Effects of Sediments from the Redwood National Park Bypass Project (CALTRANS) on Anadromous Salmonids in Prairie Creek State Park 1995-1998

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Abstract

A large storm in October 1989 deposited sediments from the highway 101 bypass project in several Prairie Creek and Klamath River tributaries. We studied chinook (*Oncorhynchus tshwaytscha*) and coho salmon (*O. kisutch*) in sections of Prairie Creek upstream and downstream of the sediments produced in this event. Many chinook salmon and fewer coho salmon spawn in Prairie Creek below Browns Creek (the area impacted by the sediment input). Similar numbers of redds were observed during the three spawning seasons, with chinook salmon comprising 74 percent of the salmon associated with redds during the three spawning seasons. Emergent nets placed over redds in the impacted sections captured fewer fry than emergent nets over redds upstream of Browns Creek. Stream gravel characteristics (percent fines, geometric mean diameter, and fredle index) were similar above and below Browns Creek. Fry emergence numbers and downstream migrating age 0+ chinook and coho salmon were lowest in 1998. The numbers of coho salmon smolts (age 1+) was more consistent from year to year, and may indicate that overwinter survival limits coho salmon production in Prairie Creek.

Introduction

Salmonid spawning, emergence, and outmigration were studied in Prairie Creek from 1995 to 1998 by personnel from Humboldt State University and Pacific Coast Fish, Wildlife, and Wetlands Restoration Associate (PCFWWRA). The studies were contracted by the California Department of Transportation as part of Cleanup and Abatement Order 90-8 issued by the Northcoast Regional Water Quality Control Board. The chronology of events that prompted this study have been described in detail in other reports (Welsh and Ollivier 1992,1999; Klein 1999; and Klatte and Roelofs 1996, 1997), and will not be repeated here.

The objectives of the salmonid studies were to:

1. Conduct surveys weekly (water conditions permitting) on the mainstem of Prairie Creek during the spawning season of coho salmon (*Oncorhynchus kisutch)* and chinook salmon (*O. tshwaytscha*) to document the location and timing of spawning.
2. Trap emergent coho salmon fry from known coho redds in Prairie Creek upstream (control reach) and downstream (treatment reach) of Browns Creek and to compare the following conditions inside and adjacent to these redds: gravel composition (percent fines), gravel permeability, and dissolved oxygen concentrations of intergravel water.
3. Trap juvenile anadromous salmonids migrating downstream to document the timing, relative numbers and age classes of various species.

STUDY AREA

The study area has been described in detail by Klein (1999) and Klatte and Roelofs (1996 and 1997). Readers are referred to these and numerous other sources (i.e., Redwood National Park 1991, 1994a, and 1994b) for information regarding the Prairie Creek basin.

METHODS AND ANALYSES

Spawner Surveys

Weekly spawning surveys (dependent upon visibility and flow conditions) beginning in November or December were conducted on Prairie Creek starting at the confluence with Streelow Creek and going upstream for 11.6 km in 1995-96 (Klatte and Roelofs (1996), 14.5 km in 1996-97 (Klatte and Roelofs 1997) and 13.6 km in 1997-98. Reach 1 extended from the confluence of Streelow Creek upstream to the confluence of Boyes Creek (station 4,070 m); reach 2 extended from the confluence of Boyes Creek upstream to Browns Creek (station 7,450 m); reach 3 extended from the Browns Creek confluence to station 10,960 m (Upper Zig-zag bridge); and reach 4 extended upstream to station 13,560 m. Two or three person crews walked upstream noting all redds, marking their location and date with survey flagging, and identifying by species and sex (when possible) all live fish observed. When possible (e.g., when the female was on the redd or in the immediate area) the species making the redd was recorded. Salmon carcasses were identified to species (when possible) and counted on each spawner survey. Carcasses were marked with hog rings secured to the jaw or with survey tape to identify those that had been counted on previous surveys.

Emergent Fry Trapping

Emergent nets (described and diagramed in Klatte and Roelofs 1997) were placed over one coho redd and four chinook redds in the spring of 1996 (Klatte and Roelofs 1996), six coho redds in spring 1997 (Klatte and Roelofs 1997) and eleven coho redds in spring 1998. In 1997 four trapped redds were upstream of Browns Creek (control reach) and two were downstream (treatment reach). Six trapped redds in 1998 were located in the control reach, five in the treatment reach. Emergent traps were installed between 12 February and 13 March 1998. Emergent fry were counted daily throughout the emergence period (from mid-April to early June).

Gravel Analysis

A 30.5cm (12 inch) McNeil sampler was used to collect gravel samples to a depth of 25cm within and adjacent to coho redds in 1997 (Klatte and Roelofs 1997) and 1998. Bulk samples from the McNeil sampler were passed through a series of screens in the field (128mm, 64mm, 32mm, 16mm, 8mm, and 4mm) and the volumes of each fraction determined by volume displacement (Klatte and Roelofs 1997). The remainder of the sample was analyzed in the laboratory at Redwood National Park facilities in Orick following procedures detailed by Klein (1999). Descriptions of percent fines, median diameter, geometric mean, and fredle index were calculated using custom software ("Gravel", Klein 1999).

