60.0	2	N
23-Dec-06	OK	M	39.0		N
24-Dec-06	OK	M	39.0		N
24-Dec-06	OM	F	62.0	1	PIT

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
25-Dec-06	OK	F	65.5	1	RT
25-Dec-06	OK	F	61.0	1	RT
25-Dec-06	OK	M	76.5	2	PIT
25-Dec-06	OT	F	75.0	1	RT
25-Dec-06	OK	M	43.0	1	PIT
25-Dec-06	OK	M	66.0	2	PIT
25-Dec-06	OK	F	66.0	1	RT
27-Dec-06	OK	M	65.0	2	PIT
27-Dec-06	OK	M	42.0	1	PIT
27-Dec-06	OK	F	78.0	3	PIT
27-Dec-06	OK	M	41.0	2	PIT
28-Dec-06	OK	M	66.0	2	PIT
28-Dec-06	OK	F	56.5	2	PIT
28-Dec-06	OK	M	55.0	3	N
29-Dec-06	OK	M	69.0	3	N
31-Dec-06	OM	M	67.0	1	PIT
31-Dec-06	OT	M	73.5	3	N
1-Jan-07	OK	M	38.0	2	PIT
2-Jan-07	OK	M	44.0	2	N
3-Jan-07	OK	F	70.0	1	RT
3-Jan-07	OK	F	74.0	1	RT
3-Jan-07	OK	F	74.0	1	RT
3-Jan-07	OK	F	67.0	1	RT
3-Jan-07	OK	M	75.0	1	RT
4-Jan-07	OK	M	44.0	3	PIT
4-Jan-07	OK	M	65.5	2	PIT
4-Jan-07	OK	M	74.0	3	N
5-Jan-07	OK	F	65.0	1	RT
5-Jan-07	OK	M	44.5	1	PIT
5-Jan-07	OK	F	69.0	1	N
6-Jan-07	OK	M	44.0	3	N
6-Jan-07	OT	M	45.5	2	PIT
7-Jan-07	OK	M	76.5	2	PIT
7-Jan-07	OK	M	43.0	1	PIT
7-Jan-07	OK	M	72.0	2	PIT
7-Jan-07	OT	M	78.0	2	N
8-Jan-07	OK	M	61.0	2	PIT
9-Jan-07	OK	M	76.5	2	PIT

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
16-Jan-07	OK	M	74.0	3	PIT
21-Jan-07	OK	M	44.0	2	PIT
23-Jan-07	OM	F	71.5	3	N
28-Jan-07	OK	M	37.5	2	PIT
4-Feb-07	OK	M	68.5	2+	PIT
5-Feb-07	OM	M	69.0	2	N
7-Feb-07	OK	M	63.0	2	PIT
7-Feb-07	OK	F	69.0	2	PIT
8-Feb-07	OM	M	87.0	2	PIT
10-Feb-07	OK	F	70.0	2+	PIT
10-Feb-07	OM	M	69.5	2	PIT
11-Feb-07	OM	M	71.0	1	PIT
11-Feb-07	OK	M	66.0	2	PIT
12-Feb-07	OK	F	63.0	2,3	PIT
15-Feb-07	OM	M	67.5	2	PIT
15-Feb-07	OM	M	59.0	2	PIT
15-Feb-07	OM	F	73.0	2	PIT
15-Feb-07	OM	M	69.0	2	PIT
15-Feb-07	OM	F	63.0	1	PIT
15-Feb-07	OM	F	59.0	1	PIT
15-Feb-07	OM	M	69.0	1	PIT
15-Feb-07	OM	M	71.5	1	PIT
15-Feb-07	OM	M	60.0	1	PIT
15-Feb-07	OM	M	84.0	2	PIT
17-Feb-07	OM	F	65.5	1	PIT
17-Feb-07	OM	F	66.5	1	PIT
19-Feb-07	OM	M	45.0	1	PIT
20-Feb-07	OK	M	46.0	2,5	PIT
20-Feb-07	OM	F	69.0	1	PIT
20-Feb-07	OM	F	75.5	2	PIT
20-Feb-07	OM	M	71.0	2	PIT
20-Feb-07	OM	F	69.0	1	PIT
21-Feb-07	OM	M	60.0	2	PIT
21-Feb-07	OM	M	69.0	2	PIT
21-Feb-07	OM	M	61.0	1	PIT
21-Feb-07	OM	F	74.0	1	PIT
21-Feb-07	OM	M	66.0	1	PIT
21-Feb-07	OM	F	68.0	1	PIT

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
22-Feb-07	OM	M	57.0	1	PIT
22-Feb-07	OM	M	58.0	1	PIT
22-Feb-07	OM	F	65.0	1	PIT
22-Feb-07	OM	F	68.0	1	PIT
23-Feb-07	OM	M	74.0	2	PIT
23-Feb-07	OM	F	70.0	1	PIT
23-Feb-07	OM	F	69.5	1	PIT
23-Feb-07	OM	M	75.0	2	PIT
23-Feb-07	OM	F	68.5	1	PIT
23-Feb-07	OM	F	64.0	1	PIT
23-Feb-07	OM	F	61.0	1	PIT
23-Feb-07	OM	F	62.5	1	PIT
23-Feb-07	OM	F	55.0	1	PIT
23-Feb-07	OM	M	63.0	2	PIT
25-Feb-07	OM	F	70.0	1	PIT
25-Feb-07	OM	M	59.0	1	PIT
25-Feb-07	OM	F	74.5	1	PIT
25-Feb-07	OM	M	72.0	1.5	PIT
25-Feb-07	OM	F	71.0	1	PIT
25-Feb-07	OM	F	69.0	1	PIT
26-Feb-07	OM	M	46.0	1	PIT
26-Feb-07	OM	F	60.0	1	PIT
26-Feb-07	OC	M	28.5	1	N
26-Feb-07	OM	M	49.0	1	PIT
26-Feb-07	OM	M	73.0	2	PIT
27-Feb-07	OM	M	52.0	1	PIT
27-Feb-07	OM	M	57.0	2	PIT
27-Feb-07	OM	F	74.0	2	PIT
28-Feb-07	OM	F	67.0	1	PIT
2-Mar-07	OM	F	70.0	1	PIT
3-Mar-07	OM	F	63.0	1	PIT
3-Mar-07	OM	M	69.0	1	PIT
4-Mar-07	OM	M	51.0	2	PIT
4-Mar-07	OM	F	66.0	1	PIT
7-Mar-07	OM	M	63.0	2	PIT
7-Mar-07	OM	M	89.0	3	PIT
12-Mar-07	OM	F	80.0	2.5	PIT
20-Mar-07	OM	F	66.0	2	PIT

Appendix B. Chinook salmon, coho salmon, chum salmon, and steelhead captured at Prairie Creek weir, Humboldt County, California, November 2006 to March 2007 (continued). Species codes are: OT=Chinook salmon, OK=coho salmon, OKE=chum salmon, and OM=steelhead. Sex codes are: M=male, F=female. Condition codes are: 1=fresh, 2=dark and milt or eggs being released, 3=spawned out, and U=not recorded. Fish lengths are measured in fork lengths (cm). Tag codes are: PIT=PIT tag, RT=radio-transmitter tag, and N=not tagged.

Date	Species	Sex	FL (cm)	Condition	Tag
20-Mar-07	OM	M	67.0	2	PIT
27-Mar-07	OM	F	69.0	1	PIT

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006. Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
18-Nov-05	1	175	OC	U	20
18-Nov-05	1	440	OC	U	25
18-Nov-05	1	440	OC	U	25
18-Nov-05	1	440	OC	U	25
18-Nov-05	1	480	OC	U	25
18-Nov-05	1	860	OC	U	25
18-Nov-05	1	3100	OT	F	55
18-Nov-05	1	3325	OC	U	20
18-Nov-05	1	3630	U	U	65
18-Nov-05	1	3630	U	U	45
18-Nov-05	1	3630	U	U	30
18-Nov-05	1	3750	OC	U	35
18-Nov-05	1	3750	OC	U	35
18-Nov-05	1	3750	OC	U	25
19-Nov-05	2	5080	U	U	35
30-Nov-05	1	2470	U	U	50
30-Nov-05	1	4020	OT	U	70
30-Nov-05	1	4175	OK	M	50
30-Nov-05	1	4175	OK	U	50
30-Nov-05	1	4175	U	U	25
5-Dec-05	2	4780	OC	U	20
5-Dec-05	2	5325	OK	M	60
5-Dec-05	2	5325	OK	F	60
5-Dec-05	2	5700	OT	U	80
5-Dec-05	2	5700	OT	F	60
5-Dec-05	2	5775	OK	M	45
5-Dec-05	2	5775	OT	M	90
5-Dec-05	2	5775	OK	F	50
5-Dec-05	2	5775	U	J	30
5-Dec-05	2	6250	U	U	65
5-Dec-05	2	6275	OK	M	65
5-Dec-05	2	6275	OK	F	60
5-Dec-05	2	6300	OK	M	65
5-Dec-05	2	6300	OK	F	50

