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2001-2002 ANNUAL REPORT
RESULTS OF JUVENILE DOWNSTREAM MIGRANT TRAPPING CONDUCTED ON FRESHWATER CREEK, 2002
PROJECT 2a6

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Steelhead Research and Monitoring Program
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ABSTRACT

Juvenile salmonid downstream migrant trapping was conducted at seven locations in the Freshwater Creek basin between March 3 and June 18, 2002. 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 migration survival of emigrating salmonids. Based on trapping results, we estimate that 5327, 2178 age 1+and 2+ steelhead (Onchorhynchus mykiss irideus), respectively and 2676 coho salmon (Onchorhynchus kisutch) smolts emigrated from Freshwater Creek during the study period. Remigration of "efficiency release" steelhead was estimated to be nearly 100%, while only 61% of juvenile coho salmon resumed migration after marking and upstream release. Forty nine percent of all the steelhead migrants and 100% of all coho salmon continued migration from the tributary traps past the lower mainstem trap. The six tributaries contributed 2.8% (153) age 1+ steelhead, and 44.6% (972) age 2+ steelhead, and 46% (1233) coho salmon to the entire yield emigrating from Freshwater Creek during the study period.

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

Acknowledgments

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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) falls 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. 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 define population structure within drainages.

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 main stem areas iv) investigate assumptions associated with mark-recapture juvenile salmonids outmigrant models.

Study Area

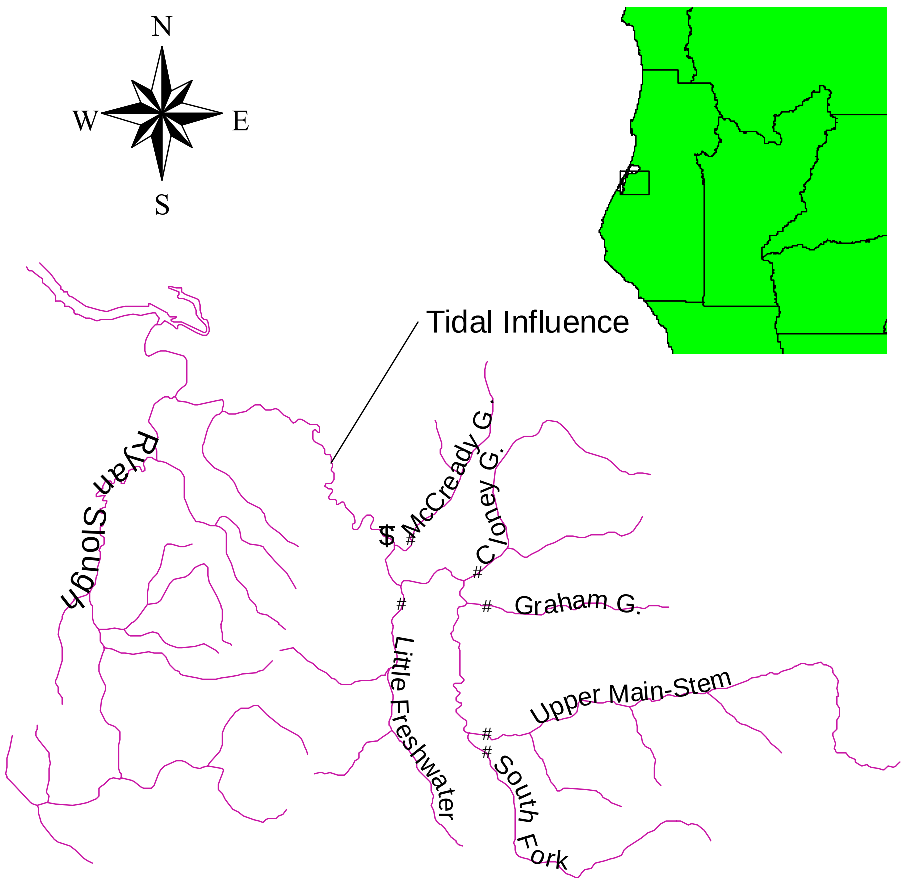
The Freshwater Creek basin is located in Humboldt County between Eureka to the south and Arcata to the north. Freshwater Creek is a fourth order stream with a drainage area of approximately 9227 hectares (31 square miles) and drains into Humboldt Bay via the Eureka Slough. Elevations in the watershed 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*).

