HATCHERY STEELHEAD SMOLT PREDATION OF WILD AND NATURAL JUVENILE CHINOOK SALMON FRY IN THE UPPER SALMON RIVER, IDAHO

IDAHO DEPARTMENT OF FISH AND GAME
FISHERIES RESEARCH

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August 1993

TABLE OF CONTENTS

LIST OF TABLES

CONTENTS

Page

LIST OF FIGURES

CONTENTS

LIST OF FIGURES (Cont.)

LIST OF APPENDICES

CONTENTS

ABSTRACT

Idaho Department of Fish and Game quantified the predation rate of hatchery steelhead smolts (Oncorhynchus mykiss) on natural chinook fry (O. tshawytscha) in the upper Salmon River near Stanley, Idaho, in the spring of 1992.

We estimated a predation rate of 1.48×10^{-3} {95% CI 0.55×10^{-3} to 2.41×10^{-3}) for the 6,762 hatchery steelhead smolts examined that consumed a total of ten chinook fry. One steelhead smolt consumed seven chinook fry. Two other steelhead smolts consumed a total of three Salmonidae fry that we assumed were chinook fry. Given several assumptions, 24,000 (±15,000) is the best estimate of total chinook fry consumed by the 774,000 hatchery steelhead smolts while in the upper Salmon River subbasin from April 15 to June 3, 1992.

Based on stomach fullness, most steelhead smolts did not start feeding extensively until about a week after release. However, two of the three steelhead that consumed chinook fry where caught during the first week. Steelhead smolts not containing chinook fry consumed invertebrates and various inanimate objects. Mean evacuation rate (90%) of fry from hatchery steelhead smolts was 25.4 h (95% CI, 20.7 - 30.1 h) at 11.4°C. Variation in evacuation rates as a function of temperature was estimated by the equation $91.1\ e^{-0.112t}$.

The major emigration of smolts began around May 10, and an estimated 95% had left the study area by May 21. Few (1,800 to 3,400) residual hatchery steelhead remained in the upper Salmon River after June 3, 1992. Hatchery steelhead smolts where observed in tributaries at varying degrees and apparently emigrated during the same time period as smolts in the main river.

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INTRODUCTION

The focus of this study was to quantify predatory effects of the stocking of hatchery steelhead smolts (*Oncorhynchus mykiss*) on natural chinook salmon fry (*O. tshawytscha*). Stocking of steelhead smolts in the upper Salmon River is conducted by the Idaho Department of Fish and Game (IDFG) in cooperation with the United States Fish and Wildlife Service (USFWS) under the Lower Snake River Compensation Plan (LSRCP).

LSRCP is a hatchery program established to compensate for the loss of chinook salmon and summer steelhead trout from the four lower Snake River hydroprojects. Spring and summer chinook salmon where recently listed as threatened under the federal Endangered Species Act (ESA) in April 1992. Sockeye salmon (*O. nerka*) were listed as endangered in November 1991 and are also present in low numbers in the drainage (Redfish Lake).

Section 7[a][2], Part 402 of the ESA of 1973 provides the impetus for assessing "agency actions" which may "jeopardize the continued existence of any endangered species or threatened species..." The large-scale stocking of juvenile steelhead trout, into waters where naturally-produced (wild) spring chinook salmon are known to exist, has been identified as such an action within the LSRCP program. Specifically, the area of concern is the upper Salmon River in the vicinity of Sawtooth Fish Hatchery where natural redds are observed each Fall (137 during the Fall of 1991; Sankovich and Bjornn, Draft, 1992, and S. Kiefer, IDFG personal communication). Large numbers of steelhead smolts are released annually at the Sawtooth Fish Hatchery Weir (744,000 in 1992; USFWS, Hagerman Hatchery and IDFG, Magic Valley Hatchery unpublished reports, 1992). The timing of these releases in mid-April generally overlaps with the emergence of natural chinook fry from redds (Peery and Bjornn, Draft 1992). The interaction of hatchery steelhead smolts with chinook fry was of primary concern because these fish are most likely to overlap spatially and temporally (Cannamela, 1992, unpublished). Washington Department of Wildlife's LSRCP program conducted a similar study in 1992.

GOAL

The goal of this study was to determine if predation by hatchery steelhead smolts released from Sawtooth Hatchery on natural chinook salmon fry in the Salmon River jeopardize listed chinook salmon.

OBJECTIVES

This study addressed the following primary objectives:

1) Estimate the predation rate of hatchery-reared steelhead smolts from their release in mid-April until few hatchery steelhead smolts remain in the system; estimate total number of chinook fry consumed.

2) Estimate the evacuation rate from the cardiac stomachs of hatchery steelhead smolts.

3) Estimate the degree of residualization occurring in the upper Salmon River;

4) Describe the temporal and spatial distribution of steelhead smolts; document sex ratios, percent precocity, and length distributions.

DESCRIPTION OF STUDY AREA

This study was conducted from April to June 1992 in the upper Salmon River drainage from the Sawtooth Fish Hatchery Weir near Stanley, Idaho, to the mouth of the East Fork Salmon River east of Clayton, Idaho, 72.9 river kilometers (rkm) downstream (Figure 1). The upper Salmon River drainage near Stanley (1,100 km^2) is composed primarily of Cretaceous and Tertiary granitics and was heavily influenced by late Pleistocene alpine glaciation. Moraines and glacial outwash plains are the dominant features of the valley floor. The lower portion of the study area upstream from the mouth of the East Fork Salmon is a mixture of Eocene volcanics, Ordovician sedimentary, and Cretaceous and Tertiary granitic formations with contorted drainage patterns which were heavily influenced by faulting and fluvial erosion (Ross, 1963). Nutrients are low (phosphorous 5-33 ug/L) and generally increase downstream. Climate is cool and dry and mean temperature is 4°C and mean precipitation is 38 cm at Stanley (Minshall et al. 1992).

Flows during the study were extremely low as a result of six years of drought in the region. Mean annual discharge for water year 1992 was 31 m^3/s, the lowest on record. The 78 year mean annual discharge is 55 m^3/s, at Salmon, 194 rkm downstream of Sawtooth Hatchery Weir (Figures 2 and 3). Based on data from a discontinued flow gauge near the mouth of the Yankee Fork, river flows in the study reaches were about 25% to 50% of the flows at the Salmon gauge. Spring flows peaked in May on the upper Salmon River and in June at Salmon. The June runoff flows at Salmon were the lowest recorded at 42 m^3/s as compared to 163 m^3/s average for 78 years of record (Harenberg et al. 1991, and USGS personnel, Idaho District Office, personal communication).

Water temperatures in the upper Salmon River ranged between about 5°C and 10°C at the beginning of the study and increased to a range of about 10°C to 15°C by June 4, 1992 (Figure 4).

Study Reaches

The study was conducted on the Salmon River from Sawtooth Fish Hatchery to the East Fork Salmon River and covered 72.2 km of chinook salmon spawning area below the Hatchery.

Reach 1 began at the Sawtooth Hatchery weir (1,975 m elevation) and extended 13.8 rkm downstream to the mouth of Valley Creek Near Stanley, Idaho (1,897 m elevation, from USGS 7.5 Minute Topographic Maps, Appendix A). This reach was typified by course cobble and boulder substrate with relatively high gradient (5.6 m/km) as the river cut through a glacial moraine. Pocket water was the dominate habitat feature within the B-2/B-3 type channel (Rosgen, 1985). A lower gradient section of this reach (3.3 m/km) extended 3.2 river km below the Sawtooth Hatchery weir and was dominated by gravel substrate and pool run riffle complexes.

Reach 2 began at the mouth of Valley Creek (1,897 m elevation) and extended 18.3 km downstream to the mouth of the Yankee Fork River near Sunbeam, Idaho (1,801 m elevation). The upper end of reach 2 was typified by a type B-3 channel, intermediate gradient (4.3 m/km), gravel-cobble substrate, little pocket water, longer runs, and wide expansive riffles. The lower end of reach 2 had a steeper gradient (6.6 m/km) in a canyon with a type A-1/A-2 channel. Cataract complexes and large pools were the dominate features with some pools being over 100 m long and 5 m deep. Cobble, large boulders and bedrock composed much of the substrate, while sands and gravels were found in the low velocity areas of larger pools.

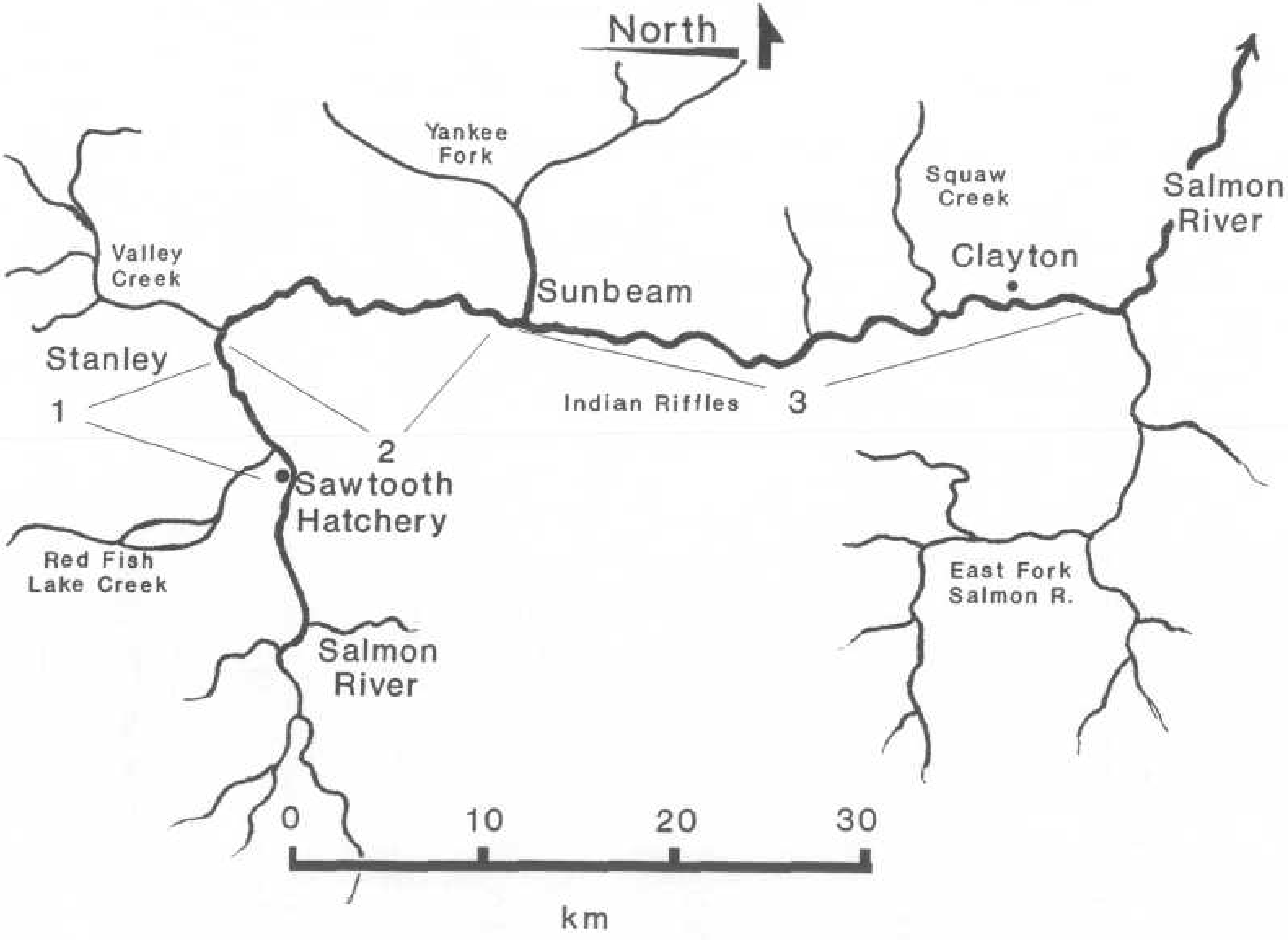

Figure 1. Map of the upper Salmon River study area in central Idaho. Study sections 1, 2, and 3 are indicated.

