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The Resources Agency
DEPARTMENT OF FISH AND GAME

ANNUAL REPORT
RESULTS OF THE JUVENILE DOWNSTREAM MIGRANT TRAPPING CONDUCTED ON FRESHWATER CREEK, 2001
PROJECT 2a6

by

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Acknowledgments

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ABSTRACT

Juvenile salmonid downstream migrant trapping was conducted at seven locations in the Freshwater Creek basin between March 22 and June 12, 2001. Pipe traps were deployed on McCready Gulch, Cloney Gulch, Graham Gulch, the upper main stem Freshwater Creek, South Fork, and Little Freshwater Creek. A fyke/pipe trap was fished on the lower main stem Freshwater Creek to provide i) basin wide estimate of salmonid migrants, ii) allow partitioning of salmonid production by sub-drainage, and iii) provide estimates of apparent survival of migrating salmonids. Based on trapping results, we estimate that 10,745 +/- 608 steelhead (*Onchorhynchus mykiss irideus*) and 6080 +/- 229 coho salmon (*Onchorhynchus kisutch*) smolts emigrated from Freshwater Creek during the study period. Two hundred and eighty–eight chinook salmon (*Onchorhynchus tschawytcha*) were captured at the lower main stem trap between March 22 and May 9. Thereafter, an estimated 2132 +/- 83 chinook salmon emigrants passed the trap from May 10 – June 5. Apparent migration survival of coho salmon was estimated to be 92% from tributary traps to the lower mainstem (LMS) trap. Steelhead migrant apparent survival from all tributaries to the LMS trap was estimated to be 51% overall and ranged from 33% for parr to 95% for smolts. An estimated 87% of the steelhead migrating from Freshwater Creek originated from the main stem section between the tributary traps and the LMS trap, leaving the remaining 17 % attributed to tributary production. An estimated 48% of all coho salmon smolts migrated from the tributaries. It is clear that main stem habitat is an important component to the juvenile life history of salmonids in Freshwater Creek.

INTRODUCTION

Many populations of salmonids in California are considered at risk of extinction and are listed or proposed for listing under the Federal Endangered Species Act (ESA) (Nehlsen et al. 1991, Federal Register 1996, Huntington et al. 1996, Federal Register 2000). In June 2000 the National Marine Fisheries Service (NMFS) formally listed steelhead populations in the northern California Evolutionary Significant Unit (ESU), as Threatened Species under the ESA (Federal Register 2000). Freshwater Creek steelhead population(s) fall within this region and listing. The listing is due in part to the lack of available information regarding the status and trends of populations (McEwan and Jackson 1996).

The NMFS identified four key parameters for assessing viable salmonid populations including; population size, population growth rate, population spatial structure, and life history diversity (McElhany et al. 2000). Juvenile out-migrant trapping is a common measure of salmonid abundance during an important life stage transition, and can lead to inference regarding the diversity of life history strategies. Information regarding the spatial structure of populations can be inferred only when multiple sites are monitored with a sampling design that has the resolution to delineate discrete populations. Smolt abundance is an appropriate measure of production from a particular drainage and when trapping can partition basin production to sub-drainages, can provide information used to delineate population structure within drainages.

Study Area

The Freshwater Creek basin is located in Humboldt County between Eureka to the south and Arcata to the north. Freshwater Creek is a fourth order stream with 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*), and three spine stickleback (*Gasterosteus aculeatus*).

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*).

Objectives

The Freshwater Creek downstream migrant program was initiated to; i) determine the yield of coho salmon and chinook salmon smolts and steelhead parr and smolts from Freshwater Creek basin, ii) determine the timing of outmigration of salmonids, iii) partition the basin yield of salmonids into that produced by tributaries and mainstem areas iv) determine apparent survival of steelhead and coho salmon from tributaries to the lower mainstem.

Freshwater Creek Basin

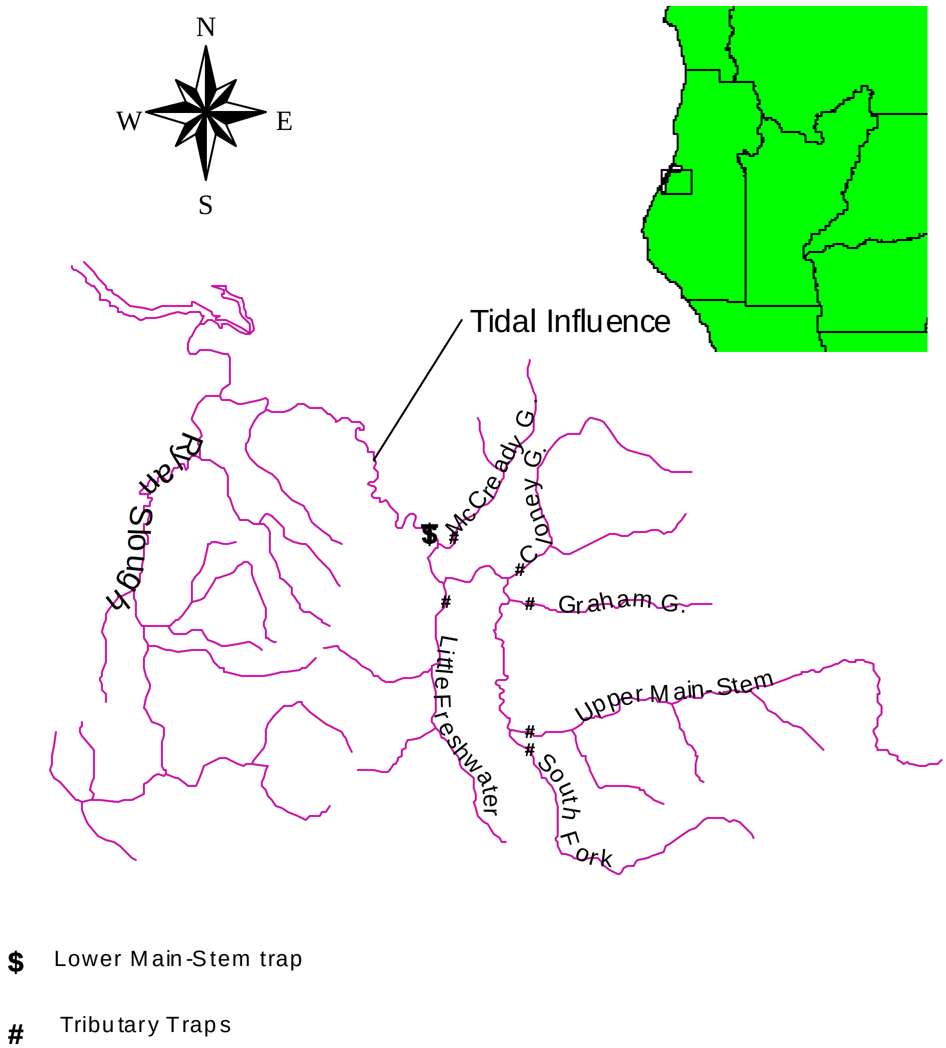

Figure 1. Freshwater Creek Basin, depicting relative location in Humboldt County, and downstream migrant trap locations.

