Estimation of the Number of Juvenile Chinook Salmon (Oncorhynchus tshawytscha) Migrating Downstream from Blue Creek, California, 1989-1992.

by

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ESTIMATION OF THE NUMBER OF JUVENILE

CHINOOK SALMON (Oncorhynchus tshawytscha)

MIGRATING DOWNSTREAM FROM BLUE CREEK,

CALIFORNIA, 1989-1992

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ABSTRACT

A four-year study was undertaken to estimate the number of juvenile chinook salmon migrating downstream from Blue Creek, the largest tributary to the lower Klamath River that supports a significant fall chinook population. Secondary objectives of this study were: (1) determine what factors affect trap efficiency, (2) evaluate the use of mark-recapture methods in determining trap efficiency, and (3) investigate the relationship between efficiency-based and discharge-based estimates of juvenile chinook salmon downstream migration.

Over a three-year period, the number of juvenile chinook salmon migrating downstream from Blue Creek during the spring/summer ranged annually from 15,615 to 48,971 and averaged 33,717. This represented only 6% of the number of juvenile chinook salmon downstream migrants that could theoretically be produced in Blue Creek based on spawning habitat assessments. The relatively low numbers of juvenile chinook salmon migrating downstream from Blue Creek coincided with some of the lowest natural fall chinook spawning escapements observed in the Klamath River Basin, suggesting that the number of juvenile chinook salmon produced may have been spawner limited.

Estimates of trap efficiency based on unmarked juvenile chinook salmon captured in the screw trap and weir indicated a general trend of increasing efficiency as stream discharge decreased; however, there was also substantial variation in trap

efficiency at similar stream discharges. Analysis of trapping effort data indicated that stream discharge was generally the principle factor affecting trap efficiency.

Mark-recapture trap efficiency estimates were negatively biased, averaging about 50% of "actual" trap efficiencies. The large negative bias in mark-recapture efficiency estimates can be attributed primarily to: (1) increased mortality of marked fish, possibly due to reduced predator avoidance resulting from handling stress, (2) delayed migration of marked fish, and (3) differential distribution of marked and unmarked fish. Data collected during this study demonstrated the importance of testing the assumptions of mark-recapture methodology when employed.

Some of the data collected during this study indicated that estimates of the number of juvenile chinook salmon migrating downstream based on the proportion of stream discharge sampled may possibly be useful for assessing the magnitude of juvenile salmonid downstream migration. These data also indicated that the relationship between "actual" trap efficiency and the proportion of stream discharge sampled can change: (1) during the sampling season, (2) from one season to the next at the same site, and (3) at different trapping sites. Discharge-based estimates of juvenile salmonid downstream migration are only useful if a relationship between trap efficiency and the proportion of stream discharge sampled exists and can be verified at varying flows and between years.

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INTRODUCTION

Salmonids have a complex life cycle and at any life stage a host of abiotic and biotic factors can influence survival and subsequent recruitment to the next life stage (Larkin 1988). The status of a salmonid population can be measured at a variety of life history stages (Ricker 1975, Hilborn and Walters 1992) and it is important for fishery resource managers to select the appropriate life stage to monitor based on management objectives. Harvest managers often measure the status of a population at the first age at which the target species becomes vulnerable to a fishery (Ricker 1975), whereas freshwater salmonid habitat managers often assess abundance prior to or while the population migrates from natal streams or rivers, most often as smolts (Everest and Sedell 1984, Solomon 1985, Baglinière and Champigneulle 1986, Reeves et al. 1991). Assessing the number of smolts produced by an estimated adult salmonid spawning population, prior to ocean entry, provides the most direct measure of the effects of the freshwater environment on incubation, hatching, emergence, and rearing.

Monitoring of downstream migrating juvenile anadromous salmonid smolts has been conducted using a variety of sampling gears, most of which sample a portion of a stream by filtering water as it passes through the sampling device. The most common sampling devices employed have been fyke nets (Craddock 1959, Davis et al. 1980, Milner and Smith 1985), inclined plane or scoop traps (Wolf 1951, Seelbach et al. 1985, McMenemy and Kynard 1988, DuBois et al. 1991), and most recently screw traps

(Thedinga et al. 1994, Ashe et al. 1995). Weirs or partial weirs have also been used (Hare 1973, Siler et al. 1981, Dempson and Stansbury 1991, Mullins et al. 1991).

Mark-recapture techniques are often integrated into juvenile salmonid downstream migration studies to allow estimation of trapping efficiency (Siler et al. 1984, Dempson and Standbury 1991, Thedinga et al. 1994, Ashe et al. 1995). Trap efficiency estimates are then utilized in conjunction with the numbers of fish captured in the trapping device to derive estimates of the number of juvenile salmonids migrating downstream. Other methods employed to estimate the number of juvenile salmonids migrating downstream have included expansion of trap catches by the proportions of stream discharge sampled (FPC 1986) and expansion of trap catches by the proportions of stream width sampled (Siler et al. 1989).

Concerns over the status of anadromous fishery resources in the Klamath River led Congress to enact the Klamath River Fish and Wildlife Restoration Act (P.L. 99-552) in 1986 and ultimately led to the initiation of studies designed to assess the status of these resources. In particular, the U.S. Fish and Wildlife Service carried out a four-year monitoring program to assess the status of the fall chinook salmon (Oncorhynchus tshawytscha) population inhabiting Blue Creek, a lower Klamath River tributary. This monitoring program included assessments of freshwater habitat, adult spawning population size, and juvenile abundance.

Blue Creek once supported fall chinook salmon runs of 5,000 to 10,000 fish annually (DeWitt 1951) and is still the most important spawning tributary in the lower Klamath River (USFWS 1979, USDOI 1985). It is known for the large fall chinook salmon, called "Blue Creekers", that utilize the creek for spawning and physically resemble fall chinook salmon from the Smith River (Snyder 1931). Gall et al. (1991) found that fall chinook salmon from Blue Creek were more genetically similar to chinook salmon originating from the Smith River and southern Oregon streams than to chinook salmon stocks within the Klamath River Basin. Attention was focused on the Blue Creek population of fall chinook salmon due to concerns over the status of this unique stock and its potential use as a brood stock source for lower Klamath River rearing and supplementation programs.

The primary objective of this study was to estimate the number of juvenile fall chinook salmon migrating downstream from Blue Creek. Three secondary objectives were to: (1) determine what factors affect trap efficiency, (2) evaluate the use of mark-recapture techniques in determining trap efficiency, and (3) investigate the relationship between estimates of the number of juvenile chinook salmon migrating downstream based on adjusting trap catches by (a) estimated trap efficiencies or (b) calculated proportions of stream discharge sampled by the trap.

STUDY SITE

Blue Creek is a fourth order stream with a watershed of 329 km^2 and 41.1 km of mainstem stream (USFWS 1979). It is the largest tributary to the Klamath River below the confluence of the Klamath and Trinity rivers and enters the Klamath River at river kilometer 26.4 (Figure 1). The upper portion of the watershed is located in the Siskiyou Wilderness Area of the Six Rivers National Forest.

Due to the proximity of Blue Creek to the coast and its relatively low elevation, the majority of precipitation occurs as rainfall, causing rapid fluctuations in stream discharge, especially from November through April.

Fall chinook salmon and steelhead (O. mykiss) are the predominant anadromous salmonid species that utilize Blue Creek. Other fish species commonly found in Blue Creek are coho salmon (O. kisutch), cutthroat trout (O. clarki), speckled dace (Rhinichthys osculus), threespine stickleback (Gasterosteus aculeatus), prickly sculpin (Cottus asper), Klamath smallscale sucker (Catostomus rimiculus) and Pacific lamprey (Lamperta tridentata). Occasionally, brown trout (Salmo trutta) are found in Blue Creek.

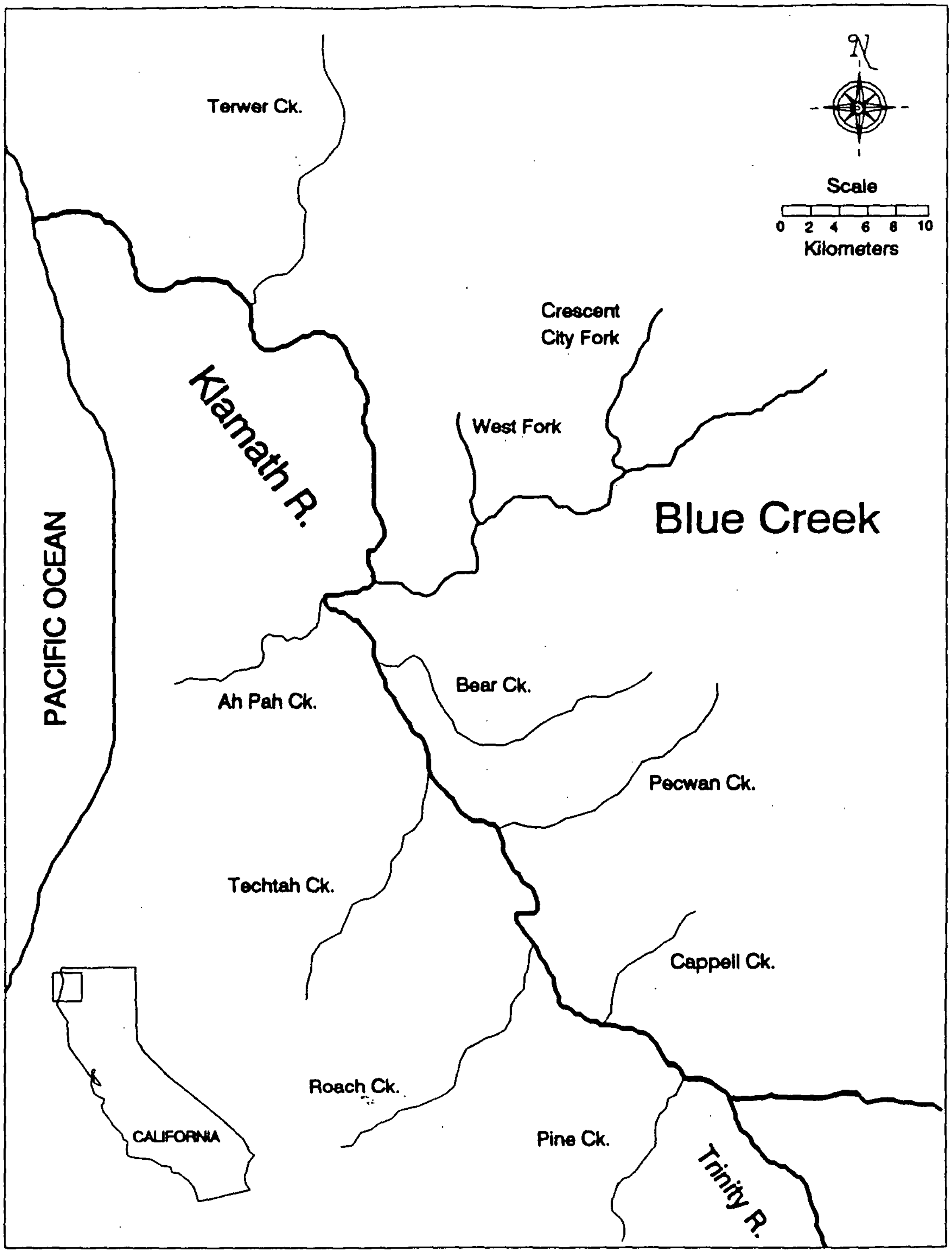


Figure 1. Location Map of Blue Creek in the Lower Klamath River Basin (Gilroy et al. 1992).

MATERIALS AND METHODS

Physical Stream Measurements

Stream discharge (Q) and stream width (W) were estimated during this study to allow for the assessment of relationships among trap efficiency and stream discharge, the proportion of stream discharge sampled by the screw trap ($P\hat{Q}$), and the proportion of stream width sampled by the screw trap ($P\hat{W}$). A stream gage station was established on Blue Creek at rkm 3.4 (Figure 2). Stream discharge in cubic feet per second was estimated at varying gage heights (GH) using a Price AA current meter and top setting rod (Platts et al. 1983) and was then converted to cubic meters per second (m^3/s). Regressions of Log(Q) against Log(GH) were used to describe the relationship between stream discharge and gage height in individual years. The resulting predictive regression equations were used to estimate the daily stream discharge based on observed gage height. For days that gage height was not recorded, an estimate of discharge was calculated by interpolation of discharge data from the previous and following days.

Stream width at the trapping sites was measured intermittently throughout this study. Stream width predictive equations were developed by linear regression of stream width on discharge data. Discharge measurements were made at the trapping sites intermittently throughout this study to provide data to compare stream discharge at these sites to that measured at the gage station. Stream discharge estimates at the trapping sites (Q_{trap}) were regressed on stream discharge estimates at the gage (Q_{gage})

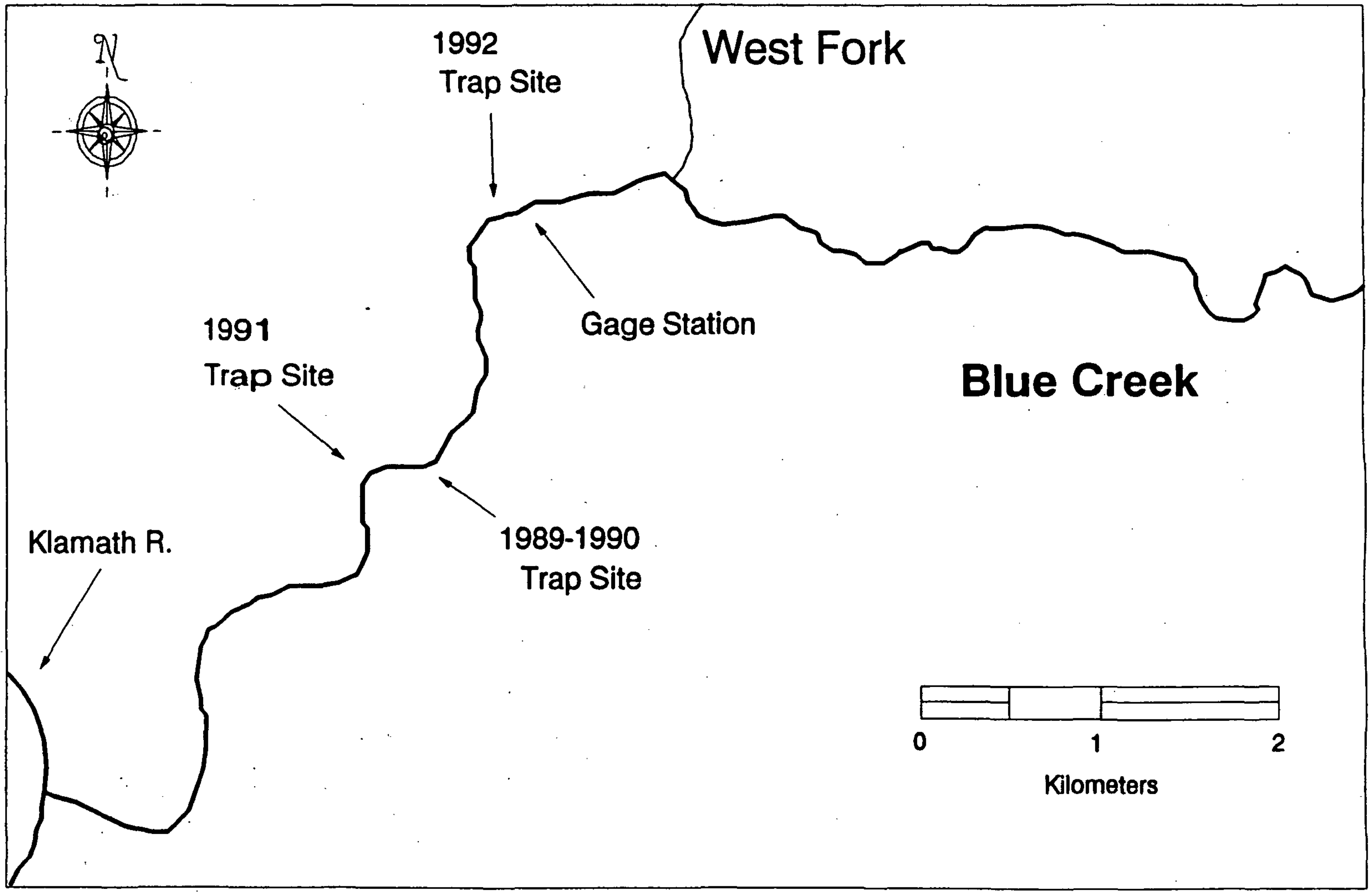


Figure 2. Blue Creek Trapping Sites for 1989-1992 and Gage Station (Gilroy et al. 1992).

station to develop equations that could be used to estimate stream discharge at the trapping sites.

Juvenile Salmonid Trapping

Trapping was conducted during the spring and early summer, encompassing the majority of the juvenile chinook salmon downstream migration period, typically from early April to mid-July. Trapping effort (days sampled) varied according to stream discharge and personnel availability. A trapping "day" was defined as the time that the trap was deployed, typically morning to early afternoon, to the following morning when it was checked. This time period encompassed the evening and night when the majority of juvenile salmonids migrate (Neave 1955, McDonald 1960, Reimers 1973). Trapping activities were typically conducted four or five days per week. In 1990 and 1992, trapping activities were conducted seven days per week during the second half of the season.

Three trapping sites were used during this study due to physical changes at the trapping sites (Figure 2). The trapping site was located at rkm 2.1 in 1989 and 1990, at rkm 1.8 in 1991, and at rkm 3.3 in 1992.

A screw trap with a 2.44 m diameter cone supported by pontoons was utilized throughout this study (Figure 3). The cone consisted of a rigid aluminum framework covered by 0.64 cm^2 hardware cloth. Within the cone two opposing screw vanes were fixed to a center axle and the surrounding framework. As water passed through the cone, the force of the water against the vanes caused the cone to rotate. Only the lower

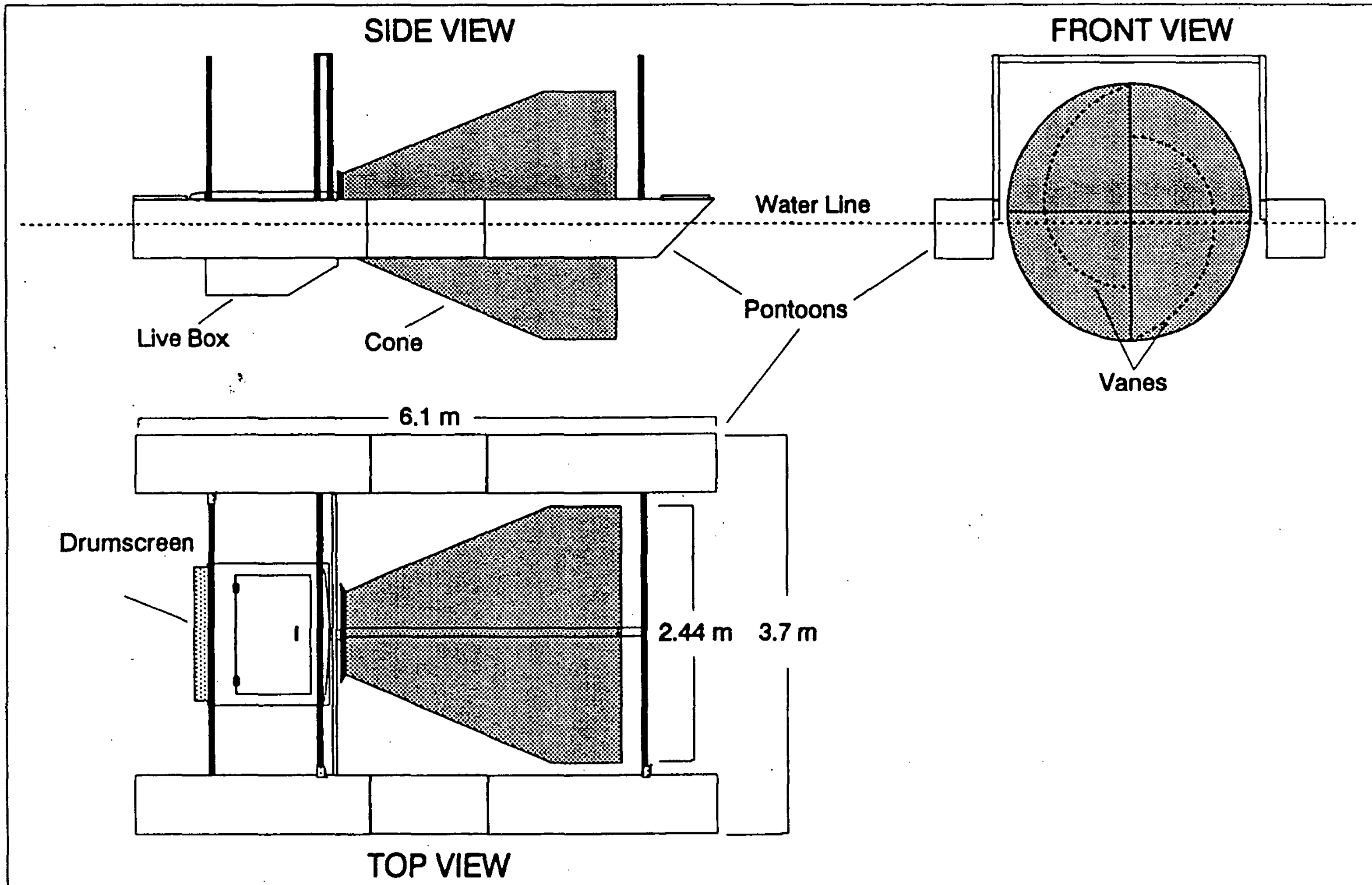


Figure 3. Schematic Diagram of the Screw Trap Used on Blue Creek.

half of the cone was submerged and, as the cone rotated, fish that entered the cone were guided into the live box by the rotating vanes which created a physical barrier and prevented fish from swimming out of the trap. The livebox was fitted with a drumscreen, driven by a worm-gear assembly attached to the center axle of the cone, to remove debris from the livebox. The trap was deployed at the head of a pool, in the thalweg, where the water velocity was sufficient to rotate the cone (Figure 4). Depending on the water depth, the cone could be positioned at varying depths but was always set as deep into the water column as possible. As stream discharge changed, the position of the trap was adjusted to maintain proper position within the stream channel. Trap position was maintained by ropes attached to anchor points (logs, trees, or fence posts) on each bank.

The volume of stream discharge sampled by the screw trap was estimated by dividing the width of the cone into three cells (left, center, and right). The products of the water velocity and area of each cell were summed to estimate the total volume sampled. Water velocity was measured at the center of each cell with a Price AA current meter and top setting rod; the area of each cell was determined by the cell width, the depth that the cone was submerged, and the radius of the cone. The proportion of stream discharge sampled by the screw trap ($P\hat{Q}$) was estimated by dividing the estimated volume of water sampled by the screw trap by the estimated stream discharge. The proportion of stream width sampled by the screw trap ($P\hat{W}$) was estimated by dividing the submerged width of the cone by estimated stream width. The number of revolutions the cone completed in one minute ($R\hat{M}$) was estimated by recording the

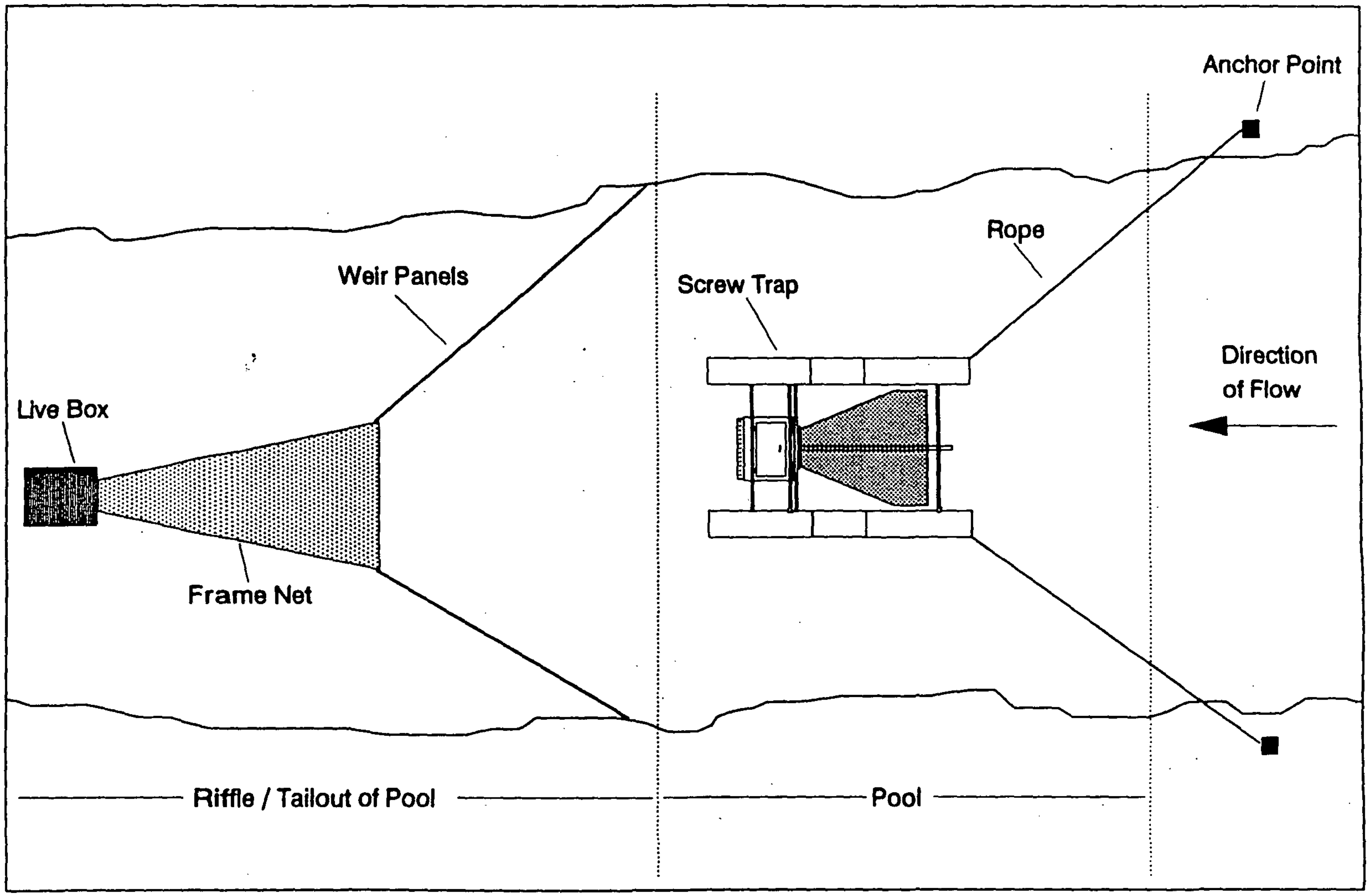


Figure 4. Trapping Site Diagram Showing the Location of the Screw Trap and Weir.

amount of time (in seconds) in which ten revolutions were completed. The revolutions per second were then multiplied by 60 to estimate the number of revolutions per minute.

