1996 Final Report

Anadromous Salmonid Escapement and Downstream Migration Studies in Prairie Creek, California, 1995-1996

Prepared by:

Bernard Klatte
and
Dr. Terry Roelofs

Humboldt State University
Arcata, California
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ABSTRACT

Humboldt State University and Pacific Coast Fish, Wildlife and Wetlands Restoration Association, under a Memorandum of Agreement with the California Department of Transportation Compliance Plan under Regional Water Quality Control Board Order 90-8, monitored the migration of adult and juvenile salmonids in Prairie Creek, an old-growth coastal stream, located in northern California. Anadromous salmonids entering and spawning in Prairie Creek were examined over a 3-month period starting in December of 1995 and ending in February of 1996. A total of 221 live fish were captured using a weir and fish trap placed 6 miles above the creek mouth. Species composition, numbers, size of fish, run timing, and sex ratios were recorded. Spawning and carcass surveys were conducted over the study period. A total of 288 individual chinook and coho salmon redds was measured within the Redwood National Park 7 mile index reach (Streelow Creek to Good Creek). Coded wire tags were recovered from chinook salmon carcass during spawning surveys. Juvenile migrating salmonids were captured using an EG Solution rotary screw trap placed 5 miles above the creek mouth. This trap was operated from 13 March 1996 to 10 July 1996. Total captures to date included 26,333 chinook young of the year (YOY); 25,492 coho YOY; 2,117 coho yearlings; 207 trout YOY; 997 trout yearlings; and 613 coastal cutthroat trout. Weekly trapping efficiencies were conducted with juvenile chinook. The rotary screw trap total mortality rate calculated over the trapping period was less than 1 %.

ACKNOWLEDGMENTS

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The United States Fish and Wildlife Service in Arcata, California provided sampling equipment and the staff to transport and install this equipment.

A special thanks to Richard and Lisa Byrns for providing access to their property and storage space at their home at all hours of the year.

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My sincerest thanks, of course, goes to my partner Ronnie for putting up with me.

CONTENTS

FIGURES

TABLES

INTRODUCTION

Prairie Creek is a tributary to Redwood Creek in Humboldt County, California. It is an important spawning and rearing area for anadromous salmonids, specifically chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). The recent decline in numbers of anadromous species has increased the potential for these species to become listed in California under both federal and state endangered species laws. In October 1989, a storm event generated numerous mud flows from a highway construction alignment project within the Prairie Creek Basin (Welsh and Olliver 1992). Several hundred tons of sediment eroded from the project and were deposited into the Prairie Creek Basin. In anticipation of damage to fish and other aquatic resources, the California Department of Transportation (Caltrans) proposed monitoring to study the impacts and persistence of this fine sediment (Myers et al. 1994). Caltrans also contracted the Pacific Coast Fish, Wildlife and Wetlands Restoration Association (PCFWWRA) to rear and release salmonids in Prairie Creek in 1990. Efforts to supplement the salmon populations using streamside incubation and rearing facilities ended in 1995 (PCFWWRA 1995). Currently, natural spawning success and rearing within the Prairie Creek Basin is being evaluated. Here we present the results of the 1995-1996 field study of the anadromous salmonids of Prairie Creek.

Objectives

In this study we proposed to quantify the impacts of a human-caused sedimentation event on salmonids in a coastal old-growth redwood forest. Our objectives were as follows:

- Determine the species composition of the anadromous fish runs,
- estimate the anadromous salmon escapements,
- determine run-timing for salmon,
- determine the age and size of salmon,
- describe sex ratios,
- document locations and success of spawning activities, and
- estimate the juvenile salmonid outmigration.

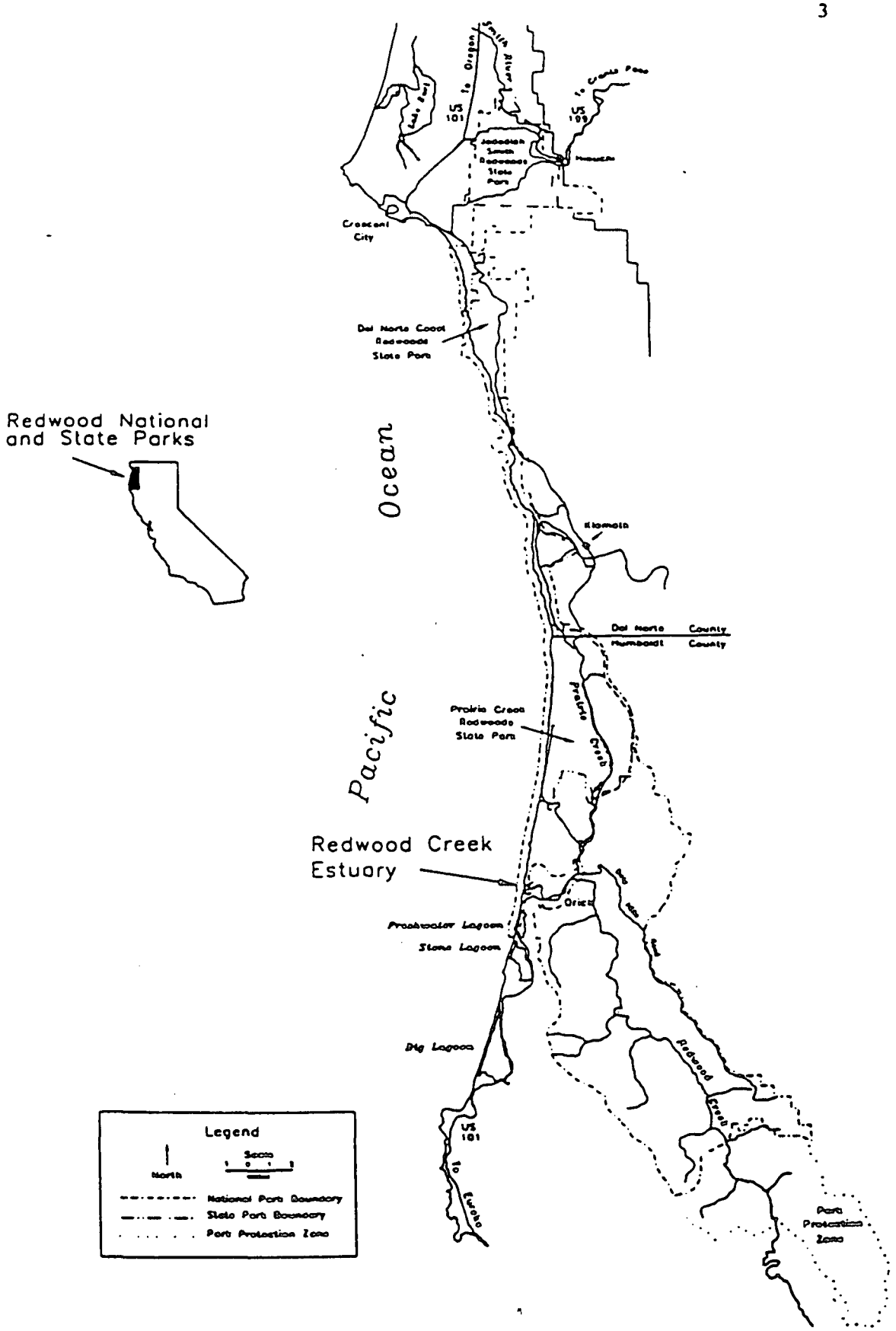


Figure 1. Location map of Prairie Creek, Redwood National and State Park, Humboldt County, California.

