SCIENTIFIC REPORT
PREPARED IN PARTIAL FULFILLMENT OF CALIFORNIA ADAPTIVE WATERSHED IMPROVEMENT
Grantee Agreement No.: CAWIP-NR-35

FRESHWATER CREEK ADULT SALMONID ESCAPEMENT, 2004

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February 2005

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ABSTRACT

Adult steelhead escapement into Freshwater Creek was estimated using a Petersen type mark-recapture experiment. Steelhead trout (*Oncorhynchus mykiss*) 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 432 ± 46 (95% C.I.). Adult salmon were marked at the weir by a small hole punched in the operculum and carcasses were recaptured on the spawning grounds. A temporally stratified mark-recapture model was used to estimate the escapement of adult coho salmon (*O. kisutch*). The escapement of coho salmon is estimated at 730 ± 50 (95% C.I.). Fourteen adult Chinook salmon (*O. tshawytscha*) were captured at the weir facility, but an estimate of total escapement could not be made. During the survey period, 592 anadromous salmonid redds and 464 live fish were observed. The large discrepancy between *observed* redds and live fish and the *estimated* number of spawning females and total fish suggest that both live salmonids and their redds were undercounted.

ACKNOWLEDGEMENTS

The Freshwater Creek Salmonid Monitoring Project would like to thank the Humboldt Fish Action Council, the landowners of Freshwater Creek who allowed us access to trapping sites, Pacific Lumber Company for their support, the Institute for River Ecosystems for their technical and administrative assistance, and the AmeriCorps Watershed Stewards Project for their help in monitoring traps. This work was made possible by a grant from California Adaptive Watershed Improvement.

INTRODUCTION

The California Department of Fish and Game and the National Oceanic and Atmospheric Administration ~ Fisheries recognize four key parameters for assessing the long term viability of salmonid populations. These VSP (viable salmonid population) parameters are population size, population growth rate (productivity), population spatial structure, and life history diversity (McElhany et al. 2000). The Freshwater Creek Salmonid Monitoring Project is designed to be a full life cycle monitoring station with three principal goals. The primary goal is to obtain all the necessary data needed to estimate the VSP parameters in one small basin. A secondary goal is to provide data that will help interpret patterns in data gathered from less intensive abundance sampling on larger spatial scales. Lastly, the project seeks to 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, the project hopes 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, the dynamics of cohort abundance through time as well as biases associated with adult and juvenile sampling techniques can be fully investigated.

The third goal is to examine 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 salmonid life cycle.

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

The difficulty of operating a counting fence to completely census adult salmonids has led to the development of various approaches for estimating salmonid spawning abundance. These methods include 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).

Data applicable to estimating salmonid escapement into Freshwater Creek was collected using a mark-recapture experiment. For the experiment, weir marking was combined with either, in the case of salmon, carcass recovery or, in the case of steelhead, recapture of downstream migrating kelts at the weir. Data gathered from a) redd enumeration and measurements and b) live fish counts were then compared with the robust weir-carcass mark-recapture abundance estimates.

Objectives

The Freshwater Creek Salmonid Monitoring Project is designed to i) monitor adult steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and Chinook salmon (*O. tshawytscha*) escapement into Freshwater Creek, ii) determine adult spawning distribution, iii) collect information on age structure, life history and genetics of adult salmon and steelhead, and 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, which drains into Humboldt Bay via the Eureka Slough, is a fourth order stream with a drainage area of approximately 9227 hectares (31 sq. mi.). Elevations in the watershed range from 823 meters at the headwaters to sea level at the mouth. The mainstem of 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 is approximately 150 cm in the headwaters and 100 cm near the mouth. Levees confine the channel in the lower 6 km and the surrounding land is primarily used for cattle grazing. This section is characterized by low gradient and limited riparian development. Upstream, the riparian community is more developed and is composed of willow (*Salix spp*.), red 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 trout (*O. mykiss*). Occasionally, chum salmon (*O. keta*) are observed. Other fish present in the basin include Pacific lamprey (*Entosphenus tridentatus*), Pacific brook lamprey (*Lampetra 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 Survey Locations