Gravel Permeability and Dissolved Oxygen of Hyporheic Water

Three plastic standpipes (after Gangmark and Bakkala 1958), a modification of the Barnard and McBain (1994) standpipes, were placed in 16 redds in 1997 (Klatte and Roelofs) and 11 redds in 1998. These standpipes were used to measure gravel permeability (Terhune 1958; Barnard and McBain 1994) within the redds calculated as inflow rate in ml/sec. A similar standpipe was placed adjacent to each redd in 1997 (Klatte and Roelofs 1997) and 1998 to measure inflow rates and dissolved oxygen in substrates undisturbed by redd construction.

Dissolved oxygen (DO) in the standpipes was measured in mg/l using a Yellow Springs Instrument Company DO and temperature meter. All readings were taken 25cm below the water surface in the standpipe.

Statistical tests of gravel characteristics, permeability, dissolved oxygen, and fry emergence were performed using Number Cruncher Statistical Systems (NCSS) (Hintze 1998). Regression analyses were calculated using Microsoft Excel version 7.0.

Downstream Migrant Trapping

Juvenile salmonids and other vertebrates were caught and counted in a 1.5m (5 foot) diameter E. G. Solutions rotary screw trap located in Prairie Creek about 50 meters upstream of the Streelow Creek confluence (the downstream end of the spawner survey section described above). This trap was operated from 13 March to 10 July 1996 (Klatte and Roelofs 1996), 18 February to 1 July 1997 (Klatte and Roelofs 1997) and 11 March to 12 June in 1998. On several dates, known numbers of juvenile fish were marked (fin clips) or dyed (Bismark Brown Y), released above the trap and the proportion recaptured were used to calculate trapping efficiency for a particular age class at a particular stream discharge (Klatte and Roelofs 1996 and 1997). Trap efficiencies can be used to estimate the actual numbers of downstream migrants (Shaw and Jackson 1994).

RESULTS

Spawner Surveys

Spawning surveys revealed 279 redds in Prairie Creek in the 1995-96 spawning season, 191 redds in 1996-97, and 237 redds in 1997-98 (Table 1).

Table 1. Spawning survey redd counts for years 1995-98 (unexpanded) in Prairie Creek.

Date	Chinook	Coho	Uknown spp.	Steelhead	Total
		Number of redds observed			
Dec-95	46	8	95		149
Jan-96	18	12	41		71
Feb-96	3	4	52		59
Total:	**67**	**24**	**188**		**279**
Nov-96	0	0	26		26
Dec-96	46	4	43		93
Jan-97	14	18	40		72
Feb-97	0	0	0		0
Total:	**60**	**22**	**109**		**191**
Nov-97	1	0	7	0	8
Dec-97	56	7	114	0	177
Jan-98	0	11	24	1	36
Feb-98	0	0	14	2	16
Total:	**57**	**18**	**159**	**3**	**237**

The species constructing the redds was unknown (live fish not seen or not identified) on 456 (64 percent) of the 707 redds observed. On the 248 redds where species were noted, 184 (74 percent) were chinook salmon, and 64 (26 percent) were coho salmon. Many coho salmon in the Prairie Creek basin spawn in tributaries, while chinook salmon are primarily mainstem spawners (personal observations and downstream migrant trapping results on Godwood, Browns, and Streelow Creeks (ancillary trapping carried out in this study) and Little Lost Man Creek (Manning 1999)).

In spawning season 1997- 98, 57 chinook redds were observed in November and December 1997; 51 of these (89 percent) were below Browns Creek (treatment section) (Appendix 1). No chinook redds were noted in the uppermost section of Prairie Creek (section 4) during the entire spawning season. Seven coho redds were observed in

December 1997, two in section 2, five in section 3 (Appendix 1). No chinook redds were seen in January or February 1998, but 11 coho redds were flagged in January; two in section 1, six in section 3, and three in section 4 (Appendix 1). All redds observed in February were made by unknown species, with 69 percent of the 16 redds in sections 1 and 2 (Appendix 1). Redd superimposition was noted throughout the spawning season (Appendix 1), and was most prevalent in sections 1 and 2. In summary, the treatment sections (1 and 2) are important spawning areas, particularly early in the season or during low water years.

Fry Emergence

Eleven coho redds were trapped with emergent nets in spring 1998 (Table 2). Redd locations for 1998 are presented in Table 3. Number of coho fry trapped in Prairie Creek redds ranged from 0 (redd numbers 7, 9, 10, and 11) to 1174 (redd number 4) (Table 2). Calender days from time of spawning to emergence ranged from 70 to 94 days (Table 2). Emergence in individual redds lasted from 23 to 48 days (Table 2). As apparent in Table 2, redd superimposition was noted in the field and was evident in the emergent trapping data. Redd 8 had three species emerge (455 coho, 305 chinook, and 2145 steelhead (Table 2), while redd 6 had 924 coho and 897 steelhead (*O. mykiss*).

Coho fry emergence in sections 3 and 4 (control reaches above Browns Creek) were significantly greater than in sections 1 and 2 (treatment reaches below Browns Creek) ($p < 0.05$) (Appendix 2). Using the data in Table 2, the mean number of coho fry per redd above Browns Creek (N =6) was 621, and below Browns Creek (N = 5) was 91, with all the fry below Browns Creek emerging from one redd. No fry emerged in the two redds below Boyes Creek (Table 2).