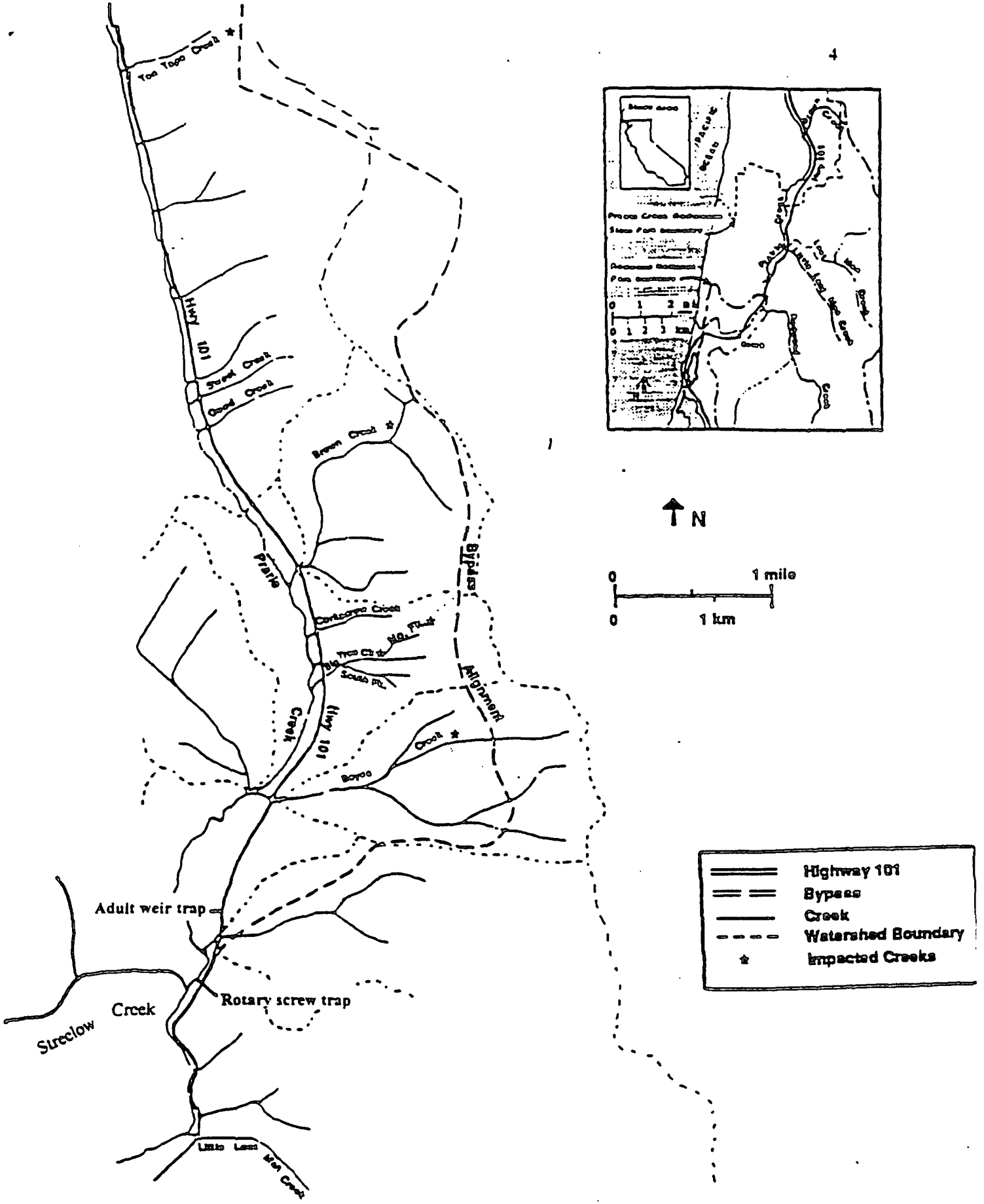


Figure 2. Location map of study site showing trap locations and impacted creeks in Prairie Creek Basin. Redwood National and State Parks. Humboldt County, California (Welsh and Ollivier 1992).

Heads from adipose fin clipped carcasses were taken to obtain coded-wire tags and sent to the California Department of Fish and Game (CDFG) in Arcata, California for analysis.

Downstream Migration

A United States Fish and Wildlife Service (USFWS) 5-foot EG Solution rotary screw trap was used for the assessment of emigrating juvenile salmonids and other species of Prairie Creek. The rotary screw trap was comprised of a 5-foot diameter cone with a spiral vein supported by foam filled aluminum pontoons. The trap was placed 500 feet above the confluence of Streelow Creek (Figure 2) and fished at a depth of 2.5 feet throughout the trapping period. As water pushes the spiral vein the cone spins, entrapping emigrating fish and forcing them into the live holding box located at the rear of the trap (Shaw and Jackson 1994). The trap was operated 24 hours per day, 7 days per week, from 13 March to 10 July 1996. The live holding box was checked daily and a simple random sample (SRS) of size n=30 fish was taken for chinook young-of-the-year (YOY) salmon. Fork length and weight were recorded for each individual. Also, samples of size n=30 were taken for all other age and species of fish present. All remaining fish were identified and counted. The separation of age was based on fork length and appearance. Fish were anesthetized with Tricaine methanesulfonate (MS-222) to facilitate handling. Each fish was measured to the nearest millimeter and weighed to the nearest 0.10 gram.

Trap efficiencies were conducted weekly, when possible, to estimate the numbers of chinook juveniles emigrating from above the trapping site in Prairie Creek. This estimate does not take into account the level of production downstream from the trap or those fish remaining in the basin beyond the trapping season. Juvenile chinook salmon were marked weekly with a Bismark Brown Y biological stain solution. The numbers marked varied due to the fluctuations in downstream migration. At least 200 or more fish were used for the efficiency tests. Bismark Brown Y (2 grams) was dissolved in 30 gallons of water and the juvenile chinook were held in this solution for 30 minutes. A compressed air tank, regulator, and air stones were used to aerate the solution (Shaw and Jackson 1994). Marked fish were transported upstream from the rotary screw trap 0.3 miles and released in a deep pool containing large woody debris for refuge. A control group of 25 marked and 25 unmarked fish was held instream in a 2.5 ft. by 4 ft. by 3 ft. live car to determine marking mortality and the duration of the stain mark. The marked chinook retained a orange coloration for 3-4 days. Recaptures were recorded and weekly estimates of outmigrant chinook were calculated using the equations of Shaw and Jackson (1994) in Table 1.

Table 1. Equations used to estimate the number of emigrating juvenile salmonids each week in Prairie Creek during 1996 (Shaw and Jackson 1994).

1. % MM = % CM - %CUM, where
   %MM = percent marked mortalities
   %CM = percent control marked mortalities
   %CUM = percent control unmarked mortalities

2. TMRS = %MM x MR, where
   TMRS = total marked released survival
   %MM = percent marked mortalities
   MR = marked released

3. TE = MR/TMRS, where
   TE = trap efficiency
   TMRS = total marked released survival
   MR = marked released

4. EWC = 1/TE x (TWC), where
   EWC = expanded weekly catch
   TE = trap efficiency
   TWC = total weekly catch

Trapping Mortality

Percent trapping mortality was calculated for all salmonids captured over the entire trapping period. An artificial refugia was created with rocks, mop heads and a small root wad placed in the live box to minimize predation.

Summer Habitat Survey

A habitat survey was conducted in Prairie Creek between 21 September 1996 and 27 September 1996. Single-phase visual estimation was used to calculate the summer habitat area. A two person team walked upstream measuring the length of each habitat type unit. Visual estimates of widths were make for every habitat type (pool, riffle, run). In a random (1 in 6 systematic) sample of each habitat type units, accurate measurements of widths were made using a 50-meter tape at three locations within the unit. Every measured unit was flagged for juvenile bounded count direct observation and electrofishing calibration if greater than 20 fish were observed.

