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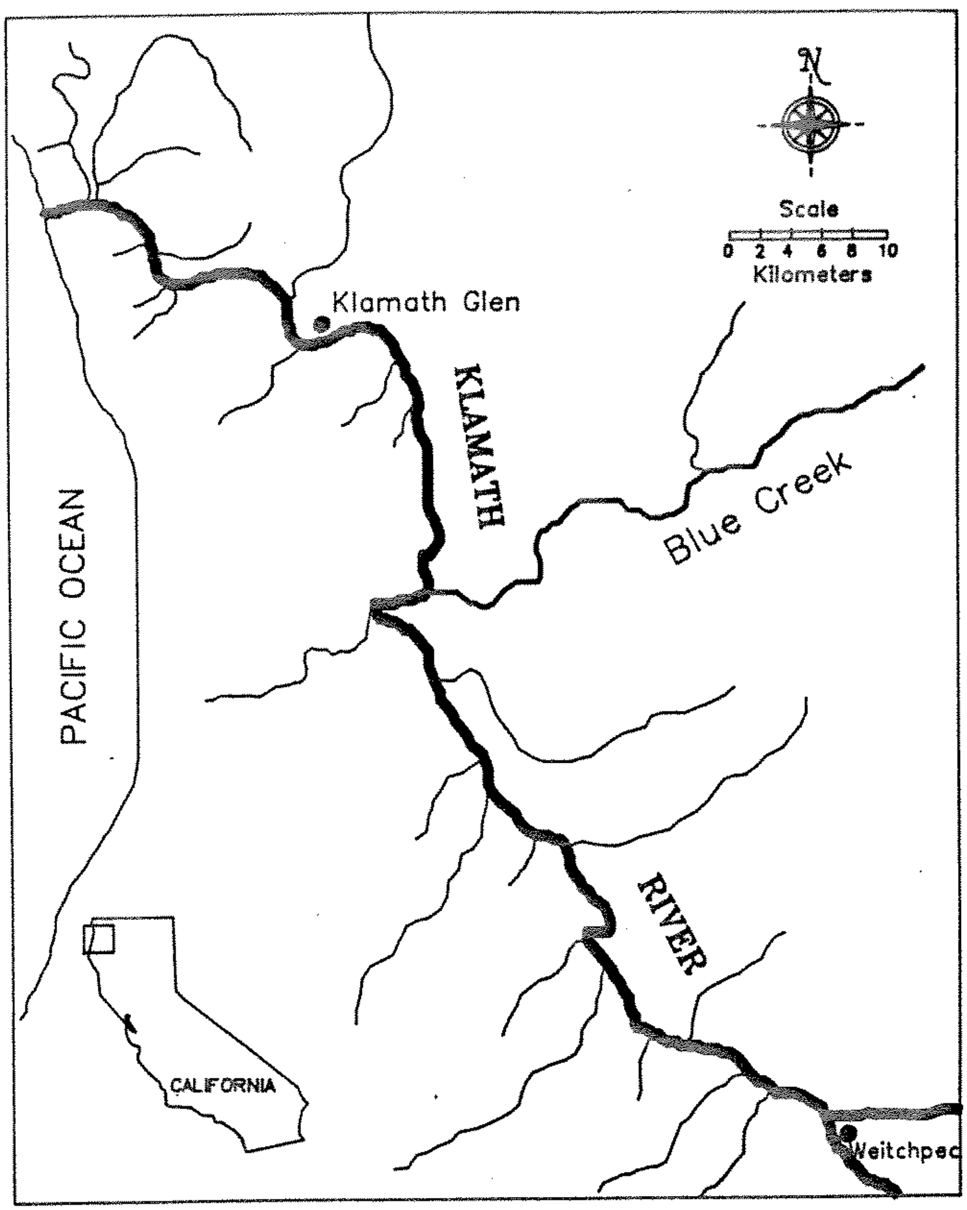
KLAMATH RIVER FISHERIES ASSESSMENT PROGRAM

INVESTIGATIONS ON BLUE CREEK

Annual Progress Report FY 1989
March 1990

Fisheries Assistance Office
Arcata, California
Western Region



PROGRESS REPORT FOR

INVESTIGATIONS ON BLUE CREEK

FY 1989

First year of investigations

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DISCLAIMER

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PROGRESS REPORT FOR
INVESTIGATIONS ON BLUE CREEK

First year of investigations - FY 1989

ABSTRACT

The U.S. Fish and Wildlife Service, Fisheries Assistance Office in Arcata, CA, is currently funded to investigate chinook salmon (Oncorhynchus tshawytscha) spawning use, juvenile outmigration characteristics, and habitat availability in Blue Creek, Klamath Basin, CA. Investigations began in October 1988, and continued through September 1989. Adult chinook spawner escapement and habitat utilization was addressed by redd, carcass, and snorkel surveys. Barriers to fish migration were identified. Available spawning gravels in the lower 14.5 kms of the creek were measured. Emigrating juvenile salmonids were trapped at river kms 2.1 and 12.5. The upper outmigrant trap, which consisted of a 1.5 x 3 m frame net and live boxes, was operated 2 or 3 days per week for 5 weeks from early April to mid May. At the lower site, a floating rotary trap was operated 3 to 5 days per week for 15 weeks from April to July. Rotary trap efficiency for capture of chinook young-of-year was tested at a range of streamflows by operation of a weir that spanned the channel 60 m downstream of the rotary trap. Snorkel survey results determined 1988 chinook spawner escapement was, at minimum, 286 adults. High streamflows, bedload movement, and animal predation limited redd and carcass identifications to 25 and 27, respectively. Outmigrant trap results demonstrated that chinook production occurs above the upper trap site and an estimated 51,096 chinook young-of-year passed through the lower trap site from April to July. Steelhead trout (O. mykiss) were the second most numerous salmonid present in Blue Creek. Steelhead young-of-year appeared in the traps during early April and captures peaked during late June. Steelhead smolt emigration occurred throughout the trapping season. Few coho salmon (O. kisutch) were captured. Back-calculation from the expanded number of chinook outmigrants estimated 1988 spawner escapement at 320 adults. Spawning, rearing, and general habitat surveys were initiated during fiscal year (FY) 1989 and will resume in FY 1990. A stream gaging station was established at river km 3.2 in January 1989. Gage heights and discharge measurements have been recorded periodically during FY 1989 and will continue in FY 1990.

PROGRESS REPORT FOR INVESTIGATIONS ON BLUE CREEK

First year of investigations - FY 1989

INTRODUCTION

The Klamath River basin, including Blue Creek, has historically supported large runs of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*). The basin has been altered substantially during the past century and particularly during the last four decades. During this period anadromous salmonid fishery resources have severely declined. Losses, including the quantity and quality of instream habitat and the population size of salmon and steelhead, have coincided with expanded logging and fishing operations, construction of roads and dams, water export, mining, and other development (U.S. Dept. of Interior 1985).

In response to problems associated with the anadromous fishery resources of the basin, Congress enacted P.L. 99-552, the Klamath River Fish and Wildlife Restoration Act of 1986. This legislation authorized the Secretary of Interior to restore anadromous salmonid stocks to historic levels in the Klamath River Basin. This action and subsequent restoration efforts have initiated interest in the Blue Creek anadromous salmonid stocks, particularly fall chinook salmon.

In a 1979 report detailing the status of anadromous stocks within the Hoopa Valley Reservation, the U.S. Fish and Wildlife Service (Service) found Blue Creek to have "the greatest potential to support anadromous fish of any tributary on the reservation" (Service 1979). Concerns have been raised about the restoration program's proposed actions for Blue Creek. Specifically, is there adequate population levels to allow Blue Creek to be considered a broodstock source, and if not, what can be done to rebuild habitat and populations to historic levels.

With these questions in mind, the Service's Fisheries Assistance Office in Arcata, California (FAO - Arcata) has implemented a four-year investigation and evaluation of Blue Creek in regards to the fall chinook salmon population. To date the study has gathered information on adult spawner escapement, juvenile outmigration characteristics, available spawning habitat, juvenile rearing habitat, general habitat and channel characteristics, stream discharge, and temperature regime. Proposal objectives were expanded in fiscal year (FY) 1989 to include information on the characteristics of juvenile steelhead during the outmigrant trapping program.

STUDY AREA

Blue Creek is a fourth-order stream which enters the Klamath River at river kilometer (RKM) 26.4 (Figure 1). The creek drains 329 square kms and is the largest tributary to the Klamath River below Weitchpec (RKM 64). It is noted for its clear water, sufficient summer flows, and large chinook salmon (Waterman 1920).

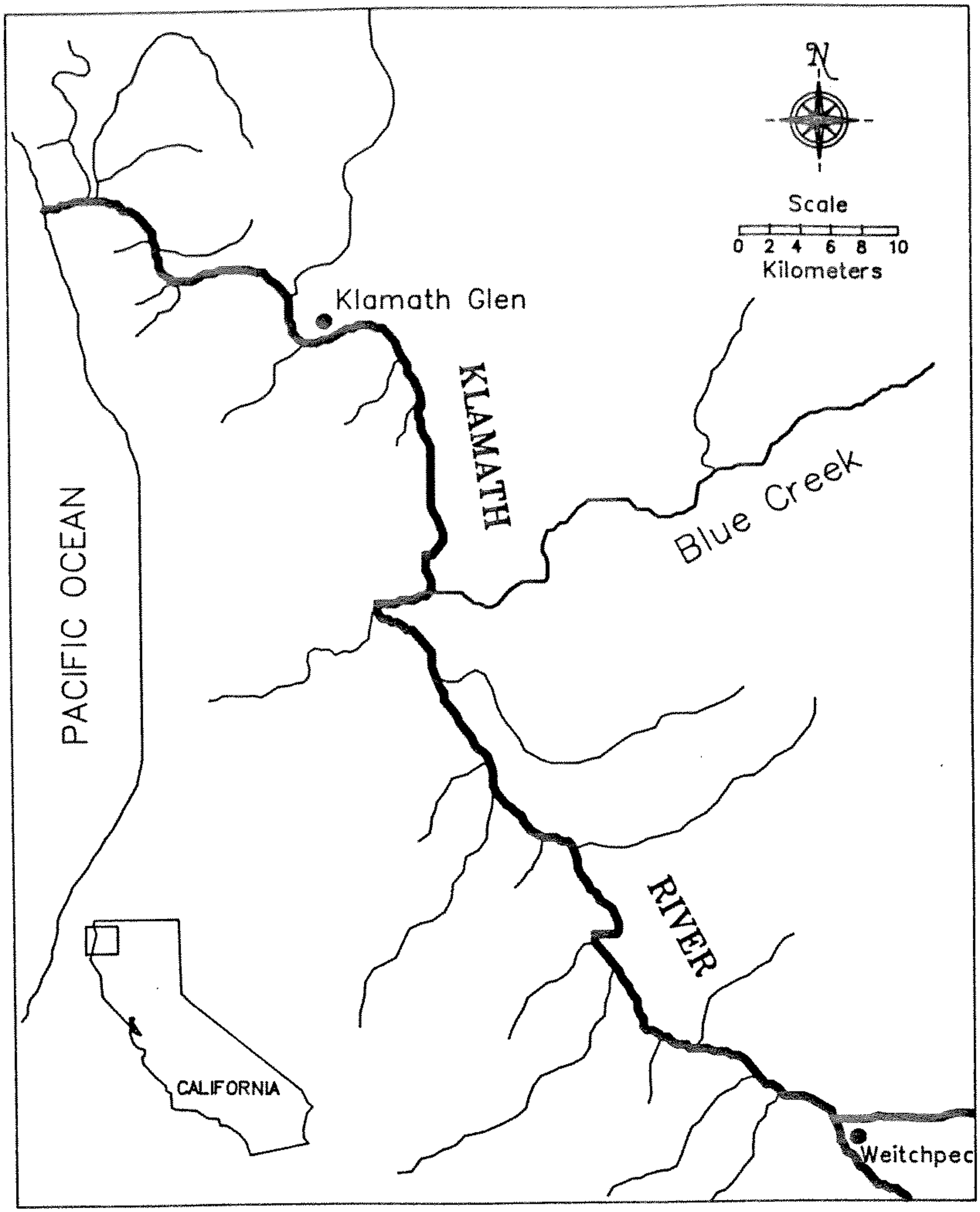

FIGURE 1. Lower Klamath River Basin with Blue Creek.

The drainage is steep and mountainous with moderate to dense timber growth of coastal redwood (Sequoia sempervirens), incense cedar (Libocedrus decurrens), Port Orford cedar (Chamaecyparis lawsoniana), Douglas fir (Pseudodtsuga menziesii), tanoak (Lithocarpus densiflora), and madrone (Arbutus menziesii). Riparian species include alder (Alnus sp.), willow (Salix sp.), California laurel (Umbellularia californica), and big leaf maple (Acer macrophyllum).

As with many of the tributaries to the lower Klamath River, extensive timber harvesting has occurred along portions of Blue Creek. Since the early 1960's, many areas on the West Fork and lower 12 kms of the mainstem have been clearcut. Timber has been removed from sections adjacent to the stream and along the upper slopes. Simpson Timber Company owns the land surrounding the lower 12.8 kms of Blue Creek and logging continues in this portion of the watershed. Upstream of Simpson Timber Company property, the creek runs through the Siskiyou Wilderness of the Six Rivers National Forest. Some of this area was logged and replanted by the U.S. Forest Service (USFS) prior to designation as "wilderness" in 1986.

Blue Creek originates at about 1500 m elevation and flows south-westerly 37 kms to its confluence with the Klamath River. The elevation at the mouth is 12 m. Annual precipitation is approximately 200 cm in the Blue Creek drainage with about 75% of it occurring during five months of the year (November - March) (U.S. Weather Bureau 1974). Precipitation runs off quickly, producing rapid fluctuations in discharge and high bedload movement.

A natural barrier to fish movements on mainstem of Blue Creek is located approximately 1.0 km below the confluence of the East Fork. This total barrier consists of a very steep boulder jammed gorge at RKM 22.8. Below the barrier, three species of anadromous salmonids occur: chinook salmon, coho salmon (O. kisutch) and steelhead trout. The mainstem and East Fork of Blue Creek above the "falls" (RKM 22.8) was planted with steelhead, rainbow trout, and eastern brook trout (Salvelinus fontinalis) during the 1930's and 40's (CDFG files, Eureka). Hereinafter, Blue Creek will refer to the lower 22 kms of stream accessible to anadromous salmonids.

Three tributaries to Blue Creek have been identified as having current and potential importance to anadromous salmonid spawning and rearing. These include the West Fork, Nickowitz Creek, and the Crescent City Fork. A fourth tributary, Slide Creek, presently has a steep gradient and a number of slides in the vicinity of the mouth, but may permit access to steelhead during high flows some years. During the summers of 1989 and 1990, the California Department of Fish and Game (CDFG) and California Conservation Corp are constructing stream habitat enhancement structures on the West Fork of Blue Creek. These structures are oriented for enhancement of coho salmon and steelhead spawning habitat (C. Harral, personal communication).

Approximately 240 m above the creek, a maintained logging road runs parallel to the stream from RKMs 3.2 to 9.6. Remnant logging roads branch off this maintained road and provide creekside access at RKMs 2.0, 3.2, 8.0, and 12.5. No road access to the watershed above RKM 12.5 is available due to its inclusion in the Siskiyou Wilderness Area. Service personnel have accessed Blue Creek RKMs 12.5 to 22.8 by wading upstream and by U.S. Coast Guard helicopter. During

FY 1990, a portion of an old path will be cleared by California Conservation Corp crews that will provide trail access between RKMs 12.5 to 16.1.

The Blue Creek watershed is underlain by four major rock types of the Coastal Range and Klamath Mountains provinces. Proceeding upstream from the mouth, Blue Creek flows through sandstone and shale of the Franciscan Complex; ultramafic rocks (serpentinized peridotite) of the Josephine Ophiolite; slate, metagraywacke, and greenstone of the Galice Formation; and an assemblage of diverse rock types (mostly metasedimentary) of the Western Paleozoic and Triassic Belt (Wagner and Saucedo 1987). The streambed substrate is generally composed of small and large cobble. Stream gradient averages 1.4 percent in the lower 22.8 kms.