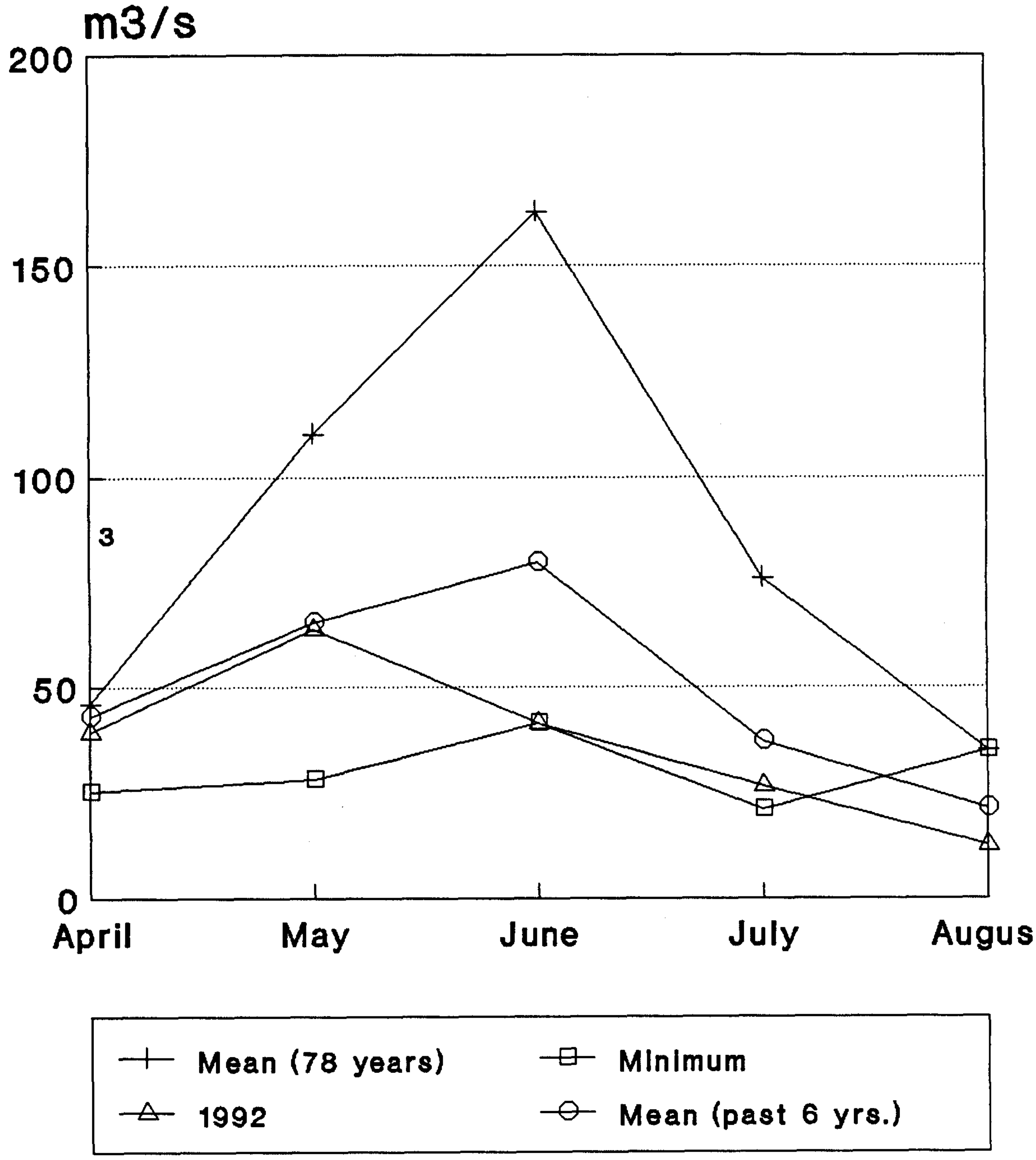

Figure 2. River discharge (m^3/s) for the Salmon River gauge at Salmon, Idaho, 193 rkm downstream from the study area. Mean and minimum plots are from 78 years of records.

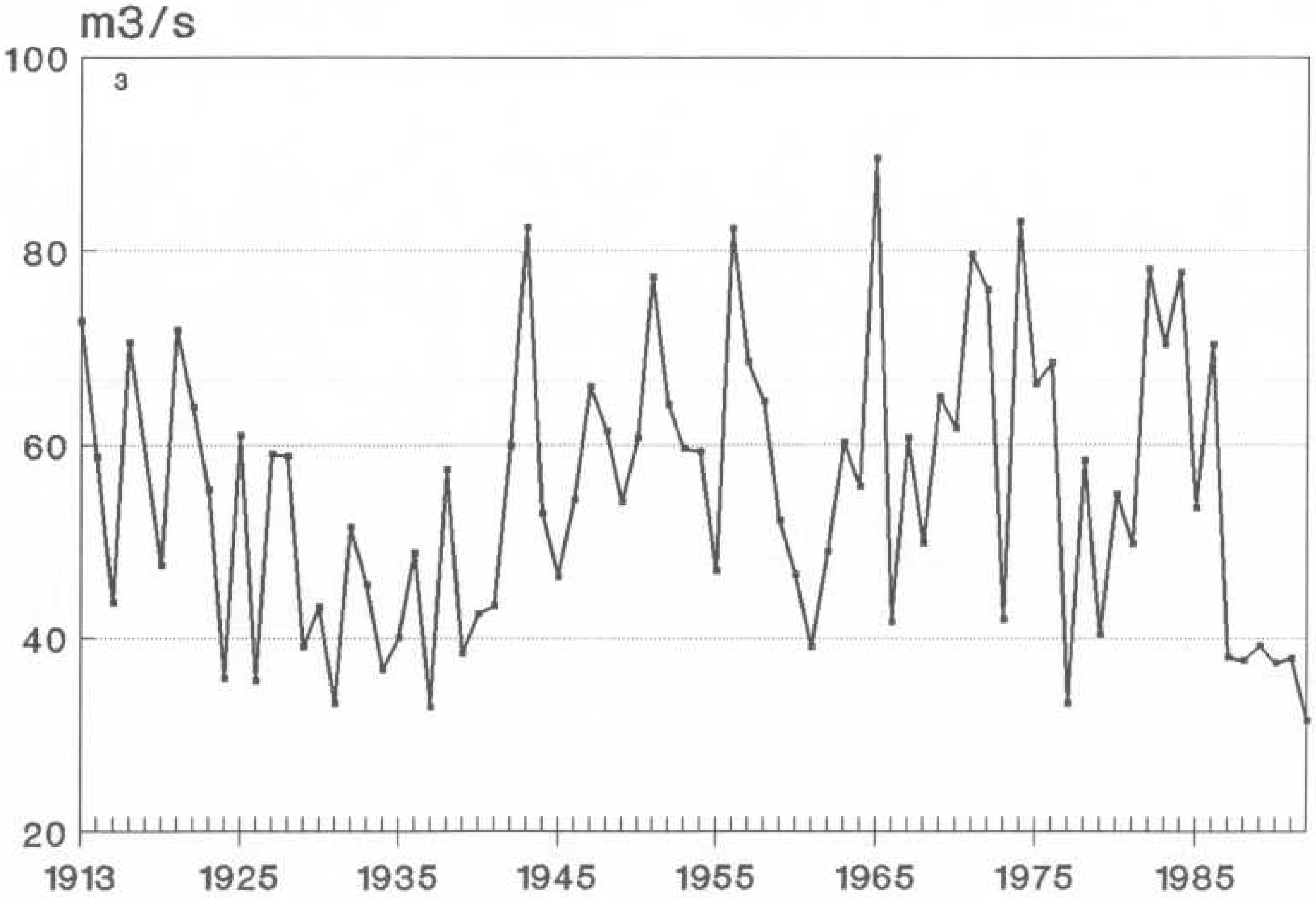

Figure 3. Mean annual flow for the Salmon River at Salmon, Idaho.

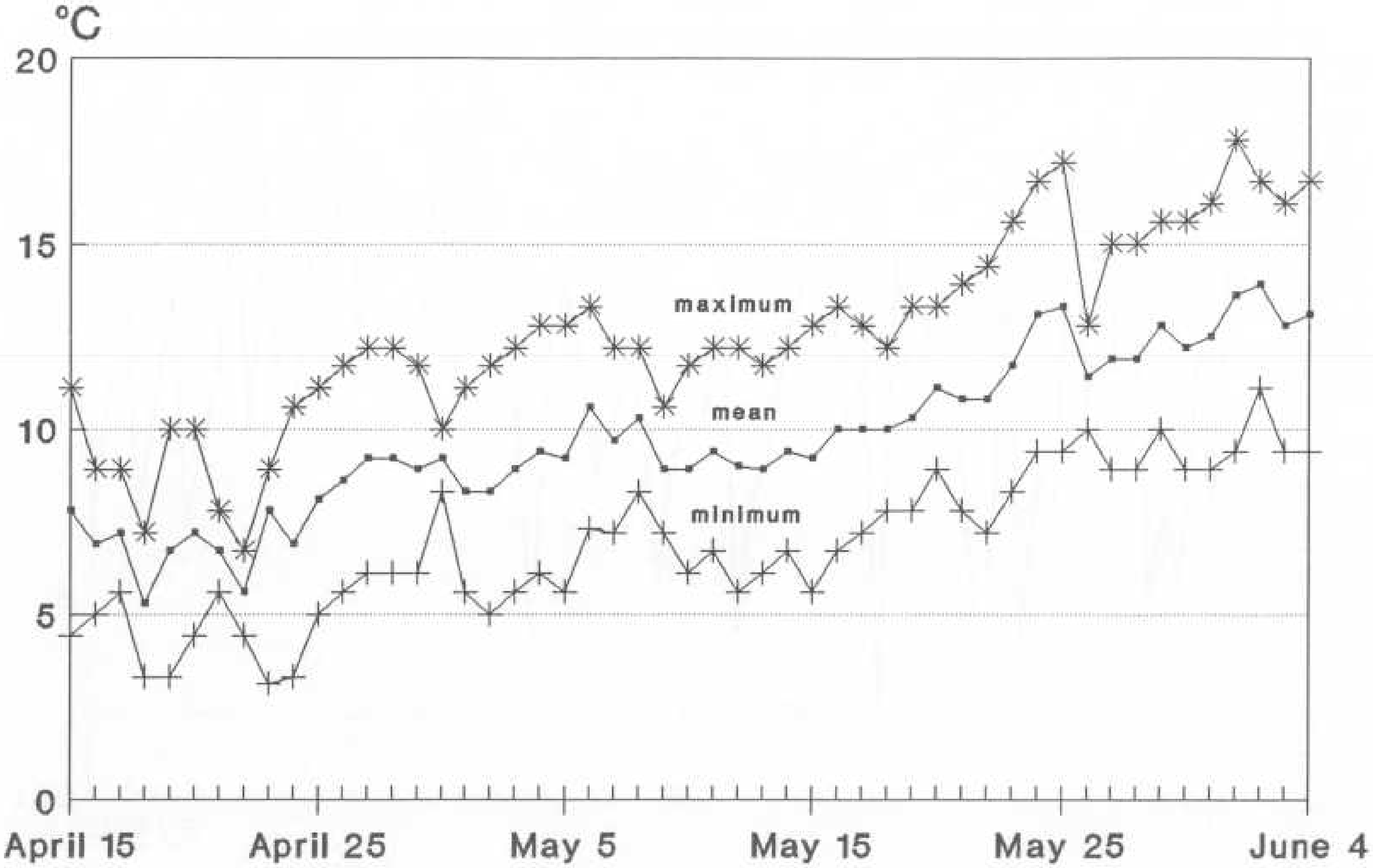

Figure 4. Mean, minimum, and maximum daily temperature at Sawtooth Hatchery, Salmon River water, from April 15, 1992 to June 4, 1992.

Reach 3 began at the mouth of the Yankee Fork River (1801 m elevation) and extended 40.7 km miles to the Mouth of the East Fork Salmon River (1630 m) east of the town of Clayton, Idaho. The upper end of reach 3 was still in the canyon and was similar to the lower end of reach 2 in gradient (5.59 m/km) and substrate. The lower end of reach 3 was lower in gradient (4.05 m/km), in a less confined valley with B-3 channel type and had a smaller substrate size. Pool, run and riffle complexes best describe the habitat.

METHODS

Predation Rate Study

The sampling regime was designed to detect predation during the period of availability and vulnerability of chinook fry and the greatest abundance of steelhead smolts. The power analysis (Lipsey, 1990, and Kraemer and Thieman, 1987) consisted of solving the standard error equation for n (Kachigan, 1986) by incorporating a target standard error of 0.1% and the expected proportion of predatory steelhead of 0.005 (Partridge, 1986). This analysis suggested that an N size of 6,000 was required or about 2,000 for each of the three study reaches. This would yield 30 predatory smolts with chinook fry, assuming the 0.005 proportion found by Partridge (1986). The assumptions were little or no variability in the number of chinook fry consumed by the estimated 30 smolts. The collection schedule required 100 smolts/reach/day for at least 20 of the first 30 days after release.

Because of the drought, there was uncertainty when and at what rate the hatchery smolts would emigrate out of the system. If large numbers of smolts residualized, predatory impacts on chinook fry by residualized smolts were to be addressed with additional sampling.

