State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

JUVENILE SPRING-RUN CHINOOK SALMON EMERGENCE, REARING AND OUTMIGRATION PATTERNS IN DEER CREEK AND MILL CREEK, TEHAMA COUNTY FOR THE 1993 BROODYEAR

ANNUAL PROGRESS REPORT

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SPORT FISH RESTORATION

INTRODUCTION

Wild populations of spring-run chinook salmon are showing an alarming decline in both Mill and Deer creeks. In Mill Creek spring run have declined from a high of 3,500 in the early 1950's to only 61 in 1993. In Deer Creek, over 4,000 were recorded in the mid-1940's and only 229 were observed in 1993. Historically, spring-run chinook salmon were the second most abundant salmon run in California. Today, Mill, Deer, and Butte creeks have the only wild stocks of spring-run chinook salmon in the Central Valley.

Although the cause of the spring-run decline in Mill and Deer creeks cannot be attributed to any one factor, increasing evidence suggests that excessive mortality is occurring after juveniles emigrate from these creeks but prior to the adults returning to spawn. One problem area contributing to increased juvenile mortality in all runs of chinook salmon is the Sacramento-San Joaquin Delta. Within the Delta, Kjelson and Brandes (1989), found salmon survival to be dependent upon a complex relationship of flow, water temperatures and percent of inflow diverted by the State and Federal water projects.

Export levels and species abundance relationships have been developed with delta exports implicated in the decline of striped bass, American shad, delta smelt, (Stevens et al., 1985, Moyle et al. 1992) and several species of invertebrates. Reduced delta outflows appears to affect bayshrimp, starry flounder and Pacific herring (State Water Resources Control Board testimony). Longfin smelt, splittail and spring-run chinook salmon are likewise affected. These facts suggest that declines are occurring in all anadromous species that reside in, migrate through, or are dependent upon the waters of the Sacramento-San Joaquin Delta.

In order to determine the effects of water management on spring-run smolts in the Delta, the basic life history needs to be defined. It is not known when spring-run smolts emigrate from Mill and Deer Creeks and enter the Delta, whether smoltification occurs as fingerlings or yearlings or a combination of both, or how long spring-run smolts reside in the Delta prior to ocean entry. Outmigrant monitoring in Mill and Deer Creeks will determine outmigration timing and whether spring-run chinook smoltification occurs as fingerlings or yearlings. Delta residency will require tagging juvenile spring-run salmon in Mill and Deer creeks and subsequent recapturing as they enter and exit the Delta. A tagging and recapturing study was not attempted in 1994.

The purpose of this initial study was to estimate the length frequency of smolts emigrating from Mill and Deer creeks and the timing of outmigration. Juvenile growth patterns were followed from egg deposition through emergence, rearing and emigration. No attempt will be made to determine smolt abundance.

METHODS--Terminology

For the purposes of this report, the various freshwater life history stages of juvenile chinook salmon are defined as follows:

A broodyear (BY) refers to the year the eggs were deposited, this report covers the 1993 BY. A fry refers to juvenile fish up to their third month after emergence and ranging in size from 32 millimeters forklength (mmFL) to 60 mmfl. A fingerling or parr refers to juvenile salmon exhibiting visible parr marks, and ranging in age from 3 months after emergence to smoltification. Fingerling range in size from 60 mmfl to 90+ mmfl. A smolt refers to a juvenile salmon undergoing the physiological transition to prepare it for salt water residency. Visibly, this is a loss of parr marks and a decrease in body fat. The term juvenile encompasses all three of these life stages: fry, fingerling and smolt. An outmigrant is defined as a juvenile exiting its natal stream. A yearling is defined as a juvenile reaching one year of age from the date of egg deposition in the gravel (Groot, Margolis, 1991).

METHODS--Spawning

To calculate the timing of egg hatching and fry emergence from the gravel, we first needed to determine the onset and termination of spring-run spawning in the fall. Additionally, water temperatures affect the length of time it takes for eggs to develop, hatch, and fry emerge. Consequently, water temperatures are collected year around for calculation of expected egg hatching and fry emergence. Spawning distribution and timing was determined by weekly surveys beginning the last week in August for redds, carcasses and live spawners within the known spawning habitat of Deer Creek and Mill Creek. Adult spring-run chinook salmon spawning habitat ranges from the Upper Falls to the vicinity of Ponderosa Way in Deer Creek. In Mill Creek the known spawning habitat ranges from the hot springs near Lassen National Park boundary to the confluence of Little Mill Creek. Indexed areas within these reaches were surveyed weekly to determine the onset, peak and termination of spring-run spawning. Total redds, live salmon and carcasses were recorded on each survey. Carcasses were marked and not recounted on subsequent surveys.

METHODS--Temperatures

Water temperatures were taken by placing temperature monitors (Ryan Instruments TempMentor) in two spawning reaches of each creek. Minimum, maximum and average daily water temperatures were calculated from these hourly recordings. In Deer Creek, monitors were located near A-Line crossing and Ponderosa Way crossing; In Mill Creek monitors were located near Hole-In-The-Ground camp and Black Rock.

METHODS--Emergence and Emigration

Beginning the first week in February, bimonthly surveys were scheduled to monitor juvenile emergence, rearing and growth patterns. Sampling intensity was increased to weekly surveys in July. In Deer Creek, sampling areas were selected at A-line and Ponderosa Way crossings. Due to the low numbers of adult spring run spawners in Mill Creek this year, we were not successful in getting consistent samples of juveniles and decided not to intensively survey Mill Creek until 1995.

For the first 5 months of sampling (February-June) we used a Smith-Root model 12 backpack electroshocker to sample fry. This proved effective until the juveniles moved into deeper pool and riffle habitat not accessible to an electroshocking unit. In July we switched to a 10'x4'x1/8" mesh beach seine for the riffle and pool habitats and continued electrofishing the edgewater areas. All juveniles were measured, weighed and released back into the creek. In September, the Department of Fish and Games Region 1 screen shop installed fish-screen by-pass traps at the upper canyon diversion on Deer Creek and the Ward diversion on Mill Creek. These traps collect any fish entrained in the irrigation ditches between the intake and the fish screen. In October, a 5 foot rotary screw trap was installed downstream of the Upper Canyon diversion on Deer Creek. This trap fished continuously and was checked at least once per day. A rotary screw trap is scheduled to be installed in Mill Creek beginning in October of 1995. Both the by-pass traps and the rotary screw trap collected spring-run chinook salmon juveniles actively emigrating out of Deer and Mill creeks.

RESULTS--Spawning

The first spring-run chinook salmon redd in Deer Creek was seen on 25 August, 1993. The reach from Lower Falls to A-Line bridge was surveyed weekly to determine the approximate peak of spawning. Forty-two redds were counted on 29 September in this reach. Of the areas surveyed, the highest density of redds was between the Upper Falls and Potato Patch Campground. Fifty-two redds were observed the week of 24 September in this reach.

Approximately 15 miles of spawning habitat was surveyed in Mill Creek and only 12 redds were observed, which supports the low number of adults (61) counted ascending Mill Creek in the spring of 1993. No redds were sighted in the upper spawning limits of Mill Creek from Hole-In-The-Ground Camp to the Lassen Park Boundary. The first redds were seen on 7 September near Savercool Place.

