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Survival of coho salmon in northern California streams of varying habitat quality.

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Introduction

This report is the second interim report on research being conducted by the **California** Cooperative Fishery Research Unit, Humboldt State University and National Marine Fisheries Service (NMFS) to determine **the** effects of habitat **quality** on Coho salmon (*Onchorhynchus kisutch*) survival rates in northern **California** coastal streams. It contains preliminary results of research conducted after May 1999, the date of our initial report. Selected data not reported in the initial report **are also** presented here.

Coho salmon populations are at **risk** of extinction from a **variety** of anthropogenic sources. In response to **declining** coho salmon populations, and to better understand life history and habitat requirements of this species, NMFS listed coho salmon **as** a threatened species (Federal Register, 1997) in May 1997. **The** listing included the Transboundary (Southern Oregon to Northern **California**) Evolutionary Significant Unit (ESU) populations. The **California** Cooperative Fishery Research Unit, Humboldt State University **and** NMFS Tiburon/Santa **Cruz** Laboratory are conducting research in northern **California** streams **with** that contributes to information needed to recover coho salmon.

Mortality **of coho salmon** can be substantial during the first winter in freshwater (**Hartman** et al. 1982). Winter habitat has been **demonstrated** to be critical to the survival of juvenile coho **salmon** during the first year of stream residence (Bustard **and** Narver 1975, Petersen 1982, Tschapliniski **and Hartman** 1983, Nickelson et al. 1992). **Our** research examines winter survival in the context of overall **survival** during the freshwater portion of this species life history **as well as** the “quality” of habitat. Here we report results of studies on adult escapement, redd construction, winter and summer survival of juvenile **fish** and their movement. We **also** report results of studies on habitat available to coho salmon in **three** streams and habitats **used** by juveniles. Results presented **here** are considered preliminary, **as** they remain under review by NMFS. After review and further **analysis**, these data will be published in appropriate outlets and released for general **use**.

Redd Surveys and Escapement

Walter Duffy and Michael Sparkman

We present data on surveys to record redd formation and to estimate spawner escapement in study reaches of Prairie Boyes and Streelow Creeks. We use these data to estimate size of the coho salmon population in each stream. We also estimate, or speculate on, the number of eggs deposited by coho salmon in the three streams.

We conducted spawning and escapement surveys weekly during 1 December 1998 – 2 March 1999 on 10 km of stream, six km on Prairie Creek and two km on each of Boyes and Streelow Creeks. Surveys were initiated after the sand barrier on Redwood Creek was breached, allowing anadromous fish to enter the basin. They were terminated after no coho salmon were encountered during two consecutive surveys. Surveys were not conducted during periods of high discharge when visibility was limited and conditions were not safe for observers. Surveys consisted of two observers walking in or along the stream, from the downstream to upstream, and recording the number of new redds constructed by coho salmon, chinook salmon and steelhead as well as the location of each. We designated a redd as being constructed by one of the three species only after observing a female constructing or on the redd, and after identifying the fish. We also recorded the number and location of live fish and carcasses of dead fish of each of the above three species. For coho salmon, the condition and location of each carcass encountered was noted. On first encountering a coho salmon carcass, a numbered metal tag was attached to the jaw of the carcass. On subsequent encounters, the number of the jaw tags was recorded. These data were used in estimating population size of spawning fish (escapement) from tag-recapture models.

Relatively few coho salmon carcasses were encountered, limiting the use of most models for estimating escapement. We attempted to apply a Jolly-Seber model to estimate escapement, but the high proportion of zero counts compromised results. Therefore, we estimated escapement using Lincoln's index (Begon 1979).

Redd Surveys

We documented 24 coho salmon redds in study reaches of the three streams, 11 in Prairie Creek, eight in Streelow Creek and five in Boyes Creek (Tables 1-3). Coho salmon redd

construction occurred **during** the period from 18 December through 17 February. Coho salmon were observed constructing redds in Prairie Creek **as** early **as** mid-December (Table 1), but not until late January in the other two streams.

Chinook salmon and steelhead redds were only found in Prairie Creek. Most of the 79 chinook salmon redds documented were constructed on or before 28 December. **Only** two steelhead **redds** were documented and both were found on 22 **January**. Overall, 175 redds of **unknown** origin were found. Of this total, 103 were found on or before 28 December, coinciding with the period when chinook **salmon** were most actively constructing redds (Tables 1-3). The number of redds of **unknown** origin exhibited a secondary peak in early February, **a** period when redds could well have been constructed by either steelhead or coho salmon.

Estimated Escapement

Most of the fish observed during surveys were chinook salmon (Table 1), even though this species occurred **only** in Prairie Creek. Chinook salmon were most common when surveys were initiated and declined thereafter. We observed **only** 24 live steelhead, the least common of the *three* species recorded. Steelhead were not observed until 16 **January**, however, and were **still** being recorded when surveys were terminated.

We observed 132 live coho salmon during surveys, **most** in Prairie Creek (Tables 1-3). Most observations occurred during **the** period from 28 December 1998 through 22 **January** 1999. Interestingly, the few observations of coho salmon in Boyes Creek were **all** after this period.

Surveys produced 33 coho salmon **carcass** observations, 27 in Prairie Creek and six in Streelow Creek. They also produced 15 carcass recaptures, 13 in Prairie Creek and two in Streelow Creek. From these data, we estimated escapement to Prairie Creek to be 70 (variance = 303) adult fish (Table 4). For Streelow Creek, our estimate of escapement **was** 36 (variance = 1,080) adult fish, but the variance of **this** estimate **was** large. No carcasses were found in Boyes Creek **and**, consequently, no escapement estimate was possible.

Potential Egg Production

We combined data on **sex** ratio, escapement, number **of** redds and **fry** emergence from redds in the **three** study streams **with** reported data from literature to **examine** potential egg production and survival. **Mean** fecundity reported for coho salmon from Prairie Creek is about

Table 1. Summary of weekly spawning survey data for Prairie Creek, Humboldt County, California during 1998/99. Dates recorded are beginning the date of the survey, carcasses recaptured are recorded for coho salmon only.

Date	Coho				Chin- ook			Steel- head			Un- known		
	New redds	Livefish	Carcass counted	Recap. carcass	New redds	Live fish	Carcass counted	New redds	Live fish	Carcass counted	New redds	Live fish	carcass counted
12/1/98	0	3	0	0	30	180	4	0	0	0	28	14	0
12/10/98	0	6	0	0	22	114	26	0	0	0	20	4	0
12/18/98	1	6	0	0	10	69	44	0	0	0	34	8	0
12/28/98	1	10	0	0	6	51	28	0	0	0	16	2	1
1/4/99	0	14	0	0	7	43	17	0	0	0	12	3	0
1/11/99	1	13	2	0	3	20	28	0	0	0	20	2	0
1/16/99	3	25	1	0	0	6	1	0	1	0	1	1	0
1/22/99	1	13	4	1	0	5	20	2	3	0	5	3	1
1/26/99	4	9	13	1	1	7	4	0	3	0	6	1	0
2/2/99	0	4	4	5	0	0	6	0	8	0	15	0	0
2/10/99	0	0	3	5	0	0	0	0	2	0	2	0	0
2/16/99	0	0	0	1	0	0	0	0	0	0	4	0	0
3/2/99	0	0	0	0	0	0	0	0	7	0	2	1	0
Total	11	103	27	13	79	495	178	2	24	0	165	39	2

¹ A single chum salmon was observed on 12/18/98 and 1/4/99. A chum salmon carcass was observed on 1/4/99.

Table 2. Summary of weekly spawning survey data for Streeflow Creek, Humboldt County, California during 1998/99. Dates recorded are beginning the date of the survey, carcasses recaptured are recorded for coho salmon only'.

Date	Coho				Chin- ook			Steel- head			Un- known		
	New redds	Livefish	Carcass counted	Recap. carcass	New redds	Live fish	Carcass counted	New redds	Livefish	Carcass counted	New redds	Live fish	Carcass counted
12/6/98	0	0	0	0	0	0	0	0	0	0	0	0	0
12/21/98	0	0	0	0	0	0	0	0	0	0	3	0	0
12/24/98	0	0	0	0	0	0	0	0	0	0	0	0	0
1/6/99	0	2	0	0	0	0	0	0	0	0	2	0	0
1/13/99	0	2	0	0	0	0	0	0	0	0	1	3	0
1/23/99	6	13	0	0	0	0	0	0	0	0	1	1	0
1/27/99	1	2	4	0	0	0	0	0	0	0	0	1	0
2/3/99	0	0	2	1	0	0	0	0	0	0	0	0	0
2/10/99	0	0	0	1	0	0	0	0	0	0	0	0	0
2/17/99	1	2	0	0	0	0	0	0	0	0	0	0	0
3/4/99	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	8	21	6	2	0	0	0	0	0	0	7	5	0

Table 3. Summary of weekly spawning survey data for Boyes Creek, Humboldt County, California, during 1998/99. Dates recorded are beginning the date of the survey, carcasses recaptured are recorded for coho salmon only¹.

	coho				Chin- ook			Steel- head			Un- known		
	New		Carcass	Recap.	New		Carcass	New		Carcass	New		carcass
12/10/98	0	0	0	0	0	0	0	0	0	0	0	0	0
12/10/98	0	0	0	0	0	0	0	0	0	0	0	0	0
12/21/98	0	0	0	0	0	0	0	0	0	0	0	0	0
12/30/98	0	0	0	0	0	0	0	0	0	0	0	0	0
1/6/99	0	0	0	0	0	0	0	0	0	0	0	0	0
1/13/99	0	0	0	0	0	0	0	0	0	0	0	0	0
1/27/99	3	2	0	0	0	0	0	0	0	0	0	0	0
1/29/99	1	4	0	0	0	0	0	0	0	0	2	0	0
2/2/99	0	1	0	0	0	0	0	0	0	0	1	0	0
2/13/99	0	0	0	0	0	0	0	0	0	0	0	0	0
3/5/99	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	4	7	0	0	0	0	0	0	0	0	3	0	0

Table 4. Estimated escapement of spawning adult coho salmon to Prairie, Stree-low and Boyes Creeks, Humboldt County, California, during 1998/99.

Stream	Σ Marked carcasses	Σ Carcasses in second sample	Σ Recaptures	Est. of N (Pop. size)	Variance of N
Prairie Cr.	27	26	10	70	303
Stree-low Cr.	6	6	1	36	1080
Boyes Cr.	0	0	0	0	0

2,500 (Briggs 1953), while number of eggs deposited per redd **has** been reported to be around 900 (Sandercock 1991).