MATERIALS AND METHODS

Adult Chinook Salmon Investigations

Chinook redd, carcass, and live adult snorkel surveys were conducted simultaneously from October 18 through January 5. Limited stream access dictated division of the lower 16 kms of Blue Creek into 5 survey reaches (Figure 2). We attempted to survey the 4 lower reaches weekly with a two person crew, one person on each bank; however storm events precluded survey of all reaches during some weeks.

Redds

All spawning areas were plotted on maps. Habitat unit types selected for redd construction were grouped into one of 22 categories originally described by Bisson, et al. (1982) and later modified by Decker (1986) (Table 1). Redd lengths and widths (tailspin and mound) were measured to the nearest 0.1 meter. Presence and activities of adult fish were noted.

Carcasses

All salmonid carcasses were recovered, classified to species, and sexed. Fish were also examined for percent of reproductive products spent, fin clips, and predation by animals. Fork lengths were measured to the nearest cm and scale samples collected. Once examined, color-coded hog rings were applied to the lower jaw of all intact carcasses for mark-recapture population estimation. Marked carcasses were returned to the site of recovery.

Live counts

Underwater direct observation and enumeration of adult salmonids were conducted regularly at a number of pools in each survey reach. On four occasions, streamflow and visibility conditions permitted systematic surveys of an entire reach. During the four complete surveys, two divers in wetsuits and snorkel gear dove all pools and deep runs in one reach. When necessary, the stream was divided into two lanes with each diver counting fish in a lane. Pools were surveyed in an upstream direction. Runs were surveyed downstream since water velocities generally prohibited moving upstream. All adult salmonids were identified to species, enumerated, and jacks differentiated.

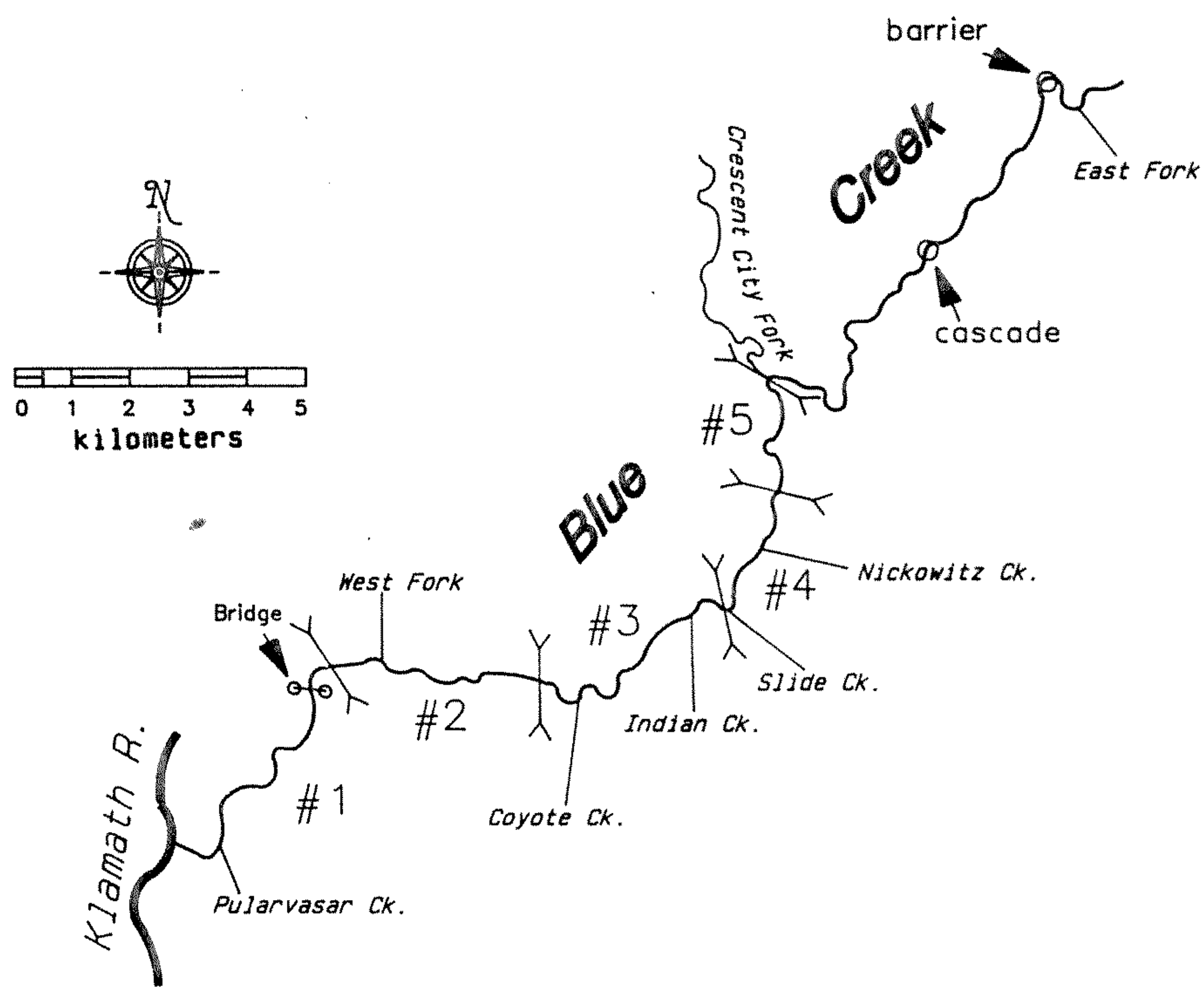

FIGURE 2. Blue Creek with spawning ground survey reaches, fall 1988.

TABLE 1. List of 22 specific habitat types (Bisson, et al. 1982, modified by Decker, 1986)

Number	General Type	Specific Type	Abbreviation
1	riffle	low gradient < 3%	LGR
2	riffle	high gradient > 3%	HGR
3	riffle	cascade	CAS
4	pool	secondary channel	SCP
5	pool	backwater boulder formed	BPB
6	pool	backwater root wad formed	BPR
7	pool	backwater log formed	BPL
8	pool	trench	TRP
9	pool	plunge	PLP
10	pool	lateral scour (log)	LSL
11	pool	lateral scour (root)	LSR
12	pool	lateral scour (bedrock)	LSBk
13	pool	dammed	DPL
17	pool	main channel	MCP
19	pool	confluence	CCP
20	pool	lateral scour (boulder)	LSBo
22	pool	corner	CRP
14	flat water	glide	GLD
15	flat water	run	RUN
16	flat water	step run	SRN
18	flatwater	edgewater	EDW
21	flat water	pocket water	POW

Live counts of adults were used to estimate spawner escapement. A second estimate of chinook spawner escapement was computed from the juvenile trapping program's expanded number of outmigrant chinook (see outmigrant trap methods below).

Juvenile Salmonid Investigations

Outmigrant traps

Emigrating juvenile salmonids were sampled at two sites on Blue Creek (Figure 3) with two trap types. At RKM 12.6 (upper trap site), a 1.5 x 3 m frame net (0.48 cm delta mesh) with 2 live boxes in tandem attached to the cod end of the net was set for 13 nights between April 12 and May 11. At RKM 2.1 (lower trap site), a floating rotary trap (Figure 4) operated for 64 nights between April 10 and July 21. The circular aperture of the rotary trap has a diameter of 2.44 m and was set at its maximum depth of 1.22 m. In general, a trap night encompassed a 24 hour period from one morning to the next. Traps were operated through the night based on observations by Hoar (1953) and Reimers (1973) that juvenile salmonids migrate under the cover of darkness. Captured fish were removed from live boxes early each morning to minimize holding and temperature induced stress. On several occasions, live boxes were examined at dusk to record captures during daylight hours. The 1989 trapping season in terms of calendar weeks is summarized in Table 2.

All fish removed from the traps were classified to species and enumerated. Up to 50 individuals from each salmonid species and age class were measured daily for fork length (to the nearest mm) and displacement volume (ml). Juvenile steelhead trout were classified in the field as young-of-year (yoy), parr, or smolts. Steelhead yoy were determined by their small size and smolts by external characteristics (e.g. silvery coloration, black fin tips, lack of parr marks). Steelhead age classes 1+ (yearlings) and 2+ (2 year olds) were determined by scale analysis and length frequency distribution.

Chinook production

Efficiency of the rotary trap for chinook capture was determined by the following method to facilitate a season production estimate. On 22 nights, a second 1.5 x 3 m frame net (0.48 cm delta mesh) with 2 tandem live boxes was fished at the lower trap site concurrently with the rotary trap. Weir panels, constructed of 0.64 cm hardware cloth mounted on wooden frames, were placed acro s the channel to completely block off the stream and funnel fish into the frame net. This full weir was placed 60 m downstream of the rotary trap. It was assumed that during a given night all downstream migrating salmonids were captured by either the rotary trap or the weir. Rotary trap efficiency at a given discharge was calculated as:

$$E_i = R_i \;/\; (W_i + R_i)$$

where E_i = efficiency of the rotary trap for chinook yoy capture at discharge i, R_i = the actual number of chinook yoy captured in the rotary trap during a trap night at discharge i, and W_i = the actual number of chinook yoy captured

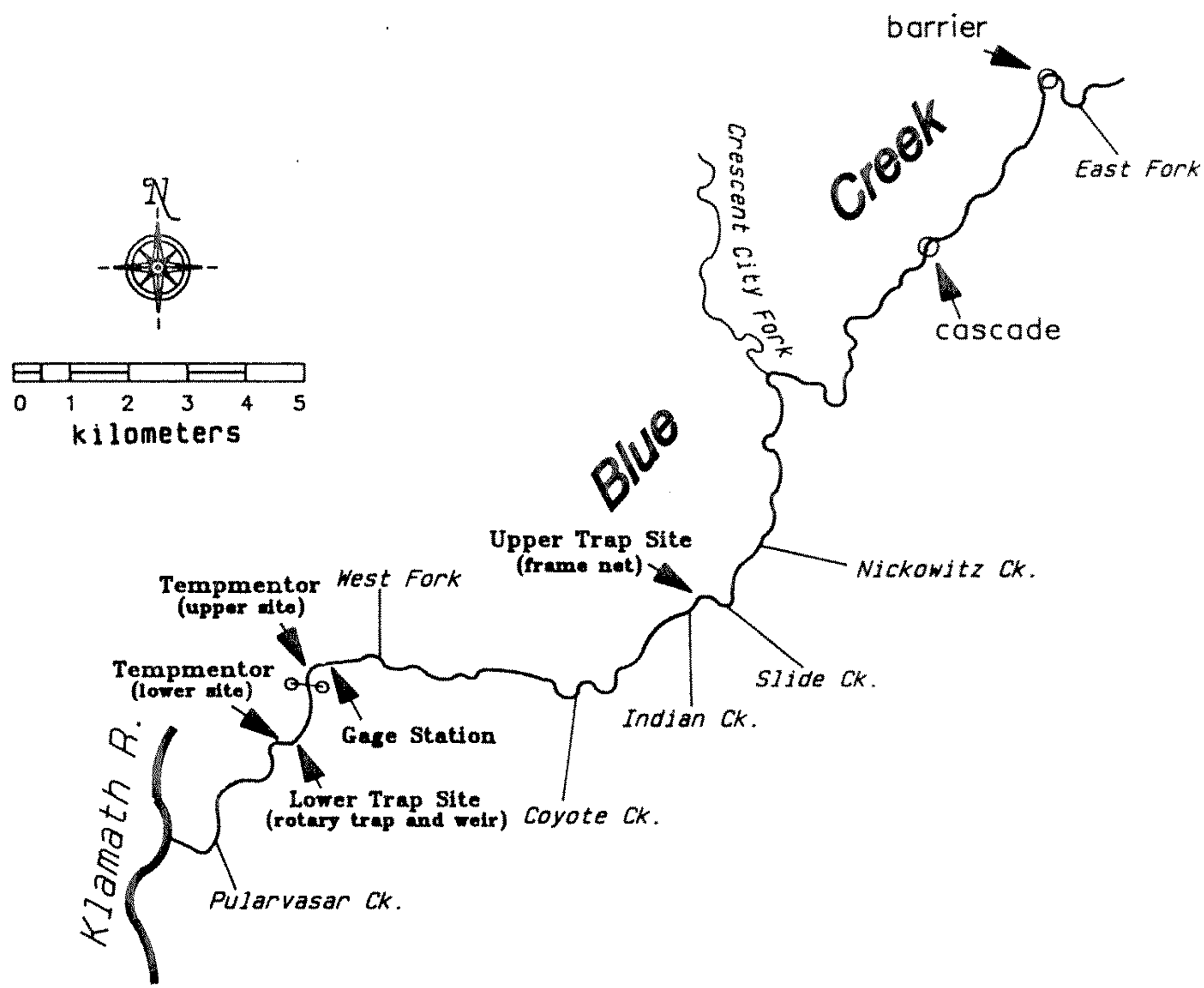

FIGURE 3. Blue Creek outmigrant trap sites, gage station, and tempementor sites, FY 1989.

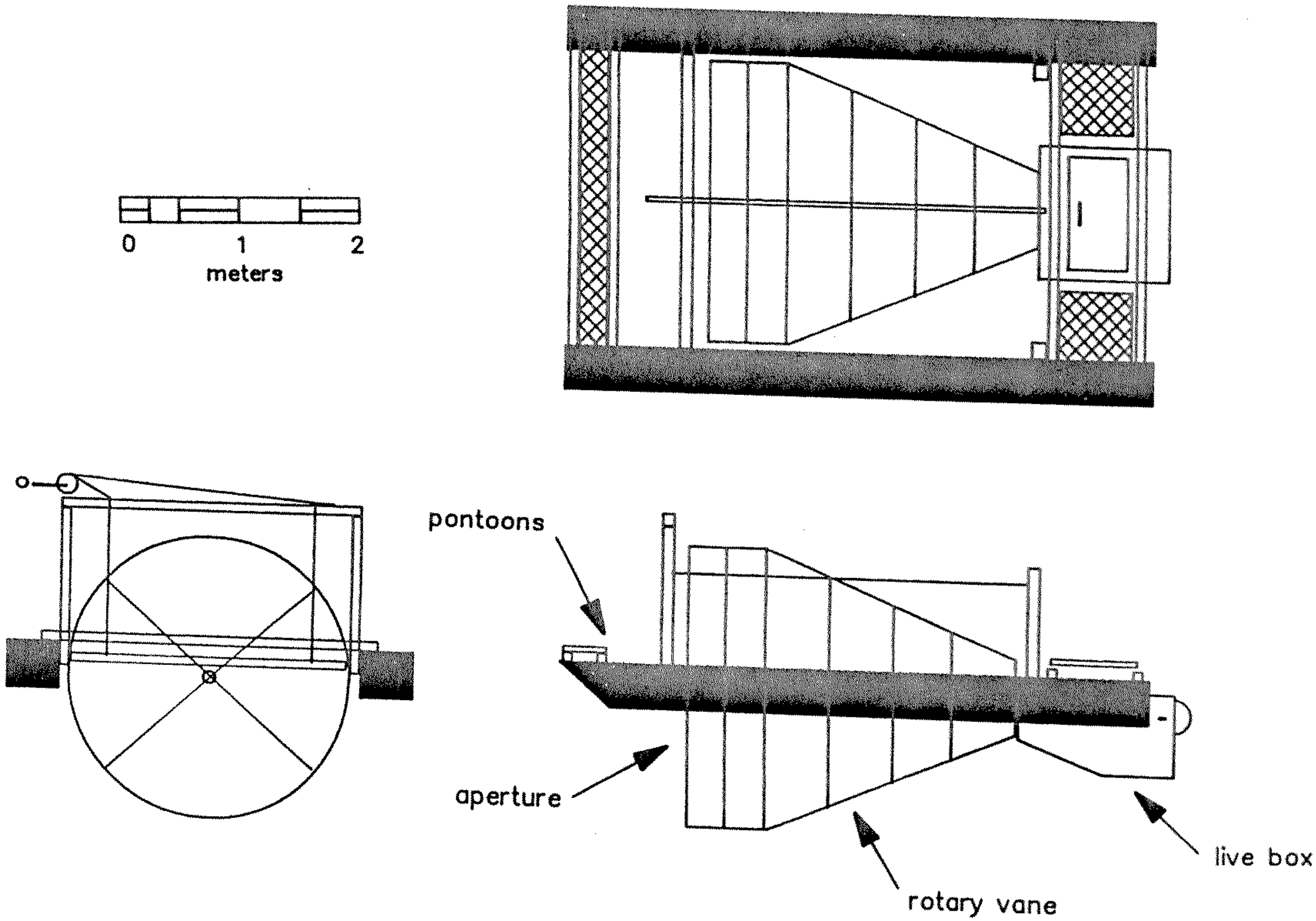

FIGURE 4. Rotary trap diagram.