A weir consisting of a frame net with a live box and weir panels was erected immediately downstream of the screw trap at the tailout of the pool (Figure 4). The weir was positioned 22 m below the screw trap in 1989 and 1990, 20 m below the screw trap in 1991, and 80 m below the screw trap in 1992. The weir panels, constructed of 0.64 cm^2 hardware cloth mounted on wooden frames, were deployed in a V-shape with the apex facing downstream. The weir panels were supported by T-bar fence posts imbedded in the stream substrate. Plastic webbing and rocks were used to seal the bottom of the weir panels with the stream bed in an attempt to minimize locations where fish could escape through the weir. A frame net (1.5 m x 3 m x 9.2 m, 0.48 cm delta mesh netting) with attached live box was placed at the apex of the weir panels. When the weir was properly set, virtually all of the fish migrating downstream through the site were guided into the net and live box. The operation of the weir was greatly dependent on stream discharge due to the difficulty in maintaining the weir at higher flows.

Biological Sampling

All salmonids captured during the trapping operations were removed from the live box and placed into buckets for identification and counting. Fish captured in the screw trap and weir were sampled separately. A subsample of fish captured in each trap, typically the first 30 to 50 fish of each salmonid species removed from the buckets, were anaesthetized with tricaine methanesulphonate (MS-222) and fork lengths were measured. As time permitted, volumetric displacements of individual fish were also measured. Once mark-recapture tests were initiated, all chinook salmon were examined for marks.

Comparisons of weekly mean fork lengths of chinook salmon captured in the screw trap and weir were conducted to determine if any selectivity based on fish size was occurring. Weekly mean fork lengths of chinook salmon captured in the screw trap and weir were compared by t-tests using an α of 0.05 for individual tests.

Mark-Recapture Efficiency Estimates

Mark-recapture methods were used to estimate the trapping efficiency of the screw trap in 1989, 1990, and 1992. A random sample of juvenile chinook salmon captured in the screw trap and weir were marked and then released above the screw trap. Subsequent recaptures in the screw trap and weir were used to estimate screw trap efficiency.

The assumptions invoked when employing mark-recapture techniques for estimating trap efficiency were:

1) marked fish experienced no mortality after release,
2) marked fish migrated downstream past the screw trap and weir immediately or soon after release,
3) marked fish had the same distribution as unmarked fish while they migrated past the trapping site and exhibited similar behavior (equal capture probability),

4) fish did not lose their marks, and

5) all marks were observed and recorded.

Two marking techniques were employed during this study. Marking techniques were changed to adjust to logistical constraints of field staffing while maintaining the quality of data necessary to estimate trap efficiency using mark-recapture techniques. In 1989 and 1990, marking was accomplished by dying fish with Bismarck Brown Y, a biological stain (Mundie and Traber 1983). Juvenile chinook salmon were immersed in a 0.021 g/l solution of Bismarck Brown Y (48% concentration) for 15 to 30 minutes. Marked fish were recognizable for up to three days.

In 1992, chinook salmon were marked with partial fin-clips. This marking technique was employed to provide a discrete mark for each release group due to the observations in previous years that not all chinook salmon migrated immediately after release. Tips of different fins were removed with scissors for different release groups. The fin-clips used were: upper caudal (UC), lower caudal (UC), left pectoral (LP), right pectoral (RP), left ventral (LV), and right ventral (RV).

Marked chinook salmon were transported upstream at least one riffle above the screw trap and released. The distances released upstream from trapping sites were 650 m in 1989 and 1990, and 200 m in 1992. In 1989 and 1990, marked fish were moved upstream and immediately released. In 1992, marked fish were moved upstream and retained in holding cages for typically six to eight hours prior to release. Marked fish were released after dark in all but two tests, when they were released in the late afternoon and early evening. Any dead or injured marked chinook salmon were removed from the holding cage prior to release.

As numbers of fish were available, a subsample of marked and unmarked chinook salmon were retained in live cages as controls for two to four days to estimate delayed mortality, or relative survival ($\hat{S}_D$), of marked chinook salmon due to the marking process. Relative survival was estimated by dividing survival rate of marked controls ($\hat{S}_M$) by the survival rate of unmarked controls ($\hat{S}_{UM}$) (Equation (1)). Survival rates for marked and unmarked controls were estimated by dividing the number of fish alive at the end of the holding period by the number of fish held. When the survival rate of unmarked controls was less than the survival rate of marked controls, it was assumed that there was no additional mortality due to the marking process ($\hat{S}_D = 1.00$). In cases when insufficient numbers of fish were available to estimate relative survival, data from the previous or following test were used. The number of marked chinook salmon released (M) was multiplied by the estimated relative survival to adjust the number released ($\hat{M}_{ADJ}$) to account for relative survival due to marking (Equation (2)).

$$\hat{S}_D = (\hat{S}_M) / (\hat{S}_{UM}) \tag{1}$$

$$\hat{M}_{ADJ} = M * \hat{S}_D \tag{2}$$

The design of this study allowed for the calculation of three distinct estimates of trap efficiency, two based on the recapture of marked fish and one based on the capture of unmarked fish. The first estimate of trap efficiency ($\hat{E}_{MR}$) based on mark-recapture data was calculated by dividing the number of marked fish recaptured in the screw trap (R_S) the day after release by the adjusted number of marked fish released (Equation (3)). The second estimate of trap efficiency ($\hat{E}_{PS}$) based on mark-recapture data was calculated by dividing the number of marked fish recaptured in the screw trap by the sum of the numbers of marked fish recaptured in the screw trap and weir (R_W) on the day following release (Equation (4)). The assumption that marked fish experience no mortality after release was not necessary in estimating trap efficiency based on Equation (4).

$$\hat{E}_{MR} = R_S / \hat{M}_{ADJ} \qquad (3)$$

$$\hat{E}_{PS} = R_S / (R_S + R_W) \qquad (4)$$

The third estimate of trap efficiency ($\hat{E}_{ACT}$), "actual" trap efficiency, was calculated by dividing the number of unmarked juvenile chinook salmon captured in the screw trap (N_S) by the sum of the numbers of unmarked juvenile chinook salmon captured in the screw trap and weir (N_W) (Equation (5)).

$$\hat{E}_{ACT} = N_S / (N_S + N_W) \qquad (5)$$

The relationships between mark-recapture efficiency estimates, ($\hat{E}_{MR}$) and ($\hat{E}_{PS}$), and "actual" trap efficiency estimates ($\hat{E}_{ACT}$) were examined using correlation analysis.

Distribution of Marked Chinook Salmon

Two-by-two contingency tables were used to test the assumption that the distribution of marked fish was similar to that of unmarked fish (Zar 1974). If marked fish were not distributed in a similar manner as unmarked fish, the assumption of equal probability of capture would be violated, resulting in efficiency estimates that would only pertain to marked fish and not to unmarked fish. In cases when more than 10% of the total recaptures occurred on the second day following release, data for both days were pooled and the analysis was also performed on these pooled data.

Screw Trap Efficiency Estimation

Data collected during trapping operations when the screw trap and weir were operated on the same day were utilized to develop predictive equations for screw trap efficiency. "Actual" trap efficiency estimates ($\hat{E}_{ACT}$, Equation (5)) were used for this analysis. Assumptions invoked for trap efficiency estimation were: (1) migrating chinook salmon did not terminate their nightly migration between the screw trap and weir and (2) the weir was 100% efficient. Variables that were expected to influence the efficiency of the screw trap included: stream discharge, the proportion of stream discharge sampled, the proportion of stream width sampled, and the trap revolutions per minute. Values used for these variables were calculated by averaging the values on the day the trap was set and the day it was checked to account for fluctuations that occurred during this time period.

Trap efficiency data were transformed using the logit transformation and stream discharge data were natural log transformed, resulting in the variables Logit($\hat{E}$) and Ln($\hat{Q}$), respectively (Ashton 1972). The logit transformation of trap efficiency was utilized because, according to this model, trap efficiency asymptotically approaches zero or one as the independent variable(s) increase or decrease, respectively. In addition, some of the collected data indicated that trap efficiency followed this functional relationship. This transformation makes intuitive sense because as stream discharge increases, trap efficiency should decrease until it becomes virtually zero. Conversely, as stream discharge decreases, efficiency should theoretically increase until the trap sampled the entire stream (100% efficiency). Operational constraints prevented this from occurring since no physical modification of the stream channel was undertaken.

Correlation analyses were conducted to determine if there were significant relationships between estimated trap efficiency (Logit ($\hat{E}$)) and potential predictor variables (Ln($\hat{Q}$), $P\hat{Q}$, $P\hat{W}$, and $R\hat{M}$). Forward stepwise multiple regression utilizing Statgraphics software was employed to develop predictive equations for trap efficiency (Zar 1974). The resulting equations were used to predict trap efficiency ($\hat{E}_i$) when the weir was not operated.

Estimation of Juvenile Chinook Salmon Downstream Migration

Two kinds of estimates of the number of juvenile chinook salmon migrating downstream were calculated from catch and effort data collected during this study: (1) estimates based on trap catches scaled by estimated trap efficiencies or "efficiency-based" estimates and (2) estimates based on trap catches scaled by the proportion of stream discharge sampled or "discharge-based" estimates. These two kinds of estimates were compared to evaluate the possibility that discharge-based estimates provide a reasonable measure of the magnitude of downstream migration.

Efficiency-Based Estimates

The daily number of juvenile chinook salmon migrating from Blue Creek ($\hat{N}_i$) was estimated by dividing the number of chinook salmon captured in the screw trap (N_s) by the predicted trap efficiency ($\hat{E}_i$) (Equation (6)) or by summing the number of chinook salmon captured in the screw trap and weir, when both were operated.

$$\hat{N}_i = N_S / \hat{E}_i \tag{6}$$

Semimonthly estimates ($\hat{N}_p$) of the number of juvenile chinook salmon migrating downstream from Blue Creek were calculated by dividing the sum of the daily estimates ($\hat{N}_i$) for each period by the proportion of days sampled in that period (σ_p) (Equation (7)).

Semimonthly periods were defined as the 1st through the 15th of each month and the 16th through the 30th or 31st of each month.

$$\hat{N}_p = \sum \hat{N}_i / \sigma_p \quad (7)$$

Estimates of the number of juvenile chinook salmon migrating from Blue Creek each year, mid-April through mid-July, were calculated by summing semimonthly estimates. This time period was selected to provide comparable estimates between years because trapping was typically initiated in early to mid-April in all years but was concluded by mid-July in 1989 and 1992.

Discharge-Based Estimates

Discharge-based estimates of juvenile chinook salmon migrating downstream ($\hat{Nq}_i$) were calculated by dividing the number of chinook salmon captured in the screw trap by the proportion of stream discharge sampled by the screw trap ($\hat{PQ}_i$) (Equation (8)).

Semimonthly ($\hat{Nq}_p$) (Equation (9)) and annual discharge-based estimates of the number of juvenile chinook salmon migrating downstream were calculated in a manner analogous to that for semimonthly and annual efficiency-based estimates.

$$\hat{Nq}_i = N_S / (\hat{PQ}_i) \quad (8)$$

$$\hat{Nq}_p = \sum \hat{Nq}_i / \sigma_p \quad (9)$$

Comparison of Efficiency-Based and Discharge-Based Estimates

To assess if there was a relationship between daily efficiency-based and discharge-based estimates of the number of juvenile chinook salmon migrating downstream, correlation analyses of trap efficiency and the proportion of stream discharge sampled by the screw trap were performed. These variables, rather than the efficiency-based and discharge-based numeric estimates, were compared because both numeric estimates were based on the screw trap catches, N_t. Estimates of trap efficiency and the proportion of stream discharge sampled were statistically independent of one another. Data used for comparing trap efficiency and the proportion of stream discharge sampled were trap efficiency data used in determining efficiency-discharge relationships and corresponding estimates of the proportion of stream discharge sampled collected between April 15 and July 15 for individual years. Estimates of trap efficiency generated from efficiency-discharge relationships and corresponding estimates of the proportion of stream discharge sampled were not subjected to this analysis because these data were not independent; both sets of data using stream discharge in their estimation.

RESULTS

Physical Stream Measurements

Fifty-three stream discharge measurements were made during this study: 20 in 1989, 9 in 1990, 13 in 1991 and 11 in 1992 (Appendix A). Regression analysis of estimated stream discharge on gage height, for individual years, resulted in highly significant predictive equations (Table 1).

Forty-one stream width measurements were made during this study; 4 in 1989, 11 in 1990, 13 in 1991, and 13 in 1992 (Appendix B). Data collected during 1989 were excluded from analyses because of small sample size. Regressing stream width on stream discharge resulted in highly significant predictive equations for each year (Table 2).

Eleven paired discharge measurements were made at the gage station and trapping sites during this study (Appendix C). Regressing stream discharge estimates at the trapping sites on stream discharge estimates at the gage station resulted in an intercept parameter that was not significantly different from zero ($t=-1.191$, $n=11$, $p=0.265$) and a slope parameter that was not significantly different from one ($t=0.138$, $n=11$, $p=0.447$). Since there was no significant difference in stream discharge between the gage station and trapping sites based on the results of the regression analysis, stream discharge at the trapping sites was assumed to be the equal to the estimated stream discharge at the gage station.

Table 1. Regression Statistics for Stream Discharge Predictive Equations on Blue Creek, California, 1989-1992.[a]

Year	n	r^2	Parameter	Estimate	Standard Error	t	p
1989	20	0.995	Intercept	1.560	0.0119	134.26	<0.001
			Slope	2.182	0.0384	56.85	<0.001
1990	9	0.987	Intercept	1.428	0.0298	7.89	<0.001
			Slope	1.765	0.0770	22.92	<0.001
1991	13	0.988	Intercept	1.453	0.0285	50.88	<0.001
			Slope	1.796	0.0606	29.65	<0.001
1992	11	0.986	Intercept	1.415	0.0359	39.41	<0.001
			Slope	1.773	0.0695	25.52	<0.001

[a] Estimated parameters are for log-transformed data: Log(Q)= Intercept+Slope*Log(GH)

Table 2. Regression Statistics for Stream Width Predictive Equations on Blue Creek, California, 1990-1992.

Year	n	r^2	Parameter	Estimate	Standard Error	t	p
1990	11	0.723	Intercept	9.063	0.9390	9.65	<0.001
			Slope	0.573	0.1183	4.85	<0.001
1991	13	0.954	Intercept	10.122	0.5976	16.94	<0.001
			Slope	0.747	0.0494	15.11	<0.001
1992	13	0.833	Intercept	13.605	0.8300	16.39	<0.001
			Slope	1.099	0.1482	7.42	<0.001

Stream Discharge

During this study, stream discharge generally decreased throughout the trapping season with moderate and minor increases due to rain events (Figure 5, Appendix D). Stream discharge generally decreased during the 1989 trapping operations with one significant increase in discharge during the third week in May. In 1990, the stream discharge pattern was unique in that stream discharge was low at the initiation of trapping and the highest flows occurred from May 26 through June 13, peaking at 27.7 m^3/s on June 4. Stream discharge decreased throughout the trapping operations in 1991 with several increases during April and May. In 1992, stream discharge was low at the initiation of trapping but quickly increased and thereafter followed the decreasing pattern observed in 1989 and 1991.

Juvenile Salmonid Trapping

During 1989, trapping was initiated on April 12 and continued until July 21 (Appendix E). The first day the weir operated was April 20 with limited operation through much of April and during the second half of May due to high stream discharge. The screw trap was operated for 62 days and captured 15,076 juvenile chinook salmon. A total of 5,794 juvenile chinook salmon were captured in the weir during 21 days of trapping.

Juvenile trapping operations occurred from April 12 to August 3 in 1990 (Appendix E). The screw trap was operated for 78 days and captured 4,883 chinook salmon. The weir was operated for 19 days with the first day of operation being

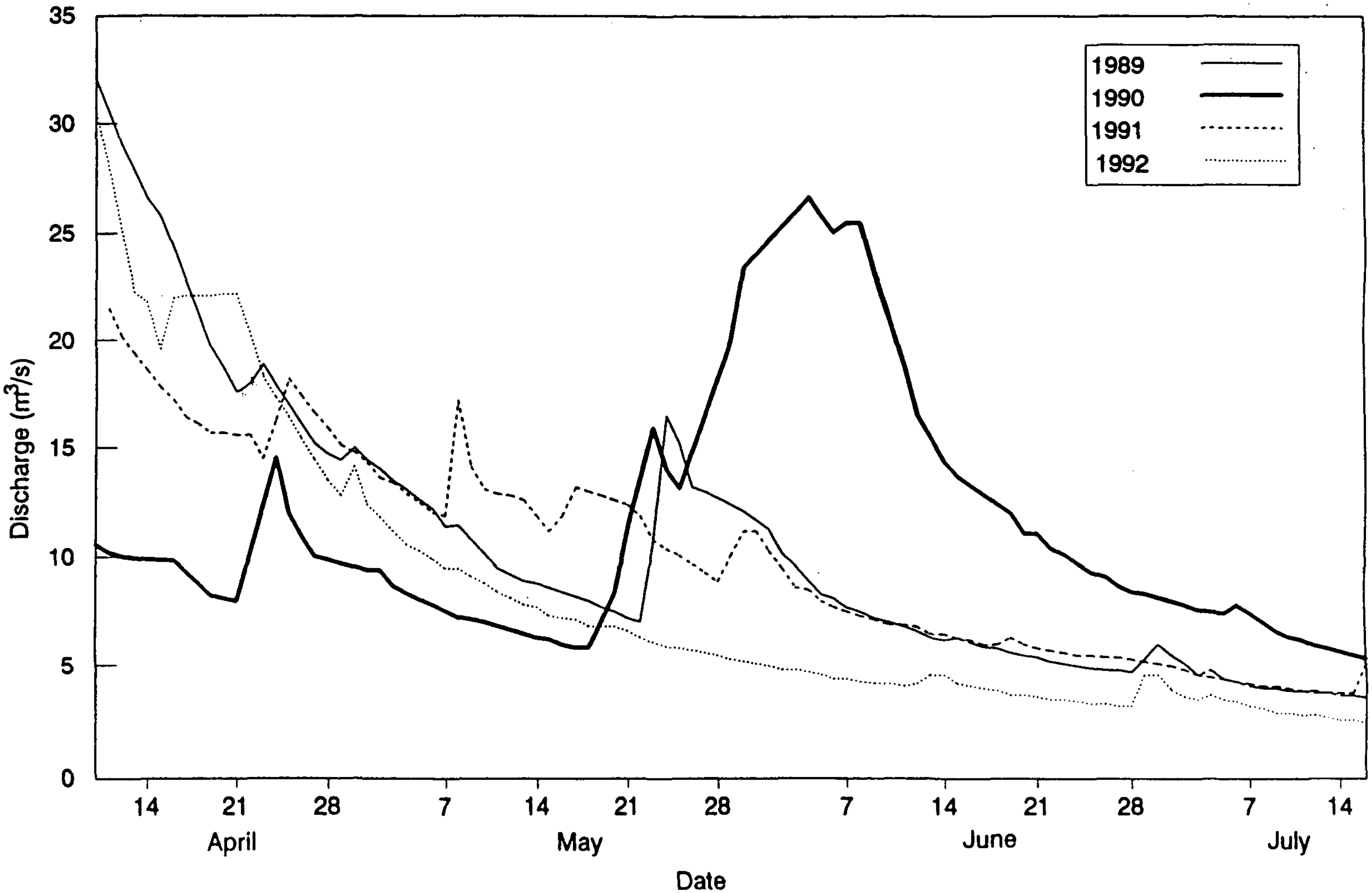


Figure 5. Daily Stream Discharge (m^3/s) of Blue Creek During Trapping Operations, 1989-1992.

April 19. High stream discharge precluded the use of the weir from the third week in May through the third week in June. A total of 2,250 chinook salmon were captured in the weir.

In 1991, trapping operations began on April 12 and concluded on August 14 (Appendix E). The screw trap was operated for 67 days and captured 1,397 chinook salmon. The weir was first installed on May 16 and was operated for 23 days, capturing 2,707 chinook salmon.

In 1992, trapping operations occurred from April 8 to July 14 (Appendix E). The screw trap was operated for 73 days and 10,647 chinook salmon were captured. The weir was first installed on May 19 and operated for 52 days, capturing 8,798 chinook salmon.

Size of Juvenile Chinook Salmon

During this study, mean length of juvenile chinook salmon captured in the screw trap generally increased throughout the trapping season (Figure 6, Appendix F). In 1989, mean length of chinook salmon captured in the screw trap ranged from 41.3 mm during the first week of trapping to 71.0 mm during the last two weeks of sampling. Mean length of juvenile chinook salmon captured in the screw trap during 1990 ranged from 48.5 mm to 58.0 mm during the first nine weeks of trapping (April 9 to June 4), then increased to 83.5 mm during the last week of trapping. Mean length of chinook salmon captured in the screw trap during 1991 generally increased throughout the

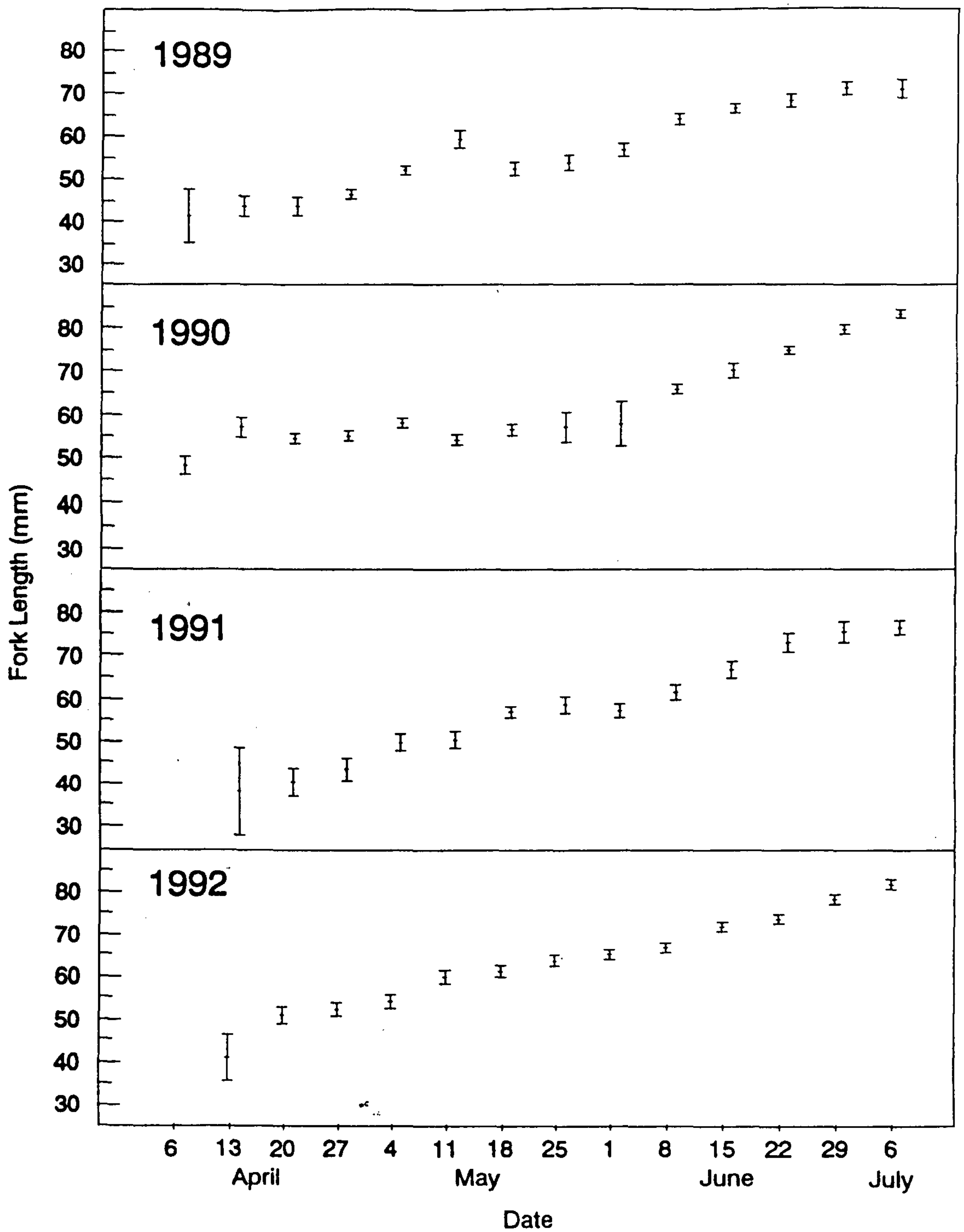


Figure 6. Weekly Mean Length (95% confidence interval) of Juvenile Chinook Salmon Captured in the Screw Trap During Trapping Operations on Blue Creek, 1989-1992.

trapping season ranging from 38.3 mm to 76.8 mm. In 1992, mean length of chinook salmon increased from 41.0 mm to 83.7 mm throughout the trapping season.