RESULTS--Temperature and Emergence

Average daily water temperatures were calculated from the temperature records collected on each creek and used to determine daily temperature units (TU's). A temperature unit is defined as the average daily temperature minus 32. From the time of egg fertilization, a cumulative total of 1550 TU's are required for the egg to hatch and fry to emerge (Amour, 1991). Based on these requirements, the calculated earliest emergence (based on 25 August spawning) in Deer Creek would be 22 November. The peak emergence would be 27 February (based on 22 September spawning). The latest calculated emergence would be 3 April (based on 13 October being the last survey live salmon were seen on redds at A-Line), (Table 1). Actual emergence appeared to be the first week of March. Sizes of juvenile chinook sampled during an electroshocking survey in Deer Creek at A-Line on 4 March ranged from 33-44 mmFL. Egg sac sutures were still visible and only two of the salmon showed visible signs of external feeding. During the week of 3 April (latest calculated emergence), juveniles ranged from 34-39 mmFL, still in the recently emerged size range. Emergence times will vary throughout the spawning range since the onset of spawning begins earliest in the headwaters and latest at the downstream limit of spawning.

TABLE 1. Calculated and actual emergence times of spring-run fry in Deer Creek at A-Line, based on spawner surveys and daily temperature units.

Deer Creek at A-Line

	Onset of Spawning	Peak	End of Spawning
Spawning	08/25/93	09/22/93	10/13/93
Calculated Emergence	11/22/93	02/27/94	04/03/94
Actual Emergence	03/04/94		03/30/94
Size @ Emergence	(33-40 mmFL)		(33-40 mmFL)

A preliminary literature review of temperature requirements of egg incubation and hatching suggests that 1550 temperature units may represent only the peak of fry emergence, whereas the range can by as high as 1900 TU.

Actual daily temperature records for Deer Creek at A-Line and Ponderosa Way and Mill Creek at Hole-in-the-Ground/Big Bend and Black Rock are in Appendix 1, Tables 1-4.

RESULTS--Rearing

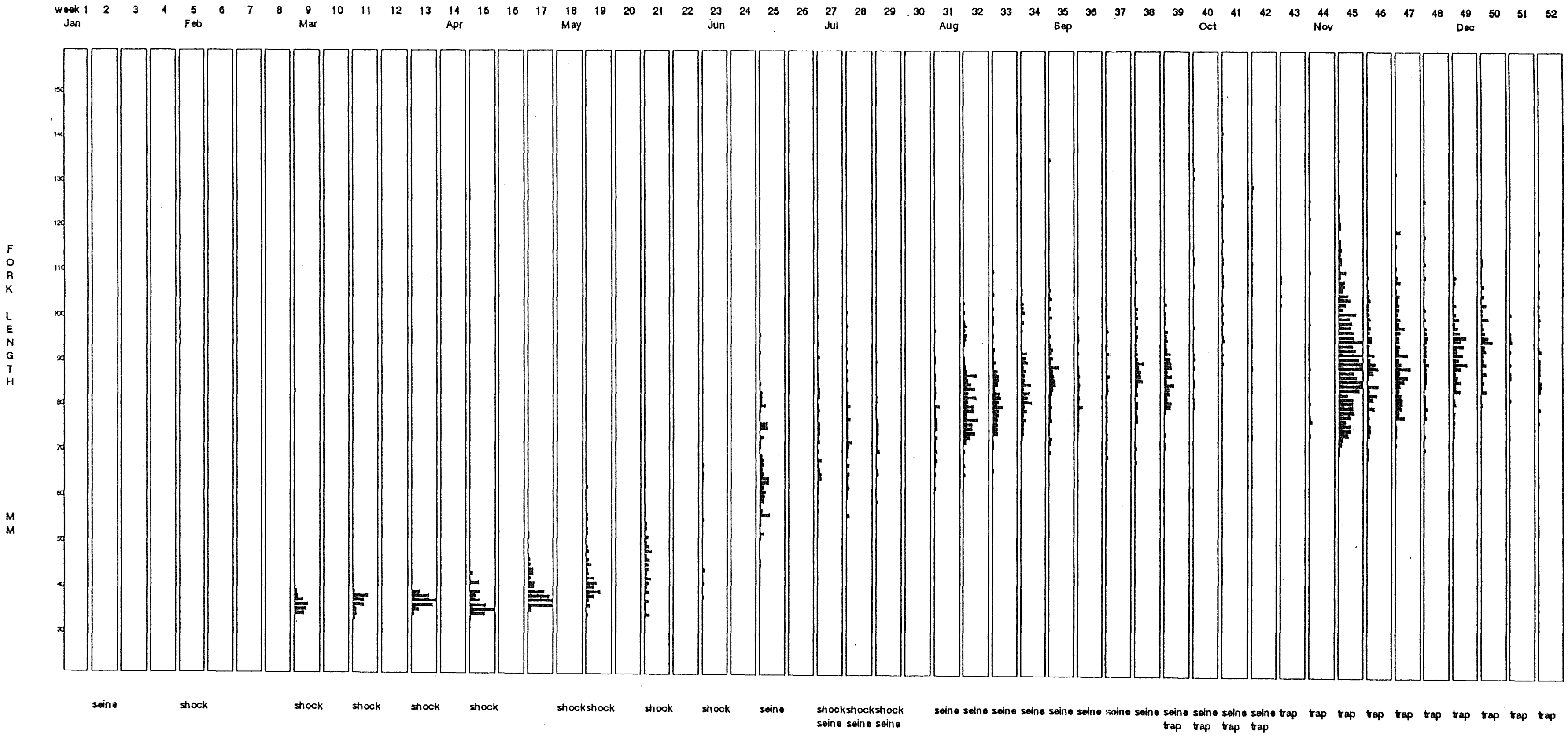
We continued to sample juveniles in the recently emerged size range of 33-40 mmFL through the second week in June. By mid-June, once juveniles reached 70 mmFL, they moved out of the edgewater habitat and into the riffle and pool areas. From mid-June to early October, length frequencies ranged from 45 to 135 mmFL with the majority of juveniles ranging from 70 to 110 mmFL (Table 2).

In January and February 1994, yearling spring-run chinook salmon were still present in Deer Creek at A-line ranging in size from 83 mmFL to 117 mmFL (Table 2).

RESULTS--Emigration

Due to the remoteness of the Mill and Deer Creek watersheds, we were unable to position an outmigrant trap upstream of fall-run spawning habitat yet downstream of spring-run juvenile rearing habitat. Fall-run salmon fry emigrate in the spring of

TABLE 2. Juvenile Spring Run Chinook Salmon length frequency distribution in Deer Creek, January – December 1994.



seine= 10'x4'x1/8' beach seine; A–line bridge and Ponderosa Way bridge
shock= Smith–Root model 12 backpack electrofisher; A–line bridge and Ponderosa Way bridge
trap= 5' rotary screw trap, and diversion ditch bypass trap; Deer Creek at canyon mouth

the year. Due to the relatively long incubation period of spring-run eggs, compared with the short incubation period of fall-run eggs, fall-run and spring-run fry emerge during the same time periods and at similar sizes. We will be unable to separate these 2 runs of fry if a portion of the spring-run fry emigrate in the spring. Although we did not fish an outmigrant trap in the spring of 1994 in Deer Creek, there did not appear to be a large emigration of spring-run fry during this time. This is evidenced by the fact that we did not start catching spring-run fry at Ponderosa Way until 23 June. We first began catching fry at A-line on 4 March. If spring-run fry had been actively moving downstream between March and June, it is likely we would have encountered them while sampling at Ponderosa Way during this same time period.