Steelhead smolts were collected by angling and electrofishing. Anglers fished with nymphs, streamers, spinners, or bait. Electrofishing was used to ensure adequate sample sizes, to allow examination of gear bias, and to provide alternate CPUE data to index the number of smolts in each reach. Electrofishing was conducted to avoid impacts on natural and wild fish. When chinook fry or possible chinook fry were observed during electrofishing, shocking was immediately terminated to avoid them. We electrofished from a drift boat with paired fixed booms with Smith Root droppers. A Coffelt VVP 15 control box was used in conjunction with a Honda 5000 Watt generator.

Captured smolts were placed on ice. Other fishes were not targeted and were released if caught by hook and line or netted during electrofishing. CPUE was recorded for each sampling period as well as date, site, water temperature, and gear type.

Fish were held on ice until they were examined in the lab. Generally, inspection was completed within 12 to 24 hours after capture. Fish were scanned for PIT (Passive Induced Transponders) tags and dissected. Cardiac stomachs were removed and examined for whole fish or fish parts. Date, water temperature, site, gear type, CPUE, fork length, sex, precocial maturity, and presence or absence of fish remains in the cardiac stomach were recorded for each fish. Sex was determined by careful examination of immature gonads. Each worker was trained individually by examining gonads under 10X-30X magnification in a bath of methyl alcohol to detect undeveloped ova. After workers became proficient in recognizing the subtle differences in shape, texture, and grain of immature gonads, they were instructed to examine a subsample of gonads microscopically in a methyl alcohol bath during each lab session or when unsure of the sex of an individual fish. Non-picsivorous smolts were separated by sex within sample groups. Sex determinations were double checked periodically before data was recorded.

When fish or fish parts were found in the cardiac stomach, the stomach contents were preserved in methyl alcohol and formalin with an enclosed label. Cardiac stomachs contents that were unidentifiable and that could possibly be ingested fish tissue were saved for further examination. Elimination of non-fish elements and the positive identification of partially digested fish was performed later by examination under 30X magnification. Diagnostic bones such as the cleithra, vertebrae, caudal bones, opercles, and Weberian occicles, used in concert with keys developed by Hansel et al. (1988) allowed the identification of fish to either orders, families, or species depending on the degree of digestion.

The proportion of steelhead smolts consuming chinook fry was estimated by the sample proportion (p);

$$p = \textit{number of fry consumed/number of smolts examined} \qquad (1)$$

$$SE = \sqrt{\frac{pq}{n}};\ \textit{where}\ q = 1-p \ \text{(Kachigan,1986)} \qquad (2)$$

The total number of chinook fry consumed by hatchery steelhead smolts was then calculated using this proportion with average daily temperatures, evacuation rates, and the estimated number of smolts remaining in the system. The total number of fry eaten per day (F) was calculated with the following formula (See Table 3 for data used in calculations.):

$$F = \frac{p \times r}{91.1 \times e^{(-0.112 \times t)}} \times 744{,}000 \times 24 \qquad (3)$$

Where

F = fry eaten per day

p = .00148 *fry/smolt = proportion of smolts consuming chinook fry*

r = proportion of smolts remaining within the study reach (based on CPUE)

$$\text{Temperature based evacuation rate (hours)} = 91.1 \times e^{(-0.112 \times t)}$$

e = base of natural logrithim

t = mean temperature for that day (°C)

744,000 = *number of hatchery steelhead smolts released*

24 = *hours/day*

Temperatures were collected by hand held thermometers in the field and with Max-Min thermometers at Sawtooth Hatchery. The total number of chinook fry eaten was calculated for each day and summed for all days from April 15 to June 3, 1992. The evacuation rate formula (91.1 $e^{-0.112t}$) driven by temperature (t) was extracted from Elliott' s work (1972) and fine tuned with results from our evacuation rate study. The percent of smolts remaining in the system was estimated from a CPUE curve with a decay function fitted by hand to the data. This was done by hand to smooth out the noise introduced into the model by variability in observed CPUE that reflects changes in catchability, but not changes in smolt abundance (Figure 5).

No direct estimation of chinook fry abundance was made. In 1991, 69 redds were counted above the Sawtooth Hatchery Weir (Sankovich and Bjornn, 1992) and 68 redds were found below the weir to the East Fork Salmon River (S. Kiefer, IDFG, 1992, personal communication). Redds below the weir were located primarily in the upper end of reach 1 or in the upper end of reach 3 near Indian Riffles (Figure 1). The number of fry in the system was estimated by assuming 5,000 eggs per redd, and 35-65% survival from egg to emergence yielding 240,000 to 450,000 chinook fry emerging in or above the study area. Chinook fry were observed and collected incidently during this study and in the intensive smolt monitoring project traps (R. Kiefer, IDFG, 1992, personal communication).

Evacuation Rate Study

Elliott (1972 and 1975) and Windell et al. (1976) suggest that evacuation rates less than 24 hours would probably be rare and that sampling time of day was not critical for detection (with the expected spring water temperatures in the upper Salmon). It was unknown if evacuation rates found by Elliott (1972) for brown trout and Windell et al. (1976) for rainbow trout fed non-fish items would provide suitable estimates for the evacuation rates of fry from steelhead smolts.

We evaluated the rate of evacuation of chinook fry from 109 hatchery steelhead smolts collected with rod and reel from the Salmon River to supplement estimated digestion rates reported in the literature. Smolts were starved for three days in a raceway at Sawtooth Fish Hatchery to evacuate their cardiac stomachs (mean water temp. 11. 4°C; range, 7.8 - 14.4°C). We assumed that starving the smolts for three days would not affect digestion rates. Elliott, (1972 and 1975) reported that brown trout starved from one to five days did not have detectible differences in digestion rates from fed fish.

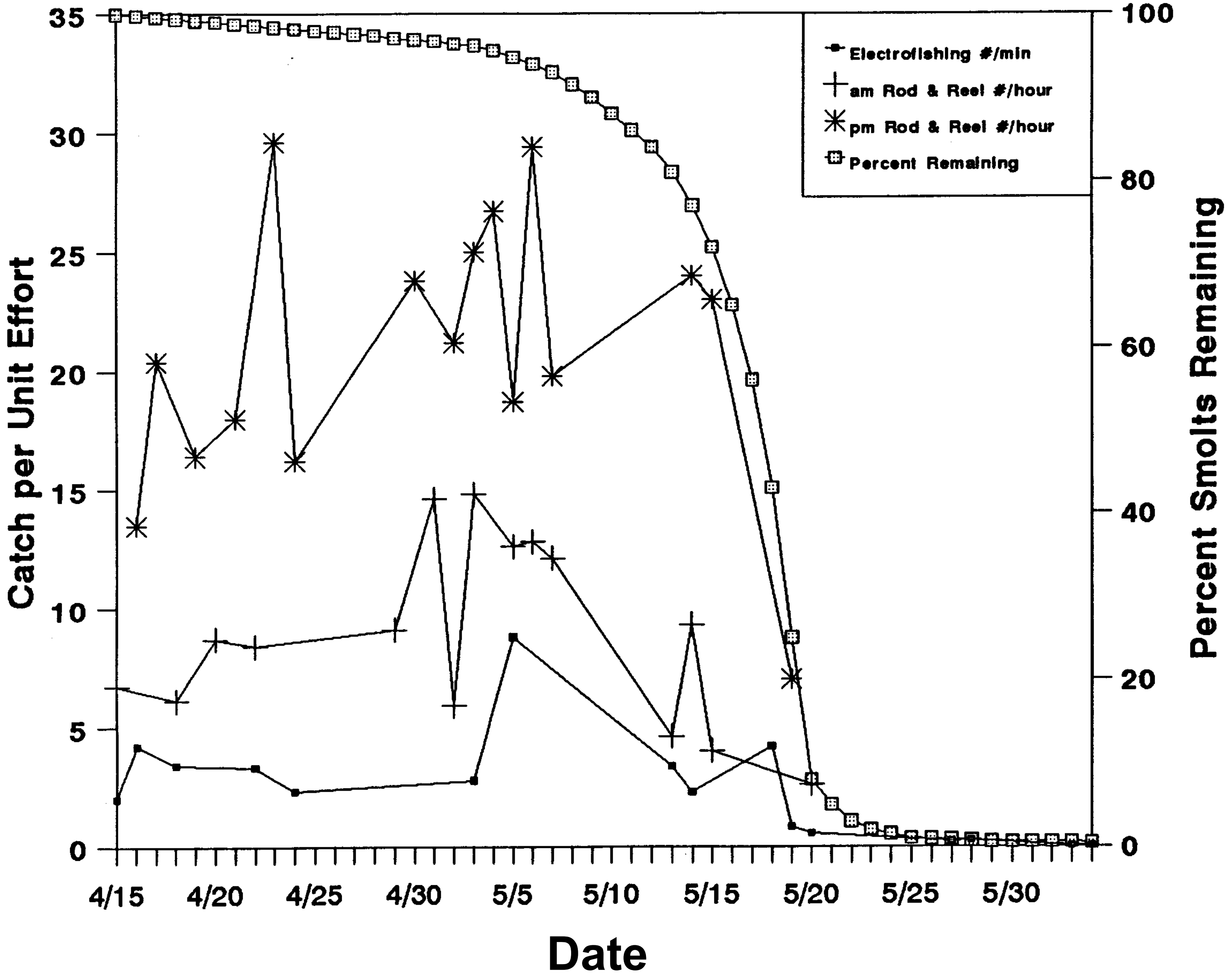

Figure 5. Catch per unit effort (CPUE) data for electrofishing (fish/min) and a.m. and p.m. rod and reel sampling (fish/h); the smooth declining curve was fitted by hand and represents the estimated percent of smolts remaining in the system after release in mid-April, 1992.

Each smolt was anesthetized with MS222. A fresh hatchery chinook fry mortality was inserted into each smolts cardiac stomach with a pair of forceps. Smolts were "hand fed" to ensure that the time of ingestion was known and because smolts would not voluntarily eat fresh hatchery chinook fry mortalities. Three live hatchery chinook fry were in the raceway while the 112 smolts were starved for 3 days. None of these fry were consumed. We assumed that "hand feeding" would not affect digestion rates.

We placed smolts in separate containers to recover from anesthetic. Smolts that regurgitated fry while in these recovery tanks were "re-fed. " Most of the hatchery chinook fry morts were much larger (up to 60 mm) than the natural fry in the Salmon River. Peery and Bjornn (Draft, 1992) found that the length of natural chinook fry in the upper Salmon River in April was 35 mm. Only the larger hatchery fry were regurgitated. We decreased fry length and diameter by clipping the tail off of all fry (to about 35 mm) and cutting off portions ventral to an imaginary line drawn from the vent to the isthmus. Trimming the fry, as described above, minimized regurgitation and standardized the size and condition of the fry used in the test. All fry were trimmed after the first 14 smolts were fed. Fry length, smolt length, time, date and water temperature was recorded.

One hundred-eleven smolts were placed into the raceway after successful isolated recovery and monitored for further regurgitation. Five regurgitated fry were found in the raceway 20 hours after feeding. Two smolts died in the raceway within the first 24 hours.

We killed 14 smolts every six hours after the initial feeding (for up to 48 hours). Stomach contents of seven smolts were immediately examined and preserved. The remaining seven were held on ice, the same technique used in field sampling, to examine the effect on postmortem digestion. All stomach contents were preserved in alcohol with an enclosed label. The presence or absence of chinook fry in the smolts cardiac stomach was recorded along with fork length, sex, and marks if present.

Binary data analysis with the proportion as the mean and standard error follows that of Kachigan (1986) and is similar to the predation study. To calculate mean evacuation time, we first found the proportion (p) of smolts with fry present in their cardiac stomachs: p = 0.529 = 55/(109-5) (five smolts regurgitated their fry). Mean evacuation time = the proportion (p) multiplied by the duration of the test (48 hours) = 0.529 x 48 hours = 25.4 hours. The standard error and the upper and lower bounds of this estimate were calculated as follows:

$$SE=\sqrt{\frac{p\times q}{n}} \quad where\ (q=1-p) \tag{4}$$

(5)

$$SE=\sqrt{\frac{0.529\times 0.471}{104}}$$

(6)

$$SE=0.0489$$

$$SE = 2.35\ hours = (0.0489 \times 48\ hours) \quad (7)$$

$$95\% = Confidence\ Interval = \pm 2xSE \quad (8)$$

$$25.4\ hours = mean\ evacuation\ time\ (95\%\ CI,\ 20.7 - 30.1) \quad (9)$$

We adjusted the Y intercept of Elliott's (1972) equation of $96.5xe^{-0.112t}$ to $91.1xe^{-0.112t}$ to make the function intercept our single data point of 25.4 hours for evacuation (90%) at 11.4°C (Figure 6). The mean daily temperature observed during our evacuation rate experiment is 11.4°C. We did not change the exponent because Elliott (1972) showed that with four different food types the exponent showed only very little change. We assumed that this function would be suitable to estimate the 90% evacuation of chinook fry flesh from steelhead smolt cardiac stomachs at various temperatures. We did not test our assumption that the function was suitable at temperatures higher or lower than the 11.4°C mean daily temperature observed during the test itself.

