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2002-2003 ANNUAL REPORT FRESHWATER CREEK ADULT SALMONID RUN-SIZE AND LIFE HISTORY STUDIES PROJECT 1a1

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Steelhead Research and Monitoring Program
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2002-2003 ANNUAL REPORT
FRESHWATER CREEK ADULT SALMON AND STEELHEAD
RUN-SIZE, SPAWNING DISTRIBUTION, AND LIFE HISTORY 2002-2003
SEASON
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ABSTRACT

Adult steelhead, coho salmon and Chinook salmon escapement into Freshwater Creek was estimated using a Petersen type mark recapture experiment. Steelhead received a PIT (Passive Integrated Transponder) tag at a permanent weir facility, and kelts were checked for tags as they immigrated back to the ocean. The escapement of adult steelhead into Freshwater Creek is estimated at 172 ±54 (95% C.I.). Adult salmon were marked with a small hole punched in the operculum at the weir and carcasses recaptured on the spawning grounds. The escapement of adult coho salmon is estimated at 1754 ± 477 (95% C.I.). The escapement of adult Chinook salmon is estimated at 133 ± 63 (95% C.I.). We observed 323 anadromous salmonid redds and 390 live fish throughout the survey period. The large discrepancy between observed redds and live fish and the estimated number of spawning females and total fish suggest we undercounted live salmonids and their redds.

[1] Steelhead Research and Monitoring Program report, available from:Department of Fish and Game, 50 Ericson Court, Arcata California 95521 (707) 825-4850

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INTRODUCTION

The California Department of Fish and Game (DFG) and National Oceanic and Atmospheric Administration ~ Fisheries (NOAA~Fisheries) recognize four key parameters for assessing the long term viability of salmonid populations. These parameters are; population size, population growth rate (productivity), population spatial structure, and life history diversity (McElhany et al. 2000). The Freshwater Salmonid Monitoring Project is designed to be a full life cycle monitoring station with three principal goals. Primarily we strive to fill the data needs necessary to estimate these VSP parameters in one small basin. Secondarily, to provide the data necessary to interpret patterns in data gathered from less intensive abundance sampling on larger spatial scales and, lastly, investigate the relationship between watershed and habitat conditions and abundance and distribution of animals.

The first goal is to estimate the four fundamental parameters used to assess population viability. Principally, the focus is placed on estimating yearly abundance of adults and juveniles. A time series of this full life cycle abundance monitoring is then used to estimate both freshwater (summer and winter) and marine survival as well as the ratio of the number of recruits to the number of adults for a given brood year (productivity). Additionally, by following individual animals, we hope to define life history patterns as well as the spatial and temporal structure of the population(s).

The second goal is to define the relationships and sampling protocols necessary to appropriately gather data and interpret abundance sampling on larger spatial scales. For example, density dependant functions can make the interpretation of population trend from a time series of juvenile abundance unclear. Similarly, evaluating abundance data of adult spawners from carcasses, live fish, or redd counts remains ambiguous when variability in observation probability is unaccounted for between years or sites. By sampling at multiple life stages and using a permanent counting fence to enumerate adults, we strive to investigate both the dynamics of cohort abundance through time as well as investigate biases associated with adult and juvenile sampling techniques.

The third goal investigates habitat-fish productivity relationships and habitat restoration effectiveness. If survival between successive life stages and associated habitat and environmental conditions are monitored, this information can be used to target recovery actions which can be taken to improve survival at specific stages in the salmonids life cycle.

Life cycle monitoring in Freshwater Creek seeks to answer: 1) whether trends in coastal salmonid abundance are due to changes in freshwater and/or marine survival, 2) what is the spatial and temporal structure of Freshwater Creek salmonid populations (e.g. spawning group distribution and connectivity), 3) is survival at various life stages and habitat and environmental conditions correlated, and 4) what life stage or stages limiting adult production are conducive to efforts to improve survival.

The difficulty in operating a counting fence to completely census adult salmonids has lead to the development of various approaches to estimate salmonid spawning abundance.   Various methods have been applied to estimate the escapement salmon including using partial fence counts and mark-recapture data (e.g. Labelle 1994), area under the curve (AUC)(English et. al. 1992), and redd areas (Gallagher 2002).

We collected data applicable to estimating salmonid escapement into Freshwater Creek by combining weir marking with either 1) carcass recovery for salmon, or 2) recapture of downstream migrating kelts for steelhead, in a simple Petersen change in ration estimator. We then confront data gathered from redd enumeration and measurements, and live fish counts with the robust weir-carcass mark-recapture abundance estimates.

Objectives

This study is designed to; i) monitor adult steelhead, coho salmon, and Chinook salmon escapement into Freshwater ii) determine adult spawning distribution iii) collect information on age structure, life history and genetics of adult salmon and steelhead iv) evaluate spawning surveys as a tool to estimate spawning escapement.

Study Area Description

The Freshwater Creek basin is located in Humboldt County between Eureka to the south and Arcata to the north (Figure 1). Freshwater Creek is a fourth order stream that has a drainage area of approximately 9227 hectares (31 square miles) and drains into Humboldt Bay via the Eureka Slough. Elevations in the watershed range from 823 meters at the headwaters to sea level at the mouth. Main stem Freshwater Creek is approximately 23 km long, of which 14.5 km is anadromous fish habitat. Five main tributaries, Little Freshwater, Graham Gulch, Cloney Gulch, McCready Gulch and South Fork Freshwater each provide 2 to 4 km of anadromous fish habitat.

Annual rainfall amounts to approximately 150 cm in the headwaters and 100 cm near the mouth. The lower 6 km of Freshwater Creek is primarily cattle grazing land and is characterized by a low gradient, with limited riparian development. Levees confine the channel in this reach. Upstream of this section, the riparian community is much more highly developed, composed of willow (*Salix spp.)*, alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), blackberry (*Rubus ursinus*), salmonberry (*Rubus spectasbilis*), and other herbaceous plants. Bordering the riparian areas are forests of redwood (*Sequoia sempervirens*), Douglas-fir (*Psuedotsuga menziesii*), white fir (*Abies concolor*) and Sitka spruce (*Picea sitchensis*).