Juvenile sampling in the headwaters continued until juveniles had apparently migrated out of their normal rearing habitat. In Deer Creek on 3 October no salmon were captured at A-line; at the Ponderosa Way sampling station, only 8 spring-run juveniles were seined. On 14 October, 3 spring run juveniles were caught at A-line but none at Ponderosa Way. By 21 October, no spring run were captured at A-line and only one was seined at Ponderosa Way. These juveniles ranged in size from 80-98 mmFL.

The first outmigrant in Deer Creek was caught in the canyon mouth screw trap on 3 October (Table 3). The first outmigrant in Mill Creek was captured in the Ward Dam bypass trap also on 3 October. Sizes were 113 mmFL and 107 mmFL respectively--both spring-run yearlings.

The first large migration of spring-run yearlings from Deer Creek occurred during the first period of runoff in the fall on November 10 when 370 yearlings were trapped. A second peak occurred on November 26 when 138 yearlings were trapped. This second peak also followed a period of significant runoff (Table 3). During periods of high flows when Deer Creek was at flood stage, the rotary screw trap was removed from the water. We were only able to sample infrequently during the months of January, February, March and May. Yearling spring run from the 1993 broodyear continued to be trapped through March of 1995 (Figure 1). In January, February and March, 70 spring-run yearlings were captured ranging in size from 76 to 117 mmFL. Smolt size at emigration during the months of October through January ranged from 69 mmFL to 127 mmFL, with monthly averages of 104, 91, 93 and 95 mmFL respectively (Table 3).

Since fall-run chinook salmon spawned above the screw trap site, any fry captured in the spring could be of either fall or spring run-origin. We began trapping fry in the screw trap in February, ranging in size from 33 to 36 mmFL. These early catches of fry appear to be fall-run. Electrofishing surveys in known spring-run spawning areas did not capture spring-run fry in February. Also, temperature records from these areas in the winter of 1994-1995, show daily temperature units too low for the 1994 broodyear to be hatched and emerged in February (preliminary data). We continued to trap chinook salmon fry in

TABLE 3. Spring–run and fall–run chinook salmon emigration from Deer Creek; Progress report for October 1994–June 21, 1995.

Method: 5'Rotary Screw Trap fished at Canyon Mouth: T25N,R1W,S22.

Bypass Trap Fished at Upper Diversion: T25N,R1W,S14

MONTH		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
DAY										
1		0	0	3	1		4			0
2		0	1	0	0		3			0
3		1	1	14	0		9	in		0
4		0	3	out	2		8	0		0
5		1	4	8	28		4	0		0
6		2	5	out	4		0	0		0
7		1	16	51	out		2	3		1
8		2	2	61			0	0	in	0
9		1	4	11			out	0	0	0
10		4	370	3				0	0	0
11		1	45	0				0	0	0
12		1	44	2				0	0	0
13		2	49	11				0	0	0
14		1	28	3				0	0	0
15		4	20	44				0	0	0
16		1	2	6				0	0	0
17		1	2	3		in		0	0	0
18		1	6	0		1		0	0	1
19		0	4	4		0		0	0	0
20		0	3	1		0		0	0	0
21		0	0	1		4		0	0	out
22		1	7	2		2		0	0	
23		2	6	1		4		0	0	
24		0	1	1		2		0	0	
25		0	0	5		0		0	0	
26		0	138	1		2		3	1	
27		0	14	1		0		1	1	
28		2	7	10		2		1	0	
29		0	8	15				2	0	
30		0	0	3				out	0	
31		1		0					0	
# TRAP DAYS		31	30	31	6	11	8	27	23	21
# TRAPPED	yearling	30	790	265	35	7	28	0	0	0
	fry	0	0	0	0	10	29	10	2	2
SIZE RANGE MMFL	yearling	80–118	69–127	68–121	76–114	84–115	94–117	0	0	0
	fry	0	0	0	0	33–36	34–39	33–35	59–60	60–85
AVERAGE MMFL	yearling	104	91	93	95	94	108	0		0
	fry	0	0	0	0	34	36	34	59.5	72.5

source: IFD Red Bluff.

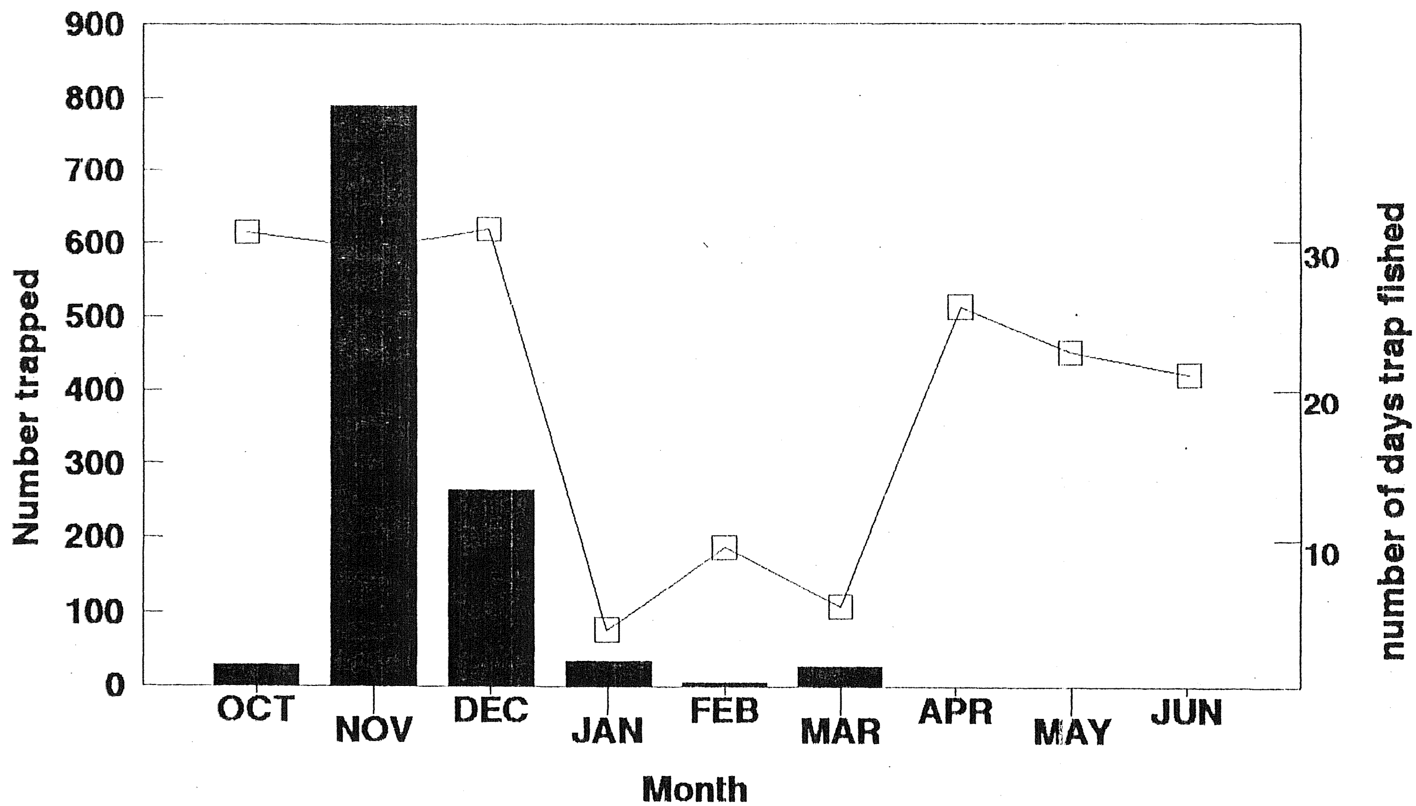


FIGURE 1 : Actual monthly catches and trap days for the 1993 broodyear of spring-run yearlings emigrating from Deer Creek, 1994-1995.

the screw trap through June, but in such low numbers that no inference can by made about the origin of the run or apparent growth. Emigration of chinook salmon fry during the months of February through June ranged in size from 33 to 85 mmFL, with monthly averages of 34, 36, 34, 59.5 and 72.5 mmFL respectively (Table 3).