Residualization

We originally planned to evaluate residualization with a Petersen mark-recapture procedure (Everhart et al. 1975) after angling and electrofishing CPUE dropped off and stabilized after emigration. However, the number of residualized smolts was so low that our mark recapture effort, in contrast to Partridge (1985), was futile. Viola and Schuck (1991) in Oregon estimated the number of residual smolts by planting a known number of hatchery catchables, assuming equal probability of capture, and examining the proportion of smolts per catchable. Hepworth et al. (1991) also successfully used supplemental stocking for estimating the population of resident rainbow trout in a Utah Reservoir. We incorporated this method by electrofishing after catchables were planted in the study area on May 27, 1992. Electrofishing was done with the same equipment and methods as described in the predation study. We could only do this for the lower 5.5 km of reach 1 and the upper 4.1 km of reach 2.

To verify our estimates of residual hatchery smolts, we snorkeled several locations within each reach after peak runoff when water clarity improved (Appendix B). Snorkelers worked in a downstream direction for a known distance and counted fish in a 2-4 m path of known length as water clarity allowed; total area snorkeled was calculated. Snorkelers worked an edge area and a mid-stream area at each of 24 sites. Valley Creek was snorkeled on May 27, and all other sites on June 9 and 10, 1992.

RESULTS AND DISCUSSION

Predation Rate Study

We examined the stomach (cardiac) contents of 6,762 hatchery steelhead smolts collected from the upper Salmon River drainage from April 15 - May 18, 1992. Fourteen of these came from Redfish Lake Creek, a small tributary joining the Salmon River about 2000 m below Sawtooth Fish Hatchery. Only three of twenty

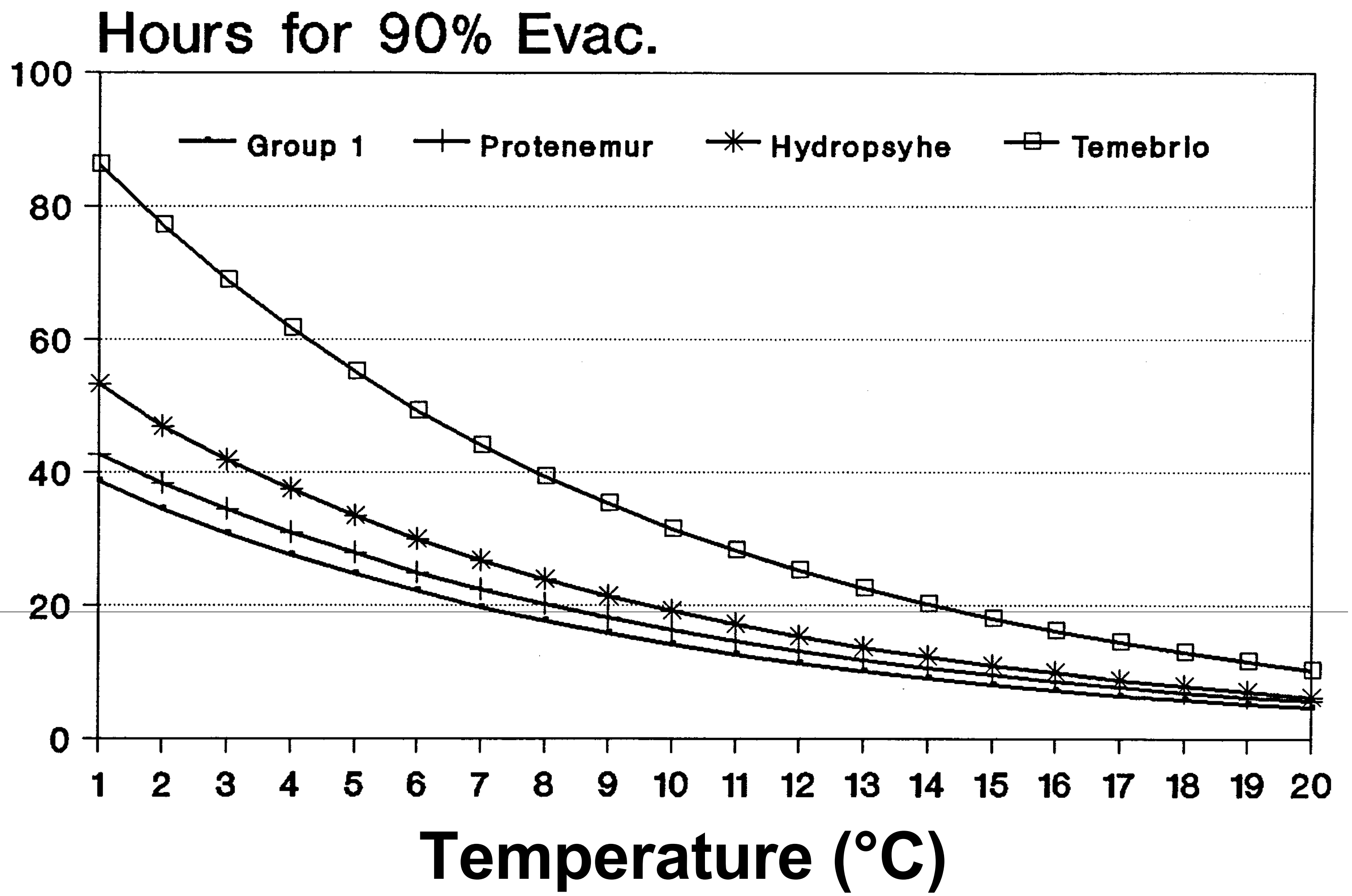

Figure 6. Evacuation rate (90%) in hours as a function of temperature in brown trout fed four different food types from Elliott's (1972) evacuation rate equations.

smolts that had some type of fish remains in the cardiac stomach contained chinook fry. Five of the twenty contained only fin rays or other fish parts which were not identifiable beyond the class osteichthyes. The remaining twelve smolts had either sculpin (*Cottus* spp.), dace (*Rhinichthys* spp.) or mountain whitefish (*Prosopium williamsoni*) in their cardiac stomachs (Table 1).

Three smolts contained a total of ten salmonidae fry in their cardiac stomachs. Two of these smolts had one and two salmonid fry in the cardiac stomach, respectively, which we identified as chinook fry. The other smolt contained seven positively identified chinook fry in the cardiac stomach. An additional ten sets of vertebrae, gill arches, and cardiac stomachs recovered from the intestines of this same smolt were identified from vertebrae as salmonidae.

The data allow us to confidently state that the predation rate of hatchery steelhead smolts on chinook fry in the upper Salmon River in the spring of 1992 was low, $p = 1.48 \times 10^{-3}$, 95% CI = 0.55×10^{-3}, 2.41×10^{-3}, assuming a normal distribution).

By examining several hypothetical scenarios we can speculate on what the magnitude might be of chinook fry consumed by the 744,000 smolts. An estimate of the number of fry consumed by smolts was calculated under the following assumptions:

1) The proportion of the 744,000 hatchery smolts remaining in the upper Salmon River for the 50 days from April 15 to June 3 can be approximated from CPUE data (Figure 5; Table 2).

2) The remaining hatchery smolt population ate chinook fry at the same proportion (p) found in the 6,762 smolts in the sample population examined, (p = .00148 fry/smolt; 95% CI .00093, assuming normality).

3) The smolts evacuated fry from their cardiac stomachs at near the same rate as in the 109 fish tested in the evacuation rate study ($91.1e^{0"21}$) and varied with temperature comparably to what Elliott (1972) found.

Under these assumptions, an estimated 24,000 chinook fry were consumed by the 744,000 hatchery steelhead smolts in the upper Salmon River during the 50 days from April 14 to June 3 (Table 3). Error bounds (95%) were 9,000 to 40,000. This estimate is similar to Cannamela's (1992) findings (13,000 to 27,500 for 700,000 smolts). His estimate was based on published consumption rates and other literature.

This study suggests that under the 1992 conditions the proportion of smolts preying on chinook fry was low. The lack of replication through time limits our ability to extrapolate among years. We do not know how predation rates will vary in the future as river discharge, residualization, and fry densities change (caused by changes in egg to fry survival, number of spawners, flow temperatures, etc). Elliott (1973) found that food availability in the drift was correlated (numbers and biomass) with items consumed.

Table 1. Summary of fish found in 6,762 hatchery steelhead smolts stomachs in the upper Salmon River, April 15 through May 19, 1992 (R&R = rod and reel, ELEC = electrofishing, M = Male, F = Female, Length = Fork Length, Temp = Water temperature in

Fish Number	Sec.	Method	Date MM/DD/YY	Temp °C	Length (mm)	Sex	Number of Prey	Prey Species or Family	Prey Length
28	1	R&R	04/16/92	6.1	252	F	1	SALMONIDAE	
29a	1	R&R	04/16/92	6.1	238	M	2	SALMONIDAE	
29b								SALMONIDAE	
655	2	R&R	04/18/92	3.9	270	F	1	CYPRINIDAE	
1362	1	R&R	04/22/92	6.1	268	F	1	COTTIDAE	
1718	3C	ELEC	04/22/92	7.2	225	M	1	COTTIDAE	
4307a	2	R&R	05/05/92	10.6	183	F	7	O. tshawytsha	31
4307b								O. tshawytsha	31
4307c								O. tshawytsha	30
4307d								O. tshawytsha	
4307e								O. tshawytsha	28
4307f								O. tshawytsha	30
4307g								O. tshawytsha	28
4307h							10	SALMONIDS IN INTESTINE	
4493	3C	ELEC	05/05/92	9.4	218	F	1	COTTIDAE	
4743	3C	ELEC	05/05/92	9.4	254	M	1	COTTIDAE	
4886	1	R&R	05/07/92	13.9	192	M	1	COTTIDAE	
5245	3B	R&R	05/07/92	12.8	251	F	1	P. williamsoni	
5298	3A	R&R	05/07/92	13.9	278	F	1	COTTIDAE	
5342	2	R&R	05/07/92	10.6	181	F	1	COTTIDAE	
5571	1	ELEC	05/13/92	13.9	273	M	1	CYPRINIDAE	78
5714	1	R&R	05/13/92	13.9	305	M	1	COTTIDAE	
6558	3C	ELEC	05/18/92	13.3	197	M	1	COTTIDAE	

Table 2. Summary of data used to estimate total chinook salmon fry consumed by juvenile hatchery steelhead.

Date		Estimated % of 744,000 smolts remaining	Temp (°C)	Estimated number fry eaten/day
April	15	100	7.8	694
	16	100	6.9	628
	17	100	7.2	649
	18	100	5.3	525
	19	100	6.7	614
	20	99	7.2	643
	21	99	6.7	608
	22	99	5.6	537
	23	99	7.8	687
	24	99	6.9	622
	25	98	8.1	704
	26	98	8.6	744
	27	98	9.2	796
	28	97	9.2	788
	29	97	8.9	762
	30	96	9.2	780
May	1	96	8.3	705
	2	96	8.3	705
	3	95	8.9	746
	4	95	9.4	789
	5	94	9.2	764
	6	93.5	10.6	888
	7	93	9.7	799
	8	92	10.3	845
	9	90	8.9	707
	10	88	8.9	691
	11	87	9.4	723
	12	84	9.0	677
	13	81	8.9	636
	14	77	9.4	640
	15	72	9.2	585
	16	65	10.0	578
	17	56	10.0	498
	18	43	10.0	382
	19	27	10.3	248
	20	11	13.9	151
	21	9	10.8	87
	22	7	10.8	68
	23	6	11.7	64
	24	5	13.1	63
	25	4	13.3	51
	26	4	11.4	42
	27	4	11.9	44
	28	4	11.9	44
	29	4	12.8	49
	30	4	12.2	45
	31	4	12.5	47
June	1	4	13.6	53
	2	4	13.9	55
	3	4	12.8	49
Total				24,289 ± 15,302

Table 3. Presence and absence of fry in the cardiac stomachs of hatchery steelhead smolts after hand feeding (mean daily temperature was 11.4°C, with fluctuations from 7.8 to 14.4°C).

	# Smolts with Fry in Cardiac Stomach		
Hours After Ingestion	Immediate Examination	Examination after Storage	Storage (h)
6	7 / 7	7 / 7	60.5
12	7 / 7	6 / 7	36.0
18	6 / 7	3 / 7	48.0
24	3 / 7	5 / 7	24.0
30	4 / 7	2 / 7	18.0
36	1 / 7	4 / 7	12.0
42	0 / 7	0 / 7	6.0
48	0 / 7	0 / 4	18.0
Totals	28/56	27/53	55/104

Evacuation Rate Study

Chinook fry were detected in the cardiac stomach of smolts for a mean of 25.4 h (95% CI 20.7 and 30.1). No fry were found 42 hours after digestion (Table 3). The temperature based evacuation rate (90%) formula for chinook fry in steelhead smolts was $91.1e^{(-0.112t)}$. Fry, removed from the stomachs of smolts which were held on ice for up to 60 hours after death, appeared similar to fry removed immediately after the smolts were killed. Digestion and/or decay of ingested fry appears to be retarded after smolts are killed and stored on ice. Storing smolts on ice overnight did not appear to impair the detection of fry in the cardiac stomach.