The fishery resources of the basin include three species of salmon, Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*). Occasionally, chum salmon (*O. keta*) are observed. Other fish present in the basin include Pacific lamprey (*Entosphenus tridentatus*), brook lamprey (*Lampreta pacifica*), cutthroat trout (*O. clarki*), and prickly and coast range sculpin (*Cottus asper*, *Cottus aleuticus*).

Amphibians and reptiles present include pacific giant salamanders (*Dicamptodon ensatus*), red legged frogs (*Rana boylii*), tailed frogs (*Ascaphus truei*) and western pond turtles (*Clemmys marmorata*).

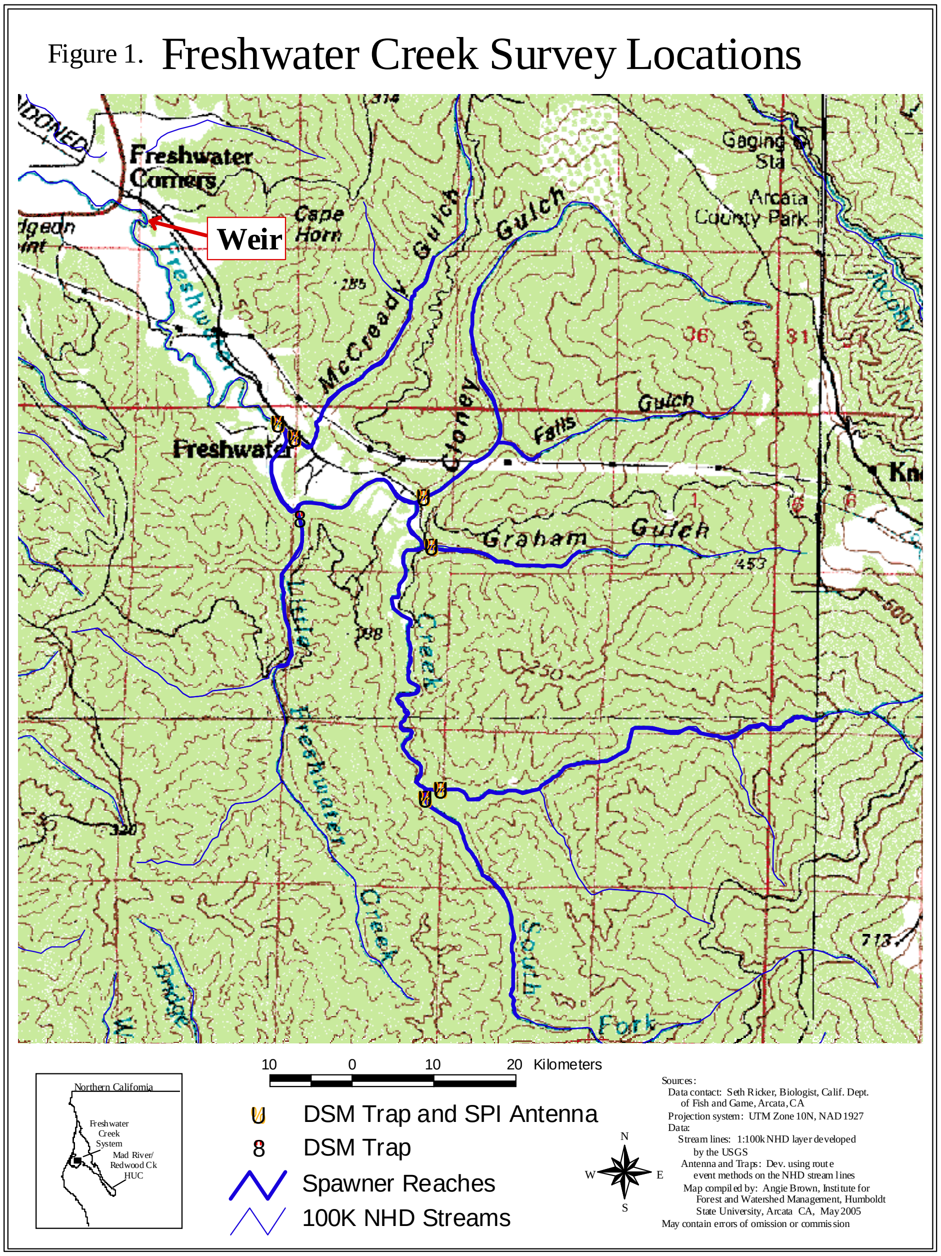

Figure 1. Freshwater Creek basin, depicting relative location in Humboldt County, and the location of the weir.

METHODS

Weir Mark – Recapture

Peterson type (change in ratio) estimator was used to calculate steelhead and salmon escapement (Ricker 1975). This estimator was applied to fish marked at a permanent weir facility, released upstream and recaptured either as carcasses (salmon and steelhead) or as post spawn downstream migrating kelts (steelhead only) post spawning.

Trapping & Marking A permanent weir site located near “Three Corners” approximately 5 river kilometers (rk) upstream from the mouth of Freshwater Creek where it enters Humboldt Bay. The weir is constructed of a series of metal panels, which are attached to a concrete base on the creek bed and concrete abutments on either bank. Each panel can be raised and lowered independently for cleaning purposes or when flows preclude trapping. The trap is located on the northern side of the weir structure and consists of two concrete walls on each side and metal panels on the up- and downstream ends. Fish volitionally enter the trap through two fyke panels attached to the downstream side of the trap. Captured fish were netted and placed in a tagging cradle for biological sampling. Each fish was measured for fork length, examined for fin-clips, punches, tags, predator marks and other wounds, and sexed. Scale samples were collected from the appropriate location, posterior to the dorsal fin between the lateral line and the dorsal. The trap is operated continuously between the first fall rains in late October or early November to early June with eight days untrappable due to high flows.

Prior to release, steelhead received an individual identifying 32mm passive integrated transponder (PIT) tag. The tag is injected anteriorly directly beneath the skin in the same area as the scale sample is taken. The skin is then sealed closed with veterinary skin adhesive. Salmon were given an hole punch to the operculum plate using a standard circular paper punch. All fish were then released immediately upstream of the trapping facility. The procedure is accomplished quickly while the fish is submerged in a sampling cradle without the use of anesthetic.