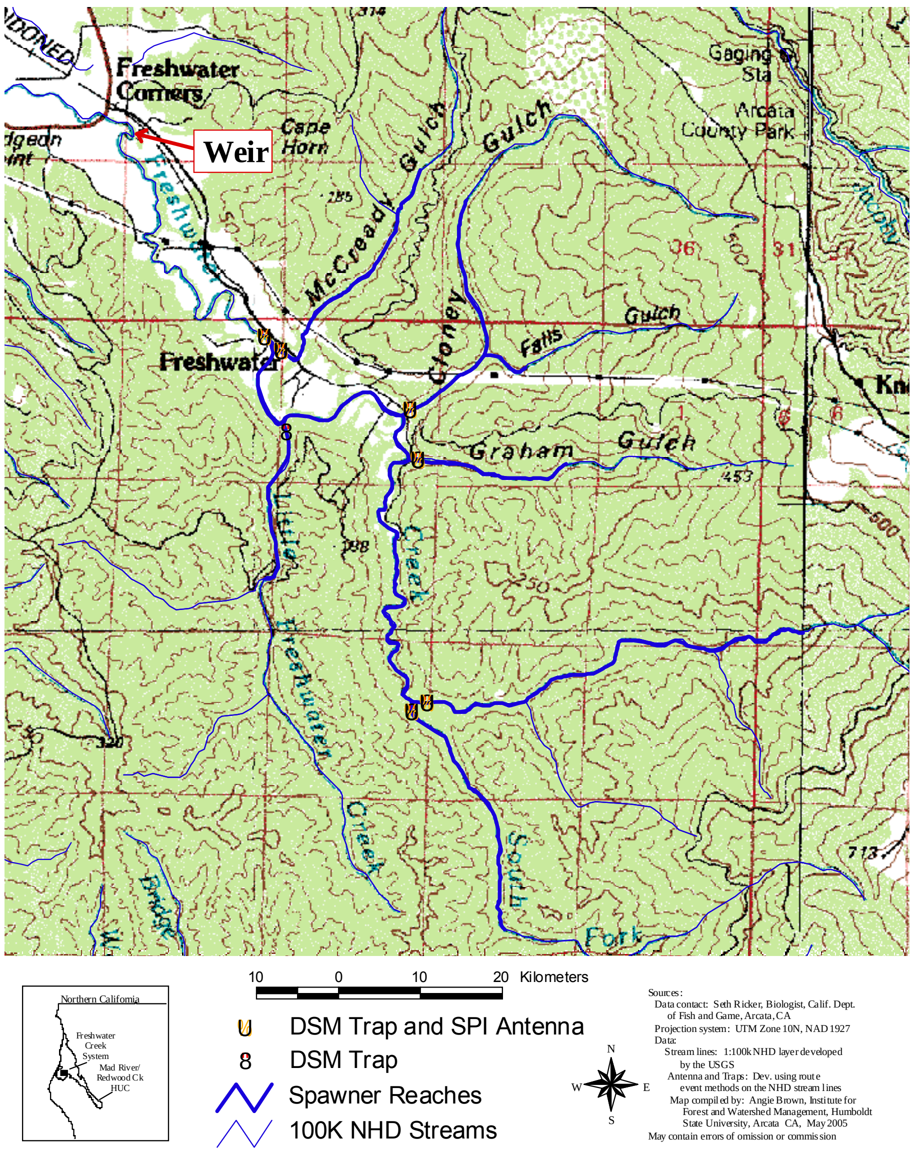

Figure 1. This figure depicts the relative location of the Freshwater Creek basin in Humboldt County, and the location of the weir.

METHODS

Escapement Estimation

Trapping & Marking

Adult fish were captured at a permanent weir facility located near “Three Corners”, which is 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 that 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 portion of the weir is located on the northern side of the structure and consists of two concrete walls on each side and metal panels on the upstream and downstream ends. Fish migrating upstream voluntarily entered the trap through two metal fyke panels attached on the downstream side. The trap was operated continuously from the first fall rains in late October or early November, 2003 until early June, 2004. During this period, the trap was inoperable for eight days due to high flows.

At the weir, captured fish were netted and placed in a tagging cradle for biological sampling. Each fish was identified to species, measured for fork length, examined for fin-clips, punches, tags, predator marks and other wounds, and sexed. Scale samples were collected from an area located posterior to the dorsal fin between the lateral line and the dorsal. Prior to release, steelhead received an individual identifying 32mm PIT (passive integrated transponder) tag. The tag was injected anteriorly, just beneath the skin, in the same area where the scale sample was taken. The broken skin was then sealed closed with veterinary skin adhesive. Salmon were given a hole-punch to the operculum using a standard circular paper hole-punch. All fish were then released immediately upstream of the trapping facility. These biological procedures were accomplished quickly while the fish was submerged in a sampling cradle without the use of anesthetic.