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
5-Dec-05	2	6475	OM	U	30
5-Dec-05	2	6725	OK	M	65
5-Dec-05	2	6775	OK	F	50
5-Dec-05	2	6775	OT	F	75
5-Dec-05	2	7175	U	U	45
8-Dec-05	3	8190	U	F	60
8-Dec-05	3	8275	U	U	70
8-Dec-05	3	8275	U	U	50
8-Dec-05	3	8650	OKE	F	65
8-Dec-05	3	8655	U	F	70
8-Dec-05	3	9040	U	U	55
8-Dec-05	3	9060	OT	U	80
8-Dec-05	3	9475	OK	M	55
8-Dec-05	3	9715	OK	M	55
9-Dec-05	4	11220	OK	F	55
9-Dec-05	4	11760	OK	F	55
9-Dec-05	4	12760	OK	M	80
9-Dec-05	4	12790	OK	F	50
9-Dec-05	4	12790	OK	M	75
10-Dec-05	1	350	OT	F	100
10-Dec-05	1	1000	U	U	55
10-Dec-05	1	1175	OT	F	65
10-Dec-05	1	1190	OT	M	80
10-Dec-05	1	1190	OT	M	30
10-Dec-05	1	1190	OT	M	30
10-Dec-05	1	3100	OT	F	65
10-Dec-05	1	3100	OK	M	55
10-Dec-05	1	3100	U	U	60
10-Dec-05	1	3530	OK	F	50
10-Dec-05	1	3530	U	M	25
10-Dec-05	1	3560	OC	U	20
10-Dec-05	1	3770	OK	F	60
10-Dec-05	1	4040	OK	F	55
10-Dec-05	1	4040	OK	M	50
10-Dec-05	1	4065	OK	M	45

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
10-Dec-05	1	4065	OK	F	50
10-Dec-05	1	4065	OT	M	25
10-Dec-05	1	4065	OT	M	25
11-Dec-05	2	4810	OT	M	80
11-Dec-05	2	4810	OT	F	85
11-Dec-05	2	5175	OK	M	70
11-Dec-05	2	5175	OK	F	60
11-Dec-05	2	5500	OK	M	60
11-Dec-05	2	5600	OK	M	65
11-Dec-05	2	5660	OT	F	75
11-Dec-05	2	5715	OT	M	90
11-Dec-05	2	5715	U	F	65
11-Dec-05	2	5750	OK	F	55
11-Dec-05	2	5750	OT	F	85
11-Dec-05	2	5750	OK	F	55
11-Dec-05	2	5750	OT	F	90
11-Dec-05	2	5790	OT	F	75
11-Dec-05	2	5790	U	F	50
11-Dec-05	2	6225	OK	M	75
11-Dec-05	2	6225	OK	M	75
11-Dec-05	2	6225	U	U	65
11-Dec-05	2	6225	U	F	65
11-Dec-05	2	6225	U	F	65
11-Dec-05	2	6270	OK	M	70
11-Dec-05	2	6270	OK	F	70
11-Dec-05	2	6270	U	M	40
11-Dec-05	2	6585	U	U	35
11-Dec-05	2	6760	OT	F	75
11-Dec-05	2	6760	OT	M	60
11-Dec-05	2	7190	OK	M	70
11-Dec-05	2	7445	OT	F	70
13-Dec-05	3	8450	OM	U	50
13-Dec-05	3	8450	OK	M	55
13-Dec-05	3	8450	OK	M	65
13-Dec-05	3	8450	OK	M	70

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
13-Dec-05	3	8450	OK	F	60
13-Dec-05	3	8450	OK	F	60
13-Dec-05	3	8450	OT	M	80
13-Dec-05	3	8450	OT	F	75
13-Dec-05	3	8825	OT	M	20
13-Dec-05	3	9035	OK	F	50
13-Dec-05	3	9040	OT	M	60
13-Dec-05	3	9040	OT	F	60
13-Dec-05	3	9070	OT	M	70
13-Dec-05	3	9560	OK	M	60
13-Dec-05	3	9560	OK	M	50
13-Dec-05	3	9560	OK	F	50
13-Dec-05	3	9560	OT	M	75
13-Dec-05	3	9560	OT	M	65
13-Dec-05	3	9560	OT	F	50
13-Dec-05	3	9780	OK	M	55
13-Dec-05	3	9915	OT	F	
13-Dec-05	3	10645	OK	F	55
14-Dec-05	4	11760	OK	F	45
14-Dec-05	4	12565	OK	M	70
14-Dec-05	4	12785	OK	F	60
14-Dec-05	4	12840	OK	M	60
16-Dec-05	1	310	OT	M	85
16-Dec-05	1	505	OT	M	90
16-Dec-05	1	3540	OK	F	60
16-Dec-05	1	3540	OK	F	55
16-Dec-05	1	3540	OK	F	55
16-Dec-05	2	4210	OK	F	60
16-Dec-05	2	4770	OK	M	50
16-Dec-05	2	4815	OT	F	70
16-Dec-05	2	5350	OK	F	60
16-Dec-05	2	5600	OK	M	55
16-Dec-05	2	5600	OK	F	55
16-Dec-05	2	5695	OM	U	35
16-Dec-05	2	5755	OK	M	65

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
16-Dec-05	2	5755	OK	F	55
16-Dec-05	2	5755	OT	F	80
16-Dec-05	2	5755	OT	M	85
16-Dec-05	2	5755	OT	M	45
16-Dec-05	2	5780	OT	F	70
16-Dec-05	2	6225	OK	M	50
16-Dec-05	2	6225	OK	M	65
16-Dec-05	2	6225	OK	F	70
16-Dec-05	2	6225	OK	M	65
16-Dec-05	2	6270	OK	M	55
16-Dec-05	2	6270	OK	F	60
17-Dec-05	3	8425	OT	M	40
17-Dec-05	3	8425	OT	M	30
17-Dec-05	3	8445	OK	M	65
17-Dec-05	3	8445	OK	F	60
17-Dec-05	3	8445	OT	F	70
17-Dec-05	3	8445	OK	M	60
17-Dec-05	3	8445	OK	F	60
17-Dec-05	3	8445	OT	M	70
17-Dec-05	3	8445	OT	F	80
17-Dec-05	3	8445	OT	F	65
17-Dec-05	3	8755	OK	F	55
17-Dec-05	3	8970	OT	M	60
17-Dec-05	3	9040	OT	F	65
17-Dec-05	3	9230	OK	M	60
17-Dec-05	3	9260	U	M	25
17-Dec-05	3	9260	U	M	40
17-Dec-05	3	9560	OK	M	55
17-Dec-05	3	9560	OK	M	50
17-Dec-05	3	9560	OK	M	60
17-Dec-05	3	9560	OT	M	30
17-Dec-05	3	9560	OT	M	30
17-Dec-05	3	9560	OT	M	25
17-Dec-05	3	9740	OT	M	35
17-Dec-05	3	10650	OK	F	55

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
9-Jan-06	4	11110	OK	M	60
9-Jan-06	4	11110	OK	M	55
9-Jan-06	4	11110	OK	M	45
9-Jan-06	4	11110	OK	F	55
22-Jan-06	3	8220	OK	F	50
22-Jan-06	3	8430	OK	M	50
22-Jan-06	3	8430	OK	M	55
22-Jan-06	3	9640	OK	M	55
22-Jan-06	3	9640	OK	F	45
22-Jan-06	3	10025	OK	F	60
23-Jan-06	4	11111	OK	M	50
24-Jan-06	1	490	OK	U	55
24-Jan-06	1	490	U	U	55
24-Jan-06	1	495	OM	U	65
24-Jan-06	1	1630	OK	F	60
24-Jan-06	2	4385	U	U	65
24-Jan-06	2	5575	OT	M	60
24-Jan-06	2	5760	OK	F	50
24-Jan-06	2	5760	U	M	jack
24-Jan-06	2	5760	OK	M	60
24-Jan-06	2	5760	OK	M	65
24-Jan-06	2	5760	OT	F	85
24-Jan-06	2	5835	OK	F	50
24-Jan-06	2	5850	OK	M	50
24-Jan-06	2	6095	U	U	65
24-Jan-06	2	6095	U	U	65
24-Jan-06	2	7175	OK	F	55
31-Jan-06	3	9335	OT	F	75
31-Jan-06	3	9500	OK	M	65
31-Jan-06	3	9940	U	F	55
31-Jan-06	3	10020	OK	M	55
31-Jan-06	3	10020	OK	F	55
31-Jan-06	3	10040	OK	M	60
31-Jan-06	3	10040	OK	F	55
31-Jan-06	3	10140	OK	M	55