Summer Fish Survey

Chinook

Juvenile chinook salmon surveys were conducted in Prairie Creek by two teams of divers between the confluence of Streetlow Creek and Godwood Creek on 8 July 1996. Visual observations were made by divers starting downstream and moving upstream in each habitat unit. Divers recorded all juvenile chinook present after reaching the upstream end of each habitat unit selected. Only those units which contained depth over 1 foot were

selected. No coho counts were made during these dives and no population estimates were generated from these dives.

Coho

Juvenile coho salmon surveys were conducted in Prairie Creek by two divers between the confluence of Streelow Creek and Browns Creek between 5 October 1996 to 12 October 1996. All pools and runs which were preselected and flagged from the habitat inventory were sampled using visual observation. Each preselected unit was dove three times and numbers of coho were recorded for each pass. If less than 20 coho were present, the flag would be removed. If 20 or more coho were counted then the flag was left and the unit was calibrated with multiple-pass depletion by electrofishing (Dolloff et al. 1993). All riffles preselected from the habitat inventory were measured using multiple-pass depletion by electrofishing.

Water Temperature and Stream Discharge

Water temperature data were measured at the United States Geological Survey (USGS) stream gaging station, located at the Wolf Creek Bridge in the Redwood National Park. RNP staff biologists provided this information for the study period. Temperatures were recorded every 40 seconds by a HOBOTEMP™ temperature monitor placed inside a protective sleeve in Prairie Creek. Discharge (Q) was calculated using a calibration curve generated by RNP from water stage heights recorded continuously at three USGS gaging stations on the main channel of Prairie Creek (R. Klein pers. comm.).

Fry Emergence

Spawning and carcass surveys helped identify redds with actively spawning salmon. From these redds, 5 were selected for a survival to emergence study (HSU senior thesis project by Michael Sparkman). Five emergent fry traps used in Prairie Creek by Coey (1990, 1991) were placed over the selected redds 10-30 days before expected emergence (17 April 1996). Each trap frame was 8 ft long by 4 ft wide, constructed from 0.5 in. diameter steel rebar and covered with 0.165 in. polyethylene netting. Each trap was anchored to the streambed using hooked rebar stakes. Streambed material was removed around the margin of the trap frame to a depth of approximately 8-15 in. to place the net apron. The apron was buried in place with gravel/cobbles to prevent lateral migration of fry beyond the trap perimeter. The placement, maintenance, and operation of the traps was in accordance with the methods of Olson (1996), and Coey (1994). Traps were inspected and maintained every two days until emergence occurred, then monitored daily. All captured fry were anesthetized with Tricaine methanesulfonate (MS-222) to facilitate handling. Each fish was measured to the nearest millimeter and released downstream upon recovery. Each trap was fished until 10 'zero catch' days were recorded after the expected emergence date.

Permeability

Early in July, standpipe inflow measurements were taken in the egg pocket and tailspill of each trapped redd, 10 ft. adjacent to each redd, and in 5 untrapped control redds. The criteria for selecting the control redds were that each redd must have positive identification of spawning fish from previous spawning surveys and the same habitat type and water depths as trapped redds. Also, each control redd must be excavated by the salmon within 10 days of the trapped redds excavation date. The substrate depth selected for permeability measurements corresponded to Briggs (1953) average depth of egg deposition in redds of chinook (12 in.) and coho (8 in.) salmon. Three measurements were taken and averaged at each specific location and the time for evacuating the water within the pipe for each measurement was held constant. A graph of permeability (cm/hr) versus standpipe inflow rate (ml/sec) was used to convert inflow rate to permeability. The permeability rate was then standardized to a stream temperature of 10°C using the equation $K_{10} = XK_T$, where K_T is the permeability value and X is the viscosity correction factor for water temperature (Barnard and McBain 1994). Survival to emergence was estimated using Chapman's (1988) survival index for chinook salmon.

RESULTS

Upstream Migration

Fall-run chinook were captured the same day that the weir trap was in place, 9 December 1995. The number of fish trapped increased through the month and into January 1996 (Figure 3). A total of 106 fish, 30 females (28%) and 76 males (62% male) were caught. Average fork length for chinook females was 89 cm and 75 cm for males. A total of 115 coho salmon were trapped, 66 females (60%) and 49 males (40%) (Figure 3). Average fork length for both female and male coho salmon was 67 cm.

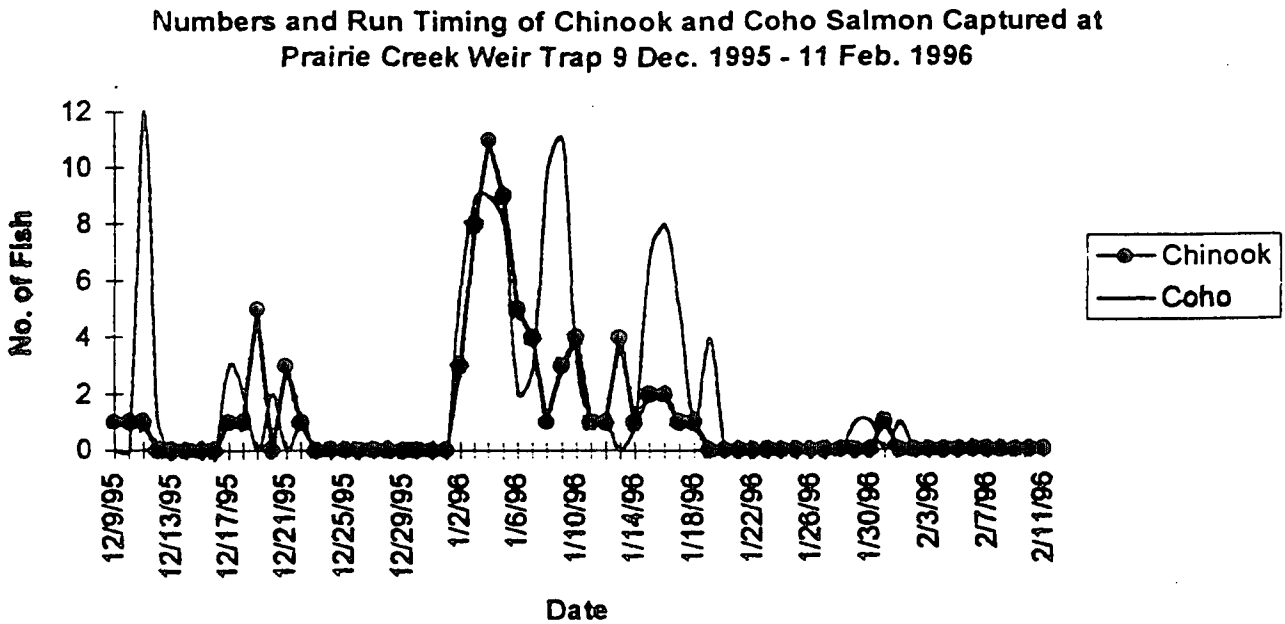


Figure 3. Adult salmon captured in Prairie Creek weir trap.

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 accounted 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

*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.

Table 3. Prairie Creek rotary screw trap salmonid catch summary for 1996.