Steelhead Tag Recovery We obtain the recovery sample by capturing post spawn downstream migrating steelhead kelts with a pipe trap at the weir and at juvenile down stream migrant traps (see project 2a6) or as carcasses found on the spawning grounds. Numbers of unmarked and marked steelhead were recorded at the downstream traps. Unmarked kelts captured at the juvenile traps received a PIT tag to identify them as “counted” if they were captured again at any of the other traps. All kelts were then released to return to the ocean.

Salmon Tag Recovery We obtain the recovery sample by inspecting carcasses during surveys of the spawning grounds. During each survey, carcasses were inspected for opercle plate punches, given a uniquely numbered jaw tag, and returned to the area of “capture” (see Spawning Ground Survey).

Spawning Ground Survey

The area of potential spawning habitat within Freshwater Creek was divided into eight distinct reaches (Table 1). Spawning surveys were conducted on each reach weekly basis from December 1, 2002 to February 23, 2003 as flows and personnel allowed (Table 2). The temporal extent of both coho and Chinook salmon spawning was covered by these surveys, however, spawning surveys were discontinued prior to end of steelhead spawning. Each reach was measured by hip chain and meter markers posted at 100m intervals. The location of observed redds and fish were referenced to the posted markers. Surveys were conducted in an upstream direction with protocols developed by Gallagher (2002).

Fish

During each survey, live fish sightings were recorded by species, sex, location within the reach, and if the fish was actively guarding or building a redd. All carcasses encountered were recorded by species, sex, location, inspected for opercle punches, and given a uniquely numbered tag affixed to the jaw.

Redds

For each redd encountered, survey crews recorded an individual record number, including date and location of the redd within the channel on flagging tape, and tied the flag to the nearest vegetation above high water. The species of fish that made the redd was recorded if the fish was identifiable and still actively guarding the area. If no fish were present, both the pot and tailspill dimensions were measured.

<u>Redd Dimensions</u> The depth, width and length of the pot, and the length and two widths of the tailspill were measured (Figure 2). The dominant substrate in the pot and tailspill was recorded categorically as: 1= gravel < 1.0", 2= small cobble 1.0"-2.5",3= medium cobble 2.5"-4", 4=large cobble >4.0". The age of the redd was recorded as; 1= fish on redd, 2= new since last survey, 3= older, tailspill flat or pot with fines, 4= old and hard to discern, 5= no redd only a flag. Pot area was calculated as either a circle or oval depending on agreement of length and width measurements. Tailspill area was calculated as either a rectangle or triangle depending on length and width measurements (See Gallagher 2002). Total redd area is the sum of pot and tail areas.

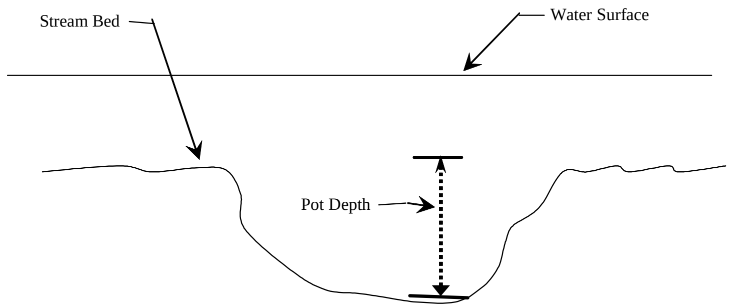

Figure 2. Schematic of salmonid redd pot depicting measurement of pot depth.

Table 1. Spawning survey reaches in Freshwater Creek, CA 2002-2003.

Reach Name	Reach Abbreviation	Start	end
McCready Gulch	MCR	300m	2500m
Cloney Gulch	CLO	Confluence with main stem	2900m
Falls Gulch	FAL	Confluence with Cloney G.	560m
Graham Gulch	GRA	Confluence with mainstem	1950m
Lower Main Stem	LMS	Howard Heights Bridge (D/S of Mcready G)	Confluence with Cloney G. 2633m
Middle Main Stem	MMS	Confluence with Cloney G.	Confluence with South Fork 4700m
Upper Main Stem	UMS (A) and (B) (Continuous)	Confluence with South Fork	4500m
South Fork	SFO	Confluence with main stem	3200m
Little Freshwater	LFR	Confluence with main stem	2510m

Data Analysis

Estimation of Population Abundance

Simple Petersen The Petersen mark- recapture method in which the recapture sample is drawn with replacement is represented by the formula:

$$\hat{N} = \frac{M(C+1)}{(R+1)}$$

Where $\hat{N}$ = Estimated population size

M = The number of marked fish

C = The number of fish in the recapture sample

R = The number of fish in the recapture sample that are marked

The estimated variance of this estimate is expressed as,

$$\hat{V}(\hat{N}) \approx \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)}$$

and 95% confidence intervals constructed as

$$\pm 2\sqrt{\hat{V}(\hat{N})}\ .$$

RESULTS

Adult Steelhead

Escapement Estimate: We captured and PIT tagged 91 upstream migrating steelhead. Eighteen of the 31 recaptured kelts were identified as having been tagged. The adult steelhead escapement to Freshwater Creek is estimated to be 172 ±54 (95% C.I.).

Size, Age and Sex Ratio: We identified 37 (41%) males and 53 (59%) female steelhead (Figure 3). Expanding the steelhead escapement point estimate by these sex ratios yields an estimated 63 male, 90 female steelhead.

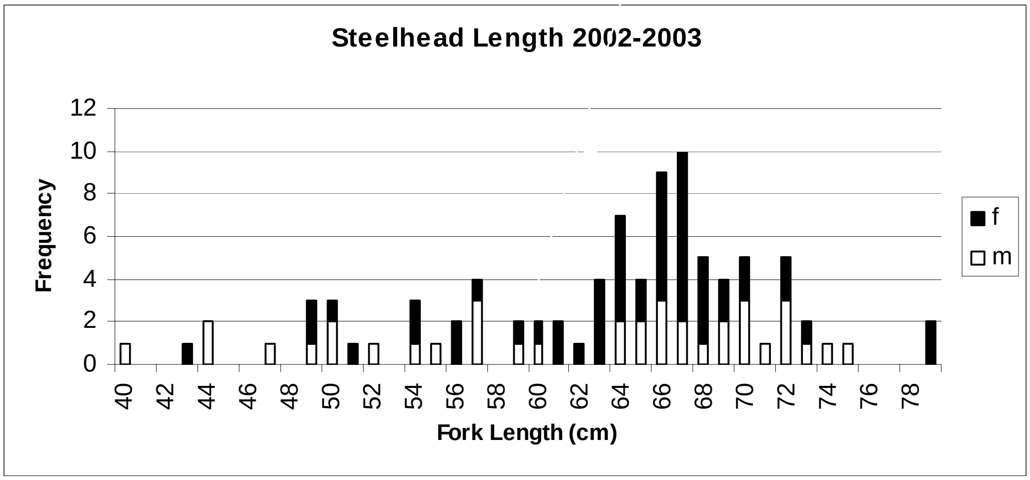

Figure 3. Length-frequency histogram of all adult steelhead captured at the weir on Freshwater Creek, 2002-2003.