Steelhead Tag Recovery

For steelhead, the recovery sample was obtained in either of two ways. Post-spawn downstream migrating kelts were captured a) at the weir using a pipe trap or b) at several locations where juvenile downstream migrant traps were set up (see project 2a6). In addition, recovery samples were also obtained from carcasses found on the spawning grounds. Numbers of marked and unmarked steelhead were recorded at the downstream traps. Unmarked kelts captured at the juvenile trap locations received a PIT tag to identify them as “counted” in the event that they were captured again at any of the other traps. All kelts were then released to return to the ocean.

Salmon Tag Recovery

Recovery samples for salmon were obtained by inspecting carcasses during surveys of the spawning grounds. During each survey, carcasses were inspected for operculum punches, given a uniquely numbered jaw tag, and returned to the area of “capture” (see Spawning Ground Survey).

Data Analysis

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

A temporally stratified mark-recapture estimator was used to calculate coho salmon escapement. The mark-recapture data was analyzed using Darroch Analysis with Ranked Regression (DARR) to produce bounded estimates of abundance (Darroch 1961, Bjorkstedt pers. comm.). Briefly, this method is a stratified mark-recapture experiment that estimates capture probability for each period, accounting for the effects of spawn timing on the pool of marked fish susceptible to capture during each period. Strata that contain problematic structure for Darroch (1961) analysis are combined to neighboring strata thereby reducing the rank of the data to the least possible extent to produce a dataset amenable to analysis (Bjorkstedt pers. comm.).

Spawning Ground Survey

The area of potential spawning habitat within Freshwater Creek was divided into eight distinct reaches (Table 1). Spawning surveys were conducted in each reach on a weekly basis from December 1, 2003 to February 23, 2004 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 the end of steelhead spawning. Each reach was measured by hip chain, and meter markers were 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, the following information was recorded for all live fish sightings: species, sex, location within the reach, and if the fish was actively guarding or building a redd. All carcasses encountered were inspected for operculum punches, given a uniquely numbered tag affixed to the jaw, and species, sex, and location within the reach were recorded.

Redds

Each redd encountered was given an individual record number, including date and location of the redd within the channel. This information was recorded on datasheets and on flagging tape tied to the nearest vegetation above high water. If the fish was identifiable and still actively guarding the area, then the species of fish that made the redd was recorded. If no fish were present the pot and tailspill dimensions were measured.

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", and 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, and 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.

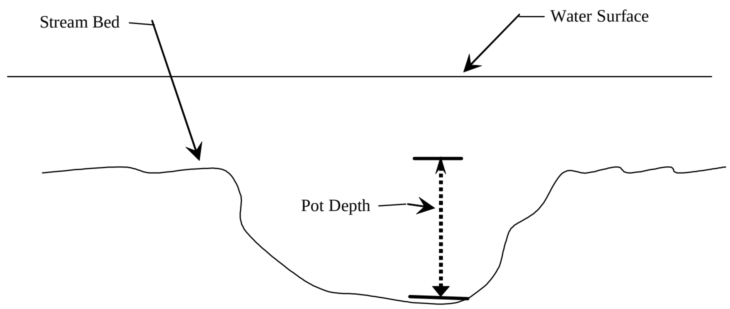

Figure 2. Schematic of salmonid redd pot depicting measurement of pot depth.

Table 1. Spawning survey reaches in Freshwater Creek, CA 2003-2004.

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 Gulch	560m
Graham Gulch	GRA	Confluence with mainstem	1950m
Lower Main Stem	LMS	Howard Heights Bridge (D/S of Mcready Gulch)	Confluence with Cloney Gulch 2633m
Middle Main Stem	MMS	Confluence with Cloney Gulch	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

RESULTS

Steelhead

Escapement Estimate: During the study period, 319 upstream migrating steelhead were captured and PIT tagged. Eighty-nine of the 121 recaptured kelts were identified as having been tagged. The adult steelhead escapement to Freshwater Creek was estimated to be 432 ± 46 (95% C.I.).

Size, Age and Sex Ratio: 128 (40%) male and 190 (60%) female steelhead were identified (Figure 3). Expanding the steelhead escapement point estimate by these sex ratios yields an estimate of 173 male and 259 female steelhead.