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
31-Jan-06	3	10460	OK	F	60
31-Jan-06	3	10800	OK	M	60
31-Jan-06	3	10890	OK	M	55
7-Feb-06	4	11335	U	U	70
7-Feb-06	4	11335	U	U	50
8-Feb-06	3	9400	OK	M	70
8-Feb-06	3	9400	OK	F	60
8-Feb-06	3	9425	OK	M	70
8-Feb-06	3	9425	OK	F	65
9-Feb-06	1	125	OK	F	55
9-Feb-06	1	945	U	U	55
9-Feb-06	1	? 1500	OT	U	90
9-Feb-06	1	3150	U	U	70
9-Feb-06	1	3675	OM	F	70
9-Feb-06	1	3675	OM	M	55
9-Feb-06	1	3675	OM	M	75
9-Feb-06	1	3740	OM	U	65
9-Feb-06	1	3770	OM	U	65
9-Feb-06	1	4025	OM	U	60
9-Feb-06	1	4025	OM	U	55
10-Feb-06	2	4235	OM	U	70
10-Feb-06	2	5080	OM	U	65
10-Feb-06	2	5080	OM	U	75
10-Feb-06	2	5080	OM	U	75
10-Feb-06	2	7580	U	U	50
14-Feb-06	3	10080	OK	F	60
14-Feb-06	3	10190	OK	F	65
14-Feb-06	3	10460	OK	F	60
16-Feb-06	1	945	OM	M	75
16-Feb-06	1	945	OM	F	60
16-Feb-06	1	1200	OM	M	60
16-Feb-06	1	1250	OM	U	60
16-Feb-06	1	1755	OM	M	85
16-Feb-06	1	1755	OM	F	65
16-Feb-06	1	1780	OM	F	70

Appendix C. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream(m)	Species	Sex	Size (cm)
16-Feb-06	1	2475	OM	F	60
16-Feb-06	1	2475	OM	M	70
16-Feb-06	1	2475	OM	U	55
18-Feb-06	2	4485	U	U	50
18-Feb-06	2	5580	OK	F	60
18-Feb-06	2	6100	OM	U	55
18-Feb-06	2	7125	OM	M	70
18-Feb-06	2	5730	OK	F	65
22-Feb-06	1	150	OK	F	55
22-Feb-06	1	350	OM	M	65
22-Feb-06	1	1200	OM	M	60
22-Feb-06	1	2175	U	U	65
22-Feb-06	2	5180	OM	F	60
22-Feb-06	2	5730	OK	F	65
23-Feb-06	3	10525	OM	M	75
23-Mar-06	1	350	OM	F	65
23-Mar-06	1	350	U	U	75
23-Mar-06	1	350	U	U	60
23-Mar-06	1	355	OM	M	85
23-Mar-06	1	355	OM	U	80
23-Mar-06	1	355	OM	U	75
23-Mar-06	1	370	OM	M	70
23-Mar-06	1	370	OM	F	65
23-Mar-06	1	1490	OM	M	55
23-Mar-06	1	2650	OM	F	60
23-Mar-06	1	2870	OM	M	60
29-Mar-06	2	5420	OM	U	50
29-Mar-06	2	5955	OM	U	40
29-Mar-06	2	6250	OM	U	45
29-Mar-06	2	6405	OM	F	55
29-Mar-06	2	6550	OM	M	60

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007. Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
19-Nov-06	1	1225	OT	F	95
19-Nov-06	1	3300	OK	F	50
19-Nov-06	1	3300	OK	M	60
20-Nov-06	2	4690	OT	U	79
20-Nov-06	2	4690	OK	M	65
20-Nov-06	2	4690	OK	F	60
20-Nov-06	2	5780	U	U	60
25-Nov-06	1	60	U	U	40
25-Nov-06	1	380	OC	U	40
25-Nov-06	1	2563	OT	M	70
25-Nov-06	1	2563	OT	F	85
25-Nov-06	1	3520	OK	U	60
25-Nov-06	1	3650	U	U	25
25-Nov-06	1	3650	U	U	45
25-Nov-06	1	3910	U	M	50
25-Nov-06	1	3910	U	F	60
26-Nov-06	2	4330	U	U	50
26-Nov-06	2	4330	U	U	50
26-Nov-06	2	4695	OT	F	75
26-Nov-06	2	5090	U	U	65
26-Nov-06	2	5750	OT	F	65
26-Nov-06	2	5845	U	F	60
28-Nov-06	4	11810	U	F	30
29-Nov-06	1	465	OK	M	65
29-Nov-06	1	465	OK	F	
29-Nov-06	1	2565	OT	F	75
29-Nov-06	1	3800	U	U	70
29-Nov-06	1	3900	OT	F	60
29-Nov-06	1	3900	OT	M	50
30-Nov-06	2	4700	OT	F	75
30-Nov-06	2	5770	OK	M	65
30-Nov-06	2	5770	OK	M	50
30-Nov-06	2	5770	OK	F	60
30-Nov-06	2	5770	OK	F	55

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
30-Nov-06	2	5770	U	F	70
30-Nov-06	2	5770	OK	M	55
30-Nov-06	2	5770	U	U	40
30-Nov-06	2	5770	U	U	40
30-Nov-06	2	5770	U	U	35
30-Nov-06	2	5805	OK	F	60
30-Nov-06	2	5805	OK	M	50
2-Dec-06	4	12795	OK	F	35
3-Dec-06	1	2470	OT	F	95
3-Dec-06	1	2600	U	U	60
3-Dec-06	1	3540	OK	U	60
3-Dec-06	1	3540	OK	M	70
3-Dec-06	1	3635	OK	U	60
3-Dec-06	1	3740	OK	F	65
3-Dec-06	1	3875	U	U	40
3-Dec-06	1	3910	OT	F	70
4-Dec-06	2	5770	OK	M	65
4-Dec-06	2	5770	OK	F	60
4-Dec-06	2	5770	OK	M	55
4-Dec-06	2	5770	OK	M	60
4-Dec-06	2	5875	OK	F	65
5-Dec-06	3	9680	OC	M	30
5-Dec-06	3	9680	OC	F	30
6-Dec-06	4	12490	OK	F	40
7-Dec-06	1	1435	OT	F	75
7-Dec-06	1	1435	U	U	50
7-Dec-06	1	2410	OT	M	55
7-Dec-06	1	2460	OT	M	50
8-Dec-06	2	5775	OK	M	70
8-Dec-06	2	5775	OK	M	65
8-Dec-06	2	5775	OK	M	55
8-Dec-06	2	5775	OK	F	60
8-Dec-06	2	5775	OK	M	65
10-Dec-06	4	12620	U	U	50
18-Dec-06	2	4175	OK	M	60

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
18-Dec-06	2	4315	OT	F	80
18-Dec-06	2	4315	U	U	50
18-Dec-06	2	4335	OK	F	60
18-Dec-06	2	4335	OK	M	40
18-Dec-06	2	4800	OT	U	90
18-Dec-06	2	4850	OT	M	35
18-Dec-06	2	4890	OT	F	75
18-Dec-06	2	4890	U	F	70
18-Dec-06	2	4890	OT	M	70
18-Dec-06	2	5565	OK	M	70
18-Dec-06	2	5565	OK	M	65
18-Dec-06	2	5565	OK	F	65
18-Dec-06	2	7450	U	U	45
19-Dec-06	1	940	U	U	70
19-Dec-06	1	1325	U	F	60
19-Dec-06	1	1325	U	M	65
19-Dec-06	1	1600	OK	M	60
19-Dec-06	1	1640	OT	M	95
19-Dec-06	1	1640	OT	F	95
19-Dec-06	1	1755	OK	M	65
19-Dec-06	1	2300	OT	F	55
19-Dec-06	1	2300	OT	F	60
19-Dec-06	1	2300	OT	M	70
19-Dec-06	1	2300	OT	M	55
19-Dec-06	1	2300	OT	F	60
19-Dec-06	1	2420	OK	M	50
19-Dec-06	1	2420	OK	F	50
19-Dec-06	1	2420	OK	M	35
19-Dec-06	1	2420	OK	M	55
19-Dec-06	1	2460	OK	M	
19-Dec-06	1	2460	OK	F	
19-Dec-06	1	3030	OT	U	85
19-Dec-06	1	3400	OK	M	45
19-Dec-06	1	3400	OK	F	55
19-Dec-06	1	3520	OK	M	50