METHODS

Fish Capture

Seven downstream migrant traps were fished in the Freshwater Creek basin from March 23, 2001 through June 12, 2001. Pipe traps were deployed in each of the five major tributaries as well as the upper main stem Freshwater Creek above the confluence with the South Fork. The pipe traps were placed within 20-300m upstream of the confluence with the mainstem of Freshwater Creek, at a pool tail out/ riffle crest. The six pipe traps consisted of a downstream "V" shaped rock and wooden pallet weir, which concentrated fish and water flow through a 10" PVC pipe. The pipes ran down a low gradient riffles and drained on to perforated inclined planes allowing water to pass through, while depositing fish into trap boxes. A fyke/pipe trap was fished on the lower mainstem Freshwater Creek, below McCready Gulch to provide an estimate of mainstem juvenile salmonid emigration (Figure1). This trap configuration consisted of a 25-foot long, ¼" mesh, fyke net, measuring 10' x 4' at the entrance. The fyke funneled fish to a 10" PVC pipe connected to the cod end. The pipe ran 32' down a low gradient riffle to a series of two trap boxes.

Abundance estimates

We estimated numbers of migrants at each trap using a single trap mark-recapture method. At least three days per week during the entire study, fish were anaesthetized with MS-222, and a systematic sample measured for fork length, weighed to the nearest 0.1g, and marked by injecting a small line of colored Visual Implant Elastomer (VIE). Each trap was designated a specific color, and four different mark locations were used to represent weekly marking groups, so that estimates of the number of migrants could be separated when trap efficiencies varied. At the end of four weeks the marking location cycle began again. Marked fish were held in a flow through live car up to 1 hour to check for handling and marking mortalities. Any mortality of marked fish prior to release were removed from the number of marks released. All marked fish were transported upstream of the trap at least one pool riffle sequence. Release sites upstream of the traps were chosen to provide cover and were rotated among three to five sites.

Each day, trapped fish were anaesthetized with MS-222, counted, checked for marks, and recaptures measured for fork length. Once processed, the fish were allowed to recover in flow through live cars and released downstream of the trap.

The mark-recapture data was analyzed separately for all age 1+ and older steelhead and coho salmon emigrants for each drainage. Numbers of age 0+ Chinook salmon were estimated from May 10 to June 12 at the lower mainstem trap only. 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 temporally stratified mark-recapture experiment that estimates capture probability for each period accounting for the effects of migration on the pool of marked fish susceptible to capture during each period. This method does not require the assumption that all fish resume migration during the period during which they were released. 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 Darroch (1961) analysis (Bjorkstedt pers. Comm.).

Age Determination

Age classes were determined with length frequencies and validated by viewing 10 scale samples randomly sampled from the two distinct modes of the frequency distribution (61 mm –105mm, and 135 mm – 180 mm) and 30 scale samples from the nadir of the frequency distribution (105mm-135mm). Age 1+ steelhead are considered <125 mm and age 2+ ≥ 125 mm (Figure 3). Percent steelhead yield by size/age class is determined by expanding the proportion of systematically measured fish within each size class to the total yield estimate.

The developmental stage of all captured and recaptured fish was determined by visual observation and consisted of three categories; parr, pre-smolt and smolt. Parr were characterized by well defined of parr marks, pre smolts exhibited partial silvering of the body and fading but still visible parr marks, and smolts exhibited total silvering of the body, no visible parr marks and blackening of the caudal fin tips.

Abundance and Survival Estimate Assumptions

Analysis of data from mark-recapture experiments requires the following assumptions be met for the estimator to remain unbiased:

1) Marked and unmarked fish are evenly mixed.
<u>Mitigation</u>: Efficiency releases occurred at least one pool riffle sequence above the traps, requiring fish to swim through a constricted riffle habitat, in an effort to maximize even mixing of all marked fish with unmarked emigrating fish.

2) All the individuals exposed to capture at a certain time period have an equal probability of capture.
<u>Mitigation:</u> The assumption of equal capture probabilities for all sizes of steelhead was assessed with Kolmogorov-Smirnov tests for each trap. These tests compare the cumulative fork length frequency distribution of marked individuals with the cumulative fork length frequency distribution of recaptures. Alpha levels were set at 0.05 for all tests. All species were estimated separately using species-specific capture probabilities.

3) marks are not lost and are unambiguously identified.
<u>Mitigation:</u> In situ mark retention and identification was tested by double marking a subset of fish with a fin clip and VIE tag. If 100% retention of the fin clip is assumed, the proportion of fish recaptures with only the fin clip represents tag loss. A secondary study of VIE mark retention was conducted in a controlled hatchery setting.

4) marked individuals experience little or known mortality and all fish resume migration past the trap site.
<u>Mitigation:</u> Immediate mortality of marked fish was assessed by allowing up to one hour for marked fish to recover prior to release. Long term marking mortality was also assessed at Mad River Hatchery.

In addition to all of the assumptions for the mark-recapture abundance estimate, estimates of apparent survival based on mark-recapture data rely upon tributary release fish and LMS trap efficiency releases being captured with the same probability at the LMS trap. The study design did not allow for a test of this assumption.

Apparent Survival From Tributary Traps to LMS trap

Estimates of apparent survival, which incorporate losses due to both migration mortality and main stem residualization, of coho salmon and steelhead migrating from each tributary trap to the lower main-stem trap (LMS) were generated using the relative recovery rate method (Ricker 1948, Thedinga et al. 1994). Fish marked at the tributary traps represent the treatment groups for each estimate (R_{t1}). The control groups (R_{c1}) are fish captured for the first time at the LMS trap, marked and released above the LMS trap. The number of the treatment group fish recovered at the LMS trap is symbolized by $m_{t12,}$ and the number of control group fish recovered at the LMS trap symbolized by m_{c12}. The maximum likelihood estimates of apparent survival (Ö) are:

$$\text{Ö} = (m_{t12}\ R_{c1}) / (R_{t1}\ m_{c12})$$

with sampling variance,

$$\text{var}(\text{Ö}) = (\text{Ö})^2\ [1/m_{t12} - 1/R_{t1} + 1/m_{c12} - 1/R_{c1}]$$

for each group. Steelhead survival estimates were generated for all tributary traps combined, combined tributaries but separate developmental stage groupings, and individual tributaries. Steelhead and coho survival estimates for Upper main-stem (UMS) and Graham Gulch (G) were combined because of trouble differentiating the yellow (UMS) and green (G) VIE marks. Coho salmon survival estimates were made for all tributary traps combined, and individual tributaries.

Chi square tests were used to determine if significant differences existed between the recapture rates at the LMS site of treatment and control group fish for all survival estimates.

Estimates of Tributary Contribution to Basin Yield

Fish emigrating from Freshwater Creek tributaries may 1) continue emigrating past the LMS trap or 2) residualize in the main stem above the LMS trap or 3) parish during migration. Estimates of basin wide fish yield (defined as fish passing the LMS trap) originating from tributaries must account for both residualization and mortality between traps. The estimates of tributary contribution to the entire basin yield is therefore calculated as:

Trib. Contribution = 3 over all tributaries ((tributary estimate) * (survival to LMS))

Length of Steelhead and Coho salmon

A systematic sample of steelhead and coho salmon were measured for fork length and weighed to the nearest 0.1 g. Kruskal Wallis one -way ANOVA on ranks tests were used to determine if steelhead sizes differed between tributary traps, and developmental stage. A one -way ANOVA was used to determine if lengths of systematically measured coho salmon differed between tributaries. Tukey's method was used for multiple comparisons between tributaries. Alpha levels were set to 0.05 for all tests.