Table 2. Summary of data collected on natural coho salmon fry emergence in Prairie Creek, Humboldt Co., Ca. 1998

Trap	Spp.	Date of redd formation	Date of first emergence	Date of last emergence	Calendar days to first emergence	Calendar days to 50% emergence	Period of emergence (calendar days)	Number of emergent fry captured
1	coho	1/22/98	4/6/98	4/28/98	74	75	23	34
2	coho	1/5/98	4/2/98	5/13/98	87	91	42	1077
3	coho	1/27/98	4/28/98	6/1/98	91	95	35	324
4	coho	1/13/98	**3/19** or 3/24	5/5/98	**65**,70	83	48	1174
5	coho	12/16/98	4/18/98	6/1/98	92	97	45	192
6co	coho	1/13/98	4/17/98	5/18/98	94	100	32	924
6shd	shd	ukn.	4/16/98	5/3/98	ukn.	ukn	18	897
7	coho	12/22/98	no emergence	-	-	-	-	0
8co	coho	ukn.	4/4/98	5/12/98	-	-	39	455
8ks	ks	ukn.	4/23/98	6/5/98	-	-	44	305
8shd	shd	ukn.	5/2/98	5/31/98	-	-	30	2145
9	ukn	12/22/98	no emergence	-	-	-	-	0
10	ukn	1/6/98	no emergence	-	-	-	-	0
11	coho	1/6/98	no emergence	-	-	-	-	0
GW	coho	12/22/98	3/17/98	5/8/98	85	89	53	46
BR	coho	1/12/98	no emergence	-	-	-	-	0

Bold indicates date when alevins were first captured, regular font is when buttoned up emergent fry were captured.

GW = Godwood Creek redd; BR = Browns Creek redd; ks = king (chinook) salmon; and shd = steelhead

Gravel Analysis

Results of the gravel analysis on 9 of 11 redds are presented in Table 4. We compared gravel composition in redds above and below Browns Creek using single factor ANOVA (Hintze 1998) with respect to percent fines < 0.85mm and < 2.0mm, geometric mean particle diameter (Dg), and fredle index (Appendices 3 - 6). There were no significant differences in any of these parameters above and below Browns Creek, although the percent fines < 0.85mm were somewhat higher below Browns Creek than above (Appendix 3).

Table 3. Redd locations for emergence traps in 1998 as numbered in Table 2.

Redd trap #	Section	Distance	
1	4	134+75	
2	4	129+85	
3	4	110+05	
4	3	102+80	
5	3	102+75	
6	3	75+20	upstream of Browns Creek
7	2	66+90	downstream of Browns Creek
8	2	57+25	
9	2	45+10	
10	1	23+05	downstream of Boyes Creek
11	1	17+90	

example: 129+85 = 12,985 m

Dissolve Oxygen and Gravel Permeability

The dissolved oxygen levels measured in standpipes placed within and adjacent to the 11 coho redds were similar and not significantly different in redds above and below

Table 4. Percent fines (< 0.85 and <2.0mm), geometric mean particle diameter (Dg), fredle index, average redd inflow rate (ml/sec), average dissolved oxygen (mg/l), and number of coho salmon fry emerging in 9 redds in Prairie Creek, 1998.

Emergent trap number	Percent Fines (<0.85 mm)	(<2.00 mm)	Dg (mm)	Fredle Index	Redd inflow rate (ml/sec)	Redd DO (mg/l)	Number of emergent fry
1	3.82	8.91	14.57	6.14	53.30	9.41	34
2	6.24	14.75	10.86	3.73	19.17	8.76	1077
3	6.27	12.98	12.38	4.51	18.20	7.42	324
4	5.72	12.51	12.06	4.51	9.10	7.96	1174
5	6.13	12.80	13.59	4.73	16.90	8.72	192
6	7.60	17.05	9.73	3.23	4.94	7.57	924
7	-	-	-	-	66.30	8.12	0
8	3.66	8.64	14.83	6.38	70.20	10.20	455
9	-	-	-	-	28.60	9.35	0
10	13.08	21.12	7.79	2.04	36.46	5.00	0
11	4.08	5.96	23.51	13.73	57.20	10.03	0

Browns Creek (Table 4, Appendix 7).The permeabilities measured within and adjacent to coho redds were highly variable (Table 4) and, we believe, unreliable. The lower portions of many standpipes were damaged during placement (as evidenced by cracks in the plastic pipe or broken seals between the plastic and wood driving points when the standpipes were removed following emergence), leading to measurement errors during permeability tests.

Downstream Migrant Trapping

Downstream migrants were trapped just upstream of Streelow Creek during the springs of 1996 (Klatte and Roelofs 1996), 1997 (Klatte and Roelofs 1997), and 1998 (Table 5). Although the total numbers of salmon redds observed in 1996-97 (191) was less than in 1997-98 (234) (Table 1), far fewer 0+ coho and chinook were trapped in 1998 (Table 5). The numbers of coho 1+ (smolts) was much more consistent during the three year period of trapping (Table 5).

Table 5. Downstream migrants counted in rotary screw trap on Prairie Creek 1996-98.

Year	Period of deployment	0+ Chinook	0+ Coho	1+ Coho	Cutthroat Trout	0+ Trout	1+ Trout	Steelhead Smolts
1996	3/13 - 7/10	26,303	25,492	2,117	613	207	997	
1997	2/18 - 7/1	25,994	3,113	2,302	430	247	710	94
1998	3/11 - 6/12	5,485	372	1,475	211	23	315	15

Discussion

The total number of redds observed during the three spawning seasons of the study were similar (Table 1). We found that the mainstem of Prairie Creek is used predominantly by chinook salmon, while coho spawn in both the Prairie Creek and its tributaries. Access to the upper sections of Prairie Creek is a function of the annual hydrograph, with November and December spawning often concentrated below Browns Creek. During low-water years, such as the early 1990's (Klein 1999), a large proportion of the spawning may be confined to this section of Prairie Creek where our studies have shown poor to no emergence of salmonid fry in known redds.