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
19-Dec-06	1	3520	OK		
19-Dec-06	1	3610	U	U	60
19-Dec-06	1	3950	OK	F	50
19-Dec-06	1	3950	OK	M	60
19-Dec-06	1	3950	OK	M	55
19-Dec-06	1	4050	OT	M	30
20-Dec-06	3	7715	OK	M	70
20-Dec-06	3	7715	OK	F	50
20-Dec-06	3	7715	OK	M	30
20-Dec-06	3	7851	OK	F	55
20-Dec-06	3	8005	OK	M	70
20-Dec-06	3	8085	OK	F	55
20-Dec-06	3	8440	OK	M	65
20-Dec-06	3	8440	U	F	55
20-Dec-06	3	8440	U	M	40
20-Dec-06	3	8502	OT	F	75
20-Dec-06	3	9048	U	U	50
20-Dec-06	3	9110	OT	M	50
20-Dec-06	3	9325	U	F	60
20-Dec-06	3	9380	OT	M	45
20-Dec-06	3	9775	OT	F	70
20-Dec-06	3	10020	OT	F	75
20-Dec-06	3	10020	OT	F	75
20-Dec-06	3	10120	OT	F	90
20-Dec-06	3	10120	OT	M	95
20-Dec-06	3	10120	OT	M	43
20-Dec-06	3	10140	OT	F	80
20-Dec-06	3	10140	OT	M	80
20-Dec-06	3	10140	OT	M	60
20-Dec-06	3	10140	OC	U	20
20-Dec-06	3	10157	OT	F	65
20-Dec-06	3	10815	OK	F	60
21-Dec-06	4	11590	OK	M	65
21-Dec-06	4	11590	OK	F	60
21-Dec-06	4	11660	OK	U	65

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
21-Dec-06	4	11660	OK	U	65
21-Dec-06	4	11660	OK	M	40
21-Dec-06	4	11705	OK	F	65
21-Dec-06	4	12310	OK	F	60
21-Dec-06	4	12310	OK	M	60
21-Dec-06	4	12310	OK	U	60
21-Dec-06	4	12560	OK	M	60
21-Dec-06	4	12655	OK	F	65
21-Dec-06	4	12870	U	U	U
21-Dec-06	4	12870	OK	M	70
21-Dec-06	4	12995	OK	F	60
21-Dec-06	4	12995	OK	M	70
21-Dec-06	4	13225	OK	U	70
23-Dec-06	1	140	U	U	40
23-Dec-06	1	140	OK	M	65
23-Dec-06	1	200	OT	M	90
23-Dec-06	1	225	OK	M	60
23-Dec-06	1	375	OK	M	45
23-Dec-06	1	420	OT	U	90
23-Dec-06	1	760	OK	F	60
23-Dec-06	1	760	OK	F	60
23-Dec-06	1	1275	OK	M	65
23-Dec-06	1	1325	U	F	75
23-Dec-06	1	1450	OK	M	70
23-Dec-06	1	1450	OK	M	80
23-Dec-06	1	1450	OK	M	65
23-Dec-06	1	1450	OK	F	70
23-Dec-06	1	1710	OK	F	75
23-Dec-06	1	1710	OK	M	55
23-Dec-06	1	1710	OK	M	65
23-Dec-06	1	2165	OK	M	60
23-Dec-06	1	2165	U	U	80
23-Dec-06	1	2270	OT	F	85
23-Dec-06	1	2300	OK	F	
23-Dec-06	1	2310	OT	F	85

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
23-Dec-06	1	2360	OK	F	70
23-Dec-06	1	2430	OK	F	70
23-Dec-06	1	3110	OK	M	50
24-Dec-06	1	3405	OK	F	50
24-Dec-06	1	3405	OK	M	65
24-Dec-06	1	3415	OK	M	75
24-Dec-06	1	3415	OK	M	75
24-Dec-06	1	3415	OK	F	70
24-Dec-06	1	3445	OK	F	70
24-Dec-06	1	3445	OK	M	65
24-Dec-06	1	3455	U	M	40
24-Dec-06	1	3605	OT	F	95
24-Dec-06	1	3760	OK	M	75
24-Dec-06	1	3760	OK	M	35
24-Dec-06	1	3945	OT	U	95
24-Dec-06	1	4015	U	M	40
24-Dec-06	1	4175	OK	U	65
24-Dec-06	1	4175	OK	M	70
24-Dec-06	1	4175	OK	M	70
24-Dec-06	1	4175	U	U	95
31-Dec-06	2	4315	OK	F	65
31-Dec-06	2	5190	OK	M	40
31-Dec-06	2	5190	OK	M	40
31-Dec-06	2	5200	OK	M	65
31-Dec-06	2	5200	OK	F	60
31-Dec-06	2	5310	OT	F	95
31-Dec-06	2	5470	OK	M	65
31-Dec-06	2	5760	OT	U	85
31-Dec-06	2	5785	OK	F	65
31-Dec-06	2	5885	OK	M	75
31-Dec-06	2	6215	OK	M	65
31-Dec-06	2	6690	OK	U	60
31-Dec-06	2	6690	OT	U	100
31-Dec-06	2	6915	OT	M	80
31-Dec-06	2	7175	OK	U	70

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
31-Dec-06	2	7250	OT	M	85
31-Dec-06	2	7280	OK	M	70
31-Dec-06	2	7290	OT	F	85
31-Dec-06	2	7410	OK	F	55
31-Dec-06	2	7410	OK	M	75
31-Dec-06	2	7450	OT	M	90
31-Dec-06	2	7450	OT	M	45
31-Dec-06	2	7590	OM	M	70
31-Dec-06	2	7590	OM	F	65
1-Jan-07	1	230	U	U	U
1-Jan-07	1	255	OT	M	95
1-Jan-07	1	290	OT	U	60
1-Jan-07	1	1435	U	U	60
1-Jan-07	1	2430	OK	M	70
1-Jan-07	1	2430	OK	F	60
1-Jan-07	1	2510	OK	M	30
1-Jan-07	1	2510	OK	F	60
1-Jan-07	1	2510	OK	M	75
1-Jan-07	1	2915	U	U	60
1-Jan-07	1	3035	OT	F	65
1-Jan-07	1	3405	OK	M	60
1-Jan-07	1	3445	OT	F	80
1-Jan-07	1	3625	OK	U	60
1-Jan-07	1	3870	OK	F	60
1-Jan-07	1	OK	M	70	
2-Jan-07	3	7760	OT	U	90
2-Jan-07	3	8630	OT	M	40
2-Jan-07	3	9305	OT	M	75
2-Jan-07	3	9350	OK	M	65
2-Jan-07	3	9382	OK	M	40
2-Jan-07	3	9400	OK	M	70
2-Jan-07	3	9400	OK	F	60
2-Jan-07	3	9595	OK	F	65
2-Jan-07	3	10040	U	U	65
2-Jan-07	3	11025	OK	M	55

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
2-Jan-07	3	??00	U	M	30
7-Jan-07	4	11215	OT	M	70
7-Jan-07	4	11361	OK	F	60
7-Jan-07	4	12060	U	M	50
7-Jan-07	4	12130	U	M	40
7-Jan-07	4	12310	U	F	60
8-Jan-07	2	5715	OK	M	65
8-Jan-07	2	5730	OK	F	60
8-Jan-07	2	5730	U	M	40
8-Jan-07	2	5730	OK	F	65
8-Jan-07	2	5730	OK	M	75
8-Jan-07	2	5730	OK	M	50
8-Jan-07	2	7405	OT	F	85
8-Jan-07	2	7410	OK	F	65
8-Jan-07	2	7440	U	M	75
8-Jan-07	2	7450	OT	M	100
8-Jan-07	2	7550	U	U	50
9-Jan-07	1	235	OK	M	75
9-Jan-07	1	253	OK	M	65
9-Jan-07	1	1700	OK		
9-Jan-07	1	2490	OK	M	60
9-Jan-07	1	2505	U	S	65
9-Jan-07	1	3035	OT	M	100
9-Jan-07	1	3450	U	F	70
9-Jan-07	1	3880	OK	F	65
9-Jan-07	3	7935	OK	F	60
9-Jan-07	3	7935	OK	M	65
9-Jan-07	3	8575	OK	F	60
9-Jan-07	3	9210	OK	M	50
9-Jan-07	3	9395	OK	F	65
9-Jan-07	3	10040	OK	F	60
13-Jan-07	4	12480	OK	F	60
13-Jan-07	4	12480	OK	M	70
14-Jan-07	1	10	U	F	90
14-Jan-07	1	585	OK	M	75