RESULTS

Abundance and Survival Estimate Assumptions

All sizes of steelhead and coho salmon were captured with equal probability at all traps (Table 1). Percent frequency of all marked and all recaptured steelhead at the LMS trap are displayed in Figure 3.

Kolmogorov-Smirnov test Results

Trap	D (Test Statistic)	D alpha (Critical Value)
Cloney	0.172	0.454
Graham	0.114	0.264
UMS	0.099	0.158
South Fork	0.152	0.331
Little Fresh	0.223	0.361
LMS	0.069	0.079

Table 1. Kolmogorov-Smirnov test Results. These tests compare the cumulative frequency distribution of all marked fish with all recaptured fish. Separate tests performed for each trap.

In situ VIE mark retention was 96% (276/288). VIE mark retention at Mad River Hatchery was 97% (97/100) over a four week period.

No immediate mortality of marked fish was observed in the field. No mortality was observed 17 days after marking at Mad River Hatchery. Thereafter, small 2% mortality in the hatchery he ld fish over the next 56 days was not different from adipose clipped control fish (Ricker In press).

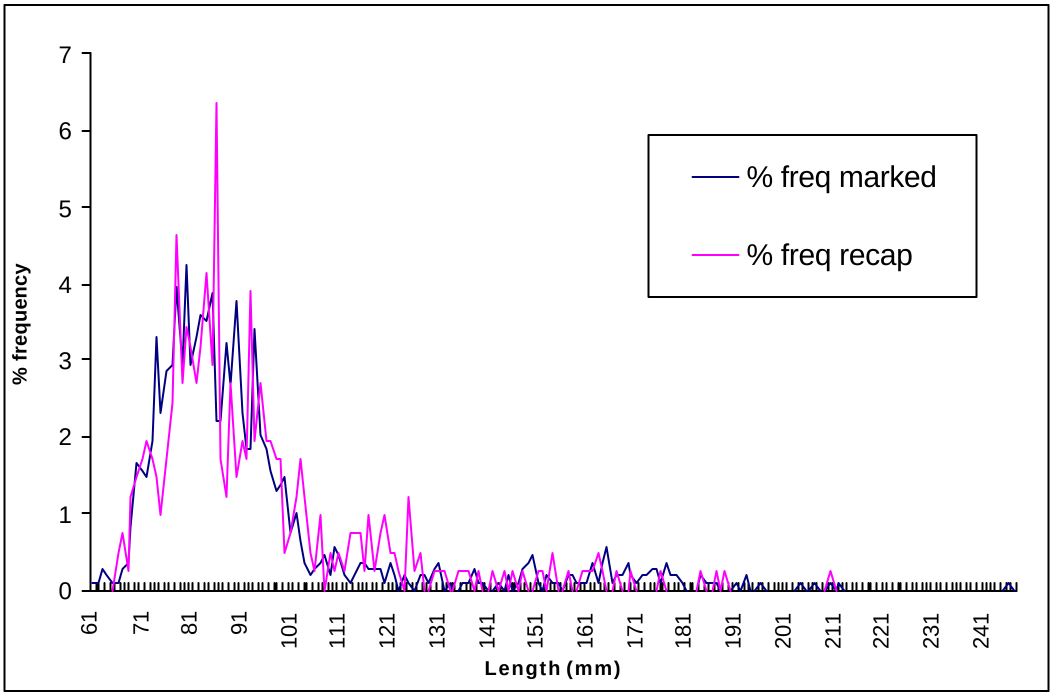

Figure 2. Percent frequency of all marked and all recaptured steelhead at the lower main-stem trap.

Abundance Estimates

Capture efficiencies ranged from 0.11 to 1.0 for coho salmon, and 0.14 to 0.75 for steelhead at all tributary traps. LMS trap capture efficiencies ranged from 0.31 to 0.81 for coho salmon, 0.18 to 0.57 for steelhead, and 0.53 to 0.89 for chinook salmon. Capture efficiencies were generally higher for coho salmon than steelhead at all traps and for all periods (Appendix A).

Basin wide steelhead emigration was estimated to be 10745 " 608 (SE) at the LMS trap. Ninety percent or 9658 of these fish were age 1+ between 62 mm and 125 mm and 9.6% or 1028 of these fish were age 2+ between 126 mm and 198 mm, and the remaining 0.4% or 43 fish >198 mm are considered age 3 and 4+ (Figure 2). Coho salmon smolt yield at the LMS trap was estimated to be 6080" 229 (SE). Chinook salmon smolt yield at the LMS trap between May 10 and June 12 is estimated to be 2132" 83 (SE). All trap abundance estimates are displayed in Table 2. Young of the year (age 0+) captures for all traps are displayed in Table 3. Mark-recapture matrices used for abundance estimates are displayed in Appendix B.

	N(hat)	SD	LCL	UCL
Lower Main-stem				
Steelhead	10745	608	9553	11937
Coho	6080	229	5631	6529
Chinook	2132 *	83	1969	2295
McCready G.				
Steelhead	10			
Coho	231	62	110	352
Cloney G.				
Steelhead	515	213	97	933
Coho	669	99	475	863
Graham G.				
Steelhead	388	82	227	549
Upper Main-stem				
Steelhead	2152	226	1710	2594
Coho	1633	266	1111	2155
South Fork				
Steelhead	199	51	99	299
Coho	224	16	194	254
Little Freshwater				
Steelhead	267	44	180	354
Coho	505	50	407	603

Table 2. Abundance estimates (N(hat)), associated error (SD) of the estimate, and lower (LCL) and upper (UCL) 95% confidence levels of smolts and parr by species and drainage. * estimate made from May10 – June 12, 2001.

Age 0+ catches

	McCready	Cloney	Graham	Upper Main	South Fork	Little Fresh	Lower Main
Coho	0	110	0	2863	0	147	93
Steelhead	54	0	672	306	0	18	733
Chinook	0	0	**15**	143	0	0	1357

Table 3. Age 0+ (young of the year) catches for the seven downstream migrant traps in Freshwater Creek basin. **Bold** indicates captures of artificially reared and planted fish, and is not believed to indicate natural spawning.