Residualization

Four hours of electrofishing effort captured only 9 residualized smolts and 8 hatchery catchables on May 27, 1992. Because of low catch rates, a mark/recapture estimate using steelhead smolts was not possible. However, the 1, 875 hatchery catchables planted in the lower end of reach 1 and the upper end of reach two on May 27, 1992 were of similar size and functioned as surrogate marked fish. Assuming equal catchability, an estimate of 3,376 (95% CI 2,923-3, 829) hatchery catchables and hatchery steelhead smolts remained in 9.1 km of the bottom of reach 1 and the top of reach 2 on May 27, 1992. Assuming that half (9/17) of these are steelhead, this yields an estimate of about 195 residual smolts/km in the 9.1 km reach we examined.

Based on CPUE, an estimated 96% (or about 400 smolts/km) of the hatchery steelhead smolts had left the upper Salmon River by May 21, 1992 (Figure 5). Electrofishing CPUE dropped from a high of 8.8 fish/min on May 5 to 0.2 fish/min on May 20th and to a low of 0.013 fish/min on June 3 (Figures 7 and 8). CPUE was variable and appeared to be influenced by the number of smolts in the system but also by water clarity, flows, temperature, collector, time of day, and weather.

After June 1, the low CPUE probably accurately portrays the relatively low number of hatchery steelhead smolts remaining in the system rather than some reduction in catchability coincident with the onset of low, clear stream conditions. Discharge in the Salmon River dropped to mid-summer levels by the June 1. Visibility was approximately 2 m on May 27 and 4 m on June 9, 1992. Despite these conditions, we still collected hatchery catchable rainbow trout, wild steelhead smolts, many whitefish, suckers, dace, sculpin, and a few hatchery steelhead smolts. Furthermore, snorkel counts (detailed below) and angling CPUE by IDFG personnel (this study) and sport anglers (personal communication) concurred with electrofishing results.

Snorkeling efforts on June 9, 1992 in the lower end of reach 1 and the upper end of reach 2 provided a similar surrogate mark/recapture estimate of 4, 925 (95% CI 3,371-6,479) as the electrofishing efforts. Snorkelers enumerated 39 residualized smolts and 23 hatchery catchables in transects within the 9.1 km where electrofishing mark recapture estimate was conducted. We assumed there was no difference in mortality or outmigration between hatchery steelhead and the catchables during the two weeks after planting the catchables and the snorkeling effort on June 9, 1992.

Snorkel counts of hatchery steelhead were low at most sites (< 1.0 fish/100 m^2). Small localized areas such as the pool below the Sawtooth Weir and the high gradient reaches of Red Fish Lake Creek held relatively higher densities of hatchery smolts than did others (Table 1). We observed relatively high densities (2-12 fish/m^2) in all three sites in the Pahsimeroi River, which we sampled for comparative and informative purposes. Either emigration had not occurred or

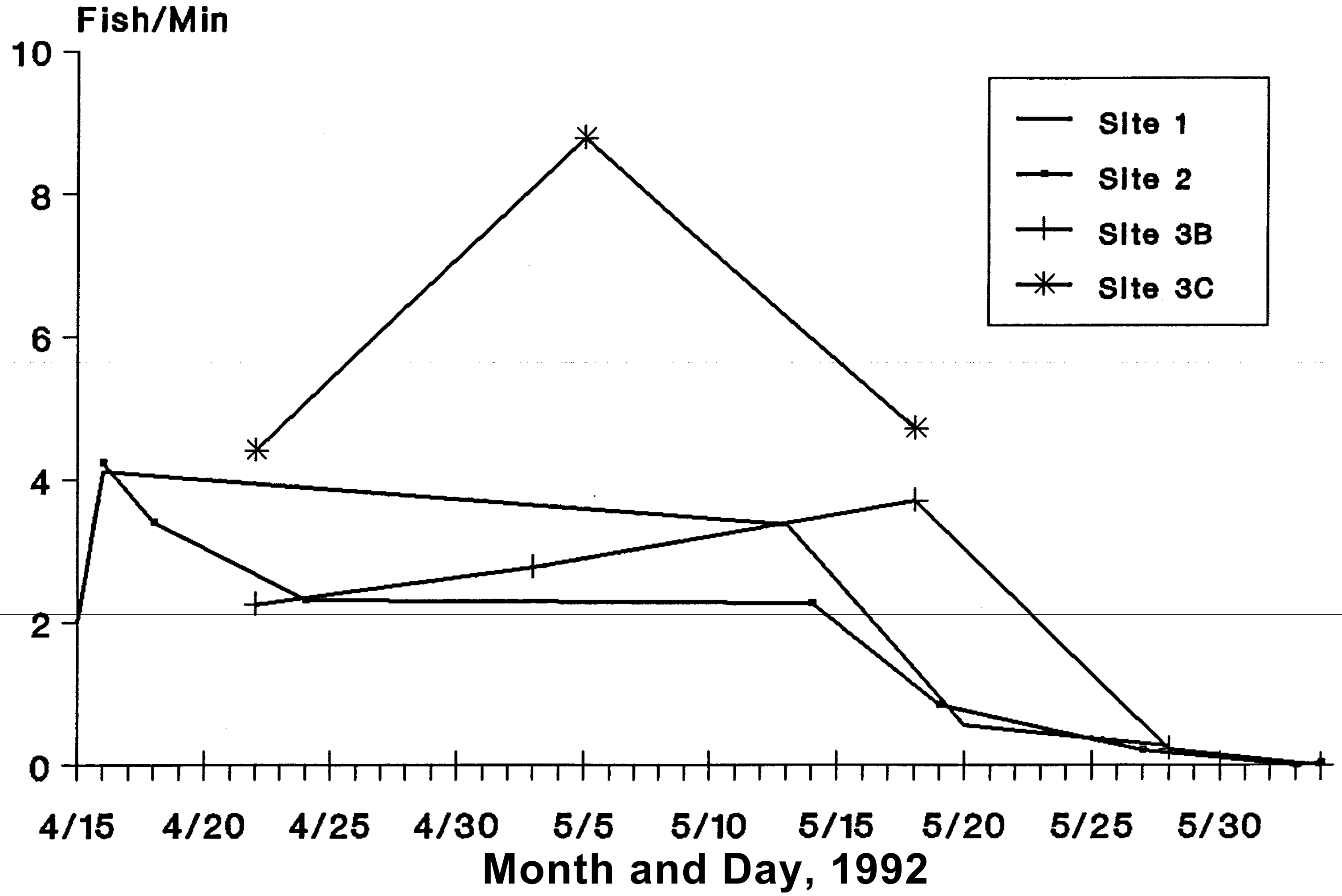

Figure 7. Hatchery steelhead electrofishing catch per unit effort data by site (fish/min) from April 15 to June 3, 1992, in the upper Salmon River near Stanley, Idaho.

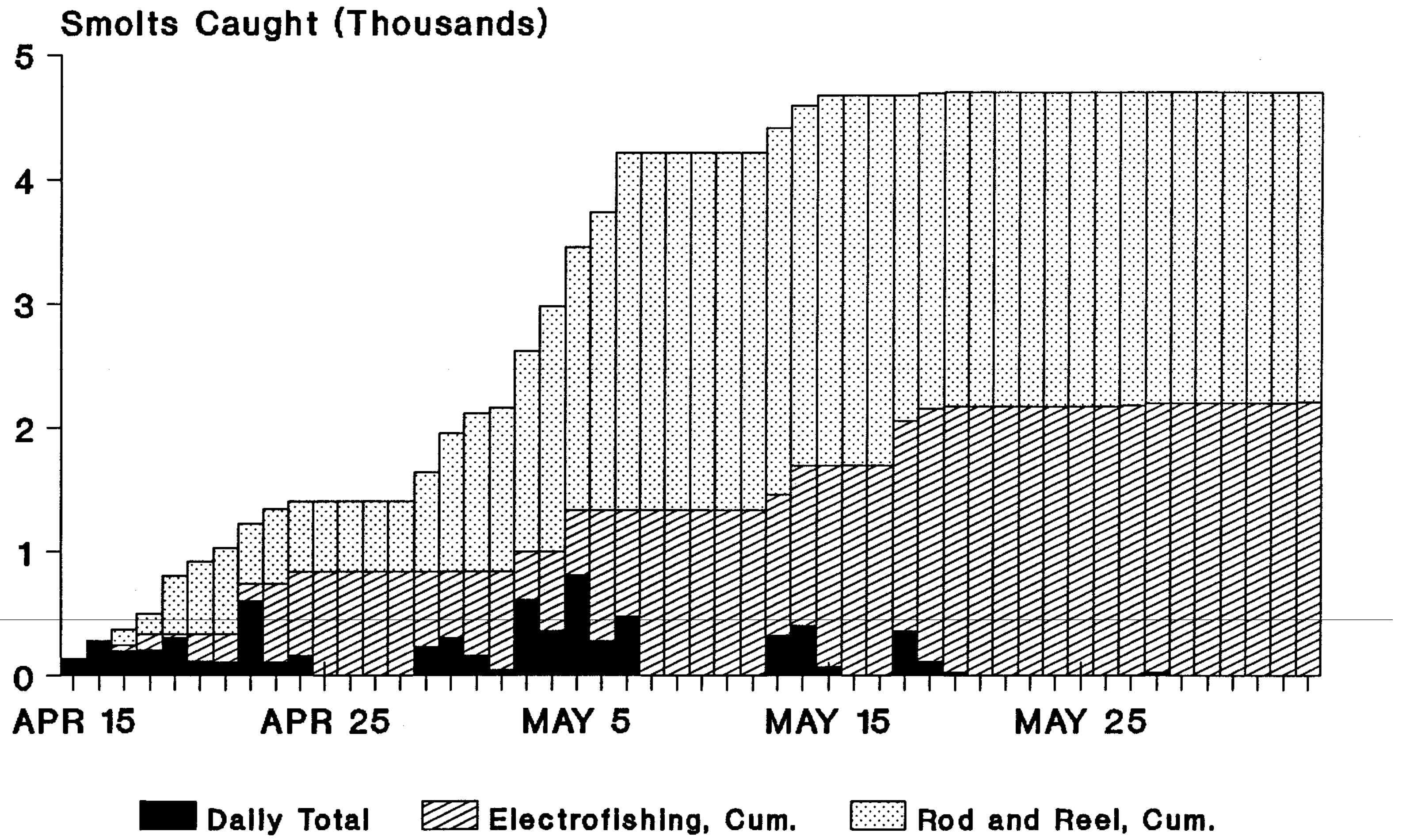

Figure 8. Number of smolts caught by all gear types (daily total) and cummulatively by gear type from April 15 to June 3, 1992, in the upper Salmon River near Stanley, Idaho.

residualization is substantial in the Pahsimeroi this year. Many large areas of the upper Salmon River were devoid of smolts by June 10, including areas where hundreds of fish were collected in early May. This contrasts to other years when hatchery smolts were readily caught by anglers in the upper Salmon River into July (Partridge, 1986). Run, riffle and shallow areas without abundant cover were devoid of hatchery smolts. We observed numerous chinook fry, whitefish, suckers, and an occasional hatchery catchable in most of the snorkeling sites.

Smolt Characteristics

Mean lengths of smolts were similar for males, females, electrofishing, and rod and reel caught fish (Figure 9; Appendix C). Males caught during the early part of the season were longer than males caught later on (Figure 9). The opposite appears true for females from site 2 (Figures 10 and 11; Appendix C).

Sex ratios remained steady at about 55% male for sites and gear type. Exceptions occurred on the first sampling day and from April 22 to April 28 (Figures 12 and 13). The first day we sampled only in the upper section of reach 1 below the hatchery weir where there was a localized group of fish with a high proportion of males. During the third week of April some erroneous sexing of fish data by laboratory personnel occurred.

Precocious males made up to 2.5% of the total catch but comprised up to 14% of all fish captured in reach 1 and 86% (12 out of 14) of fish captured in Red Fish Lake Creek. Precocious males averaged 30 mm longer than other males and females (Figures 14 and 15; Table 3). What we found in reach 1 contrasts directly to reach 3 where precocious males never comprised more than 1% of the sample.