Redd superimposition was recorded during spawning surveys (Appendix 1) and has been noted by DeVries (1997). We were surprized, however, to trap both coho and chinook fry, and sometimes steelhead fry in known coho redds (Table 2 and Klatte and Roelofs 1997). For example, redd 11 just upstream from Browns Creek produced 2403 coho and 2105 chinook in 1997 (Klatte and Roelofs 1997). In 1998 redd 8 downstream of Boyes Creek (Table 3) produced 455 coho, 305 chinook, and 2145 steelhead (Table 2).

Spawner surveys were often limited by turbidity downstream of Boyes Creek in all three years of the study. Klein (1999) calculated that although Boyes Creek drains only 13 percent of the drainage area upstream of May Creek, in 1996 it contributed 85 percent of the sediment produced in this portion of the basin. Although our studies did not document significant differences in various measures of gravel conditions (i.e., percent fines, Dg, fredle index, etc.) below Browns Creek in 1998, redds trapped in the lower two sections produce far fewer fry than redds above Browns Creek, and no fry have been trapped from the three redds sampled below Boyes Creek (Table 2 and Klatte and Roelofs).

Because salmonids are known to construct more than one redd, or may construct "test" or false redds (Briggs 1953), it is possible that some emergent nets were placed over redds with few or no eggs. Since the actual number of eggs deposited by a given female in a given redd is impossible to know precisely, it is not possible to calculate accurate measures in the field (Young et al. 1990). On average, emergent numbers on most redds trapped were lower in 1998 (Table 2) than in 1997 (Klatte and Roelofs 1997). There is no apparent explanation for this decrease in emergent numbers.

In laboratory studies Rieser and White (1988) found that smaller sized fine sediments (<0.84mm) were more detrimental to developing salmonid eggs than sediments with diameters from 0.84 - 4.6mm. As Everest et al. (1987) and Chapman (1988) noted, however, laboratory studies using unnatural gravel mixtures do not provide good estimates of survival to emergence in nature.

The dissolved oxygen levels measured in standpipes located in coho redds showed no clear pattern in redds above or below Browns Creek (Table 4), although redd 10 located downstream of Boyes Creek had the lowest value (5.0 mg/l). The expected positive relationship between gravel permeability (inflow rate) and dissolved oxygen was not observed in this study (Table 4), although as noted previously, we do not believe that the inflow measurements we made were accurate due to problems with the standpipes.

The number of 0+ coho and chinooks trapped migrating downstream in 1998 were much lower than in 1996 and 1997 (Table 5). As noted above, emergent numbers in the redds we trapped were also lower in 1998. It is interesting to look at the numbers of 0+ coho counted in each year and compare this to the number of coho smolts (age 1+) in the following year (Table 5). If one makes the assumption that similar proportions of migrating fish were trapped each year, then it might be expected that large numbers of 0+ coho in a given year would result in increased numbers of coho smolts the next year. We trapped 25,492 0+ coho in 1996 and counted 2,302 coho smolts in 1997 (Table 5). In 1997 we counted 3,113 0+ coho and caught 1,475 coho smolts in 1998 (Table 5). These data indicate that overwintering survival may be the bottleneck or constraint in coho production in Prairie Creek. Manning (1999) drew a similar conclusion in his studies on five northwestern coho streams, including Little Lost Man Creek: overwinter survival can limit the numbers of coho smolts that a stream produces.

A question of importance is whether there are continuing adverse conditions for anadromous salmonids and other organisms resulting from sediments released during the 1989 bypass erosion event. We do not feel that any definite conclusions can be drawn with respect to salmonids. As detailed above, there are differences in fry emergence in coho redds above and below Browns Creek. It is not known whether this is influenced by sediments from the bypass event, since historic timber harvest activities also contribute sediments in Browns and Boyes Creeks. Rogers (1999) found no relationships between increased sediments in five streams impacted by the bypass sediments and five control streams with respect to stream fish densities, fish species diversity, or individual fish growth rates during the summer. Klein (1999) concluded that by 1998 "effects on stream sedimentation from the 1989 Bypass erosion event were most likely gone." Boyes Creek continues to produce highly turbid water during storm events, but Klein (1999) pointed out that historic timber harvest in this basin may contribute to the high sediment production in this stream. Welsh and Ollivier (1999) found that amphibian populations in bypass-impacted streams were similar to those in control streams. They also noted, however, an increase in sediment deposition in pools and an overall increase in embeddedness between 1990 and 1996.

Last fall, the Cooperative Fisheries Research Unit at Humboldt State University, with funding from the National Marine Fisheries Service, started a three-year study of coho salmon in Prairie Creek. Portions of the project parallel this study (i.e.,spawner surveys, emergent trapping, downstream migrant trapping, etc.) Although the section of Prairie Creek between Streelow and Browns Creeks (sections 1 and 2 of the current study) are not being investigated, Prairie Creek above Browns Creek and 2.0 km sections of Streelow and Boyes Creeks are in the study. This work will help document the status of coho salmon and other organisms in Prairie Creek, and hopefully will contribute to long-term investigations in this beautiful basin.