Run Timing: The first steelhead was captured at the weir on December 22, 2002. The captures peaked February 16, 2003, and the last fish was captured April 12, 2003 (Figure 4). No steelhead carcasses were marked nor recovered.

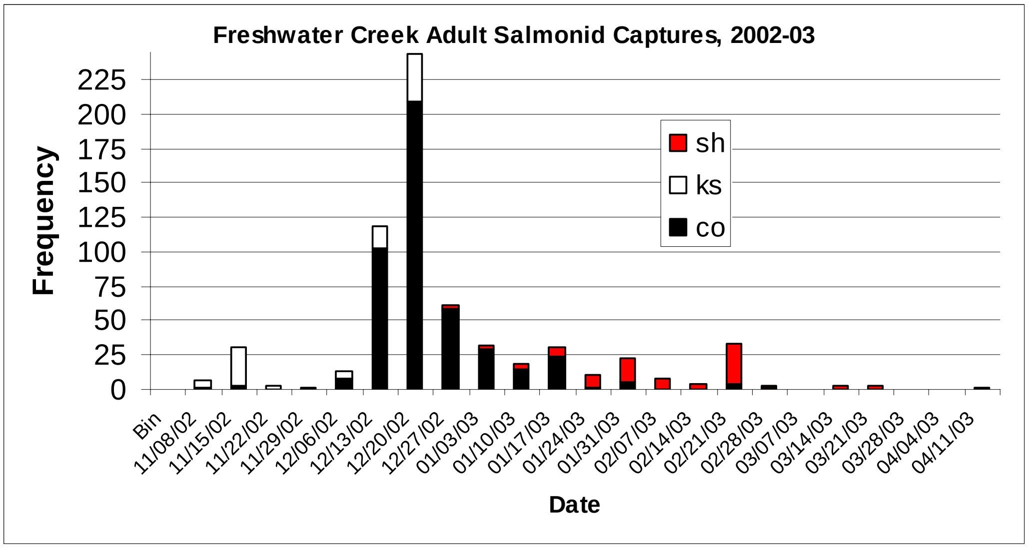

Figure 4. Temporal distribution of all salmonids captured at the Freshwater weir, 2002-2003.

Coho Salmon

Escapement Estimate :We opercle punched 456 of 459 captured adult coho salmon. Fifty Two of the 209 carcasses were identified as having received a mark at the weir. The adult coho salmon escapement into Freshwater Creek is estimated to be 1754 ± 477 (95% C.I.).

Size, Age and Sex Ratio: Coho salmon ranged in size between 34cm and 87cm averaging 65.5cm. By dividing the histogram at the nadir of 54cm, it is estimated that 20% of the adult coho run is age 2 and 80% age 3 . Ninety seven percent of the 2 year old fish are male and 3% female. Conversely, the three year old fish are comprised of equal portions of males and females (Figure 5). Expanding the coho salmon escapement point estimate by these age specific sex ratios yields an estimated 1073 male coho and 734 female coho.

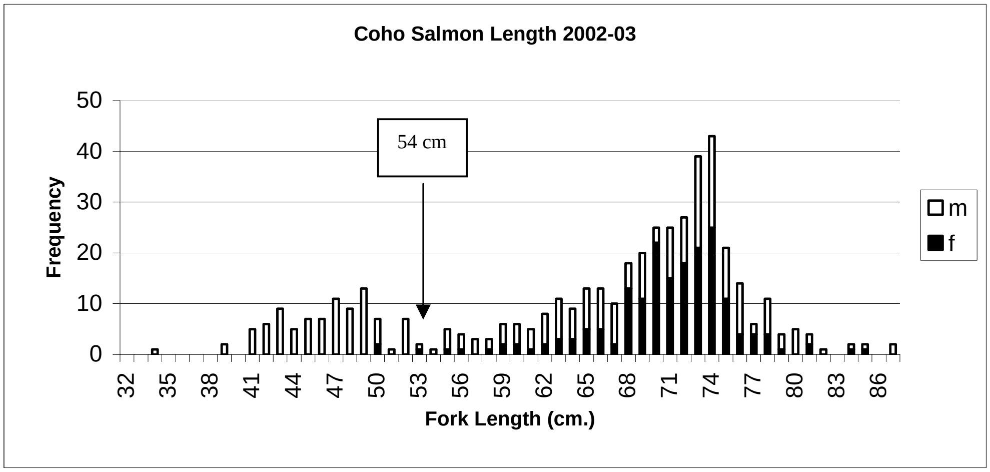

Figure 5. Length frequency histogram of adult coho salmon captured at the weir, Freshwater Creek, 2003-2003.

Run Timing: The first coho salmon was captured at the weir or November 8, 2002. Weir captures peaked on December 19, 2002, and the last coho was captured on February 22, 2003 (Figure 4). The first identified coho redd was seen on December 23, 2002. Redd observations peaked on January 9, 2003, and the last new redd was observed February 5, 2003. The first coho carcass was found and identified on January 7, 2003. Carcass numbers peaked on January 21, 2003, and the last carcass was seen on February 14, 2003 (Figure 6). The time between peak weir capture to peak redd observation is 21 days. The time between peak redd observations and peak carcass count is 12 days (Figure 6).