A total of 32 comparisons of weekly mean fork lengths of chinook salmon captured in the screw trap and weir were conducted: six in 1989, eight in 1990, nine in 1991, and nine in 1992 (Appendix G). Overall, there was a significant difference in mean fork length in 28 (88%) of the 32 comparisons with the mean length of chinook salmon captured in the screw trap significantly greater in 26 (93%) of the 28 comparisons with a significant difference (Table 3). In 1989, mean fork length of chinook salmon captured in the screw trap was significantly greater ($p<0.05$) than the mean length of chinook salmon captured in the weir for all weeks compared. Mean length of chinook salmon captured in the screw trap was significantly greater ($p<0.05$) than mean length of chinook salmon captured in the weir in seven of the eight weeks compared in 1990. In 1991, there were significant differences ($p<0.05$) in mean length of chinook salmon captured in the screw trap and weir in seven of the nine comparisons. Mean length of chinook salmon captured in the screw trap was significantly greater in five of the comparisons and significantly less in two. In 1992, mean length of chinook salmon captured in the screw trap was significantly greater ($p<0.05$) than mean length of chinook salmon captured in the weir in eight of the nine comparisons.

Table 3. Upper and Lower Confidence Limits (95%) and Significance Levels (p) of Weekly Mean Fork Length Comparisons of Juvenile Chinook Salmon Captured in the Weir and Screw Trap During Monitoring Operations in Blue Creek, 1989-1992.

		Weir		Screw Trap		
Year	Week	Lower	Upper	Lower	Upper	p
1989	Apr 17	40.5	41.7	43.3	44.9	<0.001
	May 7	44.6	47.0	50.8	53.2	<0.001
	Jun 12	56.7	61.2	62.2	67.1	0.018
	Jun 19	62.8	65.8	66.5	69.6	0.016
	Jun 26	58.4	61.0	66.8	69.4	<0.001
	Jul 3	60.7	64.6	70.2	73.7	<0.001
1990	Apr 16	42.6	45.9	53.3	58.9	<0.001
	Apr 23	45.0	47.4	51.0	53.4	<0.001
	Apr 30	45.8	49.0	52.4	55.7	<0.001
	May 7	54.0	55.7	56.9	59.2	0.002
	May 14	48.9	51.0	52.8	55.2	<0.001
	Jun 25	74.3	76.4	73.0	75.2	0.248
	Jul 2	75.5	78.8	78.9	82.3	0.043
	Jul 9	79.0	82.5	82.9	84.7	0.033
1991	May 13	57.0	59.4	50.0	54.3	<0.001
	May 20	50.5	54.1	54.6	57.6	0.025
	May 27	57.1	60.9	58.1	62.5	0.532
	Jun 3	54.9	57.1	55.5	57.8	0.589
	Jun 10	63.6	67.0	59.9	63.5	0.039
	Jun 17	62.4	64.9	65.5	68.4	0.018
	Jun 23	65.5	69.1	71.6	74.8	0.001
	Jul 1	61.3	68.3	68.7	75.4	0.037
	Jul 8	72.6	75.5	75.6	78.0	0.042
1992	May 18	53.7	55.4	60.3	61.9	<0.001
	May 25	56.9	58.8	62.6	64.7	<0.001
	Jun 1	60.7	62.3	64.3	65.9	<0.001
	Jun 8	62.8	64.4	65.9	67.6	<0.001
	Jun 15	68.8	70.4	71.0	72.6	0.008
	Jun 22	69.3	71.8	72.7	74.5	0.007
	Jun 29	73.2	74.9	77.5	79.1	<0.001
	Jul 6	78.1	80.1	81.0	82.5	0.003
	Jul 13	82.5	86.9	82.1	85.3	0.602

Mark-Recapture Trap Efficiency Estimates

Sixteen mark-recapture efficiency tests were conducted during this study: four in 1989, three in 1990, and nine in 1992. Fourteen tests to determine the differential survival of marked chinook salmon due to mortality attributable to the marking process were conducted (Appendix H). Estimates of relative survival were high (0.88 to 1.00) for all but two release groups (0.43 on July 5, 1989, and 0.83 on June 6, 1992).

During 1989, the number of marked fish released per group, after accounting for relative survival, ranged from 117 to 244 (Appendix I). Mark-recapture estimates of trap efficiency based on single day recaptures (Equation (3)) ranged from 0.307 to 0.527 (Appendix J). Trap efficiency based on the proportion of recaptured chinook salmon captured in the screw trap (Equation (4)) ranged from 0.381 to 0.773.

The number of marked fish released during 1990 mark-recapture efficiency tests, after accounting for relative survival, ranged from 80 to 311 per release group (Appendix I). Screw trap efficiency estimates ranged from 0.112 to 0.238 for the mark-recapture method and from 0.177 to 0.288 based on the proportion of recaptured fish captured in the screw trap (Appendix J).

Releases of marked chinook salmon for determining screw trap efficiency during 1992 ranged from 211 to 338 fish per release group (Appendix I). Mark-recapture estimates of trap efficiency ranged from 0.098 to 0.250 (Appendix J), whereas trap efficiency estimates utilizing the proportion of recaptured chinook salmon captured in the screw trap ranged from 0.219 to 0.672.

Comparison of Efficiency Estimates

Mark-recapture trap efficiency estimates (Equation (3)) were positively but not significantly correlated (r=0.414, n=16, p=0.111) with "actual" trap efficiency estimates (Equation (5)). These mark-recapture efficiency estimates were highly variable and were typically less than "actual" trap efficiency estimates, averaging about 50% of "actual" trap efficiencies (Figure 7A).

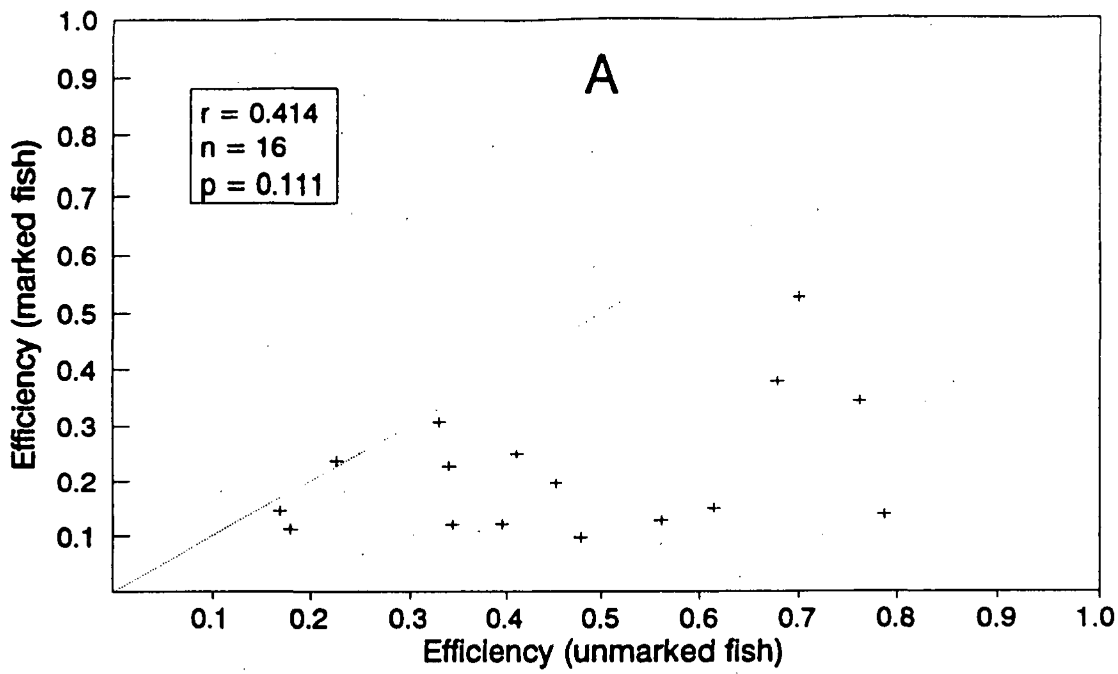
Trap efficiency estimates based on the proportion of recaptured chinook salmon captured in the screw trap (Equation (4)) were significantly correlated with "actual" trap efficiency estimates (r=0.873, n=16, p<0.001). These estimates of trap efficiency were more similar to "actual" trap efficiency estimates than mark-recapture estimates (Figure 7B), averaging 87% of "actual" trap efficiency.

Distribution of Marked Chinook Salmon

Based on Chi-squared tests, the distribution of marked chinook salmon recaptured in the screw trap and weir was not significantly different (p>0.05) from the distribution of unmarked chinook salmon in 12 (75%) of the 16 mark-recapture efficiency tests conducted during this study (Appendix K). When marked fish recaptured two days after release were included, the distribution of marked fish was not significantly different (p>0.05) in 13 (81%) of the 16 mark-recapture efficiency tests.

Downstream Migration After Release

The majority of marked chinook salmon were recaptured in the screw trap or weir the day following release, but some large catches occurred the second day after release



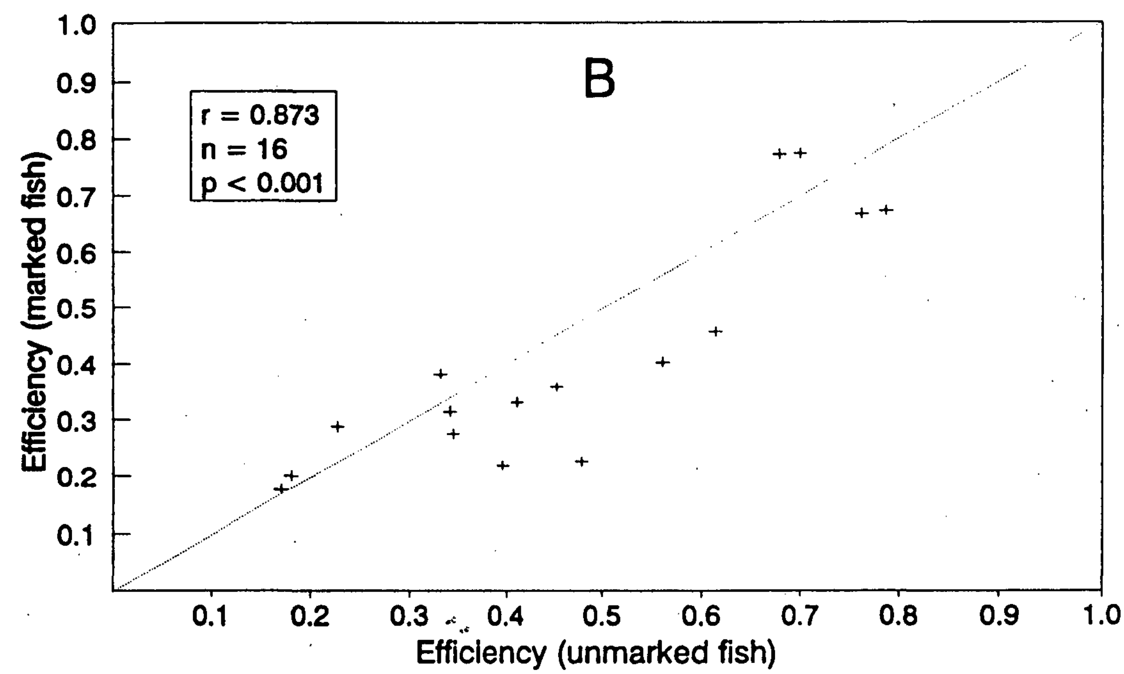


Figure 7. Estimated Screw Trap Efficiencies Based on (A) Mark-Recapture Methods (marked fish) and (B) the Proportion of Recaptured Chinook Salmon Captured in the Screw Trap (marked fish) Compared to Actual Trap Efficiencies (unmarked fish), 1989-1992. (Line Depicts Equal Efficiency Estimates for the Two Methods)

during 1989 mark-recapture tests (Appendix L). Because trap operations were not continuous and marks were not recognizable for long periods of time, data on delayed migration during these years was limited.

During 1992 mark-recapture tests, 78% of all recaptures occurred the day following release and 91% of the fish were recaptured within five days after release for all release groups combined (Appendix M). Marked fish exhibited varying delays in migration with small numbers of all release groups captured intermittently after release. The longest delay in recapture was 48 days for an individual released on May 18. Other lengthy delays in migration were 41 days after release (May 25 release group), 28 days after release (May 30 release group), 27 days after release (June 6 release group) and 19 days after release (June 10 release group). The largest percentages of a release group recaptured many days after release (June 19 release group) were 6.8% eight days after release and 4.6% nine days after release.

Recovery of Marked Chinook Salmon

For the 16 mark-recapture tests conducted during this study, the proportion of each release group that was recaptured in the screw trap and weir ranged from 0.368 for the June 6, 1992, release group, to 0.881 for the July 5, 1989, release group (Appendix I). The proportion of each release group that was recaptured was not significantly correlated with stream discharge ($r=0.304$, $n=16$, $p=0.252$). The recovery rate for the July 5, 1989, release group may be an overestimate due to the low relative survival ($S_d=0.43$) for this release group which greatly reduced the estimated number of marked chinook salmon available for recapture. Data collected in 1992, when the screw trap and weir were operated continuously for longer periods, also indicated that recovery rates were highly variable, ranging from 0.368 to 0.801, and relatively low, averaging 0.623. The proportion of each release group recovered in 1992 was not significantly correlated with stream discharge ($r=-0.191$, $n=9$, $p=0.632$).

Screw Trap Efficiency Estimates and Predictive Equations

A total of 115 estimates of screw trap efficiency, based on captures of unmarked juvenile chinook salmon in the screw trap and weir, were generated during this study (Appendix E). Due to changes in the trap location or in the physical configuration of the trapping site, data were analyzed separately for individual years.

During 1989, 21 estimates of trap efficiency were generated, ranging from 0.100 at 19.2 m^3/s on April 20 to 0.858 at 4.7 m^3/s on June 28 (Appendix E). Estimated trap efficiency increased with decreasing stream discharge (Figure 8). Logit transformed estimates of trap efficiency were significantly correlated with ($Ln(\hat{Q})$, $P\hat{Q}$, $P\hat{W}$, and $R\hat{M}$, and all potential predictor variables were also significantly correlated with each other (Table 4).

Forward stepwise multiple regression of 1989 trap efficiency data resulted in a significant model ($F=132.12$, $v_1=1$, $v_2=19$, $p<0.001$) with significant intercept and slope parameters and R^2_{ADJ} of 0.868 (Table 5). The resulting model had a single independent variable, $Ln(\hat{Q})$.

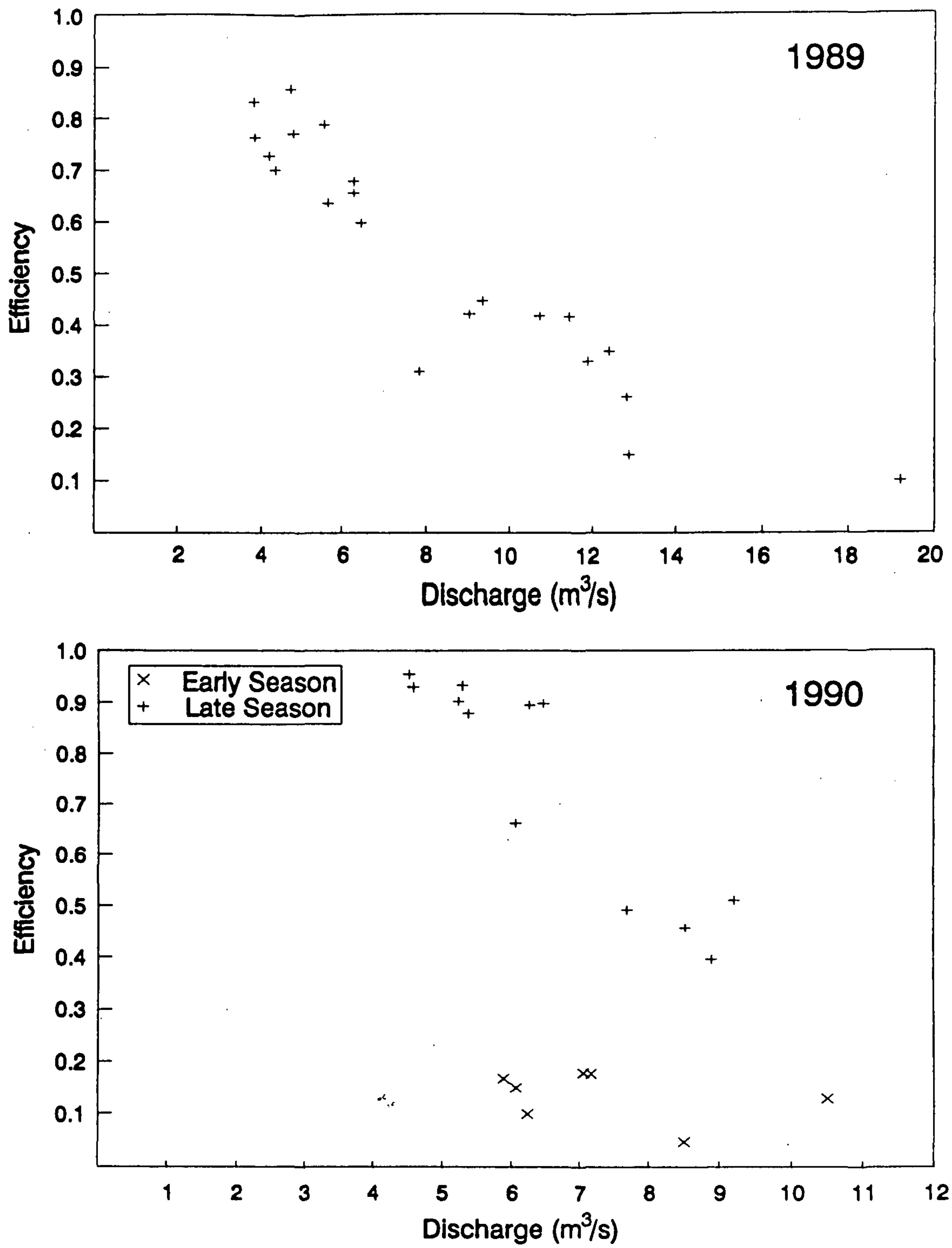


Figure 8. Screw Trap Efficiency and Stream Discharge During Juvenile Salmonid Trapping Operations in Blue Creek, 1989-1992.

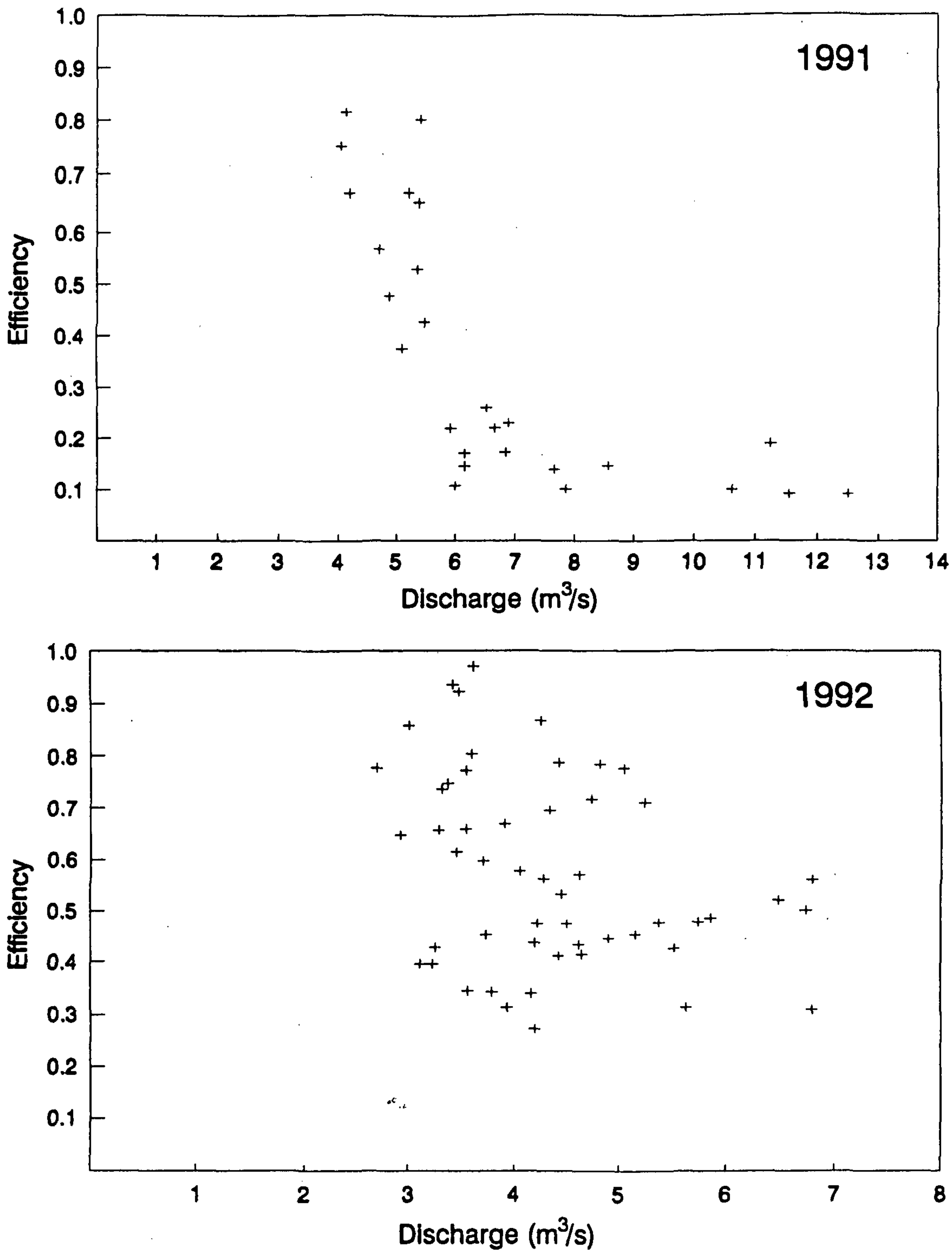


Figure 8. Screw Trap Efficiency and Stream Discharge During Juvenile Salmonid Trapping Operations in Blue Creek, 1989-1992. (continued)

Table 4. Correlation Matrixes for Juvenile Chinook Salmon Trap Efficiency and Potential Independent Variables from Data Collected During Trapping Operations on Blue Creek, 1989-1992 (significance level in parentheses). [a, b]

Year	Variable	RM	PW	PQ	Ln(Q)
1989	Logit(E)	-0.775 (<0.001)	N/A[c]	0.776 (<0.001)	-0.935 (<0.001)
	Ln(Q)	0.743 (<0.001)	N/A[c]	-0.744 (<0.001)	
	PQ	-0.438 (0.047)	N/A[c]		
	PW	-0.790 (<0.001)			
1990-Early	Logit(E)	-0.651 (0.113)	0.357 (0.432)	-0.506 (0.246)	-0.365 (0.421)
	Ln(Q)	0.860 (0.013)	N/A[d]	0.286 (0.534)	
	PQ	0.694 (0.084)	-0.262 (0.571)		
	PW	-0.849 (0.016)			
1990-Late	Logit(E)	-0.706 (0.010)	0.861 (<0.001)	0.354 (0.259)	-0.894 (<0.001)
	Ln(Q)	0.612 (0.034)	N/A[d]	-0.552 (0.063)	
	PQ	0.150 (0.643)	0.601 (0.039)		
	PW	-0.579 (0.049)			

Table 4. Correlation Matrixes for Juvenile Chinook Salmon Trap Efficiency and Potential Independent Variables from Data Collected During Trapping Operations on Blue Creek, 1989-1992 (significance level in parentheses). [a, b] (continued)

Year	Variable	RM	PW	PQ	Ln(Q)
1991	Logit(E)	-0.751 (<0.001)	0.767 (<0.001)	0.728 (<0.001)	-0.789 (<0.001)
	Ln(Q)	0.978 (<0.001)	N/A[d]	-0.965 (<0.001)	
	PQ	-0.908 (<0.001)	0.968 (<0.001)		
	PW	-0.978 (<0.001)			
1992	Logit(E)	-0.301 (0.030)	0.336 (0.015)	-0.094 (0.507)	-0.340 (0.014)
	Ln(Q)	0.923 (<0.001)	N/A[d]	-0.141 (0.318)	
	PQ	-0.135 (0.342)	0.171 (0.225)		
	PW	-0.935 (<0.001)			

[a] Sample sizes: 1989 (n=21), 1990-early season (n=7), 1990-late season (n=12), 1991 (n=23) and 1992 (n=52).