TABLE 2. Spring 1989 outmigrant trap season.

Trap Week	Calender Week
1	April 9 – 15
2	April 16 – 22
3	April 23 – 29
4	April 30 – May 6
5	May 7 – 13
6	May 14 – 20
7	May 21 – 27
8	May 28 – June 3
9	June 4 – 10
10	June 11 – 17
11	June 18 – 24
12	June 25 – July 1
13	July 2 – 8
14	July 9 – 15
15	July 16 – 22

in the weir during a trap night at discharge i. Linear regression analysis was used to establish a relationship between rotary trap efficiency and stream discharge. Estimations of rotary trap efficiency for each trap night were made with the regression model from daily records of stream discharge. All salmonids captured by the weir were sampled by the methods described above. Student's t-tests were used to compare chinook fork lengths between the weir and rotary trap.

Mark-recapture methods for determination of rotary trap efficiency were also attempted. Chinook yoy were marked by fin clip, Bismarck Brown Y stain, or fluorescent pigment. Marked fish were released 800 m upstream. Results were less than satisfactory from the mark-recapture experiments; therefore, only the aforementioned relationship between captures at the weir and rotary trap were used for establishing trap efficiency.

Expanded estimates for the total number of chinook yoy emigrating through the lower trap site each trap night were calculated as:

$$T_n = R_n / E_n$$

where T_n = total number of chinook yoy emigrating through the lower trap site on trap night n, R_n = actual number of chinook yoy captures in the rotary trap on trap night n, and E_n = rotary trap efficiency on trap night n. With expansion by week for non-trap days, the total number of chinook yoy emigrating through the lower trap site during the trapping season was estimated. ANOVA and Student's t-tests were used to compare the expanded daily estimates of chinook outmigration between phases of the lunar month, weather, and stream temperature.

The chinook yoy production estimate was then used to back-calculate 1988 chinook spawner escapement using the equation:

$$S = (T / V \times F) \times R$$

where S = estimate for male, female, or jack spawners, T = the expanded estimate of chinook yoy emigrating through the lower trap site during 1989 season, V = the survival of chinook egg to fry stage using an average estimate from Bogus Creek, tributary to the Klamath River (9.2%), F = the fecundity for adult fall chinook females in the Klamath River (n = 3,634/female reported by Allen and Hassler, 1986), and R = the average sex ratio for male:female:jack fall chinook returning to hatchery racks at Iron Gate State Fish Hatchery from 1980 to 1988 (ratio = 0.838:1.0:0.254). This estimate was made under the following assumptions: 1) the estimate of chinook yoy emigrating from Blue Creek is reliable, 2) survival of chinook fry from egg to fry stage in Blue Creek was similar to that in Bogus Creek, and 3) sex ratios for fall chinook in Blue Creek were similar to average ratios observed at hatchery racks in Iron Gate State Fish Hatchery.

Coded wire tagging

Coded wire tags (CWT) were applied to chinook yoy at the lower trap site throughout the course of the emigration season. The field CWT station consisted of a large canvas army surplus tent, a gasoline-powered generator, a gasoline-powered water pump, and a tagging machine/quality control device manufactured by Northwest Marine Technology. Six word half tags were applied to chinook yoy captured by the weir and rotary trap two or three days per week. A random sample of approximately 100 CWT fish were held as a control each week. Mortality and tag retention rates were obtained from each control group 24 to 144 hours after tagging. All other tagged fish were released within a few hours of tagging. Mortality and retention rates from weekly samples were applied to the total number of tagged fish released during the week.

Salmonid Habitat Investigations

Discharge

A stream gaging station was established at RKM 3.2 (Figure 3). The gaging station consists of a staff gage fastened with anchor bolts to bedrock and a crest gage. The crest gage is a 3.8 cm diameter clear plastic tube attached to the staff gage. Burnt cork particles floating on the water surface inside the tube rise with river stage and adhere to the sides of the tube as the stage drops. The remaining ring of cork leaves a record of the highest stage attained between readings. Staff gage readings were recorded daily during each work week.

Weekly measurements of stream discharge were made at the gage site with a Price AA current meter and top-setting rod. Linear regression analysis was used to establish a log-log relationship between gage height and discharge. The regression model was used to compute a discharge rating table for the staff gage at this site.

Temperature

A Ryan tempmentor model #RTM was deployed at two sites on Blue Creek (Figure 3). During the period of low streamflow from May to October, the tempmentor unit was placed instream at RKM 2.1. During the period of high streamflow from November to April, a remote probe was used in conjunction with a shore stationed tempmentor unit at RKM 2.9 Temperature readings were recorded continuously at 2 hour intervals in both locations.

Rearing habitat

Juvenile salmonid rearing habitat was assessed during the late spring succeeding emergence of fry. Beginning in early May, 100 m long reaches were surveyed downstream every 500 m. Survey reaches began on the mainstem at RKM 19.5 and continued to the mouth. Within each measured reach the following physical parameters were recorded: mean width, mean depth, maximum depth, habitat types present (Table 1), dominant habitat type, percent instream cover, dominant cover type, substrate composition, and quantity and quality of rearing habitat available for yoy and juvenile salmonids. Prior to these physical measurements, every other 100 m reach was snorkeled by two divers for enumeration of salmonids. Snorkel counts identified all salmonids to species, year class, and location within the stream channel (edge, intermediate, or thalweg). To date, 19.5 kms of the Blue Creek mainstem has been surveyed.

The remainder of the mainstem to RKM 22.0 will be surveyed during FY 1990. Analysis and results of all rearing habitat assessment surveys will be presented in the FY 1990 Blue Creek Progress Report.

Spawning habitat

Available spawning habitat for chinook was assessed to RKM 14.5 during FY 1989. Spawning habitat was evaluated in locations considered traditional excavation sites for chinook redds (pool-riffle interchange, runs, and deep riffles). Along three transects (upper, middle, and lower) within each site, three to five cells were established. Within each cell, the stream bottom substrate was optically grouped by percent composition into 5 size categories (fines, small gravels, large gravels, small cobble, and large cobble) and water depths were recorded. Surface area considered suitable for chinook spawning was calculated in square meters. The remainder of the mainstem to RKM 22.0 and the Crescent City Fork will be surveyed during FY 1990. Analyses and results of all available spawning habitat surveys will be presented in the FY 1990 Blue Creek Progress Report.

Habitat classification

The mainstem of Blue Creek to RKM 14.5 was habitat typed during October 1988 by methods modified from Bisson, et al. (1982). All habitat units were classified into one of 22 specific habitat types (Table 1). Each specific type is derived from one of three general habitat types; pool, riffle, or flatwater. The length of each habitat unit was measured. The minimum length of a unit was equal to the width of the wetted channel at the time of assessment.

A stratified random sampling scheme derived from Hankin and Reeves (1989) was used to obtain physical information on a subsample of the specific habitat types. Physical measurements included a unit's mean length, mean width, mean depth, maximum depth, percent shade, dominant and subdominant streambank material, percent and composition of instream cover, substrate composition, substrate embeddedness, percent substrate exposed, and percent spawning habitat. These additional physical measurements were recorded, at minimum, every fifth general habitat type (pool, riffle, or flatwater) encountered.

Blue Creek RKM 14.5 to 19.5 were habitat typed during August and September 1989 by the methods identical to that of 1988 except that physical measurements were recorded at every fifth specific habitat type to insure that all 22 types would be included in the stratified random sampling scheme. The remainder of the mainstem to RKM 22.0 will be typed by this method during FY 1990. Analyses and results of all habitat typing will be presented in the FY 1990 Blue Creek Progress Report.

Channel classification

Channel types were designated on the Blue Creek mainstem to RKM 22.8 and the Crescent City Fork to RKM 3.5 by the stream classification system developed by Rosgen (1985). Rosgen's stream classification inventory method incorporates the following channel morphological features: gradient, valley confinement, channel entrenchment, sinuosity, and dominant substrate composition. Rosgen's criteria for channel classification is outlined in Appendix E.

Water Quality

Water samples were obtained by grab collection at RKM 3.8 and RKM 13.7 during December. Samples were analyzed by USFS, Corvallis, Oregon and the EPA. Samples during summer low flow will be collected during FY 1990. Results of both analyses will be presented in the FY 1990 Blue Creek Progress Report.

RESULTS AND DISCUSSIONS

Adult Chinook Investigations

Redds

Frequent storm events during November and December created difficult survey conditions and severely limited the effectiveness of redd identification. High bedload movement rapidly obliterated surface traces of redd construction. Often redds were undiscernible within days of construction due to rising streamflows. As a result, redd counts were low.

The four lower spawning ground survey reaches were surveyed, at minimum, every other week. Reach 5 was surveyed once on December 12. A total of 25 chinook redds were identified (Appendix A). Tail-outs of bedrock lateral-scour pools were the most frequently selected habitat type for redd construction (Figure 5). Bedrock lateral-scour pools, which are common on Blue Creek, contain a significant proportion of the available spawning gravels. The average surface area of 20 redds measured was 7.6 m^2. Redds were distributed throughout the lower 16 kms of Blue Creek (Figure 6).

All redds were assumed to be constructed by fall-run chinook. Blue Creek's location, 26.4 kms upstream of the Klamath estuary, and sufficient summer streamflow permit fall-run fish early access to Blue Creek. Some chinook spawners were present in the stream at the onset of field investigations in early October. Chinook redd construction was observed from mid-October through mid-December. Spawning activity occurred in two distinct peaks. The first peak, during late October, was prior to the commencement of fall rains but coincided with a drop in stream temperature. The second peak occurred during early December following a week of heavy rains and bankfull discharge in late November. The discovery of a freshly spent female chinook carcass on February 1 suggests some chinook spawning activity continues during January.

Carcasses

Chinook carcass recovery was poor due to unfavorable survey conditions (high streamflows) and heavy predation by black bears (Ursus americanus) and otters (Lutra canadensis). Twenty seven carcasses were recovered from November 8 to February 1 (Appendix B). Eighteen carcasses were marked with color-coded hog rings. Only one marked carcass was recovered which did not permit use of any mark-recapture models for population estimation. One third of all recovered

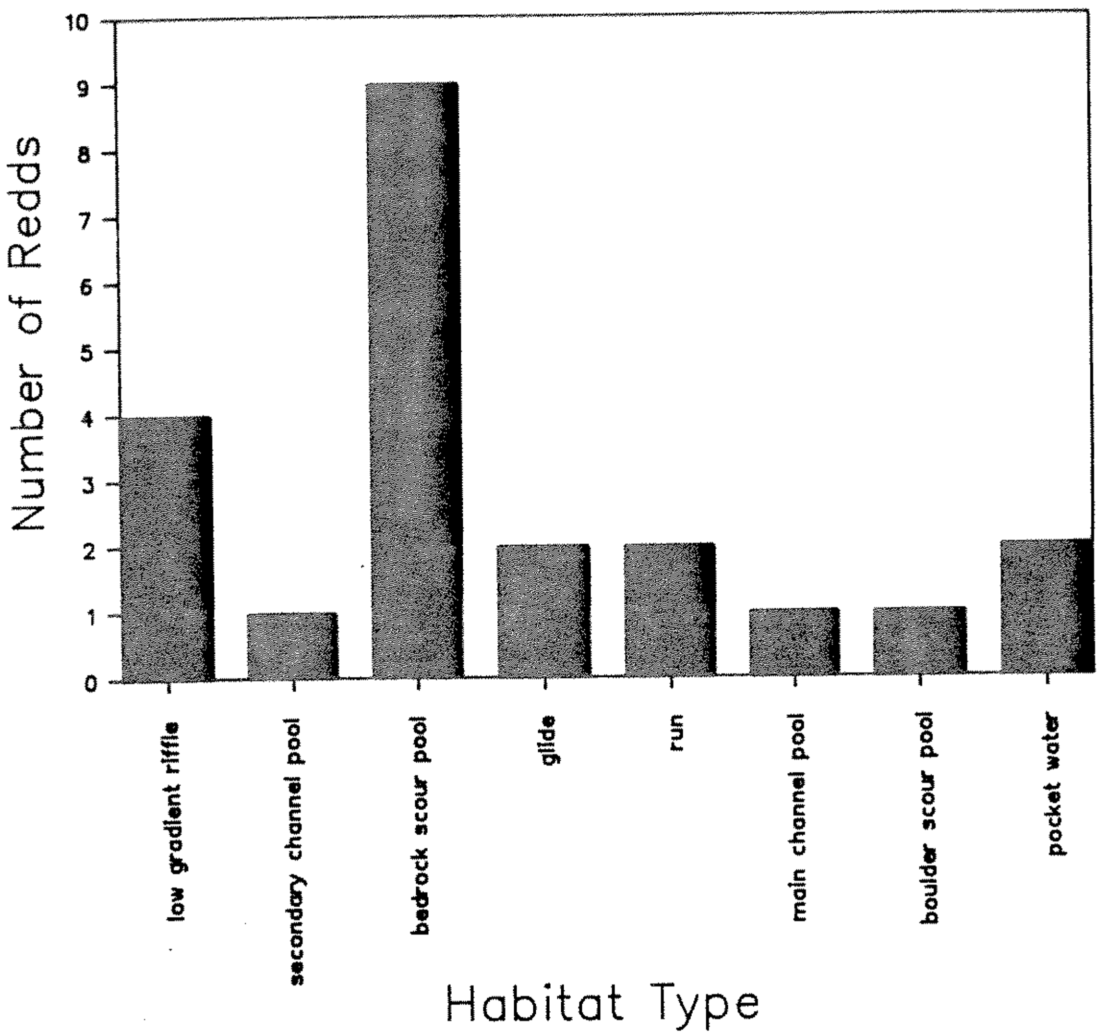

FIGURE 5. Chinook redd site selection by habitat type, fall 1988.