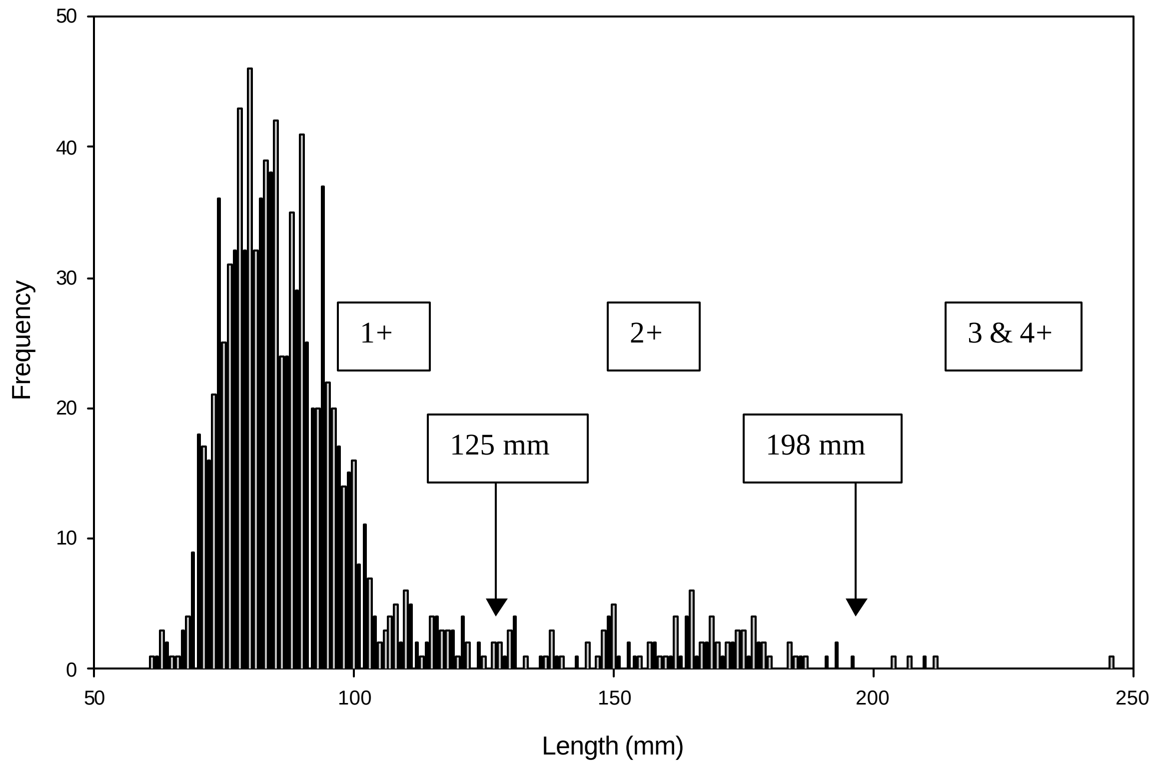

Figure 3. Length-frequency histogram of all captured steelhead at the LMS trap. Boxes indicate age classes and arrows depict fork length used for age class delineation.

Estimates of Tributary Contribution to Basin Yield

The six tributaries contributed 17% or 1812 steelhead and 48% or 2919 coho salmon to the entire yield emigrating from Freshwater Creek during the study period. The largest contribution was made by the upper mainstem which contributed 9% of the steelhead and 26% of the coho salmon to the basin wide yield.

Migration Timing

Trapping commenced on March 22, 2001 during a decline in migration of both coho salmon and steelhead. Thereafter, a second peak in migration began April 19, and peaked on April 26 (Figure 4). Chinook salmon also displayed two distinct peaks in migration. The first peak began on April 24, peaked on April 27 and dropped to minimal catches again by May 2. A second peak in migration began on May 11 and peak catches for the season occurred on May 25 (Figure 5).

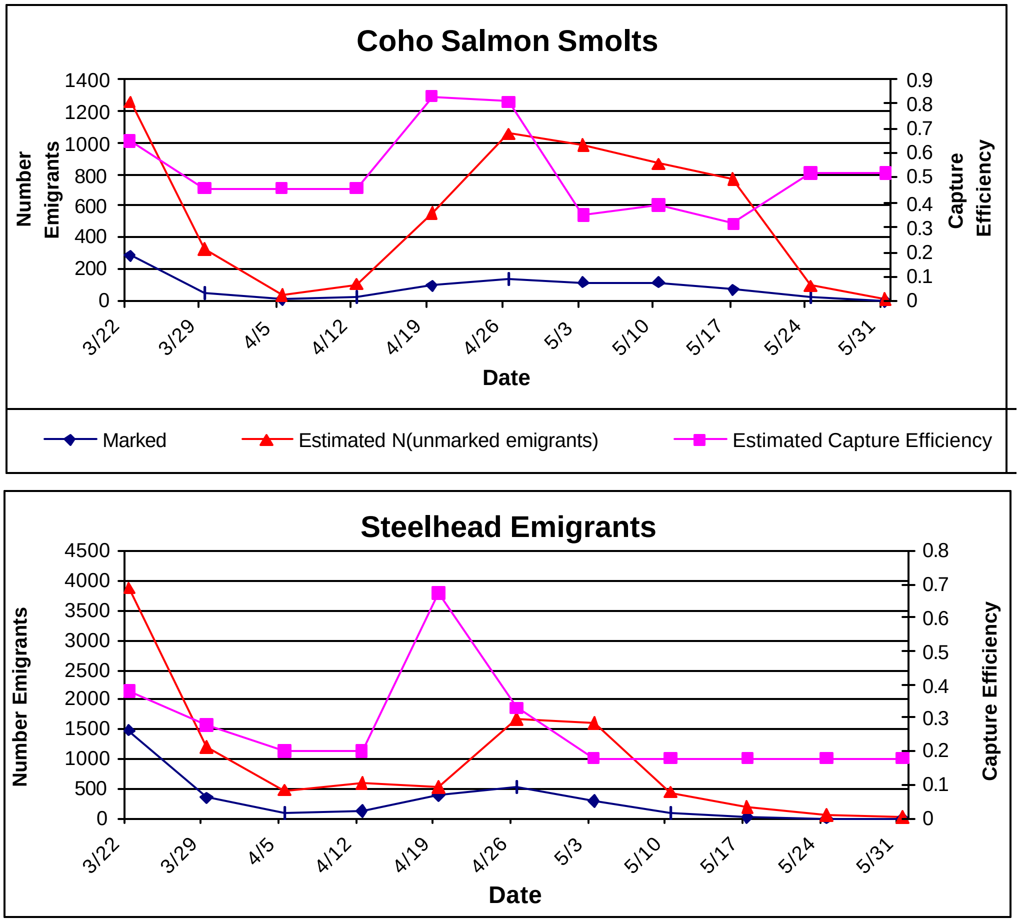

Figure 4. Timing of steelhead and coho salmon emigration at the LMS trap.

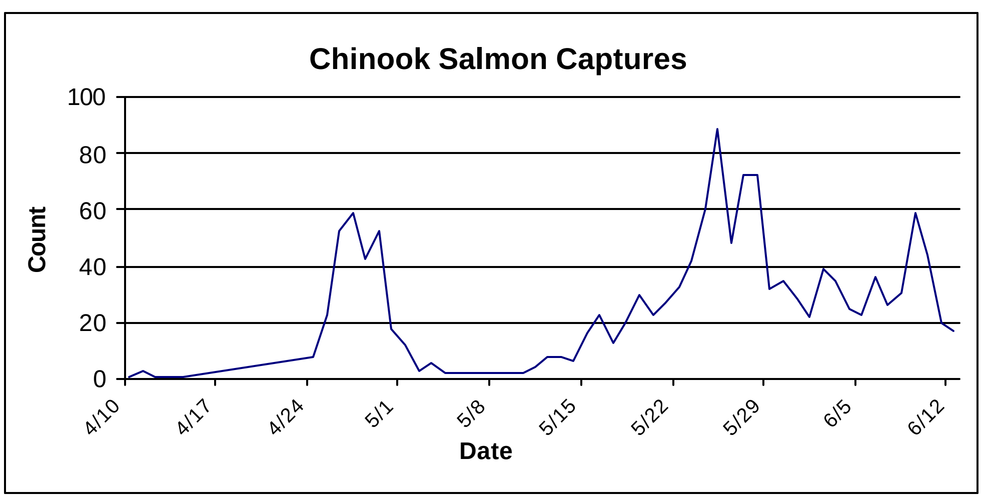

Figure 5. Timing of chinook salmon captures at the LMS trap.