It is interesting to note that of the 21 yearlings trapped while emigrating from Deer Creek between 5 October and 15 October, 29% were precocial males, a condition of premature sexual ripeness. This early maturation of males has been documented in both hatchery and wild stocks and is common in stream-type chinook salmon (Healey, 1991). Spent males survive and grow as well as their immature cohorts (Robertson, 1957). No precocial males were trapped after 15 October.

One way of easily determining the onset of smoltification in the field is by noticing changes in the physical appearance of the fish. The smolt becomes more silvery in color and more streamlined in shape. Smolts weigh less and exhibit a lower length to weight ratio than do parr (Wedemeyer et. al., 1980). This season the physical appearance of outmigrants was not recorded for individual smolts. Although measurement of the length to weight ratio (condition factor) was recorded throughout the season to determine if a drop in body weight occurred at smoltification. A condition factor is a length-weight relationship calculated as: W = L3, where W = weight in grams and L = length in millimeters. This ratio decreases as a fish loses body fat. The condition factor reached a peak of .00041 the week of 17 October and then steadily declined to .00035 the week of 30 December, Figure 1. Comparing this to the emigration patterns documented in Deer Creek this year, spring-run salmon were first trapped exiting Deer and Mill Creeks during the week of 3 October with the first peak occurring in the week of 10 November, Table 4. Spring-run smolts emigrating from Deer Creek this fall showed a decline in body weight in preparation for salt water entry.

<u>RESULTS--biases</u>

The preliminary condition factors and growth rates collected this first season may be biased by sampling methods and may not represent the true range of the population. The volumetric displacement method is only accurate to the nearest 0.5 mg which makes weighing individual fry difficult. In situations where we encountered low sample sizes, too few fry were captured to attempt an aggregate displacement. Also, the sampling gear (electroshocking, seining and screw trapping) we used may be biased towards capturing smaller salmon. This season we were unable to adequately sample smolts over 110 mmFL. Although larger juveniles are observed in pool and riffle type habitats, they frequently out-swim our sampling gear. In 1995 we will be experimenting with minnow traps at select locations in Mill and Deer Creeks to try and determine what size ranges are not being sampled and the condition factors of these fish. Because of the

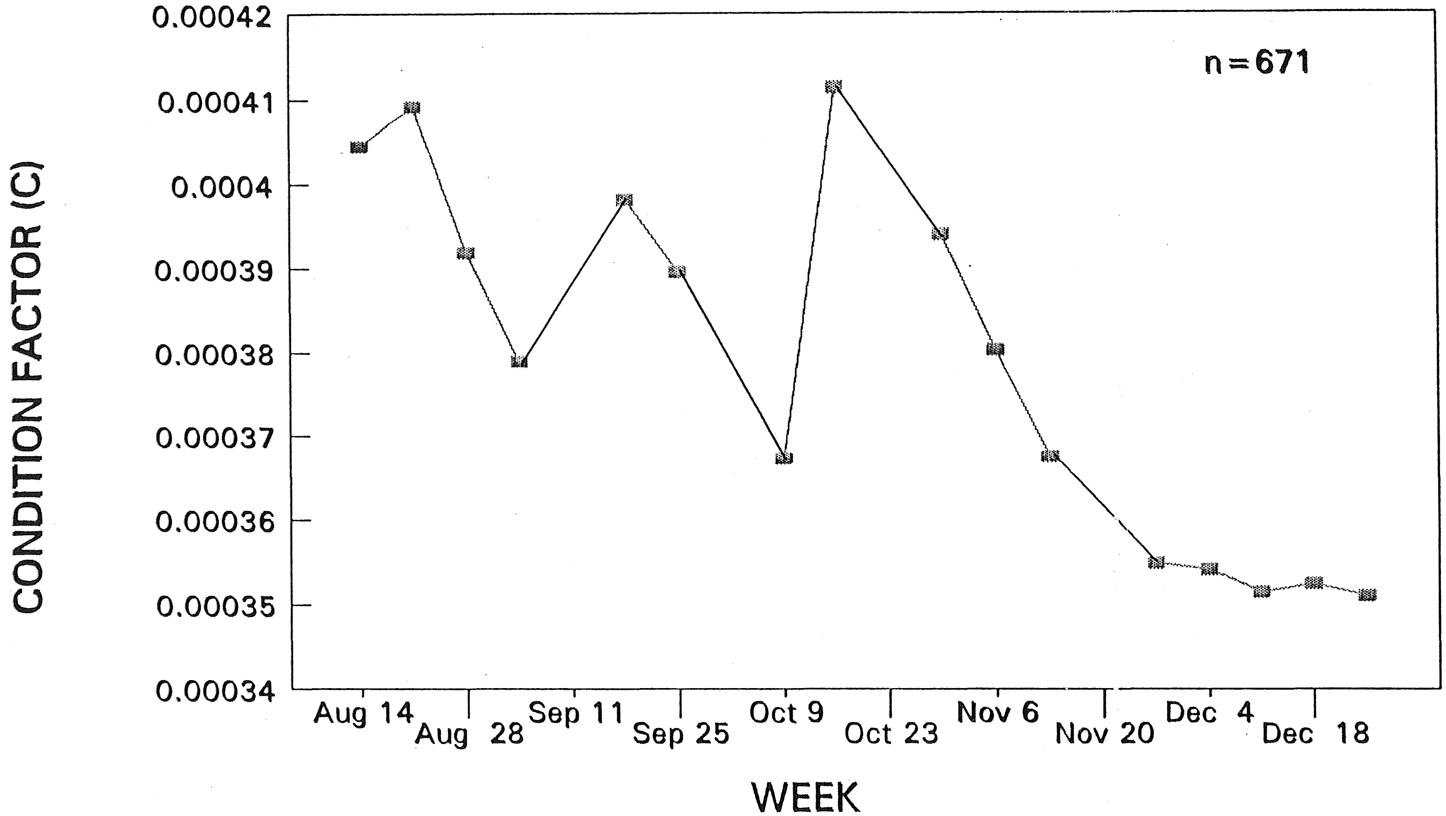


FIGURE 2. Average weekly condition factors of spring-run chinook salmon juveniles in Deer Creek, 1994.

selectivity of each type of gear and the limitations of sampling during high flows when mass migration may be occurring, no attempt will be made to determine spring-run chinook smolt abundance in these creeks. Any estimate of smolt abundance from the information presented in this report should be considered meaningless.

This spring-run outmigrant research is scheduled to continue for four complete years, if our project funding is not further reduced. This annual progress report is written to keep interested groups informed of our findings, although the data presented in this report is considered preliminary. This research will be published at the conclusion of this study.

