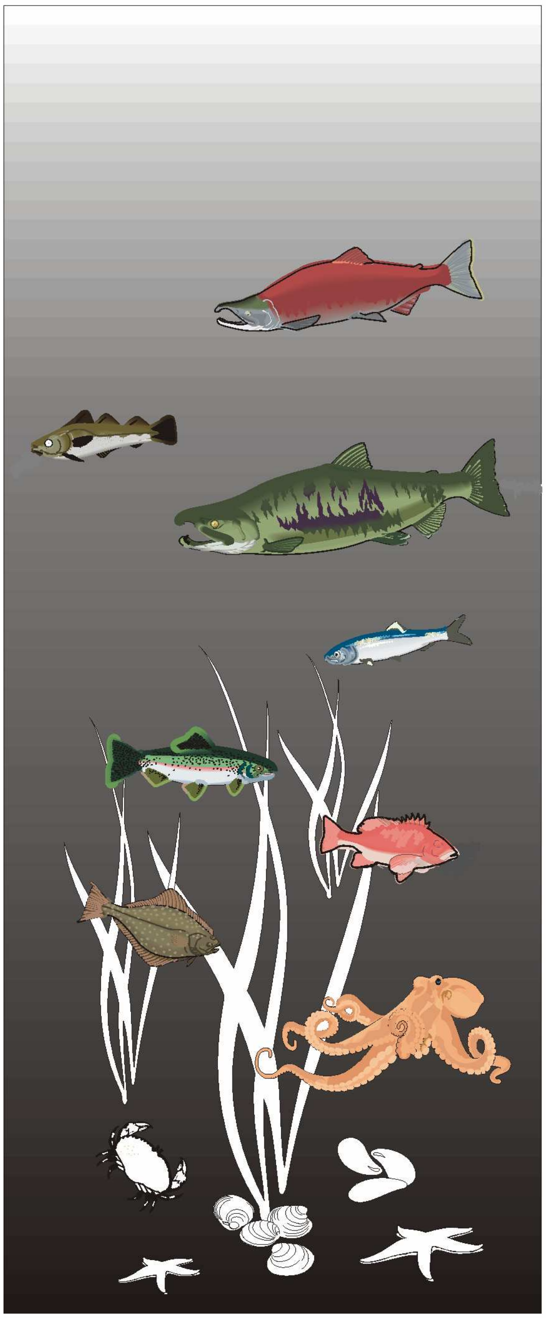
Northwest Fishery Resource Bulletin



Use of a Rotary Screwtrap to Monitor the Out-migration of Chinook Salmon Smolts from the Nooksack River: 1994-1998

By

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Northwest Indian Fisheries Commission

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Lummi Natural Resources Department

Project Report Series No. 10

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Project Report Series

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May 2000

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ABSTRACT

This report summarizes the first five years of operation of a rotary screwtrap in the lower mainstem of the Nooksack River. The screwtrap catches smolts out-migrating from the Nooksack River. The study began as a feasibility study in 1994 and, over the years, gradually expanded in operation and design. A primary objective of this study is to develop an annual index of relative abundance for the chinook salmon smolts in the out-migration. A long-range goal is to annually estimate the number of smolts produced by the two native chinook salmon stocks. This report presents summaries and analyses for the chinook salmon smolt out-migration data only.

Annual screwtrap effort (hours of sampling) ranged from 258.1 hours in 1994 to 476.5 hours in 1996. For the five years of data examined, all occurrences of weekly catch per unit effort (CPUE) values of about 20 or more chinook salmon smolts per hour could be attributed to releases of hatchery fish into the Nooksack River system above the trap. The out-migration of native chinook salmon smolts occurs at very low levels and does not produce prominent peaks in CPUE which can be directly associated with native fish. There does appear to be a constant low level of out-migration of chinook salmon smolts from at least early April through late July. Until there are methods that can better estimate the stock composition of the non-adclipped catch of chinook salmon smolts, we cannot determine the out-migration timing of the native stocks.

Capture-efficiency trials were conducted by releasing a known number of marked, hatchery-reared chinook salmon smolts upstream of the trap site and then enumerating the number of these marked smolts recaptured at the trap. Fourteen separate trials were conducted during the study years: six in 1995, five in 1996, one in 1997, and two in 1998. Several environmental parameters were measured and their correlation with capture efficiency examined. The environmental parameters examined were: secchi depth, river discharge, and river turbidity. The model which best explained the variability in capture efficiency was an inverse model with secchi depth. This model has the highest r^2 value (84.1%) and the lowest residual MSE.