	Chinook YOY	Coho YOY	Coho Smolt	Trout YOY	Trout Parr	Cutthroat Trout	Trap Mortality
Totals	26,333	25,492	2,117	207	997	613	427*

* = (<1% mortality)

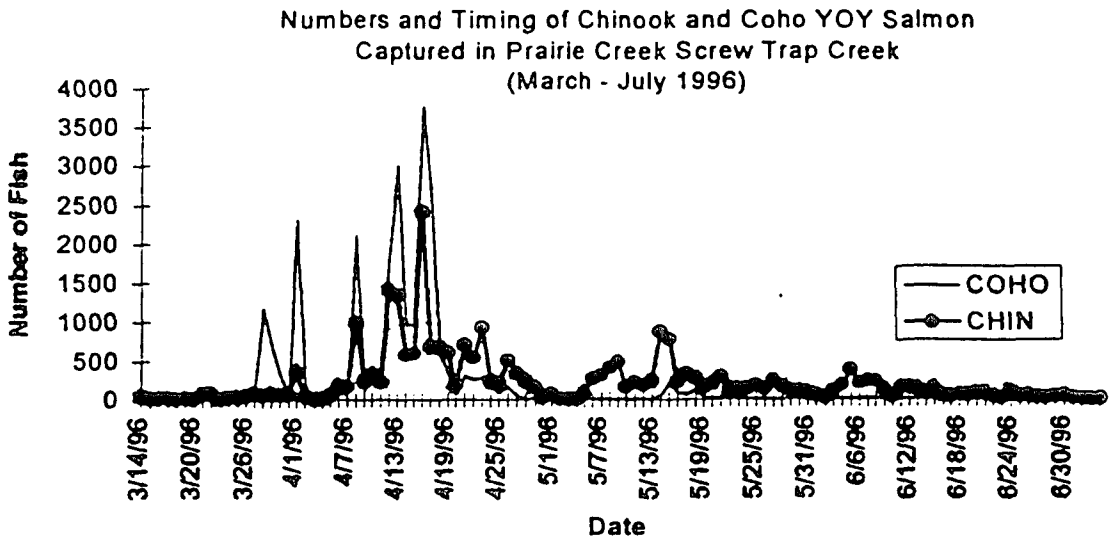


Figure 4. Juvenile salmon captured in Prairie Creek rotary screw trap.

The peak of YOY chinook captured occurred on 16 April (2,417) with numbers declining to 4 by July (Figure 4). Juvenile chinook YOY fork length (FL) ranged from 29 mm to 84 mm (Figure 5). Weekly trapping efficiency results conducted for chinook YOY are listed in Table 4. Juvenile chinook age 1+ or yearling smolts, were not captured. It is not known to what extent juvenile chinook remain in Prairie Creek over the winter and leave as yearlings. Length frequency and weight data collected from the 30 fish sample were used to generate a log transformed length-weight relationship (Figure 6). Coho salmon captured in the rotary screw trap consisted of 25,492 YOY (Figure 4) and 2,117 smolts. The peak of capture of 3,770 YOY occurred on 13 April and 158 smolts on 15 May. Coho YOY FL ranged from 32 mm to 63 mm (Figure 7).

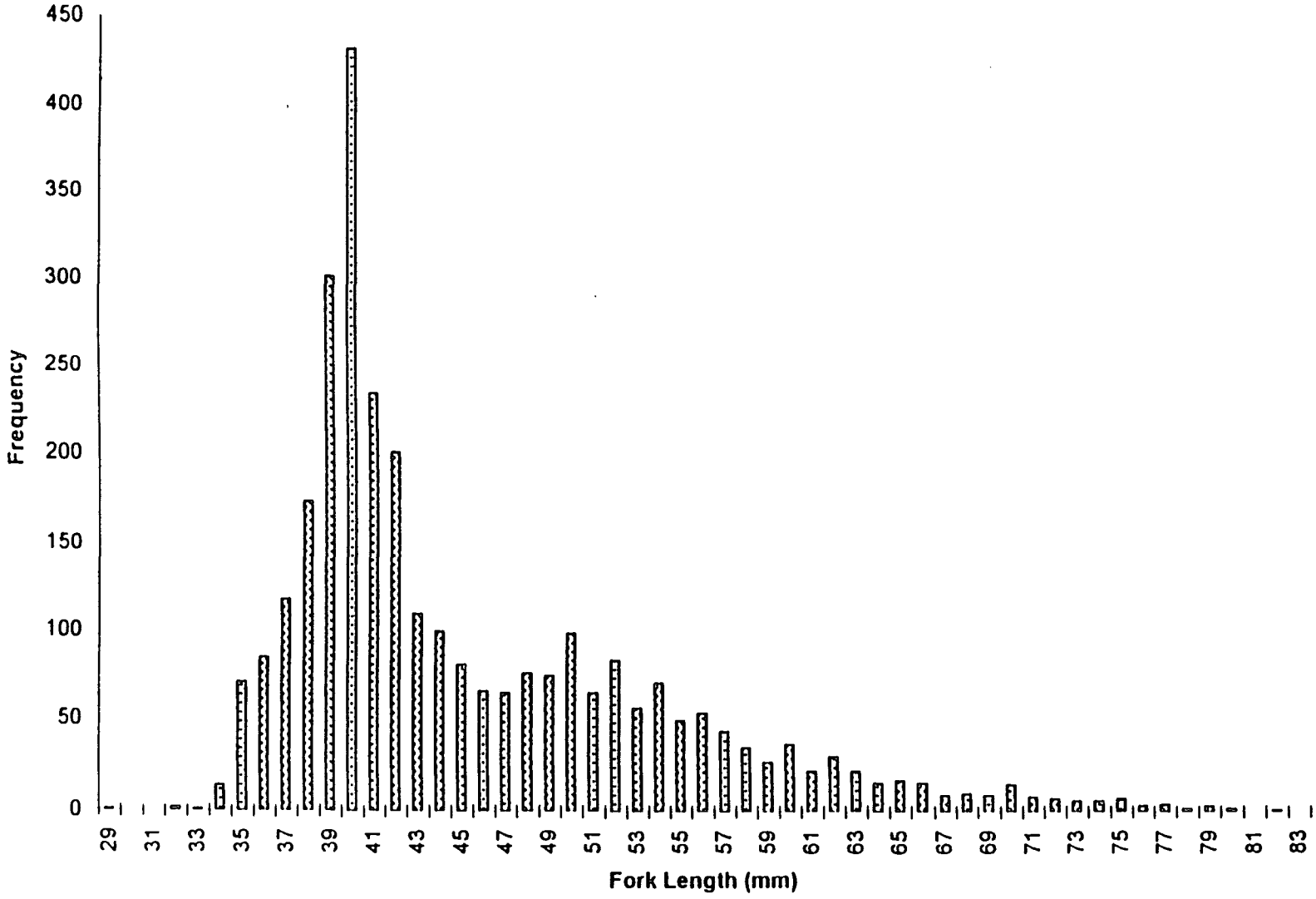


Figure 5. Length frequency histogram for chinook YOY captured in screw trap, 13 March - 10 July 1996, Prairie Creek, California.