We positively identified **24** redds **as** being constructed by coho salmon during the winter of 1998/99. A total of 7,332 fry were captured from 15 of these redds that we capped. Average number of fry emerging from redds was **889** in Prairie Creek, **453** in Stree-low Creek and **124** in Boyes Creek. Combining fry emergence and potential egg deposition in redds, we estimated preliminary egg survival rates ranging from 5.0% in Boyes Creek to **35.6%** in Prairie Creek (Table 5). At present, the greatest source of uncertainty appears to be in the discrepancy between estimated female escapement and potential number of eggs deposited in redds. Multiplying female escapement by potential fecundity yields an estimate of about **90,000** eggs. Multiplying number of known coho salmon redds by the same figure yields **an** estimate of 60,000 eggs. However, more redds of unknown **origin (45)** were constructed during **January** when most coho salmon spawned than were redds positively associated with coho salmon. The latter information suggests to us that potential egg production calculated from either the number of redds constructed or escapement estimates may well be similar.

While little more than a paper exercise until firm data are available, we believe this brief analysis may prove useful in developing our thinking about estimating egg survival **and** where effort should be focused. One area, clearly, is to estimate survival **within** redds and we are undertaking artificial redd studies this winter directed toward this end. Another is reducing the number of unidentified redds and carcasses, **something** we are **also** attempting to address this winter.

Summer and winter survival of juvenile coho salmon

Kyle Brakensiek and David Hankin

In this section we present preliminary results from studies of summer and winter survival of juvenile coho salmon in Prairie, Streeflow and Boyes Creeks. The information is presented in three parts. First, we present results from downstream migrant fish trapping in all three streams. We next present estimates for winter survival in upper Prairie Creek for the 1998-99 season. In the third section, we present estimates for summer distribution, density and survival of juvenile coho salmon in all three streams during 1999.

Winter Downstream Fish Trapping

Downstream migrant fish traps were set and operated throughout the winter and summer months of 1999 in Boyes, Streeflow and Prairie Creeks. During winter and spring months, traps were operated continuously except during periods of high flow and when trap repairs were needed. Traps were operated intermittently on a weekly basis throughout the summer. Catches in traps provide a relative measure of movement but do not in themselves indicate fish abundance. Catches provided in Table 6 are through 11 October 1999.

Streeflow Creek

A downstream migrant fyke trap was placed near the mouth of Streeflow Creek on 29 March 1999. This trap was operated 136 of possible 233 days during the period and caught an estimated 3,444 age 0+ coho salmon. Only nineteen age 1+ coho were caught. A mark-recapture design to assess trap efficiency was developed, but not implemented in Streeflow Creek due to the low number of 1+ coho captured.

Winter trap catches, even considering extremely low trap efficiency estimates, were two orders of magnitude less than the estimated summer population size. Our estimated population size age 1+ coho salmon in Streeflow Creek during October 1998 was 1,408. This trap will be operated through the fall and Winter of 1999-00 to assess possible early migrating behavior by juvenile coho salmon in Streeflow Creek.

Boyes Creek

A weir pipe trap was ~~installed~~ near the mouth of Boyes Creek on 19 March 1999 and operated **123** of **201** possible days. A total of 70 ~~age 0+~~ and **57** ~~age 1+~~ coho ~~salmon~~ were caught in this period. The low **number** of ~~fish~~ caught ~~may~~ indicate trap inefficiency, low fish abundance, early downstream migration or residency. Increased efforts will be made to accurately document the number and **timing** of coho ~~salmon~~ migrating ~~from~~ Boyes Creek during ~~the 1999-00 trapping season.~~

Prairie Creek

~~Downstream~~ migrant ~~fish~~ traps were ~~istallel~~ at two sites in Prairie Creek and operated throughout the 1999 season, The lower site was ~~-~~ 3 m upstream from ~~the mouth~~ of ~~Stree~~low Creek while a second site about 7,500 m ~~upstream was~~ located ~ 30 m upstream from the mouth of Browns Creek. The upstream site is located at the downstream end of our 6.22 km study reach on Prairie Creek.

A 1.5 m dia. floating **rotary** screw trap ~~was~~ set at the lower site an **5** February 1999 and fished ~~most~~ days through 8 June, when it ~~was~~ removed due to inadequate discharge. A fyke trap ~~was~~ installed at this site **on 9** June and fished **through** 1 July 1999. The lower Prairie Creek trap site was operated 133 of a possible **146** days. During the entire period **1,954** age 1+ and **2,702** age 0+ coho salmon were captured (Tables 6 and 7). **Rotary** screw trap catches of migrating age 1+ coho salmon were greatest during May.

A fyke trap ~~was~~ set ~~at~~ the upstream site on **20 February 1999**. This trap ~~was~~ removed during June, but reinstalled in July and operated throughout the remainder of **1999** trapping **season**. Over the entire period, ~~this~~ trap was operated on **119** of 207 possible days. In this period 792 ~~age 1+~~ and **8,862** 0+ coho salmon were caught, with a pulse of age 0+ ~~fish~~ captured the last week in April.

In Prairie Creek, we attempted to estimate trap efficiencies and coho ~~salmon~~ abundance with a mark-recapture design *using* caudal ~~fin~~ clips. The design was ineffective due to delayed migration of **marked** fish combined ~~with~~ a limited combination of Unique ~~fin~~ clips. Instead, a mark-recapture study design using PIT (passive integrated transponder) tags was used **in an** effort to estimate winter survival, trap efficiencies and absolute coho ~~salmon~~ abundance.

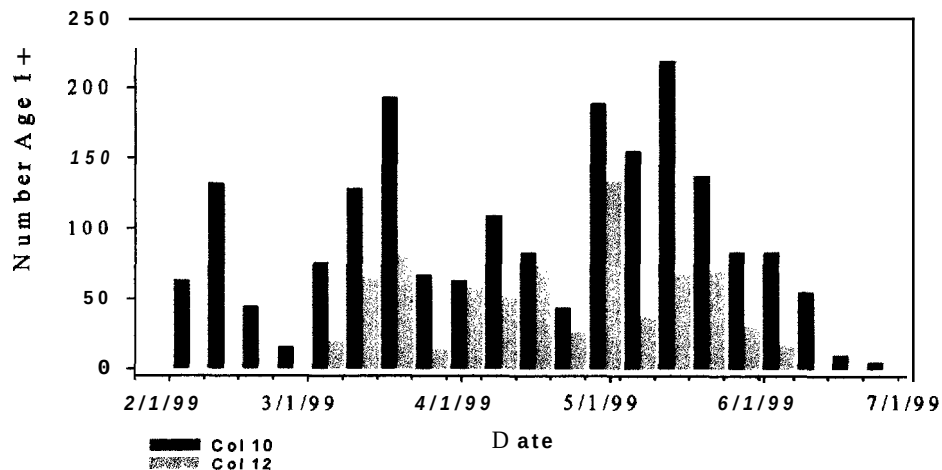


Figure 1. Weekly catch of age 1+ coho salmon with a rotary screw trap in lower Prairie Creek (black) and with a fyke trap in upper Prairie Creek (grey).

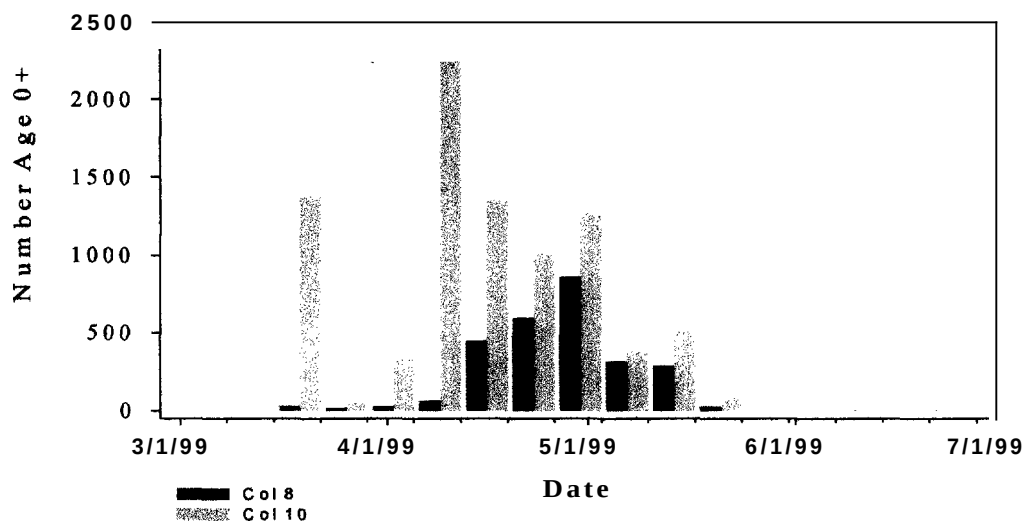


Figure 1. Weekly catch of age 0+ coho salmon with a rotary screw trap in lower Prairie Creek (grey) and with a fyke trap in upper prairie Creek (black).

Table 6. Total catch, mortality and percent mortality by species and trap site for the 1999 downstream **migrant fish** trapping efforts in Prairie Creek basin, northern California, through October 11, 1999

Species	Lower Prairie Cr. R. Screw Trap			Upper Prairie Cr. Fyke Trap			Upper Prairie Cr. Pipe Trap			Streelow Cr. Fyke Trap			Boyces Cr. Pipe Trap		
	Catch (no.)	Mort. (no.)	Mort. (%)	Catch (no.)	Mort. (no.)	Mort. (%)	Catch (no.)	Mort. (no.)	Mort. (%)	Catch (no.)	Mort. (no.)	Mort. (%)	Catch (no.)	Mort. (no.)	Mort. (%)
0+ Coho	2702	33	1.22	8862	308	3.48	0	0	0.00	3444	14	0.41	70	1	1.43
1+ Coho	1954	8	0.41	792	9	1.14	1	0	0.00	19	1	5.26	57	0	0.00
0+ Chinook	56615	427	0.75	97004	1012	1.04	0	0	0.00	431	5	1.16	110	0	0.00
Cutthroat	462	1	0.22	496	2	0.40	7	1	14.29	7	1	14.29	17	0	0.00
Steelhead	218	0	0.00	23	0	0.00	0	0	0.00	0	0	0.00	5	0	0.00
1+ Trout	828	23	2.78	117	5	4.27	0	0	0.00	10	0	0.00	31	0	0.00
0+ Trout	522	10	1.92	273	2	0.73	2	0	0.00	64	0	0.00	17	0	0.00
Ammocetes	152	2	1.32	87	2	2.30	1	0	0.00	11	0	0.00	7	0	0.00
B. Lamprey	159	0	0.00	126	0	0.00	2	0	0.00	13	2	15.38	8	0	0.00
P. Lamprey	56	0	0.00	14	0	0.00	0	0	0.00	0	0	0.00	9	0	0.00
Trap Info															
Start date	2/5/99			2/20/99			8/2/99			3/29/99			3/19/99		
End date	7/1/99			10/11/99			10/11/99			10/11/99			10/11/99		
Days/period	146			233			70			207			201		
Days fished	133			136			31			119			123		
Days not fished	13			97			39			78			83		

Table 7. Release-recapture data of PIT tagged coho salmon in Prairie Creek during 1998/99. Losses on capture are in parentheses and capture histories, up to and including trap I, are in brackets.