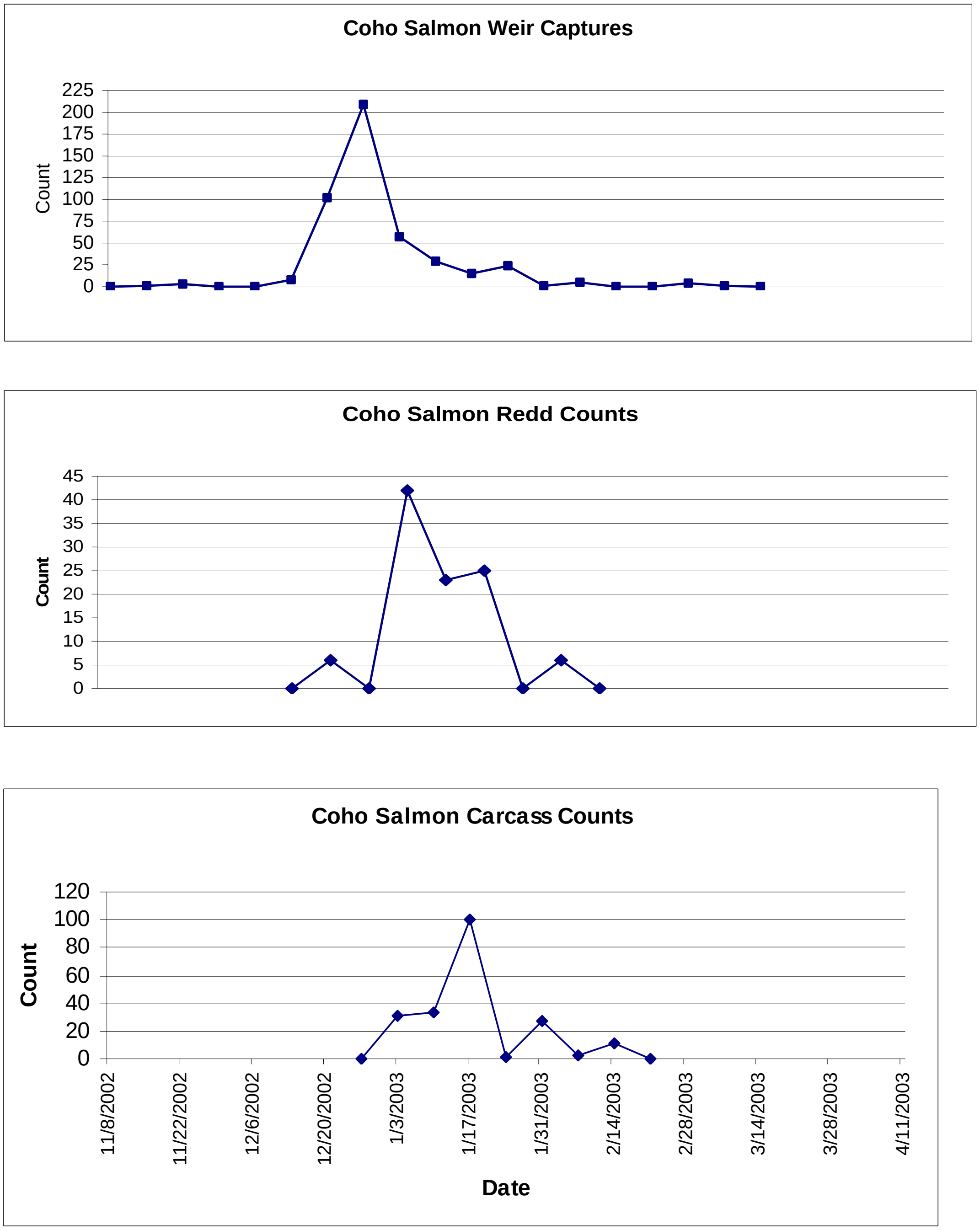

Figure 6. Date of coho salmon weir captures, redd observations, and carcass counts in Freshwater Creek, 2003-2003.

Chinook Salmon

<u>Escapement Estimate:</u> We opercle punched 52 of 95 captured adult Chinook salmon. Nine of the 25 carcasses were identified as having received a mark at the weir. The adult chinook salmon escapement into Freshwater Creek is estimated to be 133 ± 63 (95% C.I.).

<u>Size and Sex Ratio:</u> Chinook salmon ranged in size between 42 cm and 116 cm and average 84cm. Sixty two percent of the captured Chinook are female and the remaining 38% male (Figure 7). Expanding the Chinook salmon escapement point estimate by these sex ratios yields an estimated 51 male Chinook and 84 female Chinook.

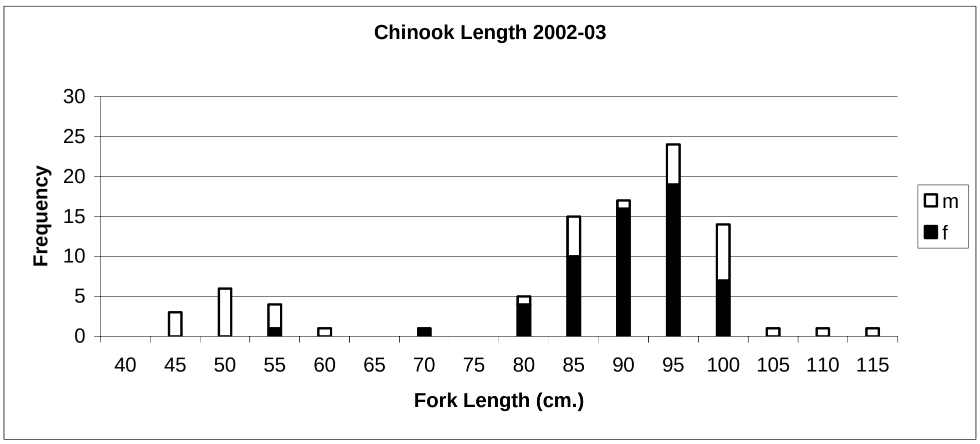

Figure 7. Length-frequency of male and female Chinook salmon captured at the Freshwater weir, 2002-2003.

<u>Run Timing:</u> The first Chinook salmon was captured at the weir or November 8, 2002. Weir captures peaked on December 14, 2002, and the last Chinook was captured on December 24, 2003 (Figure 4). The first identified Chinook redd was seen on at the peak on December 23, 2002. The last new redd was observed January 9, 2004. The first Chinook carcass was found and identified on January 6, 2004. Carcass numbers peaked on January 9, 2004, and the last carcass was seen on January 21, 2003 (Figure 7). The time between peak weir capture to peak redd observation is 9 days. The time between peak redd observations and peak carcass count is 3 days (Figure 7).