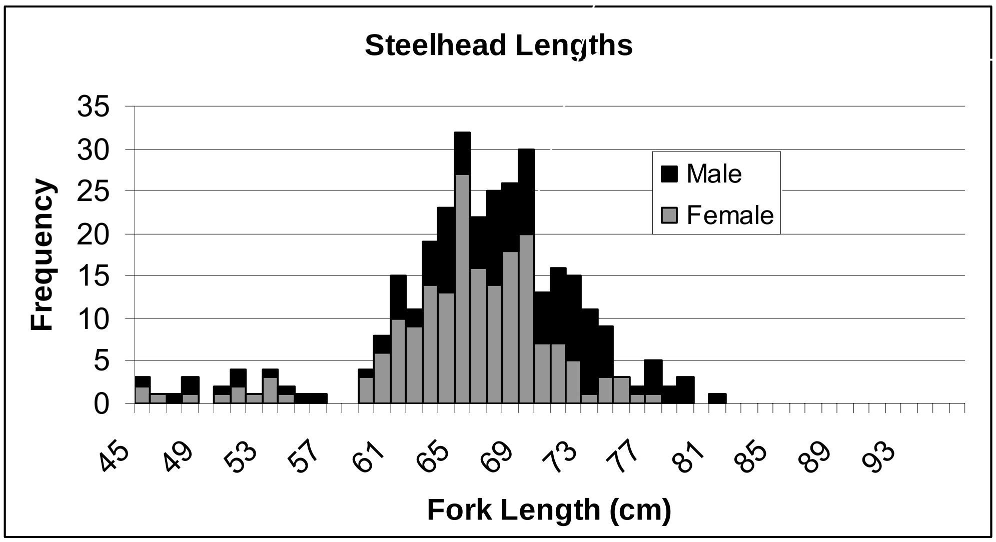

Figure 3. Length-frequency histogram of all adult steelhead captured at the weir on Freshwater Creek, 2003-2004.

Run Timing: The first steelhead was captured at the weir on December 08, 2003. The captures peaked January 27, 2004 and the last fish was captured March 23, 2004 (Figure 4). No steelhead carcasses were either marked or recovered.

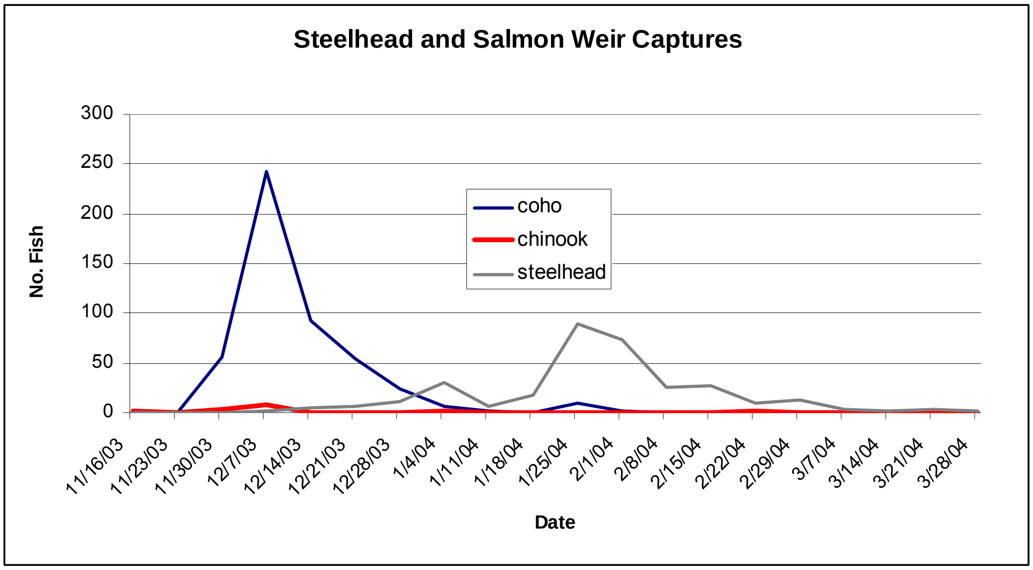

Figure 4. Temporal distribution of all salmonids captured at the Freshwater weir, 2003-2004.

Coho Salmon

Escapement Estimate: During the study period, 453 captured adult coho salmon were marked with operculum punches. Seventy-five of the 121 carcasses were identified as having received a mark at the weir. The temporally stratified mark-recapture data was amalgamated to a single mark-recapture experiment for analysis. The adult coho salmon escapement into Freshwater Creek was estimated to be 731 ± 50 (95% C.I.).

Size, Age and Sex Ratio: Coho salmon ranged in size from 39cm to 83cm, averaging 66cm. By dividing the histogram at the nadir of 54cm, it is estimated that 8% of the adult coho run are age two and 92% are age three. Seventy-five of the two year old fish are male and 25% are female. The three year old fish are comprised of 58 % female and 42% male (Figure 5). Expanding the coho salmon escapement point estimate by these age specific sex ratios yields an estimate of 352 male and 404 female coho.