Apparent Survival

Apparent survival of all steelhead from all tributaries combined to the LMS trap is estimated to be 51% " 5.3% (SE). Survival of steelhead from individual tributaries ranged from 43% from Graham Gulch to 82% from the South Fork. Survival of emigrating coho salmon from all tributaries to the LMS trap was estimated to be 92% " 4% (SE). Steelhead apparent survival estimates ranged from 33% for Parr, 54% Pre-smolt and 95% smolt developmental stage groups. All survival estimates are displayed in Table 4.

Length of Steelhead and Coho Salmon

Steelhead. The median fork length of steelhead from tributary creeks ranged from 82 mm from the South Fork to 93mm for Little Freshwater Creek. There was no significant difference in median fork lengths between tributaries (H= 7.15, P= 0.21, *df* = 5) (Figure 7). Significant differences were found between median fork lengths of steelhead Parr, Pre-smolt and smolt developmental stage groupings (H = 437, P < 0.001, *df =2*) (Figure 6). Dunn's multiple comparison procedure indicates all developmental stage groups differ in fork length from one another.

Coho Salmon. Significant differences were found in fork lengths of coho salmon between tributaries (F = 16.7, P < 0.001, *df* = 5) (Figure 8). Results of multiple comparison (Tukey test) are displayed in Table 5.

Group	R_{t1}	m_{t12}	R_{c1}	m_{c12}	X^2; P (df=1)		SE
Steelhead							
All tributaries	532	91	1089	367	27.9; < 0.001	0.51	0.053
Parr (dev. stage)	56	4	105	23	3.4; = 0.066	0.33	0.168
Pre-smolt	448	85	880	312	27.9; < 0.001	0.54	0.058
smolt	23	7	97	31	0.02; = 0.89	0.95	0.33
Individual tributaries (all SH)							
Upper main-stem + Cloney	342	52	1089	367	24.8; < 0.001	0.45	0.06
South fork	47	13	1089	367	0.22; = 0.64	0.82	0.20
Little Fresh	56	13	1089	367	1.1; = 0.29	0.69	0.17
Graham	82	12	1089	367	6.7; = 0.91	0.43	0.20
Coho salmon							
Group	R_{t1}	m_{t12}	R_{c1}	m_{c12}	X^2; P (df=1)		SE
All tributaries combined	610	320	948	541	0.84; = 0.36	0.92	0.04
Upper main stem + Cloney	356	199	948	541	0.02; = 0.88	0.98	0.05
South fork	90	40	948	541	1.38; = 0.24	0.78	0.09
Little Fresh	125	56	948	541	1.82; = 0.18	0.79	0.08

Table 4. Mark-recapture data used to calculate apparent survival ( ) for all groups of steelhead and coho salmon. Chi square tests compare proportions of release groups. P values (< 0.05) indicate significant differences between proportions fish marked at the tributary traps (**R_{t1}**) and recaptured at the LMS trap (**m_{t12}**) and efficiency marked fish released above the LMS trap (**R_{c1}**) and recaptured at the LMS trap (**m_{c12}**).

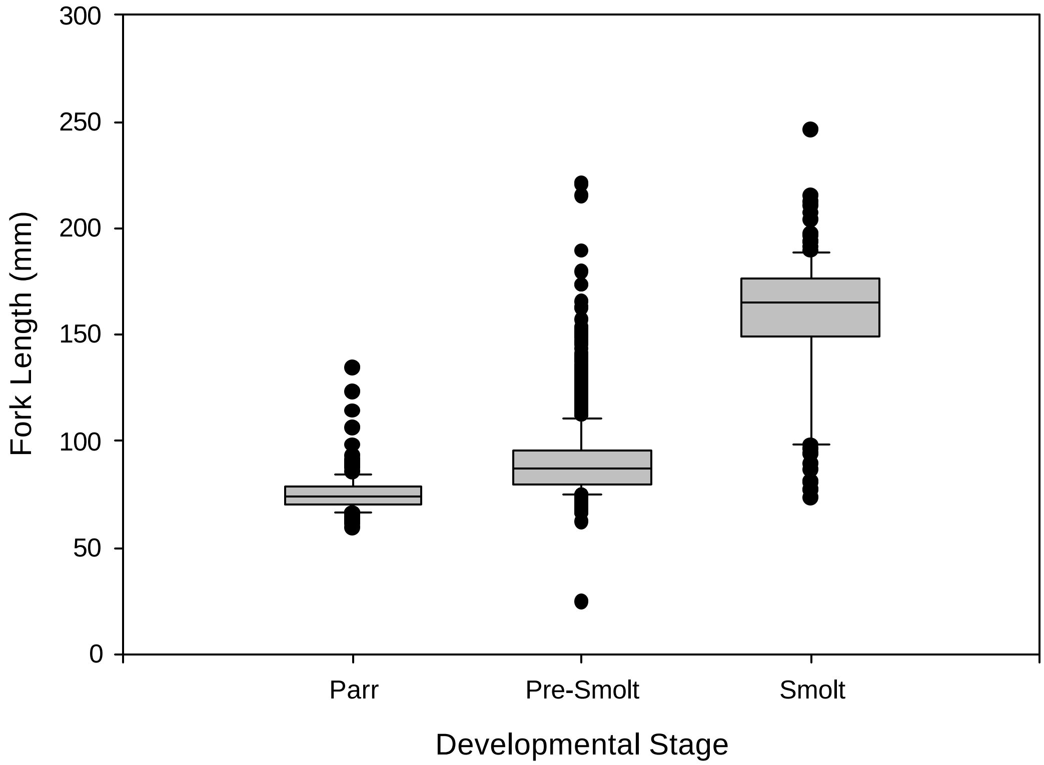

Figure 6. Comparison of fork lengths from parr, pre-smolt and smolt steelhead. Boxes depict 25th, 50th, and 75th percentiles, whiskers depict 10th and 90th percentiles and points indicate outliers.