Freshwater Creek Basin



$ Lower Main-Stem trap

Tributary Traps

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

METHODS

Fish Capture

Seven downstream migrant traps were fished in the Freshwater Creek basin from March 4, 2002 through June 18, 2002. 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 main stem 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 riffle 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 main stem Freshwater Creek, below McCready Gulch to provide an estimate of main stem 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, were designated as marking days. On these days, fish were anaesthetized with MS-222, measured for fork length, weighed to the nearest 0.1g, and marked by injecting a small line of colored Visual Implant Elastomer (VIE) on both sides of the jaw. Each trap was designated a specific color, and was injected in the right jaw. Seven different mark colors on the left jaw 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 seven 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 2+ and older steelhead and age 1+ coho salmon emigrants for each drainage. Numbers of age 0+ Chinook salmon smolts were estimated from at the lower main stem 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).

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 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.
Mitigation: 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.
Mitigation: Size/age classes were estimated separately.

3) Marks are not lost and are unambiguously identified.
Test: 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 Mitigation:
Mitigation: 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 assessed at Mad River Hatchery. Fish resuming migration was assessed with a multiple mark-recapture design.

5) Marked fish resume migration past the trap site
Test: Estimates of apparent survival, which incorporate losses due to both mortality and failure to resume migration after marking and upstream release of steelhead were generated using the relative recovery rate method (Ricker 1948, Thedinga et al. 1994). Fish marked and released above the tributary traps

represent the treatment groups for each estimate (R_{t1}). The control groups (R_{c1}) are fish recaptured at the juvenile traps and given a secondary batch fin clip. 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 ($\hat{S}$) are:

$$\hat{S} = (m_{t12}\ R_{c1}) / (R_{t1}\ m_{c12})$$

with sampling variance,

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

Steelhead remigration estimates were generated for all tributary traps combined.

Estimates of Tributary Contribution to Basin Yield

Fish emigrating from Freshwater Creek tributaries may 1) continue emigrating past the LMS trap or 2) residualize 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 estimate of tributary contribution to the entire basin yield is therefore calculated as:

Trib. Contribution = (Σ (tributary estimates)) * (survival to LMS))

Where "survival to LMS" is calculated in a like manner as remigration probability but defines test and control groups as:

R_{t1}= all fish marked at the tributary traps (regardless of tributary recapture)
R_{c1}= fish captured for the first time at the LMS trap, marked and released above the LMS trap.
m_{t12} =tributary marks recaptured at the LMS trap
m_{c12}=LMS marked fish (LMS "efficiency" releases), recaptured at LMS

Length of Steelhead and Coho salmon

All captured age 1+ steelhead and coho salmon were measured for fork length and a sample, 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 Kruskal Wallis one-way ANOVA on ranks tests was used to determine if lengths of systematically measured coho salmon differed between tributaries. Dunn's method was used for multiple comparisons between tributaries. Alpha levels were set to 0.05 for all tests.

RESULTS

Abundance Estimate Assumptions

<u>Marks are not lost and are unambiguously identified</u>. In situ VIE mark retention was 96%. VIE mark retention at Mad River Hatchery was 97% (97/100) over a four week period (Ricker, unpublished data).

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

<u>Remigration Probability of Efficiency Release Steelhead.</u> Remigration probability of efficiency marked juvenile steelhead at the tributary traps was 0.91 ± .30(SE). Remigration probability of efficiency marked juvenile coho salmon at the tributary traps was 0.61 ± 0.06 (SE) (Table 1).