ACKNOWLEDGEMENTS

I would like to acknowledge the help of the Deer Creek Conservancy and the Mill Creek Conservancy for assisting in surveys and helping us obtain landowner permission to survey on private land. Special thanks is also due to the following agencies whose assistance in both labor and equipment procurement made this study possible: Sport Fish Restoration for funding the project, Melanie McFarland and Susan Chappel of Lassen National Forest for their assistance with conducting spawner surveys, Department of Fish and Games Region 1 Screen Shop for assistance in installation and removal of fish counters and juvenile traps, to Serge Birke of the Bureau of Reclamation for the purchase and loan of a rotary screw traps for the outmigrant study, and to the Spring Run Workgroup for bringing diverse interests together with the common goal of restoring spring-run chinook salmon.

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APPENDIX TABLE 1. Daily water temperature records for Deer Creek at A–Line; May 1992–September 1994.

DAY	MAY 92	JUN 92	JUL 92	AUG 92	SEP 92	OCT 92	NOV 92	DEC 92	JAN 93	FEB 93	MAR 93	APR 93
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
1		62.7	55.4	60.8	58.7	53.6	48.8	40.9	35.3	38.1	39.2	41.4
2		63.2	57.5	60.7	57.8	52.6	50.5	41.0	34.1	38.2	41.3	42.5
3		63.1	58.3	60.1	55.7	50.2	47.5	39.9	33.0	39.9	41.8	43.2
4		63.4	58.0	59.5	54.7	51.4	46.2	37.2	33.6	40.0	41.4	42.9
5		60.8	57.5	59.8	55.3	51.4	47.0	34.9	35.9	41.0	41.9	41.9
6		60.4	57.3	59.5	55.0	51.0	45.9	37.2	36.2	40.9	42.2	42.2
7		61.2	58.5	60.1	54.3	50.7	46.0	38.6	34.7	40.7	41.7	44.0
8		61.7	59.3	60.6	54.5	49.6	44.6	38.8	37.3	41.2	41.8	43.2
9		61.4	60.1	60.3	56.1	49.9	41.2	40.0	36.8	40.6	42.0	43.0
10		58.5	61.3	61.3	56.5	51.4	39.6	39.2	35.7	40.9	41.9	43.2
11		57.0	61.6	62.5	55.0	51.6	39.4	37.6	35.4	39.9	41.7	42.3
12		54.3	61.4	64.9	54.3	51.3	40.8	37.4	34.0	40.5	42.1	42.8
13		52.2	63.0	65.3	53.5	50.9	41.9	36.4	33.2	39.3	42.3	44.0
14		52.6	63.5	64.6	53.9	50.1	42.2	36.8	37.5	38.8	41.7	44.4
15		52.3	64.6	63.9	52.5	49.3	42.5	36.5	38.1	37.7	41.1	45.5
16	56.9	53.6	65.3	64.1	53.0	49.4	42.8	36.1	38.0	37.3	40.6	44.5
17	57.4	55.3	65.6	63.7	53.5	49.3	44.1	36.4	38.8	35.7	38.8	42.2
18	56.0	54.6	64.9	62.4	53.7	49.2	42.5	33.2	39.1	38.4	39.8	42.1
19	55.3	57.3	62.9	61.4	53.9	48.3	42.0	33.3	39.6	38.7	40.6	43.9
20	54.8	60.1	61.5	61.3	54.4	48.5	39.6	35.8	38.5	38.1	41.4	45.3
21	54.7	61.8	61.6	59.8	55.4	49.8	39.7	37.9	38.2	38.6	41.6	45.9
22	55.8	62.5	60.8	56.3	55.5	48.6	41.0	37.0	38.3	39.7	42.0	45.1
23	57.6	62.7	59.8	55.9	54.6	48.7	38.8	37.3	38.0	37.3	40.8	42.2
24	59.1	63.1	60.4	56.7	53.9	48.5	38.4	37.3	37.9	38.7	40.6	44.2
25	60.6	61.7	61.7	56.9	52.7	49.3	39.9	36.8	38.1	38.6	40.2	46.5
26	60.6	60.8	63.0	57.4	53.2	49.4	40.7	35.7	37.9	37.6	41.3	47.1
27	59.5	60.8	62.8	57.8	53.4	49.5	42.6	37.4	37.8	37.2	41.5	46.5
28	59.3	57.8	62.5	58.3	53.3	49.6	40.5	36.1	38.0	38.3	42.5	47.6
29	59.8	54.8	63.2	58.3	53.3	48.3	39.3	33.1	38.8		43.7	48.8
30	60.5	53.8	63.4	59.0	53.6	47.7	39.0	34.1	38.1		43.7	48.1
31	61.6		61.4	58.9		47.4		34.9	38.1		43.3	
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
MONTHL	58.1	58.8	61.2	60.4	54.5	49.9	42.5	36.9	36.9	39.0	41.5	44.2
	range	range	range	range	range	range	range	range	range	range	range	range
	50.9.66.2	49.1.67.6	52.3–69.6	52.5–68.5	49.8–61.0	46.6–54.7	37.2–51.6	32.0–42.3	32.0–40.3	34.3–42.1	37.6–46.9	39.2–52.3