November

Release time & site	Release site		Σ Recaptured (first time)		Never recaptured
	R_{tih}	Trap 1	Trap 2	r_{tih}	
Initial	609	70(1)	26[0,1]	96	513
Released again at trap 1	619	73(11)	33[0,1]	106	513
Released again at trap 2		69	13[1,1]	13	56
		72	13[1,1]	13	59
			26[0,1]	13[1,1]	39
			33[0,1]	13[1,1]	46

March

Release time & site	Release site		Σ Recaptured (first time)		Never recaptured
	R_{tih}	Trap 1	Trap 2	r_{tih}	
Initial	146	22	7[0,1]	29	117
Released again at trap 1		22	3[1,1]	3	19
Released again at trap 2			7[1,1]		10
			3[1,1]		

January

Release time & site	Release site		Σ Recaptured (first time)		Never recaptured
	R_{tih}	Trap 1	Trap 2	r_{tih}	
Initial	416	40	16[0,1]	56	360
Released again at trap 1	422	44	20	64	358
Released again at trap 2		40	7[1,1]	7	33
		44	7[1,1]	7	37
			7[1,1]		23
			7[1,1]		27

Winter Survival in Upper Prairie Creek

We used data on the recapture of **1,187** coho salmon PIT tagged to determine winter growth and habitat fidelity to **also** estimate winter survival. PIT tags provide information on the histories of individual recaptured fish and are especially suitable for release-recapture studies. Coho salmon were PIT tagged within three distinct time periods (Table 7). **As an** initial group of **619** fish were tagged during the period 15 November - 15 December **1998**. **An** additional **422** fish were tagged during 23 December **1998** – 26 January **1999**. To better evaluate the possibility of detecting over-winter mortality, 146 fish were tagged **within** a 28 day period beginning February **18,1999**.

Downstream migrant trap recaptures of PIT **tagged** coho salmon were recorded and evaluated according to tag group and time of recapture (Table 7). A total of **199** or 16.8% of PIT tagged fish were recaptured at one or both downstream migrant traps. Recaptures **by** tag group were **17.1%** for November, **15.2%** for **January** and **19.7%** for March.

Using methods detailed in Burnham *et al.* (1987), release recapture arrays were developed **and** preliminary chi-square tests of independence between groups were applied. These **preliminary** tests indicated no treatment effect and no **significant** difference in survival rates between treatment **and** control groups. Furthermore, equations provided in Burnham *et al.* (1987, p. 69-72) **fail** to produce consistent results between calculated survivorship, trap efficiency, and total catch of coho salmon at respective trap sites. The relatively **small number** of **fish** tagged **and** recaptured in the March control group limit analyses **and** interpretation of results. Appropriate survival models **are** currently being explored.

To correct for release recapture design deficiencies, **a** greater number of coho salmon will be tagged in 2000. We will accomplish **this** by allowing more time between treatment and control groups. In addition, downstream migrant fish traps located in Prairie Creek **will** continue to be operated to evaluate and correct for early migration of PIT tagged fish **prior** to establishment of the control tag group.

In essence, a Jolly-Seber mark-recapture design will be **used** to estimate over-winter survival rates of coho salmon in upper Prairie Creek. Working within a ten-day period on two separate efforts, **814** and **674 coho salmon** were tagged in early October and the middle of November, **1999**. Approximately 400-500 coho salmon will be implanted with PIT tags in March 2000 to better evaluate winter survival rates.

Throughout October and November 1999, a total of 30 coho salmon tagged from the previous winter were recaptured. The **high** recapture rate of essentially age 2+ coho salmon complicates efforts to determine over-winter survival rates and suggests that a significant proportion of coho salmon **may** be remaining in Prairie Creek two winters after hatching. These recent **findings** will be considered in future analyses.

Summer Population Surveys

Population estimates were conducted in early **summer** and *again* in late **fall** on Boyes, Streelow and Prairie Creeks to estimate summer **survival** juvenile coho **salmon**. Sequential stratified **sampLing** designs were used to select sample units from **an** early summer stream habitat inventory. Inventoried habitat units were collapsed into pools, deep pools (>1.1m), runs, riffles, complex and 'other' habitat types for the purpose of juvenile coho **sa lmon** surveys. Habitat units classified **as** complex or 'other' were considered unsuitable for diver observations or electrofishing and excluded from juvenile surveys. **All** habitat units selected for population **surveys** during the summer **sampLing** period were retained and **sampLed** *again* during the fall. **SampLing** exactly the **same** units during both **spring** and **fall** allowed improved detection of changes in survival. Population surveys were completed **within** 10 days for each **sampling** period within the three study creeks.

Downstream migrant fish traps were installed and intermittently operated over the summer to **assess** potential migration of fish between summer population samples. In addition, a pipe trap was **placed** at the upstream end of the study section in Prairie Creek to estimate potential immigration. Traps were periodically operated on a weekly **basis**. Summer trap catches indicated essentially no emigration and in the case of upper **Prairie** Creek, immigration of juvenile **coho** salmon between the two **sampling periods**.

Streelow Creek

We sampled 2.20 **km** of Streelow Creek, beginning at the streams confluence with Prairie Creek. The survey endpoint was established as the point at which electrofishing **was** no longer practical. In early June and late September 1999, depletion removal electrofishing was used in pool, **run** and **rifle** habitat units. Using total lengths by habitat stratum, electrofishing was conducted on 19.5% of pool, 13.5% of **run** and **14.0%** of rifle habitats (Table 8). Population estimates and

standard errors (in parentheses) for summer were **3,171 (481)** fish and for **fall** were **2,340 (313)** fish. Confidence intervals **(0.95)** represented **29.5%** and **26.5%** of the total population estimate for summer and **fall** samples respectively. Not included in total population estimates, all deep pool habitats in Streelow Creek were sampled in early summer **using** multiple-pass diver observation techniques. Observation methods were not **used** in Streelow Creek **during** the fall population survey due to high tannin concentrations and reduced visibility. Stratum specific and stream total estimates **are** presented in Table 8.

Table 8. Habitat composition, habitats surveyed; estimated population **size** of coho salmon and standard errors of population estimates in Streelow Creek during June and September **1999**. (*) Totals do not include deep pool unit samples and estimates.

Habitat	units surveyed	units sampled	Pop. Est. June	S.E. Pop. Est.	Pop. Est. September	S.E. Pop. Est.
Pool	66	8	1,539	385	1,195	237
Run	49	8	1,342	272	1,029	200
Riffle	25	5	290	96	116	46
Deep pool	7	7*	95*	7	--	--
Complex	26	--	--	--	--	--
Other	3	--	--	--	--	--
Total	176	21	3,171	481	2,340	313

Preliminary summer survival can be calculated by dividing **fall** stratum specific and stream total population estimates by respective summer estimates. Using this calculation, over-summer survival rates of juvenile coho salmon in Streelow Creek during **1999** were **77.6%** in pool, **76.7%** in run and **40.0%** riffle habitats. Estimated average summer survival was **73.8%**.

Boyes Creek

We sampled **2.17 km** of Boyes Creek, **beginning** at the stream confluence with Prairie Creek. In both fall and summer population surveys, no coho salmon were found further than **1.5 km** from stream mouth. The **first** fish migration barrier in Boyes Creek is located at stream km **2.17**. The absence of coho salmon in the upstream portion of Boyes Creek coincides with the last known coho salmon redd recorded for the previous winter and suggests lack upstream movement by juvenile coho salmon in Boyes Creek.

Using depletion removal electrofishing methods, we sampled **19.5%** of pool, **13.5%** of run and **14.0%** of riffle total stratum lengths. (Table 9). Population estimates for summer and fall samples were both **1,537** with a standard error in June of **312** and in September of **298**.

Table 9. Habitat composition, habitats surveyed, estimated population size of coho salmon and standard errors of population estimates in Boyes Creek during June and September 1999.

Habitat	units surveyed	units sampled	Pop. Est. June	S.E. Pop. Est.	Pop. Est. September	S.E. Pop. Est.
Pool	75	11	720	188	750	120
Run	64	15	716	243	741	228
Riffle	55	10	102	52	45	26
Complex	7	--	--	--	--	--
Other	3	--	--	--	--	--
Total	204	36	1,537	312	1,537	298

These estimates indicate **minimal** summer **mortality**. However, population estimates for Boyes **Creek** may not be suitable for estimation of **summer** survival due to poor electrofishing capture probabilities during this period. Confidence (**0.95**) intervals for June data represented **52%** of pool, **68% of riffle** and **102%** of **run** population estimates.

Prairie Creek

A two-phase sequential random sampling design was **used** in selecting habitats for population surveys in Prairie Creek. Sequential independent sampling of units was used to select habitats for sampling. A probability of 0.5 was selected for phase I sampling, while the phase II sampling probability selected for pool habitats was **0.25** and for run habitats was 0.33. In **Prairie Creek**, phase I **sampling units** consisting of pools and runs were sampled **using** single-pass diver observation counts. In phase II sampling units, the method of **bounded** counts, based on four independent diver counts, was **used** if phase I diver counts were ≤ 30 coho salmon. If diver counts were >30 coho salmon, depletion removal electrofishing was used to estimate true number of coho salmon in conditionally selected units. In addition, **all** pools >1.1 m deep were sampled using repeated diver observations **only** and every **12* riffle** was sampled using electrofishing methods.

We sampled **6.27 km** of Prairie Creek immediately upstream **from** the confluence with Browns Creek. Juvenile coho population surveys were conducted within a ten-day period beginning in early July and again in October. Chosen **sampling** probabilities were approximately reflected in the number of units selected for **phase I** and **II** population samples (Table 10).

Table 10. Percent composition of habitat units and number of units sampled using **diving** and **electrofishing** methods for estimates of juvenile coho salmon abundance at two time periods in Prairie Creek, California **1999**.

Habitat	% Total length	Units surveyed	units sampled phase I dive	Units sampled Phase II			
				Diving (July)	E-fishing (July)	Diving (Oct.)	E-fishing (Oct.)
Pool	35.1	133	66	13	4	23	4
Run	23.3	93	50	11	5	13	3
Riffle	26.7	153	--	--	11	--	12
Deep pool	3.3	10	--	8	--	10	--
Complex	8.6	24	--	--	--	--	--
Other	3.0	16	--	--	--	--	--
Total		430	116	32	20	36	19

Two-stage regression estimation was used to determine the abundance of juvenile coho **salmon** in upper Prairie Creek. Second phase estimates were used to calibrate observation probability and 'true' abundance of phase I single-pass dive estimates. The estimated number of juvenile coho salmon in early June and October **1999** was **6,798 (564)** and **4,886 (478)** respectively (Table 11). Confidence intervals (**0.95**) represented **17%** of July and **20%** of October population estimates.