Tributary Trap "Efficiency" Release						
	R_{t1}	R_{c1}	m_{t12}	m_{c12}	$\hat{S}$	SE
All Steelhead	421	111	38	11	0.91	0.29
Coho	387	228	117	112	0.61	0.06

Table 1. Mark-recapture data used to calculate survival ($\hat{S}$) for groups of steelhead and coho salmon. *Tributary trap "Efficiency" Release* $\hat{S}$ is analogous to remigration probability.

Abundance Estimates

Basin wide age 1+ and 2+ steelhead emigration was estimated to be 5327 ∀ 909(SE) and 2178 ∀ 1503 (SE), respectively at the LMS trap. Coho salmon smolt yield at the LMS trap was estimated to be 2676 ∀182 (SE). All trap abundance estimates are displayed in Table 2. Young of the year (age 0+) captures for all traps are displayed in Table 2.

Trap Species / Age class	N(hat)	SD
Lower Main-stem		
Steelhead 1+	5327	909
Steelhead 2+	2178	1503
Coho 1+	2676	182
McCready G.		
Cutthroat 1+	123	53
Cloney G.		
Steelhead 1+	190	42
Steelhead 2+	185	85
Coho 1+	794	41
Graham G.		
Steelhead 1+	53	9
Steelhead 2+	34	18
Upper Main-stem		
Steelhead 1+	449	120
Steelhead 2+	528	128
Coho 1+	134	14
South Fork		
Steelhead 1+	99	37
Steelhead 2+	213	42
Coho 1+	56	9
Little Freshwater		
Steelhead 1+	228	131
Steelhead 2+	**13**	NA
Coho 1+	249	115

Table 2. Abundance estimates (N(hat)), associated error (SD) of the estimate, of smolts and parr by species, age class and sub-drainage. BOLD indicates number of fish captured and is not an estimated total yield.

Age 0+ catches

	McCready	Cloney	Graham	Upper Main	South Fork	Little Fresh	Lower Main
Coho	4152	26425	878	61242	36767	6483	64542*
Steelhead	25	232	0	2357	5	0	738*
Chinook	0	844	**19**	8781	0	0	11168*

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. * indicates an estimated catch.

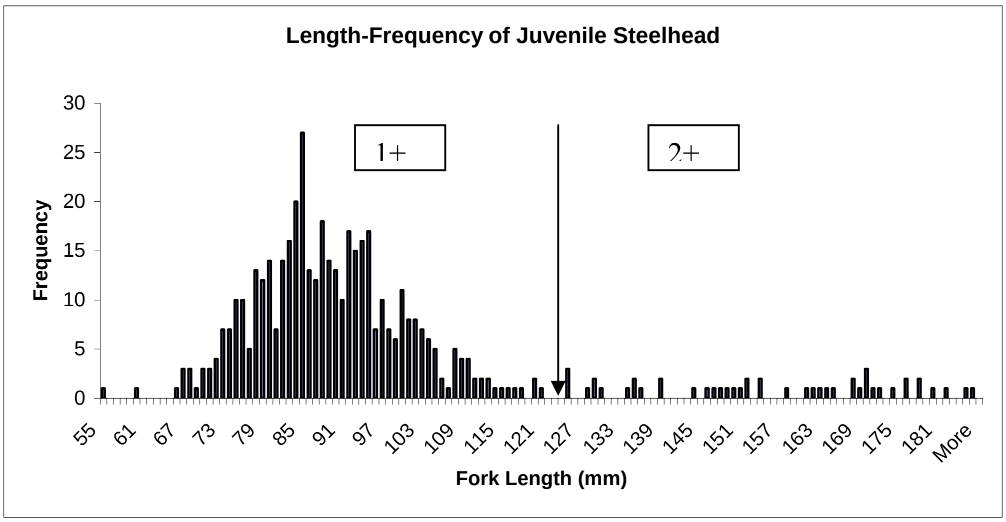


Figure 2. Length-frequency histogram of all captured steelhead at the LMS trap. Boxes indicate age classes and arrows depict fork length used for age class delineation.