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
14-Jan-07	1	1548	OK	M	65
15-Jan-07	2	4175	U	F	65
15-Jan-07	2	5545	U	U	60
15-Jan-07	2	5720	OK	F	65
15-Jan-07	2	6098	OK	U	70
15-Jan-07	2	6098	OK	M	40
15-Jan-07	2	6210	OK	F	60
15-Jan-07	2	7450	OK	M	70
16-Jan-07	3	7940	OK	F	60
21-Jan-07	1	260	U	U	60
21-Jan-07	1	260	OM	U	75
21-Jan-07	1	260	OC	U	30
21-Jan-07	1	260	OM	U	65
21-Jan-07	1	2110	OK	M	60
21-Jan-07	1	2510	OK	M	60
28-Jan-07	1	350	OM	U	75
28-Jan-07	1	400	U	U	30
28-Jan-07	1	1415	OK	M	70
28-Jan-07	1	3300	OK	M	35
29-Jan-07	2	5985	U	U	50
3-Feb-07	1	230	OC	U	30
3-Feb-07	1	230	OC	U	30
3-Feb-07	1	250	OC	U	35
3-Feb-07	1	250	OC	U	40
3-Feb-07	1	260	OC	U	25+
3-Feb-07	1	260	OC	U	20
3-Feb-07	1	260	OC	U	20
3-Feb-07	1	260	OC	U	20
3-Feb-07	1	3305	U	U	50
3-Feb-07	1	3305	OK	M	35
17-Feb-07	2	4310	OK	F	70
17-Feb-07	2	4310	OK	M	70
17-Feb-07	2	4310	OK	M	35-40
17-Feb-07	2	4475	OK	M	45
17-Feb-07	2	5035	OM	U	85-90

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
17-Feb-07	2	7170	OM	M	70-75
17-Feb-07	2	7170	OM	F	65
17-Feb-07	2	7170	OM	M	70
17-Feb-07	2	7240	OM	U	60
17-Feb-07	2	7440	OM	U	55-60
19-Feb-07	1	1405	U	U	U
19-Feb-07	1	2660	OM	M	70
19-Feb-07	1	2660	OM	M	65
19-Feb-07	1	3300	OM	M	60
19-Feb-07	1	3300	OM	F	57
19-Feb-07	1	3300	OM	M	53
19-Feb-07	1	3480	OM	U	60
19-Feb-07	1	3850	OM	U	60
19-Feb-07	1	3860	OK	F	50
6-Mar-07	2	4290	OM	M	60
6-Mar-07	2	4290	OM	F	65
6-Mar-07	2	5950	OM	F	U
6-Mar-07	2	5950	OM	M	U
6-Mar-07	2	5950	OM	M	50
6-Mar-07	2	7370	OM	M	65
6-Mar-07	2	7370	OM	U	60
6-Mar-07	2	7450	OM	M	70
6-Mar-07	2	7450	OM	M	75
6-Mar-07	2	7450	OM	M	65
6-Mar-07	2	7450	OM	M	70
6-Mar-07	2	7450	OM	U	65
6-Mar-07	2	7490	OM	U	50
10-Mar-07	1	255	OM	F	70
10-Mar-07	1	256	OM	F	75
10-Mar-07	1	257	OM	F	65
10-Mar-07	1	258	OM	F	70
10-Mar-07	1	259	OM	F	75
10-Mar-07	1	260	OM	F	70
10-Mar-07	1	261	OM	U	50
10-Mar-07	1	262	OM	U	60

Appendix D. Live Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonids observed on Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Distances upstream of the beginning of the survey area are recorded in meters. Reaches are 1-4 as described in the Methods. Sex codes are: M=male, F=female, U=unknown. Fish lengths are estimated in increments of 5 cm.

Date	Reach	Distance upstream (m)	Species	Sex	Size (cm)
10-Mar-07	1	263	OM	U	65
10-Mar-07	1	264	OM	U	70
10-Mar-07	1	265	OM	M	70
10-Mar-07	1	395	OM	M	65
10-Mar-07	1	395	OM	F	60
10-Mar-07	1	510	OM	M	70
10-Mar-07	1	3270	OM	U	65
10-Mar-07	1	3410	OM	U	70
10-Mar-07	1	3585	OM	U	55
10-Mar-07	1	3585	OM	U	65
10-Mar-07	1	4075	OM	U	70
12-Mar-07	3	9450	OC	U	25
14-Mar-07	1	225	OM	U	60
14-Mar-07	1	225	U	U	45
14-Mar-07	1	255	OM	U	75
14-Mar-07	1	255	OM	F	70
14-Mar-07	1	255	OM	U	55
14-Mar-07	1	255	OM	U	65
14-Mar-07	1	255	OM	U	65
14-Mar-07	1	255	OM	U	65
14-Mar-07	1	255	OM	U	U
14-Mar-07	1	255	OM	U	U
14-Mar-07	1	255	OM	U	U
14-Mar-07	1	255	OM	U	55
14-Mar-07	1	355	OM	U	70
14-Mar-07	1	355	OM	U	65
14-Mar-07	1	355	OM	U	65
14-Mar-07	1	355	OM	U	75
14-Mar-07	1	355	OM	U	60
14-Mar-07	1	355	OM	U	U
14-Mar-07	1	775	OM	U	65
15-Mar-07	2	6100	OM	U	60
15-Mar-07	2	6250	OM	U	65
15-Mar-07	2	7540	OM	M	60
16-Mar-07	3	8975	OM	U	60

Appendix E. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006. Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
11/18/2005	1	2095	U	3	NT	3.9	1.6
11/18/2005	1	2300	U	2	RM	4.4	2.3
11/18/2005	1	2305	U	2	RM	4.3	2.2
11/18/2005	1	2430	U	3	RM	2.9	2.1
12/5/2005	2	6290	OK	2	R	4.8	1.5
12/5/2005	2	7430	OT	2	N	5.3	2.1
12/8/2005	3	8190	U	3	N	5.9	2.3
12/8/2005	3	8225	U	1	RM	4.7	1.7
12/8/2005	3	8650	OKE	1	RC	5.5	3.4
12/8/2005	3	8655	U	2	N	4.4	3
12/8/2005	3	9040	OT	4	RC	2.4	1.5
12/8/2005	3	9475	OK	3	RC	3.2	2
12/9/2005	4	11220	OK	3	PT	1.7	1.6
12/9/2005	4	11220	U	1	PT	2.3	1.4
12/9/2005	4	11760	OK	4	RM	3	2.3
12/9/2005	4	12790	OK	3	N	1.5	1
12/10/2005	1	1175	OT	3	N	2.5	1.3
12/10/2005	1	1215	U	5	NT	4.4	1.5
12/10/2005	1	1300	U	3	NT	2.2	1.1
12/10/2005	1	1450	U	3	N	3	1.2
12/10/2005	1	2560	U	2	NT	4.4	1.5
12/10/2005	1	3305	U	3	NT	2.9	0.9
12/10/2005	1	3400	U	1	RC	2.1	0.7
12/10/2005	1	3440	U	4	RC	2.8	1.1
12/10/2005	1	3675	U	3	N	2.6	0.9
12/10/2005	1	3800	U	4	RC	5.9	2.2
12/10/2005	1	4040	OK	5	N	6.1	2.9
12/11/2005	2	5175	OK	3	N	1.4	1.2
12/11/2005	2	5240	U	1	RM	4	1.7
12/11/2005	2	5515	U	3	RM	3	2.3
12/11/2005	2	5660	OT	2	R	2.5	0.9
12/11/2005	2	5790	OT	4	RM		
12/11/2005	2	5840	U	3	N	1.7	1.4

Appendix E. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
12/11/2005	2	6760	OT	1	RM		
12/13/2005	3	7610	U	1	R	2.1	0.9
12/13/2005	3	8500	U	2	R	1.3	0.6
12/13/2005	3	8865	U	3	RC	1.8	0.7
12/13/2005	3	9030	U	3		2	0.6
12/13/2005	3	9570	U	2	N	5.5	3
12/13/2005	3	10420	U	4	RC	1.9	0.75
12/13/2005	3	10645	OK	4	RC	3.3	1.5
12/14/2005	4	11075	U	2	N	1.9	0.9
12/14/2005	4	12390	U	2	RT	1.8	0.9
12/14/2005	4	12391	U	5	RT	1.1	0.4
12/14/2005	4	12392	U	5	RT	2.4	1.2
12/14/2005	4	12470	U	3	N	2	1
12/14/2005	4	13055	U	2	RT	2.2	0.8
12/16/2005	1	225	U	3	RC	3.1	1.3
12/16/2005	1	1125	U	4	N	2.6	1.1
12/16/2005	1	1215	U	4	N	4	2.3
12/16/2005	1	1460	U	2	N	6.3	2.8
12/16/2005	1	2440	U	4	RC	2.4	1.3
12/16/2005	1	2765	U	5	RC	3.8	1.6
12/16/2005	1	3875	U	4	N	3.3	1.7
12/16/2005	2	4185	U	1	R	4.6	1.1
12/16/2005	2	4200	U	2	RC	3	1
12/16/2005	2	4705	U	1	R	4.2	1.6
12/16/2005	2	5175	U	3	RC	2.5	1.2
12/16/2005	2	5725	U	1	RC	2	1.3
12/16/2005	2	5725	U	1	RC	1.4	0.7
12/16/2005	2	5740	U	3	PT	2	1.1
12/16/2005	2	5920	U	2		2.9	1
12/16/2005	2	6225	OK	3	RC	1.5	0.8
12/16/2005	2	6240	U	3	RC	3.6	1.5
12/16/2005	2	6975	U	2	N	3.6	1.1
12/17/2005	3	8215	U	1	RM	4.5	2.2

