An Assessment of Trap Efficiency to Estimate Coho Salmon Smolt Abundance in a Small Alaskan Stream

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Anthony Alexander Eskelin, B.S.

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AN ASSESSMENT OF TRAP EFFICIENCY TO ESTIMATE COHO SALMON SMOLT ABUNDANCE IN A SMALL ALASKAN STREAM

By

Anthony Alexander Eskelin

RECOMMENDED:

Nick Hughes

Eric Rexstad

James Hasbrouck

Joseph Margraf
Advisory Committee Chair

Director, Division of Fisheries

APPROVED:

Dean, School of Fisheries and Ocean Sciences

Dean of the Graduate School

June 14, 2004
Date

Abstract

Smolt abundance is commonly estimated using trap efficiency-based methods; however, few studies have investigated the accuracy of trap efficiency estimates. The objectives of this study were to: (1) test the hypotheses that (i) trap efficiency is not affected by release timing nor release distance, (ii) trap efficiency-based estimates of smolt abundance are concordant with smolt-adult mark-recapture estimates, and (2) evaluate if water level and turbidity influence trap efficiency. In Deep Creek, Alaska, during 2001 and 2002, coho salmon *Oncorhynchus kisutch* smolt abundance was estimated using trap efficiency-based methods and compared to independent smolt-adult mark-recapture estimates. Marked smolts were released at two times of day (1200 hours and 0000 hours) and two release distances upstream of the trap (400 m and 1500 m) every 2 to 4 d throughout each year. Trap efficiency estimates were highly variable (range 0%-55%) and trap efficiency-based estimates of abundance were not concordant with smolt-adult mark-recapture estimates. Release timing and turbidity significantly influenced trap efficiency, whereas release distance did not. Several assumptions of the trap efficiency approach were not met, which produced biased estimates and conflicting results among years when comparing estimation techniques. These results suggest that assumptions of the trap efficiency-based methods be fully assessed to accurately estimate smolt abundance.

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Introduction

Sound management of salmon stocks, including management objectives that maximize sustainable yield, often include enumeration of smolts (Bradford et al. 2000). Estimates of smolt abundance provide a direct measure of freshwater productivity, which is useful in better understanding the dynamics of production, stock-recruit relationships, and life history strategies (Power 1985). Smolt numbers can be used to forecast adult returns, estimate freshwater rearing capacity, assess the health of juvenile salmonid populations and can provide a warning of changing freshwater conditions (Peterman 1981; Thedinga et al. 1994; Bradford et al. 1997). If problems arise, the warning may be given before adult runs begin to decline, thus allowing more time for a management response. Estimates of smolt abundance may also provide critical information for evaluating depleted populations (Roper and Scarnecchia 2000). In either case, rigorous methods are needed to estimate smolt abundance for most effective management of salmon stocks.

It is often not possible to capture and enumerate an entire smolt migration. As a result, sampling methods have been developed to estimate smolt production from samples of a population. A variety of sampling gears have been used to capture smolts, most commonly fyke nets (Craddock 1959; Milner and Smith 1985), incline plane traps (McMenemy and Kynard, 1988; Carlson et al. 1998), rotary screw traps (Thedinga et al. 1994; Ashe et al. 1995; Roper and Scarnecchia 1999), tributary weirs (Carlon 2003), and partial weirs (Dempson and Stansbury 1991). Mark-recapture methods serve a central role in quantifying the abundance, movement, and survival of mobile species (Seber 1982), and are often integrated into juvenile salmonid trapping to estimate smolt abundance by measuring the probability of capture (trap efficiency) of migrating smolts and expanding the unmarked catch to reflect estimated trap efficiency (Dempson and Stansbury 1991; Thedinga et al. 1994).

Typically, fish are trapped throughout an entire smolt migration and groups of captured smolts are marked and released upstream of the trap to resume downstream migration. Subsequent recaptures are used to estimate trap efficiency, which is used in conjunction with the number of unmarked fish captured by the trap to estimate smolt abundance for a segment of the population. Stratified releases over the course of a migration will yield estimates of abundance for an entire population (Darroch 1961; Carlson et al. 1998). Temporal stratification can account for potential variation in trap efficiency from a number of factors such as changes in stream flow and turbidity, changes in age structure and size of smolts, smolt behavior, and in the event of altering trap configurations (Dempson and Stansbury 1991; Roper and Scarnecchia 2000), which can result in more accurate estimates of abundance (Warren and Dempson 1995).

The accuracy of smolt abundance estimates derived from trap efficiency and trap catch is based on the critical assumption that estimates of trap efficiency represent the actual capture rate of the trap; however, this assumption is seldom tested. Trap efficiency-based methods are commonly used to estimate smolt abundance without any verification of the relative accuracy of trap efficiency estimates (Dempson and Stansbury 1991; Thedinga et al. 1994), which directly affect smolt abundance estimates and could be grossly inaccurate (Kruzic 1998; Newcomb and Coon 2001).

Smolt-adult mark-recapture experiments are also commonly used to estimate salmon smolt abundance (Skalski 1996; King and Breakfield 2002; Carlon 2003), whereby captured smolts are marked with adipose fin clips and coded-wire tags and released to resume migration. When the cohort returns to spawn, adults are examined for adipose fin clips and smolt abundance from that cohort can then be estimated using a Chapman-modified Petersen mark-recapture model (Seber 1982). This estimation technique is not immune to problems or biases either, but can produce accurate smolt abundance estimates provided the underlying assumptions are met.

In this study, objectives were to: (1) test the hypotheses that (i) trap efficiency for capturing salmon smolt is not affected by release timing nor release distance, (ii) trap efficiency-based estimates of smolt abundance are concordant with smolt-adult mark-recapture estimates, and (2) evaluate if water level and turbidity influence trap efficiency.

Methods

Study Site

Deep Creek is a coastal stream located on the Kenai Peninsula in Southcentral Alaska (60°N 151°W), 63 km southwest of Kenai (Figure 1). It originates in the Boxcar Hills, flows northwest 48 km into eastern Cook Inlet and is characterized by gravel beds and boulder fields with interspersed coal seams, large woody debris, and dense riparian vegetation. Deep Creek is approximately 12-15 m wide and 1-2 m deep with a baseline discharge of approximately 8.5 m^3/s (cubic meters per second) within the study area. The rotary screw trap (Figure 2) was placed in Deep Creek immediately upstream of the Sterling Highway Bridge, approximately 1.1 km upstream from its terminus into Cook Inlet.

Experimental Design

In 2001 and 2002, coho salmon smolt abundance was estimated using a stratified one-site mark-recapture experimental design and compared to independent smolt-adult mark-recapture estimates of each smolt population. Four treatment groups of 50 to 100 fish per group were released in every temporal stratum throughout each migration, consisting of two release distances (400 m and 1500 m) upstream of the trap and two times of day (1200 hours and 0000 hours). A treatment group j was defined as a group of fish released at a specific time of day and release location to estimate trap efficiency. These groups were used to test the hypothesis that trap efficiency was equal among treatment groups within each time strata. A series of partial fin-clips were used to differentiate fish from each treatment group. A total of six estimates of the same population in each year (2001 and 2002) were used to evaluate the accuracy of smolt abundance estimates based on trap efficiency and unmarked trap catch: one estimate from each of the four treatment groups, a pooled estimate from combining all treatment groups, and the independent estimate from smolt-adult mark-recapture. To evaluate how other factors affect trap efficiency, (1) gage heights, (2) water temperature, and (3) trap revolutions per minute and were measured between 0600 hours and 0900 hours each morning and between 2000 hours and 2300 hours each evening. In addition, (4) turbidity was measured to the nearest 0.01 nephelometric turbidity unit (NTU) during morning check of the livebox in 2002. A log-linear analysis was performed which included estimated trap efficiency from each group of fish, release timing and distance and the four variables mentioned. In addition, an underwater video camera was used in 2002 to further study smolt behavior, decipher the level of daytime migration, and identify potential trap evasion.

Trap efficiency-based estimation

Smolt abundance from trap efficiency-based methods was estimated by expanding the catch of unmarked fish to reflect the measured trap efficiency. Estimates of trap efficiency and smolt abundance were stratified every 2 to 4 d (if sufficient numbers of smolts were available) to account for potential changes in trap efficiency throughout each migration. A stratum *i* was defined as the period of time between releases of the same treatment except for the first stratum, which was from the onset of trapping until the second group was released, and the last stratum, which included all fish captured from the last release until trapping ceased. Stratified estimates of abundance in each stratum for each treatment group $\hat{n}_{ij}$ were calculated by dividing estimated trap efficiency for each treatment group $\hat{e}_{ij}$ by number of unmarked fish u_i captured in each stratum

$$\hat{n}_{ij} = u_i / \hat{e}_{ij} \qquad [1],$$

where trap efficiency $\hat{e}_{ij}$ in each stratum was estimated by dividing the number of marked fish released for each treatment group in each stratum m_{ij} by the number of recaptures for each treatment group in each stratum r_{ij}

$$\hat{e}_{ij} = r_{ij} / m_{ij} \qquad [2].$$

Abundance estimates for a smolt population $\hat{N}_j$ with fish given treatment *j* were the sum of stratified estimates of abundance, provided that trapping was conducted throughout the entire run

$$\hat{N}_j = \sum_{i=1}^{t} \hat{n}_{ij} \quad [3],$$

where t is the number of temporal strata in each year. 95% confidence intervals (CIs) for trap efficiency were approximated directly from the large sample variance of the binomial distribution (Seber 1982), given as

$$\hat{e}_{ij} \pm Z_{\alpha/2}\sqrt{\hat{e}_{ij}(1-\hat{e}_{ij})/m_{ij}} \quad [4].$$

CIs of smolt abundance in each stratum were

$$\hat{n}_{ij} \pm Z_{\alpha/2}\sqrt{var(\hat{n}_{ij})} \quad [5]$$

where,

$$var(\hat{n}_{ij}) = \frac{\hat{n}_{ij}^{\,2}(c_i - r_{ij})}{(c_i + 1)(r_{ij} + 2)} \quad [6]$$

where c_i is the number of unmarked smolts captured in stratum i, and r_{ij} is the number of smolts recaptured in stratum i for treatment j (Roper and Scarnecchia 2000). Variance of smolt abundance for an entire population $Var(\hat{N}_j)$ for each treatment group was calculated by summing all stratum variances

$$Var(\hat{N}_j) = \sum_{i=1}^{t} \text{var}(\hat{n}_{ij}) \quad [7]$$

and CIs of the population for each treatment group were calculated as

$$\hat{N}_j \pm Z_{\alpha/2}\sqrt{Var(\hat{N}_j)} \quad [8].$$

The assumptions made when using trap efficiency and unmarked smolt catch to estimate smolt abundance were (1) all fish released upstream of the trap survived and migrated past the trap during each stratified mark-recapture experiment, (2) marked fish had an equal probability of capture as unmarked fish, (3) trap efficiency was constant within each stratified mark-recapture experiment, (4) fish did not lose their marks between the time of release until either recapture or migration past the trap, and (5) all captured smolts were correctly identified by species, as to marked or unmarked, and all data were correctly recorded.

Trapping was continuous from approximately late-May to mid-July during both years (2001 and 2002) with a 2.44-m diameter rotary screw trap that consisted of a revolving stainless-steel 2-mm mesh cone on pontoons with rigid aluminum framework (Figure 2). Water entering the cone deflected off helical baffle-like vanes causing the cone to rotate (3-8 revolutions per minute). Fish entering 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 trap was positioned in the stream by a cable system spanning from each pontoon to large boulders on the adjacent bank upstream of the trap. This allowed for longitudinal movement with an adjustable steel beam against the near bank allowing for lateral movement and exact placement of the trap. The trapping location was selected based on depth and velocity such that the cone sampled the entire water column and downstream water pressure rotated the cone fast enough to prevent captured fish from escaping (more than 3 revolutions per minute). When possible, the trap was placed in the thalweg and as stream discharge changed, the location of the trap was adjusted to maintain proper positioning in the thalweg and as deep into the water column as possible. Trapping was continuous from the onset of trapping until trapping was stopped at the end of each season, barring trap malfunctions or when stream conditions were too dangerous to operate the trap.