A preliminary indication of summer survival of juvenile coho salmon can be calculated by dividing fall stratum specific and stream total estimates by respective summer estimates. Using this calculation, summer survival rates of juvenile coho **salmon** in Prairie Creek for **1999** were **66.6%** for pool, **83.1%** for run and **31.5%** for riffle habitats. Estimated average summer survival was **71.9%** in Prairie Creek for **1999**. More rigorous statistical analyses of juvenile coho salmon survival are in progress.

Table 11. Stratum-specific and total population estimates with associated errors of estimation and 95% confidence intervals for upper Prairie Creek, California in June and October, 1999.

Habitat	June Pop. Est.	June S.E.	June 95% CI	October Pop. Est.	October S.E.	October 95% CI
Pool	4,069	439	878	2,710	276	552
Run	1,760	353	706	1,463	386	772
Riffle	771	552	114	243	190	380
Deep pool	196	20	40	469	62	62
Total	6.798	564	1.128	4.886	478	956

Habitat Use and Growth of Juvenile Coho Salmon

Ethan Bell and Terry Roelofs

This portion of the study focused on the 6-km study reach of Prairie Creek, extending from Brown's Creek upstream to Ten **Taypo** Creek. Prairie Creek is a third order tributary to Redwood Creek in northwestern **California**. Elevation ranges from 11 m at the mouth to 200 m at the headwaters of **the** creek. The maximum elevation of the watershed is **554m** The watershed **has** moderately steep slopes that support old growth redwood (*Sequoia sempervirens*), Sitka spruce (*Picea sitchensis*), and **Douglas** fir (*Pseudotsuga menziesii*). Under-story vegetation is predominately huckleberry (*Vaccinium ovatum*) and ferns (*Polystichum sp.*). The riparian zone **has** nearly complete cover dominated by red alder (*Alnus rubra*), big leafmaple (*Acer mucrophyllum*), and salmonberry (*Rubus speetabilis*). There **are** no barriers to fish movement **within** the study reach. Other fish species present included: chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki clarki*), threespine stickleback (*Gasterosteus aculeatus*), prickly **sculpin** (*Cottus asper*), coastrange sculpin (*Cottus aleuticus*), Pacific lamprey (*Lampetra tridentata*), and Pacific brook lamprey (*Lampetra pacifica*).

Methods

Habitat within the study reach was surveyed in September **1998**. After the watershed had received **15.2** cm of precipitation, winter habitat **types** were present. The creek was surveyed **again** in early November 1998 using methods described by Nickelson et al. (1992) to address winter habitat conditions. Alcoves, backwaters, and **main** channel pools were delineated, and **assumed** to be preferred juvenile coho salmon winter habitat (Bustard and Narver **1975**, McMahon **1989**, Nickelson et al. **1992**, Cederholm et al. **1997**). **Winter** habitat was assessed a third time during February. Habitat typing data were used in winter **98/99** and 99/00 study designs.

Alcoves are defined **as** pools separated from the **main** channel and accessible to fish during **high** stage height. They **are** often formed by abandoned side channels and retain **surface** water **from** hyporheic flow or **small** tributaries. Current velocities in alcoves are often less than can be measured and substrate is typically silt.

original habitat units. **SamPLing** was identical to methods used during the first visit. Coho salmon without **adipose** clips were given a PIT **tag**, **as in** the first Visit. **All** fish **with** adipose clips were scanned with a hand held scanner. Fork length, wet weight, and unit of capture was recorded for each **fish** recaptured (Appendix E). Minimum distances between habitat units (m) were recorded. Low recapture rates in some **main** channel pools suggested low capture efficiency, **so** direct observation dives were conducted in early January **in all main** channel pools. Direct observation population estimates in habitat units were consistent **with** electrofishing results.

This samPLing was repeated **between** 18 February and 11 March 1999 to determine habitat retention **and** late winter **growth**. However, additional coho salmon were not PIT tagged during late winter visits.

Out-migrant traps were installed on Prairie Creek to determine the survival of juvenile coho salmon in habitat units. Capture percent was defined **as** the percentage of fish tagged in habitat units that subsequently were captured at out-migrants in traps. **A** 1.5 m dia. rotary screw trap and a fyke trap **with** a 1.2 m wide mouth were operated continuously **from** 5 February to 21 June. **The** screw trap **was** located 7,450 m below the study reach, and the fyke was at the downstream end of the study reach. Both traps were **removed** during excessively high or low discharge events, but **fished** at least **part** of each day during the period. **After 25** June, the fyke trap **was** fished three days/week to monitor late season migration; none was detected.

A laboratory study was conducted to determine PIT tag retention rate, effect of tags on growth and on survival. Thirty-three juvenile rainbow trout averaging 67 mm were tagged and placed in a tank with 33 trout that were not tagged and **used as a** control group. Observations of the **both** groups were made after 4 and 6 months. No **mortality** of PIT tagged or control fish **was** observed and tag retention was 100%. Growth of **tagged and** control fish was **similar**, but has not been statistically tested at this time.

Analysis *of* Movement

Retention and immigration of juvenile coho salmon were both measured for **all** habitat units sampled during repeat Visits. Retention was defined **as** the percentage of fish tagged in Units that were recaptured in the same unit **during** re-visits (Harvey 1998). Due to the possibility of low capture efficiency, retention is a **minimum** estimate. Differences in retention of juvenile coho

salmon among alcoves, backwaters, and **main** channel pools was tested *using* a model I unbalanced two level nested **ANOVA**. The null hypotheses tested were that retention of coho **salmon among** habitat units and between months was equal. In all statistical **analyses**, habitat **units** were defined as the experimental unit with $\alpha = 0.05$. When statistical differences were detected for percent retention, planned **comparisons** were used to test the null hypothesis that probability of retention is **equal** all habitat Units. For planned **comparisons** appropriate Bonferroni adjustments were made to level of **significance**.

Immigration **was** defined as the percentage of fish captured in a habitat unit that had been **tagged** in a different unit. Immigration is, therefore, a **minimum** estimate. Rates of immigration detected were too low for statistical testing.

Analysis of Growth

Size of juvenile coho **salmon** occupying different habitats in November, the beginning of the study, was evaluated. Differences in **size** class distribution (FL) **among** habitat units **was** tested using a one-way **ANOVA**. An unpaired t-test **was** used to compare the **size** of juvenile coho salmon in November with size of fish recaptured during **downstream** migration, and with fish that did not smolt.

Specific growth rates for **all** recaptured juvenile coho salmon were calculated as:

$$G = [(\log_e W_2 - \log_e W_1) / (t_2 - t_1)] 100.$$

Where G is specific growth rate (% · d⁻¹), W₁ is initial weight, W₂ is **final** weight of the recaptured individual, t₁ is beginning date, and t₂ is ending date. Specific growth rate is relative to the size of the fish **being** measured (Ricker 1979, Busacker *et al.* 1990). Wet weight was **used** because it provides a more precise measure of growth than length over short time intervals (Busacker *et al.* 1990). Sample sizes were large enough to **minimize** effects of gut **fullness** on growth estimates. Percent change in weight **was also used** to illustrate relative differences in growth **among** habitat types.

A model I **unbalanced** two level nested **ANOVA** design was used to test for differences in specific growth rate among habitat units and between months. Null hypotheses tested were that there is no difference in specific growth rate “among habitat units” and “between months”. **Only** Units with two or more recaptures were **used** in habitat mean calculations. Specific growth rates during November - **January**, **January** - March and March – May were compared. When

differences in **main** effects were detected planned comparisons and **orthogonal** contrasts test were used. For planned comparisons appropriate Bonferroni adjustments were made to level of significance. **only** fish tagged and recaptured in the same habitat unit were used for habitat **specific** growth rate calculations.

To determine if growth was occurring during the winter in upper Prairie Creek, paired comparisons were used to test the null hypotheses that weight of juvenile coho **salmon** in November was equal to that in March and in May. Specific growth rate of tagged coho salmon smolts recaptured at traps was also recorded. For **analysis**, all fish captured at traps were combined by month of capture.

Analysis of Post Flood Movement

A flood on **21** November 1998 having 15-year occurrence interval allowed us measure the response of juvenile coho to a **high** discharge. Before the **flood**, **250** juvenile coho salmon had been tagged in 17 habitat units. All 17 habitat units were visited again in December and retention, **immigration**, and displacement rates were determined for those units **as** described above. Data were analyzed using a one-way **ANOVA** to test the null hypothesis that there were no differences in retention and immigration of juvenile coho **among** habitat units. Planned comparisons were used to test the null hypothesis that habitats were **equal** in retaining juvenile coho salmon **and**, that immigration and displacement did not **differ among** habitats.

Analysis of Downstream Migrant Trap Recapture Data

Data were analyzed to determine if differences in survival existed between **fall** and spring **among** habitat types. We tested the null hypotheses that capture of juvenile coho salmon in **migrant** traps that were tagged in different habitat **types** did not **differ using** a one-way **ANOVA**.

RESULTS

In November 1998, 619 juvenile coho salmon were tagged in **48** discrete habitat Units, **145** in alcoves, **228** in backwaters, and **246** in **main channel** pools. During **January** 1999, an additional 419 juvenile coho salmon were tagged, increasing the total number of tagged fish to 1,038. Of **this total**, 401 coho salmon were tagged in **main** channel pools, **401** in backwaters, **and**

239 in alcoves. The total number of fish tagged represents about 20% of the population of 5,000 juvenile coho **salmon** estimated to occupy this reach of Prairie Creek during September 1998.

Movement

In January 1999, 214 tagged juvenile coho salmon were recaptured from 47 of the original **48** habitat units. In a March 1999, 167 juvenile coho salmon were recaptured from **40** habitat units. There were no differences in percent retention within habitat units during January - March (two level nested **ANOVA** $df=1$, $F=4.120921$, $P>0.10$). There were differences in percent retention of juvenile coho **among** habitat **types** (two level nested **ANOVA** $df=4$, $F=6.576437$, $P<0.01$).