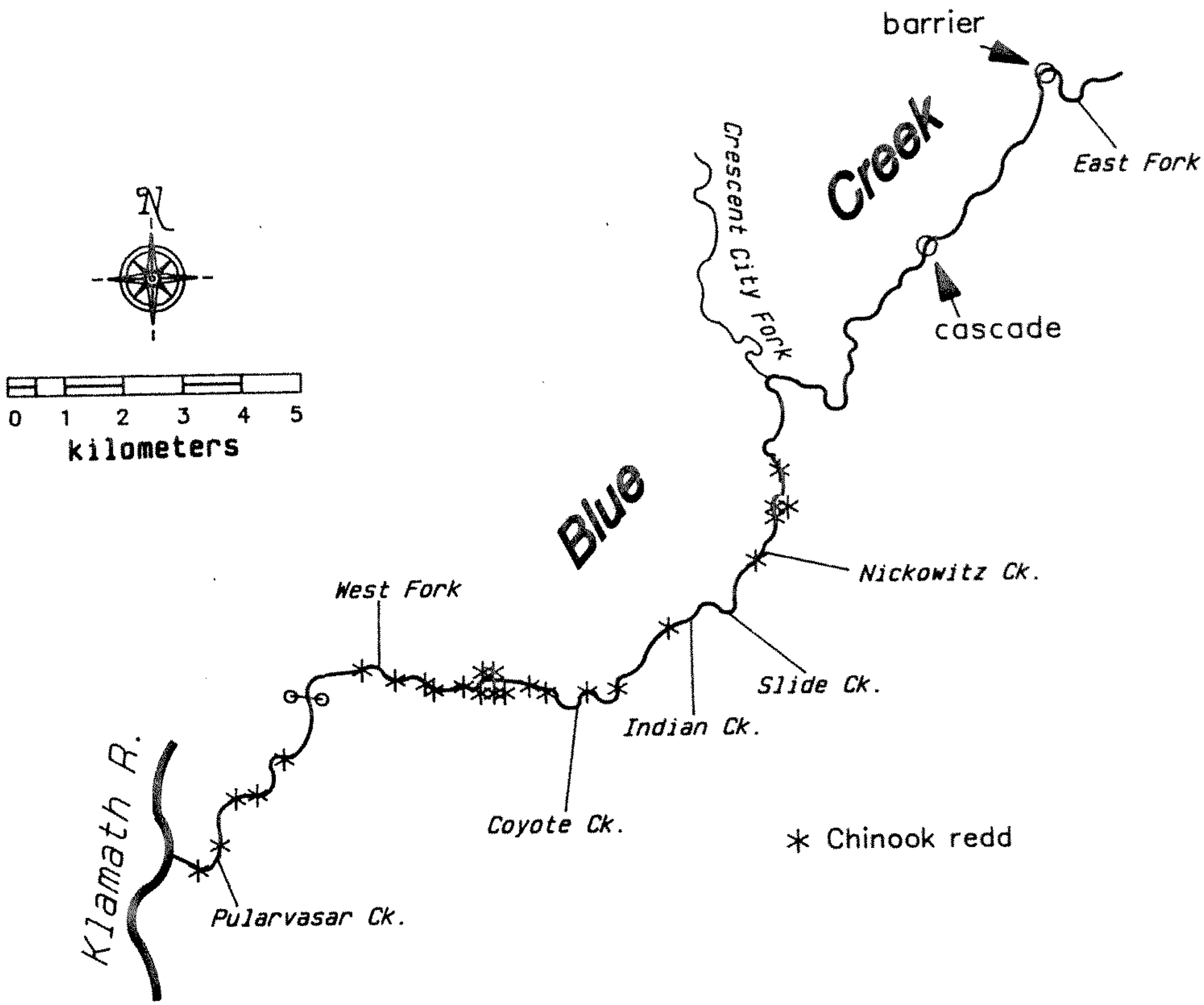

FIGURE 6. Chinook redd sites, fall 1988.

carcasses were predated by animals. Undoubtedly, the low carcass recovery rate was partially due to scavenging by animals. Stream banks in all survey reaches displayed numerous bear tracks that thoroughly combed both shores for the duration of the spawning season.

Live counts

Snorkel counts of salmonid adults were conducted regularly throughout the chinook spawning season. On all except four dates, high streamflows and turbidity severely limited our ability to thoroughly survey entire reaches. Although we were not always able to accurately enumerate adult spawners, monitoring of general movements through the lower creek and into spawning areas was accomplished. Chinook spawners probably enter the stream from August to December with peak immigration occurring during late October or early November. Numbers of adult salmonids observed during the four complete snorkel surveys are presented in Table 3.

A minimum estimate for 1988 chinook escapement was obtained from snorkel counts conducted on November 8 and 9. This estimate of 286 chinook spawners is probably conservative since only the lower 9.6 kms of stream were surveyed. Counts prior to November 8 indicated that increased streamflow on November 3 probably attracted the majority of the fall-run chinook into lower Blue Creek.

Juvenile Salmonid Investigations

Upper outmigrant trap

A summary of total salmonid captures by week is presented in Table 4. Mean fork length of chinook yoy increased from 39.7 mm in week 1 to 41.8 mm in week 5 (Figure 7). Mean fork length of steelhead yoy increased from 28.2 mm in week 3 to 31.2 mm in week 5 (Figure 8).

Chinook were captured the first night of trapping. No chinook yearlings were captured. Steelhead yoy did not appear until trap week 3 and were very few in number until the last night of trapping. A small number of coho yoy were captured at this site. The absence of steelhead age 2+ and the few age 1+ revealed the limitations of the frame net trap. When the trap is set in moderate velocity water to capture salmonid fry, larger age 1+ and 2+ fish can swim out the net. If the trap is set in faster water, smaller size fish traveling down stream margins may be missed. For our purposes, the trap was placed a few meters from the bank in moderate velocity water which served to maximize efficiency for capture of chinook yoy. Chinook represented 91.9% of the salmonids captured at this site. Installation of a fyke within the frame net may substantially improve the trap's efficiency for capture of larger fish.

Trap operations at this site were terminated on May 11 due to manpower constraints. Five weeks of trapping did confirm that chinook production occurs upstream of RKM 12.5 and this area must be included in future investigations. Other species captured in the frame net at this site included sculpins (Cottus spp.), Pacific lamprey ammocoetes (Lampetra tridentata), Pacific giant salamander (Dicamptodon ensatus), California newt (Taricha torosa), and Western toad tadpoles (Bufo boreas).

TABLE 3. Salmonid adult live counts, fall 1988.

Date	Reach	# Chinook	Steelhead
11/08/88	1	21	3
11/09/88	2	265	11
12/05/88	4	3	0
12/19/88	2	3	0
12/19/88	3	1	0

TABLE 4. Frame net (upper trap site) salmonid captures, spring 1989.

Trap Week	Trap Nights	Chinook 0+	SH 0+	SH 1+	SH 2+	Coho 0+	Coho 1+
1	3	130	0	3	0	2	1
2	1	16	0	0	0	0	0
3	4	236	6	1	0	5	0
4	4	490	33	3	0	12	0
5	1	88	18	0	0	0	0
Total	13	960	57	7	0	19	1

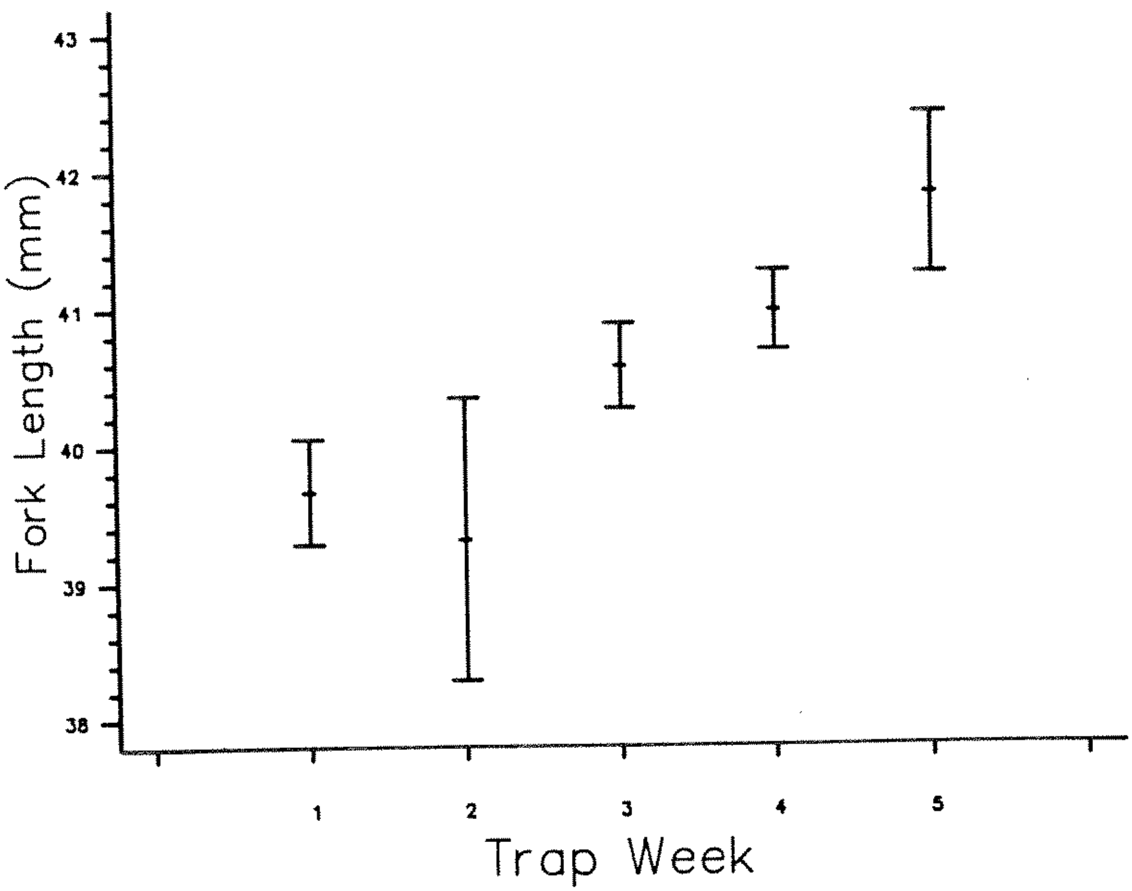

Figure 7. Mean fork lengths and 95% confidence intervals for chinook young-of-year at the frame net (upper trap site), spring 1989.

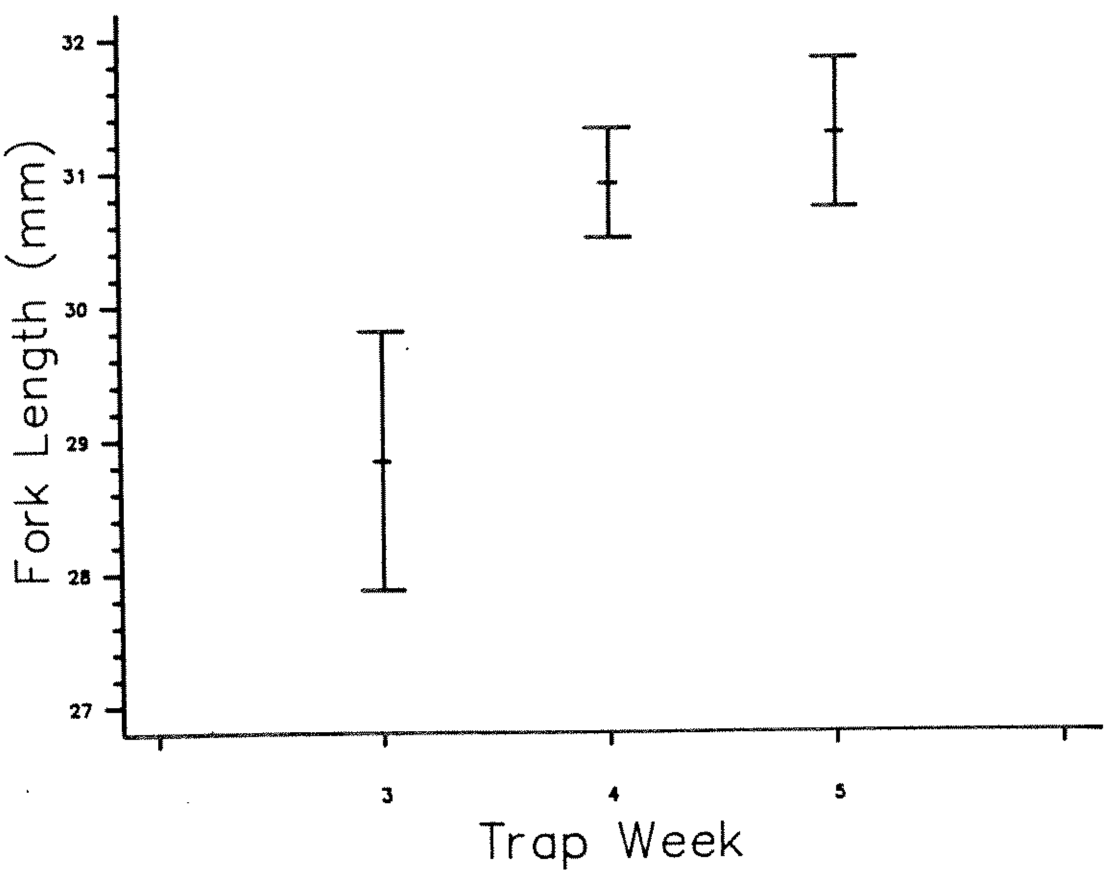

FIGURE 8. Mean fork lengths and 95% confidence intervals for steelhead young-of-year at the frame net (upper trap site), spring 1989.

Lower outmigrant trap

A summary of total salmonid captures by week is presented in Table 5. Mean fork length of chinook yoy increased from 41.3 mm in trap week 1 to 77.9 mm in week 15 (Figure 9). Chinook represented 91.7% of the salmonids captured by the rotary trap. No chinook yearlings were captured. Chinook emigration peaks and patterns are discussed below in the section on chinook production.

Steelhead trout were the second most numerous salmonid captured by the rotary trap. Steelhead fry first appeared in the trap during week 4. During 1987, the Service reported the first appearance of steelhead fry was during late April, our trap week 3 (Service 1988). The peak capture of steelhead yoy occurred during week 12. This peak corresponded with heavy rains and the resulting increased streamflow during trap week 12.

Mean fork length of steelhead yoy increased from 33.0 mm in week 5 to 61.5 mm in week 15 (Figure 10). Steelhead length frequency analysis (rotary trap and weir captures) determined a fork length of 145 mm as a general season cutoff for ages 1+ to 2+ steelhead juveniles (Figure 11). Scale analysis confirmed the length frequency estimated cutoff was accurate for steelhead during the first 9 weeks of trapping, however some overlap of sizes between cohorts occurred during weeks 10 to 15. Overlapping sizes of age classes would be expected during the latter portion of the spring due to renewed growth by age 1+ and the variability among individual age 2+ fish. Although some overlapping of modes occurred at the end of the season, the amount was minimal and a season cutoff of 145 mm was utilized for age class analysis.

Steelhead smolts emigrated at a relatively steady pace through the trap season; although the age composition of smolts shifted dramatically. During the first week of trapping, age 1+ steelhead composed only 2% of the steelhead juveniles undergoing smoltification, however during the last week of trapping, 100% of the steelhead smolts were 1+ (rotary trap and weir captures) (Figure 12).

Coho yoy appeared in small numbers throughout the trapping period. Coho yearling emigration peaked during trap weeks 4 and 5. The Service has reported that emigration by coho yearlings in Terwer Creek during 1989 peaked in the first week of May, our trap week 4 (Service 1990). Mean fork lengths of coho yoy and yearlings are presented by week in Table 6. The few individuals of this species captured during the trapping season suggests the coho salmon run in Blue Creek is small.

Other species captured by the rotary trap included sculpins, Pacific lamprey adults and ammocoetes, speckled dace (*Rhinichthys osculus*), Klamath smallscale sucker (*Catostomus rimiculus*), threespine stickleback (*Gasterosteus aculeatus*), and the western toad.

Weir outmigrant trap

A summary of weekly total salmonid captures is presented in Table 7. Mean fork length of chinook yoy increased from 41.1 mm in week 2 to 64.4 mm in week 13 (Figure 13). Steelhead fry appeared in the weir during trap week 5 and

TABLE 5. Rotary trap (lower trap site) salmonid captures, spring 1989.