A detailed examination of length data of chinook salmon smolts captured at the trap demonstrated the difficulty in using only fork length to determine whether a chinook salmon smolt is age-0 or age-1. During three of the study years (1994, 1995, and 1998), the length distributions of adclipped fish that were probably age-1 fish overlapped the distribution of the non-adclipped fish. We do not feel that the age composition of the catches can be reliably estimated using only lengths.

Four indices of relative abundance were calculated using catch and effort data from 1996, 1997, and 1998. These were the only years that the screwtrap was operated following a random sampling schedule and are the data most appropriate for developing an index. There was a significant and positive relationship between the number of chinook smolts migrating past the trap and CPUE. CPUE provides an index of the relative abundance of chinook salmon in the out-migration and can be used for comparisons within and between years. The best index of abundance based on CPUE was one which used the catch expanded for the capture efficiency of the trap estimated from secchi depth measured at the time of the set.

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Introduction

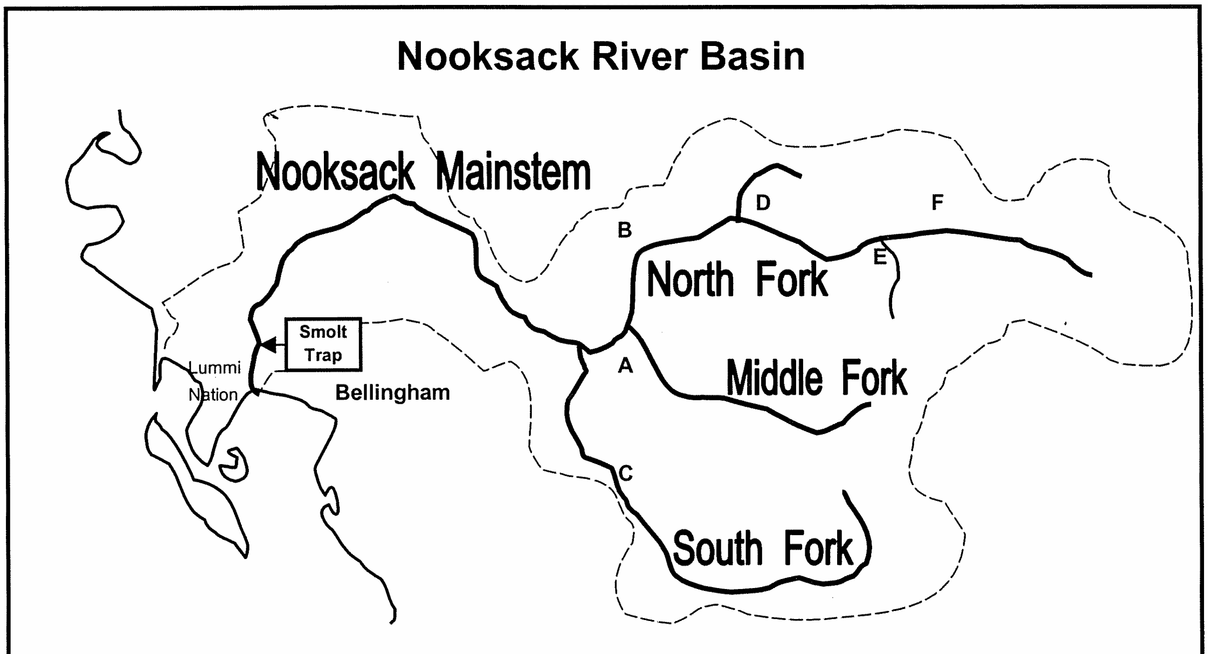
The Nooksack River basin covers about 2,139.33 km^2 of northwestern Washington (Williams et al. 1975) and extends into Canada. The Nooksack River system has three principal forks, the North Fork, Middle Fork, and South Fork (Figure 1). Each fork originates in the slopes of the Cascade Mountain Range. The South Fork enters the mainstem of the Nooksack River at about river km 59 and the Middle Fork at about river km 65. More than 500 km of the river are accessible to anadromous fish (Williams et al. 1975). The Nooksack River supports populations of all five species of Pacific salmon (*Oncorhynchus spp*.) plus anadromous populations of steelhead trout (*O. mykiss*), cutthroat trout (*Salmo clarki*), and Dolly Varden trout (*Salvelinus malma*).