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Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
12/17/2005	3	8275	U	2	RC	2.5	1.8
12/17/2005	3	8335	U	3	N	2.9	1.1
12/17/2005	3	8455	U	2	RC	3.7	2.1
12/17/2005	3	8475	U	2	RC	2.7	1.4
12/17/2005	3	8945	U	4	N	1.8	0.7
12/17/2005	3	9460	U	2	RM	2.8	1.3
12/17/2005	3	9540	U	4	N	2.7	1.5
1/9/2006	4	11110	OK	5	N	4	1.3
1/9/2006	4	11115	U	3	N	1.5	0.9
1/9/2006	4	11130	U	4	RC	4	1.7
1/9/2006	4	11255	U	4	RC	5.9	2
1/9/2006	4	11255	U	2	RC	2.8	1.3
1/22/2006	3	7685	U	2	N	5.6	2.4
1/22/2006	3	7625	U	2	RC	2.6	1.6
1/22/2006	3	7625	U	1	RC	6.8	3.5
1/22/2006	3	7850	U	2	N	3.7	2.3
1/22/2006	3	7940	U	1	RC	10.5	3.5
1/22/2006	3	8220	U	1	RM	6	3.1
1/22/2006	3	8370	U	3	N	4.6	2.7
1/22/2006	3	8520	U	2	RM	6.7	3
1/22/2006	3	8535	U	3	RC	5.3	3.1
1/22/2006	3	8590	U	5	N	6.9	3.5
1/22/2006	3	8865	U	2	RC	1.7	1.5
1/22/2006	3	9401	U	2	RC	5.6	3.5
1/22/2006	3	9535	U	2	N	2.5	1.2
1/22/2006	3	9555	U	5	RC	4.5	2.4
1/22/2006	3	9640	OK	3	RM	4.3	1.9
1/22/2006	3	9685	U	3	N	4.7	2
1/22/2006	3	9775	U	3	N	3.6	2.9
1/22/2006	3	9825	U	2	N	3.6	2.2
1/22/2006	3	10020	U	3	RC	9	4.3
1/22/2006	3	10025	OK	1	N	4.7	1.4
1/22/2006	3	10040	OK	2	RC	5.6	3.1

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Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
1/22/2006	3	10065	U	4	RC	5.3	2
1/22/2006	3	10160	U	5	N	4.7	3.3
1/22/2006	3	10190	U	4	N	5.5	3.3
1/22/2006	3	10465	U	1	N	6.2	2.3
1/22/2006	3	10725	U	3	RC	3.7	2.8
1/23/2006	4	11110	U	2	N	3	1.5
1/23/2006	4	11320	U	1.5	N	1.9	1.1
1/23/2006	4	11360	U	3	N	3.8	2
1/23/2006	4	11440	U	1	RM	1.5	0.8
1/23/2006	4	11590	U	5	PT	3.3	1.1
1/23/2006	4	11685	U	4	N	2.4	1
1/23/2006	4	11735	U	2	RC	3.7	2
1/23/2006	4	11820	U	1	PT	3.5	1.4
1/23/2006	4	12225	U	1	N	2.1	0.9
1/23/2006	4	12690	U	4	PT	1.5	0.7
1/24/2006	2	4185	U	5	RM	2.6	1.1
1/24/2006	2	4320	U	2	RC	4.7	2.1
1/24/2006	2	4375	U	3	RC	2.6	1.7
1/24/2006	2	4375	U	5	RC	4	3.1
1/24/2006	2	4430	U	4	RC	2.6	1.5
1/24/2006	2	4435	U	1	RC	7.5	3.8
1/24/2006	2	4470	U	4	RC	6.6	2.6
1/24/2006	2	4515	U	3	RC	4.2	1.9
1/24/2006	2	4655	U	1	RC	4.1	1.9
1/24/2006	2	5245	U	1	RM	7.3	1.5
1/24/2006	2	5340	OK	5	RC	4.8	3.6
1/24/2006	2	5575	U	3	RC	1.8	1.2
1/24/2006	2	5740	U	3	N	8	2.7
1/24/2006	2	5745	U	1	N	3.1	2.6
1/24/2006	2	5750	U	2	PT	3	1.6
1/24/2006	2	5830	U	3	RC	6.9	3.5
1/24/2006	2	5835	OK	1	N	4.3	2.5
1/24/2006	2	5910	U	2	N	3	1.9

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Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
1/24/2006	2	5940	U	1	N	5	2.2
1/24/2006	2	5955	U	1	RC	2.1	1.7
1/24/2006	2	5960	U	3	RC	4.4	2.8
1/24/2006	2	6135	U	1	N	4	1.7
1/24/2006	2	6245	U	2	N	3	1.5
1/24/2006	2	6245	U	1	N	3.3	1.5
1/24/2006	2	6330	U	5	RC	3	1
1/24/2006	2	7175	OK	2	RC	6.3	3.2
1/31/2006	3	9335	OT	3	N	4.3	1.9
1/31/2006	3	9580	U	2	RC	2.5	1.1
1/31/2006	3	9685	U	3	RC	3.3	1.8
1/31/2006	3	9725	U	1	RC	4.4	1.4
1/31/2006	3	10020	OK	1	RC	3.4	1.5
1/31/2006	3	10460	OK	4	N	4.9	2
2/7/2006	4	11120	U	4	RC	4.8	
2/7/2006	4	11505	U	5	RM	4	3.4
2/7/2006	4	11135	U	4.5	RC	5.3	2.3
2/7/2006	4	11685	U	4	RC	3.9	1.8
2/7/2006	4	11215	U	1	RC	3.5	3.5
2/7/2006	4	11705	U	4	N	3.4	2.6
2/7/2006	4	11320	U	1	RC	3.3	2.4
2/7/2006	4	11323	U	1	N	3.7	1.4
2/7/2006	4	11360	U	3	RC	4.7	1.8
2/7/2006	4	12715	U	4	RC	5.5	2.1
2/7/2006	4	11775	U	5	RM	5.1	1.5
2/7/2006	4	13055	U	2	RC	5.2	3.4
2/7/2006	4	12080	U	1	N	2.8	2
2/7/2006	4	12170	U	2	N	3.2	1.4
2/7/2006	4	12260	U	3	N	2.1	1.5
2/7/2006	4	13150	U	3	N	2.9	1
2/8/2006	3	7460	U	2	RC	2.2	1
2/8/2006	3	7461	U	1	RC	3.9	1.3
2/8/2006	3	7520	U	4	RC	3	1.3

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Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
2/8/2006	3	7530	U	2	N	2.4	1
2/8/2006	3	7700	U	2	RC	1.8	1.1
2/8/2006	3	8500	U	2	R	2.4	1.2
2/8/2006	3	8650	U	1	RC	3.5	1.3
2/8/2006	3	8935	U	5	RC	1.9	0.9
2/8/2006	3	9325	U	3	N	1.9	0.9
2/8/2006	3	9400	OK	2	N	4.1	2.1
2/8/2006	3	9425	OK	4	RC	3.4	1.9
2/8/2006	3	9925	U	2	RC	1.8	1.2
2/8/2006	3	10410	U	4	RC	2.9	1.2
2/8/2006	3	10510	U	5	RC	1.9	0.8
2/9/2006	1	2375	U	1	N	4.1	1.5
2/9/2006	1	3675	OM	1	N	U	U
2/10/2006	2	4235	U	4	N	2.3	0.8
2/10/2006	2	4570	U	2	R	3.5	1.6
2/10/2006	2	4610	U	4	RC	2.9	1.4
2/10/2006	2	4660	U	4	N	2.9	0.9
2/10/2006	2	4675	U	4	N	2.5	0.9
2/10/2006	2	4880	U	2	R	2.2	1.1
2/10/2006	2	5080	OM	2	RC	3.6	1.5
2/10/2006	2	5575	U	4	RC	2.6	1
2/14/2006	3	7940	U	3	RC	2	0.9
2/14/2006	3	7941	U	1	RC	2.9	1.2
2/14/2006	3	7998	U	3	RC	2.5	1
2/14/2006	3	9065	U	2	N	1.1	0.6
2/14/2006	3	9550	U	1	RC	2.7	1.2
2/14/2006	3	10180	U	2	RC	1.4	0.7
2/14/2006	3	10400	U	1	RC	3.7	2.1
2/14/2006	3	10410	U	2	RC	3.1	1.3
2/14/2006	3	10430	U	3	RC	2.5	1.1
2/14/2006	3	10460	OK	2	RC	3.3	1.2
2/16/2006	4	11375	U	1	RC	2.6	1.5
2/16/2006	4	11420	U	2	N	2.3	0.9