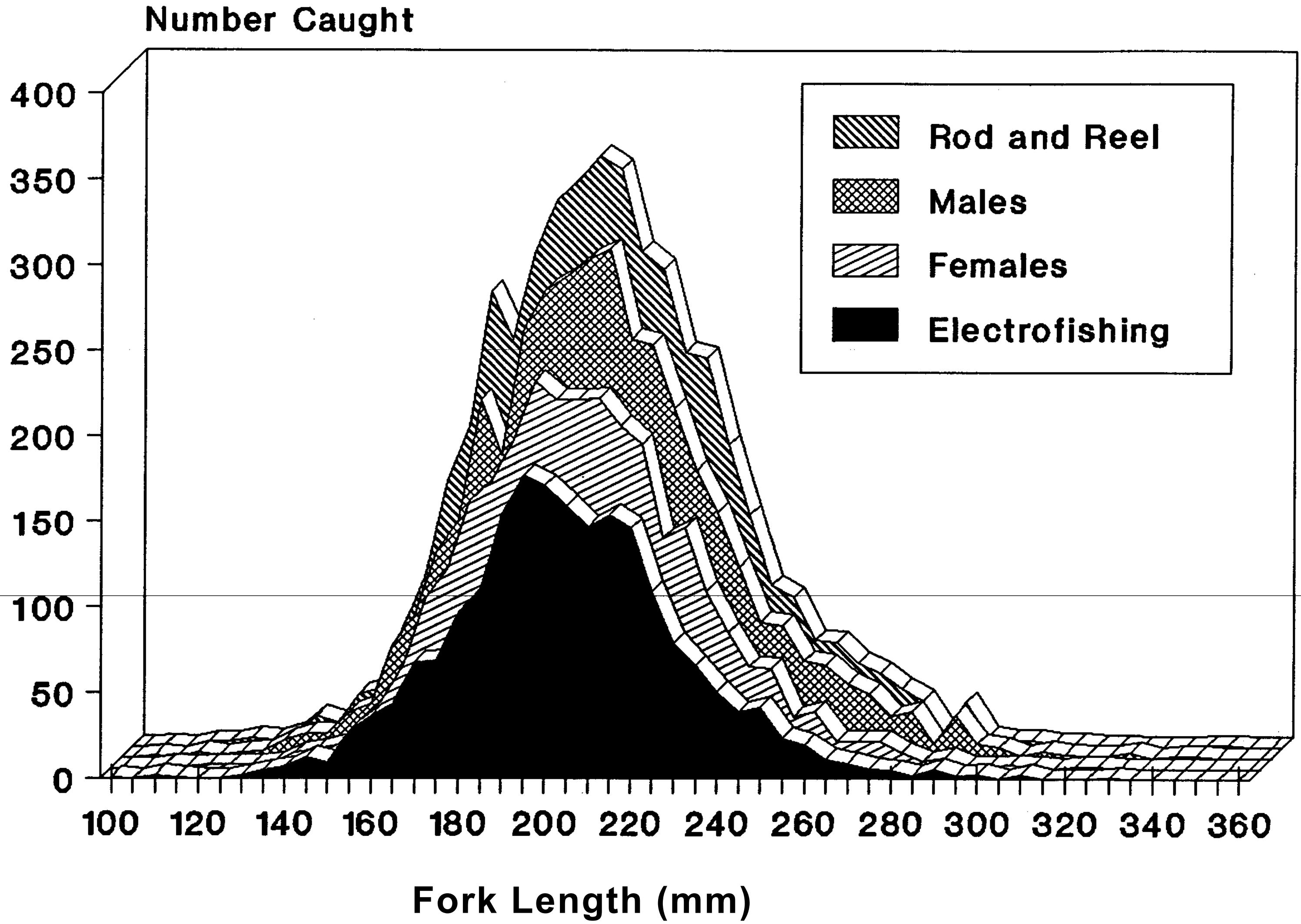

Figure 9. Length frequency area chart of smolts by sex and gear type, N = 2,109 for electrofishing, 2, 873 for females, 3,859 for males, and 4,606 for rod and reel.

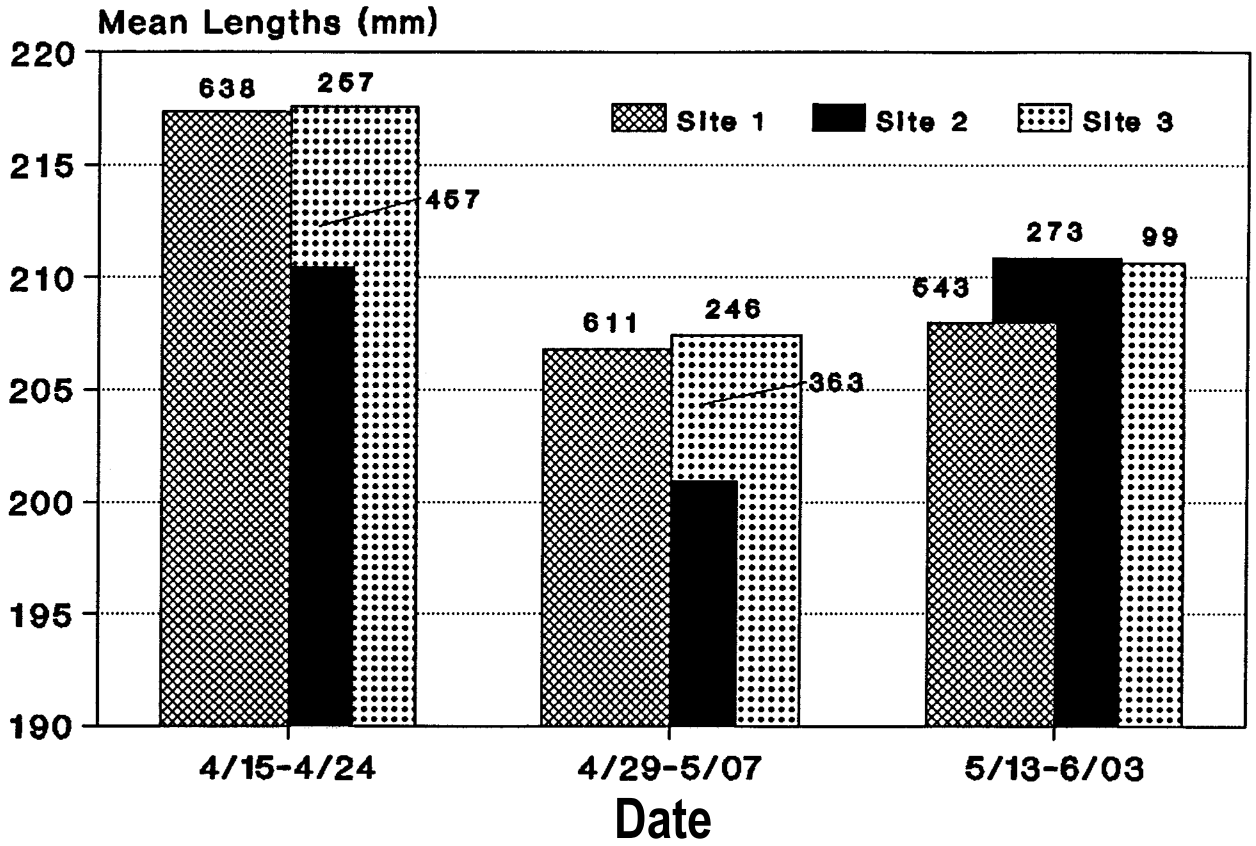

Figure 10. Mean fork lengths of male steelhead smolts caught at different dates and sites in the upper Salmon River near Stanley, Idaho. Numbers above the bars are sample size.

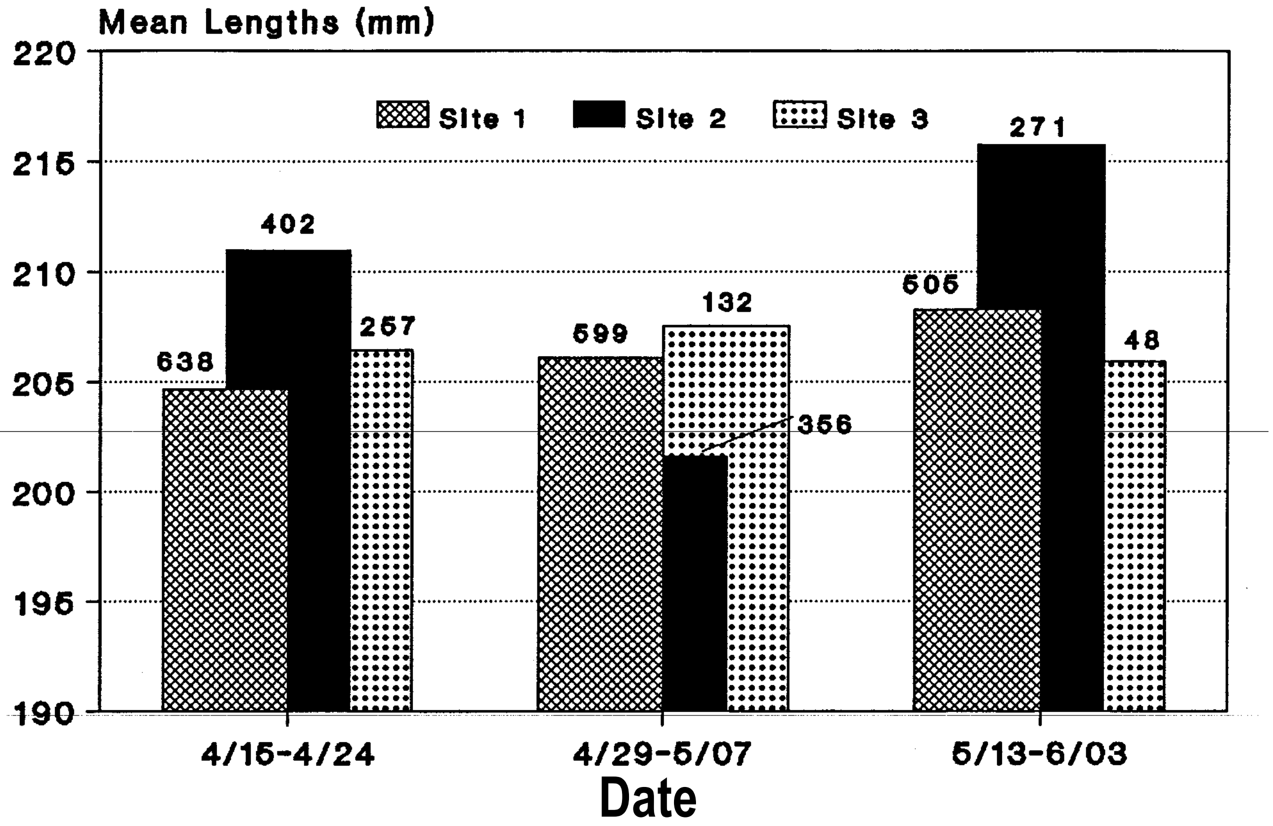

Figure 11. Mean fork lengths of female steelhead smolts caught at different dates and sites in the upper Salmon River near Stanley, Idaho. Numbers above the bars are sample size.

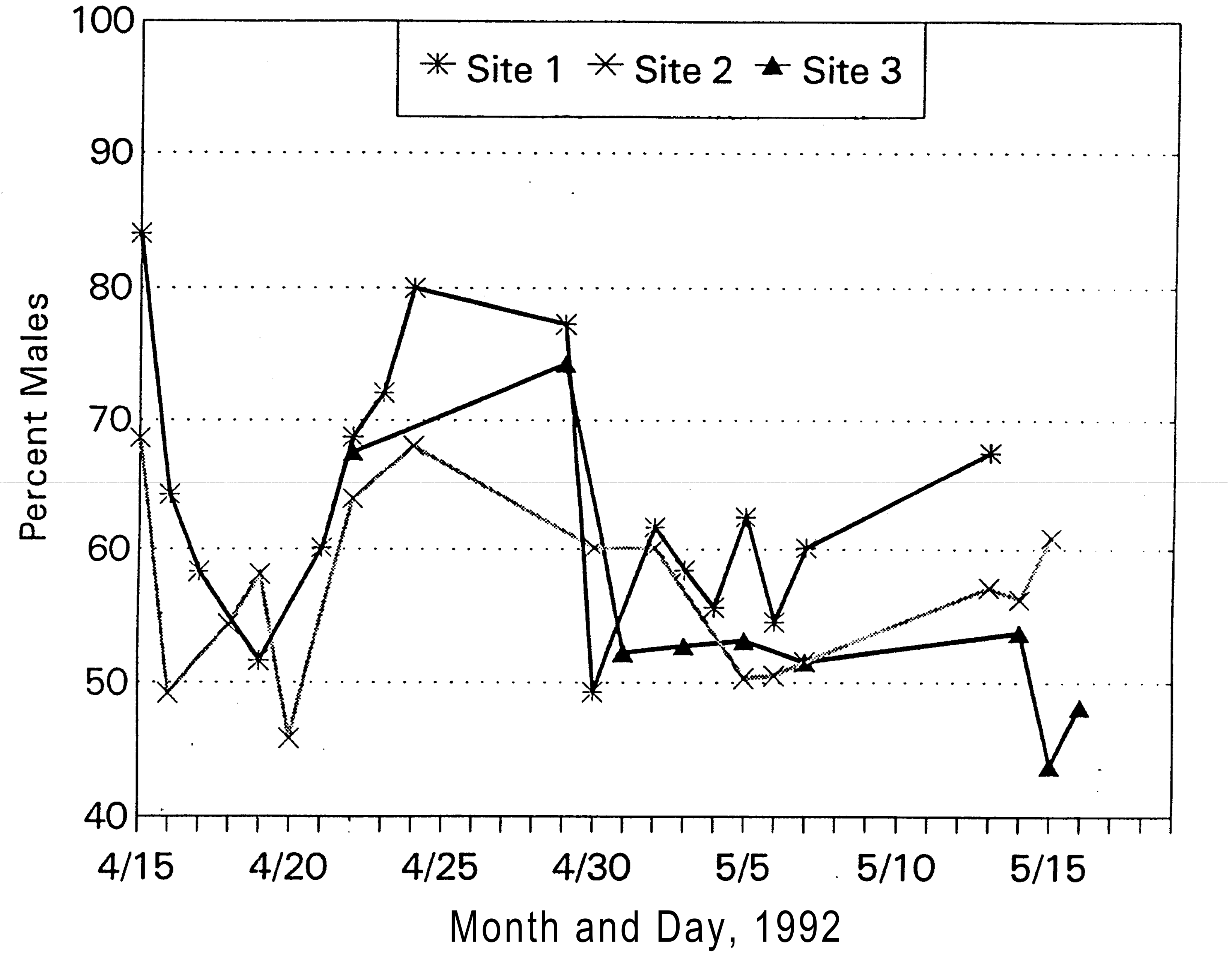

Figure 12. Percent of males caught in each site in the upper Salmon River from April 15 to May 19, 1992; from April 22 to April 28 we had sex identification problems and are uncertain what the sex ratios in the catch were during that time period.