Of 619 juvenile coho salmon tagged in November, 169 (27.3%, **SE=3.7**) were recaptured in January from habitat units where they were previously tagged. Juvenile coho salmon occupying alcove habitat had significantly greater retention **rates than** those rearing in other habitats (Figure 3; planned comparison: $df=43$, $t=6.61868$, $P<0.001$). In alcoves **65** fish (44.8%, $SE=8.3$) were recaptured, **in** backwaters **45** (**19.7%**, $S.E.=4.9$) and in main channel pools **59** (24%, $SE=4.7$). Twenty-two of the juvenile coho salmon recaptured in January 1999 (3.87% of the total, $SE=0.969$) were recaptured in habitat units other than those they were tagged in (Table 12). Nineteen of 591 (3.2%, $SE=1.78$) **fish** captured were immigrants into sampled habitat units. Recorded **movements** of juvenile coho between habitat **Units** in January 1999 were mostly in **the** downstream direction, and varied between 4.3 meters and 1992 meters (Table 12). **Most** documented movements of coho were from backwater habitat downstream to **main** channel pools (Figure 4).

In March 1999, **40** habitat units with previously tagged juvenile coho salmon were again sampled. During **this sampling**, 153 (16.26% of total, $SE=2.57$) **fish** were captured in the habitat unit where they were originally marked. Coho salmon in alcoves had greater retention rates than in **other** habitat units (Figure 5; planned comparison: $df=33$, $t=6.30774$, $P<0.001$). Seventy-four

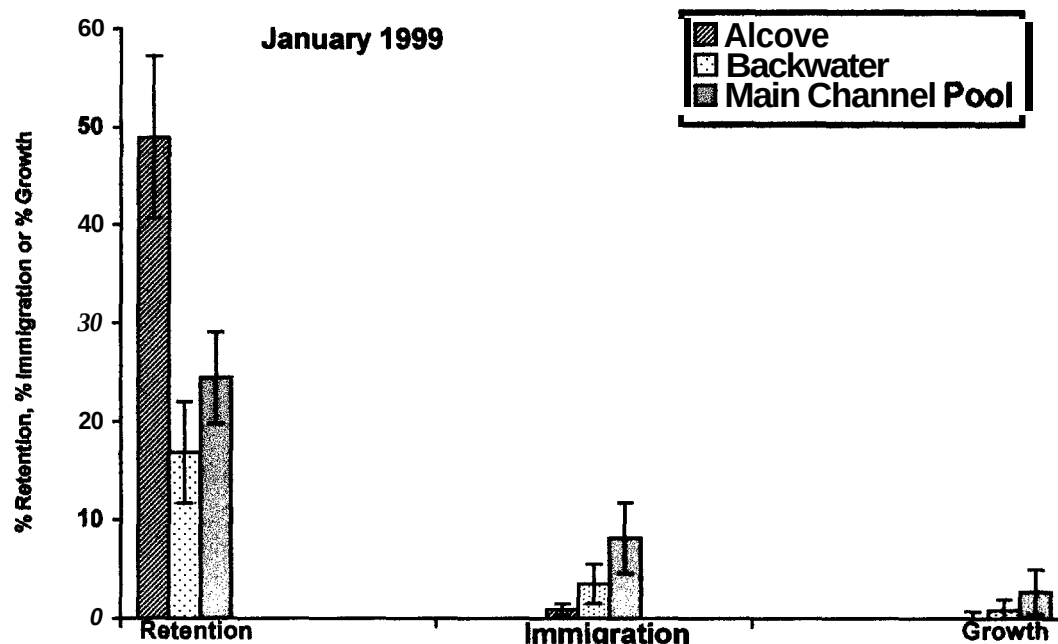


Figure 3. Mean percent and standard error of retention, immigration and growth of juvenile coho salmon rearing in alcoves, backwaters and main channel pools in Prairie Creek, California.

Table 12. Movement of tagged juvenile coho salmon in Prairie Creek, California.

Move from	Move to	Jan. UP-stream		Jan. Down-stream		March Up-stream		March Down-stream	
		n	(m)	n	(m)	n	(m)	n	(m)
AC	MCP			1	193	1	16	2	1261
Alcove	BW			5	333			3	832
MCP	BW	1	10			1	22	1	1778
MCP	AC								
MCP	MCP	1	4	2	90	1	74	4	971
BW	AC			1	16	3	10		
BW	MCP			9	7	1	8	1	3432
BW	BW	1	10	1	1574				
ALL	ALL	3	10	19	143	7	15	11	976

AC = alcove, BW = backwater, MCP = mid-channel pool

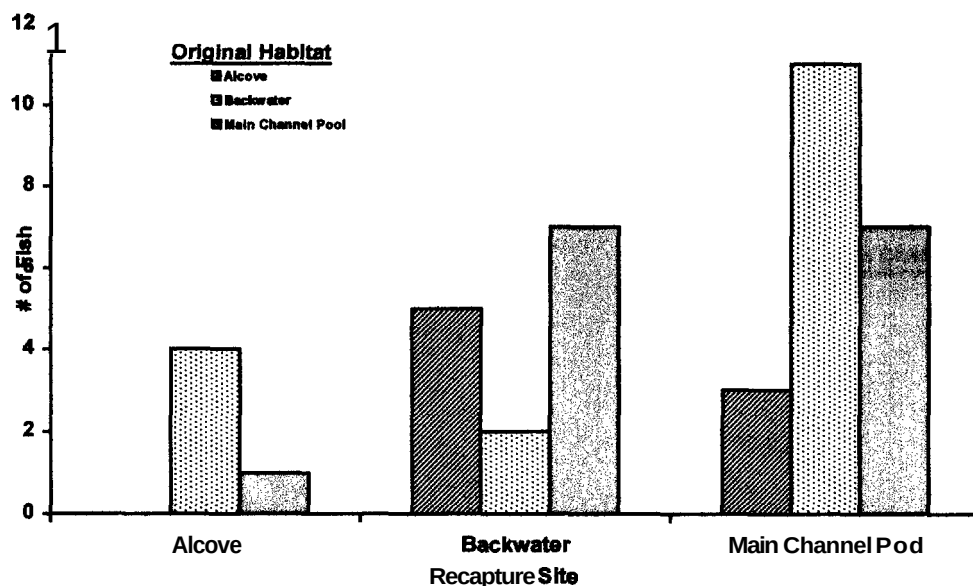


Figure 4. Movement of juvenile coho in Prairie Creek January and March 1999.

fish (33.3%, SE=6.1) were recaptured from **original** alcove habitats, **52** (13.9%, SE=2.0) **from** original backwaters and 29 (7.5%, SE=2.0) from **original main** channel pools. Eight units could not be visited **again** due to proximity to actively monitored coho **salmon** redds, or presence of adult **salmon** during, and were therefore not included in the **analysis**. Downstream migration was detected during March at traps, and probably contributed to the lower retention rates observed in March than in **January**. Eighteen juvenile coho (Table 12; 1.7% of total 1,041 marked fish, SE=0.46) were captured in habitat units other than those they were tagged in during March. Recorded movements of juvenile coho **salmon** during March were **in** both the upstream and downstream direction, **and** varied **from** 7.5 meters to 4866 meters (Table 12). **Most** documented movements were **from** main channel pools downstream to main channel pools (Figure 3). The longest **measured** upstream movement **was** 73.6 meters from a **main channel** pool to a **main** channel pool

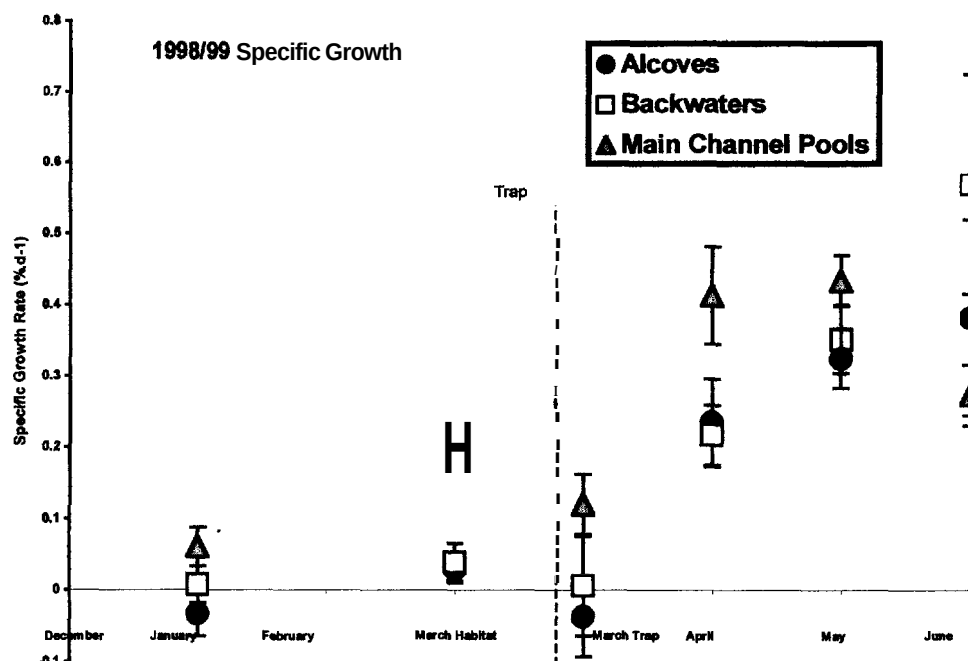


Figure 6. Specific growth rate of juvenile coho salmon rearing alcoves, backwaters, and main channel pools, in Prairie Creek, California.

Table 13. Mean absolute growth and specific growth rate of juvenile coho salmon in three habitat types within Prairie Creek, California.

Measure/month	N	Alcove	N	Backwater	N	Main-channel Pool
Absolute growth						
FL (mm)						
January	74	2.0 ± 0.3	30	2.0 ± 0.3	61	1.0 ± 0.3
March	88	2.0 ± 0.3	50	1.0 ± 0.4	39	2.0 ± 0.5
April	14	8.0 ± 0.7	23	9.0 ± 1.0	11	12.0 ± 1.6
May	19	16.0 ± 1.4	19	16.0 ± 1.5	33	20.0 ± 1.3
Specific growth rate						
(g · g⁻¹ · d⁻¹)						
January	76	0.05 ± 0.3	30	0.02 ± 0.3	61	0.27 ± 0.3
March	89	0.12 ± 0.2	53	0.45 ± 0.3	38	1.62 ± 0.3
April	14	2.30 ± 0.6	21	2.07 ± 0.4	11	6.47 ± 1.0
May	20	3.90 ± 0.9	18	4.70 ± 0.8	33	5.40 ± 0.7

backwaters and **main** channel pools (Figure 7; one-way ANOVA, $F=4.11$, $df=2,14$, $P=0.039$). Greatest retention was in alcoves (50.3%), followed by backwaters (16.2%) and **main** channel pools (6.9%) (planned comparison, $df=14$, $P=0.014$). Immigration rates were similar among alcove, backwater and **main** channel pool habitat types (one-way ANOVA test: $F=1.25$, $df=2,14$, $P=0.326$). Displacement rates were **also** similar **among** habitat **types** (one-way ANOVA test: $F=2.86$, $df=2,14$, $P=0.091$). Recorded movements of juvenile **coho** between habitat units were mostly downstream, **and varied** between 4.3 meters **and** 1992 meters (Table 12).