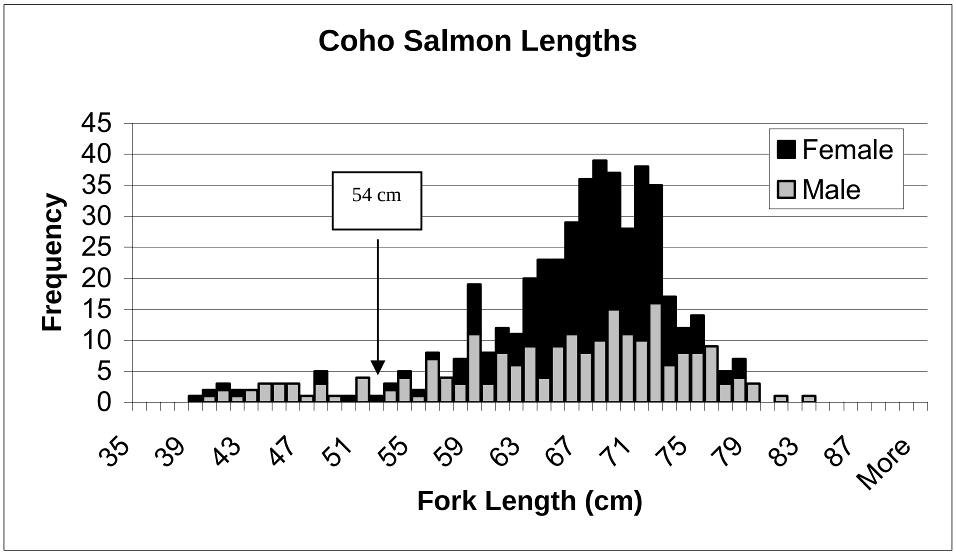

Figure 5. Length frequency histogram of adult coho salmon captured at the weir, Freshwater Creek, 2003-2004.

Run Timing: The first coho salmon was captured at the weir on November 16, 2003. Weir captures peaked on December 8, 2003, and the last coho was captured on January 31, 2004 (Figure 4). The first identified coho redd was seen on December 2, 2003. Redd observations peaked on January 5, 2004, and the last new redd was observed January 22, 2004. The first coho carcass was found and identified on January 17, 2004. Carcass numbers peaked the week of January 12, 2004 and the last carcass was seen on February 23, 2004 (Figure 6). The time between peak weir capture to peak redd observation was 28 days. The time between peak redd observations and peak carcass counts was seven days (Figure 6).

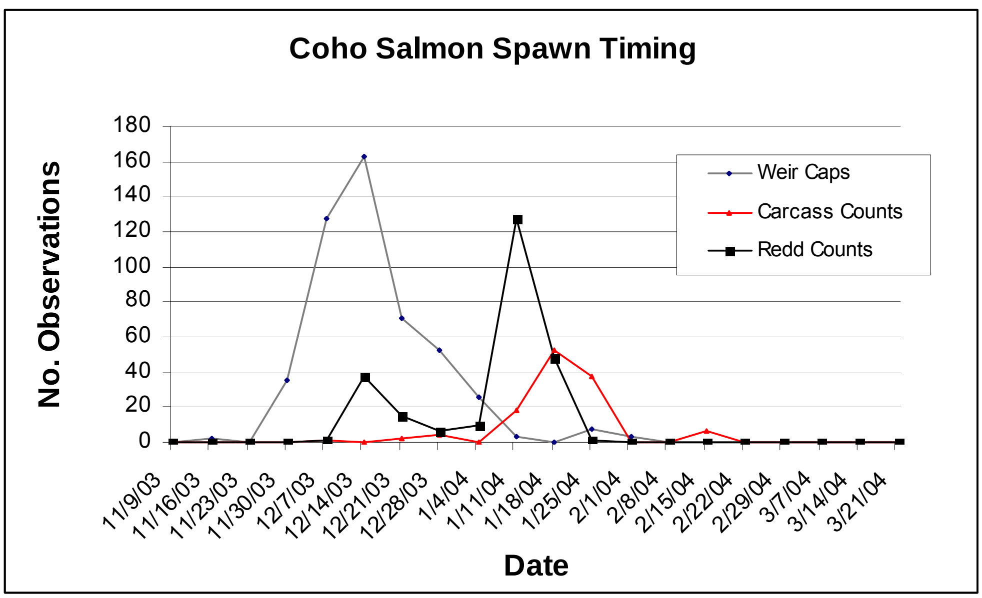

Figure 6. Date of coho salmon weir captures, redd observations, and carcass counts in Freshwater Creek, 2003-2004.

Chinook Salmon

Escapement Estimate: Only fourteen Chinook salmon were captured at the weir. No estimate of escapement is produced due to low sample size and few carcass recaptures.