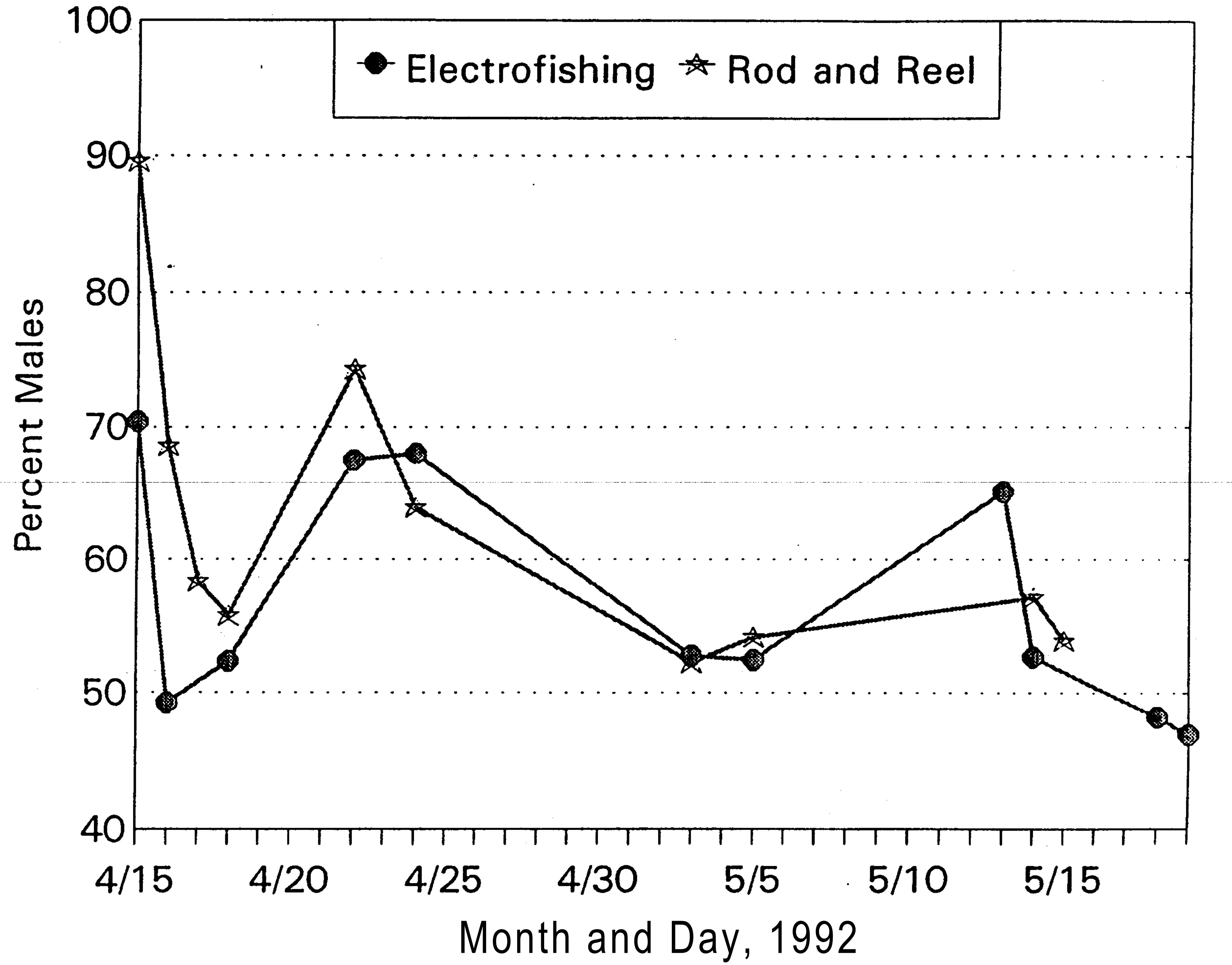

Figure 13. Percent of males caught by gear type in the upper Salmon River from April 15 to May 19, 1992; from April 22 to April 28, sex identification problems made the sex ratios in the catch during that time period uncertain, percent males were only plotted by gear type when both gear types were used in the same section within one or two days.

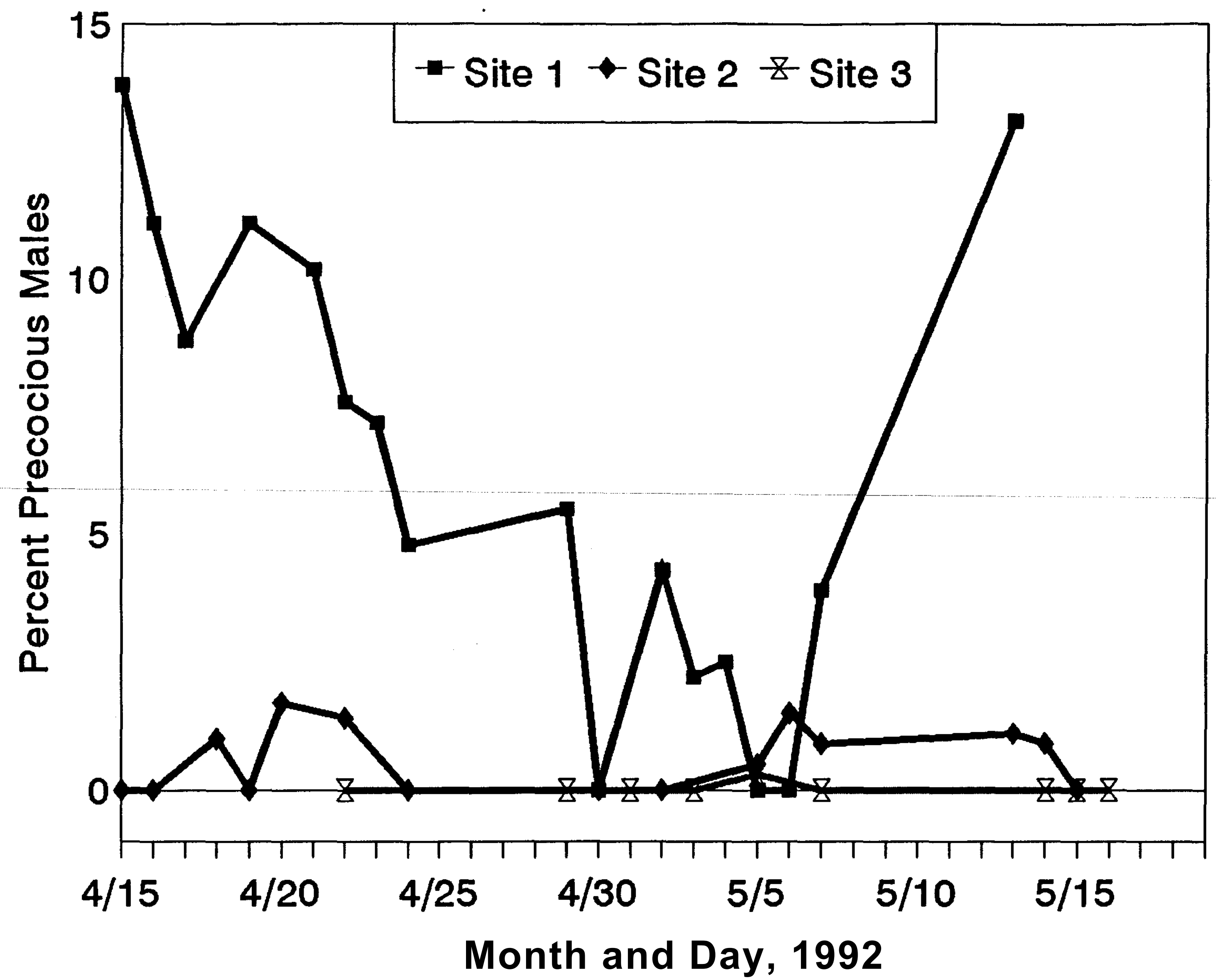

Figure 14. Percent precocious males of the total catch for each site and date, percent precocious males determinations were not determined during April 22-28, 1992.

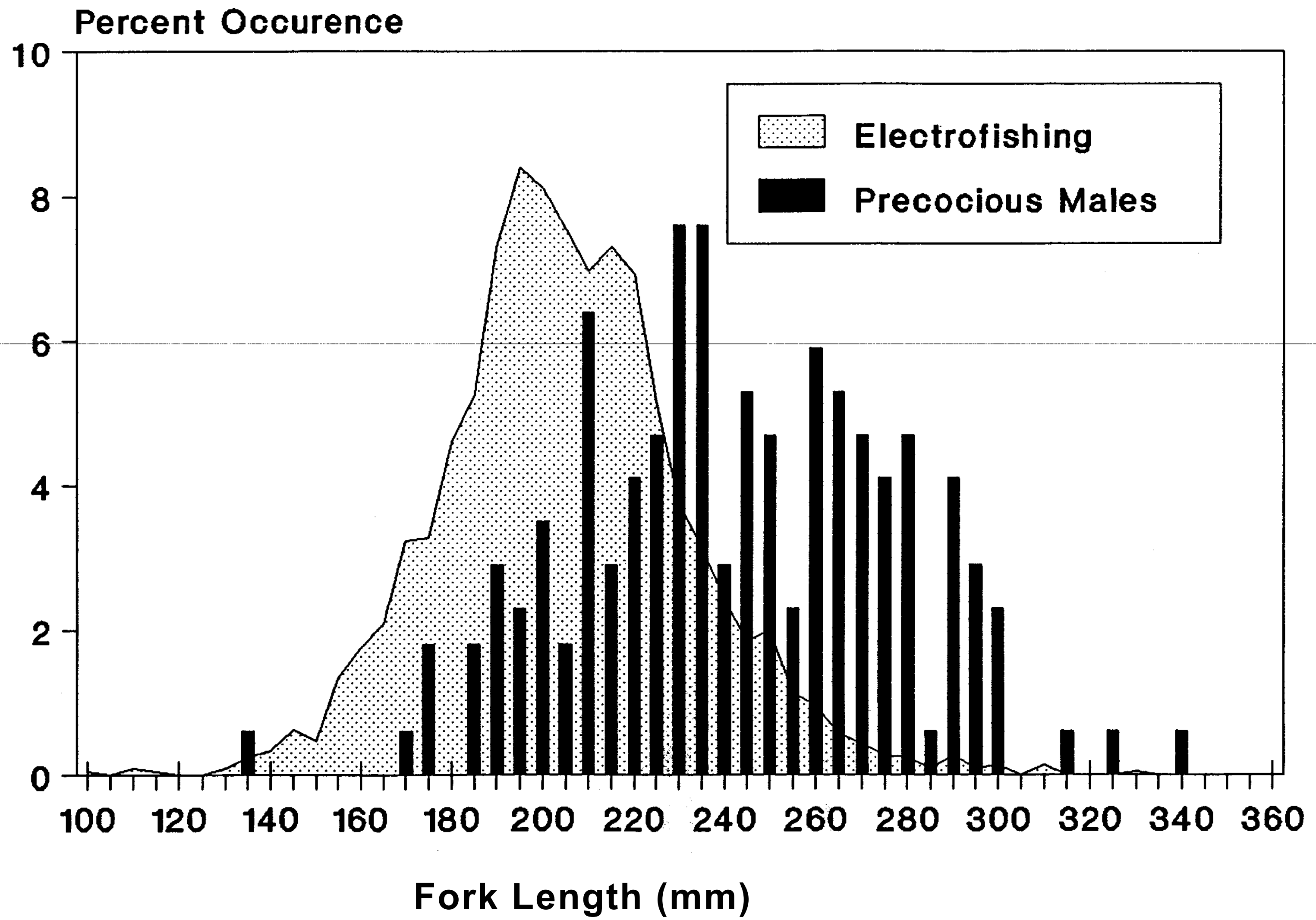

Figure 15. Length frequency histogram of mature males over a length frequency area chart of smolts caught by electrofishing gear, N = 2,109 for electrofishing, 171 for mature males.