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Appendices

Appendix 1. Spawning survey data from 1997-98.

Prairie Creek redd totals
1997-1998.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposed.
1	Nov.	7	1	0	0	8	100.0%	0
					TOTAL:	8		

November data has initial check.
8 redds were observed.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposed.
1	Dec.	53	23	0	0	76	42.9%	9
2	Dec.	48	27	2	0	77	43.5%	6
3	Dec.	12	6	5	0	23	13.0%	1
4	Dec.	1	0	0	0	1	0.6%	0
					TOTAL:	177		

December data has initial check.
177 redds were observed in December
16 (9.0%) were superimposed.
86.4 % of the redds were observed in reaches 1 and 2.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposed.
1	Jan.	3	0	2	0	5	13.9%	2
2	Jan.	1	0	0	1	2	5.6%	0
3	Jan.	12	0	6	0	18	50.0%	1
4	Jan.	8	0	3	0	11	30.6%	0
					TOTAL:	36		

January data has initial check.
36 redds were observed in January.
3 (8.3%) were superimposed.
80.6% of the redds were observed in reaches 3 and 4.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposec
1	Feb	4	0	0	0	4	25.0%	0
2	Feb	5	0	0	2	7	43.75%	0
3	Feb	4	0	0	0	4	25.0%	1
4	Feb	1	0	0	0	1	6.25%	0
					TOTAL:	16		

February data has initial check.
16 redds were observed.
1 (6.25%) was superimposed.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposec
1	March	9	0	0	0	9	27.3%	0
2	March	13	0	0	2	15	45.4%	0
3	March	9	0	0	0	9	27.3%	0
					TOTAL:	33		

March data has initial check.

Reach	Month	# of ukn. redds	# of KS redds	# of SS redds	# of SH redds	Total # of redds	% of total for month	# of redds that w superimposec
4	April	7	0	0	0	7	100%	1
					TOTAL:	7		

April data has initial check.
1 (14.28%) was superimposed.

Appendix 2. 1998 Prairie Creek Coho Salmon Emergent Fry Study, Two-Sample t-Test Comparing Treatment 1 (redds in sections 3 and 4 above Browns Creek) and Treatment 2 (sections 1 and 2 below Browns Creek).

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	95% LCL of Mean	95% UCL of Mean
Treatment=1	6	620.8333	494.4437	201.8558	101.9465	1139.72
Treatment=2	5	91	203.4822	91	-161.6565	343.6565

Note: T-alpha (Treatment=1) = 2.5706, T-alpha (Treatment=2) = 2.7764

Confidence-Limits of Difference Section

Variance Assumption	DF	Mean Difference	Standard Deviation	Standard Error	95% LCL of Mean	95% UCL of Mean
Equal	9	529.8333	392.7104	237.7979	-8.102961	1067.77
Unequal	6.88	529.8333	534.6771	221.4199	4.456532	1055.21

Note: T-alpha (Equal) = 2.2622, T-alpha (Unequal) = 2.3728

Equal-Variance T-Test Section-

Alternative Hypothesis	T-Value	Prob Level	Decision (5%)	Power (Alpha=.01)
Difference <> 0	2.2281	0.052862	Accept Ho	0.229552
Difference < 0	2.2281	0.973569	Accept Ho	0.000009
Difference > 0	**2.2281**	**0.026431**	**Reject Ho**	0.335039

Difference: (Treatment=1)-(Treatment=2)

Aspin-Welch Unequal-Variance Test Section

Alternative Hypothesis	T-Value	Prob Level	Decision (5%)	Power (Alpha=.01)
Difference <> 0	2.3929	0.048553	Reject Ho	0.233989
Difference < 0	2.3929	0.975723	Accept Ho	0.000007
Difference > 0	**2.3929**	**0.024277**	**Reject Ho**	0.348091

Difference: (Treatment=1)-(Treatment=2)

Tests of Assumptions Section

Assumption	Value	Probability	Decision(5%)
Skewness Normality (Treatment=1)	0.0000		
Kurtosis Normality (Treatment=1)		1.000000	Cannot reject normality
Omnibus Normality (Treatment=1)			
Skewness Normality (Treatment=2)	0.0000		
Kurtosis Normality (Treatment=2)		1.000000	Cannot reject normality
Omnibus Normality (Treatment=2)			
Variance-Ratio Equal-Variance Test	5.9045	0.094113	Cannot reject equal variances
Modified-Levene Equal-Variance Test	**12.2988**	**0.006650**	**Reject equal variances**

Appendix 3. Percent fines <0.85mm in coho redds above and below Browns Creek in Prairie Creek, 1998.

Analysis of Variance Report

Tests of Assumptions Section

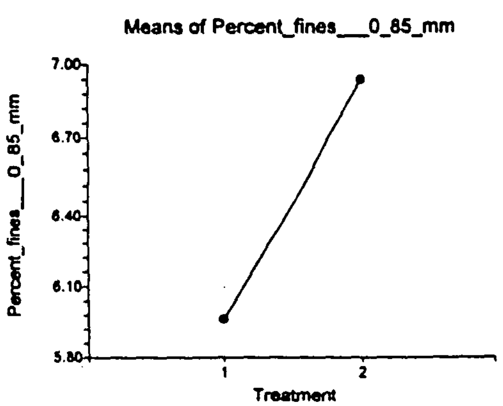
Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	1.6557	0.097775	Accept
Kurtosis Normality of Residuals	1.4802	0.138827	Accept
Omnibus Normality of Residuals	4.9324	0.084908	Accept
Modified-Levene Equal-Variance Test	1.4365	0.269706	Accept

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (Treatment)	1	1.907756	1.907756	0.21	0.662065	0.068260
S(A)	7	64.16773	9.166819			
Total (Adjusted)	8	66.07549				
Total	9					

* Term significant at alpha = 0.05

Plots of Means Section



Appendix 4. Percent fines <2.0mm in coho redds above and below Browns Creek in Prairie Creek, 1998.