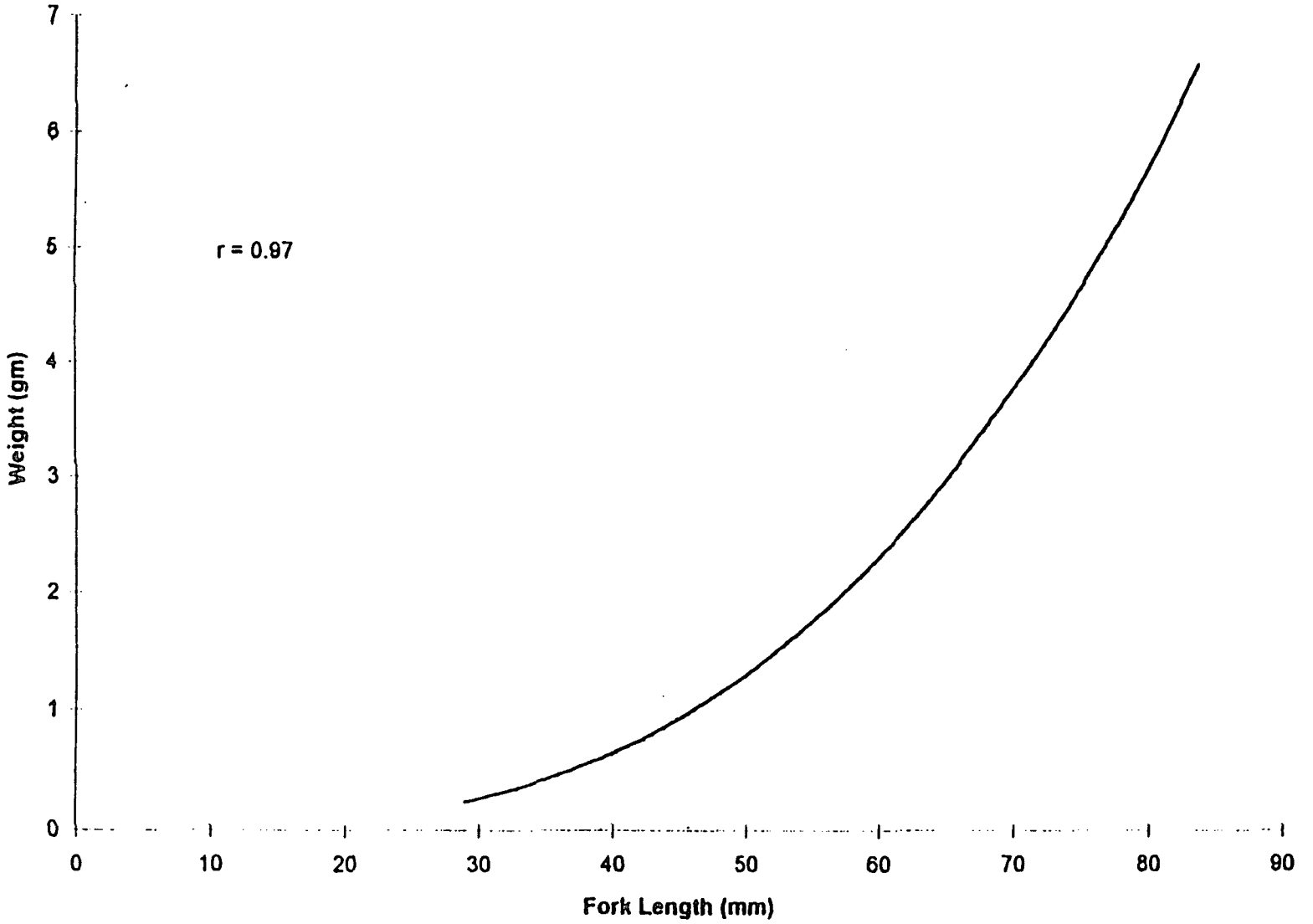


Figure 6. Prairie Creek chinook YOY log transformed length-weight relationship for 1996 trapping season.

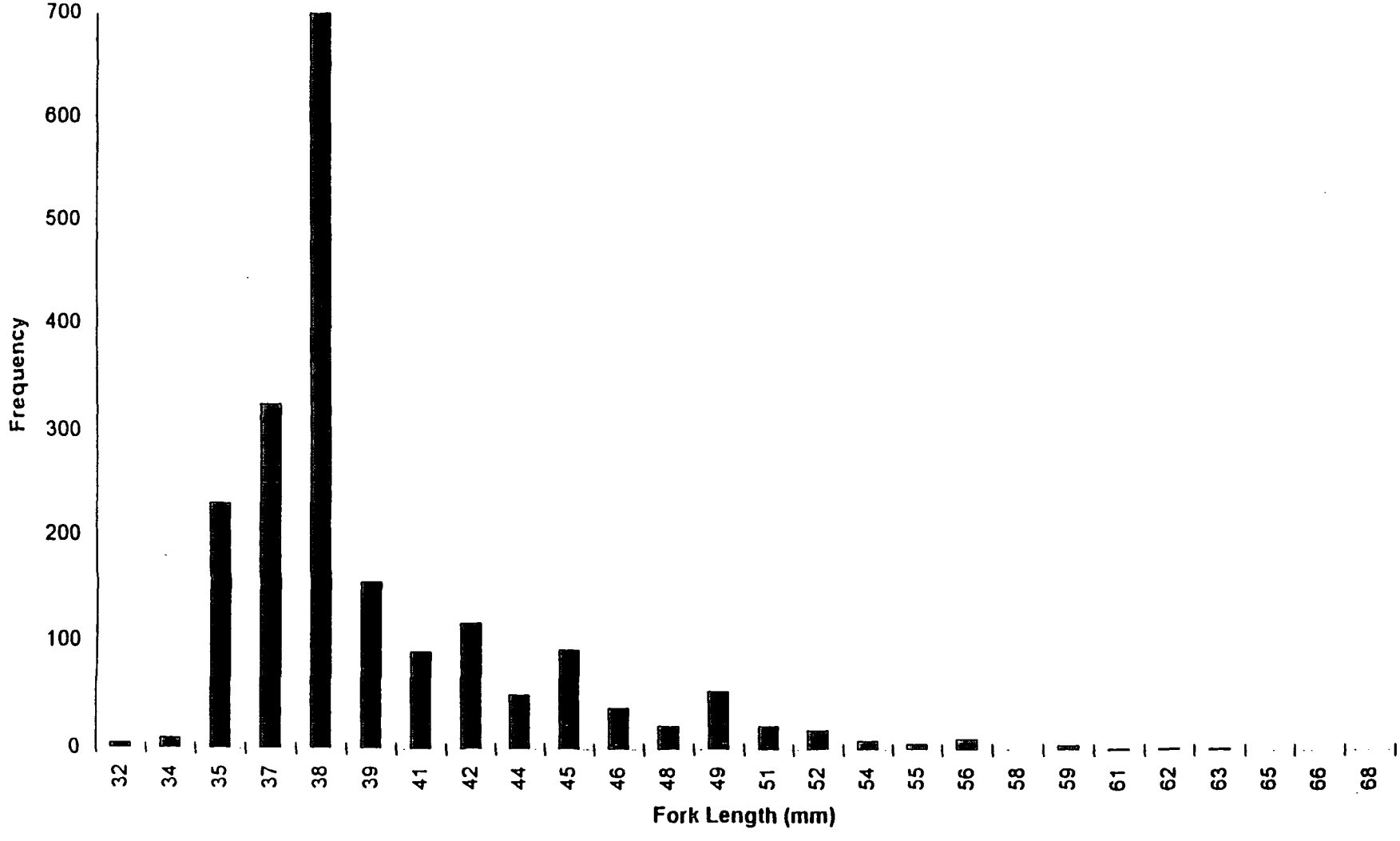


Figure 7. Length frequency histogram for coho YOY captured in screw trap, 13 March - 10 July 1196, Prairie Creek, California.

Table 4. Prairie Creek rotary screw trap (weekly) efficiency test results.

Week ending	Chinook YOY Total Catch	No. Marked and released	No. Captured with marks	Trap Efficiency	Expanded Weekly Estimate
16 March 1996	58				58+
23 March 1996	266	-	-	-	266+
30 March 1996	388	-	-	-	388+
6 April 1996	803	-	-	-	803+
13 April 1996	4738	-	-	-	4738+
20 April 1996	5757	-	-	-	5757+
27 April 1996	3512	700	0	0%	700
4 May 1996	531	-	-	-	531+
11 May 1996	1961	461	86	18.7%	2412
18 May 1996	2959	250	22	8.8%	3245
25 May 1996	1258	358	206	27.5%	1735
1 June 1996	960	300	213	71%	3310
8 June 1996	1393	300	179	60%	3483
15 June 1996	870	135	73	54.1%	1895
22 June 1996	859	-	-	-	859+
totals	**26333**				**30180**

- efficiency test not conducted

Of the 55,759 salmonids captured, a total of 427 (0.76%) mortalities were observed. The highest daily mortality (96 fish) occurred when a live beaver was trapped in the live box and could not escape. The majority of mortalities observed were regurgitated chinook YOY fish from predation in the live box.