Estimates of Tributary Contribution to Basin Yield

<u>Migration Survival.</u> Migration survival of all steelhead from all tributaries combined to the LMS trap is estimated to be 49% ∀ 8% (SE). Age 1+ and age 2+ steelhead migration survival rates were 87% ∀ 14%, and 74% ∀ 54% respectively (Table 2). Migration survival of emigrating coho salmon from all tributaries (**Bold** Table 2) to the LMS trap was estimated to be over 100%, and may indicate a violation of the assumptions of the relative recovery rate method.

Tributary Traps to LMS						
	R_{t1}	R_{c1}	m_{t12}	m_{c12}	$\hat{S}$	SE
All Steelhead	421	482	48	112	0.49	0.08
Steelhead 1+	184	438	40	110	0.87	0.14
Steelhead 2+	237	44	8	2	0.74	0.57
Coho	387	441	229	193	**1.35**	0.09

Table 4. Mark-recapture data used to calculate survival ($\hat{S}$) from the tributary traps to the lower mainstem (LMS) trap for groups of steelhead and coho salmon.

Migration Timing

Trapping commenced on March 3, 2002 during a period of low emigration. Thereafter, a peak in migration began April 11, and sporadic catches continues through May 15, 2002(Figures 3,4,5).

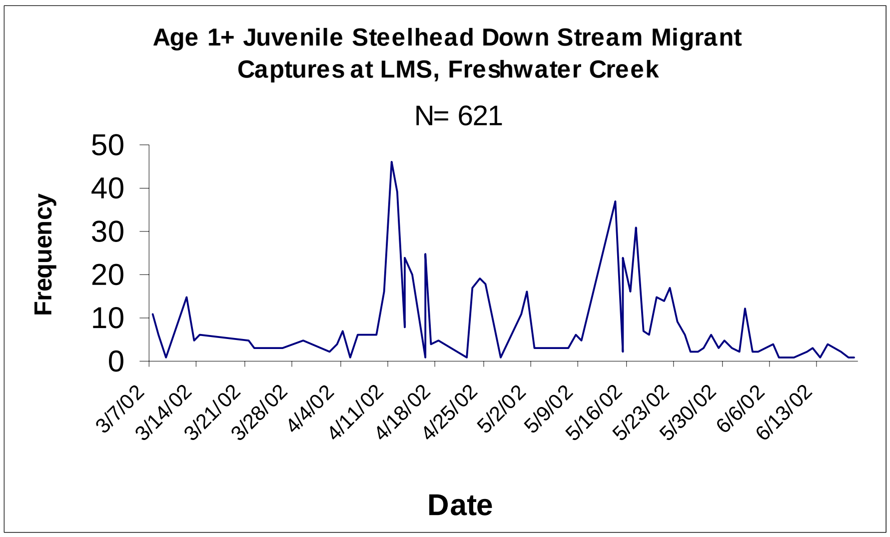


Figure 3. Timing of steelhead emigration at the LMS trap.