[b] Logit(E) = logistic transformed trap efficiency, Ln(Q) = natural log transformed stream discharge, PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute.

[c] Stream width data were not estimated for 1989 due to insufficient sample size of stream width-discharge data.

[d] Correlation between Ln(Q) and PW was not calculated because PW was estimated from stream discharge.

Table 5. Results of Multiple Regression Analyses for Juvenile Chinook Salmon Screw Trap Efficiency Data, 1989-1992.[a]

Year	n	R^2	$R^2_{(ADJ)}$	Variable[b]	Coefficient	SE	t	p
1989	21	0.874	0.868					
				Constant	4.422	0.382	11.563	<0.001
				Ln(Q)	-2.136	0.186	-11.494	<0.001
1990[c]	12	0.779	0.778					
				Constant	9.971	1.406	7.094	<0.001
				Ln(Q)	-4.759	0.776	-6.297	<0.001
1991	23	0.759	0.735					
				Constant	134.759	38.443	3.505	<0.001
				Ln(Q)	-29.678	7.887	-3.763	<0.001
				PW	-497.540	147.216	-3.380	0.003
1992	52	0.115	0.097					
				Constant	2.444	0.813	3.006	0.004
				Ln(Q)	-1.420	0.557	-2.549	0.014

[a] Predictive Equations: $Logit(E) = a+b*(Ln(Q))$ or $E = 1/[1+e^{-(a+b*Ln(Q))}]$ for 1989, 1990, and 1992 and
$Logit(E) = a+(b_1*Ln(Q)+b_2*PW)$ or $E = 1/[1+e^{-(a+(bccc1*Ln(Q)+b2*PW) b*Ln(Q))}]$ for 1989 .

[b] Ln(Q)= Natural log transformed stream discharge, PW = Proportion of stream width sampled by the screw trap.

[c] Only 1990 late season data included in this analysis.

Nineteen estimates of trap efficiency data were generated from data collected during trapping operations in 1990. Most of the trap efficiency data collected prior to May 18 (when a large increase in stream discharge began, Figure 5) were lower than expected based on the estimated trap efficiencies observed in 1989. A possible explanation for these lower than expected trap efficiencies was that the physical configuration of the trapping site changed from 1989 to 1990. A shallow gravel bar developed at the head of the pool where the screw trap was placed, resulting in a diffused stream flow pattern. This may have affected the distribution of juvenile chinook salmon while they migrated through the trapping site, resulting in the lower efficiencies. The high stream discharge that occurred from the end of May into the second week of June scoured this gravel bar, recreating a stream channel similar to that observed in 1989. Estimates of trap efficiency were therefore separated into data collected prior to May 18 (early season) and after June 18 (late season). This resulted in seven estimates of trap efficiency for the early season and 12 for the late season.

Estimated trap efficiency during the early season ranged from 0.047 on April 19 at a stream discharge of 8.5 m^3/s to 0.179 on May 10 at 7.1 m^3/s (Appendix E). Early season trap efficiency estimates did not exhibit a functional relationship with stream discharge for the early season (Figure 8) and logit-transformed trap efficiency was not significantly correlated with any of the potential predictor variables (Table 5).

Because there were no significant relationships between early season trap efficiency and any of the potential predictor variables, an estimate of average trap efficiency was used for this period in 1990. This was calculated by summing the number of juvenile chinook salmon captured in the screw trap and dividing this by the sum of the number of chinook salmon captured in the screw trap and weir for the seven days sampled. The estimated trap efficiency for the 1990 early season ($\hat{E}_{early\ 1990}$) was:

$$\hat{E}_{(early\ 1990)} = 277 / (277+1863) = 0.129.$$

Trap efficiency estimates for the late season ranged from 0.396 on June 27 to 0.954 on July 25 at stream discharges of 8.9 m^3/s and 4.5 m^3/s, respectively (Appendix E). Trap efficiency generally increased with decreasing stream discharge (Figure 8). Logit-transformed trap efficiency estimates were significantly correlated with $Ln(\hat{Q})$, $P\hat{W}$, and $R\hat{M}$, and several significant correlations also existed among the potential predictor variables (Table 4).

Regression analysis of the 1990 late season trap efficiency data resulted in a significant model ($F=39.656$, $v_1=1$, $v_2=10$, $p<0.001$) with one independent variables, $Ln(\hat{Q})$, and R^2_{ADJ} of 0.778 (Table 5).

Screw trap efficiency data were collected on 23 occasions during 1991 trapping operations (Appendix E). Estimated trap efficiencies ranged from 0.090 on May 17 at a stream discharge of 12.5 m^3/s to 0.815 on July 9 at stream discharge of 4.1 m^3/s. Estimated trap efficiencies increased with decreasing stream discharges but exhibited a sharper transition than was observed in 1989 and 1990 data (Figure 8). Logit-transformed trap efficiency estimates were significantly correlated with all potential predictor variables (Table 4).

Stepwise multiple regression of 1991 trap efficiency data resulted in a significant model ($F=31.542$, $v_1=2$, $v_2=20$, $p<0.001$) with two independent variables, $Ln(\hat{Q})$, and $P\hat{W}$, and R^2_{ADJ} of 0.735 (Table 5). Without the variable $P\hat{W}$, R^2_{ADJ} was 0.604.

Data to generate 52 estimates of screw trap efficiency were collected in 1992 (Appendix E). Due to the configuration of the trapping site utilized in 1992, the weir was not operable at stream discharges greater than 6.8 m^3/s. Trap efficiency estimates were extremely variable (Figure 8) and were only weakly correlated ($r=-0.340$, $n=52$, $p=0.014$) with stream discharge in 1992 (Table 4).

Although regression analysis of the 1992 trap efficiency data resulted in a significant model ($F=6.495$, $v_1=1$, $v_2=50$, $p=0.014$), the resulting equation was of little utility because only a small portion of the variation in efficiency ($R^2_{ADJ} = 0.097$) was explained by the model (Table 5). Trap efficiency estimates were not generated for the period when the weir was not operated because of the poor trap efficiency predictive model.

Estimates of Juvenile Chinook Salmon Downstream Migration

Based on screw trap catches scaled up by trap efficiency estimates (Equations (6) and (7)) (Appendix N), an estimated 48,970 juvenile chinook salmon migrated downstream from Blue Creek from April 15 to July 15 in 1989 (Table 6). Downstream migration peaked during the last two weeks of May (11,725), with large numbers of chinook salmon also migrating downstream during the first two weeks in June (11,407) and the last two weeks of June (10,037) (Figure 9, Appendix O). Based on trap catches

Table 6. Annual (April 16-July 15) Efficiency-Based and Discharge-Based Abundance Estimates of Juvenile Chinook Salmon Migrating Downstream from Blue Creek, 1989-1992.

Year	Efficiency-Based	Discharge-Based
1989	48,971	74,026
1990	36,565	26,243
1991	15,615	14,887
1992[a]		49,945

[a] No efficiency-based estimate was derived for 1992 because of poor discharge-trap efficiency relationship.

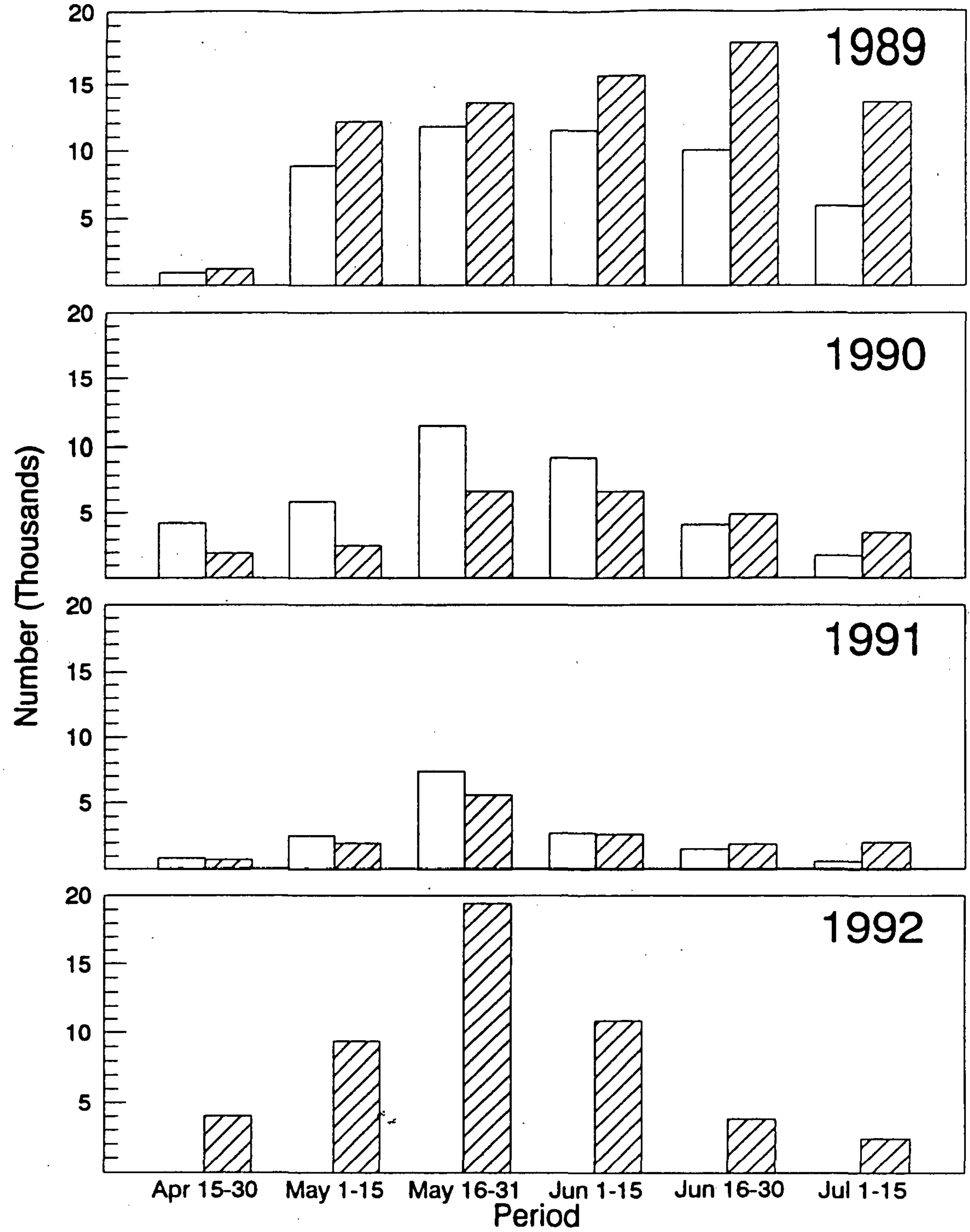


Figure 9. Semimonthly Efficiency-Based (open bars) and Discharge-Based (hatched bars) Abundance Estimates of Juvenile Chinook Salmon Migrating Downstream from Blue Creek, 1989-1992.

scaled up by the proportion of stream discharge sampled (Equations (8) and (9))(Appendix N), the estimated number of juvenile chinook salmon migrating downstream was 74,026 (Table 6), peaking (17,854) during the last two weeks of June (Figure 9, Appendix O).

Based on trap catches and corresponding trap efficiency estimates (Equations (6) and (7)) (Appendix N), an estimated 36,565 juvenile chinook salmon migrated downstream from Blue Creek in 1990 (Table 6). Migration peaked during the last two weeks in May (11,378) with a substantial number of juvenile chinook salmon (9,254) migrating downstream during the first two weeks of June (Figure 9, Appendix O). Based on trap catches and corresponding estimates of the proportion of stream discharge sampled (Equations (8) and (9))(Appendix N), the estimated number of juvenile chinook salmon migrating downstream for 1990 was 26,243 (Table 6). Discharge based estimates of downstream migration peaked during the last two weeks of May and the first two weeks of June (6,698 and 6,716, respectively) (Figure 9, Appendix O).

Based on Equations (6) and (7) (Appendix N), an estimated 15,615 juvenile chinook salmon migrated downstream from Blue Creek in 1991 (Table 6), with downstream migration peaking at 7,378 during the last two weeks of May (Figure 9, Appendix O). Based on Equations (8) and (9)(Appendix N), an estimated 14,887 juvenile chinook salmon migrated downstream in 1991 (Table 6), with the peak of the downstream migration (5,574) occurring during the last two weeks of May (Figure 9, Appendix O).

The poor trap efficiency predictive model for 1992 precluded efficiency-based estimates the number of juvenile chinook salmon migrating downstream from Blue Creek in 1992. Based on the trap catches scaled up by the proportions of stream discharge sampled (Equations (8) and (9))(Appendix N), the number of juvenile chinook salmon migrating downstream in 1992 was 49,945 (Table 6). The peak of downstream migration occurred during late-May (Figure 9, Appendix O).

Comparison of Trap Efficiency and Proportion of Stream Discharge Sampled

Estimates of screw trap efficiency when the weir was operated ("actual" efficiency) were significantly correlated ($r=0.781$, $n=21$, $p<0.001$) with estimates of the proportion of stream discharge sampled in 1989 (Table 7). Estimates of trap efficiency were generally greater than the corresponding estimates of the proportion of stream discharge sampled (Figure 10A). As stream discharge decreased, the difference between trap efficiencies and corresponding proportions of stream discharge sampled increased (Figure 10B).

Trap efficiencies were significantly correlated ($r=0.658$, $n=12$, $p=0.020$) with the proportions of stream discharge sampled for the 1990 late season data (Table 7). Estimates of trap efficiency were greater than corresponding estimates of the proportion of stream discharge sampled (Figure 11A). Estimated trap efficiencies increased as stream discharge decreased while the proportion of stream discharge sampled remained fairly constant (Figure 11B). The relationship between trap efficiency and the

Table 7. Correlation (r), Sample Size (n), and Significance Level (p) Between Juvenile Chinook Salmon Screw Trap Efficiency and the Proportion of Stream Discharge Sampled by the Screw Trap on Blue Creek, California, 1989-1991.

Year	r	n	p
1989	0.781	21	<0.001
1990-Late Season	0.658	12	0.020
1991	0.687	23	<0.001

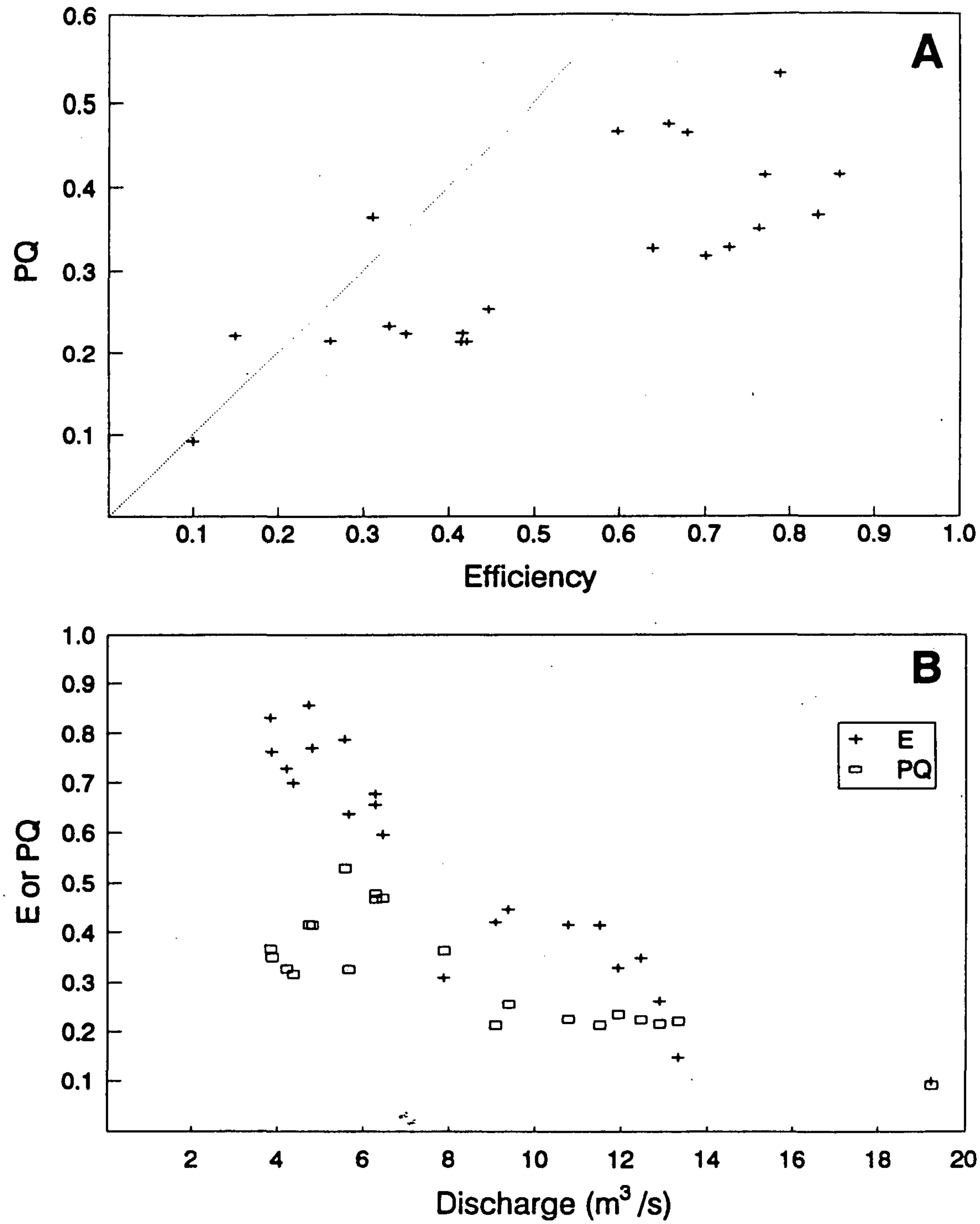


Figure 10. Proportion of Stream Discharge Sampled (PQ) Versus Screw Trap Efficiency (E) (Graph A) and PQ and E Versus Stream Discharge (Graph B) During Juvenile Salmonid Trapping Operations in Blue Creek, 1989. (Line in Graph A Depicts Equal PQ and E)

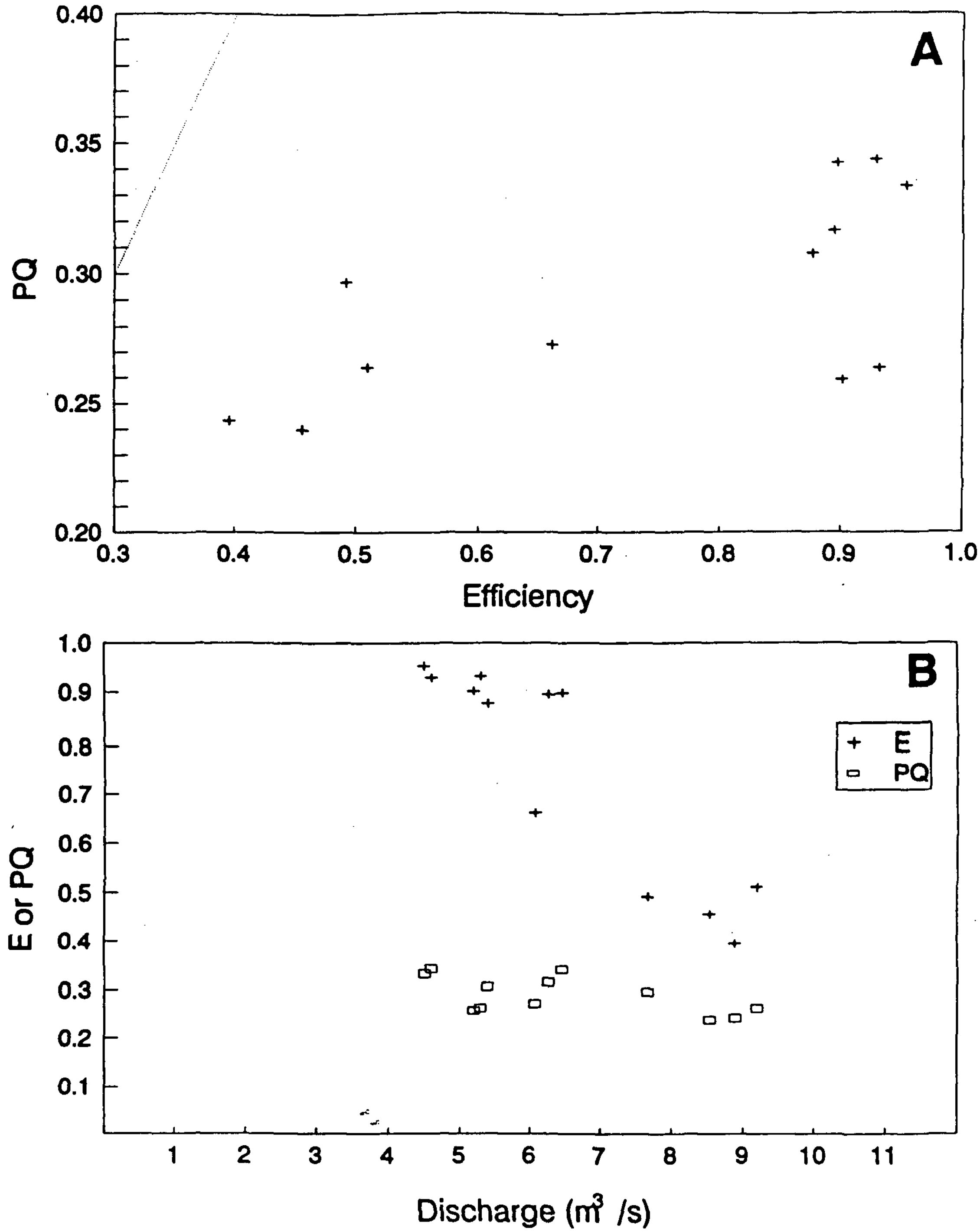


Figure 11. Proportion of Stream Discharge Sampled (PQ) Versus Screw Trap Efficiency (E) (Graph A) and PQ and E Versus Stream Discharge (Graph B) During Juvenile Salmonid Trapping Operations in Blue Creek, 1990 late season. (Line in Graph A Depicts Equal PQ and E)

proportion of stream discharge sampled was similar to that observed in 1989 (Figure 10A).

Trap efficiencies were significantly correlated ($r=0.687$, $n=23$, $p<0.001$) with the proportion of stream discharge sampled in 1991 (Table 7). Estimated trap efficiencies and the proportions of stream discharge sampled were very similar at lower values (<0.20), but above this value (0.20), the proportion of stream discharge sampled remained fairly constant as trap efficiency increased (Figure 12A). The proportion of stream discharge sampled increased slightly as stream discharge decreased (Figure 12B). As stream discharge decreased, trap efficiency remained relatively constant but then increased at a rapid rate at stream discharges below 6 m^3/s.