Direct Observation Summer Fish Surveys

Chinook

A total of 190 juvenile chinook were observed in 24 diveable habitat units sampled on 8 July 1996.

Coho

The results from the summer coho population survey are listed below. The estimates were generated by a S-PLUS program written by C. D. Moyer (1997).

Table 5. Summer coho population estimates with respective variance and confidence intervals.

Habitat Type	Population Estimate	Variance	95 % C. I. lower	95 % C. I. upper
Pools (51%)	7030.623	2214060	4054.68	10006.6
Runs (21%)	2346.531	461092	988.45	3704.6
Riffles (28%)	121.842	117.853	100.13	143.55
Total				

8 KM
- see p. 17

9497 / 8 KM = 1187 FISH/KM
= .36 FISH/FT

Water Temperature and Stream Discharge

Water temperatures in Prairie Creek follow a relatively constant seasonal pattern (Figure 8). Fluctuations in mean monthly temperatures did not exceed more than 2° to 3° C. The overall mean temperature was 9.2° C.

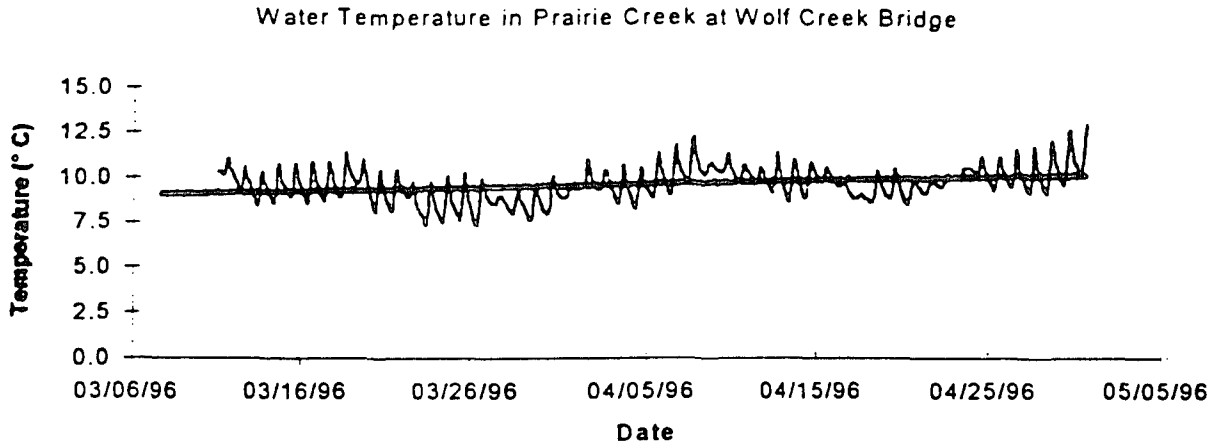


Figure 8. Water temperature in Prairie Creek, March - May 1996.

Stream Discharge -see Appendix 1.

Fry Emergence and Substrate Permeability

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 (Table 5). Fry trap 1 captured 223 chinook, trap 2 captured three coho fry, and traps 3, 4, and 5 captured zero fry.

Table Numbers of fry trapped and permeability measurements of 5 trapped redds, 10 ft. adjacent to trapped redds, and 5 control redds in Prairie Creek, California, with survival to emergence percent in relation to gravel permeability (Chapman 1988).

Trap	Fry Trapped (n)	Location measurement taken in Redd	Trapped Redds (cm/hr)	Adjacent to Redds (cm/hr)	Control Redds (cm/hr)	Percent Survival to Emergence based on Permeability Value (Chapman 1988)
1	223	Egg Pocket	10,000	530	470	52%
	-	Tailspill	1,400	-	840	56%
2*	3	Egg Pocket	< 100	1,800	2,400	0%
	-	Tailspill	< 100	-	2,200	0%
3	0	Egg Pocket	140	<100	1,400	0%
	-	Tailspill	250	-	810	0%
4	0	Egg Pocket	1,900	2,700	< 100	21%
	-	Tailspill	290	-	< 100	0%
5	0	Egg Pocket	1,400	110	1,700	19%
	-	Tailspill	2,200	-	1,500	22%

* Trapped redd 2 excavated by coho salmon, all others by chinook salmon.

Note: Permeability's above 10,000 cm/hr result in steelhead emergence survival > 85% (Barnard and McBain 1994).

DISCUSSION

Upstream Migration

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 the goal of 100,000 chinook eggs were acquired (PCFWWRA, 1995). Upstream migration will be monitored for the 1996-1997 spawning population using the same methodology as above.

Spawning and Carcass surveys

RNP staff conducted annual spawning and carcass surveys in established index reaches of several streams within the park boundaries, including 10.5 km (6.52 mi) on Prairie Creek. Over the past 5 years, RNP's best effort was during the 1992-1993 spawning season where 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 has been the highest recorded. It is not known if these numbers are due to increased effort, a strong year class, or a good year for quantity and quality of spawnable habitat due to higher winter flows. Anadromous spawning escapement will be estimated in 1996-1997. Weekly spawning and carcass surveys will be conducted within the RNP 10.5 km (6.52 mi) plus an additional 3 km (1.83 mi) above RNP index reach. All carcasses recovered will be measured and tagged with a numbered jaw tag for a capture-recapture escapement estimate using a Jolly-Seber model (Law 1994).

Downstream Migration

In April 1994, PCFWWRA installed 2 pipe traps to capture downstream migrating juvenile salmonids in Prairie Creek. The traps were monitored daily through 10 July 1994 and every other day to 1 August 1994. The traps were not operated on four days during this period due to high flows. The actual numbers trapped were 3,346 chinook YOY, 123 coho YOY, 421 coho smolts, 391 trout YOY, 81 trout smolt, 48 steelhead smolt and 107 cutthroat trout. Trap efficiencies were determined using a fin clip on chinook YOY and the total number of migrating chinook salmon was estimated to be 13,466. The 1996 downstream migration was monitored using a rotary screw trap. This screw trap was operated from 13 March to 10 July 1996 trapping 26,333 chinook YOY (almost double the 1994 estimated migration). The 1997 downstream migration of juvenile salmonids and other species of Prairie Creek will be monitored using the rotary screw trap and three tributaries (Browns, Boyes, and Godwood Creeks) will receive pipe traps. Trap efficiencies will be conducted using a capture-recapture estimator when possible.

Summer Fish Population Estimate

1997 summer population estimates for coho salmon will be produced in Prairie Creek by calibrated diver counts. The distance will be expanded from Browns Creek (1996-8 km) up to Good Creek (15 km).

Fry Emergence and Permeability

Limited inferences can be made from emergence and permeability studies due to the small sample size. Also 3 of 5 trapped redds had no fry emergence. Laboratory studies conducted by McCuddin (1977) reveal a positive correlation between survival and permeability for salmonids (r^2=0.85 for chinook salmon). The comparison of Chapman's (1988) survival index for chinook salmon with Prairie Creek permeability measurements indicates that fine sediments continue to be a limiting factor for egg incubation and fry emergence in Prairie Creek. Salmon redds will receive emergent fry traps and inflow rates within and adjacent to these redds will be measured in 1997. The number and location will be determined from the winter spawning surveys.

LITERATURE CITED

Barnard, K., and S. McBain. 1994. Standpipe to determine permeability, dissolved oxygen, and vertical particle size distribution in salmonid spawning gravels. FHR Currents: Fish Habitat Relationships Technical Bulletin. Number 15. 12 pps.