DAY	MAY 93	JUN 93	JUL 93	AUG 93	SEP 93	OCT 93	NOV 93	DEC 93	JAN 94	FEB 94	MAR 94	APR 94	MAY 94	JUN 94	JUL 94	AUG 94	SEP 94
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
1	48.4	49.7	58.4	61.2	56.6	53.2	45.8	39.[illegible]	40.0	36.5	41.7	46.6	50.5	59.0	60.1	60.6	56.5
2	49.2	49.8	58.2	62.4	56.9	53.2	44.5	40.[illegible]	40.8	36.5	41.8	47.8	51.6	57.8	60.8	59.7	55.8
3	47.3	50.1	57.5	62.2	57.3	53.2	44.1	40.[illegible]	40.1	37.0	41.7	48.0	50.9	56.8	61.8	60.3	55.2
4	45.4	48.9	57.8	60.8	57.5	52.8	44.0	41.[illegible]	41.1	36.8	42.0	45.4	51.7	56.1	62.4	60.8	55.8
5	47.4	47.3	58.5	60.1	57.4	52.1	43.7	39.[illegible]	40.1	37.2	40.7	44.4	51.0	54.4	61.5	60.8	55.9
6	48.3	47.2	59.3	60.3	57.2	52.1	43.1	40.1	37.6	39.3	41.3	45.1	50.3	53.8	60.8	59.8	55.4
7	46.9	49.0	59.3	59.4	56.3	50.8	42.7	41.2	37.7	39.0	41.5	44.0	49.4	55.0	61.9	59.8	54.9
8	47.1	50.7	59.9	57.8	57.4	48.5	41.9	41.3	39.2	39.0	42.0	44.0	52.9	55.9	63.0	59.7	54.0
9	49.0	52.4	60.6	57.3	58.0	48.7	42.7	40.3	38.8	39.0	42.6	43.2	56.0	58.0	62.3	58.5	54.2
10	50.6	53.6	60.9	56.7	57.7	50.4	43.3	42.9	38.7	38.9	43.1	45.0	57.3	60.4	62.8	58.1	52.2
11	49.7	52.7	60.7	55.7	57.2	50.8	42.6	41.1	38.9	36.6	41.2	46.6	57.9	61.5	62.9	57.8	51.8
12	46.6	52.0	59.5	56.6	55.7	50.6	39.6	37.9	39.6	36.5	42.0	47.8	57.6	61.5	63.2	57.7	51.4
13	46.4	53.9	57.9	57.7	53.7	50.2	39.9	38.7	39.7	37.5	43.0	48.3	55.6	60.9	62.6	58.1	50.9
14	48.2	55.1	57.6	58.2	52.6	49.9	38.8	36.5	40.4	36.9	43.9	49.7	54.2	57.2	63.1	58.7	51.7
15	50.1	55.1	56.3	56.7	52.2	50.6	38.9	37.5	39.6	37.7	43.3	51.2	52.1	55.0	63.8	58.3	53.2
16	51.1	54.7	55.3	55.0	51.6	49.8	38.9	36.4	39.3	39.8	43.2	51.3	46.3	55.0	64.7	58.4	53.8
17	50.9	55.9	55.8	57.0	51.3	48.1	38.9	36.0	39.9	39.2	42.8	51.2	47.3	55.5	64.5	58.6	54.4
18	51.7	57.8	56.5	58.1	51.2	47.2	39.4	36.0	39.6	37.6	43.1	51.8	47.2	56.0	63.3	58.2	54.5
19	50.9	58.69	57.7	56.5	51.4	47.1	38.9	36.1	39.1	38.3	44.1	52.7	47.6	57.3	63.8	58.6	54.3
20	50.4	58.45	57.6	54.9	50.9	47.6	38.7	36.3	39.0	37.6	43.0	51.6	49.0	58.0	65.9	57.6	54.6
21	49.6	57.43	57.0	56.1	50.5	48.6	39.0	36.3	39.9	38.6	43.4	50.1	50.8	57.6	65.7	57.1	54.5
22	50.9	55.23	57.6	58.1	50.3	47.4	40.2	36.4	40.9	37.0	40.1	49.2	52.2	57.7	64.6	56.6	53.9
23	52.4	54.73	58.6	58.7	49.6	47.5	37.1	37.0	42.1	38.9	39.4	45.9	54.2	58.0	64.1	56.4	53.8
24	51.4	56.17	58.9	57.1	49.4	47.5	35.3	36.3	38.0	40.8	40.5	45.5	55.9	58.1	62.7	56.1	54.2
25	50.1	57.68	59.0	55.8	50.0	47.8	35.5	37.2	38.1	40.8	42.3	44.1	57.7	59.2	60.6	56.1	54.9
26	50.5	59.21	59.2	55.4	50.9	47.9	36.1	38.7	38.3	41.6	43.7	44.8	57.5	59.3	61.0	55.9	54.9
27	49.9	59.31	59.3	56.2	51.4	47.4	37.8	39.[illegible]	37.8	41.6	45.2	47.0	56.6	60.6	60.7	56.3	54.4
28	49.1	57.68	59.4	56.7	51.5	47.0	40.6	39.5	37.1	41.5	45.6	48.4	56.7	60.7	61.8	55.8	54.4
29	49.5	57.04	59.0	56.7	51.9	48.0	42.0	39.3	37.5		45.7	49.0	57.7	60.0	61.4	55.3	53.2
30	51.0	57.71	58.2	56.7	52.0	47.4	39.0	39.7	37.6		46.7	50.3	58.1	59.8	61.3	56.4	51.9
31	50.2		59.5	56.2		46.9		39.8	36.4		45.9		58.3		61.0	57.1	
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
MONTHL	49.4	54.2	58.4	57.7	53.6	49.4	40.4	38.7	39.1	38.5	42.8	47.7	53.3	57.9	62.6	58.0	54.0
	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range
	41.0–54.7	45.7–60.4	52.2–64.4	51.8–66.0	47.3–60.4	45.5–54.9	34.5–46.4	35.6–43.5	35.4–42.8	35.2–43.5	37.8–48.7	41.4–55.6	45.0–62.1	50.9–65.7	55.8–69.8	52.0–64.6	48.4–59.0

APPENDIX TABLE 2. Daily water temperature records for Deer Creek at Ponderosa Way; May 1992–May 1993

	MAY 92	JUNE 92	JULY 92	AUG 92	SEP 92	OCT 92	NOV 92	DEC 92	JAN 93	FEB 93	MAR 93	APR 93	MAY 93
DAY	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
1		68.3	60.1	66.5	64.2	58.7	51.8	42.1	40.9	40.6	42.2	45.9	50.6
2		68.9	61.7	66.3	63.5	57.4	53.2	43.1	38.7	40.7	44.5	45.1	51.1
3		69.3	63.3	65.9	62.0	54.6	51.3	42.4	36.5	42.2	45.4	45.9	51.4
4		69.5	63.1	65.3	60.8	55.0	49.9	39.8	36.4	43.0	44.7	46.3	49.5
5		67.2	62.6	65.4	60.3	55.7	49.8	37.6	38.4	44.1	45.4	45.4	49.4
6		66.2	62.6	65.4	60.1	55.1	49.2	39.8	39.4	44.0	46.3	45.0	50.3
7		66.6	63.6	66.0	59.3	54.7	49.1	42.2	40.8	43.8	45.6	45.7	50.2
8		67.3	64.7	66.4	59.3	54.1	47.8	42.0	41.0	44.5	45.4	46.5	49.9
9		67.4	65.6	66.2	60.4	53.8	44.2	43.9	40.5	44.1	45.7	46.0	50.2
10		64.5	67.2	67.1	61.2	55.3	41.8	44.8	39.3	43.8	45.7	46.2	51.5
11		62.2	67.3	68.2	60.4	55.6	41.5	41.6	38.4	43.6	45.2	45.7	52.2
12		59.6	67.3	70.7	59.6	55.5	42.2	40.6	37.3	43.4	45.7	45.4	51.8
13		57.1	67.7	71.2	58.4	55.1	43.7	39.1	39.1	42.5	46.2	46.0	50.2
14		56.6	69.4	70.8	58.5	54.3	44.2	39.5	41.9	41.9	45.7	46.6	50.2
15		56.7	70.5	70.7	57.0	53.3	44.8	38.6	41.8	40.9	44.7	47.5	51.0
16		57.7	71.5	70.6	57.4	53.4	45.1	38.5	42.6	40.2	44.2	47.5	52.2
17		59.7	72.1	70.1	58.0	52.8	46.4	39.6	42.3	39.8	43.0	47.3	53.0
18		60.0	71.0	68.8	58.5	53.0	45.0	36.5	42.7	42.2	43.1	45.9	53.4
19	60.2	61.4	69.1	67.8	58.4	52.4	44.9	34.9	42.6	43.3	43.6	46.0	53.6
20	58.8	64.9	67.6	67.4	59.0	52.3	42.4	37.1	42.9	41.9	44.3	47.0	53.4
21	58.8	67.2	67.7	66.2	59.6	53.4	41.9	39.4	43.0	42.2	44.7	48.0	53.0
22	60.0	68.2	67.1	62.1	60.1	52.2	43.3	38.4	42.2	43.0	45.3	48.2	52.8
23	61.9	68.1	65.9	60.9	59.5	52.4	40.9	38.8	41.3	41.7	45.3	47.5	53.7
24	63.9	69.1	65.9	60.0	58.6	52.2	40.6	39.5	41.2	41.8	44.1	46.5	54.2
25	65.8	68.6	67.3	62.1	56.9	53.0	42.3	39.1	41.5	41.8	43.9	47.6	53.9
26	66.2	67.4	68.6	62.5	57.6	53.0	42.8	37.7	41.2	41.1	44.0	48.7	53.3
27	65.0	66.7	68.7	63.3	57.9	53.1	44.9	38.9	41.1	41.1	44.5	48.9	53.2
28	64.5	64.4	68.6	63.9	57.9	53.1	42.6	40.4	41.0	41.7	44.7	49.3	52.9
29	65.3	60.0	69.1	64.0	57.6	52.1	41.5	39.7	41.5		46.1	50.1	52.6
30	66.0	58.7	69.2	63.9	58.0	51.3	41.0	38.2	40.9		46.5	50.6	53.1
31	67.0		67.5	63.8		50.7		39.9	41.0		46.5		53.3
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
	63.3	64.3	66.9	66.1	59.3	53.8	45.0	39.8	40.6	42.3	44.9	46.9	52.0
	range	range	range	range	range	range	range	range	range	range	range	range	range
	55.2–71.2	53.4–73.8	56.5–76.1	57.6–75.0	54.1–67.1	50.1–60.1	39.6–54.9	33.4–46.6	35.1–44.8	39.0–45.1	40.6–48.2	44.6–50.9	48.7–54.5