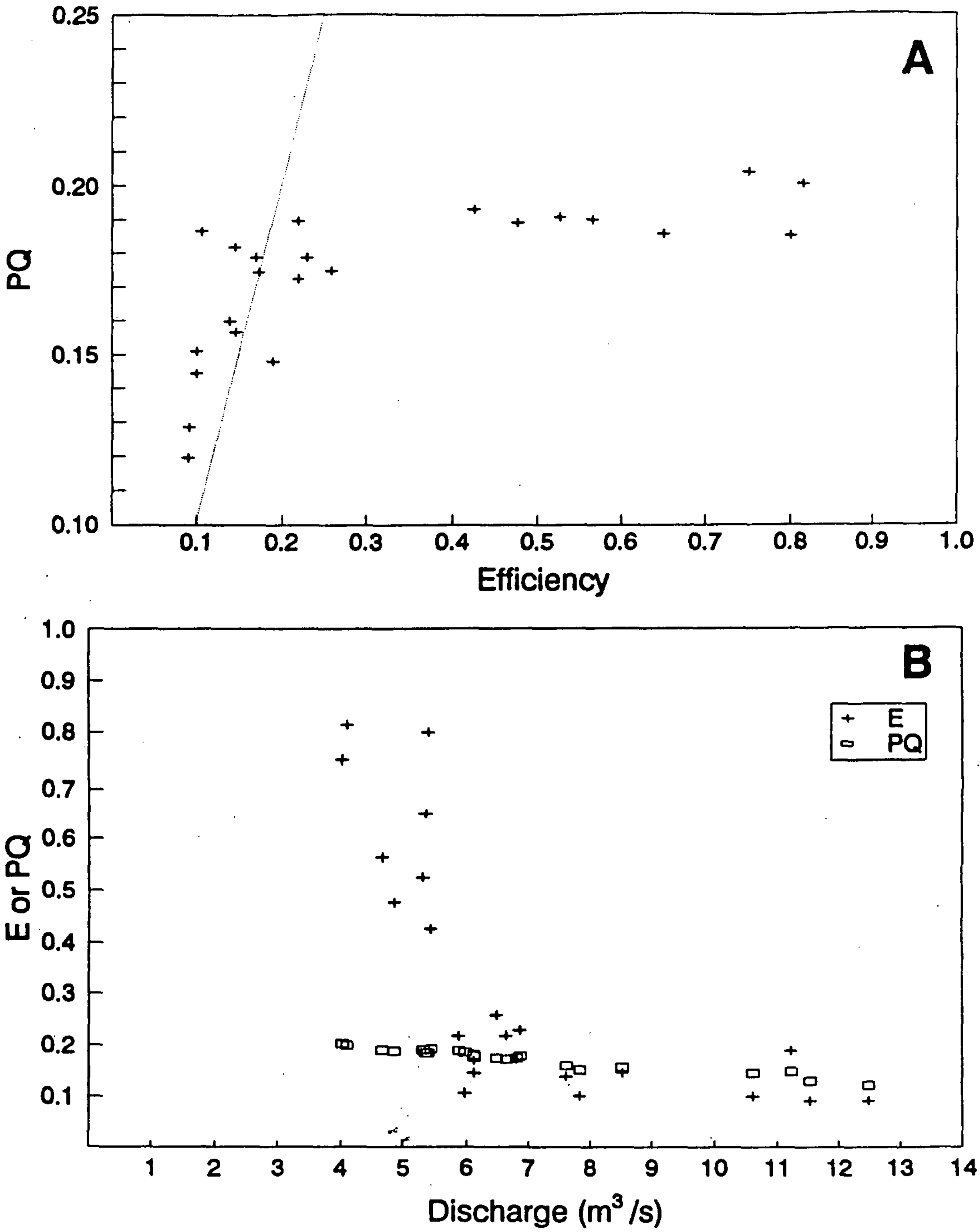


Figure 12. Proportion of Stream Discharge Sampled (PQ) Versus Screw Trap Efficiency (E) (Graph A) and PQ and E Versus Stream Discharge (Graph B) During Juvenile Salmonid Trapping Operations in Blue Creek, 1991. (Line in Graph A Depicts Equal PQ and E)

DISCUSSION

The primary objective of this study was to estimate the number of juvenile chinook salmon migrating downstream from Blue Creek. Secondary objectives were to determine what factors affect trap efficiency, evaluate the use of mark-recapture methods in determining trap efficiency, and investigate the relationships between estimates of the number of juvenile chinook salmon migrating downstream based on trap efficiency and the proportion of stream discharge sampled.

Assessment of Trap Efficiency

Thedinga et al. (1994) found that the efficiency of screw traps was affected by stream discharge, trap placement, and the speed of cone rotation, whereas Roper and Scarnecchia (1996) found that trap placement along the length of a pool did not affect the efficiency of a screw trap on wild chinook salmon but did affect the efficiency on hatchery chinook salmon. During this study several general trends between screw trap efficiency and factors that were expected to affect trap efficiency were evident. Estimated trap efficiencies were negatively correlated with stream discharge and with trap revolutions, and positively correlated with the proportion of stream width sampled (Table 4). There were also many significant correlations among potential predictor variables, specifically stream discharge and trap revolutions, proportion of stream discharge sampled and proportion of stream width sampled, and trap revolutions and proportion of stream width sampled.

Selection of the stream discharge variable, $(\mathrm{Ln}(\hat{Q}))$, during stepwise multiple regression analyses used to develop trap efficiency predictive equations indicated that stream discharge was generally the principle factor affecting trap efficiency (Table 5). The proportion of stream width sampled was also a significant factor for the 1991 efficiency predictive model. Other potential predictor variables were generally significantly correlated with the stream discharge (Table 4) which limited their utility in further defining the relationship between trap efficiency and the predictor variables (Draper and Smith 1981).

Although regression analysis of the 1992 trap efficiency data resulted in a significant model, the resulting equation was of little utility because only a small portion of the variation ($R^2_{ADJ} = 0.097$) was explained by the model (Table 5). This poor relationship was probably attributable to the violation of the assumption that downstream migrant juvenile chinook salmon did not terminate their nightly migration between the screw trap and weir. The large distance between the screw trap, located at the head of a 80 m long pool, and the weir, located at the tailout of the same pool, allowed for a significant number of fish to hold/rear in the area between the two traps. Snorkel surveys of this pool indicated that large numbers of juvenile chinook salmon utilized this pool for holding/rearing. Fin-clipped chinook salmon were also observed holding in this pool several days to weeks after their release indicating that there was a delay in migration through the trapping site.

Estimates of trap efficiency based on unmarked juvenile chinook salmon captured in the screw trap and weir indicated a general trend of increasing efficiency as stream discharge decreased but also indicated that there was substantial variation in trap efficiency at similar stream discharges (Figure 8). It was expected that at a given stream discharge, trap efficiency would be relatively stable but the data collected during this study clearly contradicted this expectation. Although Ashe et al. (1995) grouped trap efficiency estimates into three periods based on stream discharge, individual trap efficiency estimates showed an efficiency-stream discharge relationship similar to that observed during this study (Figure 13). Their data also indicated substantial variation at similar stream discharges. Other studies (Siler et al. 1984, Giorgi and Simms 1987, Thedinga et al. 1994) also found that trap efficiency estimates can be highly variable at similar or moderately stable stream discharges.

Two potential causes of the observed variability of trap efficiency were fish finding their way through the weir without being captured, a violation of the assumption that the weir was 100% efficient, and/or fish terminating their nightly migration after passing the screw trap but not the weir. Although it is unlikely that the weir was always 100% efficient, it is believed that the assumption of 100% weir efficiency was not significantly violated during this study. Difficulties in maintaining a "fish tight" weir would be expected to occur at higher stream discharges due to the increased water depth and velocity. If there had been a problem with the weir being "fish tight", then a negative correlation between stream discharge and the proportion of each mark-recapture group recovered in the screw trap and weir would be expected. This would be due to marked fish escaping through the weir, resulting in a lower recovery rates for release groups during higher stream discharges. During this study, the proportion of marked fish

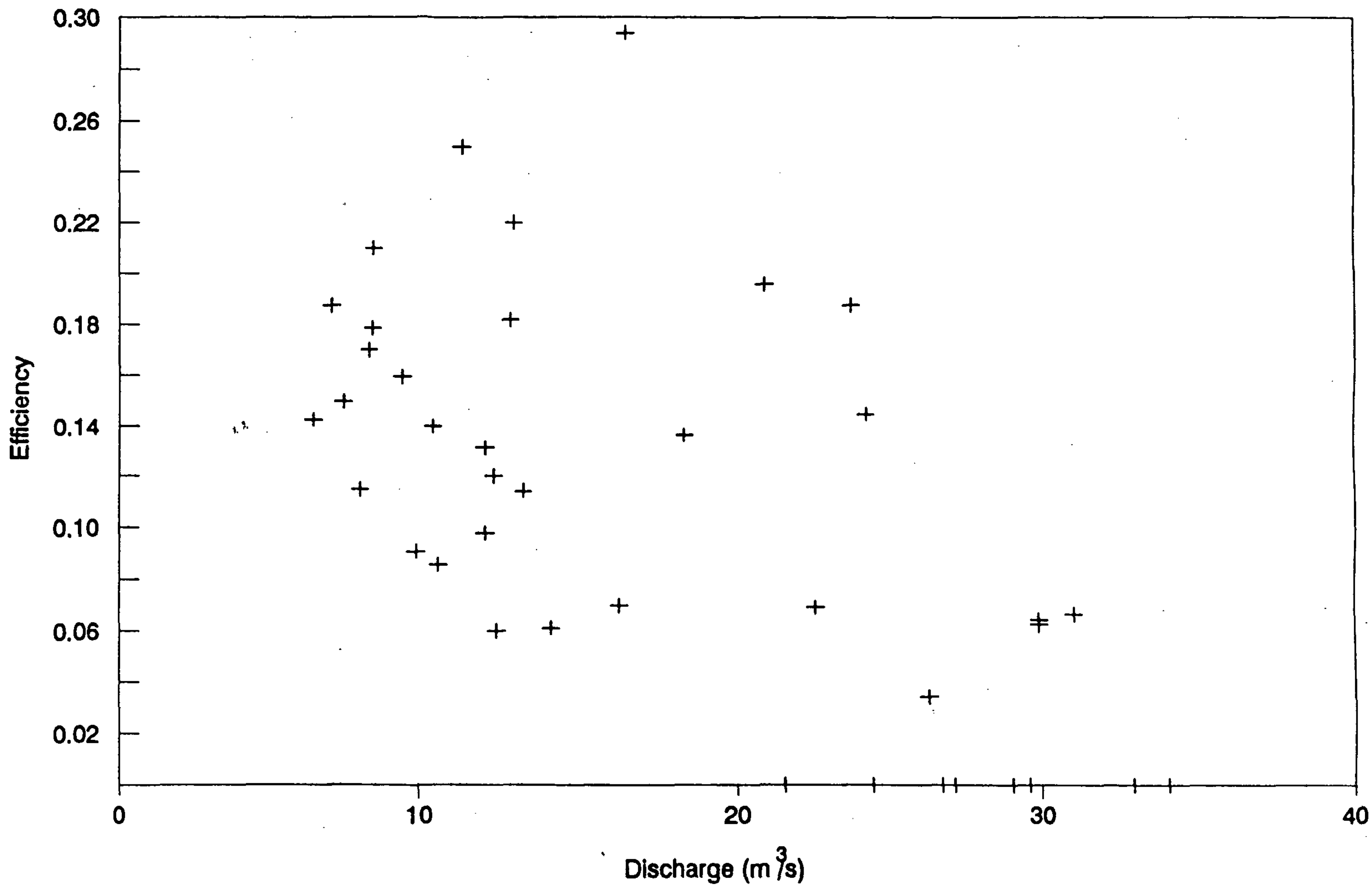


Figure 13. Mark-Recapture Screw Trap Efficiency Estimates for Juvenile Chinook Salmon on the Imnaha River, Oregon (redrawn from Ashe et al. 1995, Table C).

released that were recaptured in the screw trap and weir was not significantly correlated with stream discharge, indicating that the trapping effectiveness of the weir was not affected by stream discharge.

Delays in the downstream migration of juvenile chinook salmon between the screw trap and weir could have led to increased variation in observed trap efficiency estimates because the actual number of fish migrating past the screw trap would be unknown. This would lead to overestimation of trap efficiency if fish ceased their migration between the screw trap and weir and, conversely, if significant numbers of fish that were rearing/holding below the screw trap then entered the weir, then trap efficiency would be underestimated. The potential effect of fish not migrating through the trapping site on the variability of trap efficiency estimates was most evident in the data collected in 1992 (Figure 8). Large concentrations of fish were observed rearing/holding above the weir which greatly affected the variability in trap efficiency estimates. Although small schools of fish were intermittently observed rearing/holding above the weir during other years, it is not believed that this had a significant influence on trap efficiency estimates or their variability.

It is believed that the variability observed in trap efficiency estimates, excluding 1992 data, was an accurate representation of the variability that occurred during juvenile salmonid monitoring activities in Blue Creek. Only if the distribution of downstream migrant chinook salmon was consistent at a given flow would stable trap efficiencies be expected. Based on data collected during this study, it appears that the distribution of fish as they migrate downstream is somewhat variable. This demonstrates the importance of assessing the variability of trap efficiencies at similar stream discharges, possibly through replicate mark-recapture release groups.

Mark-Recapture Efficiency Estimation

Mark-recapture techniques are often used to estimate trap efficiencies in fish population assessments (Krema and Raleigh 1971, Siler et al. 1984, Dempson and Standbury 1991, Thedinga et al. 1994, Ashe et al. 1995) but violation of the underlying assumptions of the mark-recapture methodology can greatly affect the validity of the results. Due to the size of the Blue Creek watershed, it was possible to operate the weir and collect data to evaluate the "actual" efficiencies of the screw trap at varying flows and compare these to mark-recapture efficiency estimates.

Mark-recapture techniques used in this study resulted in estimates of trap efficiency that were negatively biased, averaging 50% of "actual" trap efficiency (Figure 7A). It is likely that the negatively biased efficiency estimates were due to violations of four of the five assumptions invoked while employing mark-recapture techniques. The assumptions that marked fish migrated downstream immediately after release (assumption #2) and marked fish had the same distribution as unmarked fish (assumption #3) were violated to varying degrees. It is also believed that the assumption that fish did not lose their marks (assumption #4) and marked fish experienced no mortality after release (assumption #1) were violated and contributed to the negative bias in efficiency estimates.

It was expected that virtually all of the marked chinook salmon would be recaptured in the screw trap or weir within a day or two after release but total recoveries of marked chinook only averaged 63% for all release groups and substantial delays in migration were observed, the longest being 48 days after release. In 1989 and 1990, it was impossible to determine if the failure to recover the majority of the marked fish was due to delays in migration (violation of assumption #2), potentially leading to poor mark retention (violation of assumption #4), and/or to the intermittent operation of the weir which would have allowed marked fish to pass the trapping site without being accounted for unless they were captured in the screw trap. Lack of continuous trapping, especially with the weir, and a short term mark had an unquantifiable negative affect on the estimates of total recovery for 1989 and 1990 data. In 1992, changes in the mark used (partial fin clips) and weir operation (almost continuous operation once it was installed) were initiated in an attempt to obtain a better accounting of the marked fish and delays in migration. These data indicated that the assumption that marked fish migrated soon after release was consistently violated with an average of 78% of recovered marked fish being recaptured the day following release and 91% within five days after release.

Violation of the assumption that marked chinook salmon had the same distribution as unmarked chinook salmon (assumption #3) also contributed to the negative bias in mark-recapture efficiency estimates. The distributions of marked and unmarked fish were significantly different in 25% of the mark-recapture efficiency tests based on recaptures within one day of release and 19% when recaptures within two days of release were included. Mark-recapture efficiency estimates based on the proportion of recaptured chinook salmon captured in the screw trap, averaging 87% of "actual" trap efficiency (Figure 10B), provided a measure of the negative bias due to the violation of this assumption because these estimates of trap efficiency are free of the assumptions of "no mortality" and "immediate migration".

It appears that the assumption that marked fish experience no mortality after release (assumption # 1) was violated during this study. Overall, only 63% of marked fish were recovered during this study and only 61% were recovered during 1992 trapping operations when continuous trapping was conducted. The "loss" of marked fish was probably primarily due to mortality of marked fish and most likely due to predation, since marking mortality was generally low (Appendix H). During this study, reduced ability for predator avoidance due to stress induced by capture, marking, transporting, and release may have had a significant impact on survival of marked fish once they were released. Fish exposed to significant levels of stress are more susceptible to increased predation (Sigismondi and Weber 1988, Schreck et al. 1989, Mesa 1994). Physiology studies (Wedemeyer 1972, Barton et al. 1986, Mesa 1994) have demonstrated that juvenile salmonids typically require 3 to 24 h to recover from stress; in some cases recovery may take up to three days (Taylor 1988).

Blue Creek supports a large population of prickly sculpin (C. asper) which were often captured in the screw trap and usually contained juvenile salmonids in their stomachs, some of which were marked fish. Although the unnatural condition of being retained in the live box in close proximity to each other may have increased sculpin predation, it probably also occurs at high levels in the stream, especially on marked fish suffering from handling stress. Steelhead and cutthroat trout also inhabit Blue Creek and were potential predators of marked chinook. Rodgers et al. (1992) believed that coho salmon population estimates in Beaver Creek, Oregon, may have been affected by mortality of marked fish or by predation by cutthroat trout, while Hillman (1989) found that shorthead sculpin (C. confusus) were effective predators of juvenile chinook salmon in streams.

Overall, the use of the mark-recapture methodology to estimate trap efficiency was ineffective in Blue Creek due to violations of several of the assumptions invoked while utilizing this method. The large negative bias in mark-recapture efficiency estimates observed during this study can be attributed primarily to: (1) mortality of marked fish, possibly due to a reduced predator avoidance resulting from handling stress, (2) delayed migration affecting the capture probability of marked fish, and (3) differential distribution of marked fish and unmarked fish, also affecting capture probability.

Use of trap efficiency estimates from mark-recapture data to generate estimates of abundance would have led to substantial overestimates of the number of juvenile chinook salmon migrating downstream in this study. These results demonstrate the importance of testing the assumptions of mark-recapture techniques, especially the critical assumptions of no mortality and equal capture probability, as suggested by Cormack (1968), Seber (1970), and Cone et al. (1988).

Size Differences of Chinook Salmon Captured in the Screw Trap and Weir

Juvenile chinook salmon captured in the screw trap were generally larger than chinook salmon captured in the weir (Table 3, Appendix G). This can be attributed to: (1) placement of the trap in the thalweg, where water velocities were the greatest, and (2) preference for faster water velocities by larger fish (Chapman and Bjornn 1969). Although many of the size differences of chinook salmon captured in the screw trap and weir were statistically significant, the differences were relatively small, averaging 5.0 mm for all tests.

Cramer et al. (1990) found that the mean size of marked chinook salmon recaptured below an agricultural diversion facility was significantly larger than the mean size of fish released. They attributed this to the loss of smaller sized fish through the diversion due to their reduced capability of avoiding entrainment because of weaker swimming ability. Thedinga et al. (1994) noted that the size distribution of recaptured salmonids represented the "middle size range" when compared to the size distribution of release groups. They did not believe that these differences would affect population estimates because the differences were slight and recaptured fish represented the middle of the distribution of released fish.

In this study, the difference in the size of fish captured in the screw trap and weir indicated that the operation of the screw trap was selective for larger fish. Size selection could lead to biases in population estimates when utilizing mark-recapture techniques to determine trap efficiency. Fish captured in the screw trap, marked, and then released, may have higher probability of recapture than unmarked fish due to the trap's selectivity, violating the assumption of equal capture probability. Cone et al. (1988) found that the major cause of unreliable brook trout (Salvelinus fontinalis) population estimates was a violation of the equal capture probability assumption. Beukema and DeVos (1974) found that population estimates of carp (Cyprinus carpio) were either negatively or positively biased when the same method of capture and recapture was used. They also found that population estimates were not biased when different sampling gears with a different selectivities were used for capture and recapture.

Although the screw trap operated in Blue Creek was selective for larger juvenile chinook salmon, it is not believed that this had any affect on mark-recapture efficiency estimates because a representative sample of fish captured in the screw trap and weir, which sampled the entire migrating population, was used for each mark group. The observed selectivity of the screw trap for larger individuals does indicate that the potential biases due to the selectivity of this sampling device and its potential affect on capture probability.

Estimates of Juvenile Chinook Salmon Downstream Migration

Based on efficiency-based estimates, the number of juvenile chinook salmon migrating downstream from Blue Creek during the spring/summer time period ranged from 15,615 in 1991 to 48,971 in 1989, and averaged 33,717 during this study. The relatively low numbers of juvenile chinook salmon migrating downstream from Blue

Creek coincided with some of the lowest natural fall chinook spawning escapements observed in the Klamath River Basin since comprehensive monitoring was initiated in 1978 (KRFCRT 1994), suggesting that production may have been spawner limited. Although it is believed that the majority of juvenile chinook salmon migrate downstream from Blue Creek as subyearlings, the estimates of juvenile chinook salmon downstream migration generated during this study do not include fish that continue to rear in the stream throughout summer. Juvenile chinook salmon downstream migration generally peaked during the last two weeks of May but downstream migration continued until the end of trapping operations and juvenile chinook salmon were observed in Blue Creek throughout the summer.

Although the spawning escapement in Blue Creek was once thought to be 5,000 to 10,000 fall chinook (DeWitt 1951), the spawning escapements during this study were undoubtedly much smaller than this. Due to the highly variable stream discharge in Blue Creek during fall chinook salmon spawning, recent spawning surveys (redd and live fish counts) conducted by U.S. Fish and Wildlife Service have not provided consistent redd or fish counts (Stern and Noble 1990). This lack of consistent spawning escapement data precludes a comparison of spawners and resultant progeny. Gilroy et al. (1992) estimated that Blue Creek contained sufficient spawning habitat to accommodate a minimum of 1,153 pairs of fall chinook salmon. Based on this estimate of 1,153 potential redds, 4,000 eggs/female (Rowdy Creek Hatchery, Smith River, 1992-1993 data), and egg to downstream migrant survival averaging 0.12 (weighted average for Fall Creek fall chinook salmon in Wales and Coots 1954), Blue Creek has the potential to produce approximately 550,000 juvenile chinook salmon downstream migrants, providing that fry/juvenile rearing habitat is not limited. The estimated number of juvenile chinook salmon migrating downstream from Blue Creek during this study averaged only 6% of the potential number of downstream migrants that might reasonably be produced in Blue Creek.

Comparison of Efficiency-Based and Discharge-Based Estimates of Juvenile Chinook Salmon Downstream Migration

Although fishery managers often desire numerical estimates of fish abundance, difficulties in estimating trap efficiencies often make such estimates unattainable. One of the objectives of this study was to assess the relationship between efficiency-based and discharge-based estimates of juvenile chinook salmon downstream migration and to determine if discharge-based estimates were a valid surrogate for efficiency-based estimates. For data collected during 1989 and 1990-late season monitoring operations, estimated trap efficiencies were positively and significantly correlated with the proportions of stream discharge sampled (Table 7). Trap efficiencies were generally greater than corresponding proportions of stream discharge sampled but the relationships between trap efficiencies and the proportions of stream discharge were very similar for both years.

Trap efficiency and proportion of stream discharge sampled data collected in 1991 were significantly correlated, but the linear relationship between these data deteriorated above efficiencies of approximately 0.20 (Figure 12A) and stream flows of less than

6.0 m^3/s (Figure 12B). The relationship between trap efficiency and the proportion of stream discharge sampled was ideal at trap efficiency values of less than 0.20, in that values of trap efficiency and the corresponding proportion of stream discharge sampled were very similar (Figure 12A).

As stream discharge decreased, the difference in values of trap efficiency and the proportion of stream discharge sampled may have been minimized if modifications to the stream were undertaken to guide more of the flow through the trap. This would have increased the proportion of stream discharge sampled at lower flows, when the differences between efficiency and the proportion of stream discharge sampled increased (1989 and 1990-late season data, Figures 10 and 11) or the relationship completely deteriorated (1991 data, Figure 12). But modifications to the stream to increase flow through the trap would have undoubtably affected the distribution of juvenile chinook salmon downstream migrants which could have compromised the relationship between trap efficiency and the proportion of stream discharge sampled.

The relationships between trap efficiency and the proportion of stream discharge sampled influenced the differences between semimonthly efficiency-based and discharge-based estimates of juvenile chinook salmon downstream migration. As stream discharge decreased, the difference between values of trap efficiency and proportion of stream discharge sampled generally increased which led to increased differences of semimonthly efficiency-based and discharge-based estimates (Figure 9). This was especially evident in the 1989 data.

The ease with which discharge-based estimates of juvenile salmonid downstream migration can be generated makes them desirable, but they are of little utility unless a significant relationship between trap efficiency and the proportion of stream discharge sampled exists and can be verified. The similarity of the relationships between trap efficiency and the proportion of stream discharge sampled in 1989 and 1990-late season suggest that there may be some utility in discharge-based estimates (Figures 10A and 11A). But data collected during this study also indicate that the relationship between trap efficiency and the proportion of stream discharge sampled can change: (1) during the sampling season (1990 early- and late-season data), (2) from one season to the next at the same site (1989 and 1990 data), and (3) at different trapping sites (1989 and 1991).

Some of the data collected during this study indicate that discharge-based estimates of may be useful for assessing the magnitude of juvenile salmonid downstream migration, but only if a relationship between trap efficiency and the proportion of stream discharge sampled exists and can be verified at varying flows and between years. Caution should also be used in relying solely on discharge-based estimates of downstream migration, even if the relationship between trap efficiency and the proportion of stream discharge sampled is verified and consistent. Changes in the timing of downstream migration can lead to the generation of discharge-based estimates that are not comparable between years, unless the corresponding values of trap efficiency and the proportion of stream discharge sampled are very similar throughout the range of discharges sampled.

REFERENCES CITED

Ashe, B.L., A.C. Miller, P.A. Kucera, and M.L. Blenden. 1995. Spring outmigration of wild and hatchery chinook salmon and steelhead trout smolts from the Imnaha River, March 1-June 15, 1994. USDOE, Bonneville Power Administration, DOE/BP-38906-4. 76 pp.

Ashton, W.D. 1972. The logit transformation with special reference to its uses in bioassay. Hafner Publishing Company, London, England. 87 pp.

Baglinière, J.L., and A. Champigneulle. 1986. Population estimates of juvenile Atlantic salmon, Salmo salar, as indices of smolt production in the R. Scorff, Brittany. Journal of Fish Biology 29(4):467-482.

Barton, B.A., C.B. Schreck, and L.A. Sigismondi. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile chinook salmon. Transactions of the American Fisheries Society 115(2):245-251.

Beukema, J.J., and G.J. DeVos. 1974. Experimental tests of a basic assumption of the capture-recapture method in pond populations of carp Cyprinus carpio L. Journal of Fish Biology 6(3):317-329.

Chapman, D.W., and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T.G. Northcote (editor) Symposium on salmon and trout in streams. H.R. McMillan. Vancouver, B.C., Canada.