Smolt-adult mark-recapture

In Deep Creek, nearly all coho salmon return to spawn after one winter at sea (King and Breakfield 2002; Begich 2002). This simple life history makes it possible to estimate smolt abundance by marking smolts with adipose fin clips and then examining returning adults for adipose fin clips the following year. Smolt abundance was estimated based on smolt-adult mark-recapture during year t using the Chapman modified Petersen estimator given as:

$$\hat{N}_t = \frac{(m_t + 1)(c_{t+1} + 1)}{(r_{t+1} + 1)}, \quad [9]$$

where, m_t is the number of smolts marked and surviving to emigrate with an adipose fin clip during year t, c_{t+1} is the number of adult coho salmon examined for adipose fin clips the following year after smolts were marked (t+1), and r_{t+1} is the number of adult coho salmon sampled with an adipose fin clip the year after smolt marking. The variance of the smolt abundance estimate during year t was estimated as:

$$V\hat{a}r(\hat{N}_t) = \frac{(m_t+1)(c_{t+1}+1)(m_t+r_{t+1})(c_{t+1}-r_{t+1})}{(r_{t+1}+1)^2(r_{t+1}+2)} \qquad [10]$$

and CIs of the smolt abundance estimate based on smolt-adult mark-recapture during year t were given as:

$$\hat{N}_t \pm Z_{\alpha/2}\sqrt{V\hat{a}r(\hat{N}_t)} \qquad [11].$$

This model will produce unbiased estimates of abundance if (1) all juveniles marked with an adipose fin clip in Deep Creek were actually smolt, (2) survival and catchability were the same for marked and unmarked fish, (3) no adipose fins were regenerated nor lost between the marking and recovery events, and (4) fish were correctly identified by species and for adipose fin clips.

Coho salmon smolts captured in the trap and not used to estimate trap efficiency were given a complete adipose fin clip and injected with a coded-wire tag into their snout using a NMT Mark IV tag injector following standard coded-wire tagging procedures (Moberly et al. 1977). Tagged smolt were allowed to recuperate in freshwater holding bins for a minimum of 4-6 hours and released below the trap to resume migration. As a quality control measure, a sample of 200 tagged fish or the total tagged that day, whichever was less, were held for 24 hours to measure short-term mortality and tag-retention, then released below the trap. In addition to fin clipping and tagging, scales were taken at times from unmarked coho salmon juveniles to determine the age structure of the migration.

Coho salmon adults returning to spawn were sampled for marks as the recapture event in each year's smolt-adult mark-recapture experiment. In 2002, a floating-type weir was installed 4.0 km upstream from Cook Inlet, impeding upstream migration. This consisted of PVC tubing adjoined longitudinally and attached to a rail imbed in the substrate. A live trap with an adjustable fyke opening permitted fish to move upstream and into the trap. All coho salmon adults entering the trap were examined for adipose fin clips, given a distinct caudal fin punch to eliminate double sampling in the event of weir failure and released upstream. Logistical constraints prevented the use of a weir in 2003; during that year, adult fish were sampled by beach seining. All coho salmon adults captured in 2003 were examined for adipose fin clips and given a distinct caudal fin punch to eliminate double sampling. In addition, scales were taken from systematically during both years to determine respective ages from captured coho salmon adults.

Results

Estimates of trap efficiency differed significantly with time of day of release (χ^2=12.33, df 1, p<0.0004), but not with release location (χ^2=0.17, df 1, p=0.68). Trap efficiency was also influenced by turbidity (χ^2=4.32, df 1, p=0.04) and there was an interaction with time of day of release and turbidity (χ^2=6.58, df 1, p=0.01) (Tables 1 and 2). Trap efficiency estimates varied widely among treatment groups within a given stratum and throughout each season with no definitive patterns (Figures 3 and 4). Fish released at night tended to have less variability in trap efficiency over the course of a migration compared to daytime released fish and generally had higher estimates of trap efficiency, but not always. Trap efficiency averaged 0.20 and ranged from 0.00 to 0.52 among all treatment groups in 2001 (Tables 1 & 3). In 2002, trap efficiency averaged 0.27 and ranged from 0.03 to 0.55 (Tables 2 & 4). Greater than 90% of all recaptures were within 1 d and 98% within 2 d of release. A chi square-test of homogeneity indicated significant temporal change in trap efficiency for all treatment groups in 2002, except for fish released at the lower site at 0000 hours (χ^2=8.70, df 10, p=0.561). There was significant temporal change in estimated trap efficiency for all treatment groups in 2001.

The majority (>90%) of coho salmon smolts were trapped in June both years (Appendix A). Coho salmon smolts began migrating by mid-May and continued through mid-July, peaking in mid-June (Figure 5). Daily catches exhibited a protracted low-level decline after approximately 3 July during both years. Capture rates showed a strong diel pattern. Periodic checks of the livebox revealed daytime catches were low and that there was a dramatic increase in catch rate beginning at dusk with high catches continuing until just before dawn.

2001 smolt trapping and abundance estimates

Water levels were high and turbid, including over flood stage at times from the onset of trapping in late-May until approximately mid-June, which made it difficult for safe and effective operation of the trap until stream conditions subsided close to baseline flows. Problems with the trap becoming plugged with debris were prevalent for the first three weeks of trapping. At times, the cone needed to be washed every 20 min to prevent the trap from sinking. After water levels subsided, the trap was moved to the opposite bank and repositioned in the thalweg on 20 June. Despite problems with water levels, trap repositioning, and lapses in both trapping and trap efficiency estimates, a total of 4,785 coho salmon smolts were captured in the trap of which 2,538 (Appendix A) were given adipose fin clips and coded-wire tags as the marking event in the smolt-adult mark-recapture, and 1,942 were used to estimate trap efficiency in 9 release strata (Tables 3 and 4). Short-term survival was estimated as 99.9% for all tagged fish.

Based on the number of coho salmon smolts marked in 2001 with adipose fin clips (M_t=2,538), the number of adults examined for adipose fin clips in 2002 (C_{t+1}=6,164), and the number recaptured with adipose fin clips in 2002 (R_{t+1}=377), the abundance estimate and CIs for coho salmon smolts in 2001 based on smolt-adult mark-recapture was 38,473 (35,034-41,912). This independent estimate was compared to trap efficiency-based abundance estimates from each of the four treatment groups and the estimate from pooling of all treatment groups (Figure 6). Abundance estimates from fish released at night were most similar to the smolt-adult mark-recapture estimate. The estimate from fish released at the lower site at 0000 hours, 41,594 (35,409-47,779) was closest to the independent estimate (8% higher), whereas the estimate from fish released at the lower site at 1200 hours, 57,171 (40,521-73,821) was 49% higher than the independent estimate. The pooled abundance estimate of 35,653 (29,485-41,822) was estimated by combining all treatment groups in each stratum and was 9% lower than the smolt-adult mark-recapture abundance estimate (Figure 6).

A change in the predominant age class of coho salmon juveniles captured in the trap occurred after approximately 5 July. Approximately 90% of coho salmon smolts aged prior to 5 July were age 2.0 and nearly all fish (>90%) aged after 5 July were age 1.0. Most of these fish were less silvery in appearance; however, it was unclear at the time if these fish were smolting or not. Of the 348 adult coho salmon aged in 2002, 10% were age 1.1, 87% age 2.1, and approximately 3% were age 3.1

2002 smolt trapping and abundance estimates

Stream flows in Deep Creek were relatively stable in 2002 (Figure 3) and allowed for constant trapping effort and trap placement without many lapses in trap operation or trap efficiency estimates. The only significant interruption to trap operation was on 15 June when large debris floated into the trap at night, stopping the cone's rotation. All of the four treatment groups were released in each stratum throughout the time the trap was operational from 30 May to 16 July. Seventy-four coho salmon smolts were captured on the initial day of operation with estimates of trap efficiency from each treatment group between 0.08 and 0.27 for the first release (Table 2). A total of 10,660 coho salmon smolts were captured in 2002, over twice as many as were captured in 2001. Of those, 3,397 coho salmon smolts were released upstream of the trap to estimate trap efficiency for each treatment group in 11 strata (Table 2). The remaining healthy coho salmon smolts (7,412) were adipose fin clipped, injected with a coded-wire tag and released as the marking event in the smolt-adult mark-recapture experiment (Appendix B).

Based on the number of coho salmon smolts marked in 2002 with adipose fin clips (M_t=7,412), the number of adults sampled for adipose fin clips in 2003 (C_{t+1}=1,485), and the number recaptured with adipose fin clips in 2003 (R_{t+1}=190), the estimate and CIs for coho salmon smolts migrating from Deep Creek in 2002 was 57,672 (50,156-65,190), a 50% increase from 2001 estimates. Trap efficiency estimates were on average higher for fish released at 0000 hours (0.31) than fish released at 1200 hours (0.23), a pattern seen in both 2001 and 2002 (Figure 7). Abundance estimates from fish released at the lower site at 1200 hours 59,139 (48,100-70,195) were within 3% of the independent smolt-adult mark-recapture estimate, whereas estimates from fish released at night were 30% to 60% lower than the independent estimate. The fifth trap efficiency-based abundance estimate 40,785 (29,114-52,457) from pooling was 40% less than the independent smolt-adult mark–recapture estimate.

2001 and 2002 comparison

Smolt abundance estimates based on trap efficiency had conflicting results in 2001 and 2002 when compared to abundance estimates based on smolt-adult mark-recapture. In 2001, smolts released at 0000 hours had abundance estimates closest to smolt-adult mark-recapture estimates (within 5%), and smolts released at 1200 hours had estimates approximately twice that of the independent estimate. In 2002, smolts released at 1200 hours had abundance estimates closest to smolt-adult mark-recapture estimates (within 15%) and smolts released at 0000 hours had abundance estimates 34% to 40% lower than the independent estimate (Figure 6). Average trap efficiency estimates for all fish released were 38% lower in 2001 than 2002. Despite the conflicting results when comparing trap efficiency-based estimates to smolt-adult mark-recapture estimates, the same patterns in average trap efficiency for each treatment group were observed during each year (Figure 7).

Discussion

The objectives of this study were to: (1) test the hypotheses that (i) trap efficiency is not affected by release timing nor release distance, (ii) trap efficiency-based estimates of smolt abundance are concordant with smolt-adult mark-recapture estimates, and (2) evaluate if water level and turbidity influence trap efficiency. Time of day of release and turbidity significantly affected trap efficiency, whereas release distance did not. Time of day of release and turbidity had a significant interaction, which suggests that release timing will impact trap efficiency more during clear conditions than when turbid. Daytime trap efficiency may increase with higher turbidity; however, turbidity was positively related to discharge, thereby lessening the effect of turbidity on trap efficiency. Trap efficiency-based estimates were not concordant with smolt-adult mark-recapture estimates. There were conflicting results among years and high variation in trap efficiency even with relatively stable discharge and turbidity. Probability of recapture seemed mainly dependent on where a fish was traveling in the water column and if the trap was encountered, then light level at that time and turbidity strongly influenced the rate of capture.

Trap efficiency-based methods to estimate smolt abundance from each treatment group and from pooling were within 15% from 2001 to 2002 except for fish released at the upper site at 1200 hours (Figure 6), whereas the smolt-adult mark-recapture estimates were 50% higher in 2002 than 2001. It is not entirely known whether this discrepancy is from biased trap efficiency-based abundance estimates, imprecise smolt-adult mark-recapture estimates or some combination of the two.

Trap efficiency-based estimates

There were biases associated with each estimation technique, particularly with trap efficiency-based estimates, which requires five assumptions to be met to attain unbiased estimates. Violations of these assumptions were difficult to test or avoid. Abundance estimates from trap efficiency-based methods are suspected to have significant bias in both 2001 and 2002. All fish released upstream of the trap must survive to migrate past the trap within each stratum for assumption one to be met. Even with essentially no short-term mortality of marked fish (less than 0.1%), it is doubtful all fish survived to migrate past the trap. Several piscivorous species could be responsible for some mortality of marked fish and delayed handling-induced mortality was also possible.

A series of partial fin-clips identified marked fish from each treatment group. Although this marking technique did not allow for discrete temporal resolution between strata, more than 90% of fish released upstream of the trap were recaptured within 1 d and fish were not released to initiate the next stratum until 1 d had passed with no recaptures. Bias was considered minimal from fish recaptured in overlapping strata. However, the release of non-smolting fish could be responsible for some bias as well as fish that desmoltified. Released fish that are smolting at the time of capture are not guaranteed to promptly migrate downstream after being transported and released. Some fish released may have desmoltified from handling-induced stress, which can and does occur (Folmar et al. 1982). Population estimates can be biased high from the release of non-smolting fish; only 15% of marked coho salmon juveniles passed the trap a second time in a South Umpqua River study (Kruzic 1998). The release of non-smolting fish or desmoltification may have biased estimates of smolt abundance, but the enormity of bias is undetectable.