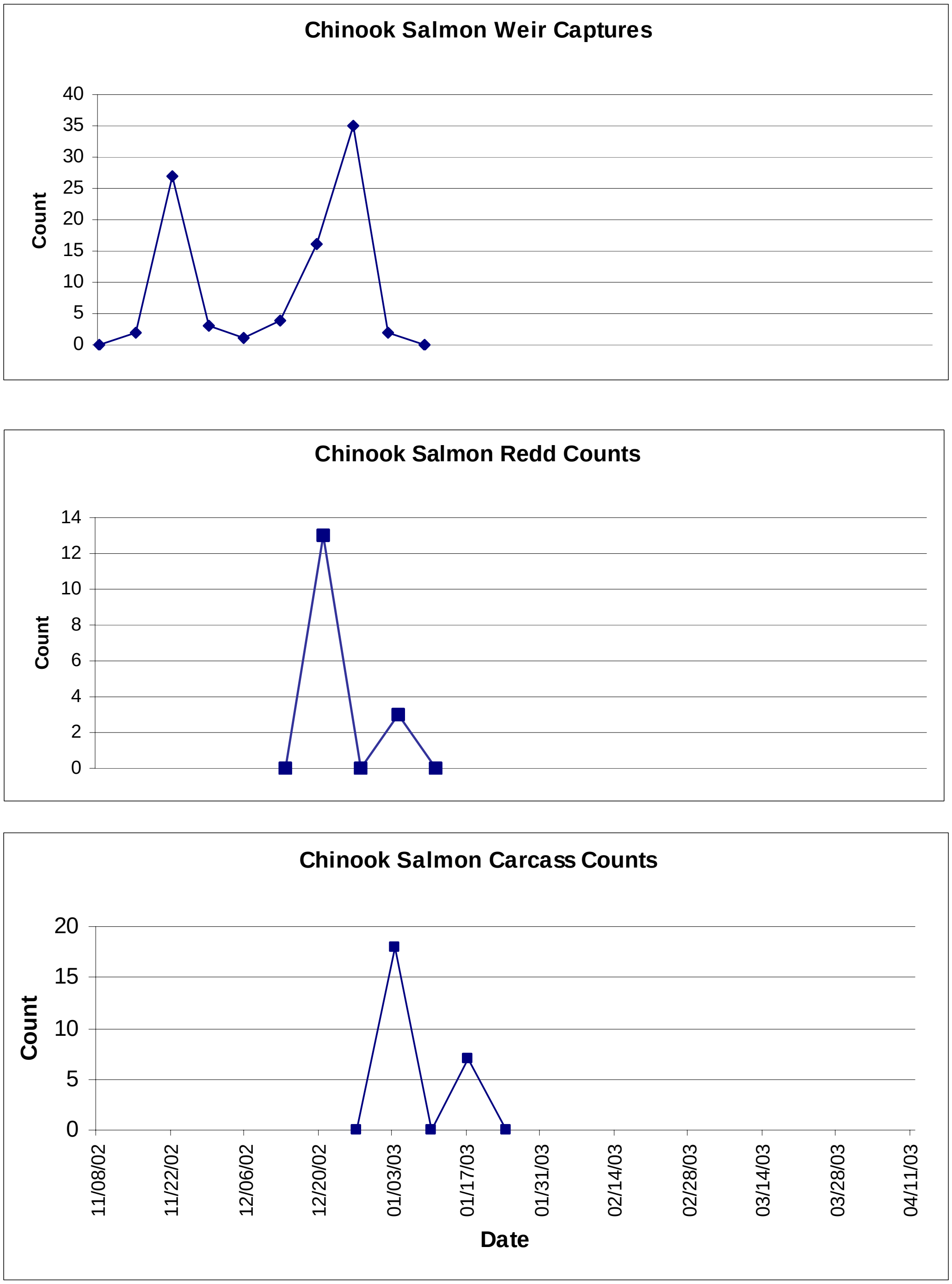

Figure 8. Date of Chinook salmon weir captures, redd observations, and carcass counts in Freshwater Creek, 2003-2003.

Spawner Survey

Forty three spawner surveys were conducted between December 1, 2002 and February 23, 2003 (Table 2) . A total of 323 redds were observed. Categorizing observed redds by species observed either building or guarding the redds, or as unknown (no or unidentifiable fish present) generates 117 coho salmon, 13 Chinnook salmon, 0 Steelhead and 193 unidentified redds. Forty-eight Chinook, 327 coho, and 15 unknown live fish observations were made throughout the entire survey. The highest density of redds occurred in the UMS reach. Figure 8 depicts the distribution of redds within Freshwater Basin.

Table 2. Spawning surveys conducted in Freshwater Creek, 2002-2003.

Week \ Reach	LMS	MMS	UMSA	UMSB	MCR	LFW	CLO	FAL	GRA	SFO
12/1/2002	X	X	X	X						
12/8/2002	X	X				X			X	X
12/15/2002										
12/22/2002			X							
12/29/2002										
1/5/2003	X	X	X	X	X	X			X	X
1/12/2003			X							X
1/19/2003	X	X	X	X	X	X	X	X	X	X
1/26/2003										
2/2/2003	X	X	X	X	X	X	X	X	X	X
2/9/2003										X
2/16/2003										
2/23/2003			X	X						

Redd Characteristics

Coho Salmon : Coho salmon total redd areas ranged from 0.35 m^2 to 4.5 m^2, and averaged 2.07 m^2 (Figure 9). Pot areas ranged from 0.22 m^2 to 3.6 m^2 and averaged 1.39 m^2. Pot depths ranged from .03m to .40m and averaged 0.26m.

Chinook Salmon : Chinook salmon total redd areas ranged from 2.02 m^2 to 6.06 m^2, and averaged 3.54m^2(Figure 9). Pot areas ranged from 1.42 m^2 to 4.48 m^2 and averaged 2.60m^2. Pot depths ranged from 0.18m to 0.40m and averaged 0.29m (n=9).

Steelhead : No Steelhead redds were unambiguously identified this season.