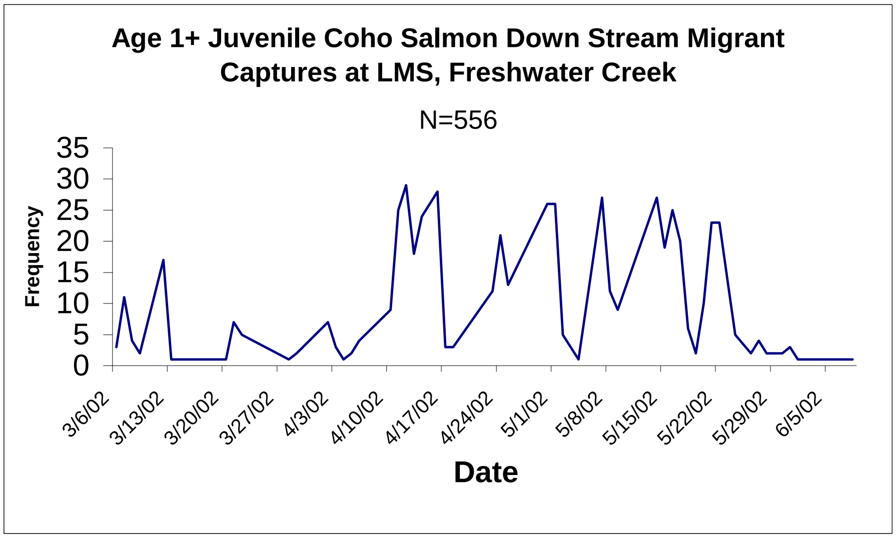


Figure 4. Timing of coho salmon captures at the LMS trap.

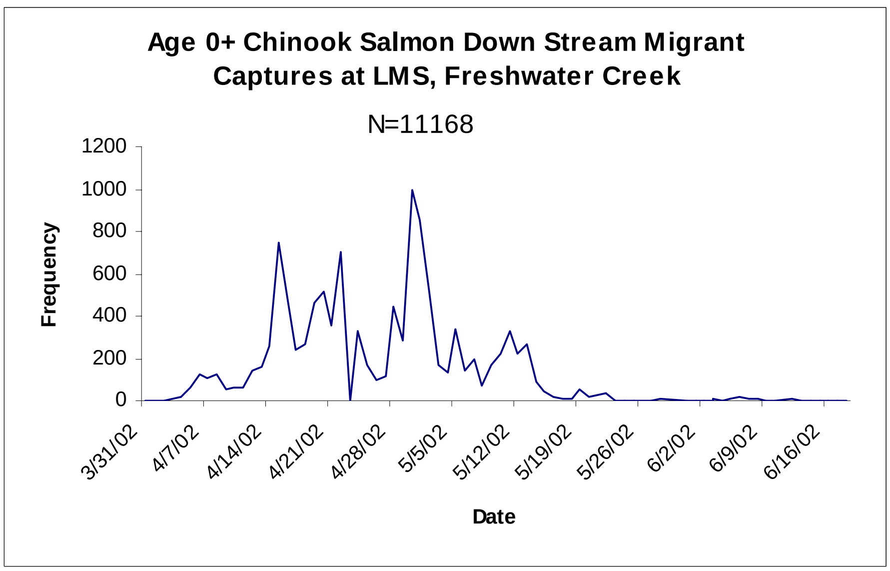


Figure 5. Timing of chinook salmon captures at the LMS trap.

Length of Steelhead and Coho Salmon

Steelhead. The median fork length of steelhead from tributary creeks ranged from 86 mm from the Little Freshwater to 147mm for the upper main-stem (UMS) Freshwater Creek. There was a significant difference in median fork lengths between tributaries (H= 59.03, P< 0.001, *df* = 4) (Figure 6). Results of multiple comparisons (Dunn's test) are displayed in table 3.

Comparison	Diff of Ranks	Q	P<0.05
South Fork vs Little Fresh	140.006	6.15	Yes
South Fork vs Graham G	98.914	4.027	Yes
South Fork vs Cloney G	30.604	1.663	No
South Fork vs UMS	3.621	0.228	NA
UMS vs Little Fresh	136.385	6.539	Yes
UMS vs Graham G	95.293	4.179	Yes
UMS vs Cloney G	26.983	1.688	NA
Cloney G vs Little Fresh	109.402	4.788	Yes
Cloney G vs Graham G	68.31	2.772	No
Graham G vs Little Fresh	41.092	1.465	No

Table 5 . Results of multiple comparison (Dunn's test) of juvenile steelhead fork lengths.