Analysis of Variance Report

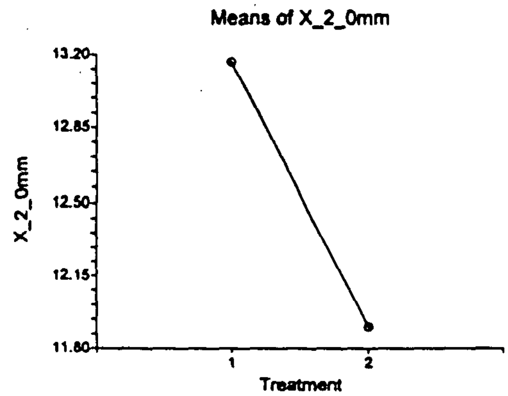
Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	1.2409	0.214634	Accept
Kurtosis Normality of Residuals	0.8674	0.385706	Accept
Omnibus Normality of Residuals	2.2923	0.317853	Accept
Modified-Levene Equal-Variance Test	1.4530	0.267210	Accept

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (Treatment)	1	3.1752	3.1752	0.13	0.726196	0.061626
S(A)	7	167.2264	23.88949			
Total (Adjusted)	8	170.4016				
Total	9					

* Term significant at alpha = 0.05



Appendix 5. Average geometric mean particle diameter (Dg) in coho redds above and below Browns Creek, Prairie Creek, 1998.

Analysis of Variance Report

Tests of Assumptions Section

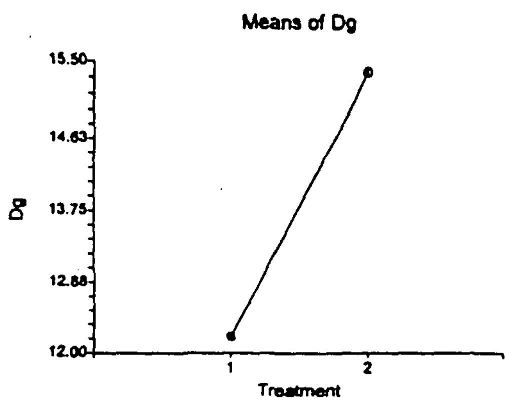
Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	0.3155	0.752378	Accept
Kurtosis Normality of Residuals	1.5000	0.133626	Accept
Omnibus Normality of Residuals	2.3494	0.308910	Accept
Modified-Levene Equal-Variance Test	4.5257	0.070945	Accept

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (Treatment)	1	20.20361	20.20361	1.01	0.347531	0.141164
S(A)	7	139.5049	19.92928			
Total (Adjusted)	8	159.7086				
Total	9					

* Term significant at alpha = 0.05

Plots of Means Section



Appendix 6. Fredle index of coho redds above and below Browns Creek, Prairie Creek, 1998.

Analysis of Variance Report

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	0.8360	0.403128	Accept
Kurtosis Normality of Residuals	1.7815	0.074832	Accept
Omnibus Normality of Residuals	3.8727	0.144230	Accept
Modified-Levene Equal-Variance Test	4.9620	0.061192	Accept

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (Treatment)	1	16.91681	16.91681	1.58	0.248604	0.193709
S(A)	7	74.78218	10.68326			
Total (Adjusted)	8	91.69962				
Total	9					

* Term significant at alpha = 0.05

Appendix 7. Average dissolved oxygen (mg/l) of coho redds above and below Browns Creek, Prairie Creek, 1998.

Analysis of Variance Report

Tests of Assumptions Section

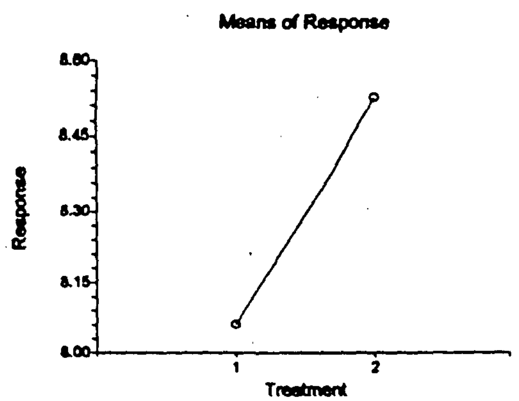
Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	-2.0621	0.039195	Reject
Kurtosis Normality of Residuals	1.3976	0.162222	Accept
Omnibus Normality of Residuals	6.2058	0.044919	Reject
Modified-Levene Equal-Variance Test	0.1863	0.676158	Accept

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (Treatment)	1	0.5880148	0.5880148	0.23	0.646217	0.071070
S(A)	9	23.472	2.608			
Total (Adjusted)	10	24.06002				
Total	11					

* Term significant at alpha = 0.05

Plots of Means Section



the goal of 100,000 chinook eggs were acquired (PCFWWRA, 1995). The past two seasons the trap was operated as many days as possible until several zero catch days were recorded. Although the trap was removed several times due to high flow events, we still captured over 200 salmon each year. The sex ratios were similar for chinook, but reversed for coho salmon with less females captured in 1997 than 1996 and more males in 1997 than 1996.