thermograph stolen after May 31, 1993

replaced 12/20/94

APPENDIX TABLE 3. Daily water temperatures for Mill Creek at Hole–In–The–Ground and Big Bend, May 1992–October 1994.

DAY	MAY 92 mean	JUN 92 mean	JUL 92 mean	AUG 92 mean	SEP 92 mean	JUN 93 mean	JUL 93 mean	AUG 93 mean	SEP 93 mean	OCT 93 mean	NOV 93 mean	DEC 93 mean	JAN 94 mean	FEB 94 mean	JUN 94 mean	JUL 94 mean	AUG 94 mean	SEP 94 mean	OCT 94 mean
1		59.0	53.2	58.0	56.5		53.2	58.3	54.6	52.0	44.2	39.0	38.7	35.2		58.0	58.1	54.8	51.4
2		59.3	55.9	58.3	55.6		52.9	59.4	54.8	51.8	42.5	39.6	39.6	35.7		58.7	57.2	54.3	51.4
3		59.4	56.0	57.5	53.8	46.5	52.3	58.8	55.3	51.9	43.0	39.7	38.7	36.7	54.1	59.5	58.0	53.8	48.8
4		59.6	56.0	57.2	54.0	45.2	53.1	57.8	55.4	51.5	43.1	41.2	40.0	36.1	53.2	59.8	58.4	54.2	46.2
5		56.2	55.1	57.7	53.9	45.0	53.5	57.0	55.3	50.4	42.3	38.8	39.0	36.6	51.7	58.9	58.5	54.7	46.9
6		56.9	55.4	57.3	53.5	44.8	54.3	57.0	55.0	51.2	41.5	39.2	36.4	38.5	50.4	57.9	57.8	54.1	47.5
7		58.0	56.9	58.3	52.7	47.5	54.0	56.0	54.5	49.0	41.6	39.9	36.6	36.7	52.5	59.5	57.6	53.4	
8		58.0	57.5	58.5	53.7	47.2	54.6	54.9	55.6	46.3	40.9	38.3	38.2	38.6	53.4	60.5	57.4	52.4	
9		58.2	58.3	58.6	55.7	49.1	55.3	54.5	56.1	47.3	41.9	41.0	37.8	38.3	54.6	59.7	56.0	53.2	
10		54.1	59.3	59.3	55.1	49.4	55.5	54.3	55.7	49.5	42.5	42.6	37.1	35.6	58.3	60.3	55.8	51.1	
11		54.4	58.4	60.5	53.3	48.5	54.9	53.4	55.2	49.9	41.2	39.1	38.2	35.1	59.4	60.4	55.5	50.6	
12		50.1	59.0	63.1	53.1	48.2	54.1	53.6	53.4	50.4	38.6	37.4	37.6	35.3	59.0	60.4	55.4	49.4	
13		48.2	60.1	62.5	51.3	50.1	53.1	55.3	51.3	48.7	39.1	37.7	37.8	37.0	58.1	59.6	55.8	49.0	
14		49.7	60.5	61.6	52.7	50.2	53.2	55.1	50.6	48.5	37.4	33.3	38.2	36.3	53.7	60.2	56.5	50.8	
15		49.8	61.7	61.0	50.7	50.1	51.1	53.3	50.5	49.6	37.6	36.5	38.5	37.1	51.6	61.0	56.1	52.1	
16		52.2	61.9	61.0	52.1	49.7	51.5	52.7	50.4	48.4	38.3	35.2	37.8	39.2	52.0	61.9	56.2	52.5	
17		53.1	62.6	60.6	52.1	51.0	52.6	54.6	49.3	46.8	38.6	35.2	38.4	35.3	53.4	61.9	56.5	53.3	
18		53.0	61.2	59.3	52.9	51.7	53.4	55.9	49.5	45.6	39.1	34.6	38.1	34.7	54.0	60.4	56.2	53.1	
19	52.4	56.5	59.4	55.6	53.0	52.2	54.4	53.7	49.9	45.9	37.9	34.7	38.1	37.0	55.3	61.1	56.7	53.4	
20	51.6	58.2	57.8	58.0	53.6	51.6	54.3	52.7	49.7	47.0	37.5	34.9	38.1	34.9	56.1	63.4	55.6	53.3	
21	52.0	59.9	58.8	56.3	54.7	50.6	53.4	54.2	48.9	48.1	38.3	34.5	39.2	1_/	55.7	63.1	55.3	53.0	
22	53.8	60.2	57.1	53.0	54.1	49.9	54.8	56.1	48.8	46.1	39.0	34.7	40.0		55.9	61.8	55.0	52.4	
23	55.4	59.8	57.0	53.7	52.7	50.1	55.7	56.1	48.0	46.9	35.8	35.4	41.2		55.8	61.3	54.7	52.4	
24	55.5	60.2	58.1	54.5	52.7	51.3	55.4	54.3	48.0	46.9	34.5	35.3	34.9		56.1	59.9	54.5	52.9	
25	57.0	56.6	59.4	55.0	50.7	52.7	55.9	53.0	48.9	46.5	34.7	35.8	37.6		57.5	57.6	54.5	53.9	
26	56.4	58.5	60.2	55.3	51.7	53.4	55.8	53.1	49.6	46.1	35.5	37.9	37.6		57.0	58.3	54.3	53.6	
27	55.1	57.8	60.1	55.7	52.1	53.0	56.1	54.1	50.4	45.6	37.4	39.1	36.7		58.6	58.6	54.6	53.4	
28	55.7	53.4	59.9	56.5	51.9	51.7	56.3	54.7	50.4	45.7	40.1	38.9	36.0		58.5	59.5	54.1	53.1	
29	55.7	50.7	60.5	56.9		51.9	56.1	54.5	50.8	47.2	40.4	38.4	36.0		57.6	59.4	53.6	51.2	
30	57.2	51.9	60.5	57.4		52.8	55.1	54.3	50.9	45.6	38.9	38.5	36.8		57.5	59.2	55.0	50.2	
31	58.3		58.4	56.3			56.8	54.2		45.8		38.7	36.0			58.6	55.5		
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	
	55.1	55.8	58.6	57.9	53.2	49.8	54.3	55.1	51.9	48.1	39.5	37.6	37.9	34.8	55.4	60.0	56.0	52.6	
	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	
	43.0–68.2	43.3–70.7	47.1–71.2	46.2–71.4	44.1–63.3	42.1–60.6	46.0–62.6	47.3–64.4	43.5–60.1	42.6–55.2	33.3–46.0	32.0–43.5	31.8–41.9	32.5–40.6	44.8–64.6	52.0–68.4	49.1–63.9	45.3–59.5	

Thermograph replaced 9/29/92
lost in landslide in spring 93
Relocated to Big Bend

1_/ Because of snow, unable to retrieve until June 94.