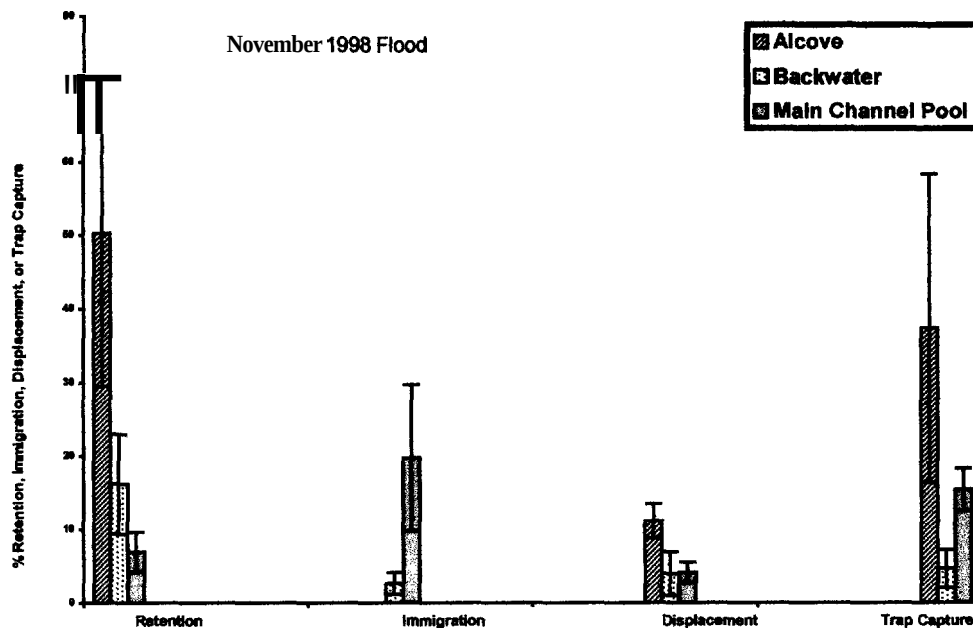


Figure 7. Mean percent and **standard** error of retention, immigration, displacement and trap capture of juvenile coho salmon in Prairie Creek, California, following a **15-year** flood in November 1998.

Recapture at Downstream Migrant Traps

A total of 743 coho salmon smolts were captured from the study reach in downstream migrant traps, of which 170 were tagged. Percent recapture at traps for **all** juvenile coho **salmon** tagged in November and **January** was 16.3% ($n=170$). There was no difference in percent of recapture of juvenile coho salmon tagged in alcoves, backwaters, or **main** channel pool habitats (Figure 8).

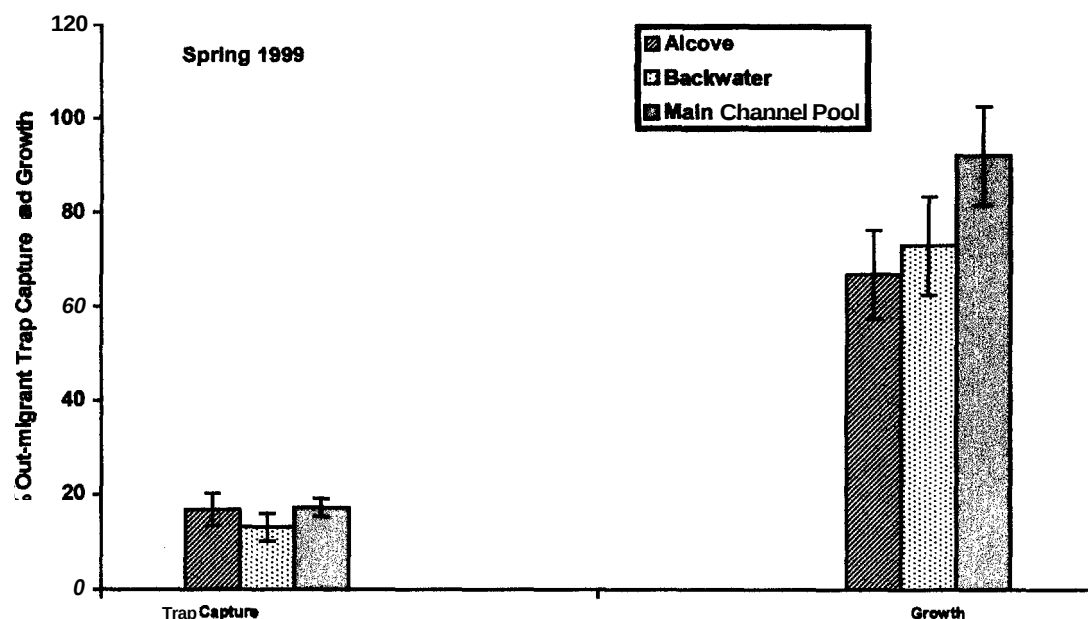


Figure 8. Mean and standard error of percent growth and percent recapture at out-migrant traps of juvenile coho tagged in habitat units in Prairie Creek, California.

DISCUSSION

We found that retention of juvenile coho in alcove habitats during January and March was greater than in other habitats. Retention rates in January exceeded 33% in nine of 10 alcove habitats originally sampled. The single Unit in which retention was < 33% had been captured by channel meandering during the 21 November flood and was classified as a **main** channel pool in January. Our documenting immigration into and displacement from alcove habitats suggests these habitats were separated from the main-channel at most stream stage heights recorded.

Unlike alcoves, retention of juvenile coho salmon in backwater habitats in January was variable. Many backwater habitat units became *dry* during a **period of** low discharge in December, probably forcing fish into the main channel. Retention rates exceeded 15% in backwater habitat units that did not become *dry*. Greatest displacement rates were recorded from backwaters that dried out. It is likely that fish leaving backwaters did **so** because **of** drying, rather than **high** discharge. Although immigration and displacement rates were both greatest in backwater habitats, differences among habitat types were not statistically significant.

Retention of juvenile coho salmon in **main** channel **pools** was **also** variable. Many of the main channel pools sampled experienced high water velocity during **high** discharge events. It

appeared that movement between **main** channel pool habitats was common, with immigration rates **as great as** 50% in two units. Displacement rates **as great as 16.7%** were recorded in **main** channel pool habitats. Most movement was from one **main** channel pool downstream to another.

In March, rates of retention, immigration, and displacement were similar to those detected in **January**. Rates of retention were in March were less **among** all habitat types than they were in January, suggesting the population **size** was **smaller** due to mortality during the interval combined **with** the **beginning** of smolting and migration downstream. We collected smolting coho **salmon** in downstream migrant traps **as early as** 5 February. High displacement rates from backwater and **main** channel pools suggests that many **fish** could be rearing in lower Prairie Creek. Because there was no downstream **migrant** trap in lower Prairie Creek, survival estimates of those units could be under-estimated.

Although retention rates were greatest in alcoves, **size** of juvenile coho salmon did not differ **among** habitat types. Previous researchers have observed that **larger** fish have greater **survival** rates **in high** water velocities, suggesting that smaller fish might fare better in low water velocity habitat such **as** alcoves, but we cannot corroborate these observations. **Furthermore**, the fate of emigrants **could** not be determined **and** it is possible that fish emigrating were moving to more favorable habitat in lower Prairie Creek.

Growth of juvenile coho salmon in **all** habitat **types was** minimal during the period November - March, **whether** expressed **as** absolute growth or specific growth rate. Growth in **fish** is expressed only after **metabolic** demands are met. In alcove habitats where activity costs should be low, it is possible that the absence of aquatic **drift** limited food availability. However, increased food chasing behavior in low velocity habitat has **been** observed, suggesting that fish in alcoves **may** be more aggressive than those in the **main** channel. In **Main** channel pools where water current velocity is greater, aquatic **drift should** be more available but activity costs should **also** be greater. Backwater habitats should provide some access to aquatic drift and water velocity should demand intermediate activity costs. Water temperatures were similar among habitats, so thermal effects on metabolism should be **similar**. Periods of active feeding in alcove and backwater habitats were observed following high discharge events. Stomach pumping revealed that diet following periods of higher discharge was composed of mainly terrestrial invertebrates, but not enough fish were examined to draw **definite** conclusions. Still, it **is** possible that in years with greater discharge, food availability may be higher in off channel



habitats (alcoves, backwaters), and greater growth rates could result. Bilby et al. (1998) observed significant growth rates of juvenile coho during the winter in southwestern **Washington**. Growth rates increased by 215% following addition of 1,014 salmon carcasses in a 500-meter reach. We observed 166 salmon carcasses in the study reach, suggesting that a low number of carcasses could be limiting winter growth in Prairie Creek. However, **Bilby** et al. (1998) also observed growth rates of up to 78% in reference reaches with **no** carcasses, which is much greater than **those** observed in Prairie Creek. Low winter growth rates followed by a spring surge in **growth**, as we observed in Prairie Creek, **has** also been documented by Shapovalov and Taft (1954) in central California.

We hypothesized that juvenile coho salmon wintering in alcove habitats would exhibit greater retention, growth, and survival rates **than** fish rearing in other habitat types. We considered winter **survival** as the ultimate measure of habitat suitability. However, we found no difference in winter survival of fish rearing in alcoves, backwaters, and **main** channel pools. Recapture rates in downstream migrant traps of juvenile coho salmon tagged in backwater and **main** channel pool habitats was 18.2 and 18.5 % respectively, while retention rates in those habitats was < 10% in March. Together, these results suggest that fish either survived in those habitats **and** smolted before March sampling, or emigrated from these habitats and survived elsewhere in the creek. Retention in January was not correlated with trap recapture, suggesting that early winter retention rates may not be **a** good indicator of habitat quality. Retention rates in March were weakly correlated with trap capture, suggesting late winter retention rates may provide **an** indication of habitat **suitability**. Either interpretation suggests **some** portion of the wintering juvenile coho salmon population is moving between habitat units, and **surviving**.

Proportion of **fish** tagged in alcoves that were recaptured in the downstream migrant trap was < 50% of recorded March retention. **This** suggests that either the downstream migrant traps were inefficient, there was **high mortality** between March and smolting, or some proportion of fish occupying alcoves never smolted. We examined the possibility that **fish** were not molting and **leaving** alcove habitats by sampling 10 of the original alcove habitat units on 30 June and 7 July. This **sampling** revealed tagged juvenile coho salmon in four of the alcove units. Using these data to **correct** recapture rates, we found recapture in the downstream migrant traps of fish tagged in alcove habitats was 21.4%, slightly greater than fish tagged in backwater or **main** channel pool habitats. Fish captured in alcove habitats during June **and** July averaged 61 mm ($\pm$

2.47mm) the previous November, essentially the **smallest** fish in present in these habitats. **Although almost 15%** of the fish sampled in alcove habitats in November were < 60mm, none of these *fish* were recaptured at **downstream** migrant traps. Juvenile **rho** salmon sampled in July did not appear to be smolting **and** habitats were isolated from the **main** channel, although they **retained** water from tributaries or hyporheic flow. Although juvenile coho salmon remaining in alcoves **through** summer were **smaller**, their growth rates were **similar** to fish recaptured at downstream migrant traps.