The Lummi Natural Resources Department has a long-range goal of annually estimating the freshwater production of chinook (*O. tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), and pink (*O. gorbuscha*) salmon originating from the Nooksack River. Annual estimates of smolt production will provide an indicator of the health of the freshwater rearing habitat in the watershed relative to salmon production. Smolt production estimates will also be used to forecast future adult salmon returns to the river and to help determine appropriate harvest rates for the stocks. Sampling the smolt out-migration may provide insight into hatchery/wild stock interactions that impact weak populations limited by freshwater and estuary habitats.

Three distinct stocks of chinook salmon have been identified in the Nooksack River. They are differentiated by their genetic composition, time of spawning, and location of spawning (SASSI 1994). Two of the stocks are of native origin and are referred to as the North Fork Nooksack and South Fork Nooksack stocks. The third stock is a hatchery stock originally introduced from the Green River; this stock is considered a fall run stock and has a spawning distribution that partially overlaps that of the North Fork and South Fork stocks. Both the North Fork and South Fork native stocks are considered spring run stocks and both produce juveniles that out-migrate as age-0 and age-1 smolts, although most yearlings are thought to originate from the South Fork.

Annual smolt production by both native stocks is of particular interest since chinook salmon in Puget Sound have recently been listed as “threatened” by the National Marine Fisheries Service under the Endangered Species Act (Fed. Reg. 1999). Estimates of smolt production have been identified as one possible method of monitoring the abundance trends of listed stocks in order to determine whether biological delisting criteria have been met (NMFS 2000).

This reports summarizes the first five years of operation of a rotary screwtrap in the lower Nooksack River. The screwtrap catches smolts out-migrating from the Nooksack River. The study began as a feasibility study in 1994 and, over the years, gradually expanded in operation and design. Currently, a primary objective of this study is to develop an annual index of relative abundance for out-migrating chinook salmon smolts. A long-range objective is to annually estimate the number of smolts produced by the two native chinook salmon stocks. This report presents summaries and analyses for the chinook salmon smolt out-migration data only. A summary of the catches and associated biological data for the other salmon species will be presented in another report currently being prepared.



Release Site	Release Facility	Kilometers to Trap
A	McKinnin Ponds	65.2
B	Kendall Hatchery	66.6
C	Skookum Hatchery	73.5
D	Kidney Creek Pond	89.5
E	Deadhorse Cr. Pond	94.3
F	Excelsior Pond	96.1

Figure 1. Map of the Nooksack River basin showing the locations of the smolt trap, hatcheries, and the off-station release sites for hatchery-reared chinook salmon smolts (map not to scale).

This report is divided into five major sections. The first section of the report describes the operation of the screwtrap, sampling procedures used at the trap, and the annual period of operation of the trap. It also summarizes annual screwtrap effort and the annual catch of out-migrating chinook salmon smolts by the screwtrap. Analyses which examine the relationship between catch rates and two environmental factors thought to influence the catch rates of chinook salmon smolts are presented. A summary of the annual releases of hatchery-reared chinook salmon juveniles into the Nooksack River system is also presented.

The second section of the report summarizes the experiments conducted to estimate the capture efficiency of the screwtrap for out-migrating chinook salmon smolts. Capture efficiency is defined as the percentage of chinook salmon smolts that migrate downstream past the screwtrap and are caught by the screwtrap. This section describes the methods used to estimate capture efficiency and the statistical models used to examine the relationships between capture efficiency and three environmental variables. Also described are analyses conducted to examine the relationship between capture efficiency and the time of day of the capture-efficiency experiments. Estimates of capture efficiency will be used to develop the indices of relative abundance described in section four of the report.

Fork length data collected from chinook salmon smolts captured by the screwtrap are summarized and presented in the third section of the report. Length data were collected from samples of chinook smolts captured by the screwtrap and from hatchery-reared chinook smolts used in the capture-efficiency experiments. There is little existing information on the length composition of the chinook salmon smolt population out-migrating from the Nooksack River. Length data may be useful in: (1) estimating the age composition of the out-migrating smolt population and (2) estimating the native stock and hatchery-reared components in the smolt out-migration. This report presents an initial examination of these possibilities.