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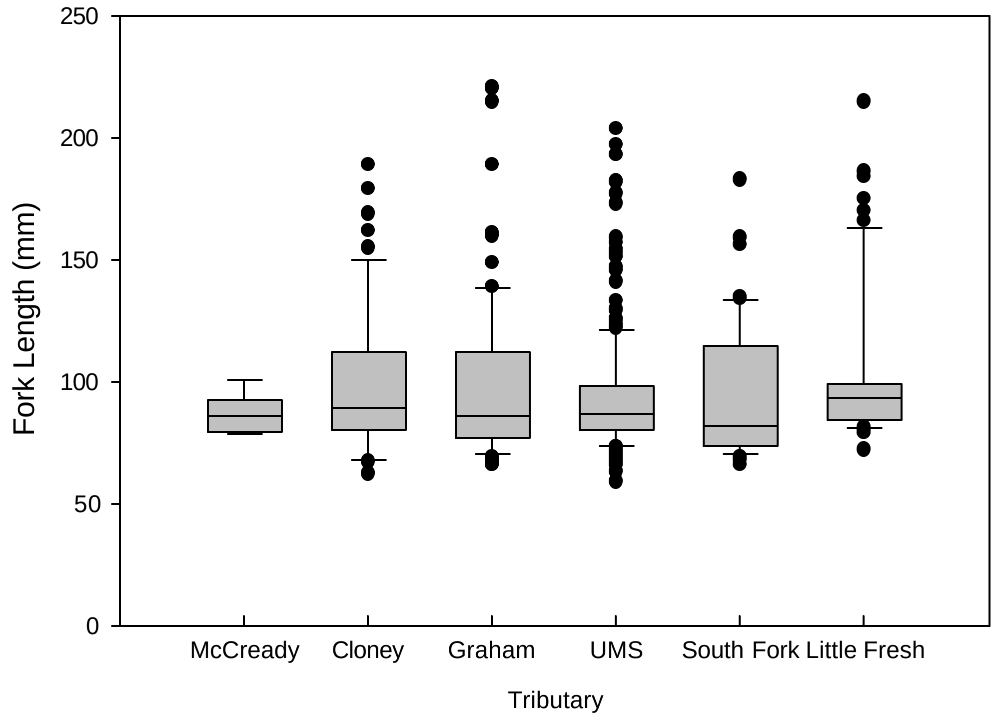

Figure 7. Comparison of fork lengths of systematically measured steelhead from each tributary trap. Box plots depict 25th, 50th, and 75th percentiles, whiskers depict 10th and 90th percentiles and points indicate outliers.

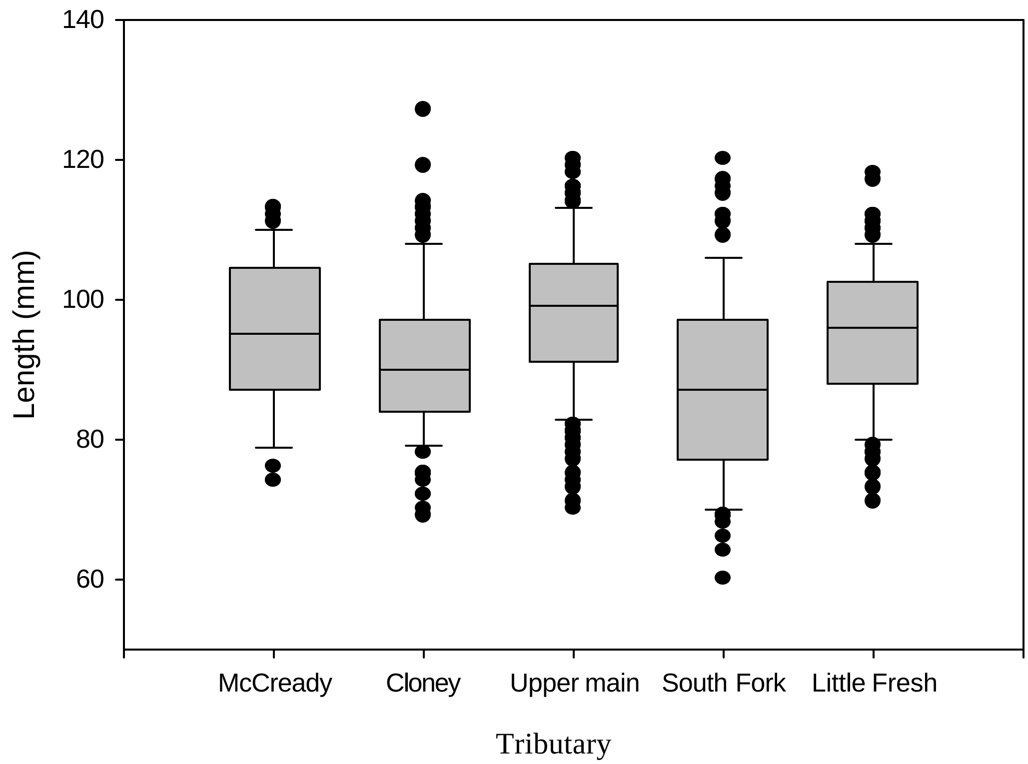

Figure 8. Comparison of fork lengths of systematically measured coho salmon smolts captured at each trap. Box plots depict 25^{th}, 50^{th}, and 75^{th} percentiles, whiskers depict 10^{th} and 90^{th} percentiles and points indicate outliers.

Comparison	Diff of Means	q	P
Upper Main vs. South Fork	10.713	10.721	**<0.001**
Upper Main vs. Cloney	6.555	7.305	**<0.001**
Upper Main vs. McCready	3.612	2.593	0.354
Upper Main vs. Little Fresh	3.124	3.500	0.096
Little Fresh vs. South Fork	7.589	6.818	**<0.001**
Little Fresh vs. Cloney	3.431	3.355	0.123
Little Fresh vs. McCready	0.487	0.330	0.999
McCready vs. South Fork	7.102	4.601	**0.010**
McCready vs. Cloney	2.944	1.990	0.623
Cloney vs. South Fork	4.158	3.723	0.065

Table 5. Results of multiple comparison procedure (Tukey Test) used to define differences in fork lengths of coho salmon smolts between tributaries. P- values <0.05 (**Bold**) indicate significant differences between tributaries.

DISCUSSION

Yield of smolts and parr

The estimates of abundance presented in this report capture the period from March 22 to June 12, and do not include fish migrating earlier or later. It should be noted that trapping commenced during what appears to be a declining limb of an early peak in migration. The estimates presented cannot therefore be viewed as the sum total yield from Freshwater Creek. The multi-modal timing of fish captures observed this season is consistent with past trapping efforts on Freshwater Creek (unpublished data).

The vast majority (90%) of steelhead emigrating past the LMS trap are considered age 1+. Scale analysis of 48 returning adult steelhead to Freshwater Creek reveals none of these successful returning adults entered the ocean as age 1+ (see study 1a1). This large discrepancy leads to the possibilities that either; 1) the juveniles that produces the 2000-2001 adult run emigrated exclusively as age 2+, 2) age 1+ steelhead that enter the ocean suffer zero or very low survival to adult, or 3) this age class of fish is migrating to the lower river/estuary and either residing there for a second year or migrating back upstream to rear until age 2+. Shapovolov and Taft (1954) found a strikingly similar migration of age 1+ steelhead during the spring migration in Waddell Creek, California. These researchers presumed these fish resided in the estuary/lagoon for the summer. An upstream counting fence captured an unknown but significant portion of age 1+ steelhead migrating back upstream during November and December to over winter in the stream. Cunjak and Chadwick (1988) found a similar strategy was employed by Atlantic salmon (*Salmo Solar*) down stream migrants. In this study of Western Arm Brook, a fourth order stream in Newfoundland, the authors found that an unknown but "significant" portion of the rivers production of salmon spent the summer rearing in the estuary. Further more, these authors found the smaller parr utilized the estuary environment while the larger smolts passed to the ocean with little estuary residence time.