Size and Sex Ratio: Chinook salmon ranged in size from 55 cm to 104 cm, averaging 73cm. Six of the fourteen captured Chinook were female; the remaining eight were male.

Run Timing: The first Chinook salmon was captured at the weir on November 15, 2003. The last Chinook was captured on February 9, 2004.

Spawner Survey

Eighty-five spawner surveys were conducted between November 23, 2003 and March 24, 2004 (Table 2). A total of 547 redds were observed. Redds were categorized by species if a fish was observed either building or guarding the redd *and* the fish could be identified to species. If no fish was observed near the redd or if the species type could not be identified, then the redd was categorized as unknown. Categorizing the redds in this way attributed 159 redds to coho salmon, 3 to Chinook salmon, 1 to steelhead trout, and left 429 as unknown. Four Chinook, 447 coho, and 17 unknown live fish observations were made throughout the entire survey. The highest density of redds occurred in the upper mainstem reach. Figure 8 depicts the distribution of redds within the Freshwater Creek basin.

Table 2. Spawning surveys conducted in Freshwater Creek, 2003-2004.

Week	**Reach**									
	MCR	CLO	FAL	GRA	UMSA	UMSB	SFO	LFR	LMS	MMS
11/23	X	X	X	X	X	X	X	X	X	X
11/30	X	X	X	X	X	X	X	X	X	X
12/07	X	X			X	X	X			X
12/14				X	X	X		X		X
12/21	X	X	X		X	X	X			
12/28									X	
01/04	X	X	X	X	X	X	X	X	X	X
01/11	X	X	X	X	X	X	X			
01/18	X	X	X	X	X	X	X	X	X	X
01/25					X					
02/01										
02/08	X	X	X	X	X	X	X	X	X	X
02/15										
02/22	X	X	X	X			X			
02/29										
●	●	●	●	●	●	●	●	●	●	●
03/24					X	X			X	X