Equal capture probabilities for marked and unmarked fish is critical for accurate trap efficiency-based estimation (assumption two); however, this assumption is inherently difficult to test. Changes in capture probability can significantly affect abundance estimates, especially during the peak of migration. In this study, up to 22% of all fish captured each year were in a 3 d period. If actual trap efficiency was 0.40 and estimated trap efficiency was only 0.20 during this period, abundance estimates for the entire population would be biased high by over 5% even if all other estimates of trap efficiency were accurate.

Altered behavior and survival from handling, unequal mixing, and learned behavior may have influenced the capture rate of marked fish. Also, marked fishes ability to avoid predators may have been influenced by both turbidity and handling-induced alteration of behavior (Gregory 1993; Mesa 1994; Healy and Reinhardt 1995).

Trap efficiency was not constant during each stratified mark-recapture experiment in either season and should be constant to yield accurate estimates (assumption three). Trap efficiency was continually changing, depending on discharge, turbidity, light levels, hydrology near the trap, and probably many other factors. In 2002, stream conditions were considerably more stable than in 2001; however, high variation in estimated trap efficiency continued. Fish should not have lost their marks between sampling events (assumption four). The short time period between release and recapture (usually less than 2 d) would not allow for significant fin regeneration and recaptured fish were easily identified (assumption five). Long-term effects on survival of fish given partial fin clips were not measured. Fins do regenerate if clipped only partially; many adult coho salmon had regenerated caudal and pelvic fins from clips received as smolts.

Smolt-adult mark-recapture estimates

The mark-recapture model based on marking smolts and recapturing adults requires all fish that marked were smolts (assumption one). If non-smolting fish were marked, smolt abundance estimates would be biased high using this estimation technique. This model also requires equal survival and catchability for marked and unmarked fish (assumption two). Survival and catchability of adults was likely similar for marked and unmarked fish, but changes in survival rates or catchability could bias estimates considerably. Stress, scale loss, and tagging can reduce survival of salmon smolts (Bouck and Smith 1979; Wedemeyer et al. 1980). However, if done properly, adipose fin clipping has been shown to not affect survivability of coho salmon smolts (Vincent-Lang 1993), and every effort was made to minimize any handling and marking effects. Catchability was similar for marked and unmarked adults sampled each year. In 2002, the weir formed a complete blockage to upstream migration and allowed for every fish to be sampled; in 2003, beach seining was not selective for or against adipose fin clipped fish. Adipose fins do not regenerate if clipped properly (Thompson and Blankenship

1997), so no adipose fin regenerations are suspected, nor are appreciable amounts of naturally missing or lost adipose fins (assumption three). All fish were easily identified for marks and strict protocols were adhered to for data collection and data entry (assumption four). Abundance estimates for coho salmon smolts based on smolt-adult mark-recapture are considered accurate even with conflicting results when comparing each estimation technique (i.e. fish released at 0000 hours were closest to the independent estimate in 2001 and fish released at 1200 hours were closest to the independent estimate in 2002).

Underwater Video

To study smolt behavior at fish approached the trap, an underwater video camera was placed at several locations near the trap opening. Sighting distance was approximately 2 m in the clearest conditions and video was not possible at night or with even slightly turbid conditions. There were several interesting observations of the behavior of smolts approaching the trap. Fish in small schools (less than 6 fish) exhibited positive rheotactic behavior when less than 1 m from the upstream orifice and made minor adjustments in their swimming pattern to avoid capture. Several larger schools of smolt (greater than 40 fish) actually swam into the trap entrance but darted out just before capture. It was not possible to discern between all fish species using underwater video; however, there was downstream migration not reflected by capture rates of the trap. This suggests that trap efficiency may be considerably lower during the day. Also, there were very few recaptures of fish released during the day that were recaptured during the day.

Assessment of Trap Efficiency

Both recreational and commercial fishermen relentlessly demand more accurate predictions of salmon escapements and available harvests. Stock-recruit models can be unreliable in predicting adult returns (Armstrong and Shelton 1988; Walters 1990). Smolt numbers can improve forecasting of adult returns; however, imprecise estimates of numbers of migrating smolts and variation in marine mortality further confound the problem of obtaining accurate predictions of returning adults. Sampling methods vary in success of accurately estimating smolt numbers (Rodgers et al. 1992; Newcomb and Coon 2001). Smolts can be difficult to monitor because of their crepuscular migration and often begin migrating in spring when high flows can be problematic for sampling (Hoar 1951; Mason 1975; Hartman et al. 1982; Ashe et al. 1995; Brege and Absolon 1996; Roper and Scarnecchia 1996). Regression techniques can be used to estimate the number of smolts migrating when the trap is not in operation (Roper and Scarnecchia 2000), but daily numbers of migrating smolts vary considerably, making it difficult to accurately predict smolt abundance during lapses in trapping.

This study took place in the high latitude of southcentral Alaska (60° N) where there is a short period of time between approximately 0100 and 0330 where it actually becomes dark. Light levels when fish encounter the trap were a major factor affecting the rate of capture in this study. The release stratum with highest average trap efficiencies (greater than 40%) coincided with the only time period when dense fog was overhead, which lasted for over 24 hours. There also was a timing effect where probability of recapture depended on the exact time of day a fish passed the trap and light levels at that time. Fish released at the upper site at 0000 hours had recapture rates slightly lower than fish released at the lower site at 0000 hours. Fish released at the upstream site took longer to reach the trap, possibly after light levels increased, whereas fish released close to the trap traveled past the trap more during the darkest part of the night. In the analysis, release distance did not significantly affect recapture rates, but release distance did affect on when fish passed the trap, which does affect trap efficiency.

Incomplete mixing from release distance was not considered a problem. Even the lower release site (400 m upstream of the trap) should have been an adequate distance to ensure adequate mixing with four sharp bends between the release site and the trap. Other studies have indicated that complete mixing can occur within a short distance (Raymond 1979). Release timing may have been responsible for inadequate mixing. Most fish released at night were recaptured by the following morning (mixing for less that 4 h), whereas, most fish released during the day did not resume downstream migration at least until night (mixing for at least 12 h). If fish released at night only migrate at night, then any daytime migration that occurs would be unaccounted for. Fish released during the day may actually be a more representative sample of the unmarked population because they mix with the unmarked population for a longer period of time.

Different age classes of migrating smolts may have biased estimates. Both smolt-adult mark-recapture and trap efficiency-based estimates were estimated as the total number of smolts leaving Deep Creek each year. Most fish reared in Deep Creek for two year before smolting, but at least 10% of the smolt migration was composed of age 1.0 fish. With increased size and swimming ability, age 2.0 smolts may have higher a survival rate than age 1.0 smolts and could bias estimates. An abundance estimate of both age classes of smolts would be ideal; however, with the relatively low numbers of age 1.0 fish, it is difficult to produce unbiased abundance estimates of age 1.0 fish using either estimation technique.

Estimating salmon smolt abundance using trap efficiency as an index to scale trap catch is commonly used (Power 1985; Dempson and Stansbury 1991; Thedinga 1994; Roper and Scarnecchia 1999), but few studies have investigated and verified the accuracy of trap efficiency-based estimates. Bias is common in mark-recapture applications and is a overestimation is a significant problem for trap efficiency-based estimates of smolt abundance. Most studies that have compared smolt abundance estimates using trap efficiency-based methods to the actual numbers of migrating smolts were incredibly inaccurate, sometimes orders of magnitudes from the true value (Zafft 1992; Polos 1997), including nine times greater than actual abundance (Newcomb and Coon 2001). The only study found with relatively accurate trap efficiency-based estimates (only 4% overestimation) when compared to actual abundance was with sockeye salmon *O. nerka* smolts using incline plane traps (Carlson et al. 1998). Success of trap efficiency-based estimates may depend on many factors including fish species, marking technique, location and stream characteristics, and numbers of migrants. Different species have different rearing strategies, migratory behavior, mortality rates, and handling-induced behavior alteration. Sockeye salmon juveniles spend most of their freshwater residence rearing in lakes before smolting and can have extremely large migrations, whereas coho salmon have a completely different life history. The life history of sockeye salmon smolts, including a large migration (approximately 200,000) leaving a lake system, and use of incline plane traps may have been beneficial to success in Akalura Creek for Carlson et al. (1998).

In conclusion, trap efficiency estimates were not significantly affected by release distance upstream of the trap but were significantly affected by time of day of release and turbidity. Light level and sighting distance can significantly affect capture rates as shown by release timing and turbidity interactions and should be accounted for when using this estimation technique. Release distance can affect the time of day when a fish passes the trap, which can affect estimated trap efficiency, and should not be overlooked. Using trap efficiency estimates and trap catch to estimate smolt abundance has utility to determine general trends and ranges of abundance and may (at times) yield estimates close to the actual numbers of migrating smolts. However, overestimation is common and relatively unbiased estimates can be extremely difficult to attain. Stream conditions can significantly affect the ability to meet the underlying assumptions and violations of assumptions are difficult to test, which can greatly affect the accuracy of the estimate. Significant variation in trap efficiency estimates can occur from many factors as witnessed in this study and variation is difficult to account for or predict. Contemporary methods of stock assessment require precise estimates of abundance. Robson and Regier (1964) suggest using $\alpha = 0.05$ with a relative error of 10% for fisheries research. Achieving these levels of precision may be difficult, especially in small systems with few migrants, and testing the accuracy of smolt abundance estimates may be more difficult. Even precise estimates of abundance may not be accurate. More research needs to be done investigating the reasons for such high variation in trap efficiency estimates and the relative accuracy of smolt abundance estimates based on trap efficiency. Before basing management decisions on smolt abundance estimates from trap efficiency-based methods, the underlying assumptions should be fully assessed.

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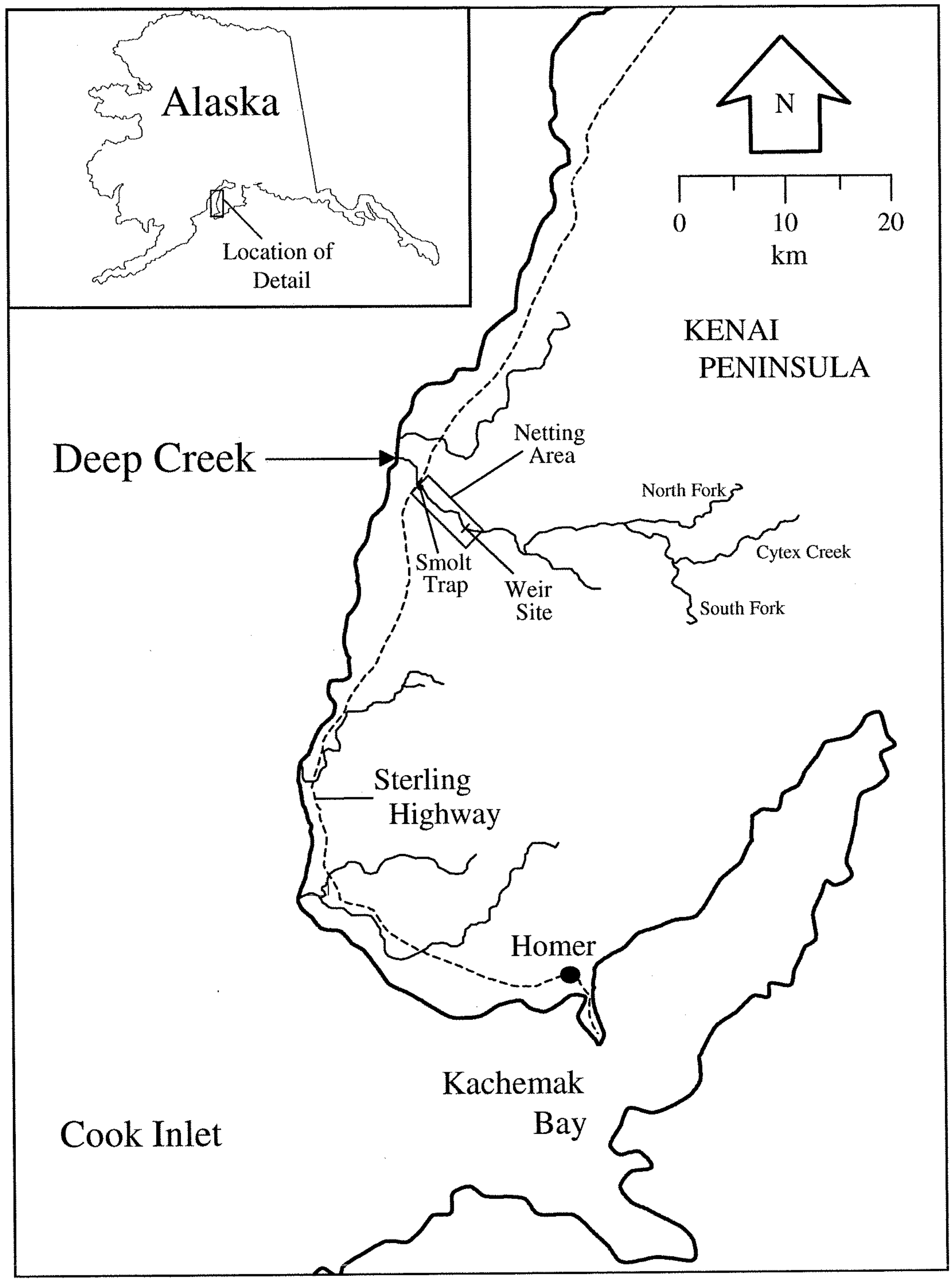

Figure 1.—Study area map.