Redd Longevity : Redds remained visible for an average of 33 d (SD=12). Figure 10 graphically depicts the attrition in visibility of all observed redds with stream discharge.

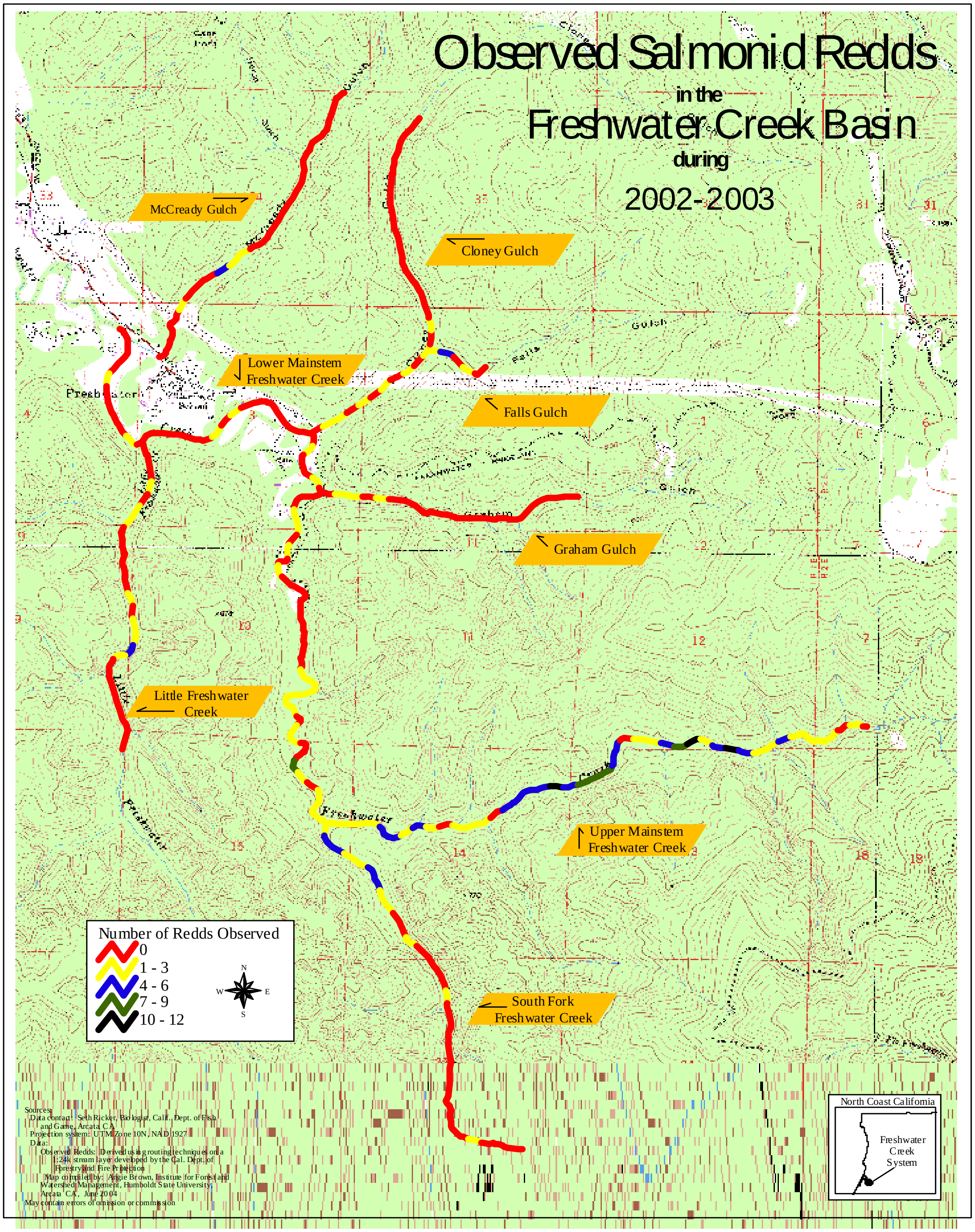

Figure 9. Map of Freshwater Creek basin depicting the density of observed redds during 2002-03 spawning ground surveys.

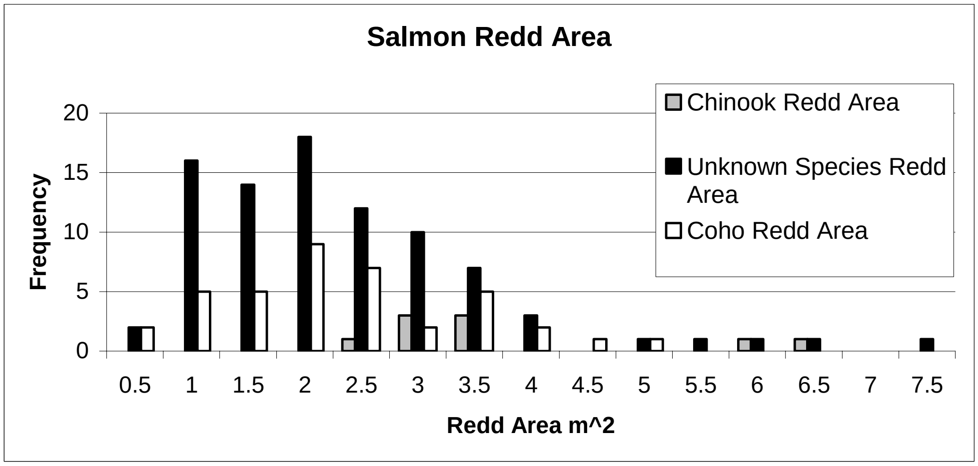

Figure 10. Frequency of Chinook salmon, coho salmon and unknown species redd areas.