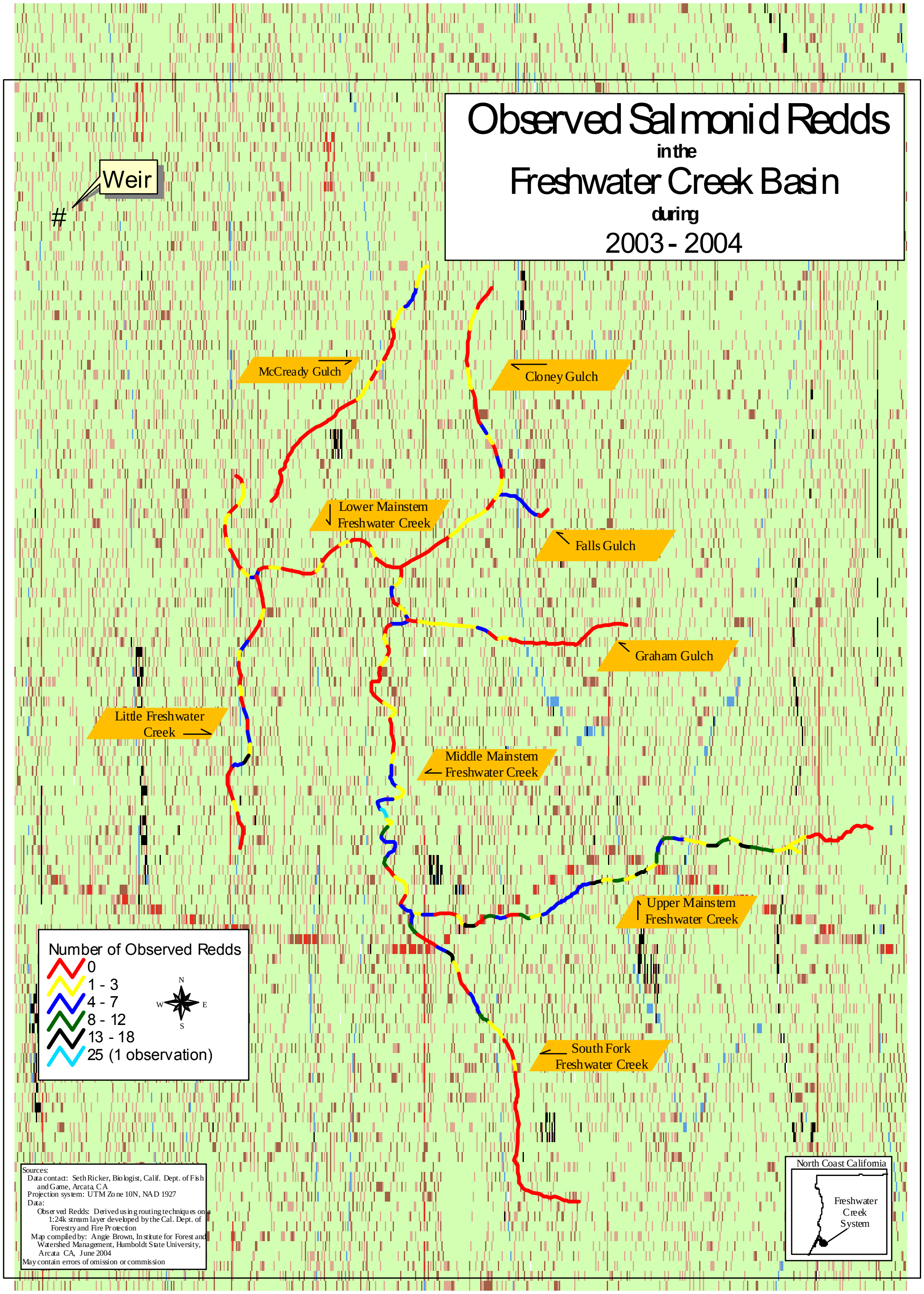

Figure 7. Map of Freshwater Creek basin depicting the density of observed redds during 2003-04 spawning ground surveys.

Redd Characteristics

Coho Salmon: Coho salmon total redd areas ranged from 0.75 m^2 to 9.2 m^2 and averaged 3.1 m^2 (Figure 8). Pot areas ranged from 0.3 m^2 to 7.0 m^2 and averaged 2.0 m^2. Pot depths ranged from 0.03m to 0.3m and averaged 0.11m.

Redd Longevity: Redds remained visible for an average of 35 days (Figure 9.).

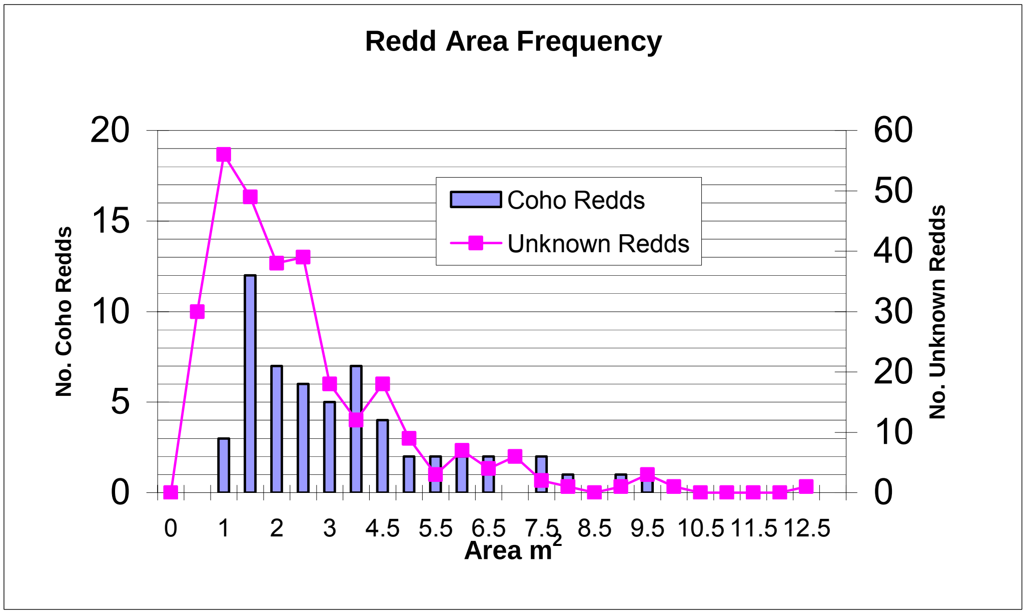

Figure 8. Frequency of Chinook salmon, coho salmon, and unknown species redd areas.