Our finding that low numbers **of** juvenile coho salmon remain in alcove habitats over summer suggests **fish that are small in fall may** spend **a** second **year** in fresh water before smolting. Since not **all** habitat types were visited in July, it could not be discerned **if this** 2-year life history possibility is limited to alcove habitat, or if it occurs **in all** habitat **types**. However, while recapture rates of fish < 60mm in November that occupied alcove habitats **was** 0%, it was 6.9% for fish from backwater habitats **and** 1.89% for fish from **main** channel pool habitats.

Habitat Evaluations

Walter Duffy and Bethany Reisburger

Habitat present in Prairie, Streeflow and Boyes Creeks during **fall**, winter and summer was surveyed to **assess seasonal** change. Surveys of habitat reported here consist of aerial measurements of classified habitats within each stream during October 1998, February and July 1999. We **also summarize** surveys conducted in August of large woody debris (LWD) present in two of the three **streams**. LWD survey data collected at the same time for Prairie Creek, the third stream, by the National **Park** Service will be presented in a future report. Last, we **also** summarize environmental data collected for each stream and watershed. Environmental data include air temperature, light, water temperature and, for **Prairie** Creek, discharge.

Habitat surveys were completed on the entire study reach of each **stream**. Methods used were adopted from Pacific Southwest Region, U.S. Forest Service guidelines which classify stream habitats into **25** separate categories. Methods generally consisted of two or three observers **walking** the up the stream, using a hip-chain to measure both total distance (m) and length of each habitat unit **classified**. In addition to length, width (m) and depth (m) of habitat units was measured with **a surveyors rod** and condition of substrate was recorded. Absence of many habitat **types** within the coastal streams under study allowed us to reduce the number of habitats considered. However, we did add a category which, in the previous section of this report, we define **as** “alcoves.” Overall, we report frequency of occurrence and **area** of 16 separate habitat types in each stream.

Large woody debris surveys were also carried out **by** walking the entire length of each stream **study** reach. Methods for these surveys consisted of two or three observers **walking** the up the stream, using a hip-chain to measure both total distance (m) and recording the location and **dimensions** of LWD. We defined LWD as wood ≥ 2 m long and ≥ 0.3 m in diameter. This definition is consistent with **California** Department of Fish and Game guidelines. Finally, we distinguished LWD within the wetted channel perimeter **from** that within the area defined by **bank-111** discharge, but outside the wetted perimeter.

Environmental information for each **stream** and watershed were gathered with data loggers. Data loggers for water temperature were deployed in the upper and lower portions of

each study reach stream. Air temperature, light and precipitation data loggers were located in the riparian area, at about the middle of each study reach.

Seasonal Habitat Surveys

The number of habitat units in each stream study reach was greatest in fall and lowest in Winter (Tables 14 – 16). Among specific habitats, low gradient riffles, lateral scour pools and runs were the most common habitats in each stream during each season. Pool habitats were, collectively, the most common habitat type recorded. Pools comprised from 33 – 54% of habitat units in all seasons in each stream except during winter in Boyes Creek when they represented only 19% of the total habitat units.

These same habitats comprised most of the surface area of habitat in each stream, although more variation was noted in area. The area represented by pools collectively in each stream ranged from 10% in Boyes Creek during winter to 66% in Streelow Creek during fall. Run habitat generally made up a greater proportion of total habitat area during winter than during fall or summer, as might be expected with increased discharge. Major shifts in either the frequency or area of habitats among seasons were, however, not noted.

Backwater and alcove habitats are worthy of attention because of the importance of these habitat types to juvenile coho salmon during Winter. Together, these habitat types represent $\leq 9.8\%$ of the total units and $\leq 5.4\%$ of the surface area measured in each stream during all seasons (Tables 14 – 16). Seasonally, they were least common in fall and most common during winter. The area these habitat types represented in Prairie Creek was also greatest during winter. In the other two streams, the area of backwater habitat decreased from fall to winter and summer. The reason for this apparent contradiction in patterns is not obvious to us and we plan further analysis of these data.

Large Woody Debris

Volume of LWD in Streelow Creek was more than twice that in Boyes Creek. This difference was particularly apparent within the wetted perimeter (Table 17). Log jams in both streams that were located 1100 – 1199 m up the study reach contributed substantial amounts to the total volume of wood in the streams. Elsewhere, the volume of wood in Boyes Creek was greater in the upper reaches than in the lower reaches. LWD in Streelow Creek appeared more evenly distributed, except for the above mentioned jam.

Table 14. Number of units in each habitat type, % of the total units each represents, mean area of units in each habitat type and % of the total area each represents in Prairie Creek during October 1998, February and July 1999.

Habitat type	No. units			% units			Avg Area/unit			% Area		
	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July
Dry Channel	12	0	1	2.6	0.0	0.2	11.8	0.0	127.9	0.6	0.0	0.5
Low gradient riffle	151	120	158	33.1	~~43.6~~ 30.4	35.9	40.8	56.5	38.9	24.0	22.0	24.4
High gradient riffle	1	0	1	0.2	0.0	0.2	44.4	0.0	22.7	0.2	0.0	0.1
Mid-channel pool	38	26	30	8.3	~~9.5~~ 6.6	6.8	75.4	68.5	98.6	11.1	5.8	11.7
Secondary channel pool	17	1	0	3.7	~~0.4~~ 0.2	0.0	28.5	24.0	0.0	1.9	0.1	0.0
Channel confluence pool	0	1	0	0.0	~~0.4~~ 0.2	0.0	0.0	25.5	0.0	0.0	0.1	0.0
Corner pool	17	8	7	3.7	~~2.9~~ 2.0	1.6	53.7	122.7	100.2	3.5	3.2	2.8
Plunge pool	3	3	2	0.7	~~1.1~~ 0.8	0.5	56.8	62.9	29.5	0.7	0.6	0.2
Lateral scour pool	108	91	125	23.7	~~33.1~~ 28.6	28.4	282.5	334.1	240.0	32.8	24.8	33.8
Dammed pool	5	9	0	1.1	~~3.3~~ 2.3	0.0	87.1	52.3	0.0	1.7	1.5	0.0
Glide	30	13	6	6.6	~~4.7~~ 3.3	1.4	102.5	110.7	157.7	11.9	4.7	3.8
Run	64	73	81	14.0	~~26.5~~ 18.5	18.4	39.7	101.0	49.3	9.8	24.0	15.8
Step run	6	20	20	1.3	~~7.3~~ 5.1	4.5	68.8	138.7	71.6	1.6	9.0	5.7
Edgewater	2	3	0	0.4	~~1.1~~ 0.8	0.0	9.1	62.6	0.0	0.1	0.6	0.0
Backwater	5	16	6	1.1	~~5.8~~ 4.1	1.4	105.6	99.3	40.4	0.8	2.5	1.0
Alcove	0	11	5	0.0	~~4.0~~ 2.8	1.1	0.0	21.3	21.0	0.0	0.8	0.4
Total	456	~~275~~	440	100.0	100.0	100.0				100.0	100.0	100.0

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Table 15. Number of units in each habitat **type**, % of the total units each represents, mean area of units in each habitat type and % of the total area each represents in Streelow Creek **during** October 1998, February and July 1999.

Habitat type	No.			% units			Avg			% Area		
	units						Area/unit			/unit		
	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July
Dry Channel	1	2	0	2.6	1.4	0.0	4.7	98.5	0.0	1.3	1.7	0.0
Low gradient riffle	26	29	25	13.5	20.7	14.2	32.2	37.6	47.9	7.2	9.5	13.8
High gradient riffle	1	0	0	0.5	0.0	0.0	59.2	0.0	0.0	0.5	0.0	0.0
Mid-channel pool	16	5	41	8.3	3.6	23.3	74.9	53.7	56.2	10.3	2.3	26.5
Secondary channel pool	3	0	0	1.6	0.0	0.0	14.4	0.0	0.0	0.4	0.0	0.0
Channel confluence pool	1	1	0	0.5	0.7	0.0	210.2	22.8	0.0	1.8	0.2	0.0
Corner pool	19	1	0	9.8	0.7	0.0	56.5	20.8	0.0	9.2	0.2	0.0
Plunge pool	4	1	0	2.1	0.7	0.0	83.3	106.8	0.0	2.9	0.9	0.0
Lateral scour pool	59	49	39	30.6	35.0	22.2	335.8	277.9	166.7	37.7	25.9	21.9
Dammed pool	3	0	11	1.6	0.0	6.3	159.5	0.0	52.5	4.1	0.0	6.7
Glide	9	11	0	4.7	7.9	0.0	144.1	66.9	0.0	11.1	6.4	0.0
Run	44	35	46	22.8	25.0	26.1	36.2	168.3	40.6	13.6	51.3	21.5
Step run	1	1	11	0.5	0.7	6.3	40.0	222.7	73.1	0.3	1.9	9.3
Edgewater	1	0	0	0.5	0.0	0.0	20.0	0.0	0.0	0.2	0.0	0.0
Backwater	5	4	2	2.6	2.9	1.1	152.2	40.5	11.0	2.3	0.4	0.3
Alcove	0	2	1	0.0	1.4	0.6	0.0	8.0	8.9	0.0	0.1	0.1
Total	193	140	176	100.0	100.0	100.0				100.0	100.0	100.0

Table 16. Number of units in each habitat type, % of the total units each represents, **mean** area of units in each habitat type and % of the total area each represents in Boyes Creek during October 1998, February and July 1999.