Appendix E. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2005 to March 2006 (continued). Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance upstream(m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
2/18/2006	2	4835	U	3	R	4	1.4
2/18/2006	2	5085	U	3	RC	3.1	1.6
2/18/2006	2	5290	U	3	RC	1.5	0.9
2/18/2006	2	5291	U	4	RC	1.8	0.9
2/18/2006	2	6120	U	2	RC	1.5	0.8
2/18/2006	2	4670	U	4	N	4.1	1.4
2/18/2006	2	5730	OK	1	R	4.3	1.5
2/18/2006	2	6240	U	2	RC	4.4	1.7
2/22/2006	1	2125	U	2	PT	1.1	0.6
2/22/2006	1	2135	U	5	PT	5.2	2.4
2/22/2006	2	5945	U	3	R	3.9	1.4
2/23/2006	3	9430	U	1	RC	1.6	1
2/23/2006	3	9730	U	3	RC	2.2	1.5
2/23/2006	3	10640	U	4	RC	2.4	1.4
2/24/2006	4	11075	U	2	R	1.6	0.7
3/23/2006	1	2250	U	3	RC	2.2	1.4
3/23/2006	1	2450	U	4	RC	3	1.5
3/23/2006	1	2650	OM	5	RC	3.4	1.5
3/23/2006	1	3700	U	2	RC	1.8	0.9
3/29/2006	2	5735	U	4	RC	3.4	1.7
3/30/2006	3	7670	U	2	RC	2.3	1
3/30/2006	3	7670	U	2	RC	2	0.9
3/30/2006	3	7670	U	4	RC	1.5	0.9

Appendix F. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007. Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance Upstream (m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
11/19/2006	1	795	U	2	RT	1.4	0.84
11/19/2006	1	3300	OK	3	PT	3.9	1.2
11/19/2006	1	3405	U	2	PT	2.9	1.9
11/20/2006	2	4690	OT	1	RT	8	2.9
11/25/2006	1	2563	OT	2	PT	9.5	3.9
11/25/2006	1	3520	U	4	PT	1.8	0.8
11/25/2006	1	3910	OT	3	RM	7	1.9
11/26/2006	2	4200	U	4	RM	4.5	1.8
11/26/2006	2	4435	U	2	PT	6.9	3.2
11/26/2006	2	5015	U	4.5	RM	4.6	2.7
11/26/2006	2	5750	OK	2	PT	7.5	4.1
11/26/2006	2	5750	U	4	PT	3	1.7
11/26/2006	2	5845	U	3	N	6.8	4.2
11/28/2006	4	11810	U	2	PT	2	1
11/29/2006	1	465	OK	2	RM	7.8	3
11/29/2006	1	1620	U	1	PT	6.5	3.1
11/30/2006	2	5805	OK	5	PT	4.5	2.4
11/30/2006	2	7170	U	2	PT	3.6	1.3
12/2/2006	4	12795	OK	2	PT	2.2	1.1
12/3/2006	1	3875	OK	4	NT	4.2	1.9
12/5/2006	3	9680	OC	2	RC	1.2	0.5
12/18/2006	2	4335	OK	2	PT		
12/18/2006	2	4890	OT	1	RM	6.9	4.4
12/18/2006	2	5565	OK	2	PT	5	2.1
12/19/2006	1	1325	U	3	PT	4.6	1.8
12/19/2006	1	1600	OK	3	PT	4.5	1.4
12/19/2006	1	2300	OT	2	RM	3.5	1.8
12/19/2006	1	2300	OT	1	RM	4.2	1.8
12/19/2006	1	2360	OK	1	RM	7.4	1.5
12/19/2006	1	2420	OK	4		5.3	3.6
12/20/2006	3	7851	OK	2	NT	4	2.6
12/20/2006	3	8085	OK	1	PT	3	1
12/20/2006	3	8225	U	1	R	2.7	1.3

Appendix F. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance Upstream (m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
12/20/2006	3	8502	OT	4	R	2.8	1.5
12/20/2006	3	9325	U	5	NT	3.5	1.4
12/20/2006	3	10020	OT	3	PT	6.7	3.1
12/20/2006	3	10040	U	4	PT	7	2.5
12/20/2006	3	10140	OT	3	R	6	2
12/20/2006	3	10157	OT	3	NT	4.5	2.5
12/20/2006	3	10405	U	1	NT	5	1.4
12/20/2006	3	10815	OK	3	PT	4	1.3
12/21/2006	4	11135	U	5	PT	3.4	1.5
12/21/2006	4	11590	OK	5	PT	4	0.8
12/21/2006	4	11705	OK	5	N		
12/21/2006	4	12310	OK	2	PT	3.2	1.1
12/21/2006	4	12655	OK	4	PT	2	1
12/21/2006	4	12995	OK	5	PT	4	1
12/23/2006	1	760	OK	4	RC	3.4	1.8
12/23/2006	1	1450	OK	2	N	2.5	1.3
12/23/2006	1	1710	OK	1	N	2.9	1
12/24/2006	1	3400	U	5	PT	3.2	1.8
12/24/2006	1	3405	OK	1	PT	4.4	1.7
12/24/2006	1	3445	OK	4	PT		
12/31/2006	2	5200	OK	4	RM		
12/31/2006	2	7410	OK	4	PT		
1/1/2007	1	2510	OK	1	R	6	2.2
1/1/2007	1	3035	OT	1	RT		
1/1/2007	1	3870	OK	4	N	7.2	3.1
1/2/2007	3	7590	OM	2	RM	5.2	2.6
1/2/2007	3	8220	U	2	RM	2.3	1.2
1/2/2007	3	9380	U	3	NT	2.3	1
1/2/2007	3	9400	OK	4	PT	5.5	2.6
1/2/2007	3	9595	OK	1	NT	3.6	1.05
1/2/2007	3	10040	U	1,2	PT	5.5	1.8
1/7/2007	4	11360	U	5	PT	2.3	1.6
1/7/2007	4	11361	OK	1	PT	3.3	1.1

Appendix F. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance Upstream (m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
1/7/2007	4	12140	U	2	NT	3.6	2
1/8/2007	2	5335	U	4	NT	3.8	2.4
1/8/2007	2	5730	OK	4	NT	5.6	1.5
1/9/2007	1	15	U	2	PT	5.6	1.7
1/9/2007	1	16	U	1	PT	7.5	2.2
1/9/2007	3	7935	OK	1	PT	3.2	1.2
1/9/2007	3	10410	U	1	NT	4	1.4
1/9/2007	3	10710	U	3	NT	2.4	1
1/13/2007	4	12480	OK	3,4	PT	3.2	1.1
1/14/2007	1	170	U	3	PT		
1/14/2007	1	1625	U	4	PT	4	2.1
1/15/2007	2	4440	U	1	PT	7.7	3.4
1/15/2007	2	6245	U	3	PT	3.6	1.5
1/17/2007	4	11295	U	2	PT	2.7	1.7
1/28/2007	1	780	U	4	PT	7.8	2.2
1/28/2007	1	1160	U	3	RM	2.4	1.3
1/28/2007	1	2100	U	3,4	PT	3.5	2.4
1/28/2007	1	3300	OK	5	PT	4.5	1.6
2/3/2007	1	580	U	1	NT	4.4	1.9
2/6/2007	3	8860	U	2	PT	2.8	1.3
2/17/2007	2	4310	OK	1	PT	3.4	1.2
2/17/2007	2	5075	U	1	PT	3	0.8
2/17/2007	2	7170	OM	2	PT	5.1	2.4
2/19/2007	1	105	U	1	NT	6.3	2.6
2/19/2007	1	2660	OM	5	N	3.9	1.4
2/19/2007	1	3860	OK	1	N		
3/6/2007	2	4235	U	4	N	3.8	1.9
3/6/2007	2	4290	OM	2.5	PT		
3/6/2007	2	4375	U	3	PT	2.5	1.2
3/6/2007	2	5335	U	4	PT	3.1	1.3
3/6/2007	2	5900	U	2	NT	3.3	1.4
3/6/2007	2	5950	OM	5	N		
3/6/2007	2	7185	U	5	N	4.8	1.9

Appendix F. Chinook salmon, coho salmon, steelhead, chum salmon, cutthroat trout, and unknown salmonid redds observed during Prairie Creek stream surveys, Humboldt County, California, November 2006 to March 2007 (continued). Dates of observances are shown. Reaches are 1-4 as described in the Methods. Distances upstream of the beginning of the survey area are recorded in meters. Species codes are: OT=Chinook salmon, OK=coho salmon, OM=steelhead, OKE=chum salmon, OC=cutthroat trout, and U=unknown. Lateral positions are: 1=left bank, 3=middle channel, 5=right bank. Habitat types are: R=riffle, RC=riffle crest, N=run, P=pool, PT=pool tail. Redd length and width was measured in meters.