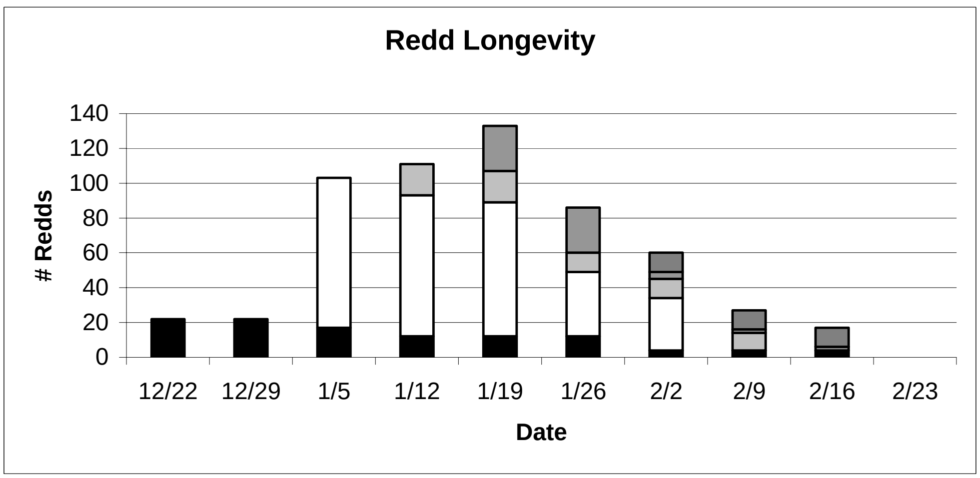

Figure 11. Attrition in visibility of observed redds in Freshwater Creek, 2002-2003. Colored bars depict total new redds observed by date of first observation and during subsequent surveys.

DISCUSSION

The timing between peak counts of fish captured at the weir, live fish observations and carcass captures is an indirect means of determining the average timing of spawning events (i.e. stream residence time, residence time of spawners constructing redds). The timing of these events directly effect Area Under the Curve (AUC) escapement estimates, particularly when residence time is not directly estimated with fish marking data (English et.al. 1992). It is apparent that the duration of time between these peak observations varies by species. Chinook salmon spent less time in the system, spawned and perished more quickly than coho salmon. At thirty three days between peak weir captures and peak carcass counts, individual live coho salmon could have potentially been counted four times if surveys are conducted on a weekly basis. At this timing, surveys directed at collecting live fish counts of coho salmon could be conducted less frequently than once per week (every 15d) without missing the opportunity to count all fish. Conversely, at 12 days between peak Chinook salmon wier counts and peak carcass counts, surveys directed toward enumerating Chinook need be conducted at least weekly.

The number of live fish observations made during the course of this study was small when we consider the number of adult fish estimated from the weir mark-recapture. Presumably, live fish counts alone would over-estimate fish abundance during multiple surveys by double counting individual fish. The AUC method for estimating spawning escapement compensates for double counting of live fish by dividing total fish days by an average residence time, then multiplies this by an estimate of observation probability (English et. al. 1992). We did not directly measure our observation efficiency, but by retrospectively comparing our counts to the number of fish we estimate to be in the basin, it appears our probability of seeing live fish was significantly less than 1.

Strict enumeration of redds has often been used as a relative measure spawning escapement. Expanding observed redd counts to the number of fish producing these redds, however, rests upon two basic assumptions that may be stated a variety of different ways. I will choose one permutation for the object of this discussion. First, we must assume that a fixed number of fish produce a single redd. Second, we observe the all the redds within the area of interest. Recent work by Gallagher et. al. (2002), consider the potential area of redd produced by a single female to be static, while allowing the number of individual redds produced by a single female to be dynamic, and thereby relieving the constraints of assumption one. These data collected in Freshwater Creek, however, do not support assumption two. We observed 323 total salmon redds and estimated an abundance of 907 combined female andromous Chinook and coho salmon and anadromous steelhead. If we assume we observed all redds, this ratio implies it takes an average of 2.8 females to build a single redd, or reciprocally a 0.36 redd to female ratio. This implication is unintuitive, and is likely due to failure of assumption 2 (i.e. true redd observation probability < 1). Similarly, the average redd area of 49 completed and measured redds is 2.3 m^2 in this study, and when multiplied by 323 total observed salmon redds yields 743m^2 of total redd area. Dividing this total redd area by the estimated number of females produces an average of 0.9m^2 per female. This is well below the figure of 5.25m^2 average coho redd area presented by Gallagher (2002) and is likely due to our survey crews failing to observe all redds.

The cause of this apparent discrepancy is likely due to variability in redd observation probability between sites. The hydrology and water clarity regimes may be drastically diverse across the landscape and between survey years. The temporal distribution of surveys in relation to hydrologic events could also potentially effect redd observation probability. For example, if a redd is constructed before or during a flow event, the substrate may become mobilized obscuring the redd and making it unavailable for observation during any survey period. Redds in this study were visible for an average of 33 days. This statistic however belies the individual fidelity of redds which is highly affected by the timing of hydrologic events (e.g. some redds visible for 3 days others 45).

The distribution of redds throughout the basin was not uniform. Spawning grounds in certain areas were highly utilized while others we apparently abandoned. This clumping of redds in both space and time, lead to a significant number of redds being superimposed upon other redds. This spawning behavior was problematic to individual redd discrimination. Once high density spawning sites were fully utilized it was very difficult for surveyors to discern if new redds were constructed upon older redds. Redd superimposition likely lead to under-counting in Freshwater Creek. This variability in redd observation probability, if unaccounted for, may make inference into status and trends in abundance from redd survey data unclear.

RECOMENDATIONS

The simple Petersen mark-recapture experiment used to estimate salmon and steelhead escapement in this study is likely an over-simplified model, which may lead to biased escapement estimates. We understand the capture efficiency of the weir varies through the salmon run with the magnitude and duration of stream discharge. A mark-recapture model applied to this scenario should be sensitive to heterogeneity in capture efficiency. It is recommended that marks given at the weir be stratified by time, and applied in a model structure that accounts for variable proportions of fish marked throughout the period of salmon immigration.

The timing of spawning events described in this report are derived from differences in observed peaks of spawning events, and therefore do not represent the true distribution of spawning event timing based on individual data. It is therefore recommended that individual PIT tags be given to salmon as well as steelhead. This data will allow future surveys to detect timing in spawning events at the individual level imposing no potential bias.

More research needs to be conducted to evaluate the magnitude of biases in estimates of salmon escapement derived from spawning survey data only. Research directed at illuminating the underlying behavior of spawning salmon, the timing of spawning events, and the potential sources of observation variability will likely lead to a greater understanding of the efficacy of spawning ground surveys to track trends in salmon abundance.

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