The fourth section of the report develops an annual index of the relative abundance of chinook salmon smolts out-migrating from the Nooksack River using the screwtrap catch and effort data. Several methods of estimating an index of relative abundance are examined. Two of the indices use estimates of capture efficiency based on a relationship, developed in section two, with an environmental parameter. The indices are evaluated using the known numbers of hatchery-reared chinook salmon juveniles released above the trap.

The last section of the report focuses on an interpretation and discussion of all the data and analyses presented in the previous sections. It also develops a series of recommendations for improving the chinook salmon smolt out-migration study in the future.

Screwtrap Effort and Chinook Salmon Smolt Catch Summary and Analyses

This section of the report describes the operation of the rotary screwtrap and the sampling conducted at the trap. Summaries of the annual effort and the catch of out-migrating chinook salmon smolts by the screwtrap are presented. Also described are several analyses of the chinook salmon smolt catch-and-effort data. Summaries of the annual releases of hatchery-reared chinook salmon juveniles into the Nooksack River system are provided.

Study Site

The screwtrap was operated at the same location during the five years of the study covered by this report: 1994, 1995, 1996, 1997, and 1998. The trap is located about 7.6 km (4.8 river miles) from the river mouth on the mainstem of the Nooksack River. At this location there is a large point bar composed of sand and fine silt along the east bank (Figure 2). This section of the river is constrained by flood control levees on both banks. At the location where the trap was positioned, the distance between the levees is approximately 101 m. During average flow conditions, the distance between the wetted perimeters on each bank is approximately 66 m. The maximum channel depth at the sampling site is approximately 3.3 m at a low flow discharge of 2,850 cfs[1]. When operating, the trap is located on the outside edge of the river channel near the west bank (Figure 2). When not in operation, the screwtrap is secured to the sand bar along the east bank where it is protected from debris during periods of high water.

When the trap is fishing, it is placed approximately three meters to the east of a row of pilings near the west bank that are aligned with the current and are parallel to the bank. The pilings were used many years ago as a mooring site for log rafts and provide a convenient reference to assist in positioning the trap within the channel. A temporary staff gauge is mounted on one of the pilings to determine if the river stage is increasing or decreasing during trap operation. The pilings extend approximately four meters upstream of the screwtrap and provide some protection against large logs which occasionally drift downstream during high flows. During some flow conditions, the pilings may act as a short "lead" to bring smolts into the trap opening.

Figure 3 shows the screwtrap site and its proximity to U. S. Geological Survey (USGS) stream gauging station #12213100. Also shown is the location where marked chinook salmon smolts were released during experiments conducted to estimate the screwtrap capture efficiency for out-migrating chinook smolts.

[1] Cubic feet per second. All flows are reported in English units of cubic feet per second (cfs) as this is how they are reported by the U. S. Geological Survey.