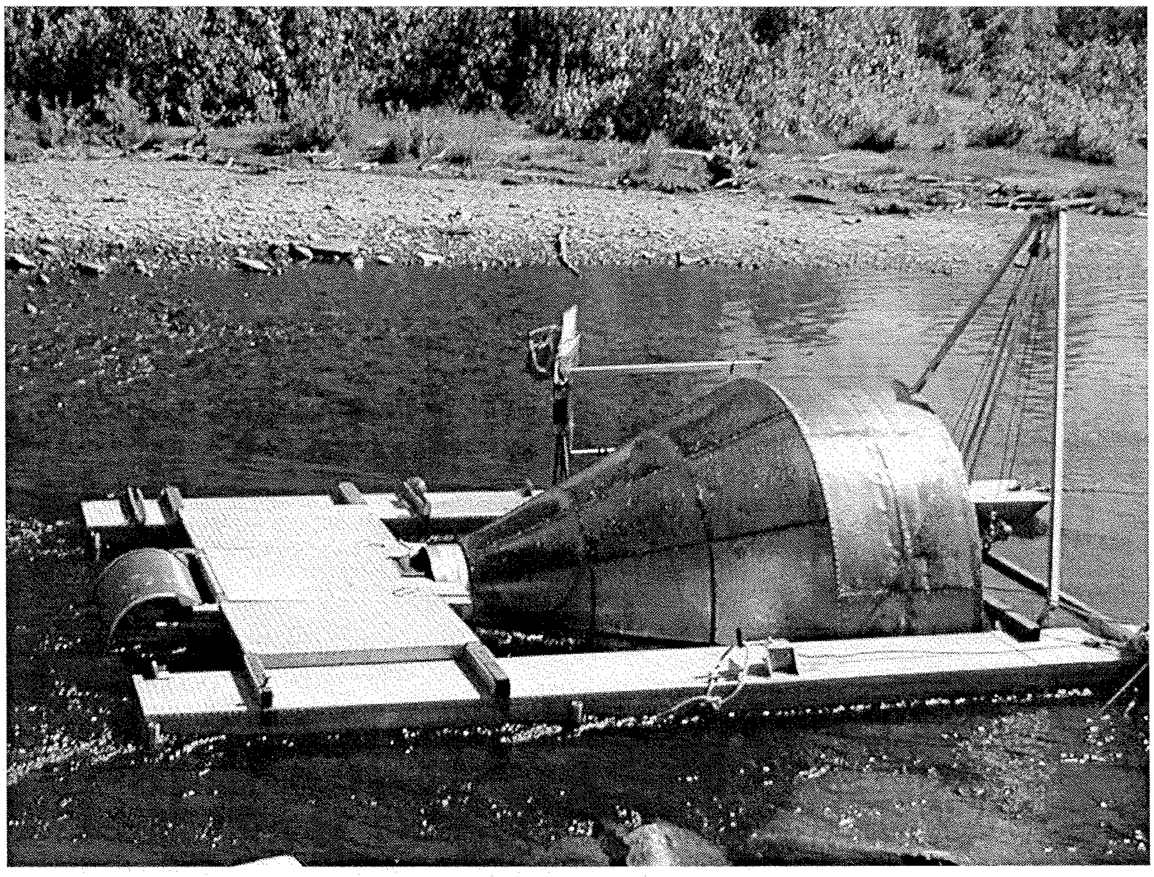

Figure 2.—The rotary screw trap on Deep Creek, June 2002.

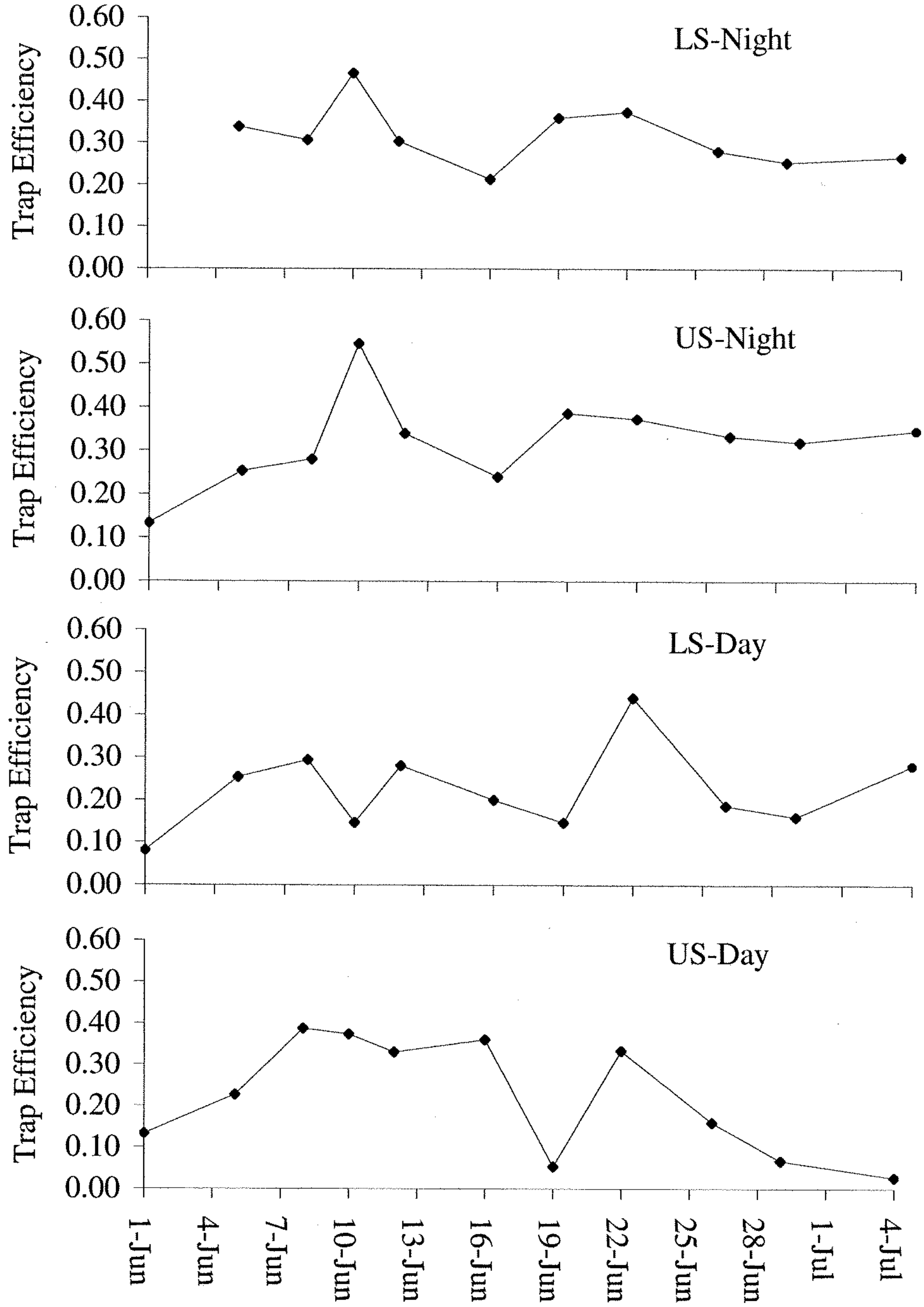

Figure 3.—Trap efficiency for each release location and time of day of release in 2002. LS-Night represent coho salmon smolts released at the lower site at 0000 hours, US-Night represent fish released at the upper site at 0000 hours, LS-Day and US-Day represent fish released at 1200 hours at each location.

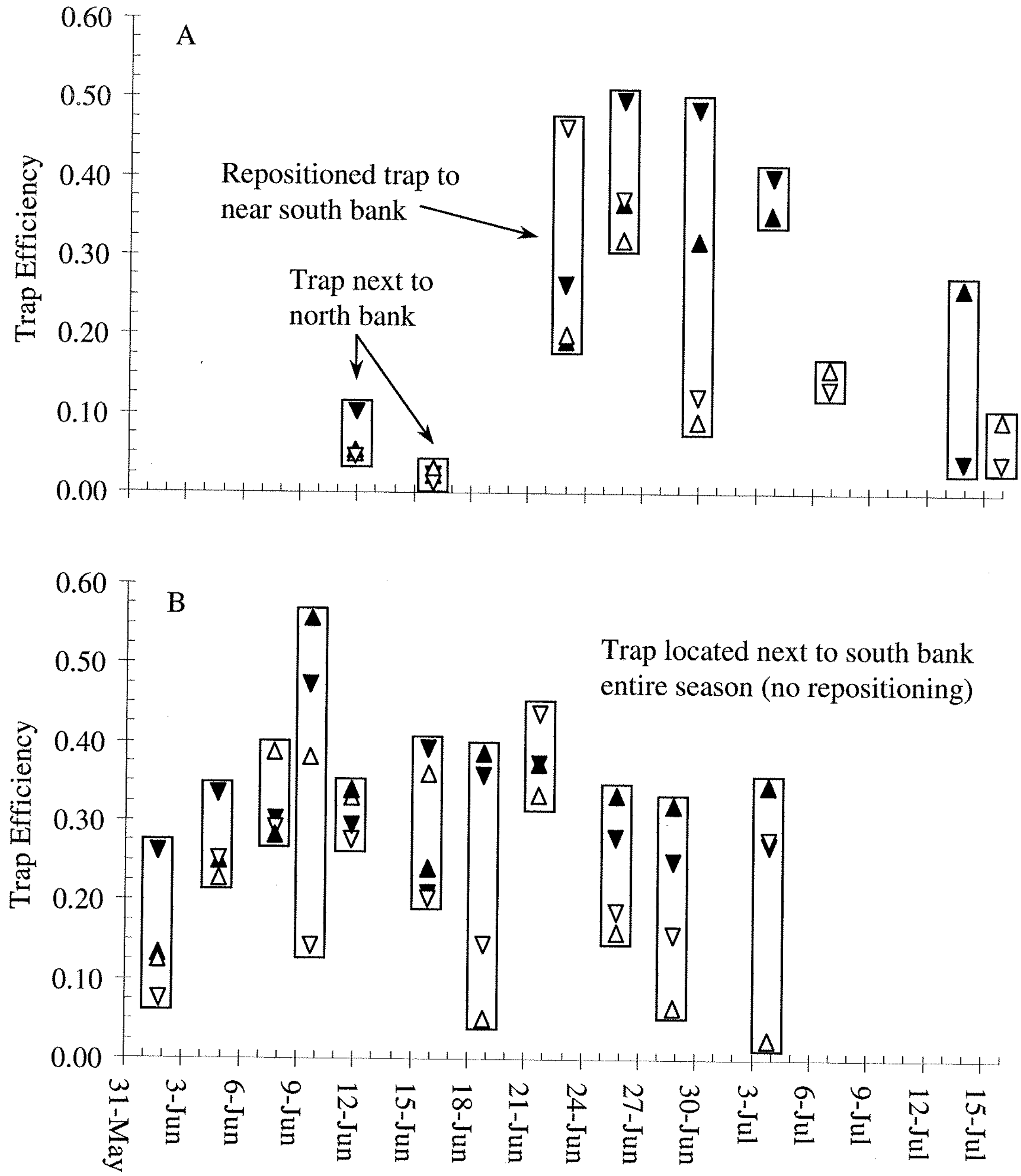

Figure 4.—Graph depicting the variability of trap efficiency in 2001 (A) and 2002 (B). Each vertical rectangular box denotes one release stratum. LS-Night (▼) represents coho salmon smolt released at the lower site (400 m upstream of trap) at 0000 hours, US-Night (▲) represents fish released at the upper site (1500 m upstream) at 0000 hours, LS-Day (▽) and US-Day (△) represent fish released at 1200 hours, 400 m and 1500 m upstream of the trap.