Trap Week	Trap Nights	Chinook 0+	SH 0+	SH 1+	SH 2+	Coho 0+	Coho 1+
1	5	6	0	74	45	1	7
2	4	38	0	17	14	0	6
3	4	32	0	11	4	0	0
4	5	257	1	82	46	0	25
5	5	830	1	123	46	2	22
6	3	452	0	45	17	0	16
7	4	950	7	40	10	0	7
8	3	549	11	8	3	0	0
9	4	2387	21	30	11	2	1
10	4	1266	29	31	10	2	1
11	5	1794	19	72	15	1	0
12	4	3393	127	58	10	0	2
13	4	1362	42	32	10	0	1
14	4	1280	52	24	9	0	1
15	4	258	16	7	0	0	1
Total	62	14854	326	654	250	8	90

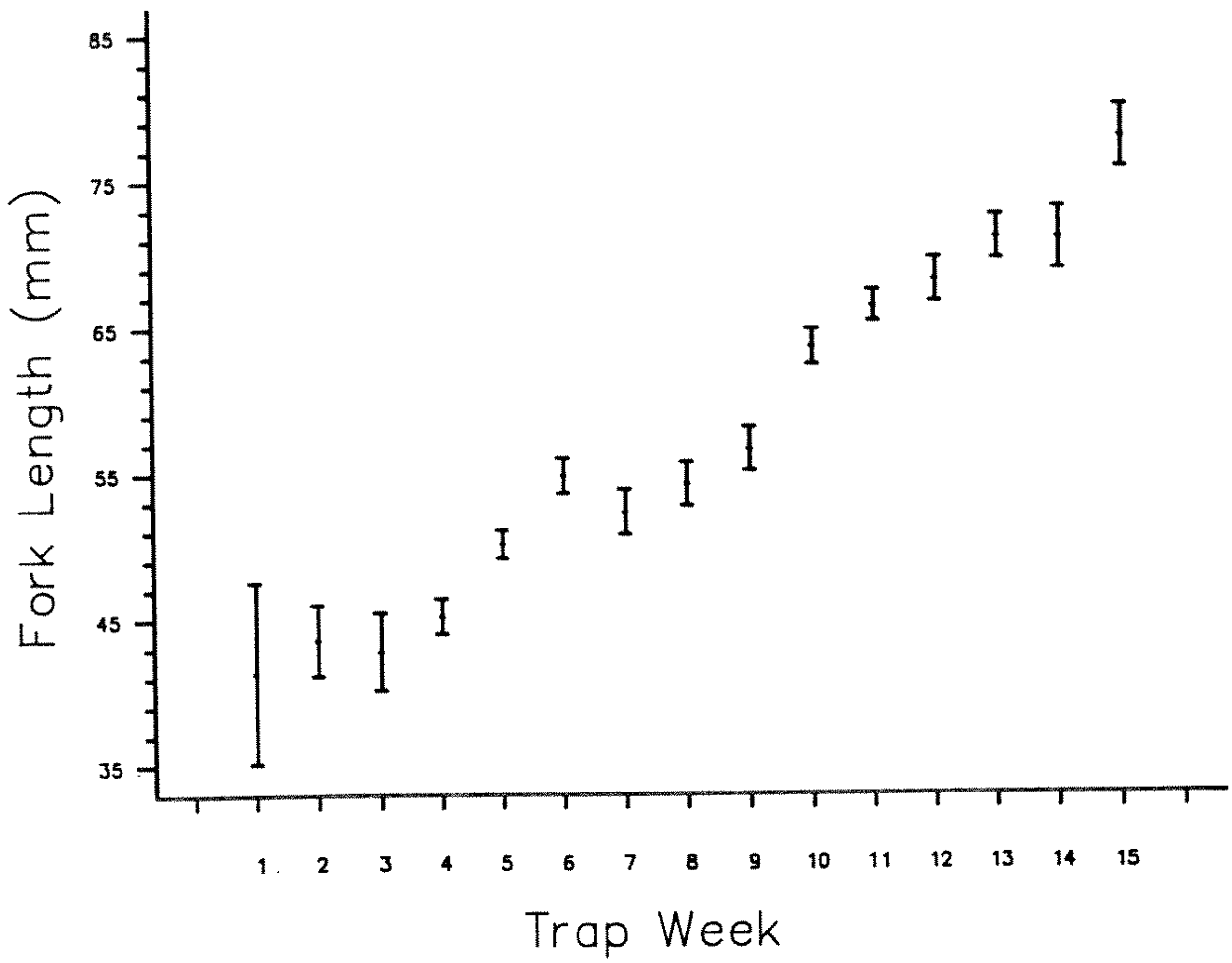

FIGURE 9. Mean fork lengths and 95% confidence intervals for chinook young-of-year at the rotary trap (lower trap site), spring 1989.

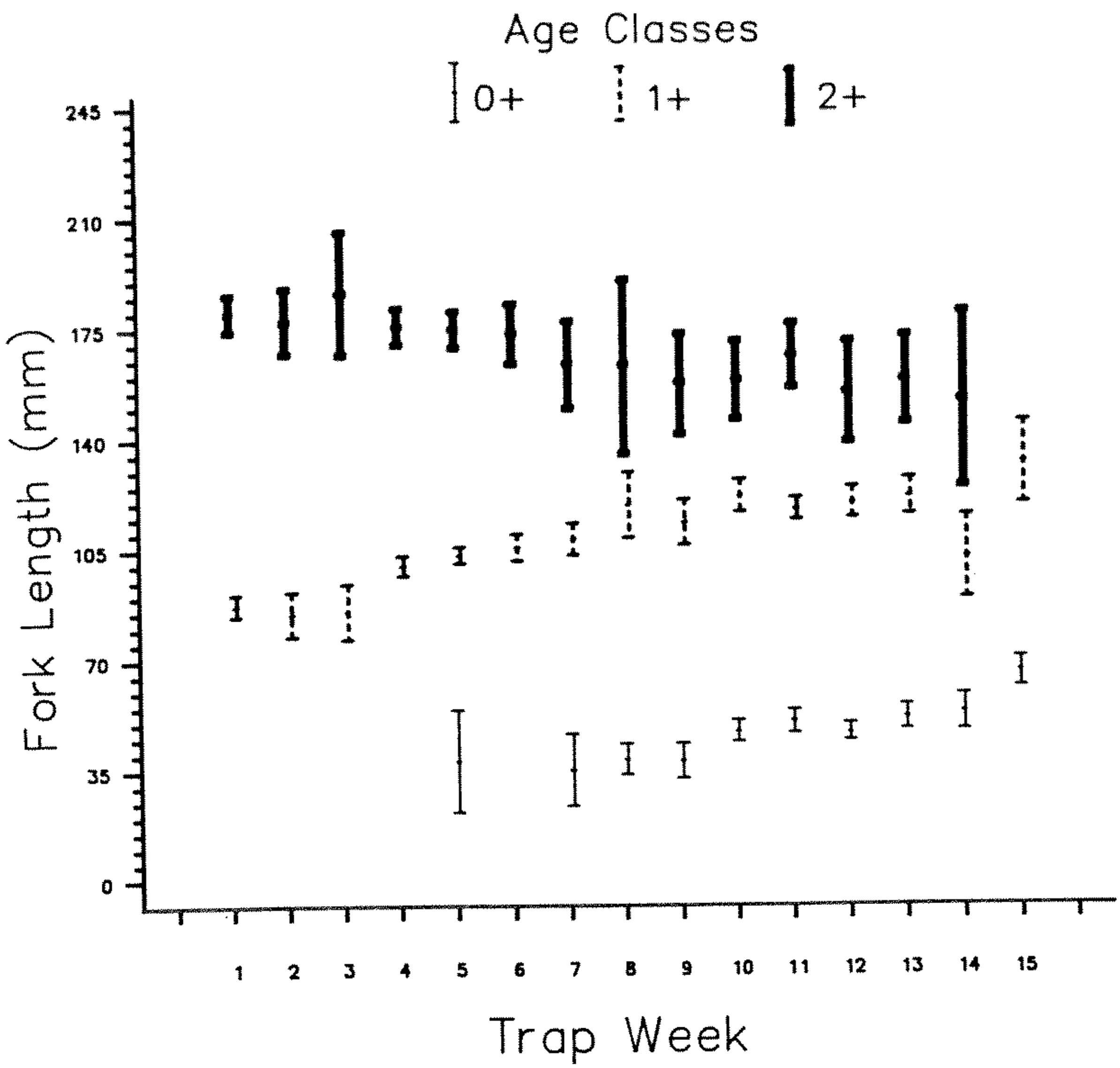

FIGURE 10. Mean fork lengths and 95% confidence intervals for steelhead at the rotary trap (lower trap site), spring 1989.

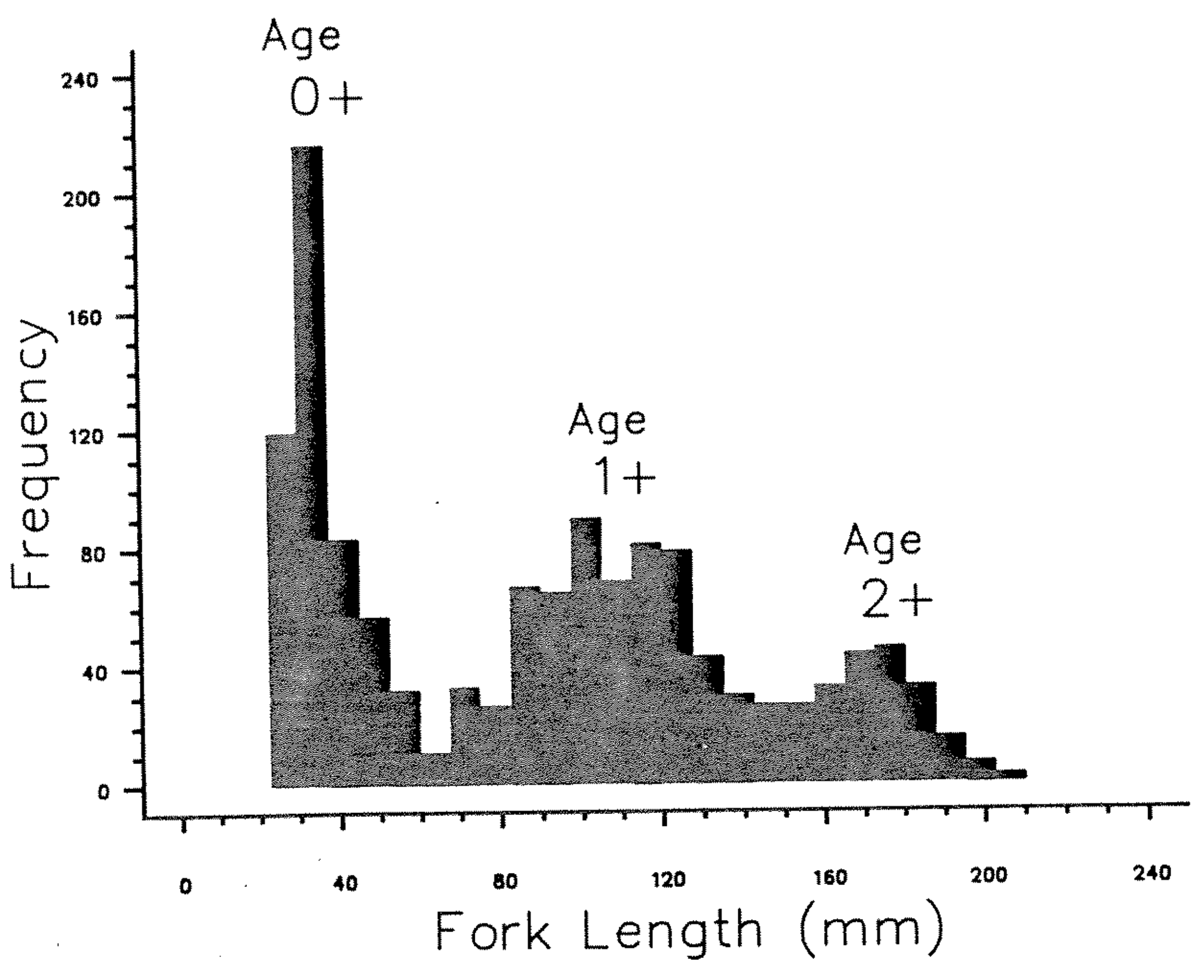

FIGURE 11. Steelhead length frequency distribution (weir and rotary trap captures), spring 1989.

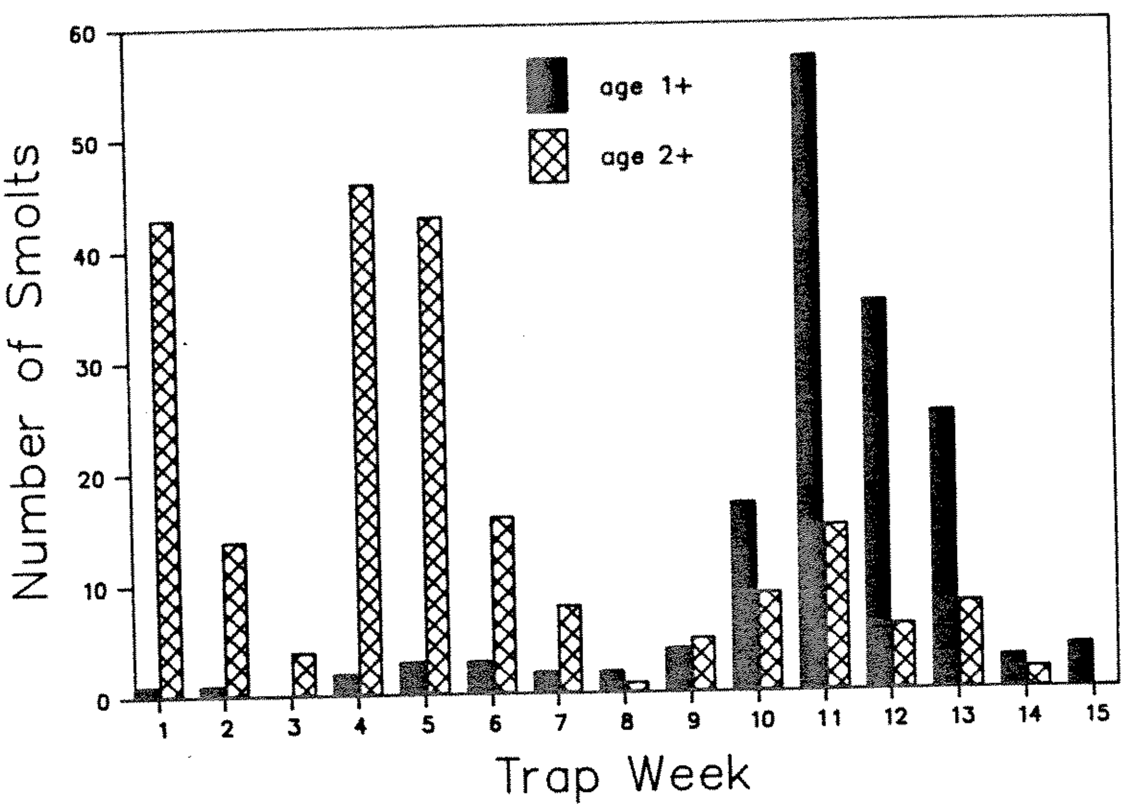

FIGURE 12. Numbers of age 1+ and 2+ steelhead smolts at the lower trap site (rotary and weir) by week, spring 1989.

TABLE 6. Coho mean fork lengths by week (rotary trap), spring 1989.

Trap Week	Coho 0+ Mean	Coho 0+ S.D.	Coho 0+ Range	Coho 1+ Mean	Coho 1+ S.D.	Coho 1+ Range
1	48.0	–	–	93.1	8.07	(79–104)
2	n/a	n/a	n/a	105.7	7.47	(97–115)
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	105.2	7.40	(94–120)
5	41.5	4.95	(38–45)	111.9	6.16	(96–122)
6	n/a	n/a	n/a	108.8	10.47	(92–126)
7	n/a	n/a	n/a	106.0	11.53	(95–118)
8	n/a	n/a	n/a	n/a	n/a	n/a
9	46.0	9.90	(39–53)	n/a	n/a	n/a
10	47.0	–	(47–47)	114.0	–	–
11	55.0	–	–	n/a	n/a	n/a
12	n/a	n/a	n/a	n/a	n/a	n/a
13	n/a	n/a	n/a	104.0	–	–
14	n/a	n/a	n/a	n/a	n/a	n/a
15	n/a	n/a	n/a	n/a	n/a	n/a

n/a = no coho captured

TABLE 7. Weir (lower trap site) salmonid captures, spring 1989.