Age 0+ Captures

Spring downstream redistribution of young of the year (YOY) salmonids has been well documented and can serve as evidence of spawning adults. The fact that we captured age 1+ steelhead in Cloney Gulch and McCready Gulch but no YOY may indicate a degree of instability in population structure. Low flow conditions in Freshwater Creek over the spawning season may have blocked access to some tributaries, and more data is necessary to establish the spatial dynamics of Freshwater Creek salmonid populations.

Apparent Survival and Partition of Salmonids Yield by Drainage

If it is assumed that migration mortality of steelhead is low, the estimates of apparent survival presented in this report suggests a relatively large portion of the smaller parr and pre-smolt steelhead migrating from the tributaries of Freshwater Creek took up residence within the main-stem and did not continue past the LMS trap. The estimate of the tributary contribution to the basin yield is undoubtedly somewhat biased by the fact that a portion of the migration was missed prior to trapping. I believe the large inequality between tributary and main stem contribution of steelhead migrants, however, is not entirely due to the timing of trap instillation relative to migration timing, and underscores the importance of main stem habitat to the production of steelhead from Freshwater Creek. Steelhead typically spawn in low order tributaries, generally higher in drainages than other Pacific salmonids. The high yield of springtime steelhead outmigrants originating from the main stem habitat therefore suggests a downstream trend in habitat utilization of juveniles at some point during the freshwater rearing stage prior to the initiation of spring trapping. Movement, spatial redistribution, and the timing of these events for juvenile steelhead over the freshwater life stage is, however, not well understood.

The high apparent survival rates of coho salmon smolts from the tributaries to the LMS trap indicate these animals are highly motivated to leave the Freshwater system during their spring migration and that mortality during this exodus is low. The relatively high contribution of tributary emigrants to the entire basin yield implies tributary habitat is of considerable importance throughout the entire freshwater life stage of juvenile coho salmon.

Recommendations

Partitioning smolt yield between different areas within a basin can yield information of the spatial dynamics of population structure. Spatial structure is an important parameter for assessing population viability and extinction risk (McElhany et al. 2000). Identification of source and sink sub-populations and the interactions of these populations can lead to inference about the stability of the population as a whole. Productivity in terms of smolt per spawner relationships at the sub-basin level is needed to define source-sink population dynamics. It is recommended that research into Freshwater Creek steelhead be expanded to include methods to quantify the number of spawners per sub-basin. This type of data over time can determine what spatial and temporal scales are important to population viability and extinction risk.

Little is known of the spatial structure of populations and meta-populations, or regional abundance of Northern California steelhead. In order to define this structure, a large spatial scale of data collection is needed. A current proposal to define population abundance indices and spatial structure of populations is currently being produced by and evaluated by Steelhead Research and Monitoring Project personnel. The proposed data collection comprises over-summer density estimates of age 0+ juvenile steelhead as an index of population strength. This relationship has rarely been identified (exception Ward and Slaney 1993) and has not been validated for northern California. Freshwater Creek is unique to northern California in the fact that is has a permanent weir structure that can successfully quantify adult spawner abundance (see study 1a1). It is recommended that investigation into the abundance of summer age 0+ steelhead in Freshwater Creek be conducted to help validate the underlying assumption of using 0+ densities as a meaningful population parameter.

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Appendix A. Capture probabilities (P (Cp)) and population estimates (N(hat)) by weekly strata for all species and all traps.

Trap	Species	Parameter	Date (strata)										
			3/22-3/28	3/29-4/4	4/5-4/11	4/12-4/18	4/19-5/2	5/3-5/9	5/10-5/16	5/17-5/23	5/24-530	5/31-6/5	6/6-610
McCready	Coho	P(Cp)	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.75	0.75	0.75	0.75
		N(hat)	81	7	3	23	46	33	20	17	3	1	0
Cloney	Coho	P(Cp)	0.24	0.68	0.68	0.93	0.93	0.86	0.83	0.83	0.83	0.83	0
		N(hat)	396	21	2	46	113	65	18	4	1	5	0
	Steelhead	P(Cp)	0.25	0.14	0.14	0.14	0.14	0.14	0	0	0	0	0
		N(hat)	200	77	42	49	105	42	0	0	0	0	0
Graham	Steelhead	P(Cp)	0.35	0.67	0.2	0.2	0.2	0.86	0.5	0.2	0.2	0	0
		N(hat)	147	26	30	44	54	20	18	30	20	0	0
Upper main	Coho	P(Cp)	0.11	0.29	0.29	0.29	0.33	0.45	0.67	0.57	0.36	0.36	0
		N(hat)	448	25	4	28	270	235	159	307	113	11	0
	Steelhead	P(Cp)	0.23	0.45	0.45	0.3	0.28	0.48	0.38	0.51	0.15	0.15	0.15
		N(hat)	602	101	42	181	351	284	243	126	221	7	7
South Fork	Coho	P(Cp)	0.55	0.8	1	1	0.67	0.96	1	0.8	0	0	0
		N(hat)	92	29	4	11	36	30	12	11	0	0	0
	Steelhead	P(Cp)	0.84	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0	0
		N(hat)	34	42	40	24	28	12	12	8	4	0	0
Little Fresh	Coho	P(Cp)	0.39	0.86	0.86	0.86	0.86	0.98	0.67	1	1	0	0
		N(hat)	265	1	1	10	79	80	42	15	1	0	0
	Steelhead	P(Cp)	0.42	0.39	0.39	0.39	0.39	0.67	0.5	0.5	0.5	0.5	0
		N(hat)	90	28	15	64	26	18	18	4	2	2	0
Lower main	Coho	P(Cp)	0.65	0.46	0.46	0.46	0.83	0.81	0.35	0.39	0.31	0.52	0.52
		N(hat)	1254	335	33	107	556	1060	983	867	777	96	13
	Steelhead	P(Cp)	0.38	0.28	0.2	0.2	0.67	0.33	0.18	0.18	0.18	0.18	0.18
		N(hat)	3882	1203	476	601	550	1674	1609	435	196	76	43
	Chinook	P(Cp)			N/A	N/A	N/A	N/A	0.53	0.78	0.65	0.89	0.56
		N(hat)			N/A	N/A	N/A	N/A	156	339	806	318	512

Appendix B. Mark-recapture matrices used to estimate emigrant abundance.

McCready Gulch: Coho Salmon													
	Checked	Marked	Recaptures										
Strata			1	2	3	4	5	6	7	8	9	10	11
1	25	21	1	0	0	1	1	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	0	0	0	1	0	0	0	0	0	0	0
4	7	4	0	0	0	0	3	1	0	0	0	0	0
5	14	1	0	0	0	0	0	0	0	0	1	0	0
6	10	2	0	0	0	0	0	0	0	2	0	0	0
7	6	1	0	0	0	0	0	0	0	0	0	0	0
8	13	7	0	0	0	0	0	0	0	4	1	0	1
9	2	1	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0

Cloney Gulch: Coho Salmon												
	Checked	Marked	Recaptures									
Strata			1	2	3	4	5	6	7	8	9	10
1	95	50	12	0	0	0	0	0	0	0	0	0
2	14	3	0	2	0	0	0	0	0	0	0	0
3	1	1	0	0	0	1	0	0	0	0	0	0
4	43	6	0	0	0	2	2	0	0	0	0	0
5	106	29	0	0	0	0	20	7	1	0	0	0
6	56	28	0	0	0	0	0	20	2	2	0	0
7	15	4	0	0	0	0	0	0	4	0	0	0
8	3	2	0	0	0	0	0	0	0	1	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0
10	4	0	0	0	0	0	0	0	0	0	0	0

Cloney Gulch: steelhead								
	Checked	Marked						
Strata			1	2	3	4	5	6
1	50	36	9	0	0	0	0	0
2	11	4	0	0	1	0	0	0
3	6	4	0	0	0	0	0	0
4	7	2	0	0	0	0	0	0
5	15	2	0	0	0	0	1	0
6	6	2	0	0	0	0	0	0

Appendix B (cont.)