Briggs, John C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Department of Fish and Game Marine Fisheries Branch. Fish Bulletin No. 94. 62 pp.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Am. Fish. Soc. Special Publication 19:83-138.

CDFG, 1991. Anadromous salmonid escapement studies, South Fork Trinity River, 1984 through 1990. Klamath-Trinity Program, Inland Fisheries Division, Administrative Report No. 92, Draft.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Trans. Am. Fish. Soc., 117(1): 1-24.

Coey, R. 1994 Effects of sedimentation on incubating coho salmon (*Oncorhynchus kisutch*), Prairie Creek, California. Draft M.S., Humboldt State University, Arcata California.79 pp.

McCuddin, M. E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. University of Idaho, Moscow, Idaho.

Meyer, C. B., R.M. Coey, R.D. Klein, M.A. Madej, D.W. Best, and V.L. Ozaki. 1994. Monitoring the impacts and persistence of fine sediment in the Prairie Creek watershed: water years 1991-1992. Final Report, Redwood National Park, Orick, CA. 143 pp.

Moyer, C. D. 1997. Field testing the modified Hankin and Reeves methodology. M.S. in progress. Humboldt State University, Arcata, California.

Law, P.M.W. 1994. Simulation study of salmon carcass survey capture-recapture methods. Calif. Fish and Game, (80)1:14-28.

Olson, A. D. 1996. Freshwater rearing strategies of spring chinook salmon (*Oncorhynchus tshawytscha*) in Salmon River tributaries, Klamath Basin, California. M.S. Humboldt State University, Arcata, California.

PCWWRA. 1995. Prairie Creek salmon project progress report. Pacific Coast Fish, Wildlife and Wetlands Restoration Association, Arcata, California. 15pp.

Sparkman, M. 1996. A proposal to qualify the timing and period of fry emergence from chinook and coho salmon redds in Prairie Creek, Humboldt County, California. Humboldt State University, Arcata, CA. 14 pp.

Shaw, T. A., and C. Jackson. 1994. Little River juvenile salmonid outmigration monitoring 1994. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California. 35 pp.

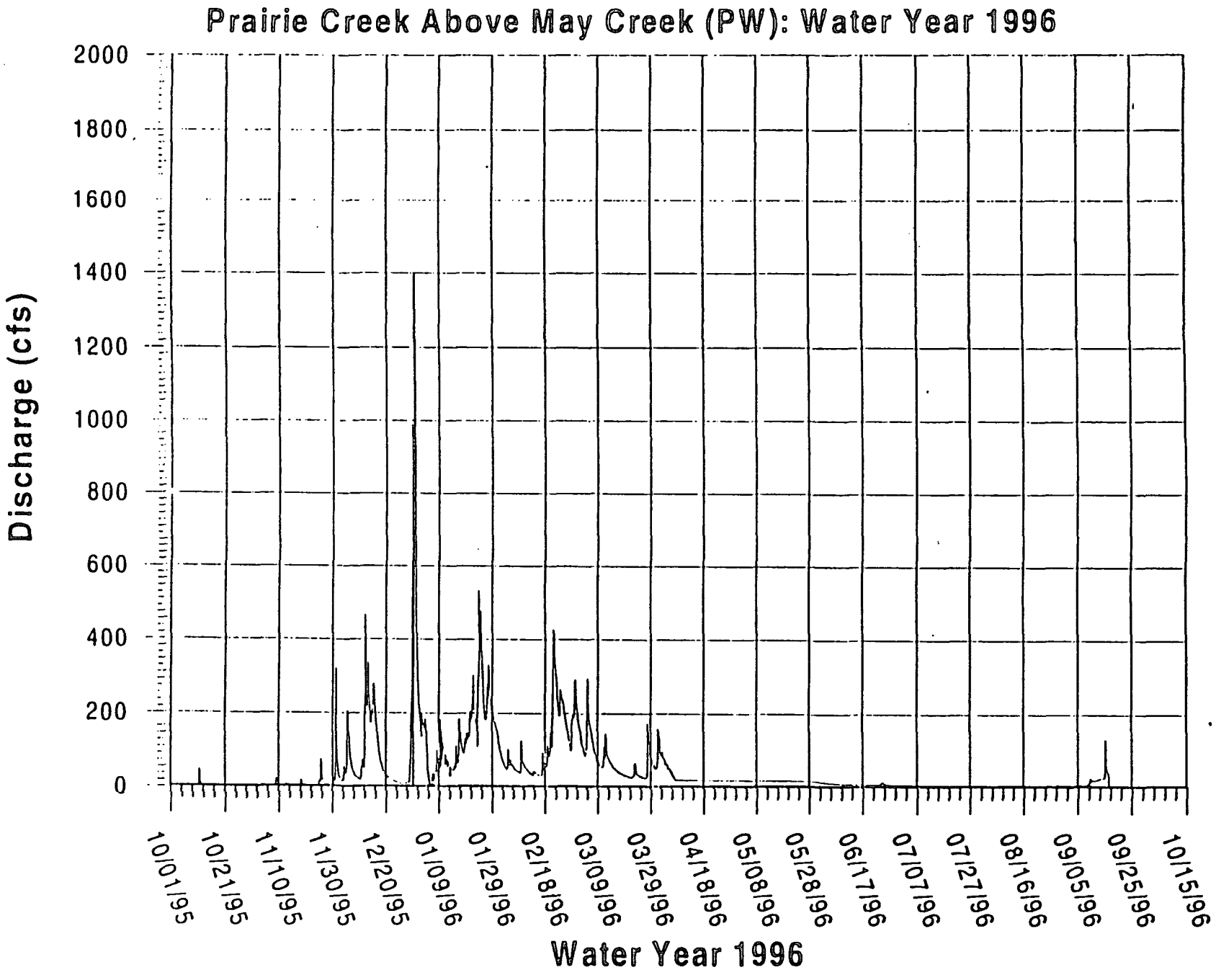
Taggart, J. V. 1984. Coho salmon survival from egg deposition to fry emergence. *In* Walton, J.M.,Houston, D.B., editors. Proceeding of the Olympic Wild Fish Conference, Fishery Technology Program; 1983 March 23-25: Olympic National Park, Peninsula College, Port Angeles, Washington. p 173-181.