Cone, R.S., D.S. Robson, and C.C. Krueger. 1988. Failure of statistical tests to detect assumption violations in the mark-recapture population estimation of brook trout in Adirondack ponds. North American Journal of Fisheries Management 8(4):489-496.

Cormack, R.M. 1968. The statistics of capture-recapture methods. Oceanography and Marine Biology, An Annual Review 6:455-506.

Craddock, D.R. 1959. A modified fyke net for the live capture of seaward migrating salmon. Progressive Fish Culturist 21(1): 46-46.

Cramer, S.P., D. Demko, C. Fleming, and T. Loera. 1990. Survival of juvenile chinook at the Glenn-Colusa Irrigation District's intake. S.P. Cramer and Associates, Corvallis, OR. 91 pp.

Davis, S.K., J.L. Congleton, and R.W. Tyler. 1980. Modified fyke net for the capture and retention of salmon smolts in large rivers. Progressive Fish Culturist 42(4): 235-237.

Dempson, J.B., and D.E. Stansbury. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. North American Journal of Fisheries Management 11(1):27-37.

DeWitt, J.W. 1951. Personal letter (August 25, 1951) to the California Division of Fish and Game from J.W. DeWitt, Fisheries Department, Humboldt State University, Arcata, CA. 1 pp.

Draper, N.R., and H. Smith. 1981. Applied regression analysis. Wiley and Sons. New York, New York, USA.

DuBois, R.B., J.E. Miller, and S.D. Plaster. 1991. An inclined-screen smolt trap with adjustable screen for highly variable flows. North American Journal of Fisheries Management 11(2): 155-159.

Everest, F.H., and J.R. Sedell. 1984. Evaluating effectiveness of stream enhancement projects. Pages 246-256 in T.J. Hassler (editor) Proceedings: Pacific Northwest Stream Management Workshop. Humboldt State University, Arcata, CA. 329 pp.

FPC (Fish Passage Center). 1986. Smolt monitoring program, part II: Migrational characteristics of Columbia Basin salmon and steelhead trout, 1985. 287 pp.

Gall, G.A.E., B. Bentley, C. Panattoni, E. Childs, C. Qi, S, Fox, M. Mangel, J. Brodziak, and R. Gomulkiewicz. 1991. Chinook mixed fishery project, 1986-1989. University of California, Davis. 27 pp.

Gilroy, I.B., M. Longenbaugh, and J.C. Polos. 1992. Progress report for investigations on Blue Creek, FY 1990-1991. U.S. Fish and Wildlife Service, Coastal California Fishery Resource Office, Arcata, CA. 83pp.

Giorgi, A.E., and C.W. Simms. 1987. Estimating the daily passage of juvenile salmonids at McNary Dam on the Columbia River. North American Journal of Fisheries Management 7(2):215-222.

Hare, G.M. 1973. A modified stake net for collecting migrating smolts of Atlantic salmon (Salmo salar). Journal of Fisheries Research Board of Canada 30(1): 128-129.

Hilborn, R., and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall. New York, New York, USA. 570 pp.

Hillman, T.W. 1989. Nocturnal predation by sculpins on juvenile chinook salmon and steelhead. Pages 248-264 in Don Chapman Consultants, Inc. (editor) Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Final Report to Chalan County Public Utility District, Washington, June 1989. 301 pp.

Krema, R.F., and R.F. Raleigh. 1971. Migration of juvenile salmon and trout into Brownlee Reservoir, 1962-1965. Fishery Bulletin 68(2): 203-217.

KRFCRT (Klamath River Fall Chinook Review Team). 1994. An assessment of the status of the Klamath River fall chinook stock as required under the salmon fishery management plan. Pacific Fishery Management Council, Portland, OR. 20pp and technical appendixes.

Larkin, P.A. 1988. Pacific salmon. Pages 153-183 in J.A. Gulland (editor) Fish population dynamics: the implications for management. 2nd edition. John Wiley and Sons. Chichester, England.

McDonald, J. 1960. The behavior of Pacific salmon fry during their downstream migration to fresh and saltwater nursery areas. Canadian Fisheries Research Board Journal 17(5): 655-676.

McMenemy, J.R., and B. Kynard. 1988. Use of inclined-plane traps to study movement and survival of Atlantic salmon smolts in the Connecticut River. North American Journal of Fisheries Management 8(4):481-488.

Mesa, M.G. 1994. Effects of multiple acute stressors on the predator avoidance ability and physiology of juvenile chinook salmon. Transactions of the American Fisheries Society 123(5): 786-793.

Milner, A., and L. Smith. 1985. Fyke nets used in a southeastern Alaskan stream for sampling salmon fry and smolts. North American Journal of Fishery Management 5(3B): 502-506.

Mullins, C.C., P.L. Caines, D. Caines, and J.L. Peppar. 1991. A two-compartment fish trap for simultaneously counting downstream and upstream migrants in small rivers. North American Journal of Fisheries Management 11(3):358-363.

Mundie, J.H., and R.E. Traber. 1983. Movements of coho salmon (Oncorhynchus kisutch) fingerlings in a stream following marking with a vital stain. Canadian Journal of Fisheries and Aquatic Sciences 40(8):1318-1319.

Neave, F. 1955. Notes on the seaward migration of pink and chum salmon fry. Journal of Fisheries Research Board Canada 12(3):369-374.

Platts, W.S., W.F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138. Ogden, UT, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 70pp.

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1991. Responses of anadromous salmonids to habitat modifications: how do we measure them? American Fisheries Society Symposium 10:62-67.

Reimers, P.E. 1973. The length of residence of juvenile fall chinook salmon in the Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4(2)3-39.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada. Bulletin 191. 382 pp.

Rodgers, J.D., M.F. Solazzi, S.L. Johnson, and M.A. Buckman. 1992. Comparison of three techniques to estimate juvenile coho salmon populations in small streams. North American Journal of Fisheries Management 12(1):79-86.

Roper, B., and D.L. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 chinook salmon. North American Journal of Fisheries Management 16(1):214-217.

Schreck, C.B., M.F. Solazii, S.L. Johnson and T.E. Nickelson. 1989. Transportation stress affects performance of coho salmon, Oncorhynchus kisutch. Aquaculture 82(1-4):15-20.

Seber, G.A.F. 1970. The effects of trap response on tag recapture estimates. Biometrics 26(1):13-22.

Seelbach, P.W., R.N. Lockwood, and G.R. Alexander. 1985. A modified inclined screen trap for catching salmonid smolts in large rivers. North American Journal of Fisheries Management 5(3B):494-498.

Sigismondi, L.A., and L.J. Weber. 1988. Changes in avoidance response time of juvenile chinook salmon exposed to multiple acute handling stresses. Transactions of the American Fisheries Society 117(2):196-201.

Siler, D., S. Neuhauser, and T. Ackley. 1981. Upstream/downstream salmonid trapping project, 1977-1980. Progress Report No. 144. Washington Department of Fisheries. 197 pp.

Siler, D., S. Neuhauser, and T. Ackley. 1984. Upstream/downstream salmonid trapping project, 1980-1982. Progress Report No. 200. Washington Department of Fisheries. 152 pp.

Siler, D., P. Hanratty, S. Neuhauser, M. Ackley, and P. Topping. 1989. Wild salmon production and survival evaluation, Annual Performance Report, October 1988 - September 1989. Washington Department of Fisheries. 33 pp.

Snyder, J.O. 1931. Salmon of the Klamath River. California Division of Fish and Game, Fish Bulletin No. 34. 129 pp.

Stern, G.R., and S.M. Noble. 1990. Progress report for investigations on Blue Creek, FY 1989. USFWS Fisheries Assistance Office, Arcata, CA. 48 pp.

Solomon, D.J. 1985. Salmon stock and recruitment. Journal of Fish Biology 27(Supplement A): 45-57.

Taylor, P.B. 1988. Effects of anaesthetic MS 222 on the orientation of juvenile salmon, Oncorhynchus tshawytscha Walbaum. Journal of Fish Biology 32(2): 161-168.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14(4):837-851.

USDOI (U.S. Department of the Interior). 1985. Klamath River Basin fisheries resource plan. Prepared for the U.S. Bureau of Indian Affairs, Department of the Interior by CH2M Hill. 391 pp.

USFWS (U.S. Fish and Wildlife Service). 1979. Hoopa Valley Indian Reservation: Inventory of reservation waters, fish rearing feasibility study and a review of the history and status of anadromous fishery resources of the Klamath River Basin. U.S. Fish and Wildlife Service, Arcata Field Station, Arcata, CA. 134 pp.

Wales, J.H., and M. Coots. 1954. Efficiency of chinook salmon spawning in Fall Creek, California. Transactions of the American Fisheries Society 84:137-149.

Wedemeyer, G. 1972. Some physiological consequences of handling stress in the juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board Canada 29(2):1780-1783.

Wolf, P. 1951. A trap for the capture of fish and other organisms moving downstream. Transactions of the American Fisheries Society 80:41-45.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc. Englewood Cliffs, NJ, USA. 620 pp.

Appendix A. Gage Height (GH) and Stream Discharge (Q) Data for Blue Creek, 1989-1992.

Date	GH (m)	Q (m^3/s)	Date	GH (m)	Q(m^3/s)
Jan 20, 1989	0.90	34.1	Aug 22, 1990	0.29	3.0
Jan 26, 1989	0.85	28.2	Oct 10, 1990	0.21	1.9
Jan 31, 1989	0.87	30.8	Apr 17, 1991	0.74	18.8
Feb 13, 1989	0.63	13.5	May 6, 1991	0.62	1.9
Feb 21, 1989	0.77	22.6	May 10, 1991	0.65	13.1
Mar 1, 1989	0.75	21.0	Jun 25, 1991	0.40	5.0
Apr 14, 1989	0.83	26.5	Jul 25, 1991	0.30	3.1
Apr 22, 1989	0.70	17.6	Aug 7, 1991	0.27	2.5
Apr 27, 1989	0.64	14.2	Sep 5, 1991	0.24	2.1
May 7, 1989	0.56	11.2	Sep 24, 1991	0.20	1.7
May 14, 1989	0.50	8.9	Oct 9, 1991	0.18	1.6
May 19, 1989	0.47	7.6	Oct 28, 1991	0.31	3.2
May 22, 1989	0.45	6.7	Nov 18, 1991	0.77	19.5
May 31, 1989	0.57	11.3	Dec 5, 1991	0.36	4.0
Jun 7, 1989	0.47	7.5	Dec 16, 1991	0.43	5.7
Jun 14, 1989	0.43	5.9	Jan 3, 1992	0.42	5.5
Jun 19, 1989	0.41	5.8	Jan 24, 1992	0.46	5.9
Jul 12, 1989	0.34	4.8	Feb 6, 1992	0.65	12.8
Sep 4, 1989	0.26	2.0	Feb 18, 1992	0.83	21.7
Oct 3, 1989	0.24	1.7	Jun 24, 1992	0.32	3.0
Apr 24, 1990	0.70	15.9	Jul 8, 1992	0.30	2.8
May 11, 1990	0.46	6.0	Jul 23, 1992	0.26	2.4
May 18, 1990	0.42	5.5	Aug 5, 1992	0.23	2.0
May 24, 1990	0.67	14.6	Aug 25, 1992	0.19	1.5
Jun 21, 1990	0.60	10.8	Sep 30, 1992	0.16	1.2
Jun 26, 1990	0.54	8.5	Nov 3, 1992	0.33	3.2
Jul 20, 1990	0.39	4.8			

Appendix B. Stream Width (W) at the Trapping Site at Various Stream Discharges (Q) in Blue Creek, 1989-1992.

Date	W (m)	Q (m^3/s)
Apr 30, 1989	36.9	15.0
May 6, 1989	24.6	12.2
May 11, 1989	24.0	9.5
Jun 9, 1989	16.4	7.2
May 3, 1990	12.6	8.7
May 11, 1990	11.5	6.8
May 17, 1990	11.1	5.8
Jun 16, 1990	17.1	13.7
Jun 21, 1990	17.1	11.1
Jun 29, 1990	13.4	8.3
Jul 6, 1990	13.4	7.8
Jul 11, 1990	12.9	6.2
Jul 20, 1990	12.9	5.2
Jul 26, 1990	12.5	4.5
Aug 3, 1990	12.0	3.7
Apr 16, 1991	23.1	17.2
Apr 22, 1991	21.5	14.8
Apr 25, 1991	23.1	18.2
Apr 29, 1991	21.5	15.4
May 8, 1991	23.1	17.2
May 9, 1991	21.5	14.1
May 31, 1991	18.5	11.2
Jun 4, 1991	15.4	8.5
Jun 18, 1991	12.3	6.0
Jun 19, 1991	15.4	6.3
Jun 24, 1991	15.4	5.6
Jul 11, 1991	13.8	3.9
Aug 2, 1991	2.3	2.8
May 4, 1992	25.8	10.8
May 5, 1992	25.8	10.3
May 20, 1992	18.4	6.8
Jun 20, 1992	16.6	3.7
Jun 21, 1992	16.6	3.6
Jun 29, 1992	19.7	4.6
Jun 30, 1992	19.1	4.6
Jul 1, 1992	19.1	3.9
Jul 3, 1992	16.2	3.5
Jul 4, 1992	16.6	3.7
Jul 6, 1992	18.8	3.5
Jul 10, 1992	18.8	2.9
Jul 14, 1992	16.3	2.6

Appendix C. Estimated Stream Discharge (m^3/s) at the Gage Station (Q_{gage}) and Trapping Sites (Q_{trap}) in Blue Creek, 1990-1992.

Date	Q_{gage}	Q_{trap}
May 18, 1990	5.6	5.3
May 24, 1990	14.6	14.4
Sep 5, 1990	2.1	2.2
Sep 24, 1990	1.7	1.6
Oct 9, 1991	1.6	1.4
Oct 28, 1991	3.5	3.3
Dec 5, 1991	4.0	3.8
Dec 16, 1991	5.7	5.6
Jan 3, 1992	5.5	5.4
Jan 24, 1992	5.9	6.2
Feb 6, 1992	12.8	12.8

Appendix D. Estimated Daily Stream Discharge (Q (m^3/s)) at the Blue Creek Gage Station During Trapping Operations, 1989-1992.

Date	Q	Date	Q	Date	Q
04/11/89	30.6	05/21/89	7.2	06/30/89	6.0
04/12/89	29.0	05/22/89	7.0	07/01/89	5.5
04/13/89	27.9	05/23/89	10.7	07/02/89	5.1
04/14/89	26.6	05/24/89	16.5	07/03/89	4.6
04/15/89	25.8	05/25/89	15.2	07/04/89	4.8
04/16/89	24.3	05/26/89	13.2	07/05/89	4.4
04/17/89	22.8	05/27/89	13.0	07/06/89	4.3
04/18/89	21.3	05/28/89	12.7	07/07/89	4.1
04/19/89	19.7	05/29/89	12.4	07/08/89	4.0
04/20/89	18.7	05/30/89	12.1	07/09/89	4.0
04/21/89	17.6	05/31/89	11.7	07/10/89	3.9
04/22/89	18.0	06/01/89	11.3	07/11/89	3.9
04/23/89	18.9	06/02/89	10.2	07/12/89	3.8
04/24/89	17.9	06/03/89	9.6	07/13/89	3.8
04/25/89	17.0	06/04/89	8.9	07/14/89	3.7
04/26/89	16.1	06/05/89	8.3	07/15/89	3.7
04/27/89	15.2	06/06/89	8.1	07/16/89	3.6
04/28/89	14.7	06/07/89	7.7	07/17/89	3.6
04/29/89	14.4	06/08/89	7.5	07/18/89	3.6
04/30/89	15.0	06/09/89	7.2	07/19/89	3.6
05/01/89	14.4	06/10/89	7.0	07/20/89	3.6
05/02/89	14.0	06/11/89	6.8	07/21/89	3.5
05/03/89	13.5	06/12/89	6.6		
05/04/89	13.1	06/13/89	6.3	04/11/90	10.2
05/05/89	12.6	06/14/89	6.2	04/12/90	10.0
05/06/89	12.2	06/15/89	6.3	04/13/90	9.9
05/07/89	11.4	06/16/89	6.1	04/14/90	9.9
05/08/89	11.5	06/17/89	5.9	04/15/90	9.9
05/09/89	10.8	06/18/89	5.8	04/16/90	9.8
05/10/89	10.2	06/19/89	5.6	04/17/90	9.3
05/11/89	9.5	06/20/89	5.5	04/18/90	8.8
05/12/89	9.2	06/21/89	5.4	04/19/90	8.2
05/13/89	8.9	06/22/89	5.2	04/20/90	8.1
05/14/89	8.8	06/23/89	5.1	04/21/90	8.0
05/15/89	8.6	06/24/89	5.0	04/22/90	10.2
05/16/89	8.4	06/25/89	4.9	04/23/90	12.3
05/17/89	8.2	06/26/89	4.8	04/24/90	14.5
05/18/89	8.0	06/27/89	4.8	04/25/90	12.0
05/19/89	7.7	06/28/89	4.7	04/26/90	11.0
05/20/89	7.5	06/29/89	5.3	04/27/90	10.0

Appendix D. Estimated Daily Stream Discharge (Q (m^3/s)) at the Blue Creek Gage Station During Trapping Operations, 1989-1992. (continued)

Date	Q	Date	Q	Date	Q
04/28/90	9.9	06/07/90	25.5	07/17/90	5.4
04/29/90	9.7	06/08/90	25.5	07/18/90	5.2
04/30/90	9.5	06/09/90	23.2	07/19/90	5.2
05/01/90	9.4	06/10/90	21.0	07/20/90	5.2
05/02/90	9.4	06/11/90	18.7	07/21/90	5.0
05/03/90	8.7	06/12/90	16.5	07/22/90	4.8
05/04/90	8.3	06/13/90	15.4	07/23/90	4.6
05/05/90	8.0	06/14/90	14.3	07/24/90	4.5
05/06/90	7.8	06/15/90	13.7	07/25/90	4.5
05/07/90	7.5	06/16/90	13.2	07/26/90	4.5
05/08/90	7.2	06/17/90	12.8	07/27/90	4.4
05/09/90	7.1	06/18/90	12.4	07/28/90	4.3
05/10/90	7.0	06/19/90	12.0	07/29/90	4.1
05/11/90	6.8	06/20/90	11.1	07/30/90	4.0
05/12/90	6.6	06/21/90	11.1	07/31/90	3.9
05/13/90	6.4	06/22/90	10.4	08/01/90	3.8
05/14/90	6.3	06/23/90	10.1	08/02/90	3.7
05/15/90	6.2	06/24/90	9.7	08/03/90	3.6
05/16/90	6.0	06/25/90	9.3		
05/17/90	5.8	06/26/90	9.1	04/11/91	21.5
05/18/90	5.8	06/27/90	8.7	04/12/91	20.2
05/19/90	7.1	06/28/90	8.4	04/13/91	19.4
05/20/90	8.3	06/29/90	8.3	04/14/91	18.6
05/21/90	11.4	06/30/90	8.1	04/15/91	17.8
05/22/90	13.6	07/01/90	8.0	04/16/91	17.2
05/23/90	15.9	07/02/90	7.8	04/17/91	16.4
05/24/90	14.0	07/03/90	7.5	04/18/91	16.1
05/25/90	13.1	07/04/90	7.5	04/19/91	15.7
05/26/90	14.8	07/05/90	7.4	04/20/91	15.7
05/27/90	16.5	07/06/90	7.8	04/21/91	15.6
05/28/90	18.2	07/07/90	7.4	04/22/91	15.6
05/29/90	19.9	07/08/90	7.0	04/23/91	14.5
05/30/90	23.4	07/09/90	6.6	04/24/91	16.3
05/31/90	24.1	07/10/90	6.3	04/25/91	18.2
06/01/90	24.7	07/11/90	6.2	04/26/91	17.4
06/02/90	25.4	07/12/90	6.0	04/27/91	16.6
06/03/90	26.0	07/13/90	5.8	04/28/91	15.9
06/04/90	26.7	07/14/90	5.7	04/29/91	15.1
06/05/90	25.9	07/15/90	5.5	04/30/91	14.8
06/06/90	25.1	07/16/90	5.4	05/01/91	14.3

Appendix D. Estimated Daily Stream Discharge (Q (m^3/s)) at the Blue Creek Gage Station During Trapping Operations, 1989-1992. (continued)

Date	Q	Date	Q	Date	Q
05/02/91	13.6	06/11/91	6.9	07/21/91	3.6
05/03/91	13.4	06/12/91	6.8	07/22/91	3.5
05/04/91	12.9	06/13/91	6.5	07/23/91	3.5
05/05/91	12.5	06/14/91	6.5	07/24/91	3.4
05/06/91	12.0	06/15/91	6.3	07/25/91	3.4
05/07/91	11.9	06/16/91	6.2	07/26/91	3.3
05/08/91	17.2	06/17/91	6.0	07/27/91	3.2
05/09/91	14.1	06/18/91	6.0	07/28/91	3.2
05/10/91	13.1	06/19/91	6.3	07/29/91	3.1
05/11/91	12.9	06/20/91	6.0	07/30/91	3.0
05/12/91	12.8	06/21/91	5.8	07/31/91	2.9
05/13/91	12.6	06/22/91	5.7	08/01/91	2.9
05/14/91	11.9	06/23/91	5.6	08/02/91	2.8
05/15/91	11.2	06/24/91	5.5	08/03/91	2.8
05/16/91	11.9	06/25/91	5.5	08/04/91	2.8
05/17/91	13.2	06/26/91	5.4	08/05/91	2.8
05/18/91	13.0	06/27/91	5.4	08/06/91	2.7
05/19/91	12.8	06/28/91	5.3	08/07/91	2.7
05/20/91	12.6	06/29/91	5.2	08/08/91	2.6
05/21/91	12.4	06/30/91	5.1	08/09/91	2.6
05/22/91	11.9	07/01/91	5.0	08/10/91	2.5
05/23/91	10.8	07/02/91	4.8	08/11/91	2.4
05/24/91	10.4	07/03/91	4.6	08/12/91	2.4
05/25/91	10.1	07/04/91	4.5	08/13/91	2.4
05/26/91	9.7	07/05/91	4.4	08/14/91	2.3
05/27/91	9.3	07/06/91	4.3		
05/28/91	8.9	07/07/91	4.2	04/07/92	7.1
05/29/91	10.1	07/08/91	4.1	04/08/92	7.0
05/30/91	11.2	07/09/91	4.1	04/09/92	11.8
05/31/91	11.2	07/10/91	4.0	04/10/92	30.7
06/01/91	10.3	07/11/91	3.9	04/11/92	27.9
06/02/91	9.5	07/12/91	3.9	04/12/92	25.1
06/03/91	8.6	07/13/91	3.8	04/13/92	22.3
06/04/91	8.5	07/14/91	3.8	04/14/92	21.8
06/05/91	8.0	07/15/91	3.8	04/15/92	19.6
06/06/91	7.7	07/16/91	5.2	04/16/92	22.0
06/07/91	7.5	07/17/91	5.1	04/17/92	22.1
06/08/91	7.3	07/18/91	4.2	04/18/92	22.1
06/09/91	7.1	07/19/91	3.9	04/19/92	22.1
06/10/91	6.9	07/20/91	3.8	04/20/92	22.2

Appendix D. Estimated Daily Stream Discharge (Q (m^3/s)) at the Blue Creek Gage Station During Trapping Operations, 1989-1992. (continued)

Date	Q	Date	Q	Date	Q
04/21/92	22.2	05/19/92	6.8	06/17/92	4.0
04/22/92	20.4	05/20/92	6.8	06/18/92	3.9
04/23/92	18.3	05/21/92	6.6	06/19/92	3.7
04/24/92	17.3	05/22/92	6.3	06/20/92	3.7
04/25/92	16.4	05/23/92	6.1	06/21/92	3.6
04/26/92	15.4	05/24/92	5.9	06/22/92	3.5
04/27/92	14.4	05/25/92	5.8	06/23/92	3.5
04/28/92	13.5	05/26/92	5.7	06/24/92	3.4
04/29/92	12.8	05/27/92	5.6	06/25/92	3.3
04/30/92	14.1	05/28/92	5.5	06/26/92	3.3
05/01/92	12.4	05/29/92	5.3	06/27/92	3.2
05/02/92	11.8	05/30/92	5.2	06/28/92	3.2
05/03/92	11.2	05/31/92	5.1	06/29/92	4.6
05/04/92	10.6	06/01/92	5.0	06/30/92	4.6
05/05/92	10.3	06/02/92	4.8	07/01/92	3.9
05/06/92	9.9	06/03/92	4.8	07/02/92	3.6
05/07/92	9.5	06/04/92	4.7	07/03/92	3.5
05/08/92	9.5	06/05/92	4.6	07/04/92	3.7
05/09/92	9.1	06/06/92	4.4	07/05/92	3.5
05/10/92	8.8	06/07/92	4.4	07/06/92	3.4
05/11/92	8.4	06/08/92	4.3	07/07/92	3.2
05/12/92	8.1	06/09/92	4.2	07/08/92	3.1
05/13/92	7.8	06/10/92	4.2	07/09/92	2.9
05/14/92	7.7	06/11/92	4.1	07/10/92	2.9
05/15/92	7.3	06/12/92	4.2	07/11/92	2.8
05/16/92	7.2	06/13/92	4.6	07/12/92	2.8
05/17/92	7.1	06/15/92	4.2	07/13/92	2.7
05/18/92	6.8	06/16/92	4.1	07/14/92	2.6

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency].