Coho Salmon. Median sizes of coho salmon captured at the tributary traps ranged from 91mm in Cloney Gulch to 116 mm from the South Fork. Significant differences were found in fork lengths of coho salmon between tributaries ($H = 66.51$, $P < 0.001$, $df = 3$) (Figure 7). Results of multiple comparisons (Dunn's test) are displayed in Table 4.

Comparison	Diff of Ranks	Q	P<0.05
SF vs Cloney	158.68	5.712	Yes
SF vs LF	121.119	3.759	Yes
SF vs UMS	44.306	1.385	No
UMS vs Cloney	114.374	6.22	Yes
UMS vs LF	76.813	3.124	Yes
LF vs Cloney	37.561	1.999	No

Table 6. Results of multiple comparisons (Dunn's test) of coho salmon fork lengths.

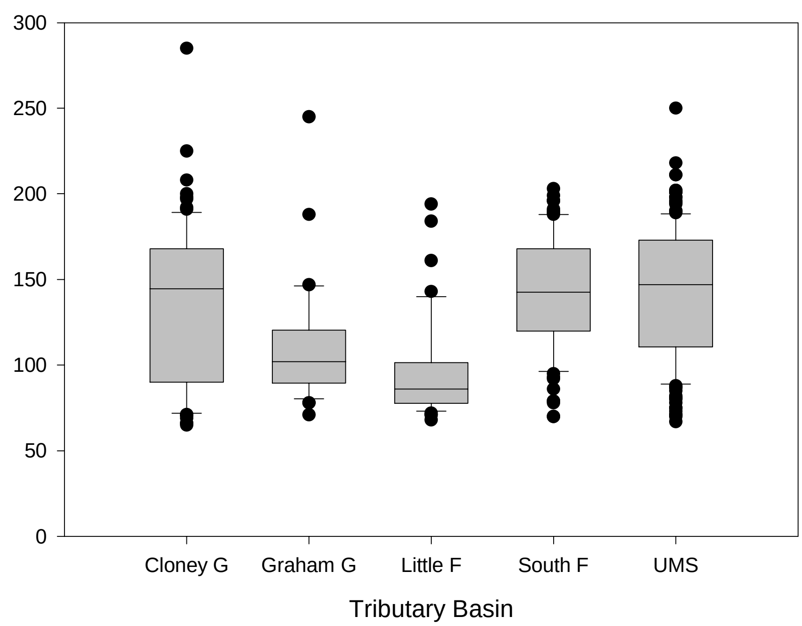


Figure 6. Comparison of fork lengths of measured steelhead from each tributary trap. Box plots depict 25th, 50th, and 75th percentiles, whiskers depict 10th and 90th percentiles and points indicate outliers.