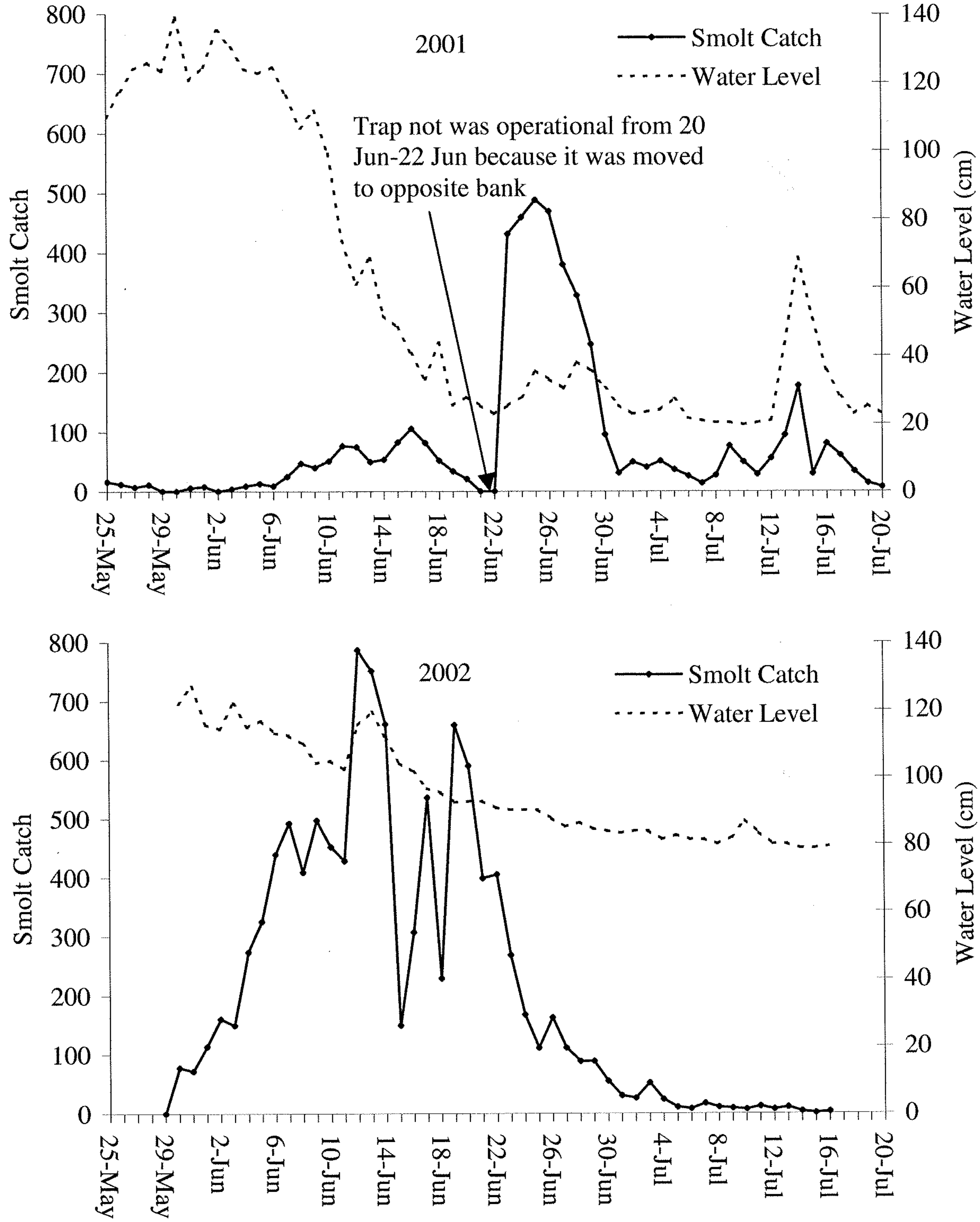

Figure 5.—Daily coho salmon smolt catch and water levels (cm) in 2001 and 2002.

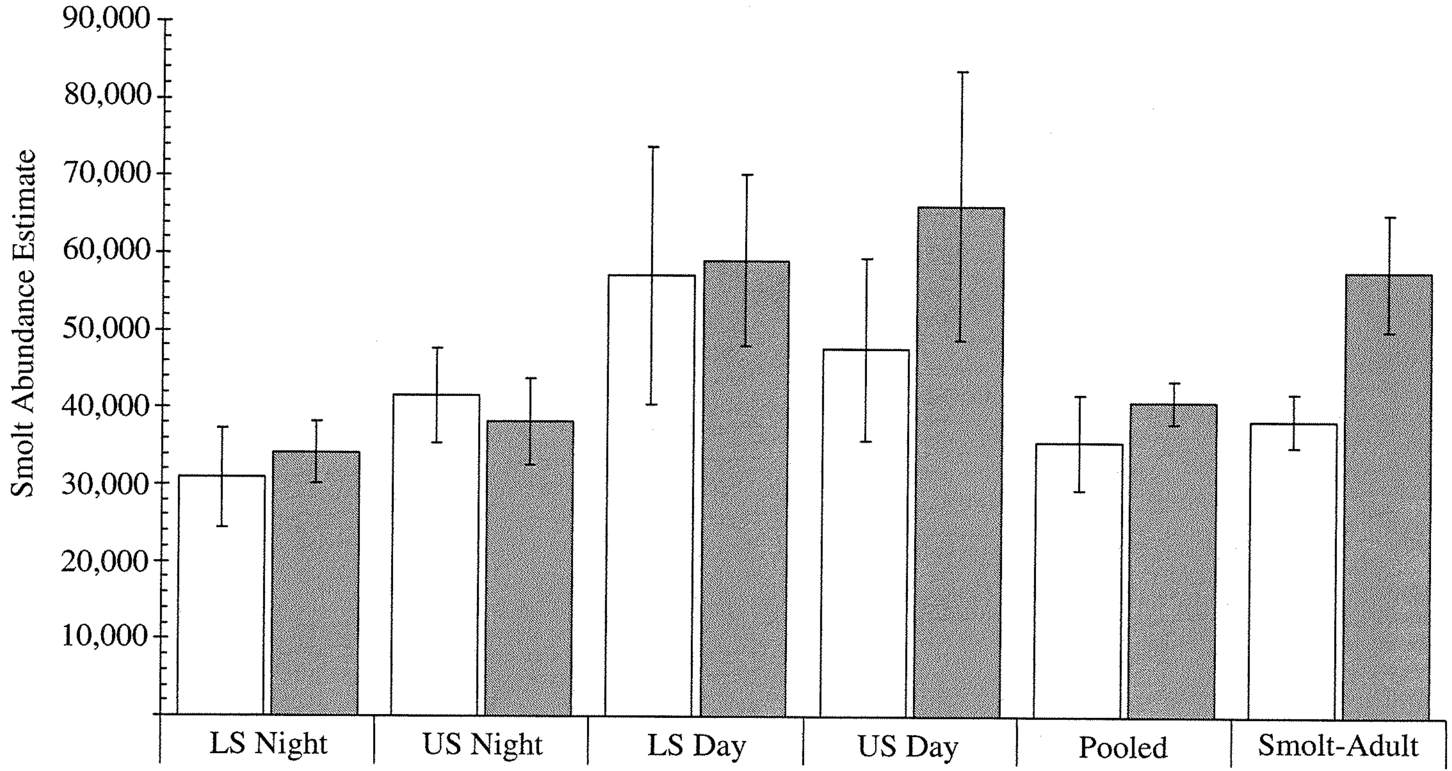

Figure 6.—Coho salmon smolt abundance estimates and 95% CIs in 2001 □ and 2002 ▩. LS Night represents coho salmon smolt released at 0000 hours at the lower site (400 m upstream). US Night represents fish released at 0000 hours at the upper site, (1500 m upstream), LS Day and US Day represent fish released at 1200 hours, 400 m and 1500 m upstream of the trap. Pooled represents all fish released in each strata throughout each year and Smolt-Adult represents abundance estimates based on smolt-adult mark-recapture.

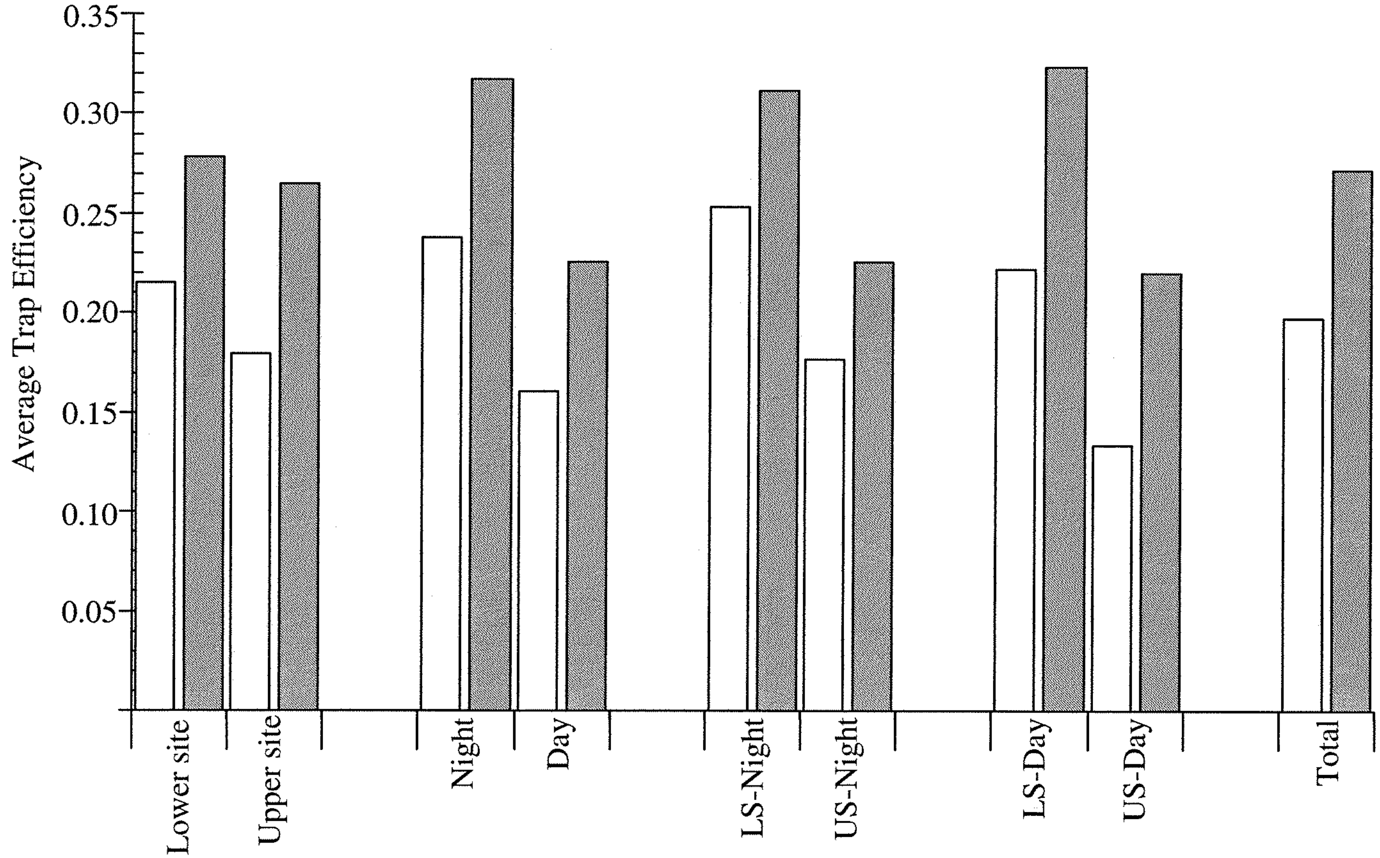

Figure 7.—Comparison of average trap efficiency for each treatment in 2001 □ and 2002 ▩. Each vertical bar represents all coho salmon smolt released for each release location and time of day in each year. Lower site represents all fish released 400 m upstream of trap, Upper site represents all fish released 1500 m upstream of the trap. Night represents all fish released at 0000 hours. Day represents all fish released at 1200 hours. LS-Day, US-Night, LS-Day and US-Day represent all fish released at each location and time of day. Total releases represent all fish released and recaptured each year.