Date	Q	PQ	PW	RM	N_s	N_w	E
04/12/89	29.8	0.099	0.035	11.6	19		
04/13/89	28.5	0.105	0.037	10.6	24		
04/14/89	27.3	0.110	0.038	10.3	1		
04/15/89	26.2	0.102	0.040	9.6	2		
04/19/89	20.5	0.085	0.051	6.2	14		
04/20/89	19.2	0.092	0.055	6.3	16	144	0.100
04/21/89	18.2	0.102	0.058	6.6	3		
04/22/89	17.8	0.103	0.059	6.6	5		
04/23/89	18.4	0.104	0.057	6.8	3		
04/27/89	15.6	0.141	0.067	6.3	12		
04/28/89	14.9	0.154	0.070	4.2	14		
04/29/89	14.6	0.139	0.072	3.4	8		
04/30/89	14.7	0.139	0.071	5.8	6		
05/01/89	14.7	0.157	0.071	6.5	41		
05/04/89	13.3	0.221	0.079	8.1	125	712	0.149
05/05/89	12.9	0.215	0.082	8.1	222	627	0.261
05/06/89	12.4	0.224	0.084	7.8	234	435	0.350
05/07/89	11.8	0.249	0.889	8.1	314		
05/08/89	11.5	0.261	0.092	8.5	191		
05/11/89	9.8	0.287	0.107	7.7	289		
05/12/89	9.4	0.255	0.112	7.2	214	265	0.447
05/13/89	9.1	0.214	0.116	6.7	227	312	0.421
05/14/89	8.8	0.226	0.119	6.4	125		
05/15/89	8.7	0.240	0.121	6.2	127		
05/19/89	7.9	0.365	0.134	7.7	199	442	0.310
05/23/89	8.9	0.346	0.119	8.3	505		
05/24/89	13.6	0.218	0.077	7.8	137		
05/25/89	15.8	0.169	0.066	6.8	169		
05/26/89	14.2	0.193	0.074	7.0	131		
05/31/89	11.9	0.234	0.088	7.1	180	365	0.330
06/01/89	11.5	0.214	0.092	5.8	153	216	0.415
06/02/89	10.7	0.225	0.098	5.5	142	199	0.416
06/06/89	8.2	0.366	0.128	6.0	427		
06/07/89	7.9	0.375	0.133	6.1	597		
06/08/89	7.6	0.393	0.137	7.0	662		

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
06/09/89	7.4	0.440	0.142	7.6	690		
06/13/89	6.4	0.470	0.163	6.2	374	252	0.597
06/14/89	6.3	0.468	0.168	5.9	268	127	0.678
06/15/89	6.3	0.479	0.168	5.8	318	166	0.657
06/17/89	6.0	0.518	0.174	6.2	138		
06/18/89	5.9	0.523	0.179	6.0	206		
06/19/89	5.7	0.536	0.184	6.0	307		
06/20/89	5.5	0.531	0.189	5.7	457	123	0.788
06/21/89	5.4	0.497	0.194	5.2	218		
06/22/89	5.3	0.441	0.199	5.2	227		
06/23/89	5.1	0.436	0.204	5.6	242		
06/27/89	4.8	0.415	0.219	5.0	418	125	0.770
06/28/89	4.7	0.416	0.223	4.9	495	82	0.858
06/29/89	5.0	0.362	0.211	5.4	997		
06/30/89	5.6	0.327	0.186	6.6	1,486	845	0.637
07/04/89	4.7	0.332	0.217	5.5	207		
07/05/89	4.6	0.306	0.221	5.1	554		
07/06/89	4.4	0.318	0.233	5.0	275	118	0.700
07/07/89	4.2	0.328	0.242	5.0	216	81	0.727
07/11/89	3.9	0.346	0.260	2.5	361		
07/12/89	3.9	0.352	0.264	2.3	269	84	0.762
07/13/89	3.8	0.368	0.266	4.6	368	74	0.833
07/14/89	3.8	0.386	0.269	2.3	190		
07/18/89	3.6	0.384	0.282	5.0	65		
07/19/89	3.6	0.377	0.281	5.0	65		
07/20/89	3.6	0.415	0.293	5.0	64		
07/21/89	3.5	0.499	0.296	5.0	64		
04/12/90	10.1	0.280	0.163	9.8	32		
04/13/90	10.0	0.253	0.165	9.3	20		
04/16/90	9.9	0.301	0.166	9.4	25		
04/19/90	8.5	0.398	0.175	10.9	18	363	0.047
04/20/90	8.2	0.404	0.178	10.7	16		
04/21/90	8.0	0.387	0.179	10.1	32		
04/24/90	13.4	0.189	0.144	8.6	18		

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
04/25/90	13.3	0.195	0.147	8.6	78		
04/26/90	11.5	0.246	0.156	9.3	16		
04/27/90	10.5	0.247	0.162	9.0	56	377	0.129
05/01/90	9.5	0.290	0.169	9.0	58		
05/02/90	9.4	0.288	0.169	9.0	41		
05/03/90	9.0	0.291	0.172	8.8	87		
05/04/90	8.5	0.351	0.175	8.7	62		
05/08/90	7.4	0.338	0.184	7.0	68		
05/09/90	7.2	0.344	0.185	7.0	36	166	0.178
05/10/90	7.1	0.315	0.186	6.5	33	151	0.179
05/11/90	6.9	0.313	0.188	5.9	54		
05/15/90	6.2	0.254	0.193	4.8	29	261	0.100
05/16/90	6.1	0.256	0.195	4.8	41	230	0.151
05/17/90	5.9	0.253	0.196	4.7	64	315	0.169
05/18/90	5.8	0.284	0.197	4.3	80		
05/21/90	9.9	0.235	0.166	6.8	322		
05/24/90	14.9	0.180	0.120	8.5	98		
05/25/90	13.6	0.198	0.145	7.9	40		
05/30/90	21.7	0.167	0.110	11.8	20		
06/07/90	25.3	0.117	0.104	10.0	6		
06/08/90	25.5	0.117	0.103	10.0	3		
06/12/90	17.6	0.165	0.128	9.4	120		
06/13/90	15.9	0.182	0.134	8.5	152		
06/14/90	14.9	0.189	0.139	7.9	116		
06/15/90	14.0	0.190	0.143	7.6	82		
06/19/90	12.2	0.189	0.152	5.5	14		
06/20/90	11.5	0.179	0.156	5.2	21		
06/21/90	11.1	0.191	0.158	5.7	18		
06/22/90	10.7	0.218	0.160	6.1	37		
06/23/90	10.3	0.244	0.163	6.4	204		
06/24/90	9.9	0.266	0.166	6.5	198		
06/25/90	9.5	0.265	0.168	5.6	128		
06/26/90	9.2	0.264	0.170	5.8	98	94	0.510
06/27/90	8.9	0.243	0.173	5.8	40	61	0.396
06/28/90	8.5	0.240	0.175	5.6	53	63	0.457

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
06/29/90	8.4	0.303	0.176	7.0	112		
06/30/90	8.2	0.342	0.177	7.7	85		
07/01/90	8.1	0.326	0.178	7.4	77		
07/02/90	7.9	0.309	0.180	7.2	69		
07/03/90	7.7	0.297	0.181	6.9	94	97	0.492
07/04/90	7.5	0.285	0.183	6.7	38		
07/05/90	7.4	0.270	0.183	6.6	29		
07/06/90	7.6	0.325	0.182	7.0	134		
07/07/90	7.6	0.381	0.181	7.3	55		
07/08/90	7.2	0.371	0.184	7.0	26		
07/09/90	6.8	0.358	0.187	6.7	72		
07/10/90	6.5	0.343	0.190	6.4	70	8	0.897
07/11/90	6.3	0.317	0.191	5.6	68	8	0.895
07/12/90	6.1	0.273	0.193	5.0	55	28	0.663
07/13/90	5.9	0.336	0.195	6.0	127		
07/14/90	5.7	0.416	0.191	6.9	154		
07/15/90	5.6	0.384	0.192	6.6	109		
07/16/90	5.4	0.358	0.194	6.5	64		
07/17/90	5.4	0.308	0.194	5.9	57	8	0.877
07/18/90	5.3	0.264	0.195	5.0	69	5	0.932
07/19/90	5.2	0.259	0.196	4.7	46	5	0.902
07/20/90	5.2	0.295	0.196	5.4	35		
07/21/90	5.1	0.332	0.197	6.0	43		
07/22/90	4.9	0.337	0.199	5.8	79		
07/23/90	4.7	0.327	0.201	5.6	75		
07/24/90	4.6	0.344	0.207	5.1	79	6	0.929
07/25/90	4.5	0.334	0.202	4.6	83	4	0.954
07/26/90	4.5	0.294	0.203	4.8	41		
07/27/90	4.4	0.284	0.201	4.9	28		
07/28/90	4.3	0.279	0.202	4.8	19		
07/29/90	4.2	0.296	0.203	4.5	12		
07/30/90	4.1	0.320	0.207	4.4	11		
07/31/90	4.0	0.332	0.208	4.4	11		
08/01/90	3.9	0.315	0.209	4.3	10		
08/02/90	3.8	0.311	0.210	4.2	8		

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
08/03/90	3.7	0.320	0.211	4.1	7		
04/12/91	20.9	0.135	0.094	9.3	6		
04/16/91	17.5	0.134	0.105	7.9	3		
04/17/91	16.8	0.128	0.107	7.2	0		
04/18/91	16.2	0.129	0.109	6.8	0		
04/19/91	15.9	0.127	0.110	6.6	0		
04/23/91	15.1	0.120	0.113	6.4	15		
04/24/91	15.4	0.124	0.112	6.6	10		
04/25/91	17.3	0.123	0.105	7.3	4		
04/30/91	14.9	0.119	0.114	6.0	13		
05/01/91	14.5	0.120	0.116	5.9	13		
05/02/91	14.0	0.121	0.118	5.5	9		
05/03/91	13.5	0.120	0.120	5.2	8		
05/07/91	11.9	0.123	0.127	5.0	26		
05/08/91	14.5	0.138	0.116	6.3	20		
05/09/91	15.6	0.146	0.111	6.9	17		
05/10/91	13.6	0.144	0.120	6.1	16		
05/14/91	12.3	0.142	0.126	5.5	27		
05/15/91	11.6	0.141	0.129	4.9	23		
05/16/91	11.6	0.129	0.129	4.6	17	169	0.091
05/17/91	12.5	0.120	0.124	4.5	16	161	0.090
05/21/91	12.5	0.140	0.124	5.1	98		
05/22/91	12.1	0.150	0.126	4.8	74		
05/23/91	11.4	0.154	0.130	4.4	91		
05/24/91	10.6	0.145	0.134	4.3	46	414	0.100
05/29/91	9.5	0.156	0.141	4.8	39		
05/30/91	10.7	0.154	0.134	4.9	14		
05/31/91	11.2	0.148	0.131	4.8	63	270	0.189
06/04/91	8.5	0.157	0.147	3.9	42	245	0.146
06/05/91	8.3	0.157	0.149	3.8	37		
06/06/91	7.9	0.151	0.152	3.3	26	231	0.101
06/07/91	7.6	0.160	0.153	3.3	27	167	0.139
06/11/91	6.9	0.179	0.159	3.6	28	94	0.230
06/12/91	6.8	0.174	0.159	3.2	18	86	0.173

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
06/13/91	6.7	0.173	0.160	3.1	25	89	0.219
06/14/91	6.5	0.175	0.162	3.1	31	89	0.258
06/18/91	6.0	0.187	0.166	2.9	8	67	0.107
06/19/91	6.1	0.179	0.165	2.9	44	215	0.170
06/20/91	6.1	0.182	0.165	2.8	28	165	0.145
06/21/91	5.9	0.190	0.167	2.8	37	132	0.219
06/25/91	5.5	0.193	0.170	2.8	37	50	0.425
06/26/91	5.4	0.185	0.171	2.5	12	3	0.800
06/27/91	5.4	0.186	0.171	2.5	13	7	0.650
06/28/91	5.3	0.191	0.172	2.5	10	9	0.526
07/02/91	4.9	0.189	0.176	2.0	10	11	0.476
07/03/91	4.7	0.190	0.178	2.1	13	10	0.565
07/04/91	4.5	0.197	0.179	2.1	17		
07/05/91	4.4	0.201	0.180	2.0	33		
07/09/91	4.1	0.201	0.183	2.0	44	10	0.815
07/10/91	4.0	0.204	0.184	2.0	39	13	0.750
07/11/91	4.0	0.202	0.185	2.0	27		
07/12/91	3.9	0.206	0.186	1.9	38		
07/16/91	4.5	0.195	0.180	2.3	12		
07/17/91	5.2	0.177	0.173	2.5	18		
07/18/91	4.7	0.181	0.178	2.2	6		
07/19/91	4.1	0.197	0.184	1.9	5		
07/24/91	3.4	0.195	0.191	1.6	6		
07/25/91	3.4	0.197	0.192	1.6	10		
07/26/91	3.3	0.203	0.192	1.7	0		
07/31/91	3.0	0.209	0.196	1.7	18		
08/01/91	2.9	0.209	0.197	1.4	2		
08/02/91	2.8	0.209	0.198	1.3	1		
08/06/91	2.7	0.198	0.199	1.0	1		
08/07/91	2.7	0.198	0.199	1.0	0		
08/08/91	2.7	0.201	0.200	1.0	3		
08/09/91	2.6	0.210	0.201	1.0	1		
08/13/91	2.4	0.238	0.203	1.0	1		
08/14/91	2.3	0.241	0.204	1.0	1		

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
04/08/92	7.1	0.267	0.113	7.1	33		
04/09/92	9.4	0.201	0.101	5.3	6		
04/10/92	21.2	0.098	0.066	4.4	2		
04/14/92	22.1	0.079	0.064	4.9	3		
04/15/92	20.7	0.085	0.067	5.2	1		
04/16/92	20.8	0.089	0.066	5.7	6		
04/22/92	21.3	0.093	0.065	6.9	22		
04/23/92	19.3	0.100	0.069	6.8	53		
04/28/92	14.0	0.149	0.084	7.4	56		
04/29/92	13.2	0.152	0.086	7.1	36		
04/30/92	13.4	0.154	0.085	7.2	24		
05/01/92	13.2	0.151	0.086	7.0	55		
05/05/92	10.5	0.185	0.096	5.8	33		
05/06/92	10.1	0.182	0.098	5.3	47		
05/07/92	9.7	0.195	0.100	6.1	120		
05/08/92	9.5	0.215	0.101	7.2	136		
05/12/92	8.2	0.268	0.107	7.0	343		
05/13/92	7.9	0.269	0.108	7.0	233		
05/14/92	7.7	0.263	0.110	7.0	234		
05/15/92	7.5	0.271	0.111	6.8	147		
05/18/92	6.9	0.297	0.114	7.0	340		
05/19/92	6.8	0.299	0.115	6.8	370	290	0.561
05/20/92	6.8	0.269	0.115	6.5	429	957	0.310
05/21/92	6.7	0.247	0.115	6.3	364	362	0.501
05/22/92	6.5	0.273	0.117	6.2	352	324	0.521
05/25/92	5.9	0.271	0.121	5.0	263	279	0.485
05/26/92	5.7	0.276	0.122	5.0	520	567	0.478
05/27/92	5.6	0.270	0.122	4.5	346	756	0.314
05/28/92	5.5	0.280	0.123	4.2	199	268	0.426
05/29/92	5.4	0.293	0.124	4.3	310	341	0.476
05/30/92	5.2	0.292	0.125	4.4	302	123	0.711
05/31/92	5.1	0.313	0.126	4.5	257	311	0.452
06/01/92	5.0	0.303	0.126	4.0	275	79	0.777
06/02/92	4.9	0.291	0.127	4.2	331	412	0.445
06/03/92	4.8	0.305	0.128	4.3	222	61	0.784

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
06/04/92	4.7	0.309	0.129	4.3	297	117	0.717
06/05/92	4.6	0.301	0.129	4.3	207	293	0.414
06/06/92	4.5	0.276	0.130	3.6	178	197	0.475
06/07/92	4.4	0.280	0.131	3.4	196	53	0.787
06/08/92	4.3	0.310	0.132	3.7	354	155	0.695
06/09/92	4.3	0.319	0.132	3.9	205	160	0.562
06/10/92	4.2	0.318	0.133	3.8	198	219	0.475
06/11/92	4.1	0.319	0.133	3.7	182	353	0.340
06/12/92	4.2	0.315	0.133	3.7	184	238	0.436
06/13/92	4.4	0.325	0.131	4.0	183	161	0.532
06/14/92	4.6	0.299	0.130	4.0	151	197	0.434
06/15/92	4.4	0.295	0.131	3.9	150	215	0.411
06/16/92	4.2	0.305	0.133	3.5	48	129	0.271
06/17/92	4.1	0.287	0.134	3.0	30	22	0.577
06/18/92	3.9	0.297	0.135	3.2	21	46	0.313
06/19/92	3.8	0.311	0.136	3.3	34	65	0.343
06/20/92	3.7	0.292	0.137	3.1	43	29	0.597
06/21/92	3.6	0.263	0.138	2.8	67	2	0.971
06/22/92	3.5	0.280	0.138	2.9	44	13	0.772
06/23/92	3.5	0.300	0.139	3.0	60	5	0.923
06/24/92	3.4	0.301	0.139	3.0	60	4	0.938
06/25/92	3.4	0.303	0.140	3.0	104	35	0.748
06/26/92	3.3	0.302	0.140	3.0	70	25	0.737
06/27/92	3.3	0.308	0.141	2.9	133	178	0.428
06/28/92	3.2	0.325	0.141	2.7	112	171	0.396
06/29/92	3.9	0.318	0.135	3.7	168	83	0.669
06/30/92	4.6	0.319	0.130	4.8	171	129	0.570
07/01/92	4.3	0.334	0.132	4.5	84	13	0.866
07/02/92	3.7	0.326	0.137	3.8	90	109	0.452
07/03/92	3.5	0.286	0.138	3.3	60	31	0.659
07/04/92	3.6	0.262	0.138	3.2	40	76	0.345
07/05/92	3.6	0.262	0.138	3.3	49	12	0.803
07/06/92	3.5	0.285	0.139	3.1	35	22	0.614
07/07/92	3.3	0.313	0.141	3.0	48	25	0.658
07/08/92	3.1	0.311	0.142	3.0	38	58	0.396

Appendix E. Juvenile Chinook Salmon Catch and Effort Data Collected During Trapping Operations in Blue Creek, 1989-1992. [Q = stream discharge (m^3/s), PQ = proportion of stream discharge sampled, PW = proportion of stream width sampled, RM = trap revolutions per minute, N_s = number of chinook captured in the screw trap, N_w = number of chinook captured in the weir, E = screw trap efficiency]. (continued)

Date	Q	PQ	PW	RM	N_s	N_w	E
07/09/92	3.0	0.304	0.143	2.7	36	6	0.857
07/10/92	2.9	0.305	0.144	2.3	33	18	0.647
07/14/92	2.7	0.209	0.146	2.8	14	4	0.778

Appendix F. Weekly Mean Fork Length (mm), Standard Deviation, and Sample Size of Juvenile Chinook Salmon Captured in the Screw Trap During Monitoring Operations on Blue Creek, 1989-1992.

Year	Date	$\bar{X}$	s	n	Year	Date	$\bar{X}$	s	n
1989	Apr 10	41.3	4.18	6	1990	Apr 9	48.5	6.06	51
	Apr 17	43.6	3.49	41		Apr 16	57.3	7.41	43
	Apr 24	43.6	4.72	50		Apr 23	54.7	6.42	166
	May 1	46.4	6.47	209		Apr 30	55.3	6.69	191
	May 8	52.0	5.81	250		May 7	58.3	6.58	168
	May 15	59.1	8.60	50		May 14	54.3	7.79	167
	May 22	52.3	6.18	100		May 21	56.7	7.21	139
	May 29	53.7	7.52	80		May 28	57.3	11.12	20
	Jun 5	56.6	7.67	100		Jun 4	58.0	13.65	9
	Jun 12	63.9	10.45	136		Jun 11	65.9	8.94	200
	Jun 19	66.4	8.46	200		Jun 18	70.3	11.20	86
	Jun 26	68.1	9.94	100		Jun 25	75.0	9.40	289
	Jul 3	71.0	8.96	100		Jul 2	79.9	8.22	200
	Jul 10	71.0	7.44	50		Jul 9	83.5	7.44	273
1991	Apr 15	38.3	1.53	3	1992	Apr 13	41.0	7.42	10
	Apr 22	40.6	4.08	29		Apr 20	51.0	7.65	72
	Apr 29	43.7	8.65	43		Apr 27	52.4	7.47	114
	May 6	50.0	8.55	80		May 4	54.2	7.92	120
	May 13	50.6	8.99	82		May 11	59.8	7.75	126
	May 20	57.2	7.68	196		May 18	61.1	7.80	163
	May 27	58.9	8.00	83		May 25	63.7	10.30	158
	Jun 3	57.5	7.78	113		Jun 1	65.1	9.17	216
	Jun 10	61.8	12.01	102		Jun 8	66.8	8.58	212
	Jun 17	66.9	11.49	96		Jun 15	71.8	8.79	205
	Jun 24	73.2	10.26	65		Jun 22	73.6	9.62	218
	Jul 1	75.7	11.01	53		Jun 29	78.3	8.43	221
	Jul 8	76.8	9.35	117		Jul 6	81.8	7.36	185
						Jul 13	83.7	7.10	44

Appendix G. Weekly Mean Fork Length (mm), Standard Deviation, and Sample Size of Juvenile Chinook Salmon Captured in the Screw Trap and Weir During 1989-1992 Monitoring Operations with Results of t-tests Comparing Weekly Mean Lengths.

		# of Days	Screw Trap			Weir					
Year	Date	Sampled	$\bar{X}$	s	n	$\bar{X}$	s	n	t	df	p
1989	Apr 17	1	44.1	2.99	16	41.1	1.82	30	4.325	45	<0.001
	May 8	1	52.0	6.09	50	45.8	6.05	50	5.090	99	<0.001
	Jun 12	1	64.7	11.70	36	58.9	9.32	42	2.410	77	0.018
	Jun 19	1	68.1	7.97	50	64.3	7.45	50	2.451	99	0.016
	Jun 26	2	68.1	9.94	100	59.7	8.55	100	6.430	199	<0.001
	Jul 3	1	72.0	8.93	50	62.7	8.52	41	5.047	90	<0.001
1990	Apr 16	1	56.1	5.63	18	44.2	9.21	52	5.136	69	<0.001
	Apr 23	1	52.2	6.03	50	46.2	5.86	50	5.046	99	<0.001
	Apr 30	1	54.1	7.56	50	47.4	8.74	50	4.087	99	<0.001
	May 7	2	58.1	7.59	68	54.8	6.48	125	3.094	192	0.002
	May 14	3	54.0	7.87	117	49.9	10.13	150	3.585	266	<0.001
	Jun 25	3	74.1	9.93	139	75.3	8.46	150	-1.159	288	0.248
	Jul 2	1	80.6	7.86	50	77.2	8.86	50	2.054	99	0.043
	Jul 9	3	83.8	7.88	150	80.8	7.61	39	2.146	188	0.033
1991	May 13	2	52.2	7.78	33	58.2	8.93	103	-3.472	135	<0.001
	May 20	1	56.1	6.89	46	52.3	7.69	32	2.287	77	0.025
	May 27	1	60.3	7.88	30	59.0	8.99	41	0.638	70	0.532
	Jun 3	3	56.7	7.50	83	56.0	7.84	92	0.550	174	0.589
	Jun 10	3	61.7	13.04	77	65.3	9.40	90	-2.080	166	0.039
	Jun 17	4	66.9	11.49	96	63.7	8.72	122	2.386	217	0.018
	Jun 24	4	73.2	10.26	65	67.3	7.19	50	3.460	114	0.001
	Jul 1	2	72.1	12.74	23	64.8	9.28	21	2.148	43	0.037
	Jul 8	4	76.8	9.35	117	74.0	9.69	83	2.044	199	0.042
1992	May 18	4	61.1	7.80	163	54.6	6.47	150	8.061	312	<0.001
	May 25	5	63.7	10.30	158	57.8	8.37	184	5.790	341	<0.001
	Jun 1	7	65.1	9.17	216	61.5	7.96	223	4.425	438	<0.001

Appendix G. Weekly Mean Fork Length (mm), Standard Deviation, and Sample Size of Juvenile Chinook Salmon Captured in the Screw Trap and Weir During 1989-1992 Monitoring Operations with Results of t-tests Comparing Weekly Mean Lengths. (continued)

			Screw Trap			Weir					
Year	Date	# of Days Sampled	$\bar{X}$	s	n	$\bar{X}$	s	n	t	df	p
1992	Jun 8	7	66.8	8.58	212	63.6	8.47	222	3.811	433	<0.001
	Jun 15	7	71.8	8.79	205	69.6	7.78	208	2.658	412	0.008
	Jun 22	7	73.6	9.62	218	70.6	9.17	109	2.711	326	0.007
	Jun 29	7	78.3	8.43	221	74.1	8.86	200	5.029	420	<0.001
	Jul 6	6	81.8	7.36	185	79.1	7.80	113	2.983	297	0.003
	Jul 13	2	83.7	7.10	44	84.7	7.81	23	-0.524	66	0.602

Appendix H. Numbers (#) of Marked and Unmarked Chinook Salmon Held for Relative Survival Tests, Number of Chinook Salmon Alive After Test (#S), and Estimated Relative Survival (S_d).