Spawning and Carcass Surveys

Spawning surveys

Measured redds that were greater or equal to 1.5 m long by 1.0 m wide were considered to be excavated by a coho or chinook salmon in Prairie Creek (Briggs, 1953; Bjornn and Reiser, 1991; M. Farro pers. comm. 1996). Surveys were conducted weekly beginning 25 November 1996 to 3 March 1997. A total of 191 salmon redds were measured over the first 10 weeks and 21 steelhead redds recorded in the next 4 weeks. Of these 191 salmon redds, 82 had adult female salmon on them at the time of the survey. Chinook salmon account for 73 % (60 fish) of these fish and coho salmon contributed 27 % (22 fish). Applying the percentage of chinook and coho redds each week to the unknown redds (109) gives a total 111 chinook redds, 54 coho redds, and 26 unknown (Table 2). The average dimensions of all redds measured was 2.7 m long by 1.5 m wide (4.05 m^2). Chinook salmon average redd size was 3.5 m long by 2.1 m wide (7.35 m^2) by 14.3 cm deep. Coho salmon average redd size was 2.5 m long by 1.5 m wide (3.75 m^2) by 14.1 cm deep.

Table 2. Spawning survey results from November 1996 to March 1997 in Prairie Creek.

Survey Date (Week starting)	Chinook Redds	Coho Redds	Unknown Redds	Percentages Chin	Coho	Total Redds Chin	Coho	Unk.
25 November	0	0	26	0	0	0	0	26
2 December	16	0	11	100	0	27	0	0
9 December	0	0	0	0	0	0	0	0
16 December	23	1	23	96	4	45	2	0
23 December	7	3	9	70	30	13	6	0
30 December	0	0	0	0	0	0	0	0
6 January	12	9	13	57	43	19	15	0
13 January	1	5	16	17	83	4	18	0
20 January	1	3	8	25	75	3	9	0
27 January	0	1	3	0	0	0	4	0
Totals	60	22	109	-	-	111	54	26

Carcass Survey

All salmon carcasses recovered were tagged, identified and released back to the exact place of capture for a spawning escapement estimate (in progress). A total of 164 chinook salmon carcasses were recovered. Of these, 4 were not identifiable by sex, 85 were female, and 71 male. A total of 61 coho salmon carcasses were recovered. Of these 1 was were not identifiable by sex, 26 female, and 34 male. The average lengths and results are listed below in Table 3.

Results and Discussion

Upstream Migration

The weir and trap was operated and monitored 24 hours per day, 7 days per week except when flows prevented safe operation or were too low for adult migration. The trap and weir was in place on 21 November 1996 and was fished until 1 February 1997. The trap was removed from the creek during high flow events and replaced when flows receded.

Chinook Salmon

Fall-run chinook were captured the same day that the weir trap was in place, 21 November 1996 (Figure 7). The peak occurred on 23 November 1996 (n=15) and fluctuated into January 1997. A total of 113 chinook were captured, 33 females (29%) and 80 males (71%, 37 jacks). Average fork length for chinook females was 85 cm and 66 cm for males.

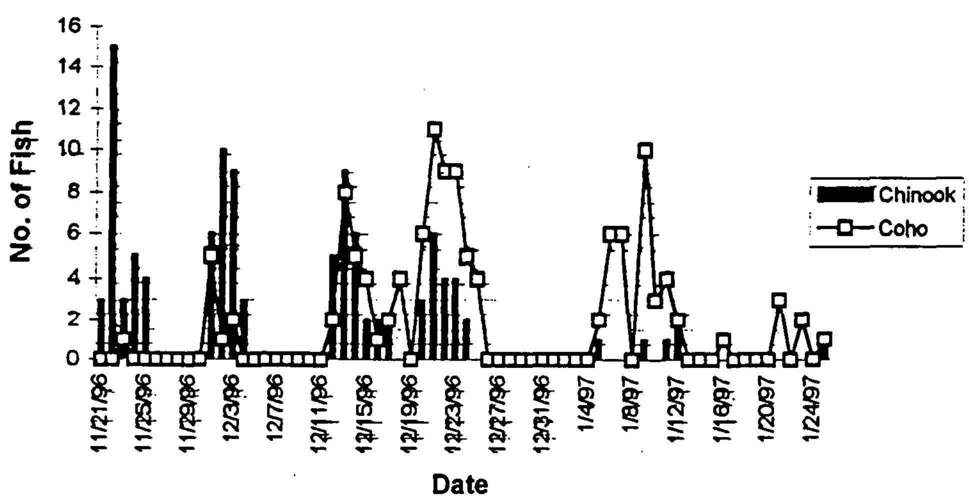


Figure 7. Run timing of chinook and coho adult salmon captured at Prairie Creek weir trap, 1997.

Coho Salmon

A total of 124 coho salmon were trapped, 45 females (36%) and 79 males (64%, 10 grilse). The peak occurred on 21 December 1996 (n=11) (Figure 7). Average fork length for female coho was 65 cm and male coho was 63 cm.