Table 1.—Estimated trap efficiency for each treament group released in 2002.

Release Date	Time of day of release	Release Distance		Number Released	Number Recaptured	Trap Efficiency	Fin[a] Clip
12-Jun-2001	0000 hours	400 m		75	8	0.11	UC
	0000 hours	1500 m		76	4	0.05	LC
	1200 hours	400 m		75	1	0.01	LP
	1200 hours	1500 m		73	4	0.05	RP
			Total	299	17	0.06	
16-Jun-2001	0000 hours	400 m		74	1	0.01	LP
	0000 hours	1500 m		74	1	0.01	RP
	1200 hours	400 m		74	2	0.03	LC
	1200 hours	1500 m		74	0	0.00	UC
			Total	296	4	0.01	
23-Jun-2001	0000 hours	400 m		76	21	0.28	RP
	0000 hours	1500 m		74	15	0.20	LP
	1200 hours	400 m		74	36	0.49	UC
	1200 hours	1500 m		82	17	0.21	LC
			Total	306	89	0.29	
26-Jun-2001	0000 hours	400 m		75	39	0.52	LC
	0000 hours	1500 m		77	30	0.39	DC
	1200 hours	400 m		76	29	0.38	RP
	1200 hours	1500 m		75	25	0.33	LP
			Total	303	123	0.41	
30-Jun-2001	0000 hours	400 m		55	28	0.51	UC
	0000 hours	1500 m		55	18	0.33	LC
	1200 hours	400 m		63	8	0.13	LP
	1200 hours	1500 m		55	5	0.09	RP
			Total	228	59	0.26	
4-Jul-2001	0000 hours	400 m		55	23	0.42	RP
	0000 hours	1500 m		55	20	0.36	LP
			Total	110	43	0.39	
7-Jul-2001	1200 hours	400 m		50	7	0.14	LC
	1200 hours	1500 m		50	8	0.16	UC
			Total	100	15	0.15	

-Continued-

Table 1.—Continued.

Release Date	Time and Distance			Number Released	Number Recaptured	Trap Efficiency	Fin[a] Clip
14-Jul-2001	0000 hours	400 m		75	3	0.04	LP
	0000 hours	1500 m		75	20	0.27	RP
			Total	150	23	0.15	
16-Jul-2001	1200 hours	400 m		75	3	0.04	UC
	1200 hours	1500 m		75	7	0.09	LC
			Total	150	10	0.07	

a. Partial fin clip type DC=Dorsal Caudal, VC=Ventral Caudal
LP=Left Pelvic, RP=Right Pelvic

Table 2.—Estimated trap efficiency for each treatment group released in 2002.

Release Date	Time of day of release	Release Distance	Number Released	Number Recaptured	Trap Efficiency	Fin Clip [a]	NTU[b]
2-Jun-2002	0000 hours	400 m	75	20	0.27	UC	1
	0000 hours	1500 m	75	10	0.13	LC	1
	1200 hours	400 m	75	6	0.08	LP	1
	1200 hours	1500 m	75	10	0.13	RP	1
			Total 300	46	0.15		
5-Jun-2002	0000 hours	400 m	74	25	0.34	LP	2
	0000 hours	1500 m	75	19	0.25	RP	2
	1200 hours	400 m	75	19	0.25	LC	2
	1200 hours	1500 m	75	17	0.23	UC	2
			Total 299	80	0.27		
8-Jun-2002	0000 hours	400 m	75	23	0.31	RP	2
	0000 hours	1500 m	75	21	0.28	LP	2
	1200 hours	400 m	75	22	0.29	UC	2
	1200 hours	1500 m	75	29	0.39	LC	2
			Total 300	95	0.32		
10-Jun-2002	0000 hours	400 m	75	35	0.47	LC	3
	0000 hours	1500 m	75	41	0.55	DC	3
	1200 hours	400 m	75	11	0.15	RP	3
	1200 hours	1500 m	75	28	0.37	LP	3
			Total 300	115	0.38		
12-Jun-2002	0000 hours	400 m	99	30	0.30	UC	1
	0000 hours	1500 m	100	34	0.34	LC	1
	1200 hours	400 m	100	28	0.28	LP	1
	1200 hours	1500 m	100	33	0.33	RP	1
			Total 399	125	0.31		
16-Jun-2002	0000 hours	400 m	75	16	0.21	RP	3
	0000 hours	1500 m	75	18	0.24	LP	3
	1200 hours	400 m	75	15	0.20	LC	3
	1200 hours	1500 m	75	27	0.36	UC	3
			Total 300	76	0.25		

-Continued-

Table 2.— Continued.

Release Date	Release Time of day	Release Distance	Number Released	Number Recaptured	Trap Efficiency	Fin Clip[a]	NTU[b]
19-Jun-2002	0000 hours	400 m	75	27	0.36	LP	3
	0000 hours	1500 m	75	29	0.39	RP	3
	1200 hours	400 m	75	11	0.15	UC	3
	1200 hours	1500 m	75	4	0.05	LC	3
			Total 300	71	0.24		
22-Jun-2002	0000 hours	400 m	75	28	0.37	RP	3
	0000 hours	1500 m	75	28	0.37	LP	3
	1200 hours	400 m	75	33	0.44	LC	3
	1200 hours	1500 m	75	25	0.33	UC	3
			Total 300	114	0.38		
26-Jun-2002	0000 hours	400 m	75	21	0.28	UC	3
	0000 hours	1500 m	75	25	0.33	RP	3
	1200 hours	400 m	75	14	0.19	LP	3
	1200 hours	1500 m	75	12	0.16	LC	3
			Total 300	72	0.24		
29-Jun-2002	0000 hours	400 m	75	19	0.25	LC	3
	0000 hours	1500 m	75	24	0.32	UC	3
	1200 hours	400 m	75	12	0.16	RP	3
	1200 hours	1500 m	74	5	0.07	LP	3
			Total 299	60	0.20		
4-Jul-2002	0000 hours	400 m	75	20	0.27	UC	3
	0000 hours	1500 m	75	26	0.35	LC	3
	1200 hours	400 m	75	21	0.28	LP	3
	1200 hours	1500 m	75	2	0.03	RP	3
			Total 300	69	0.23		

a. Partial fin clip type — DC=Dorsal Caudal, VC=Ventral Caudal LP=Left Pelvic, RP=Right Pelvic,

b. NTU (Nephelometric Turbidity Unit) — 1=12 to 18 NTU, 2=6<NTU<12, 3=NTU<6

Table 3.—Total number of coho salmon smolts released, recaptured, and estimated trap efficiency for each treatment in 2001. LS-Total represents all fish released 400 m upstream of the trap, US Total represents all fish released 1500 m upstream, Day Total represents all fish released at 1200 hours. Night total represents all fish released at 0000 hours. Total releases represent all fish released, recaptured, and estimated trap efficiency.

Release Location and Time of Day of Release	Number Released	Number Recaptured	Trap Efficiency
LS Total	972	209	0.22
US Total	970	174	0.18
Night Total	971	231	0.24
Day Total	971	156	0.16
LS-Night Total	485	123	0.25
LS-Day Total	487	86	0.18
US-Night Total	486	108	0.22
US-Day Total	494	66	0.13
Total Releases	1,942	383	0.20

Table 4.—Total number of coho salmon smolts released, recaptured, and estimated trap efficiency for each treatment in 2002. LS-Total represents all fish released 400 m upstream of the trap, US Total represents all fish released 1500 m upstream, Day Total represents all fish released at 1200 hours. Night total represents all fish released at 0000 hours. Total releases represent all fish released, recaptured, and estimated trap efficiency.

Release Location and Time of Day of Release	Number Released	Number Recaptured	Trap Efficiency
LS Total	1,698	473	0.28
US Total	1,699	450	0.26
Night Total	1,698	539	0.32
Day Total	1,699	384	0.23
LS-Night Total	848	264	0.31
LS-Day Total	850	192	0.23
US-Night Total	850	275	0.32
US-Day Total	849	187	0.22
Total Releases	3,397	923	0.27

Appendix A

Daily and cumulative unmarked catch and number of adipose fin clipped coho salmon smolt released in 2001 and 2002.

Table A-1.—Daily unmarked catch, cumulative unmarked catch, and number of adipose fin clipped and coded-wire tagged coho salmon smolt released in 2001.

Release Number	Date	Daily Unmarked Catch	Cumulative Unmarked Catch	Number Adipose Fin Clipped
	25-May-2001	16	16	8
	26-May-2001	12	28	7
	27-May-2001	7	35	10
	28-May-2001	11	46	11
	29-May-2001	0	46	0
	30-May-2001	0	46	0
	31-May-2001	6	52	6
	1-Jun-2001	8	60	8
	2-Jun-2001	0	60	0
	3-Jun-2001	4	64	4
	4-Jun-2001	9	73	9
	5-Jun-2001	13	86	13
	6-Jun-2001	9	95	9
	7-Jun-2001	25	120	25
	8-Jun-2001	47	167	46
	9-Jun-2001	40	207	0
	10-Jun-2001	51	258	9
	11-Jun-2001	77	335	0
1	12-Jun-2001	75	410	0
	13-Jun-2001	50	460	0
	14-Jun-2001	54	514	0
	15-Jun-2001	83	597	0
2	16-Jun-2001	106	703	0
	17-Jun-2001	82	785	0
	18-Jun-2001	52	837	0
	19-Jun-2001	34	871	0
	20-Jun-2001	21	892	0
	21-Jun-2001	0	892	0
	22-Jun-2001	0	892	0
3	23-Jun-2001	432	1,324	126
	24-Jun-2001	460	1,784	454

Table A-1.—Continued.

Release Number	Date	Daily Unmarked Catch	Cumulative Unmarked Catch	Number Adipose Fin Clipped
	25-Jun-2001	489	2,273	0
4	26-Jun-2001	470	2,743	651
	27-Jun-2001	381	3,124	214
	28-Jun-2001	329	1,784	411
	29-Jun-2001	247	3,700	0
5	30-Jun-2001	96	3,796	14
	1-Jul-2001	31	3,827	0
	2-Jul-2001	50	3,877	0
	3-Jul-2001	41	3,918	0
6	4-Jul-2001	51	3,969	0
	5-Jul-2001	37	4,006	0
	6-Jul-2001	26	4,032	0
7	7-Jul-2001	14	4,046	0
	8-Jul-2001	27	4,073	0
	9-Jul-2001	77	4,150	50
	10-Jul-2001	50	4,200	79
	11-Jul-2001	29	4,229	29
	12-Jul-2001	56	4,285	56
	13-Jul-2001	95	4,380	71
8	14-Jul-2001	178	4,558	28
	15-Jul-2001	30	4,588	0
9	16-Jul-2001	81	4,669	81
	17-Jul-2001	61	4,730	61
	18-Jul-2001	34	4,764	27
	19-Jul-2001	14	4,778	14
	20-Jul-2001	7	4,785	7
Total	55 Days	4,785	4,785	2,538

Table A-2.—Daily unmarked catch, cumulative unmarked catch, and number of adipose fin clipped and coded-wire tagged coho salmon smolt released in 2002.

Release Number	Date	Daily Unmarked Catch	Cumulative Unmarked Catch	Number Adipose Fin Clipped
	30-May-2002	78	78	74
	31-May-2002	72	150	0
	1-Jun-2002	114	264	0
1	2-Jun-2002	161	425	45
	3-Jun-2002	150	575	104
	4-Jun-2002	274	849	274
2	5-Jun-2002	326	1,175	294
	6-Jun-2002	439	1,614	435
	7-Jun-2002	492	2,106	190
3	8-Jun-2002	409	2,515	409
	9-Jun-2002	497	3,012	197
4	10-Jun-2002	452	3,464	451
	11-Jun-2002	428	3,892	425
5	12-Jun-2002	787	4,679	383
	13-Jun-2002	752	5,431	748
	14-Jun-2002	661	6,092	655
	15-Jun-2002	150	6,242	0
6	16-Jun-2002	308	6,550	156
	17-Jun-2002	536	7,086	530
	18-Jun-2002	230	7,316	208
7	19-Jun-2002	660	7,976	352
	20-Jun-2002	590	8,566	584
	21-Jun-2002	399	8,965	247
8	22-Jun-2002	405	9,370	252
	23-Jun-2002	269	9,639	269
	24-Jun-2002	168	9,807	0
	25-Jun-2002	112	9,919	0
9	26-Jun-2002	163	10,082	0
	27-Jun-2002	112	10,194	18
	28-Jun-2002	89	10,283	11
10	29-Jun-2002	89	10,372	0
	30-Jun-2002	55	10,427	0
	1-Jul-2002	30	10,457	0
	2-Jul-2002	26	10,535	0
	3-Jul-2002	52	10,535	0

Table A-2.—Continued.