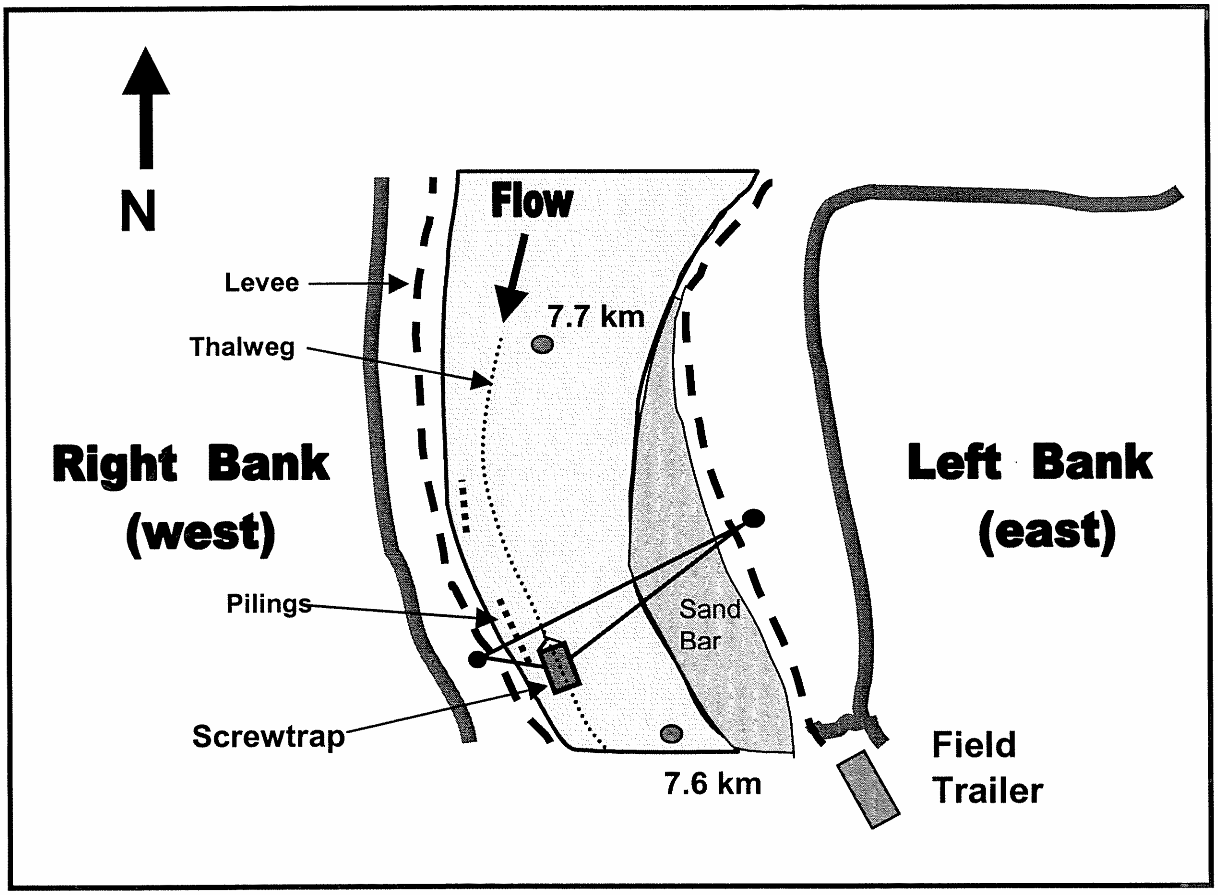


Figure 2. Schematic of the site in the mainstem of the lower Nooksack River where the screwtrap was operated, 1994-1998 (not drawn to scale). Distances are km from the river mouth.