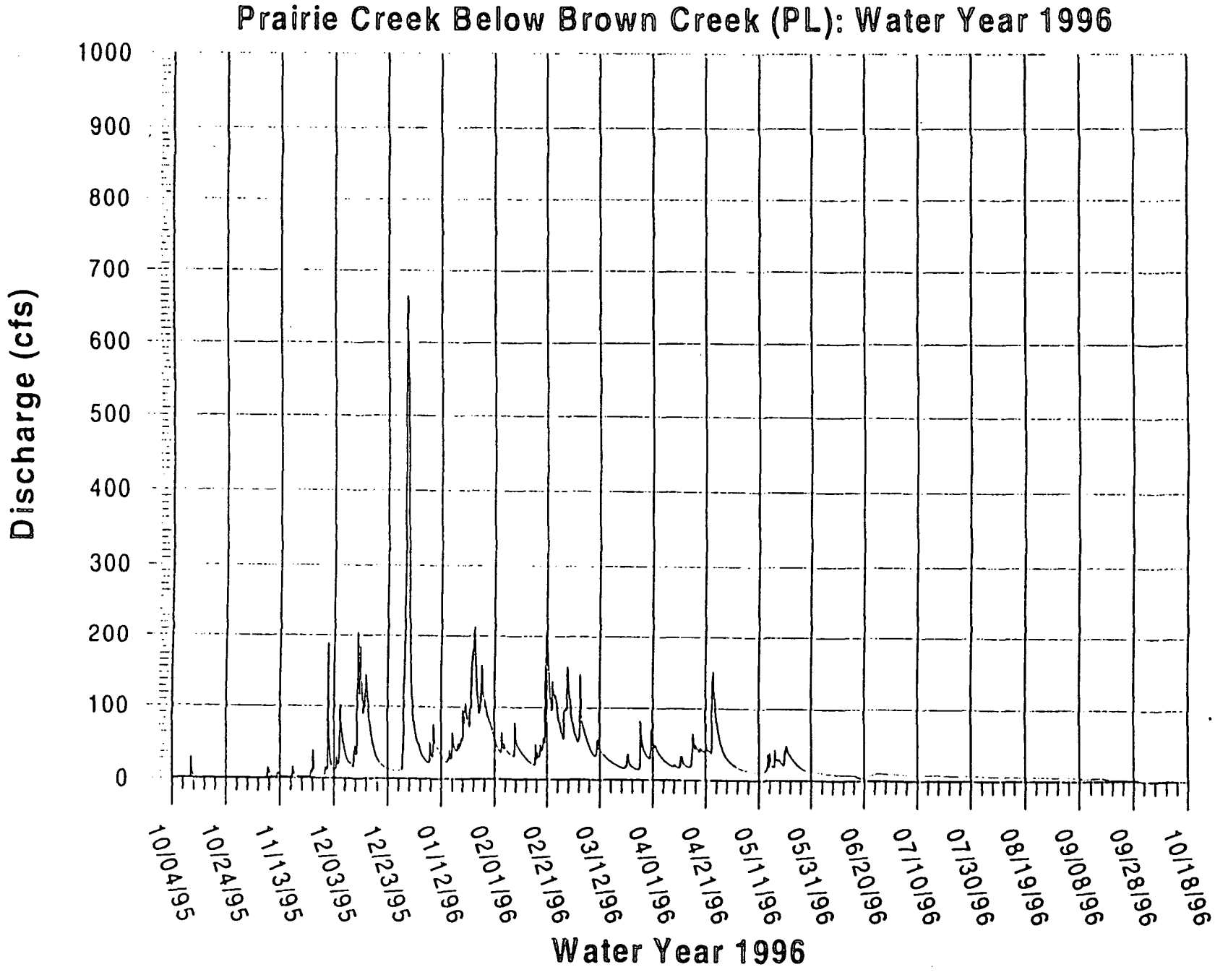
Welsh, Jr., H.H., and L.M. Olliver. 1992 Effects of sediments from the Redwood National Park Bypass Project (Caltrans) on the amphibian communities in streams in Prairie Creek State Park. Final Report, USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA. 68 pp.

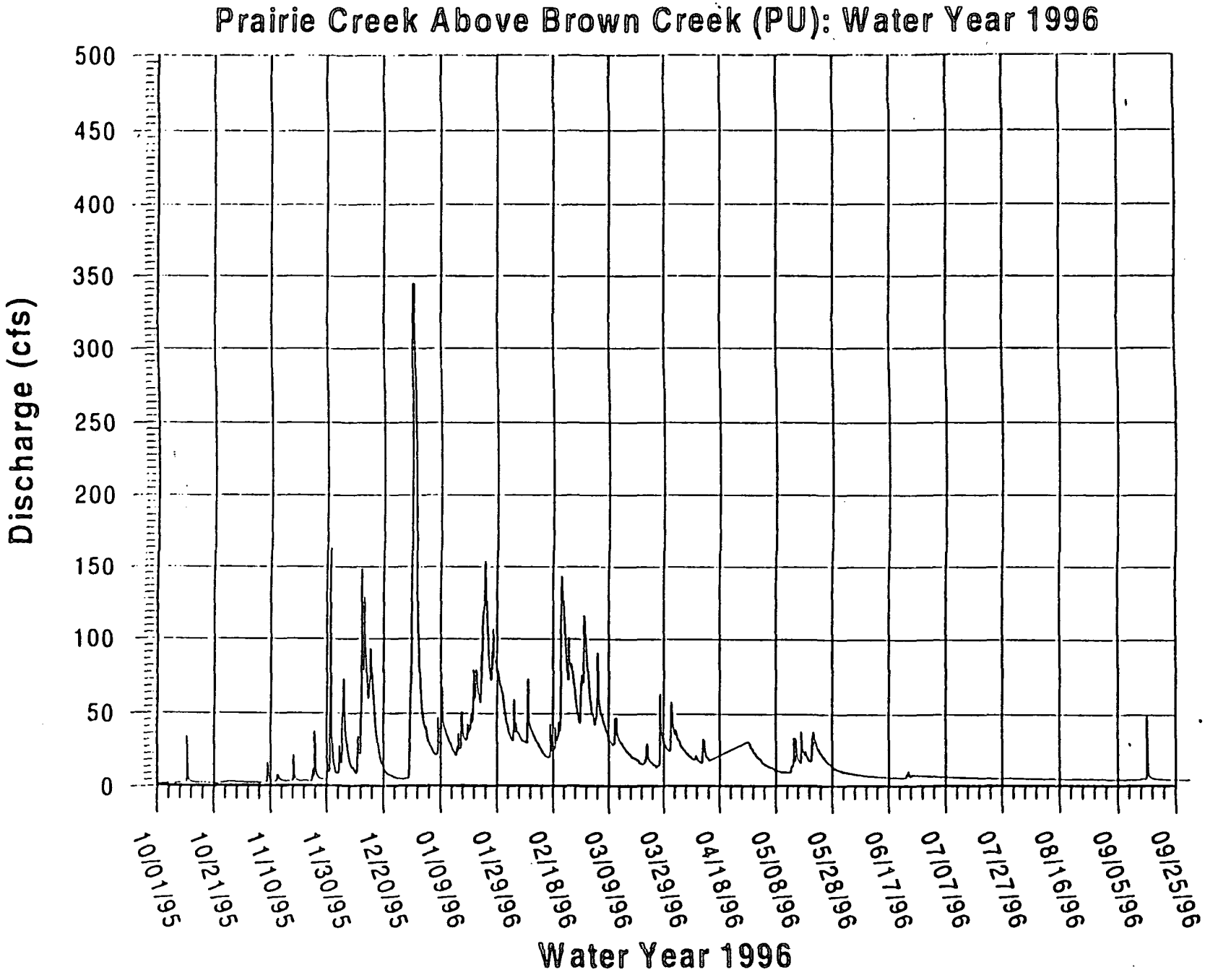
Personal Communications

Farro, M. Pacific Coast Fish, Wildlife, and Wetlands Restoration Association, Arcata, California.

Klein, R. Geologist, Redwood National Park, Orick, California.


Prairie Creek Above May Creek (PW): Water Year 1996
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10/01/95
10/21/95
11/10/95
11/30/95
12/20/95
01/09/96
01/29/96
02/18/96
03/09/96
03/29/96
04/18/96
05/08/96
05/28/96
06/17/96
07/07/96
07/27/96
08/16/96
09/05/96
09/25/96
10/15/96
Water Year 1996


Prairie Creek Below Brown Creek (PL): Water Year 1996
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
10/04/95
10/24/95
11/13/95
12/03/95
12/23/95
01/12/96
02/01/96
02/21/96
03/12/96
04/01/96
04/21/96
05/11/96
05/31/96
06/20/96
07/10/96
07/30/96
08/19/96
09/08/96
09/28/96
10/18/96
Water Year 1996


Prairie Creek Above Brown Creek (PU): Water Year 1996
Discharge (cfs)
500
450
400
350
300
250
200
150
100
50
0
10/01/95
10/21/95
11/10/95
11/30/95
12/20/95
01/09/96
01/29/96
02/18/96
03/09/96
03/29/96
04/18/96
05/08/96
05/28/96
06/17/96
07/07/96
07/27/96
08/16/96
09/05/96
09/25/96
Water Year 1996