Release Number	Date	Daily Unmarked Catch	Cumulative Unmarked Catch	Number Adipose Fin Clipped
11	4-Jul-2002	24	10,559	0
	5-Jul-2002	11	10,570	11
	6-Jul-2002	8	10,578	8
	7-Jul-2002	17	10,595	16
	8-Jul-2002	11	10,606	11
	9-Jul-2002	9	10,615	9
	10-Jul-2002	7	10,622	7
	11-Jul-2002	12	10,634	11
	12-Jul-2002	7	10,641	7
	13-Jul-2002	11	10,652	11
	14-Jul-2002	4	10,656	4
	15-Jul-2002	1	10,657	1
	16-Jul-2002	3	10,660	3
Total	48 Days	10,660	10,660	7,410

Appendix B

Estimated trap efficiency, abundance estimates, and statistics for each treatment group released in 2001.

Table B-1.—Trap efficiencies and population estimates from smolt released at 0000 hrs, 400 m above smolt trap in 2001.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
25-May-01	16								
26-May-01	12								
27-May-01	7								
28-May-01	11								
29-May-01	0								
30-May-01	0								
31-May-01	6								
1-Jun-01	8								
2-Jun-01	0								
3-Jun-01	4								
4-Jun-01	9								
5-Jun-01	13								
6-Jun-01	9								
7-Jun-01	25								
8-Jun-01	47								
9-Jun-01	40								
10-Jun-01	51								
11-Jun-01	77								
12-Jun-01	75	75	8						
13-Jun-01	50								
14-Jun-01	54								
15-Jun-01	83								
16-Jun-01	106	74	1	0.06	14,768	14,768	5,837,695	19,503	10,032

Pooled releases and recaptures to estimate trap efficiency and population estimates from 12 June and 16 June because there were less than 7 recaptures from 16 June release. The trap was moved to the south bank on 21 June to increase efficiency. It was operational on 23 June and was not moved for the remainder of the season.

Table B-1.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
	(C_j)	(M_j)	(R_j)	(E_j)	($\hat{N}_j$)				
17-Jun-01	82								
18-Jun-01	52								
19-Jun-01	34								
20-Jun-01	21								
21-Jun-01	0								
22-Jun-01	0								
23-Jun-01	432	76	21	0.28	6,699	21,466	1,289,354	8,924	4,473
24-Jun-01	460								
25-Jun-01	489								
26-Jun-01	470	75	39	0.52	2,025	23,491	44,575	2,439	1,611
27-Jun-01	381								
28-Jun-01	329								
29-Jun-01	247								
30-Jun-01	96	55	28	0.51	340	23,831	1,512	416	264
1-Jul-01	31								
2-Jul-01	50								
3-Jul-01	41								
4-Jul-01	51	55	23	0.42	1,408	25,240	41,557	1,808	1,009
5-Jul-01	37								
6-Jul-01	26								
7-Jul-01	14								
8-Jul-01	27								
9-Jul-01	77								
10-Jul-01	50								
11-Jul-01	29								
12-Jul-01	56								

Table B-1.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
	(C_j)	(M_j)	(R_j)	(E_j)	($\hat{N}_j$)				
13-Jul-01	95								
14-Jul-01	178	75	3	0.04	5,675	30,915	3,493,325	9,338	2,012
15-Jul-01	30								
16-Jul-01	81								
17-Jul-01	61								
18-Jul-01	34								
19-Jul-01	14								
20-Jul-01	7								
Total	4,651	485	123	0.25	30,915		10,708,018	37,328	24,501

Table B-2.—Trap efficiencies and population estimates from smolt released at 0000 hrs, 1500 m above smolt trap in 2001.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
25-May-01	16								
26-May-01	12								
27-May-01	7								
28-May-01	11								
29-May-01	0								
30-May-01	0								
31-May-01	6								
1-Jun-01	8								
2-Jun-01	0								
3-Jun-01	4								
4-Jun-01	9								
5-Jun-01	13								
6-Jun-01	9								
7-Jun-01	25								
8-Jun-01	47								
9-Jun-01	40								
10-Jun-01	51								
11-Jun-01	77								
12-Jun-01	75	76	4						
13-Jun-01	50								
14-Jun-01	54								
15-Jun-01	83								
16-Jun-01	106	74	1	0.03	26,760	26,760	6,325,329	31,689	21,831
17-Jun-01	82								

Pooled releases and recaptures to estimate trap efficiency and population estimates from 12 June and 16 June because there were less than 7 recaptures from 16 June release. The trap was moved to the south bank on 21 June to increase efficiency. It was operational on 23 June and was not moved for the remainder of the season.

Table B-2.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate $(\hat{N}_j)$	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
18-Jun-01	52								
19-Jun-01	34								
20-Jun-01	21								
21-Jun-01	0								
22-Jun-01	0								
23-Jun-01	432	74	15	0.20	9,132	35,892	3,457,308	12,776	5,487
24-Jun-01	460								
25-Jun-01	489								
26-Jun-01	470	77	30	0.39	2,703	38,594	128,539	3,405	2,000
27-Jun-01	381								
28-Jun-01	329								
29-Jun-01	247								
30-Jun-01	96	55	18	0.33	529	39,123	7,740	701	356
1-Jul-01	31								
2-Jul-01	50								
3-Jul-01	41								
4-Jul-01	51	55	20	0.36	1,620	40,743	18,956	1,890	1,350
5-Jul-01	37								
6-Jul-01	26								
7-Jul-01	14								
8-Jul-01	27								
9-Jul-01	77								
10-Jul-01	50								
11-Jul-01	29								

Table B-2.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
	(C_j)	(M_j)	(R_j)	(E_j)	$(\hat{N}_j)$				
12-Jul-01	56								
13-Jul-01	95								
14-Jul-01	178	75	20	0.27	851	41,594	20,334	1,131	572
15-Jul-01	30								
16-Jul-01	81								
17-Jul-01	61								
18-Jul-01	34								
19-Jul-01	14								
20-Jul-01	7								
Total	4,733	486	108	0.22	41,594		9,958,205	47,779	35,409

Table B-3.—Trap efficiencies and population estimates from smolt released at 1200 hrs, 400 m above smolt trap in 2001.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate $(\hat{N}_j)$	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
25-May-01	16								
26-May-01	12								
27-May-01	7								
28-May-01	11								
29-May-01	0								
30-May-01	0								
31-May-01	6								
1-Jun-01	8								
2-Jun-01	0								
3-Jun-01	4								
4-Jun-01	9								
5-Jun-01	13								
6-Jun-01	9								
7-Jun-01	25								
8-Jun-01	47								
9-Jun-01	40								
10-Jun-01	51								
11-Jun-01	77								
12-Jun-01	75	75	1						
13-Jun-01	50								
14-Jun-01	54								
15-Jun-01	83								
16-Jun-01	106	74	2	0.03	41,720	41,720	69,535,785	58,064	25,376
17-Jun-01	82								
18-Jun-01	52								
19-Jun-01	34								

Pooled releases and recaptures to estimate trap efficiency and population estimates from 12 June and 16 June because there were less than 7 recaptures from 16 June release. The trap was moved to the south bank on 21 June to increase efficiency. It was operational on 23 June and was not moved for the remainder of the season.

Table B-3.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
20-Jun-01	21								
21-Jun-01	0								
22-Jun-01	0								
23-Jun-01	432	74	36	0.49	2,917	44,637	107,589	3,560	2,274
24-Jun-01	460								
25-Jun-01	489								
26-Jun-01	470	76	29	0.38	2,760	47,396	139,999	3,493	2,026
27-Jun-01	381								
28-Jun-01	329								
29-Jun-01	247								
30-Jun-01	96	63	8	0.13	2,725	50,121	263,965	3,732	1,718
1-Jul-01	31								
2-Jul-01	50								
3-Jul-01	41								
4-Jul-01	51								
5-Jul-01	37								
6-Jul-01	26								
7-Jul-01	14	50	7	0.14	4,150	54,271	1,211,023	6,307	1,993
8-Jul-01	27								
9-Jul-01	77								
10-Jul-01	50								
11-Jul-01	29								
12-Jul-01	56								
13-Jul-01	95								
14-Jul-01	178								
15-Jul-01	30								

Table B-3.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
	(C_j)	(M_j)	(R_j)	(E_j)	($\hat{N}_j$)				
16-Jul-01	81	75	3	0.04	2,900	57,171	904,316	4,764	1,036
17-Jul-01	61								
18-Jul-01	34								
19-Jul-01	14								
20-Jul-01	7								
Total	4,711	487	86	0.18	57,171		72,162,678	73,821	40,521

Table B-4.—Trap efficiencies and population estimates from smolt released at 1200 hrs, 1500 m above smolt trap in 2001.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
25-May-01	16								
26-May-01	12								
27-May-01	7								
28-May-01	11								
29-May-01	0								
30-May-01	0								
31-May-01	6								
1-Jun-01	8								
2-Jun-01	0								
3-Jun-01	4								
4-Jun-01	9								
5-Jun-01	13								
6-Jun-01	9								
7-Jun-01	25								
8-Jun-01	47								
9-Jun-01	40								
10-Jun-01	51								
11-Jun-01	77								
12-Jun-01	75	73	4						
13-Jun-01	50								
14-Jun-01	54								
15-Jun-01	83								
16-Jun-01	106	74	0	0.03	27,930	27,930	31,100,357	38,860	17,000
17-Jun-01	82								
18-Jun-01	52								
19-Jun-01	34								

Pooled releases and recaptures to estimate trap efficiency and population estimates from 12 June and 16 June because there were less than 7 recaptures from 16 June release. The trap was moved to the south bank on 21 June to increase efficiency. It was operational on 23 June and was not moved for the remainder of the season.

Table B-4.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
20-Jun-01	21								
21-Jun-01	0								
22-Jun-01	0								
23-Jun-01	432	82	17	0.21	8,928	36,858	2,976,687	12,310	5,547
24-Jun-01	460								
25-Jun-01	489								
26-Jun-01	470	75	25	0.33	3,159	40,017	225,583	4,090	2,228
27-Jun-01	381								
28-Jun-01	329								
29-Jun-01	247								
30-Jun-01	96	55	5	0.09	2,750	42,767	683,278	4,370	1,130
1-Jul-01	31								
2-Jul-01	50								
3-Jul-01	41								
4-Jul-01	51								
5-Jul-01	37								
6-Jul-01	26								
7-Jul-01	14	50	8	0.16	3,631	46,399	839,643	5,427	1,835
8-Jul-01	27								
9-Jul-01	77								
10-Jul-01	50								
11-Jul-01	29								
12-Jul-01	56								
13-Jul-01	95								
14-Jul-01	178								
15-Jul-01	30								

Table B-4.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
	(C_j)	(M_j)	(R_j)	(E_j)	$(\hat{N}_j)$				
16-Jul-01	81	75	7	0.09	1,243	47,641	337,535	2,382	104
17-Jul-01	61								
18-Jul-01	34								
19-Jul-01	14								
20-Jul-01	7								
Total	4,643	484	66	0.14	47,641		36,163,083	59,428	35,855

Appendix C

Estimated trap efficiency, abundance estimates, and statistics for each treatment group released in 2002.