Habitat type	NO.						Avg			% Area		
	units			% units			Area/unit			/unit		
	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July	Oct	Feb	July
Dry Channel	5	2	0	1.5	1.2	0.0	31.7	19.2	0.0	2.5	0.6	0.0
Low gradient riffle	122	69	54	35.5	40.6	26.3	19.2	51.0	25.1	37.2	53.8	23.2
High gradient riffle	0	0	1	0.0	0.0	0.5	0.0	0.0	26.5	0.0	0.0	0.5
Mid-channel pool	16	1	11	0.3	0.6	7.3	29.7	80.6	26.3	0.5	1.2	6.7
Secondary channel pool	9	2	0	2.6	1.2	0.0	6.2	19.6	0.0	1.1	0.6	0.0
Channel confluence pool	2	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corner pool	15	6	0	0.6	3.5	2.0	13.4	40.4	22.0	0.4	3.7	1.5
Plunge pool	7	6	6	2.0	3.5	2.9	11.4	11.0	14.9	1.3	1.0	1.5
Lateral scour pool	92	15	59	26.7	8.8	28.8	96.0	40.4	90.9	25.5	3.2	24.0
Dammed pool	3	2	2	0.9	1.2	1.0	41.0	20.8	26.7	2.0	0.6	0.9
Glide	42	9	3	12.2	5.3	1.5	23.0	44.3	53.9	15.4	6.1	2.8
Run	32	49	53	9.3	28.8	25.9	12.5	37.7	34.7	6.4	28.2	31.4
Step run	1	0	0	0.0	0.0	5.4	0.0	0.0	44.9	0.0	0.0	8.4
Edgewater	0	1	15	4.7	0.6	0.0	14.5	3.0	0.0	3.7	0.0	0.0
Backwater	5	10	3	5.5	5.9	1.0	22.5	23.1	13.0	4.9	1.2	0.4
Alcove	0	4	4	0.3	2.4	0.5	34.4	10.1	10.8	0.5	0.6	0.2
Total	344	170	205	100.0	100.0	100.0				100.0	100.0	100.0

Table 17. Volume of large **woody** debris found **within** the wetted channel and **within** the area of bankfull discharge of **Streel**ow and **Boyes** Creeks **during** August 1999.

Distance upstream (m)	Streelow Cr.			Boyes Cr.		
	Vol within wetted perimeter (cu. m)	Vol outside Wetted perimeter (cu. m)	Total vol (cu. m)	Vol within Wetted perimeter (cu. m)	Vol outside wetted perimeter (cu. m)	Total vol (cu. m)
0-99	4.2	0.4	4.7	13.3	4.8	18.1
-199	31.3	1.4	32.7	6.4	0.2	6.6
-299	23.2	1.3	24.4	0.6	0.4	1.1
-399	7.2	1.0	8.1	0.1	0.0	0.1
-499	31.7	1.7	33.4	2.2	1.2	3.4
-599	30.5	0.7	31.2	4.1	2.7	6.8
-699	49.1	13.0	62.0	1.4	0.5	1.8
-799	28.2	9.2	37.4	1.0	0.4	1.4
-899	12.3	5.7	18.0	3.9	1.4	5.3
-999	19.3	7.3	26.6	11.2	9.0	20.2
-1099	10.5	4.0	14.5	6.1	3.5	9.6
-1199	294.3	14.1	308.4	189.8	60.5	250.3
-1299	10.0	13.2	23.1	14.8	0.1	14.9
-1399	18.8	19.9	38.7	1.4	0.2	1.6
-1499	17.0	15.8	32.7	0.9	0.2	1.0
-1599	37.1	25.5	62.5	46.0	10.9	56.9
-1699	96.7	12.4	109.1	3.8	1.7	5.6
-1799	33.6	2.7	36.3	35.9	29.0	64.9
-1899	33.7	12.6	46.3	35.3	12.3	47.6
-1999	79.3	28.1	107.3	0.5	0.0	0.5
Total	867.9	189.9	1057.8	378.7	139.1	517.7

Environmental Conditions

Water temperature varied little among streams and habitat types (Tables 18 – 20). Monthly average water temperature during October 1998 through October 1999 ranged from 6.8 – 12.9°C in pool habitats, 7.1 – 12.0 °C in backwater habitats and **7.4–9.8 °C** in riffle habitats. Average water temperatures in winter were generally **7 – 8 °C**, while in summer they were generally 10 – 11 °C. Monthly average degree days in pool habitats were greater than in backwaters or riffles, when summer months were considered (Table 18). In **all** other habitats this measure of physiological time ranged from **195 to 227 degree days**.

Table 18. Monthly average water temperature in pool habitats of Prairie, Streeflow and Boyes Creeks.

Month-Year	Upper Prairie Cr.	Lower Prairie Cr.	Lower Streeflow Cr.	Upper Boyes Cr.
Oct. 98	9.7		9.5	9.8
Nov. 98	9.3		9.6	9.9
Dec. 98	7.5	6.8	7.7	7.8
Jan. 99	7.7	7.6	7.5	7.9
Feb. 99	7.6	7.7	7.9	7.6
Mar. 99	7.7	7.8	8.1	8.3
Apr. 99	7.9	8.1	8.3	8.5
May 99	8.5	9.0	8.8	8.8
June 99	9.7	11.0	10.1	
July 99	10.4	12.0	10.9	
Aug. 99	10.3	12.9	11.9	
Sep. 99	10.7	11.9	10.8	
Oct. 99	9.8	10.4	9.3	
Mean Degree Days/Mo	275	285	276	200

Table 19. Monthly average water temperature in backwater habitats of Prairie, Streeflow and Boyes Creeks.

Month-Year	Upper Prairie Cr.	Lower Prairie Cr.	Upper Streeflow Cr.	Lower Streeflow Cr.	Upper Boyes Cr.	Lower Boyes Cr.
Oct. 98	10.0	12.0	9.7	9.5	9.8	9.7
Nov. 98	9.4	9.7	9.7	9.6	9.8	9.7
Dec. 98	7.4	7.3	7.9	7.7	7.4	7.6
Jan. 99	7.7	7.5	7.7	7.5	7.1	7.7
Feb. 99	7.6	7.8	7.9	7.9	7.9	7.9
Mar. 99	7.7	7.8	8.1	8.1	8.1	8.1
Apr. 99	7.9	8.2	8.3	8.3	8.5	8.5
May 99	8.2	8.5	8.6	8.5	8.8	8.5
Mean Degree Days/Mo	208	227	211	209	213	215

Air temperature, like water temperature, did not exhibit great variation during fall and winter. Air temperature in the Boyes Creek watershed during summer months average 1.5 – 2.0 degrees warmer than in other watersheds (Table). This is, in part, the result of a large tree

Table 20. Monthly average water temperature in riffle habitats of Prairie, Streelow and Boyes Creeks.

Month-Year	Lower Prairie Cr.	Upper Streelow Cr.	Lower Streelow Cr.	Lower Boyes Cr.
Oct. 98	9.6	9.7	9.7	9.8
Nov. 98	7.4	9.8	9.8	9.8
Dec. 98	7.6	7.9	7.9	8.2
Jan. 99	7.7	7.7	7.6	8.0
Feb. 99	8.2	8.0	8.0	8.1
Mar. 99	8.4	8.2	8.2	8.3
Apr. 99		8.3	8.5	8.7
May 99		8.6	8.7	8.7
Mean Degree Days/Mo	195	212	213	222

falling near the weather station that opened the surrounding canopy **and** also the result of the lower half of this basin being more open than the other watersheds.

Table 21. Monthly average **air** temperature in the Prairie, Streelow and Boyes Creek watersheds.

Month-Year	Prairie Cr.	Streelow Cr.	Boyes Cr.
Jan. 99	5.8	5.4	5.7
Feb. 99	6.1	6.3	5.9
Mar. 99	5.8	6.8	6.1
Apr. 99	7.5	7.7	9.0
May 99	8.9	9.1	11.1
June 99	11.4	11.6	13.6
July 99	12.0	12.1	14.4
Aug. 99	13.6	13.5	15.1
Sep. 99	11.7	10.9	11.6
Oct. 99	9.9	8.6	8.8

Precipitation data are available from the Prairie Creek watershed for the entire period. Equipment failure limited **data** collection to portions of the year for the other watersheds. Average daily precipitation in the Prairie Creek watershed increased from 4.2 mm per day in October 1998 to 18.6 mm per day in November and fluctuated through winter before declining to only 1.8 mm/day in May 1999 (Figure 7). From 10 October 1998 through 31 May 1999, 1,656

mm of precipitation was recorded. No precipitation was recorded during June – September 1999.

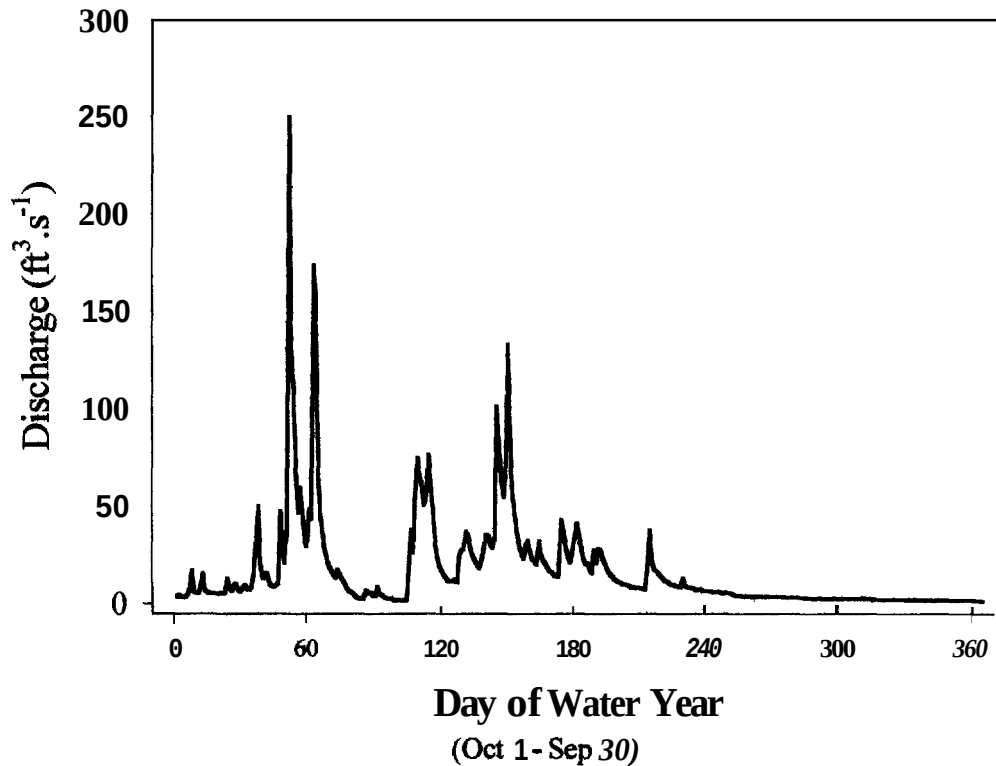


Figure 7, Discharge in Prairie Creek, **California** measured at station below confluence with Browns Creek.

Light data loggers were installed in each watershed in February 1999. **One** data logger failed for a two month period, but others operated continuously. **As** we expected, light received by the Boyes Creek watershed is greater **than** in either the Prairie or Boyes Creek watersheds (Table 22). During winter when deciduous riparian vegetation have dropped leaves, light intensity in the Boyes **Creek** watershed was two times that measured in other watersheds. With leaf-out in spring and summer, the **difference** in light intensity within the Boyes and Prairie Creek watersheds **became** even greater.

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