Prior to the 1995-1996 adult trapping season, adult salmonids were trapped in Prairie Creek to supplement the salmon populations using streamside incubation and rearing facilities. The weir trap was operated during permissible flows until an adequate number of adults were captured to artificially spawn. Trapping continued, intermittently, to determine the run size and timing until

Table 3. Carcass recovery results from surveys conducted in Prairie Creek (November 1996 to March 1997).

	Chinook salmon		Coho salmon	
	n	ave.ln.	n	ave.ln.
Female	85	78 cm	26	65 cm
Male	71	81 cm	34	66 cm
Unknown	4	75 cm	1	63 cm
Total	**160**	-	**61**	-

Prior to 1995, RNP staff conducted annual spawning and carcass surveys in established index reaches of several streams within the park boundaries, including the 10.5 km in Prairie Creek. RNP's best effort was during the 1992-1993 spawning season when RNP staff measured 167 redds, recovered 87 chinook carcasses, and 18 coho carcasses. No surveys were conducted in Prairie Creek for the 1994-1995 spawning season. The number of carcasses and redds measured during the 1995-1996 season in Prairie Creek is the highest recorded (279 redds, 314 carcasses). The 1996-1997 numbers are not as high as 1995-1996 numbers but a big storm prevented any surveys and trapping from occurring between 25 December 1996 and 5 January 1997. This was a 15-20 year recurrence interval according to RNP staff (R.Klein pers. com.). Most redds and carcasses were lost during this event which was during the 1995-1996 peak salmon run. It is not known if the past two years numbers are due to increased effort, a strong year class, or good quality and quantity of spawnable habitat available due to higher winter flows. An attempt to estimate the spawning escapement is in progress using a Jolly-Seber capture-recapture estimator (Law 1994) above Boyes Creek for 1996-1997. Poor visibility below the confluence of Boyes Creek prevented weekly surveys from occurring between Streelow Creek and Boyes Creek (Reach 1), therefore, 4 surveys were completed over the entire spawning season. This may explain some of the discrepancies in the two years. Weekly spawning and carcass surveys conducted within the RNP 10.5 km index reach plus an additional 4 km upstream is proposed for 1998. All carcasses recovered will be identified, measured, cut in half and returned to the creek. All adipose fin clipped carcass heads will be removed and delivered to CDFG for coded wire tag removal and reading.

Coho Fry Emergence

Preliminary studies on the effect of sediments on salmonid fry emergence in Prairie Creek were conducted by Coey (1994). Results from Coey suggests that fine sediments were responsible for causing 100% mortality in 6 of the 10 redds trapped. Sparkman (1996) found 100% mortality in 3 of the 5 redds trapped in 1996. In 1997 5 of the 6 coho redds trapped produced salmon (Table 4). Also, two redds produced chinook salmon as well as coho salmon, Redds 15 and 8. The lowest trap in the system, Redd 3, did not produce any fish although this redd was the best identification of spawning coho due to the location. This redd was located 10 feet below the adult weir trap. The redd escavation and deposition of eggs/sperm by male and female coho was observed over the entire duration of spawning by the trap operators. This redd did have a high amount of fines with poor intragravel flow (Figure 9). A high spring flow event eroded the

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WY 1996

Spawning and Carcass Surveys

Spawning surveys

Measured redds that were greater or equal to 1.5 m long by 1.0 m wide were considered to be excavated by a coho or chinook salmon in Prairie Creek (Briggs, 1953; Bjornn and Reiser, 1991; M. Farro, pers. comm. 1996). A total of 149 redds was measured during the month of December 1995. Of these 149 redds, 54 had adult fish present at the time of the survey. Chinook salmon account for 85 % (46 fish) of these fish and coho salmon contributed 15 % (8 fish). Applying these percentages to the 149 redds measured gives 127 chinook redds and 22 coho redds.

A total of 71 new salmonid redds were measured during the month of January 1996. Of these 71 redds, 30 had adult fish present at the time of the survey. Chinook salmon accounted for 60 % (18 fish) of these fish and coho salmon contributed 40 % (12 fish). Applying these percentages to the 71 redds measured gives 43 chinook redds and 28 coho redds.

A total of 59 new salmonid redds were measured during the month of February 1996. Of these 71 redds, 7 had adult fish present at the time of the survey. Chinook salmon accounfed for 43 % (3 fish) of these fish and coho salmon contributed 57 % (4 fish). Applying these percentages to the 149 redds measured gives 25 chinook redds and 34 coho redds.

Overall, chinook salmon accounted for 70 % (195) of the 279 redds observed in Prairie Creek.

Carcass Survey

Table 2. Carcass recovery results from 56 surveys conducted in Prairie Creek (December 1995-February 1996.

	Chinook salmon		Coho salmon		Unidentified	
	n	ave.ln.	n	ave.ln.	n	ave.ln.
Female	101	86 cm	53	65 cm	-	-
Male	115	86 cm*	45	66 cm	-	-
Unknown	-	-	-	-	54	71
LIVE	100		115			

*Floy tags recovered from surveys = 27 tags out of 190 tagged fish.
*Adipose fin clipped fish recovered = 24 with an average length of 74 cm (CDFG still reading tags).

Downstream migration

The rotary screw trap was operated 24-hours per day, between 13 March and 10 July 1996 for a total of 89 days. Chinook age 0+ or YOY constitute the bulk of the catch throughout the sampling period. Other salmonids captured included coho YOY, coho smolts, trout YOY, trout parr, cutthroat trout and steelhead smolts (Table 3). Nongame species captured include sculpin, lampreys, and salamanders.