ACKNOWLEDGMENTS

Craig Contour conducted the field work, initial data analysis, and report preparation. Virgil Moore edited the final report. The Department also acknowledges the help of Tom McArthur, Ed Bowles, Dr. Robert E. Dillinger, Kent Ball, Gretchen Kruse-Malle, Robert L. Downing, Rusty Sisiam, Larry Barrett, Mike Wood, Anne Tibbetts, Jim Usa, Bill Stutz, Phillip Koontz, and Sawtooth Hatchery Personnel of IDFG, as well as Rip Shively and Dave Johnson at the USFWS National Fisheries Research Center in Cook Washington.

LITERATURE CITED

Cannamela, D.A. 1992. Potential impacts of releases of hatchery steelhead trout "smolts" on wild and natural juvenile chinook and sockeye salmon. White Paper. Idaho Department of Fish and Game, Boise, Idaho.

Elliott, J.M. 1972. Rates of gastric evacuation in brown trout Salmo trutta L. Freshwater Biology 2:1-18.

Elliott, J.M. 1973. The food of brown and rainbow trout (Salmo trutta and S gairdneri) in relation to the abundance of drifting invertebrates in a mountain stream. Oecologia (Berl.) 12:329-374.

Elliott, J.M. 1975. Number of meals in a day, maximum weight of food consumed in a day and maximum rate of feeding for brown trout, Salmo trutta L. Freshwater Biology 5:287-303:

Everhart, W.H., A.W. Eipper, and W.D., Yongs. 1975. Principles of fishery science. Cornell University Press, Ithaca, New York. 288 pages.

Hansel, H.C., S.D. Duke, P.T. Lofy and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transaction of the American Fisheries Society 117:55-62.

Harenberg, W.A., M.L. Jones, I.O. Dell, T.S. Brennan, A.K. Lehmann. 1991. Water resources data, Idaho, water year 1991, volume 2. U.S. Geological Survey Water-Data Report ID-91-2. USGS, 230 Collins Road, Boise, ID 83702-4520.

Hepworth, D.K., and D.J. Duffield, and T. Modde. 1991. Supplemental stocking for estimating population size and first year survival of fingerling rainbow trout stocked in a Utah reservoir. North American Journal of Fisheries Management 11:11-19.

Kraemer, H.C., and S. Thieman. 1987. How many subjects?: statistical power analysis in research. Sage Publications, Newbury Park, California. 118 PP.

Lipsey, M.W. 1990. Design sensitivity: statistical power for experimental research. Sage Publications, Newbury Park, California. 207 pp.

Partridge, F.E. 1985. Effects of steelhead smolt size on residualism and adult return rates. US Fish and Wildlife Service Lower Snake River Compensation Plan. Contract No. 14-16-001-83605 (1983 Segment). Idaho Department of Fish and Game, Boise. 26p.

Partridge, F.E. 1986. Effects of steelhead smolt size on residualism and adult return rates. US Fish and Wildlife Service Lower Snake River Compensation Plan. Contract No. 14-16-001-83605 (1984 Segment). Idaho Department of Fish and Game, Boise. 59p.

Kachigan, S.K. 1986. Statistical analysis. Radius Press, New York, New York. pp. 589

Minshall, G.W., R.C. Petersen, T.L. Bott, C.E. Cushing, K.W. Cummins, R.L. Vannote, and J.R. Sedell. 1992. Stream ecosystem dynamics of the Salmon River, Idaho: an 8th-order stream. Journal of the North American Benthological Society. 11(2):11-137

Peery, C.A. and T.C. Bjornn. 1992. DRAFT. Downstream movements of juvenile chinook salmon soon after emergence in the upper Salmon River - 1991. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho 83843. 31 p.

Rosgen, D. 1985. A stream classification system. IN: Riparian Ecosystems and Their Management; Reconciling Conflicting Uses. Proceedings of the First North American Riparian Conference, April 16-18, Tucson, Arizona. BTR-RM120, pp. 91-95.

Sankovich, P. and T.C. Bjornn. DRAFT 1992. Distribution and spawning behavior of hatchery and natural adult chinook salmon released upstream of weirs in two Idaho rivers. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho, 83843. 31 p.

Viola, A.E. and M.L. Schuck. 1991. Estimates of residualism of hatchery reared summer steelhead and population size of yearling rainbow trout (Oncorhynchus mykiss) in Southeast Washington, 1991. Report No. AFF 1/LSR-92-02, Washington Department of Wildlife, 600 Capitol Way N. Olympia, Washington 98501-1091.

Windell, J.T., J.F. Kitchell, D.O. Norris, J.S. Norris, and J.W. Foltz. 1976. Temperature and rate of gastric evacuation by rainbow trout, Salmo gairdneri. Transactions of the American Fisheries Society. 105:712-717.

A P P E N D I C E S

Appendix A. Unites States Geological Survey 7.5 minute topographic Maps for Study Area.

Stanley

Casino Lakes

Basin Butte

East Basin Creek

Mt. Cramer

Obsidian

Robinson Bar

Sun Beam

Thompson Creek

Livingston Creek

Potaman Creek

Clayton

Ziegler Basin

Bald Mountain

Lone Pine Peak

Bayhorse

Bradbury Flat

Appendix B. Summary of snorkel surveys for hatchery steelhead Smolts in the upper Salmon River and selected tributaries, June 9 and 10, 1992. Valley Creek sites were snorkeled May 27, 1992

Stream, Section, Site and General Habitat Type	Xsec Length (m)	Xsec Width (m)	Area (m^2)	Number Smolts Observed	Density N/100 m^2
Salmon 1. Pool Below Sawtooth Hatchery Weir; Pool and Tailout	50	20	1000	75 - 150	7.5 - 15
Salmon 1. Reach Below Sawtooth Hatchery Weir Pool to Highway Bridge; Run, Riffle and a little Pocket Water	700	3	2100	12	0.6
Salmon 1. High Gradient Reach Near Forest Service Headquarters; Pocket Water	178	8	1424	28	2.0
Salmon 1. Bridge Just Above Upper Stanley; Run and Pocket Water	200	8	1600	10	0.6
Salmon 2. Below Valley Creek; Run, Riffles, and Pocket Water	440	8	7040	1	0.01
Salmon 2. Below Mormon Bend; Pool and Rapids	200	8	1600	16	1.0
Salmon 2. Above "Shotgun" Rapids; Pool, Tailout and Run	400	8	3200	2	0.1
Salmon 3A. Below "Piece of Cake" Rapids; Pool, Tailout and Run	350	8	2800	12	0.4
Salmon 3A. O'brien; Run and Pocket Water	450	8	3600	32	0.8
Salmon 3B. Deadman's Hole at Holeman's Creek; Pool and Tailout	350	8	2800	21	0.7
Salmon 3B. Above Thompson Creek; Run and Riffle	650	8	5200	14	0.3
Salmon 3C. Clayton; Run, Riffle and Pocket Water	420	8	3360	7	0.2
Salmon 3C. Above Mouth of the East Fork Salmon River; Run	300	8	2400	1	0.04
Red Fish Lake Creek 1. Upper High Gradient Reach; Pocket Water	250	8	2000	5	0.3
Red Fish Lake Creek 2. Lower High Gradient Reach; Pocket Water	400	8	3200	82	2.6
Valley Creek 1. First Sportsman's Access Above Upper Stanley; Run, Riffle and Pocket Water	700	3	2100	0	0
Valley Creek 2. Bridge at Upper Stanley; Run	100	2	200	0	0
Valley Creek 3. Mouth; Run and Pocket	100	2	200	0	0
Basin Creek 1. 1000 m above the Mouth; Pool, Pocket, Run, Riffle	150	3	450	2	0.4
East Fork Salmon 1. Mouth; Run and Pocket Water	100	6	600	1	0.2
East Fork Salmon 2. Near the East Fork Dump Site; Side Pocket and Run	190	8	1520	27	1.8
Pahsimeroi 1. Mouth; Pool and Run	300	5	1500	32	2.1
Pahsimeroi 2. Below Hatchery Weir; Pool and Run	100	5	500	63	12.6
Pahsimeroi 3. Above First Bridge Above Hatchery; Pool and Run	100	5	500	24	4.8

Appendix C. Summary of descriptive statistics of fork lengths (mm) of hatchery steelhead smolts captured after release in the upper Salmon River near Stanley, Idaho, 1992, date 1 = 4/15-4/28, date 2 = 4/29-5/7, date 3 = 5/13-6/3, 1992.

SUBGROUP NAME	N	MIN	MAX	RANGE	MEAN	VAR	S.D.	S.E.	SKEW	KURT.	SUM	C.V.	MED.
Electrofishing	2109	104	332	228	206.7	719.275	26.819	0.584	0.277	0.931	435963	0.130	205
Rod and Reel	4606	107	350	243	209.0	846.963	29.103	0.429	0.412	0.586	962854	0.139	207
Females	2873	111	325	214	207.3	724.725	26.921	0.502	0.292	0.541	595661	0.130	205
Males	3859	107	345	238	209.8	881.222	29.685	0.478	0.467	0.770	809557	0.142	208
Electrofish- Females	904	111	310	199	207.0	658.637	25.664	0.854	0.282	1.015	187139	0.124	206.5
Electrofish- Males	1931	118	332	214	207.1	684.164	26.157	0.595	0.336	0.763	399942	0.126	205
Rod and Reel- Females	1157	119	323	204	206.9	856.936	29.273	0.861	0.269	0.222	239384	0.141	205
Rod and Reel- Males	2638	107	345	238	210.3	891.303	29.855	0.581	0.417	0.491	554676	0.142	208
Females Site 1 Date 1	638	125	309	184	204.7	1081.329	32.884	1.302	0.427	-0.038	130574	0.161	
Females Site 1 Date 2	599	141	280	139	206.1	585.467	24.196	0.989	0.175	-0.006	123466	0.117	
Females Site 1 Date 3	505	111	323	212	208.3	817.942	28.600	1.273	0.218	1.090	105193	0.137	
Females Site 2 Date 1	402	119	292	173	211.0	564.943	23.769	1.185	0.298	0.510	84803	0.113	
Females Site 2 Date 2	356	146	280	134	201.6	589.893	24.288	1.287	0.255	-0.127	71784	0.120	
Females Site 2 Date 3	271	150	294	144	215.8	554.192	23.541	1.430	0.132	0.093	58470	0.109	
Females Site 3 Date 1	257	158	290	132	206.4	497.153	22.297	1.391	0.448	0.656	53054	0.108	
Females Site 3 Date 2	132	159	325	166	207.5	629.076	25.081	2.183	1.289	3.648	27393	0.121	
Females Site 3 Date 3	48	127	251	124	205.9	533.312	23.094	3.333	-0.323	1.615	9884	0.112	
Males, Site 1, Date 1	638	107	345	238	217.4	1625.647	40.319	1.596	0.280	-0.153	138684	0.185	
Males, Site 1, Date 2	611	115	315	200	206.8	875.508	29.589	1.197	0.445	0.613	126371	0.143	
Males, Site 1, Date 3	543	130	312	182	208.0	829.981	28.809	1.236	0.308	0.435	112950	0.138	
Males, Site 2, Date 1	457	129	300	171	210.5	684.833	26.169	1.224	0.460	0.595	96188	0.124	
Males, Site 2, Date 2	363	145	290	145	200.9	676.794	26.015	1.365	0.351	-0.108	72933	0.129	
Males, Site 2, Date 3	273	157	296	139	210.9	553.083	23.518	1.423	0.394	-0.030	57573	0.112	
Males, Site 3, Date 1	257	165	300	135	217.6	608.294	24.664	1.538	0.397	0.120	55913	0.113	
Males, Site 3, Date 2	246	120	300	180	207.4	471.117	21.705	1.384	0.309	1.764	51024	0.105	
Males, Site 3, Date 3	99	166	283	117	210.6	517.974	22.759	2.287	0.424	-0.085	20851	0.108	

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