Trap Week	Trap Nights	Chinook 0+	SH 0+	SH 1+	SH 2+	Coho 0+	Coho 1+
1	0	n/a	n/a	n/a	n/a	n/a	n/a
2	1	144	0	1	0	3	0
3	1	195	0	0	0	0	0
4	0	n/a	n/a	n/a	n/a	n/a	n/a
5	2	577	2	0	0	0	0
6	1	442	2	4	0	1	0
7	1	989	121	1	0	0	0
8	0	n/a	n/a	n/a	n/a	n/a	n/a
9	1	177	899	2	0	0	0
10	3	576	2782	8	0	1	0
11	2	157	65	2	0	0	0
12	3	1052	5387	5	1	7	0
13	2	227	433	1	0	1	0
14	2	202	368	0	0	0	0
15	0	n/a	n/a	n/a	n/a	n/a	n/a
Total	19	4738	10059	24	1	13	0

n/a = weir not operated

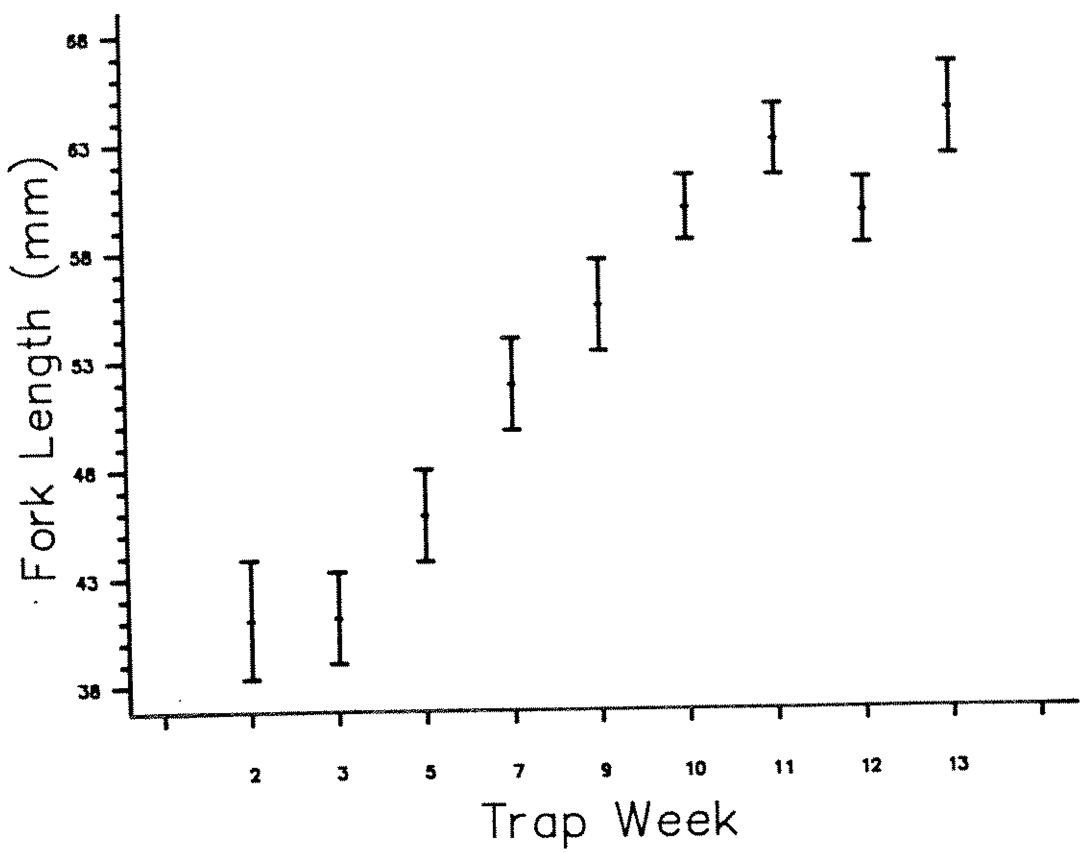

FIGURE 13. Mean fork lengths and 95% confidence intervals for chinook young-of-year at the weir (lower trap site), spring 1989.

peaked in week 12. Few coho yoy and no yearlings were captured by the weir. Other species captured by the weir include sculpins, Pacific lamprey adults and ammocoetes, speckled dace, Klamath smallscale sucker, threespine stickleback, Pacific giant salamander, foothills yellow-legged frog (Rana boylei), and the western toad.

Concerns about size selectivity of rotary trap and weir captures were substantiated by statistical analysis. T-tests showed mean fork lengths of weir-captured chinook yoy differed significantly ($P<.05$) from those captured by the rotary trap during 7 of 9 weeks. Larger chinook were captured by the rotary trap than the weir and the distribution of chinook fork lengths from the weir was skewed towards smaller fish (Figure 14). This is most likely a result of the placement of the rotary trap above the weir in the stream's thalweg. Larger size chinook migrants tend to concentrate in the midstream where current velocities are greatest (Schaffter 1980). Smaller chinook moving along the stream margins may not have been sampled effectively by the rotary trap. If the larger chinook were sorted out by the rotary trap, only the smaller fish remained in the stream to be captured by the weir below.

Another factor that could have contributed to the traps' size selectivity includes placement of the weir and design of the frame net. The weir was operating in a wide portion of the channel with moderate to low water velocities. As with the frame net at the upper trap site, larger sized fish may have been able to negotiate their way out of the net. As mentioned previously, placement of a fyke in the frame net may reduce escapement by larger fish.

Chinook production

Regression analysis established a relationship between the proportion of chinook captured by rotary trap and stream discharge (Figure 15). As stream discharge declined, a larger percentage of the stream was funneled into the rotary trap and hence, it captured a larger proportion of the outmigrant chinook population. Daily efficiency of the rotary trap was predicted by the equation:

$$E_n = 0.998 - 0.0016\ D_n$$
$$r^2 = 0.85$$

where E_n = rotary trap efficiency on trap night n and D_n = stream discharge in cfs on trap night n.

With the regression model and expansion by week for non-trap days, a season total of 51,096 chinook yoy was estimated. The expanded number of outmigrant chinook per trap night is presented in Figure 16. This estimate could be moderately conservative for several reasons: a number of fish could have emigrated prior to the commencement of the trapping program on April 11; juvenile chinook emigration continued after the termination of trap operations on July 21; and some chinook production is known to have occurred in the 2.1 kms of creek below the trap site.

During the final trap week, an estimated 570 chinook yoy emigrated out of the stream. Operation of a trap through July and August may be desirable to

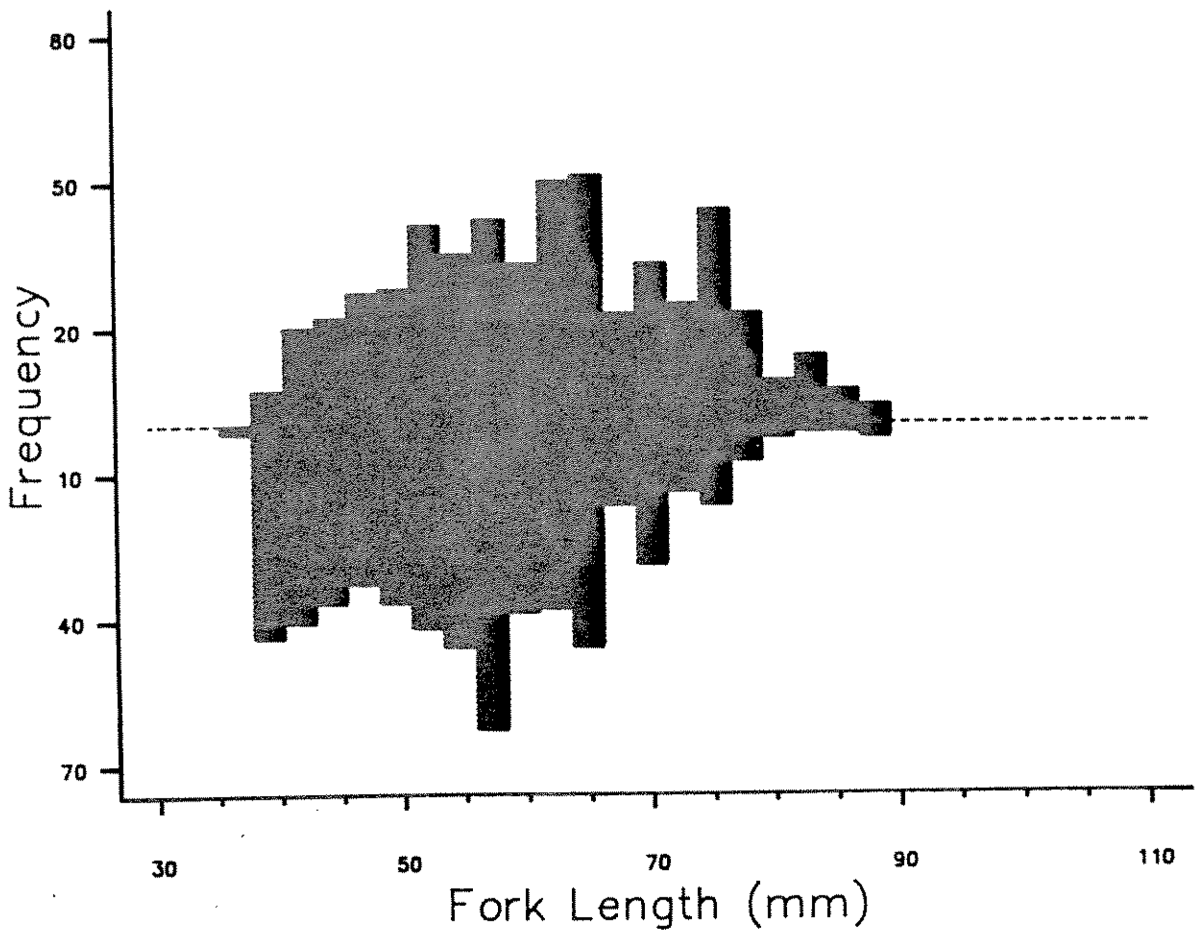

FIGURE 14. Chinook length frequency distributions from the rotary trap above dashed line) and weir (below dashed line), spring 1989.

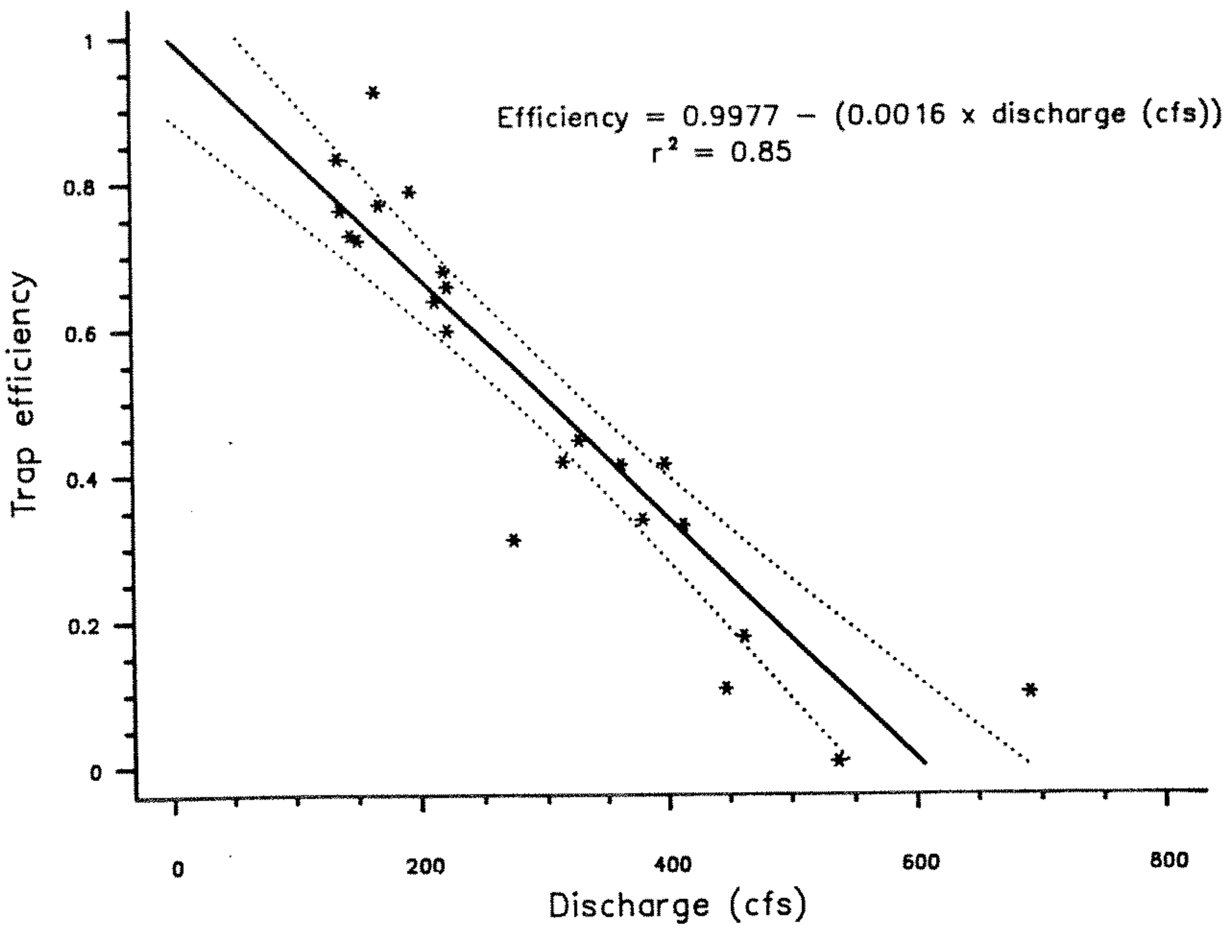

FIGURE 15. Regression of rotary trap efficiency on discharge with model, fitted line, and 95% confidence intervals, spring 1989.

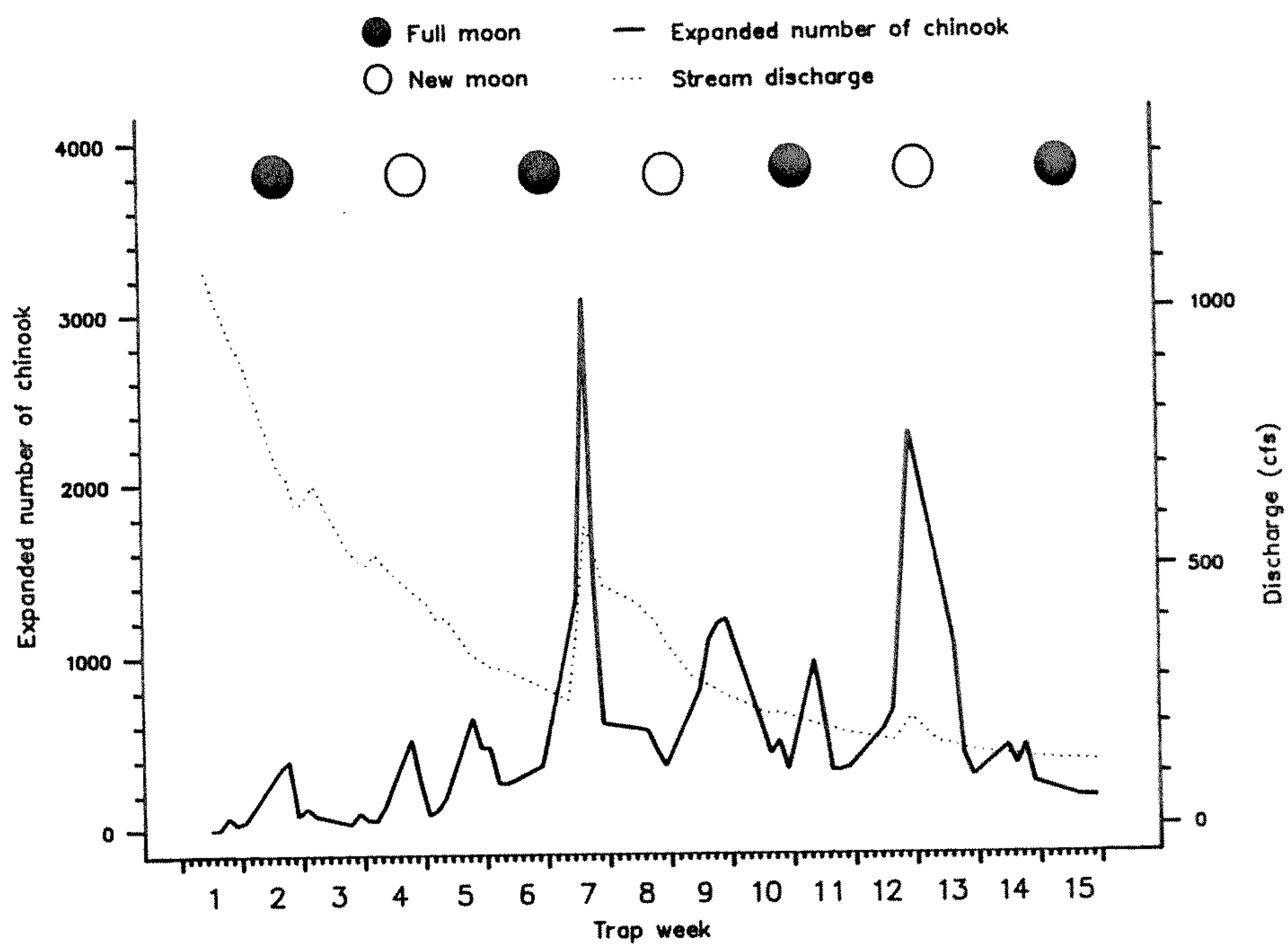

FIGURE 16. Expanded estimates of chinook outmigrants with stream discharge (cfs) and lunar phase, spring 1989.

confirm the duration and magnitude of chinook summer outmigration. In addition, potentially favorable summer rearing conditions for chinook are offered by Blue Creek's cool temperatures and sufficient summer flows. If some chinook are residing through the summer in Blue Creek and outmigrating as yearlings during the fall or winter months, they would go undetected by our current trap operations in the spring. Snorkel surveys of Blue Creek during the late summer and fall of 1990 will be conducted to establish the presence (or absence) of yearling chinook.