Date	Reach	Distance Upstream (m)	Species Present	Lateral Position	Habitat Type	Length (m)	Width (m)
3/10/2007	1	220	U	2	PT	3.7	1.7
3/10/2007	1	1065	U	3	PT	3.4	2
3/10/2007	1	1705	U	2	PT	3.2	1.2
3/10/2007	1	1785	U	1.5	PT	6.5	2.5
3/10/2007	1	3400	U	2	PT	6	2.4
3/12/2007	3	7620	U	1.5	N	5.8	2.2
3/12/2007	3	9020	U	2	N	3.5	1.9
3/12/2007	3	9555	U	4	PT	3	1.4
3/14/2007	1	220	U	4	PT	2.8	1.7
3/14/2007	1	480	U	3	PT	3.3	2.3
3/14/2007	1	1875	U	4	PT	3.5	2.3
3/14/2007	1	3225	U	4	PT	4.7	1.1
3/14/2007	1	3305	U	3	PT	4.3	2.3
3/15/2007	2	4220	U	4	PT	6.3	1.9
3/15/2007	2	4290	U	2.5	PT	4.3	1.5
3/15/2007	2	5225	U	3	PT	5	2
3/15/2007	2	5950	U	5	N	5	1.8
3/15/2007	2	6025	U	2.5	N	3.4	1.6
3/16/2007	3	8250	U	1	PT	3.4	1.5
3/16/2007	3	9085	U	1	PT	3	1.2
3/16/2007	3	9140	U	5	PT	2.6	0.9
3/16/2007	3	9275	U	4.5	N	6.6	2.5
3/16/2007	3	9425	U	4	PT	2.8	1.5
3/16/2007	3	9780	U	4	PT	2.7	1.2
3/18/2007	4	11125	U	5	PT	5.6	1.6

Appendix G. Chinook salmon carcass encounter history in Prairie Creek, Humboldt County, California, November 2005 to April 2006. Dates of stream surveys are shown in the first row. These were broken up into 9 time intervals, with each interval including surveys of all 4 study reaches. The encounter codes are given for each individual carcass (Carcass ID) for the time intervals. Encounter codes: 1=encountered; 0=not encountered.

Date	Nov 18 -21	Nov30- Dec9	Dec10- 14	Dec16- Jan 9	Jan22- 31	Feb8- 10	Feb14- 18	Feb22- 24	Mar23- Apr7
Time interval, i	1	2	3	4	5	6	7	8	9
Carcass ID									
1	1	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0
3	0	0	0	1	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0
5	0	0	0	1	0	0	0	0	0
6	0	0	0	0	1	1	0	1	0
7	0	0	0	0	1	0	0	0	0

Appendix H. Coho salmon carcass encounter history in Prairie Creek, Humboldt County, California, December 2005 to April 2006. Dates of stream surveys are shown in the first row. These were broken up into 6 time intervals, with each interval including surveys of all 4 study reaches. The encounter codes are given for each individual carcass (Carcass ID) for the time intervals. Encounter codes: 1=encountered; 0=not encountered.

Date	Dec16-Jan9	Jan2-31	Feb8-10	Feb14-18	Feb22-24	Mar23-Apr7
Time interval, i	1	2	3	4	5	6
Carcass ID						
1	1	0	0	0	0	0
2	1	0	0	0	0	0
3	1	1	0	0	0	0
4	1	0	0	0	0	0
5	1	1	0	0	0	0
6	1	0	0	0	0	0
7	0	1	0	0	0	0
8	0	1	1	0	0	0
9	0	1	0	0	0	0
10	0	1	0	0	0	0
11	0	1	0	0	0	0
12	0	1	0	0	0	0
13	0	1	0	0	0	0
14	0	1	0	0	0	0
15	0	1	0	0	0	0
16	0	1	0	0	0	0
17	0	1	0	0	0	0
18	0	1	1	1	0	0
19	0	1	0	0	0	0
20	0	1	0	0	0	0
21	0	1	1	1	0	0
22	0	0	1	0	0	0
23	0	0	1	0	0	0
24	0	0	1	0	0	0
25	0	0	0	0	1	0
26	0	0	0	0	1	0
27	0	0	0	0	1	0

Appendix I. Chinook salmon carcass encounter history in Prairie Creek, Humboldt County, California, December 2006 to March 2007. Dates of stream surveys are shown in the first row. These were broken up into 11 time intervals, with each interval including surveys of all 4 study reaches. The encounter codes are given for each individual carcass (Carcass ID) for the time intervals. Encounter codes: 1=encountered; 0=not encountered.

	Dec	Dec	Dec	Dec	Jan	Jan	Jan	Jan		Feb	Mar
Date	Dec	Dec	Dec	Dec	Jan	Jan	Jan	Jan	Feb	Feb	Mar
	3-6	7-10	11-14	15-18	19-22	23-26	27-30	31	1-4	5-8	9-12
Time interval, i	1	2	3	4	5	6	7	8	9	10	11
Carcass ID											
1	1	1	0	1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0	0	0	0	0
5	0	0	0	1	1	1	1	1	1	0	0
6	0	0	0	1	0	0	1	1	1	1	1
7	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	1	1	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	0	0	0
11	0	0	0	1	0	0	0	0	0	0	0
12	0	0	0	1	0	0	0	0	0	0	0
13	0	0	0	1	1	1	0	1	1	0	0
14	0	0	0	0	1	0	0	0	0	0	0
15	0	0	0	0	1	1	1	1	1	1	0
16	0	0	0	0	1	1	1	1	1	0	0
17	0	0	0	0	1	1	1	0	0	0	0
18	0	0	0	0	1	1	0	0	0	0	0
19	0	0	0	0	1	0	1	0	1	1	0
20	0	0	0	0	1	0	1	0	1	0	0
21	0	0	0	0	0	1	1	1	1	0	0
22	0	0	0	0	0	1	1	0	0	0	0
23	0	0	0	0	0	1	1	1	1	1	0
24	0	0	0	0	0	1	0	0	0	0	0

Appendix J. Coho salmon carcass encounter history in Prairie Creek, Humboldt County, California, November 2006 to March 2007. Dates of stream surveys are shown in the first row. These were broken up into 14 time intervals, with each interval including surveys of all 4 study reaches. The encounter codes are given for each individual carcass (Carcass ID) for the time intervals. Encounter codes: 1=encountered; 0=not encountered.

Date	Nov 25- 28	Nov 29- Dec 2	Dec 3-6	Dec 7-10	Dec 18- 21	Dec 23- Jan 7	Jan 8-13	Jan 14- 17	Jan 21- 24	Jan 28- 31	Feb 3-7	Feb 17- 20	Mar 6-12	Mar 14- 18
Time interval, i	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Carcass ID														
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	1	1	1	1	0	0	0	0	0	0
3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	0
8	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11	0	0	0	0	0	1	0	0	0	0	0	0	0	0
12	0	0	0	0	0	1	0	0	0	0	0	0	0	0
13	0	0	0	0	0	1	0	0	0	0	0	0	0	0
14	0	0	0	0	0	1	0	0	1	0	0	0	0	0
15	0	0	0	0	0	1	0	0	0	0	0	0	0	0
16	0	0	0	0	0	1	0	0	0	0	0	0	0	0
17	0	0	0	0	0	1	1	1	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	0	0
19	0	0	0	0	0	1	0	0	0	0	0	0	0	0
20	0	0	0	0	0	1	0	0	0	0	0	0	0	0
21	0	0	0	0	0	1	0	0	0	0	0	0	0	0
22	0	0	0	0	0	1	0	0	0	0	0	0	0	0
23	0	0	0	0	0	1	1	1	1	0	1	0	0	1
24	0	0	0	0	0	1	1	0	0	0	0	0	0	0
25	0	0	0	0	0	1	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	1	1	1	1	1	0	0	0
27	0	0	0	0	0	0	1	1	1	0	1	1	0	0
28	0	0	0	0	0	0	1	1	1	0	1	0	0	0
29	0	0	0	0	0	0	1	1	0	0	0	1	0	0
30	0	0	0	0	0	0	1	1	0	0	0	0	0	0

[illegible]

[illegible]