Graham Gulch: steelhead											
	Checked	Marked									
Strata			1	2	3	4	5	6	7	8	9
1	52	44	11	2	2	0	0	0	0	0	0
2	17	6	0	4	0	0	0	0	0	0	0
3	6	4	0	0	0	0	0	0	0	0	0
4	9	5	0	0	0	1	0	0	0	0	0
5	11	2	0	0	0	0	1	1	0	0	0
6	17	14	0	0	0	0	0	12	0	0	0
7	9	2	0	0	0	0	0	0	1	0	0
8	6	4	0	0	0	0	0	0	0	1	0
9	4	1	0	0	0	0	0	0	0	0	0

Upper Main-Stem: Coho Salmon												
	Checked	Marked										
Strata			1	2	3	4	5	6	7	8	9	10
1	48	28	3	0	0	0	0	0	0	0	0	0
2	7	1	0	0	0	0	0	0	0	0	0	0
3	1	1	0	0	0	1	0	0	0	0	0	0
4	8	5	0	0	0	1	0	0	0	0	0	0
5	90	42	0	0	0	0	14	0	0	0	0	0
6	106	37	0	0	0	0	0	16	1	0	0	0
7	106	39	0	0	0	0	0	0	26	0	0	0
8	176	68	0	0	0	0	0	0	0	39	0	0
9	41	9	0	0	0	0	0	0	0	0	4	0
10	4	2	0	0	0	0	0	0	0	0	0	0

Upper Main-Stem: steelhead													
	Checked	Marked	Recaptures										
Strata			1	2	3	4	5	6	7	8	9	10	11
1	136	62	14	0	0	0	0	0	0	0	0	0	0
2	46	15	0	7	0	0	0	0	0	0	0	0	0
3	19	7	0	0	0	2	0	0	0	0	0	0	0
4	55	29	0	0	0	8	0	0	1	0	0	0	0
5	97	47	0	0	0	0	13	0	0	0	0	0	0
6	136	48	0	0	0	0	0	23	0	0	0	0	0
7	91	48	0	0	0	0	0	0	18	0	0	0	0
8	65	24	0	0	0	0	0	0	0	9	1	0	0
9	34	12	0	0	0	0	0	0	0	0	2	0	0
10	1	1	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B (cont.)

South Fork: Coho Salmon										
	Checked	Marked	Recaptures							
Strata			1	2	3	4	5	6	7	8
1	51	35	18	2	0	0	0	0	0	0
2	23	11	0	8	1	0	0	0	0	0
3	4	0	0	0	0	0	0	0	0	0
4	11	4	0	0	0	4	0	0	0	0
5	24	11	0	0	0	0	6	2	0	0
6	29	18	0	0	0	0	0	12	3	2
7	12	6	0	0	0	0	0	0	6	0
8	9	5	0	0	0	0	0	0	0	4

South Fork: steelhead											
	Checked	Marked	Recaptures								
Strata			1	2	3	4	5	6	7	8	9
1	29	23	16	0	0	0	1	0	0	0	0
2	21	12	0	4	1	0	0	0	0	0	0
3	10	6	0	0	0	0	0	0	0	0	0
4	6	1	0	0	0	0	0	0	0	0	0
5	7	2	0	0	0	0	2	0	0	0	0
6	3	1	0	0	0	0	0	0	0	0	0
7	3	0	0	0	0	0	0	0	0	0	0
8	2	1	0	0	0	0	0	0	0	0	1
9	1	1	0	0	0	0	0	0	0	0	0

Little Freshwater: Coho Salmon											
	Checked	Marked	Recaptures								
Strata			1	2	3	4	5	6	7	8	9
1	102	53	17	2	1	0	2	3	0	0	0
2	1	1	0	0	0	0	0	0	0	0	0
3	1	1	0	0	0	1	0	0	0	0	0
4	9	5	0	0	0	3	1	0	0	0	0
5	68	15	0	0	0	0	7	5	2	0	0
6	78	34	0	0	0	0	0	26	5	0	0
7	28	9	0	0	0	0	0	0	6	0	0
8	15	7	0	0	0	0	0	0	0	5	2
9	1	0	0	0	0	0	0	0	0	0	0

Appendix B. (Cont.)

Little Freshwater: steelhead												
	Checked	Marked	Recaptures									
Strata			1	2	3	4	5	6	7	8	9	10
1	38	26	11	0	0	0	0	0	0	0	0	0
2	11	3	0	0	2	0	0	0	0	0	0	0
3	6	3	0	0	1	1	0	0	0	0	0	0
4	25	10	0	0	0	3	0	0	0	0	0	0
5	10	2	0	0	0	0	0	0	0	0	0	0
6	12	6	0	0	0	0	0	4	0	0	0	0
7	9	3	0	0	0	0	0	0	1	1	0	0
8	2	2	0	0	0	0	0	0	0	1	0	0
9	1	1	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0

Lower Main-Stem: Coho Salmon													
	Checked	Marked	Recaptures										
Strata			1	2	3	4	5	6	7	8	9	10	11
1	818	288	185	2	0	0	0	0	0	0	0	0	0
2	154	51	0	30	0	0	1	0	0	0	0	0	0
3	15	9	0	0	1	1	0	0	0	0	0	0	0
4	49	25	0	0	0	1	10	0	0	0	0	0	0
5	462	97	0	0	0	0	69	7	1	1	0	0	0
6	859	137	0	0	0	0	0	100	3	2	0	0	0
7	345	124	0	0	0	0	0	0	29	15	1	0	0
8	341	114	0	0	0	0	0	0	0	39	4	1	0
9	240	77	0	0	0	0	0	0	0	0	22	3	0
10	50	20	0	0	0	0	0	0	0	0	0	12	1
11	7	5	0	0	0	0	0	0	0	0	0	0	0

Lower Main-Stem: steelhead													
	Checked	Marked	Recaptures										
Strata			1	2	3	4	5	6	7	8	9	10	11
1	1478	611	224	5	1	0	0	0	0	0	0	0	0
2	342	88	0	25	0	0	0	0	0	0	0	0	0
3	95	58	0	0	12	1	3	0	0	0	0	0	0
4	120	55	0	0	0	6	9	0	0	0	0	0	0
5	370	73	0	0	0	0	34	2	3	0	0	0	0
6	546	79	0	0	0	0	0	24	0	0	1	0	0
7	296	76	0	0	0	0	0	0	15	0	0	0	0
8	80	29	0	0	0	0	0	0	0	6	1	1	0
9	36	8	0	0	0	0	0	0	0	0	0	0	0
10	14	8	0	0	0	0	0	0	0	0	0	0	0
11	8	4	0	0	0	0	0	0	0	0	0	0	0