The two largest peaks of chinook emigration (trap weeks 7 and 12) both corresponded with two periods of increased streamflow (Figure 16). Two possible scenarios for these peaks during high streamflows are that the chinook yoy took advantage of the rising flow to emigrate or were washed downstream involuntarily. The reduction of mean fork length for chinook during week 7 (Figure 9) suggests many chinook yoy were flushed out by high flows. It is generally thought that salmonids attain a certain size prior to actively outmigrating (Shapovalov and Taft 1954). This decrease in mean fork length during week 7 and 8 implies that a component of the chinook yoy captured in the rotary trap were smaller than the desirable size for voluntary outmigration during that week.

No significant ($P<.05$) association with weather, temperature, or lunar phase and the number of chinook outmigrants was detected by ANOVA or Student's t-tests. However, lunar phase appeared to influence the magnitude of emigrating chinook (Figure 16). Chinook numbers were slightly higher during the new moon phase of the lunar month and lower during the full moon phase. Similar patterns with lunar phase have been observed by Miller (1970), Reimers (1973), Mason (1975), and Service (1988). The additional darkness offered by the new moon may have induced an increased outmigration by chinook.

Back-calculation for the number of chinook spawners from the expanded juvenile estimate presented results similar to the snorkel counts. Chinook spawner escapement was computed to be 320 (153 females, 128 males, and 39 jacks). This second independent estimate of chinook spawner escapement compares well to the estimate obtained by the snorkel count results (286 adults).

Examination of the live box at dusk on several occasions confirmed that the vast majority of salmonid emigration occurs at night. Little downstream movement of either fry or smolts occurred during daylight hours. Similar observations of salmonid emigration during night hours were recorded by Hoar (1953), Miller (1970), Reimers (1973), and Faudskar (1980). As discussed above, the degree of lunar illumination offered by the various moon phases appeared to influence chinook emigration patterns.

Coded wire tagging

Coded wire tagging of chinook yoy commenced in late April and continued through mid July. A total of 11,808 tags were applied and an estimated total of 10,071 tags released. This represented more than 50% of the total number of chinook (19,592) captured at the lower trap site (weir and rotary trap) and approximately 20% of the total estimated production. Tag retention averaged 81% and mortality averaged 3%. CWT operations are summarized in Appendix C.

Salmonid Habitat Investigations

Discharge

The first two attempts to establish a permanent location for the staff gage both ended prematurely. The first site remained operational from November 7 to November 21 when flood flows knocked the gage off the bedrock mounts. The gage operated at a second site from December 19 to January 17 until it was buried by a rock slide. The gage was then installed at a third site January 19 where it continues to operate. Discharge measurements and gage heights are presented in Appendix D. A log-log plot of gage height versus discharge is presented in Figure 17. The highest and lowest flows attained during Water Year 1989 (October, 1988 - September, 1989) were estimated at 13,000+ cfs on November 24, 1988 and 74 cfs on September 4, 1989, respectively.

Temperature

In general, Blue Creek temperatures were within the ranges considered suitable for spawning, incubation, and rearing of salmonid fishes (Reiser and Bjornn 1979). Maximum and minimum stream temperatures (°C) from July 1988 to October 1989 are presented in Figure 18. Flood flows in late November washed out the tempmentor unit and data from November 29 to January 30 was lost. July and August temperatures reached 19° C. Salmonid juveniles were observed congregating in areas of cold water inflow from tributaries and ground water seeps during the periods of warmer temperatures. Winter stream temperatures dropped to 5° C during December and January. Few juvenile salmonids were observed during winter cold temperatures.

Winter temperatures did approach the lower tolerance limit for chinook spawning, but occurred after the two observed peaks of redd building activity. Utilizing hatchery thermal units, 113 and 128 days from spawning to emergence was required for chinook eggs spawned in late October and early December, respectively. Timing of emergence for these two groups of spawners should have been about February 14 and April 8. Captures during the first trap week did confirm that chinook fry were present in the stream at the start of our trapping program.

Channel classification

Four channel types were identified on the Blue Creek mainstem and a fifth type on the Crescent City Fork (Figure 19). Stream surveys identified low gradient C-channels, moderate gradient B-channels and steep A-channels. Mainstem channel types C1, B2, B3, and A2 totaled 7.2, 6.9, 7.4, and 1.3 kms, respectively. The surveyed portion of the Crescent City Fork (3.5 kms) was classified as B1 channel. The portion of the Crescent City Fork accessible to anadromous salmonids above RKM 3.5 will be inventoried in FY 1990.

Channel type C1 was characterized by an open valley bottom with wide floodplains and a gentle gradient. B-channels were characterized by a slightly higher gradient, a narrow valley bottom, and an active floodplain. Channel type

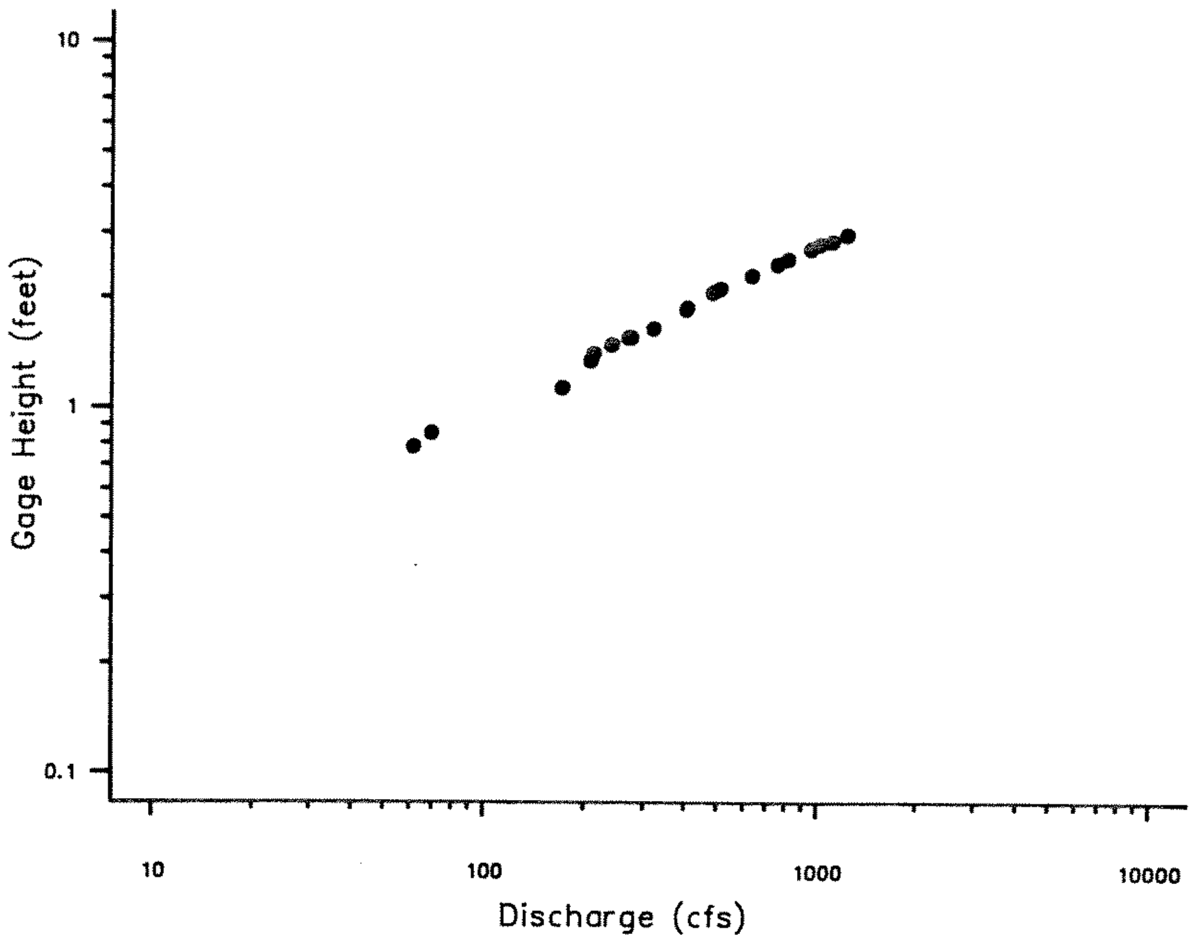

FIGURE 17. Log–log plot of gage height on discharge.

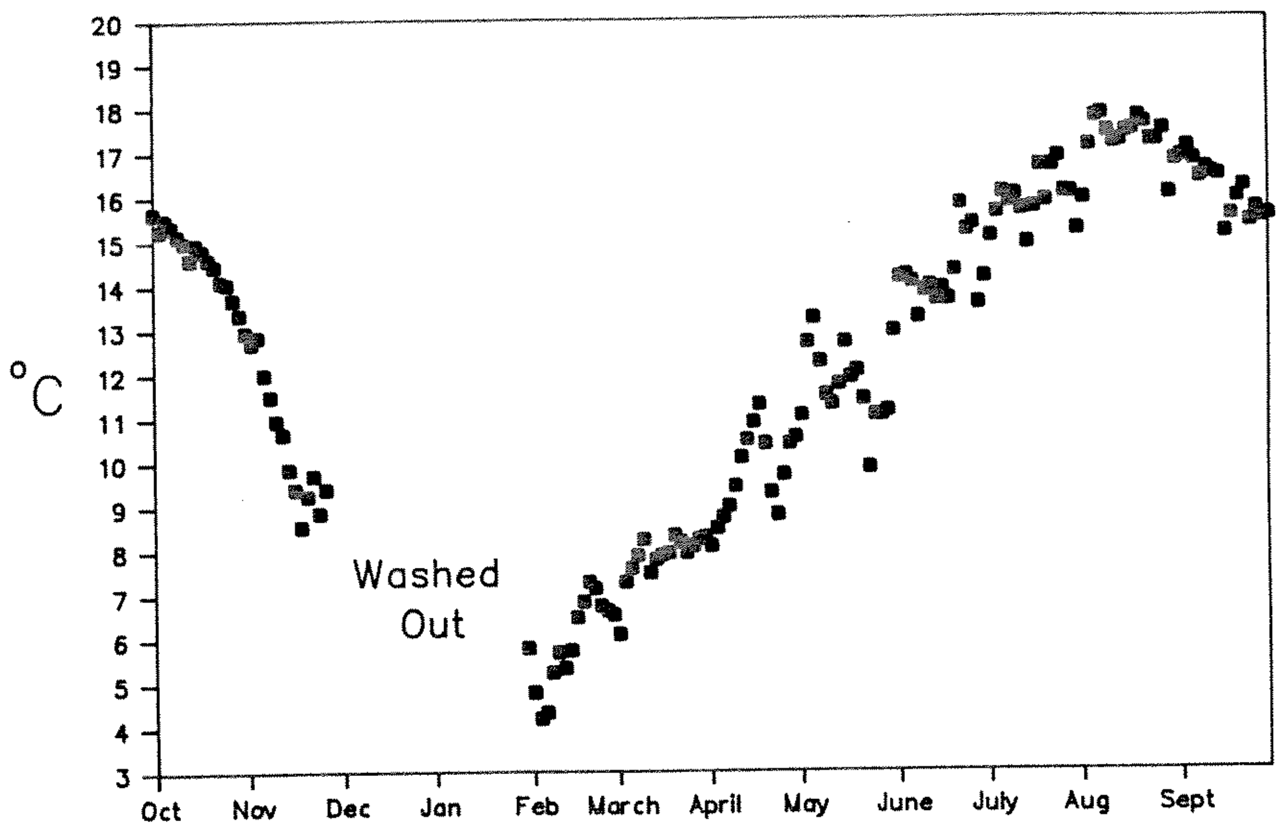

FIGURE 18. Average stream temperatures (°C) in Blue Creek, October 1988 to September 1989.

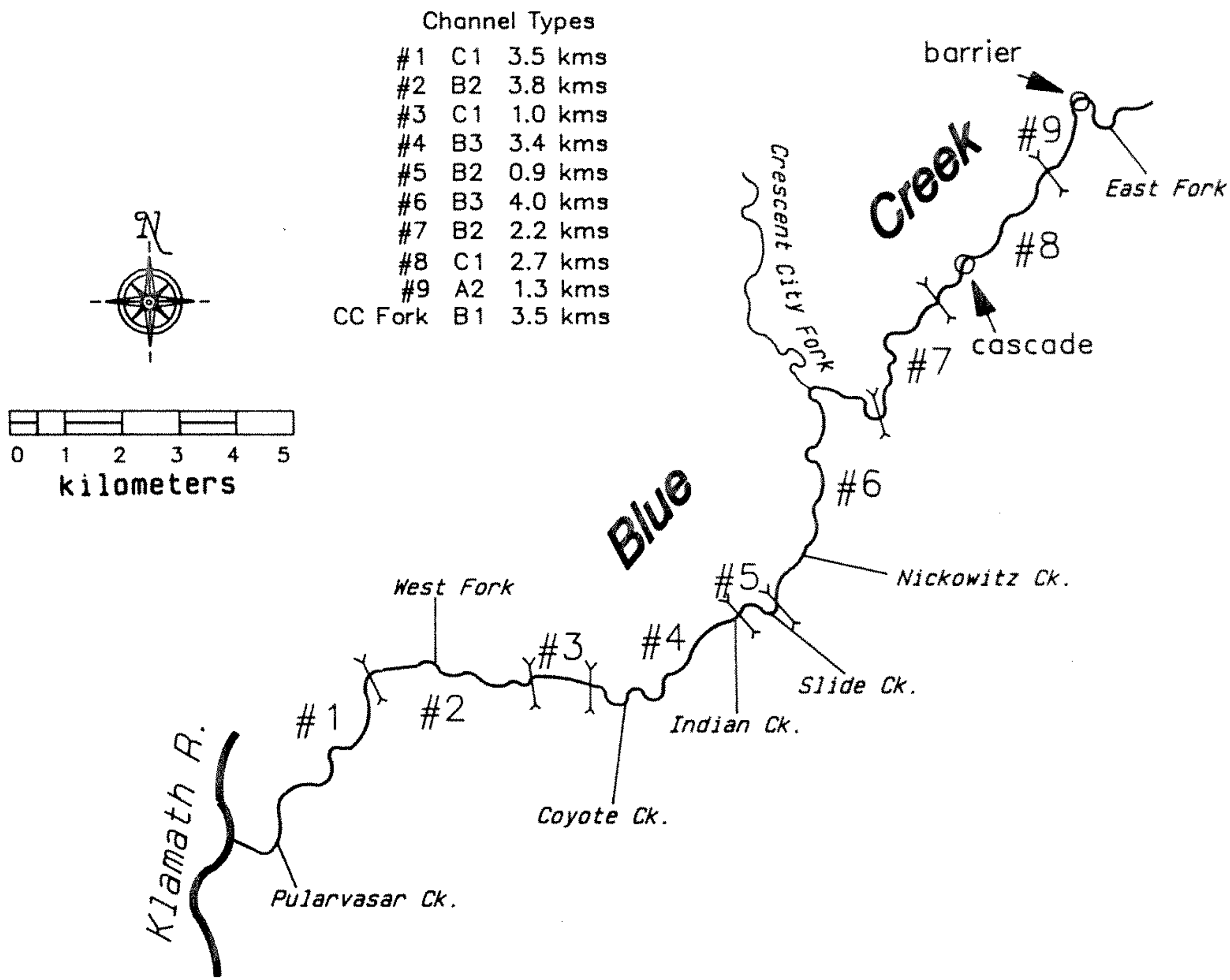

FIGURE 19. Blue Creek and Crescent City Fork channel types according to Rosgen's criteria (Rosgen 1985).