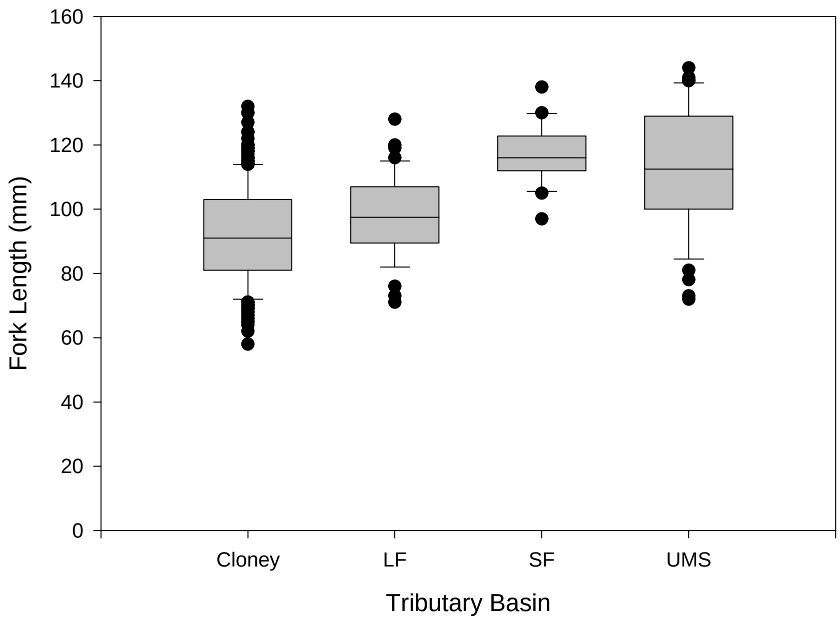


Figure 7. Comparison of fork lengths of systematically measured coho salmon smolts captured at each trap. Box plots depict 25th, 50th, and 75th percentiles, whiskers depict 10th and 90th percentiles and points indicate outliers.

DISCUSSION

Yield of Smolts and Parr

Age 2+ steelhead captures and trap efficiency were low this season and produced fairly unreliable basin wide estimates of this age group. The estimates of steelhead emigrants, however, are lower than the previous year (10,745 vs. 7505). Estimates of coho salmon smolts were estimated at less than half the previous year (6080 vs. 2676).

Age 0+ Captures

A large adult escapement into Freshwater Creek during November 2001 to January 2002, produced a large exodus of age 0+ coho salmon fry from the system. This magnitude of down stream movement of juvenile coho may indicate the habitat in the basin was saturated and a carrying capacity was reached. Steelhead escapement into Freshwater Creek the previous winter was estimated to be twice the number estimated in 2000-2001 and yet the number of age 0+ steelhead captures in all traps, but the upper main stem, was not significantly higher than the previous year. This leads to the postulate that Freshwater Creek tributaries, with the possible exception of the upper main stem, were not fully seeded with young of the year. The distribution of YOY captures in Freshwater Creek sub-basins indicates either a preference for spawning areas or unequal survival of YOY steelhead from egg deposition to migrant trap.

Migration Survival and Partition of Smolt Yield

This year's trapping effort commenced during a low period of emigration. It may be therefore, assumed that the estimates of smolts contributed by the tributaries and main stem area are not biases by trap timing. The majority of steelhead emigrated from the main stem areas downstream of the tributary traps. Nearly 50% of the larger older age fish however, migrated from the tributary reaches, and most of these originating from the upper main stem.

Shapovolov and Taft (1954) noted a migration of juvenile steelhead upstream during the fall months. These authors speculated that these fish migrate back upstream in search of over wintering habitat. Twenty eight steelhead were captured this year that had been marked migrating downstream the previous spring (2001). Due to lack of information on VIE tag retention for a year, it is unknown how many of the now age 2+ steelhead were tagged as age 1+ fish the previous season. Analysis the juvenile life history from return adult scales reveals the majority of successfully returning adults entered the ocean environment at age 2 and 3 (see study 1a1). These juvenile marking data as well as adult scale analysis support the conclusions that age 1+ that are captured migrating downstream in the spring do not enter the ocean, and may migrate back upstream to rear.

Remigration of Efficiency Release Fish

Steelhead, regardless of size or age, appear to resume migration after marking and release above the tributary traps. This apparent remigration after marking and release not only validates the mark-recapture model assumption but also indicates a directed downstream migration of steelhead during this season. All coho salmon, however, do not appear to resume migration past the tributary traps, but do not appear to residualize in the mainstem between the tributaries and the LMS. These contradictory findings may be due to a failure of the study design to adequately assess this behavior.

RECOMMENDATIONS

Additional work needs to be done to adequately address the critical assumptions of a single trap stratified mark-recapture experiment aimed at estimating smolt yield.

Additional studies need be developed to understand the relationship between spring emigration, estuary residence, ocean entry, and the survival benefit of these life history strategies to further understand age 1+ steelhead spring movement.

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