		Marked		Unmarked		
Date	Mark[a]	#	#S	#	#S	S_d
05/30/89	BRN	55	55	80	80	1.00
06/13/89	BRN	47	47	-[b]	-[b]	1.00
07/05/89	BRN	50	20	-[c]	-[c]	0.43
07/11/89	BRN	50	44	48	45	0.94
05/09/90	BRN	35	33	55	54	0.96
05/16/90	BRN	25	24	25	25	0.96
05/18/92	UC	25	24	25	25	0.96
05/25/92	LC	25	23	25	20	1.00[d]
05/30/92	LV	25	21	25	24	0.88
06/06/92	RV	25	25	25	25	1.00
06/10/92	LP	25	24	25	24	1.00
06/14/92	RP	25	19	25	23	0.83
06/19/92	UC	25	23	25	23	1.00
06/27/92	LC	20	16	20	16	1.00

[a] Mark: BRN=Bismark Brown-Y dye, UC=upper caudal clip, LC=lower caudal clip, LV=left ventral clip, RV=right ventral clip, LP=left pectoral clip, RP=right pectoral clip.

[b] Used unmarked mortality from 05/30/89 test.

[c] Used unmarked mortality from 07/11/89 test.

[d] Relative survival assumed equal to 1.00 because unmarked controls had a lower survival rate than marked controls.

Appendix I. Numbers of Marked Chinook Salmon Released (M), Relative Survival Due to Marking (S_d), Adjusted Number Released (M_{ADJ}), Recaptures and Proportion of Marked Chinook Salmon Recovered During Mark-Recapture Efficiency Tests in Blue Creek, 1989-1992.

Date	Mark [a]	M	S_d	M_{ADJ}	Recaptures [b] Screw Trap	Weir	Total	Proportion [c] Recovered
05/30/89	BRN	241	1.00	241	74	120	194	0.805
06/13/89	BRN	224	1.00	224	96	31	127	0.567
07/05/89	BRN	274	0.43	117	75	28	103	0.881
07/11/89	BRN	260	0.94	244	92	44	136	0.556
04/26/90	BRN	83	0.96[d]	80	19	47	66	0.828
05/09/90	BRN	232	0.96	223	25	100	125	0.561
05/16/90	BRN	324	0.96	311	51	210	261	0.839
05/18/92	UC	220	0.96	211	41	67	110	0.521
05/25/92	LC	246	1.00	246	43	106	149	0.606
05/30/92	LV	277	0.88	244	57	96	153	0.628
06/06/92	RV	296	1.00	296	57	52	109	0.368
06/10/92	LP	298	1.00	298	68	157	225	0.786
06/14/92	RP	304	0.83	252	63	139	202	0.801
06/19/92	UC	325	1.00	325	53	144	197	0.606
06/27/92	LC	338	1.00	338	63	177	240	0.710
07/05/92	LV	249	1.00[e]	249	54	63	117	0.470

[a] Mark: BRN=Bismark Brown-Y dye, UC=upper caudal clip, LC=lower caudal clip, LV=left ventral clip, RV=right ventral clip, LP=left pectoral clip, RP=right pectoral clip.

[b] Total recoveries during trap operations.

[c] Proportion recovered based on adjusted number released.

[d] Used marking mortality estimate from 05/09/90.

[e] Used marking mortality estimate from 06/27/92.

Appendix J. Screw Trap Efficiency Estimates Based on Mark-Recapture Method (E_{MR}), the Proportion of Recaptured Chinook Salmon Captured in the Screw Trap (E_{PS}), and Actual Trap Efficiency (E_{ACT}) Based on the Proportion of Unmarked Chinook Salmon Captured in the Screw Trap During Mark-Recapture Efficiency Tests in Blue Creek, 1989-1992. (R_S = number of marked chinook recaptured in the screw trap, R_W = number of marked chinook recaptured in the weir, M_{ADJ} = number of marked chinook released after accounting for relative survival due to marking)

Release Date	Recapture Date(s)	R_S	R_W	M_{ADJ}	# Unmarked Screw Trap	# Unmarked Weir	E_{MR}	E_{PS}	E_{ACT}
05/30/89	05/31	74	120	241	180	365	0.307	0.381	0.330
06/13/89	06/14	85	25	224	268	127	0.380	0.773	0.679
"	06/14 -15	95	31	224	586	293	0.424	0.754	0.667
07/05/89	07/06	58	17	110	275	118	0.527	0.773	0.700
"	07/06-07	75	28	110	491	199	0.682	0.728	0.712
07/11/89	7/12	84	42	244	269	84	0.344	0.667	0.762
"	07/12-13	91	44	244	637	158	0.373	0.674	0.801
04/26/90	04/27	19	47	80	56	191	0.238	0.288	0.227
05/09/90	05/10	25	100	223	33	151	0.112	0.200	0.179
05/16/90	05/17	45	210	311	64	315	0.145	0.177	0.169
05/18/92	05/19	27	40	211	370	290	0.128	0.403	0.561
"	05/19-20	34	55	211	799	1,247	0.161	0.382	0.391
05/25/92	05/26	24	82	246	520	567	0.098	0.226	0.478

Appendix J. Screw Trap Efficiency Estimates Based on Mark-Recapture Method (E_{MR}), the Proportion of Recaptured Chinook Salmon Captured in the Screw Trap (E_{PS}), and Actual Trap Efficiency (E_{ACT}) Based on the Proportion of Unmarked Chinook Salmon Captured in the Screw Trap During Mark-Recapture Efficiency Tests in Blue Creek, 1989-1992. (R_S = number of marked chinook recaptured in the screw trap, R_W = number of marked chinook recaptured in the weir, M_{ADJ} = number of marked chinook released after accounting for relative survival due to marking) (continued)

Release Date	Recapture Date(s)	R_S	R_W	M_{ADJ}	# Unmarked Screw Trap	# Unmarked Weir	E_{MR}	E_{PS}	E_{ACT}
05/25/92	05/26-27	29	94	246	866	1,323	0.118	0.236	0.396
05/30/92	05/31	48	86	244	257	311	0.197	0.358	0.453
06/06/92	06/07	41	20	296	196	53	0.139	0.672	0.787
"	06/07-08	49	24	296	550	208	0.166	0.671	0.726
06/10/92	06/11	65	142	286	182	353	0.227	0.314	0.340
06/14/92	06/15	63	127	252	150	215	0.250	0.332	0.411
06/19/92	06/20	39	102	325	34	65	0.120	0.277	0.343
06/27/92	06/28	41	146	338	112	171	0.121	0.219	0.396
"	06/28-29	53	167	338	280	254	0.157	0.241	0.524
07/05/92	7/06	37	44	246	35	22	0.150	0.457	0.614

Appendix K. Results of the Chi-Square Analysis (df=1) of the Distribution of Marked and Unmarked Juvenile Chinook Salmon Captured in the Screw Trap (N_s) and Weir (N_w) During Mark-Recapture Efficiency Tests in Blue Creek, 1989-1992.

Release Date	Recapture Date(s)	Marked N_s	Marked N_w	Unmarked N_s	Unmarked N_w	χ^{2} [a]	p
05/30/89	05/31	74	120	180	365	1.442	0.230
06/13/89	06/14	85	25	268	127	3.198	0.074
"	06/14 -15	95	31	586	293	3.456	0.063
07/05/89	07/06	58	17	275	118	1.322	0.250
"	07/06-07	75	28	491	199	0.053	0.818
07/11/89	7/12	84	42	269	84	3.879	0.049
"	07/12-13	91	44	637	158	10.244	0.001
04/26/90	04/27	19	47	56	191	0.760	0.383
05/09/90	05/10	25	100	33	151	0.095	0.758
05/16/90	05/17	45	210	64	315	0.020	0.888
05/18/92	05/19	27	40	370	290	5.477	0.019
"	05/19-20	34	55	799	1,247	0.003	0.956
05/25/92	05/26	24	82	520	567	23.713	<0.001
"	05/26-27	29	94	866	1,323	11.876	0.001
05/30/92	05/31	48	86	257	311	3.546	0.060
06/06/92	06/07	41	20	196	53	2.990	0.084
"	06/07-08	49	24	550	208	0.726	0.394
06/10/92	06/11	65	142	182	353	0.350	0.554
06/14/92	06/15	63	127	150	215	3.002	0.083
06/19/92	06/20	39	102	34	65	0.932	0.334
06/27/92	06/28	41	146	112	171	15.184	<0.001
"	06/28-29	53	167	280	254	49.617	<0.001
07/05/92	7/06	37	44	35	22	2.715	0.099

[a] Chi-square statistic was calculated using the Yates' correction for continuity (Zar 1974)

Appendix L. Recoveries of Marked Juvenile Chinook Salmon During 1989 and 1990 Mark-Recapture Efficiency Tests.[a]

	Release Date						
Days	05/30/89	06/13/89	07/05/89	07/11/89	04/26/90	05/09/90	05/16/90
1	194	110	75	126	66	125	255
2	0	16	28	9	-	0	6
3	0	0	-	1	-	-	-
4	-	-	-	-	0	-	-
5	-	-	-	-	0	-	0
6	-	1	0	-	0	0	-

[a] Days = number of days recapture occurred after release.

Appendix M. Recoveries of Marked Juvenile Chinook Salmon During 1992 Mark-Recapture Efficiency Tests.[a]

	Release Date								
Days	May 18	May 25	May 30	Jun 6	Jun 10	Jun 14	Jun 19	Jun 27	Jul 5
1	67	106	134	61	207	190	141	187	81
2	22	17	7	12	4	6	3	33	7
3	5	2	3	6	4	1	1	5	19
4	0	1	1	8	2	0	1	2	3
5		0	0	0	6	0	0	9	6
6		1	0	2	0	0	0	2	
7	0	4	1	1	0	0	3	0	
8	1	2	0	4	0	0	22	0	
9	1	0	0	8	0	0	15	0	0
10	0	0	0	2	0	0	8	1	
11	0	0	0	0	0	0	0	1	1
12	2	2	0	0	0	0	0	0	
13	0	1	0	0	0	2	1	0	
14	1	0	0	0	0	2	2		
15	1	1	1	0	0	1	0		
16	0	0	5	0	0	0	0		
17	1	0	0	0	0	0	0	0	
18	0	0	0	0	0	0	0		
19	0	2	0	0	2	0	0	0	
20	0	2	0	0	0	0	0		
21	0	0	0	1	0	0	0		
22	0	0	0	3	0	0			
23	0	0	0	0	0	0			
24	0	0	0	0	0	0			
25	0	0	0	0	0	0	0		
26	0	0	0	0	0	0			
27	2	1	0	1	0		0		
28	1	0	1	0	0				
29	1	0	0	0	0				
30	0	1	0	0	0	0			
31	0	0	0	0					
32	0	0	0	0		0			
33	0	1	0	0					
34	0	1	0	0	0				
35	0	1	0						
36	0	1	0		0				
37	0	0	0						
38	0	1	0	0					
39	0	0	0						
40	2	0	0	0					
41	0	1	0						
42	0	0							
43	0	0							
44	0	0							
45	0	0	0						
46	0	0							
47	0		0						
48	1								
49	0								
50	0	0							
51	0								
52	0	0							
53	0								
54									
55									
56									
57	0								
58									
59	0								

[a] Days = number of days recapture occurred after release.

Appendix N. Daily Number of Juvenile Chinook Salmon Captured in the Screw Trap (N_s) and Efficiency-Based (N) and Discharge-Based (Nq) Estimates of Juvenile Chinook Salmon Downstream Migration in Blue Creek, 1989-1992. (Screw trap and weir were operated on dates followed by asterisks. Numeric estimates for other dates are based on the number of chinook captured in the screw trap and estimated trap efficiency)

Date	N_s	N	Nq
04/12/89	19	341	192
04/13/89	24	393	230
04/14/89	1	15	9
04/15/89	2	28	20
04/19/89	14	121	164
04/20/89*	16	160	174
04/21/89	3	21	30
04/22/89	5	33	49
04/23/89	3	21	29
04/27/89	12	63	85
04/28/89	14	68	91
04/29/89	8	37	58
04/30/89	6	29	43
05/01/89	41	195	261
05/04/89*	125	837	565
05/05/89*	222	849	1,032
05/06/89*	234	669	1,045
05/07/89	314	1,050	1,262
05/08/89	191	611	730
05/11/89	289	746	1,008
05/12/89*	214	479	840
05/13/89*	227	539	1,061
05/14/89	125	282	553
05/15/89	127	282	529
05/19/89*	199	641	545
05/23/89	505	1,144	1,460
05/24/89	137	571	629
05/25/89	169	909	997
05/26/89	131	586	680
05/31/89*	180	545	770
06/01/89*	153	369	716
06/02/89*	142	341	632
06/06/89	427	883	1,166
06/07/89	597	1,192	1,593
06/08/89	662	1,274	1,684
06/09/89	690	1,281	1,567
06/13/89*	374	626	796
06/14/89*	268	395	573
06/15/89*	318	484	664
06/17/89	138	214	266
06/18/89	206	314	394
06/19/89	307	460	572
06/20/89*	457	580	861
06/21/89	218	315	439
06/22/89	227	322	515
06/23/89	242	338	555
06/27/89*	418	543	1,007
06/28/89*	495	577	1,189
06/29/89	997	1,366	2,756
06/30/89*	1,486	2,331	4,540
07/04/89	207	274	623
07/05/89	554	727	1,812
07/06/89*	275	393	865
07/07/89*	216	297	658
07/11/89	361	441	1,045
07/12/89*	269	353	765
07/13/89*	368	442	999
07/14/89	190	229	493
07/18/89	65	77	169
07/19/89	65	77	172
07/20/89	64	76	154
07/21/89	64	75	128
04/12/90	32	247	114
04/13/90	20	155	79
04/16/90	25	193	83
04/19/90*	18	381	45
04/20/90	16	124	40
04/21/90	32	247	83
04/24/90	18	139	95
04/25/90	78	603	400
04/26/90	16	124	65
04/27/90*	56	433	227
05/01/90	58	448	200
05/02/90	41	317	142
05/03/90	87	672	299
05/04/90	62	479	177
05/08/90	68	526	201
05/09/90*	36	202	105
05/10/90*	33	184	105
05/11/90	54	417	173
05/15/90*	29	290	114
05/16/90*	41	271	160
05/17/90*	64	379	253

Appendix N. Daily Number of Juvenile Chinook Salmon Captured in the Screw Trap (N_s) and Efficiency-Based (N) and Discharge-Based (Nq) Estimates of Juvenile Chinook Salmon Downstream Migration in Blue Creek, 1989-1992. (Screw trap and weir were operated on dates followed by asterisks. Numeric estimates for other dates are based on the number of chinook captured in the screw trap and estimated trap efficiency) (continued)

Date	N_s	N	Nq	Date	N_s	N	Nq
05/18/90	80	618	282	07/19/90*	46	51	177
05/21/90	322	2,488	1,370	07/20/90	35	39	119
05/24/90	98	757	544	07/21/90	43	48	130
05/25/90	40	309	202	07/22/90	79	85	233
05/30/90	20	155	120	07/23/90	75	81	230
06/07/90	6	46	510	07/24/90*	79	85	230
06/08/90	3	23	26	07/25/90*	83	87	248
06/12/90	120	927	727	07/26/90	42	43	139
06/13/90	152	1,175	836	07/27/90	28	30	99
06/14/90	116	896	615	07/28/90	19	20	69
06/15/90	82	634	431	07/29/90	12	12	40
06/19/90	14	111	74	07/30/90	11	11	33
06/20/90	21	132	118	07/31/90	11	11	32
06/21/90	21	97	94	08/01/90	10	10	33
06/22/90	37	177	170	08/02/90	8	8	24
06/23/90	204	824	835	08/03/90	7	7	23
06/24/90	198	706	744				
06/25/90	128	398	484	04/12/91	6	67	45
06/26/90*	98	192	371	04/16/91	3	29	22
06/27/90*	40	101	164	04/17/91	0	0	0
06/28/90*	53	116	221	04/18/91	0	0	0
06/29/90	112	240	370	04/19/91	0	0	0
06/30/90	85	174	247	04/23/91	15	143	125
07/01/90	77	150	235	04/24/91	10	99	84
07/02/90	69	128	222	04/25/91	4	35	29
07/03/90*	94	191	317	04/30/91	13	124	109
07/04/90	38	65	135	05/01/91	13	124	108
07/05/90	29	47	106	05/02/91	9	86	75
07/06/90	134	231	412	05/03/91	8	77	67
07/07/90	55	94	144	05/07/91	26	249	211
07/08/90	26	40	69	05/08/91	20	191	145
07/09/90	72	102	201	05/09/91	17	162	116
07/10/90*	70	78	204	05/10/91	16	153	111
07/11/90*	68	76	215	05/14/91	27	259	190
07/12/90*	55	83	201	05/15/91	23	220	163
07/13/90	127	154	378	05/16/91*	17	186	132
07/14/90	154	183	369	05/17/91*	16	177	134
07/15/90	109	127	284	05/21/91	98	940	701
07/16/90	64	74	179	05/22/91	74	710	493
07/17/90*	57	65	185	05/23/91	91	868	591
07/18/90*	69	74	262	05/24/91*	46	460	318

Appendix N. Daily Number of Juvenile Chinook Salmon Captured in the Screw Trap (N_s) and Efficiency-Based (N) and Discharge-Based (Nq) Estimates of Juvenile Chinook Salmon Downstream Migration in Blue Creek, 1989-1992. (Screw trap and weir were operated on dates followed by asterisks. Numeric estimates for other dates are based on the number of chinook captured in the screw trap and estimated trap efficiency) (continued)

Date	N_s	N	Nq	Date	N_s	N	Nq
05/29/91	39	345	251	08/13/91	1	1	4
05/30/91	14	132	91	08/14/91	1	1	4
05/31/91*	63	333	425				
06/04/91*	42	287	268	04/08/92	33		124
06/05/91	37	279	235	04/09/92	6		30
06/06/91*	26	257	172	04/10/92	2		20
06/07/91*	27	194	169	04/14/92	3		38
06/11/91*	28	122	157	04/15/92	1		12
06/12/91*	18	104	103	04/16/92	6		68
06/13/91*	25	114	145	04/22/92	22		236
06/14/91*	31	120	177	04/23/92	53		532
06/18/91*	8	75	43	04/28/92	56		375
06/19/91*	44	259	246	04/29/92	36		237
06/20/91*	28	193	154	04/30/92	24		156
06/21/91*	37	169	195	05/01/92	55		363
06/25/91*	37	87	192	05/05/92	33		179
06/26/91*	12	15	65	05/06/92	47		258
06/27/91*	13	20	70	05/07/92	120		615
06/28/91*	10	19	52	05/08/92	136		633
07/02/91*	10	21	53	05/12/92	343		1,280
07/03/91*	13	23	68	05/13/92	233		867
07/04/91	17	25	86	05/14/92	234		889
07/05/91	33	47	164	05/15/92	147		542
07/09/91*	44	54	219	05/18/92	340		1,143
07/10/91*	39	52	191	05/19/92*	370	660	1,237
07/11/91	27	31	134	05/20/92*	429	1,386	1,597
07/12/91	38	43	184	05/21/92*	364	726	1,476
07/16/91	12	18	61	05/22/92*	353	676	1,289
07/17/91	18	39	101	05/25/92*	263	542	972
07/18/91	6	10	33	05/26/92*	520	1,087	1,881
07/19/91	5	6	25	05/27/92*	346	1,102	1,279
07/24/91	6	6	31	05/28/92*	199	467	711
07/25/91	10	10	51	05/29/92*	310	651	1,058
07/26/91	0	0	0	05/30/92*	302	425	1,033
07/31/91	18	18	86	05/31/92*	257	568	822
08/01/91	2	2	10	06/01/92*	275	354	907
08/02/91	1	1	5	06/02/92*	331	743	1,137
08/06/91	1	1	5	06/03/92*	222	283	728
08/07/91	0	0	0	06/04/92*	297	414	961
08/08/91	3	3	15	06/05/92*	207	500	689
08/09/91	1	1	5	06/06/92*	178	375	645

Appendix N. Daily Number of Juvenile Chinook Salmon Captured in the Screw Trap (N_s) and Efficiency-Based (N) and Discharge-Based (Nq) Estimates of Juvenile Chinook Salmon Downstream Migration in Blue Creek, 1989-1992. (Screw trap and weir were operated on dates followed by asterisks. Numeric estimates for other dates are based on the number of chinook captured in the screw trap and estimated trap efficiency)

Date	N_s	N	Nq	Date	N_s	N	Nq
06/07/92*	196	249	701	06/25/92*	104	139	343
06/08/92*	354	509	1,142	06/26/92*	70	95	232
06/09/92*	205	365	644	06/27/92*	133	311	431
06/10/92*	198	417	623	06/28/92*	112	283	344
06/11/92*	182	535	571	06/29/92*	168	251	529
06/12/92*	184	422	584	06/30/92*	171	300	535
06/13/92*	183	344	563	07/01/92*	84	97	251
06/14/92*	151	348	505	07/02/92*	90	199	276
06/15/92*	150	365	509	07/03/92*	60	91	210
06/16/92*	48	177	157	07/04/92*	40	116	153
06/17/92*	30	52	105	07/05/92*	49	61	187
06/18/92*	21	67	71	07/06/92*	35	57	123
06/19/92*	34	99	109	07/07/92*	48	73	154
06/20/92*	43	72	147	07/08/92*	38	96	122
06/21/92*	67	69	255	07/09/92*	36	42	119
06/22/92*	44	57	157	07/10/92*	33	51	108
06/23/92*	60	65	200	07/14/92*	14	18	67
06/24/92*	60	64	199				

Appendix O. Semimonthly Efficiency-Based and Discharge-Based Abundance Estimates of Juvenile Chinook Migrating Downstream from Blue Creek, 1989-1992. (d= number of days sampled in the period, D= number of days in the period, N_s = number of juvenile chinook captured in the screw trap, N_d= sum of daily efficiency-based estimates during period, Nq_d= sum of daily discharge-based estimates for the period, N_p= efficiency-based estimate for the period, Nq_p= discharge-based estimate for the period)

Year	Period	d	D	N_s	N_d	Nq_d	N_p	Nq_p
1989	Apr 16-30	9	15	81	581	742	968	1,237
	May 1-15	11	15	2,109	6,539	8,887	8,916	12,119
	May 16-31	6	16	1,321	4,397	5,082	11,725	13,553
	Jun 1-15	9	15	3,631	6,844	9,391	11,407	15,652
	Jun 16-30	11	15	5,191	7,360	13,093	10,037	17,854
	Jul 1-15	8	15	2,440	3,156	7,259	5,917	13,611
	Total	54	91	14,773	28,877	44,454	48,970	74,026
1990	Apr 16-30	8	15	259	2,244	1,038	4,207	1,946
	May 1-15	9	15	468	3,535	1,515	5,892	2,525
	May 16-31	7	16	665	4,978	2,930	11,378	6,698
	Jun 1-15	6	15	479	3,702	2,687	9,254	6,716
	Jun 16-30	12	15	1,008	3,267	3,892	4,084	4,865
	Jul 1-15	15	15	1,177	1,750	3,492	1,750	3,492
	Total	57	91	4,056	19,476	15,554	36,565	26,242
1991	Apr 16-30	8	15	45	431	369	807	693
	May 1-15	9	15	159	1,521	1,186	2,534	1,977
	May 16-31	9	16	458	4,150	3,136	7,378	5,574
	Jun 1-15	8	15	234	1,477	1,426	2,770	2,674
	Jun 16-30	8	15	189	837	1,017	1,569	1,906
	Jul 1-15	8	15	221	297	1,100	557	2,062
	Total	50	91	1,306	8,713	8,234	15,615	14,887

Appendix O. Semimonthly Efficiency-Based and Discharge-Based Abundance Estimates of Juvenile Chinook Migrating Downstream from Blue Creek, 1989-1992. (d= number of days sampled in the period, D= number of days in the period, N_s = number of juvenile chinook captured in the screw trap, N_d= sum of daily efficiency-based estimates during period, Nq_d= sum of daily discharge-based estimates for the period, N_p= efficiency-based estimate for the period, Nq_p= discharge-based estimate for the period) (continued)

Year	Period	d	D	N_s	N_d	Nq_d	N_p	Nq_p
1992[a]	Apr 16-30	6	15	197	-	1,604	-	4,009
	May 1-15	9	15	1,348	-	5,625	-	9,375
	May 16-31[b]	11	16	3,712	8,290	13,355	12,058	19,425
	Jun 1-15	15	15	3,313	6,223	10,907	6,223	10,907
	Jun 16-30	15	15	1,165	2,101	3,815	2,101	3,815
	Jul 1-15	11	15	527	901	1,770	1,229	2,414
	Total	67	91	10,262	17,515	37,076	21,611	49,945

[a] Numeric estimates for Apr 16-30 and May 1-15 periods were not calculated due to poor trap efficiency predictive relationship.

[b] Discharge-based estimate for May 18 was not used in this sum because no numeric estimate was calculated for this date.