A2, which only occurred in a short reach directly below the barrier, was characterized by a steep gradient, large substrate, and lack of a floodplain.

SUMMARY

Initial investigations have shown that a significant number of fall-run chinook salmon spawn in Blue Creek. Chinook spawners probably enter the stream from August to December with peak immigration occurring during late October or early November. Snorkel survey results determined spawner escapement during 1988 was, at minimum, 286 chinook. Back-calculation from the expanded juvenile estimate computed spawner escapement at 320.

Winter discharge is commonly sustained at about 1000 cfs. This streamflow is excessively high for wading most portions of Blue Creek. Rapid changes in discharge and the subsequent high bedload movement produce difficult conditions for many traditional spawning ground survey techniques (e.g. redd surveys, snorkel counts). A large population of black bear eliminates the opportunity for estimation of adult escapement by carcass survey. High winter flows can often wash out the only bridge on Blue Creek, which adds to the difficulty of accessing many reaches of the stream. Redd and carcass surveys identified 25 chinook redds and 27 carcasses from October 18 to February 1.

High streamflows and bedload movement probably scour some salmonid redds and reduce the percent survival-to-emergence of eggs and alevins. The detrimental effects of scouring flows are particularly pronounced in the lower 3.0 kms of Blue Creek where in late November 1988 pools, riffles and channel braids were created and others completely eliminated.

Peak chinook emigration occurred during increased streamflows in late May and again in late June. Lunar phase also appeared to influence outmigration patterns. Chinook captures were slightly higher during the new moon phase and lower during the full moon phase. Capture of steelhead yoy peaked during high streamflows in late June. Steelhead smolt outmigration had no clear peak, but 2+ age fish emigrated earlier in the season than age 1+ fish. Few coho yoy and smolts were captured, suggesting the run in Blue Creek is small. Coho smolt emigration peaked during early May.

The 1988-89 chinook production estimate may be moderately conservative at 51,096 fish. CWTs applied to 10,071 chinook yoy is low for expecting reliable results from tag returns; however the potential for CWT recovery is high due to extensive coverage by the Service's Indian net harvest monitoring program.

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PERSONAL COMMUNICATION

Harral, C., California Department of Fish and Game, Redding, California.

SUMMARY OF EXPENDITURES FY 1989

OBJECT		COST ($)	
Salaries			
Field crew (1 GS-7 Fishery Biologist and 1 GS-5 Biological Technician)		27,641	
Oversite (1 GS-9 Fishery Biologist)		7,304	
Per diem (overnight in field)		950	
Travel and training		286	
Vehicle (GSA rental and gas)		4,670	
Equipment:			
Minor		2,895	
Major		1,285	
	TOTAL	$45,031	(funded at $45,000)

APPENDIX A. Chinook redd characteristics, fall 1988.

Date	Reach (RKM)	Hab* Type	Length (m)	Width (m)	Area (m2)	Adults Present
10/18	3 (10.5)	12	4.5	2.0	9.0	
10/18	3 (11.6)	12	4.0	1.5	6.0	1 chin
10/28	1 (.4)	1	3.0	1.3	3.9	
10/28	2 (4.7)	12	4.5	3.5	15.8	
11/01	2 (7.2)	20	2.5	1.8	4.5	
11/01	2 (6.6)	14	5.0	1.5	7.5	
11/01	2 (5.3)	17	8.0	1.5	12.0	
11/01	2 (7.6)	12	4.0	1.6	6.4	
11/01	2 (7.6)	12	5.2	1.5	7.8	
11/01	2 (7.6)	1	4.0	1.5	6.0	
11/01	2 (8.2)	14	incomplete			2 chin
11/01	3 (8.7)	12	3.5	1.5	5.3	
12/02	1 (1.8)	1	2.5	1.8	4.5	1 chin
12/05	4 (14.5)	12	3.0	1.5	4.5	1 chin
12/06	3 (9.7)	12	5.0	1.8	9.0	
12/07	1 (0.6)	1	4.0	2.6	10.4	2 chin
12/07	1 (2.1)	4	4.0	3.0	12.0	1 chin
12/12	4 (14.5)	15	2.5	1.1	2.7	1 chin
12/12	5 (15.1)	12	3.5	1.5	5.3	2 chin
12/12	5 (15.4–15.8)		3 redds	unmeasured		
12/12	4 (13.5)	21	1 redd	unmeasured		1 chin
12/15	2 (6.4)	15	5.0	2.5	12.5	2 chin
12/16	4 (13.5)	21	3.0	2.3	6.9	
Average			3.7	1.6	7.6	
Total	25				151.9	14

* Habitat types by Bisson et al. (1982) modified by Decker (1986).

APPENDIX B. Chinook carcass survey results, fall 1988.

Date	Reach	Fork Length (cm)	Sex	Tag Applied	Percent Spent	Scale Sample	Condition
11/08/88	1	66	F	yellow	100	yes	
11/09/88	2	n/a	F	none	n/a	no	predated
11/09/88	2	58	M	yellow	100	yes	
12/01/88	1	n/a	M	red	0	yes	decayed
12/02/88	1	46	M	red	90	yes	fresh
12/02/88	1	51	M	red	100	yes	
12/05/88	4	49	M	white	100	yes	
12/05/88	4	n/a	n/a	none	n/a	no	predated
12/07/88	1	51	M	recovery	–	–	red tag
12/07/88	1	102	M	white	100	yes	
12/07/88	1	n/a	M	none	100	no	predated
12/07/88	2	n/a	n/a	none	n/a	no	predated
12/08/88	1	55	M	white	100	yes	
12/14/88	1	44	M	green	100	yes	
12/14/88	1	45	M	none	100	yes	predated
12/14/88	1	61	M	none	80	yes	
12/14/88	1	54	M	green	90	yes	
12/15/88	2	106	M	green	100	yes	
12/19/88	2	77	M	orange	100	yes	
12/19/88	2	88	M	orange	100	yes	
12/19/88	2	n/a	M	none	50	no	predated
12/19/88	2	87	n/a	orange	n/a	no	predated
12/19/88	2	n/a	n/a	none	n/a	no	predated
12/20/88	1	74	M	orange	95	yes	
12/20/88	1	91	F	orange	100	yes	
01/03/89	2	81	n/a	gray	n/a	yes	predated
01/05/89	1	85	n/a	gray	n/a	yes	
02/01/89	1	94	F	none	90	yes	fresh

	Totals
Carcasses	27
Tags applied	18
Tags recovered	1

n/a = indeterminable

APPENDIX C. Chinook CWT application, retention, mortality, and releases, spring 1989.

Date	# Applied	Control #	Control Hours Held	Control Mortality	Control Tag Loss	Percent Retention	Tags Released
04/29	32	32	24	1	4	87	27
05/04	508	271	24	6	130	51	253
05/06	81	81	20	0	44	46	37
05/07	214	92	70	3	5	94	195
05/12	406	94	48	3	5	95	371
05/13	587	0					541
05/19	571	0					433
05/26	721	50	72	2	10	79	548
05/30	64	0					47
06/01	631	94	96	6	1	99	584
06/02	431	51	72	3	5	90	363
06/08	1724	102	120	4	9	91	1504
06/09	649	0					567
06/15	471	0					434
06/16	780	100	96	6	2	98	718
06/20	110	100	72	4	22	77	81
06/23	636	98	144	0	2	98	623
07/03	1796	99	96	4	6	94	1615
07/07	172	0					139
07/14	976	100	164	4	15	84	791
07/21	248	0					200
Totals	11808	1364		46	260		10071
Averages			77			81	

APPENDIX D. Gage heights and discharge measurements, November 1988 - October 1989.

Date	Time	G.H. (ft)	Discharge (cfs)
11/08/88	1100	n/a	172
12/02/88	1500	n/a	1080
12/08/88	800	n/a	625
12/16/88	1300	n/a	383
01/04/89	900	n/a	803
01/12/89	1300	n/a	2087
01/20/89	1000	1.96	1205
01/26/89	1530	1.79	998
01/31/89	1345	1.84	1087
02/13/89	1400	1.06	475
02/21/89	1100	1.54	798
03/01/89	1100	1.46	742
04/14/89	1300	1.71	936
04/22/89	1200	1.29	623
04/27/89	1500	1.11	502
05/07/89	1800	0.85	396
05/14/89	1300	0.64	315
05/19/89	800	0.55	270
05/22/89	1400	0.48	237
05/31/89	1600	0.87	399
06/07/89	1600	0.55	266
06/14/89	1500	0.40	210
06/19/89	1500	0.34	206
07/12/89	1200	0.13	170
09/04/89	1500	-0.15	69
10/03/89	1000	-0.22	61

Appendix E. Rosgen's criteria for channel classification (Rosgen 1985).

STREAM TYPE	GRADIENT	SINUOSITY	W/D RATIO	DOMINANT PARTICLE SIZE OF CHANNEL MATERIALS	CHANNEL ENTRENCHMENT-VALLEY CONFINEMENT	LANDFORM FEATURE SOILS/STABILITY
A1	4-10	1.0-1.1	10 or less	Bedrock.	Very deep/very well confined.	Deeply incised bedrock drainageway w/ steep side slopes and/or vertical rock walls.
A1-a	10 +	(Criteria	same as	A1)		
A2	4-10	1.1-1.2	10 or less	Large & small boulders w/mixed cobble.	Same	Steep side slopes w/predominantly stable materials.
A2-a	10 +	(Criteria	same as	A2)		
A3	4-10	1.1-1.3	10 or less	Small boulders, cobble, coarse gravel.	Same	Steep, depositional features w/predominantly coarse textured soils. Debris avalanche is the predominant erosional process. Stream adjacent slopes are rejuvenated with extensive exposed mineral soil.
A3-a	10 +	(Criteria	same as	A3)		
A4	4-10	1.2-1.4	10 or less	Predominantly gravel, sand, and some silts.	Same	Steep side slopes w/mixture of either depositional landforms with fine textured soils such as glaciofluvial or glaciolacustrine deposits or highly erodable residual soils such as grussic granite, etc. Slump-earthflow and debris avalanche are dominant erosional processes. Stream adjacent slopes are rejuvenated.
A4-a	10 +	(Criteria	same as	A4)		
A5	4-10	1.2-1.4	10 or less	Silt and/or clay bed and bank materials.	Same	Moderate to steep side slopes. Fine textured cohesive soils, slump-earthflow erosional processes dominate.
A5-a	10 +	(Criteria	same as	A5)		
B1-1	1.5-4.0	1.3-1.9	10 or greater ($\bar{X}$:15)	Bedrock bed, banks, cobble, gravel, some sand.	Shallow entrenchment. Moderate confinement.	Bedrock controlled channel with coarse textured depositional bank materials.
B1	2.5-4.0 ($\bar{X}$:3.5)	1.2-1.3	5-15 ($\bar{X}$:10)	Predominantly small boulders, very large cobble.	Moderately entrenched/ well confined.	Moderately stable, coarse textured resistant soil materials. Some coarse river terraces.
B2	1.5-2.5 ($\bar{X}$:2.0)	1.3-1.5	8-20 ($\bar{X}$:14)	Large cobble mixed w/ small boulders & coarse gravel.	Mod. entrenched/ Mod. confined.	Coarse textured, alluvial terraces with stable, moderately steep, side slopes.
B3	1.5-4.0 ($\bar{X}$:2.5)	1.3-1.7	8-20 ($\bar{X}$:12)	Cobble bed w/ mixture of gravel & sand - some small boulders.	Mod. entrenched/ well confined.	Glacial outwash terraces and/or rejuvenated slopes. Unstable, moderate to steep slopes. Unconsolidated, coarse textured unstable banks. Depositional landforms.
B4	1.5-4.0 ($\bar{X}$:2.0)	1.5-1.7	8-20 ($\bar{X}$:10)	Very coarse gravel w/ cobble mixed sand and finer material.	Deeply entrenched/ well confined.	Relatively fine river terraces. Unconsolidated coarse to fine depositional material. Steep side slopes. Highly unstable banks.
B5	1.5-4.0 ($\bar{X}$:2.5)	1.5-2.0	8-25 ($\bar{X}$:15)	Silt/clay.	Same	Cohesive fine textured soils. Slump-earthflow erosional processes.

(continuation Appendix E)

C1	1.2-1.5 ($\bar{X}$:1.3)	1.5-2.0	10 or greater ($\bar{X}$:18)	Cobble bed with mixture of small boulders and coarse gravel.	Mod. entrenched/ Mod. confined.	Predominantly coarse textured, stable high alluvial terraces.
C2	0.3-1.0 ($\bar{X}$:0.6)	1.3-1.5	15-30 ($\bar{X}$:20)	Large cobble bed w/ mixture of small boulders & coarse gravel.	Mod. entrenched/ well confined.	Overfit channel, deeply incised in coarse alluvial terraces and/or depositional features.
C3	0.5-1.0 ($\bar{X}$:0.8)	1.8-2.4	10 or greater ($\bar{X}$:22)	Gravel bed w/mixture of small cobble & sand.	Mod. entrenched/ slight confined.	Predominantly moderate to fine textured multiple low river terraces. Unstable banks, unconsolidated, noncohesive soils.
C4	0.1-0.5 ($\bar{X}$:0.3)	2.5 +	5 or greater ($\bar{X}$:25)	Sand bed w/mixtures of gravel & silt (no bed armor).	Mod. entrenched/ slight confined.	Predominantly fine textured, alluvium with low flood terraces.
C5	0.1 or less ($\bar{X}$:.05)	2.5 +	5 or greater ($\bar{X}$:10)	Silt/clay w/mixtures of medium to fine sands (no bed armor).	Mod. entrenched/ slight confined.	Low, fine textured alluvial terraces, delta deposits, lacustrine, loess or other fine textured soils. Predominantly cohesive soils.
C6	0.1 or less ($\bar{X}$:.05)	2.5 +	3 or greater ($\bar{X}$:5)	Sand bed w/mixture of silt & some gravel.	Deep entrenched/ slight confined.	Same as C4 except has more resistant banks.
D1	1.0 or greater ($\bar{X}$:2.5)	N/A Braided	N/A	Cobble Bed w/mixture of coarse gravel & sand & small boulders.	Slight entrenched/ no confinement.	Glacial outwash, coarse depositional material, highly erodable. Excess sediment supply of coarse size material.
D2	1.0 or less ($\bar{X}$:1.0)	N/A Braided	N/A	Sand bed w/mixture of small to medium gravel & silts.	Slight entrenched/ no confinement.	Fine textured depositional soils, very erodable - excess of fine textured sediment.