Table C-1.—Trap efficiencies and population estimates from smolt released at 0000 hrs, 400 m above smolt trap in 2002.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
30-May-02	78								
31-May-02	72								
01-Jun-02	114								
02-Jun-02	161	75	20	0.27	4,406	4,406	585,200	5,906	2,907
03-Jun-02	150								
04-Jun-02	274								
05-Jun-02	326	74	25	0.34	3,966	8,373	355,060	5,134	2,798
06-Jun-02	439								
07-Jun-02	492								
08-Jun-02	409	75	23	0.31	3,095	11,467	241,429	4,058	2,132
09-Jun-02	497								
10-Jun-02	452	75	35	0.47	2,604	14,071	90,967	3,195	2,012
11-Jun-02	428								
12-Jun-02	787	99	30	0.30	6,174	20,245	773,277	7,898	4,451
13-Jun-02	752								
14-Jun-02	661								
15-Jun-02	150								
16-Jun-02	308	75	16	0.21	6,684	26,929	1,734,356	9,266	4,103
17-Jun-02	536								
18-Jun-02	230								
19-Jun-02	660	75	27	0.36	3,872	30,802	305,973	4,956	2,788
20-Jun-02	590								
21-Jun-02	399								

Table C-1.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
22-Jun-02	405	75	28	0.37	1,457	32,259	39,814	1,848	1,066
23-Jun-02	269								
24-Jun-02	168								
25-Jun-02	112								
26-Jun-02	163	75	21	0.28	1,036	33,295	28,859	1,369	703
27-Jun-02	112								
28-Jun-02	89								
29-Jun-02	89	75	24	0.32	584	33,879	7,309	752	417
30-Jun-02	55								
01-Jul-02	30								
02-Jul-02	26								
03-Jul-02	52								
04-Jul-02	24	75	26	0.35	291	34,170	1,396	365	218
05-Jul-02	11								
06-Jul-02	8								
07-Jul-02	17								
08-Jul-02	11								
09-Jul-02	9								
10-Jul-02	7								
11-Jul-02	12								
12-Jul-02	7								
13-Jul-02	11								
14-Jul-02	4								
15-Jul-02	1								
16-Jul-02	3								
Totals	10,492	848	275	0.32	34,170		4,163,641	38,170	30,171

Table C-2.—Trap efficiencies and population estimates from smolt released at 0000 hrs, 1500 m above smolt trap in 2002.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
	(C_j)	(M_j)	(R_j)	(E_j)	$(\hat{N}_j)$				
30-May-02	78								
31-May-02	72								
01-Jun-02	114								
02-Jun-02	161	75	10	0.13	8,813	8,813	4,661,155	13,044	4,581
03-Jun-02	150								
04-Jun-02	274								
05-Jun-02	326	75	19	0.25	5,289	14,102	897,540	7,146	3,433
06-Jun-02	439								
07-Jun-02	492								
08-Jun-02	409	75	21	0.28	3,389	17,491	325,017	4,507	2,272
09-Jun-02	497								
10-Jun-02	452	75	41	0.55	2,223	19,714	48,633	2,655	1,790
11-Jun-02	428								
12-Jun-02	787	100	34	0.34	5,503	25,217	519,807	6,916	4,090
13-Jun-02	752								
14-Jun-02	661								
15-Jun-02	150								
16-Jun-02	308	75	18	0.24	5,942	31,158	1,205,530	8,094	3,790
17-Jun-02	536								
18-Jun-02	230								
19-Jun-02	660	75	29	0.39	3,605	34,764	238,602	4,563	2,648
20-Jun-02	590								
21-Jun-02	399								
22-Jun-02	405	75	28	0.37	1,457	36,221	39,814	1,848	1,066
23-Jun-02	269								
24-Jun-02	168								

Table C-2.—Continued.

Date	Unmarked Fish Captured	Marked Fish Released	Total Recaptures	Trap Efficiency	Population Estimate	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
	(C_j)	(M_j)	(R_j)	(E_j)	$(\hat{N}_j)$				
25-Jun-02	112								
26-Jun-02	163	75	25	0.33	870	37,091	16,055	1,118	622
27-Jun-02	112								
28-Jun-02	89								
29-Jun-02	89	75	19	0.25	738	37,829	16,003	986	490
30-Jun-02	55								
01-Jul-02	30								
02-Jul-02	26								
03-Jul-02	52								
04-Jul-02	24	75	20	0.27	379	38,208	3,560	496	262
05-Jul-02	11								
06-Jul-02	8								
07-Jul-02	17								
08-Jul-02	11								
09-Jul-02	9								
10-Jul-02	7								
11-Jul-02	12								
12-Jul-02	7								
13-Jul-02	11								
14-Jul-02	4								
15-Jul-02	1								
16-Jul-02	3								
Totals	10,492	850	264	0.31	38,208		7,971,715	43,742	32,674

Table C-3.—Trap efficiencies and population estimates from smolt released at 1200 hrs, 400 m above smolt trap in 2002.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
30-May-02	78								
31-May-02	72								
01-Jun-02	114								
02-Jun-02	161	75	6	0.08	14,688	14,688	18,390,708	23,093	6,282
03-Jun-02	150								
04-Jun-02	274								
05-Jun-02	326	75	19	0.25	5,289	19,977	897,540	7,146	3,433
06-Jun-02	439								
07-Jun-02	492								
08-Jun-02	409	75	22	0.29	3,235	23,212	279,400	4,271	2,199
09-Jun-02	497								
10-Jun-02	452	75	11	0.15	8,284	31,496	3,804,064	12,107	4,461
11-Jun-02	428								
12-Jun-02	787	100	28	0.28	6,682	38,178	994,415	8,637	4,728
13-Jun-02	752								
14-Jun-02	661								
15-Jun-02	150								
16-Jun-02	308	75	15	0.20	7,130	45,308	2,109,730	9,977	4,283
17-Jun-02	536								
18-Jun-02	230								
19-Jun-02	660	75	11	0.15	9,505	54,813	5,012,843	13,893	5,116
20-Jun-02	590								
21-Jun-02	399								
22-Jun-02	405	75	33	0.44	1,236	56,049	21,971	1,527	946
23-Jun-02	269								
24-Jun-02	168								

Table C-3.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
25-Jun-02	112								
26-Jun-02	163	75	14	0.19	1,554	57,603	103,429	2,184	923
27-Jun-02	112								
28-Jun-02	89								
29-Jun-02	89	75	12	0.16	1,169	58,772	66,579	1,674	663
30-Jun-02	55								
01-Jul-02	30								
02-Jul-02	26								
03-Jul-02	52								
04-Jul-02	24	75	21	0.28	361	59,132	3,008	468	253
05-Jul-02	11								
06-Jul-02	8								
07-Jul-02	17								
08-Jul-02	11								
09-Jul-02	9								
10-Jul-02	7								
11-Jul-02	12								
12-Jul-02	7								
13-Jul-02	11								
14-Jul-02	4								
15-Jul-02	1								
16-Jul-02	3								
Totals	10,492	850	192	0.23	59,132		31,683,688	70,165	48,100

Table C-4.—Trap efficiencies and population estimates from smolt released at 0000 hrs, 1500 m above smolt trap in 2002.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate $(\hat{N}_j)$	Cumulative Estimate	Variance	UCI $(\hat{N}_j)$	LCI $(\hat{N}_j)$
30-May-02	78								
31-May-02	72								
01-Jun-02	114								
02-Jun-02	161	75	10	0.13	8,813	8,813	4,661,155	13,044	4,581
03-Jun-02	150								
04-Jun-02	274								
05-Jun-02	326	75	17	0.23	5,912	14,724	1,270,374	8,121	3,703
06-Jun-02	439								
07-Jun-02	492								
08-Jun-02	409	75	29	0.39	2,454	17,179	109,516	3,103	1,806
09-Jun-02	497								
10-Jun-02	452	75	28	0.37	3,254	20,433	204,352	4,140	2,368
11-Jun-02	428								
12-Jun-02	787	100	33	0.33	5,670	26,103	575,469	7,157	4,183
13-Jun-02	752								
14-Jun-02	661								
15-Jun-02	150								
16-Jun-02	308	75	27	0.36	3,961	30,064	320,319	5,070	2,852
17-Jun-02	536								
18-Jun-02	230								
19-Jun-02	660	75	4	0.05	26,138	56,201	69,754,092	42,507	9,768
20-Jun-02	590								
21-Jun-02	399								
22-Jun-02	405	75	25	0.33	1,632	57,833	58,889	2,108	1,156
23-Jun-02	269								
24-Jun-02	168								

Table C-4.—Continued.

Date	Unmarked Fish Captured (C_j)	Marked Fish Released (M_j)	Total Recaptures (R_j)	Trap Efficiency (E_j)	Population Estimate ($\hat{N}_j$)	Cumulative Estimate	Variance	UCI ($\hat{N}_j$)	LCI ($\hat{N}_j$)
25-Jun-02	112								
26-Jun-02	163	75	12	0.16	1,813	59,646	163,711	2,606	1,019
27-Jun-02	112								
28-Jun-02	89								
29-Jun-02	89	75	5	0.07	2,805	62,451	722,338	4,471	1,139
30-Jun-02	55								
01-Jul-02	30								
02-Jul-02	26								
03-Jul-02	52								
04-Jul-02	24	75	2	0.03	3,788	66,238	1,556,214	6,233	1,342
05-Jul-02	11								
06-Jul-02	8								
07-Jul-02	17								
08-Jul-02	11								
09-Jul-02	9								
10-Jul-02	7								
11-Jul-02	12								
12-Jul-02	7								
13-Jul-02	11								
14-Jul-02	4								
15-Jul-02	1								
16-Jul-02	3								
Totals	10,492	850	192	0.23	66,238		79,396,429	83,703	48,774

Appendix D

Daily number of coho salmon adults sampled for adipose fin clips in 2002 and 2003.

Table D-1.—Daily unmarked and adipose fin clipped adult coho salmon sampled at Deep Creek weir and daily marked proportions in 2002.

Date	Number Marked	Number Unmarked	Daily Total	Cumulative Total	Daily Marked Proportion
1-Aug-02	0	2	2	2	0.00
2-Aug-02	0	13	13	15	0.00
3-Aug-02	1	2	3	18	0.33
4-Aug-02	2	28	30	48	0.07
5-Aug-02	1	22	23	71	0.04
6-Aug-02	11	67	78	149	0.14
7-Aug-02	4	53	57	206	0.07
8-Aug-02	11	97	108	314	0.10
9-Aug-02	6	66	72	386	0.08
10-Aug-02	3	45	48	434	0.06
11-Aug-02	17	152	169	603	0.10
12-Aug-02	17	224	241	844	0.07
13-Aug-02	22	162	184	1,028	0.12
14-Aug-02	12	91	103	1,131	0.12
15-Aug-02	16	89	105	1,236	0.15
16-Aug-02	8	85	93	1,329	0.09
17-Aug-02	7	66	73	1,402	0.10
18-Aug-02	7	59	66	1,468	0.11
19-Aug-02	8	71	79	1,547	0.10
20-Aug-02	18	388	406	1,953	0.04
21-Aug-02	29	413	442	2,395	0.07
22-Aug-02	21	383	404	2,799	0.05
23-Aug-02	26	375	401	3,200	0.06
24-Aug-02	6	133	139	3,339	0.04
25-Aug-02	7	82	89	3,428	0.08
26-Aug-02	1	51	52	3,480	0.02
27-Aug-02	2	39	41	3,521	0.05
28-Aug-02	9	121	130	3,651	0.07
29-Aug-02	4	62	66	3,717	0.06
30-Aug-02	14	273	287	4,004	0.05
31-Aug-02	38	718	756	4,760	0.05
1-Sep-02	6	158	164	4,924	0.04
2-Sep-02	3	240	243	5,167	0.01

Table D-1.—Continued

3-Sep-02	2	30	32	5,199	0.06
4-Sep-02	2	14	16	5,215	0.13
5-Sep-02	4	103	107	5,322	0.04
6-Sep-02	7	174	181	5,503	0.04
7-Sep-02	2	83	85	5,588	0.02
8-Sep-02	2	46	48	5,636	0.04
9-Sep-02	18	455	473	6,109	0.04
10-Sep-02	3	40	43	6,152	0.07
11-Sep-02	0	12	12	6,164	0.00
Total	377	5,787	6,164	6,164	0.06

Table D-2.—Daily marked and unmarked adult coho salmon sampled and daily marked proportions from beach seining in 2003.

Date	Number Marked	Number Unmarked	Daily Total	Cumulative Total	Daily Marked Proportion
5-Aug-03	2	15	17	17	0.12
7-Aug-03	11	74	85	102	0.13
12-Aug-03	20	121	141	243	0.14
14-Aug-03	31	259	290	533	0.11
19-Aug-03	30	229	259	792	0.12
20-Aug-03	23	115	138	930	0.17
26-Aug-03	14	107	121	1,051	0.12
27-Aug-03	8	44	52	1,103	0.15
2-Sep-03	25	180	205	1,308	0.12
4-Sep-03	26	151	177	1,485	0.15
Totals	190	1,295	1,485	1,485	0.15