APPENDIX TABLE 4. Daily water temperature records for Mill Creek at Blackrock, May 1992–December 1993.

DAY	MAY 92	JUN 92	JUL 92	AUG 92	SEP 92	OCT 92	NOV 92	DEC 92	JAN 93	FEB 93	MAR 93	APR 93	MAY 93	JUN 93	JUL 93	AUG 93	SEP 93	OCT 93	NOV 93	DEC 93
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean
1		63.1	55.8	61.7	60.0	55.2	50.6	42.4	38.2	40.3	41.5	43.3	48.5	48.6	56.2	61.2	57.4	54.7	47.0	41.2
2		63.8	58.3	61.7	59.1	53.7	51.1	42.7	35.7	40.5	43.9	44.0	49.1	49.1	56.0	62.3	57.7	54.7	45.6	41.4
3		63.6	59.3	61.3	57.4	51.3	48.5	40.6	34.6	42.2	44.3	44.7	46.8	49.0	55.1	62.0	58.3	54.4	45.4	42.2
4		64.0	58.7	60.7	56.2	52.7	47.5	37.9	35.5	42.4	43.6	44.3	45.6	47.9	56.0	60.8	58.5	54.1	45.5	43.3
5		61.2	58.2	61.1	56.8	52.9	48.3	36.0	36.9	43.3	44.5	43.3	47.4	47.1	56.2	60.0	58.4	52.7	44.8	41.0
6		60.5	58.3	61.2	56.5	52.3	47.5	38.6	37.0	43.0	44.8	43.4	48.3	47.3	57.3	60.3	57.8	53.1	44.1	41.3
7		61.8	59.5	61.7	55.6	51.4	48.0	39.9	37.9	42.9	44.3	45.3	47.0	49.6	57.0	59.3	57.1	51.8	43.9	42.5
8		62.2	60.6	62.1	55.8	51.3	45.9	40.6	39.3	43.2	44.4	44.5	47.2	50.6	57.7	57.7	58.2	49.1	43.3	
9		62.2	61.4	61.7	57.6	51.8	41.8	40.4	38.6	42.6	44.6	44.2	49.2	51.9	58.5	57.3	58.9	49.5	44.1	
10		59.1	62.6	62.5	58.1	53.2	40.2	41.7	37.0	42.9	44.3	44.4	50.2	52.3	58.6	56.8	58.9	51.3	44.8	Thermograph stolen after 12/9/93;
11		57.0	63.1	63.9	56.8	53.3	40.3	40.4	36.8	41.6	44.0	43.1	48.5	51.3	58.2	55.9	58.3	51.8	44.0	replaced 12/19/94.
12		54.7	63.1	66.1	56.0	53.1	41.9	39.0	35.6	42.4	44.7	43.8	45.9	50.7	57.1	56.5	56.6	51.8	41.4	
13		51.8	64.1	66.6	54.6	52.7	43.6	38.2	35.3	41.2	44.9	45.3	47.0	52.9	56.0	57.9	54.1	51.1	40.7	
14		52.3	64.9	65.9	54.8	51.8	43.9	39.2	38.9	40.5	44.2	45.7	48.5	53.3	55.9	58.4	53.4	50.6	39.4	
15		52.6	65.7	65.7	53.7	50.7	44.4	38.3	40.3	39.5	43.7	46.5	50.0	53.1	54.8	56.9	53.1	51.6	39.8	
16	56.5	54.6	66.5	65.7	54.3	50.9	44.5	37.8	40.7	38.7	43.2	45.7	50.6	52.7	54.2	54.9	52.7	50.6	39.8	
17	57.4	56.2	66.6	65.0	55.2	50.9	45.6	38.1	41.1	37.9	41.0	43.0	50.3	54.0	55.0	57.1	52.0	48.8	40.2	
18	55.7	55.9	65.9	63.9	55.2	50.9	43.7	34.4	41.4	40.9	42.3	43.5	50.4	54.7	55.9	58.4	52.0	47.9	40.6	
19	55.3	58.1	63.8	62.9	55.4	50.0	43.4	34.4	41.8	41.6	43.0	44.9	49.2	55.1	57.2	57.3	52.4	47.9	40.1	
20	54.2	61.7	62.3	62.7	56.1	50.3	40.4	37.1	40.7	40.1	43.9	46.3	49.2	54.7	57.3	55.5	52.1	49.0	39.8	
21	54.4	63.4	62.6	61.1	57.0	51.5	40.9	39.7	42.0	40.4	44.0	47.2	49.3	53.5	56.1	56.6	51.6	50.1	40.1	
22	55.9	63.9	61.8	56.6	57.1	50.2	42.1	38.2	41.1	41.6	44.5	46.3	50.2	52.5	57.1	58.8	51.2	48.7	41.2	
23	58.1	63.9	60.7	56.5	56.1	50.2	39.8	38.7	40.4	40.0	43.0	43.5	51.2	52.6	58.9	59.4	50.6	49.0	37.5	
24	59.7	64.1	61.4	57.4	55.3	50.2	39.6	38.9	40.6	40.6	42.5	45.3	49.6	54.0	58.2	57.5	50.6	49.1	35.7	
25	60.8	63.0	62.8	58.1	53.5	51.2	41.5	38.0	40.8	40.4	42.0	47.2	48.9	55.6	58.7	55.9	51.3	49.5	36.6	
26	60.9	61.5	64.0	58.6	54.3	51.4	42.6	36.9	40.6	39.3	43.2	47.6	49.0	56.6	58.7	55.9	52.3	49.2	37.3	
27	59.2	61.7	63.9	59.1	54.6	51.5	44.5	39.1	40.6	39.3	43.6	47.0	48.2	56.2	58.8	56.8	52.8	48.5	39.2	
28	59.3	58.9	63.8	59.8	54.9	51.4	41.8	38.3	40.7	40.7	44.3	48.3	48.2	54.5	59.2	57.4	53.0	48.3	42.3	
29	60.1	54.8	64.3	59.8	54.8	49.3	40.8	36.0	41.1		45.7	49.3	49.3	54.5	58.9	57.5	53.3	49.5	43.8	
30	60.5	53.8	64.3	60.0	55.4	48.7	40.2	36.0	40.2		45.2	48.1	50.2	55.5	58.0	57.1	53.4	48.9	40.9	
31	62.0		62.3	60.0		48.8		37.3	40.4		45.0		48.1		59.4	56.8		48.3		
	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	mean	
	58.1	59.5	62.3	61.6	55.9	51.4	43.8	37.3	39.1	41.1	43.8	45.3	48.7	52.4	57.2	57.9	54.6	50.5	41.6	
	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	range	
	51.4–65.5	49.1–68.5	53.2–71.1	53.2–70.7	50.9–63.3	48.2–57.0	20.1–53.6	33.3–44.1	31.6–43.7	36.7–44.4	39.6–47.5	40.6–52.7	41.5–55.4	45.1–60.6	50.[illegible]–61.9	52.0–64.4	48.4–62.4	46.6–57.7	34.3–48.2	