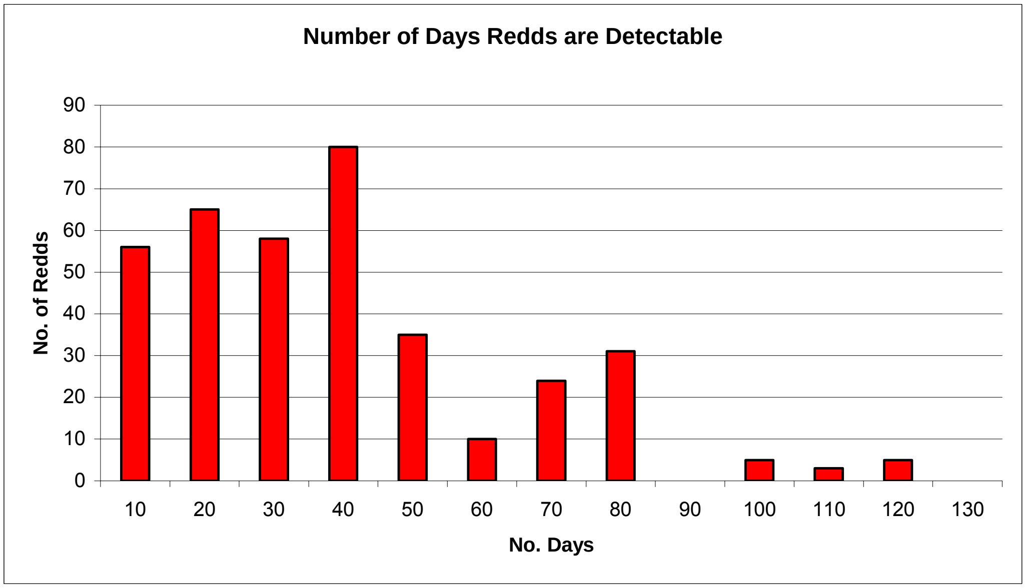

Figure 9. Distribution of the number of days redds remained visible from first observation to obscurity in Freshwater Creek, 2003-2004.

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 effects Area Under the Curve (AUC) escapement estimates, particularly when residence time is not directly estimated with fish marking data (English et. al. 1992). Given that there are thirty-five days between peak weir captures and peak carcass counts and that spawner surveys are conducted on a weekly basis, individual live coho salmon could potentially be counted four times. If this timing structure holds true from year to year, surveys directed at collecting live fish counts of coho salmon could be conducted less frequently than once per week (every 17 days) without missing the opportunity to count all fish.

The number of live fish observations made during the course of this study is low relative to the number of adult fish estimated from the weir mark-recapture. This suggests that live fish counts alone are likely to under-estimate 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 multiplying the result by an estimate of observation probability (English et. al. 1992). Observation efficiency was not directly measured; however, when the live fish counts observed in this study were compared to the number of fish that were estimated to be in the basin, the probability of seeing live fish appears to be significantly less than 1.

Strict enumeration of redds has often been used as a relative measure of spawning escapement. Expanding observed redd counts to the number of fish producing these redds, however, rests upon two basic assumptions. These assumptions may be stated in a variety of ways, so to clarify for this discussion, the following permutations will be used. The first assumption is that a fixed number of fish produce a single redd. The second assumption is that field personnel observe *all* the redds within the area of interest. In Freshwater Creek, 590 total salmon redds were directly observed and of 404 female coho salmon, 259 female steelhead were estimated , and four female Chinook salmon were counted. The redd to female ratio (590/667) of 0.88 implies, paradoxically, that it takes more than one female to build a redd. The redd/female ratio observed this season is higher than that (0.36) derived from the previous year's data (Ricker 2003). The number of individual spawner surveys conducted this study year (N=85) is nearly twice the number from the previous year (N= 43). This increased survey effort may be responsible for more redds to be observed in proportion to the estimated number of female fish available to produce them. The redd/female ratio remains, however, <1 indicating it either 1) more than one female build a redd, or 2) redd observation efficiency is <1.

Redd distribution throughout the basin was not uniform. Spawning grounds in certain areas were highly utilized while others were apparently abandoned. This clumping of redds in both space and time led to a significant number of redds being superimposed on 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 on top of older redds. Redd superimposition likely resulted in under-counting of redds in Freshwater Creek.

If unaccounted for, unknown redd observation probability may make inference into status and trends in abundance from redd survey data unclear.

RECOMENDATIONS

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 variability in estimates of salmon escapement derived from spawning survey data alone versus known or robust estimates of spawning escapement. 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.

LITERATURE CITED

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

English, K. K., R.C. Bocking, and J.C. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve-method. Can. J. Fish. Aquat. Sci. 49:1982-1989.

Gallagher, S. P. 2003. Development and application of a technique to distinguish between coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) redds and estimate adult populations from spawner surveys in several coastal Mendocino County, California streams. California Department of Fish and Game. 50 Ericson Ct, Arcata CA. 95521

Labelle, M. 1994. A likelihood method for estimating Pacific salmon escapement based on fence counts and mark-recapture data. Can. J. Fish. Aquat. Sci. 51: 552-556.

McElhany, P., M. Ruckelshaus, M. Ford, T. Wainwright, and E. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42, 158p.

Ricker, W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada. Bull 191. 382 p.

Personal Communications:

Eric Bjorkstedt. January 2005. National Marine Fisheries Service, Santa Cruz, CA.