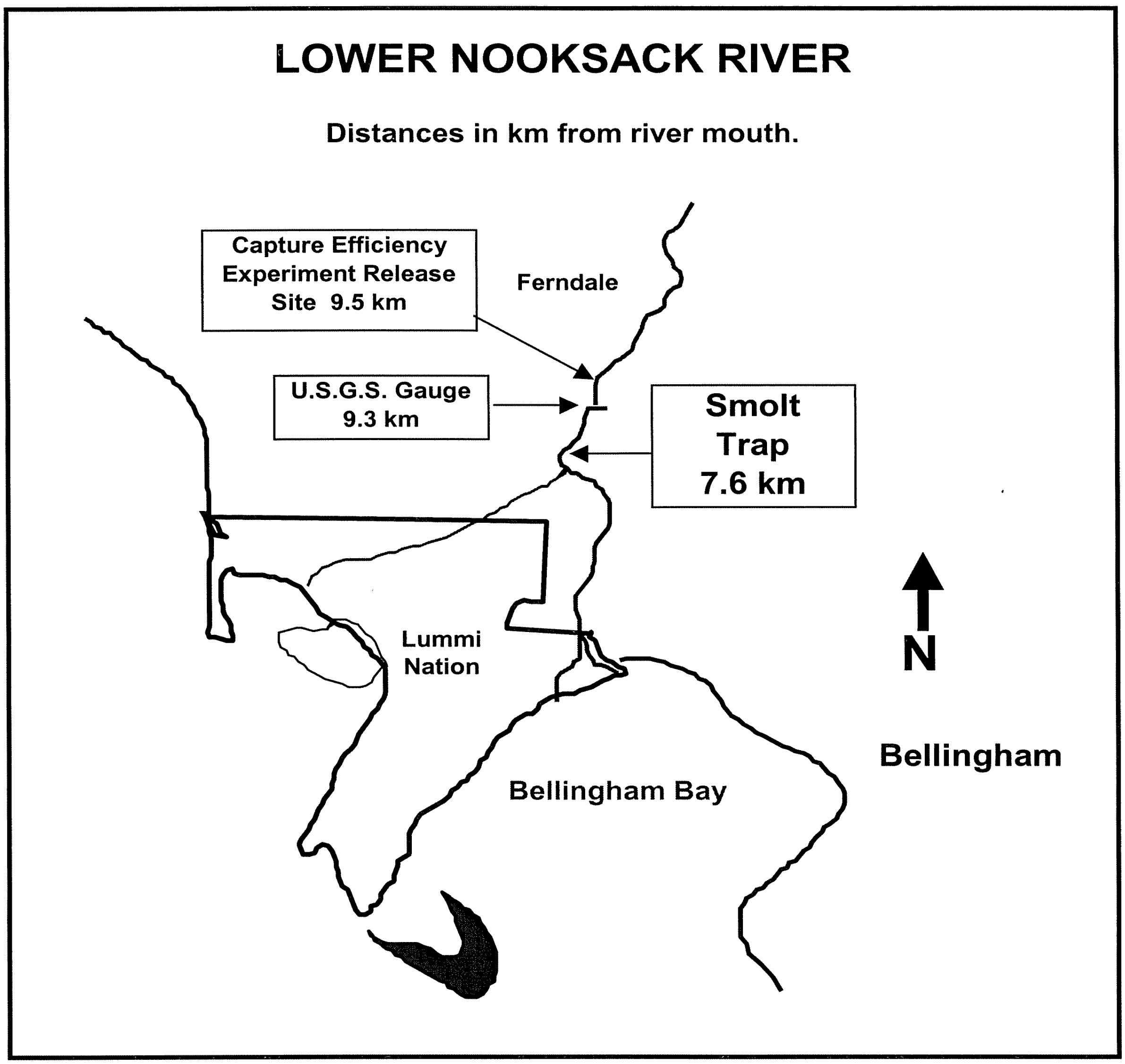


Figure 3. Map of the lower Nooksack River showing the locations of the screwtrap, U. S. G. S. river gauging station (#12213100), and the release sites for the chinook salmon smolts used in the capture-efficiency experiments.

When sampling, the screwtrap is positioned in the channel where there is the swiftest surface velocity, as indicated by a visible debris line at higher flows. This position in the channel varied by less than three meters during all flow conditions. This location is approximately four meters east of the thalweg.

The channel cross-section of the river at the screwtrap site was measured in 1997. We calculated the cross-sectional areas for a low flow condition of 3,000 cfs, a medium flow of 5,000 cfs, and high flow of 8,000 cfs. The percent of the channel cross-section covered by the screwtrap opening was approximately 3.4%, 2.0%, and 0.8% for low, medium, and high flow conditions, respectively. Generally, the trap was not operational during flows which exceeded 8,000 cfs due to the large amount of debris in the river which threatened the safety of the trap and crew.

Methods

Screwtrap Description

The rotary screwtrap used in this study was a modification of the original designed by E. G. Solutions[2]. Figure 4 shows the trap in both the raised and operating configurations. The opening of the screwtrap is 2.43 m in diameter giving it an effective sampling depth of 1.23 m. The area of the screwtrap opening is 2.3 m^2.

The cone and live box assembly are unmodified from the manufacturer. They are attached to a steel frame which allows them to be raised or lowered as shown in Figure 4. The frame is attached to overhead supports which are mounted on pontoons which are 7.3 m long and 4.6 m wide. The pontoons and overhead supports are fabricated from aluminum and are of our own design. The pontoons are assembled from four smaller sections and two crosswalk members allowing them to be easily transported and assembled on site. Plans are available from the second author on request.

The trap is positioned near the thalweg as described previously and shown in Figure 2 by using three, 9.5 mm (3/8") low-stretch, synthetic "Spectron 12" cables[3]. These lines are secured to large trees on either bank approximately three or four m above ground level. The "Spectron" cable used in the rigging system has a working load similar to 9.5 mm galvanized steel cable. Besides being much easier to handle and store, this synthetic material is light in weight which is important because it reduces cable sag. Minimizing cable sag is important in keeping the cable away from other craft navigating the river.

Two of the cables are attached to a hand winch mounted on each pontoon. The winches are rated for two tons and have up to a 22:1 mechanical advantage. The winch-lines run through a snatch block mounted on a stanchion attached to the pontoon which raises the lines crossing the river to avoid interference with boat traffic on the river. A third cable spans the river

[2] E. G. Solutions, Inc. PO Box 2437, Corvallis, OR 97339. Phone: (541) 752-7810.
[3] Samson Ocean Systems, Inc., 2090 Thornton St., Ferndale, WA 98248. Phone: (360) 384-4669

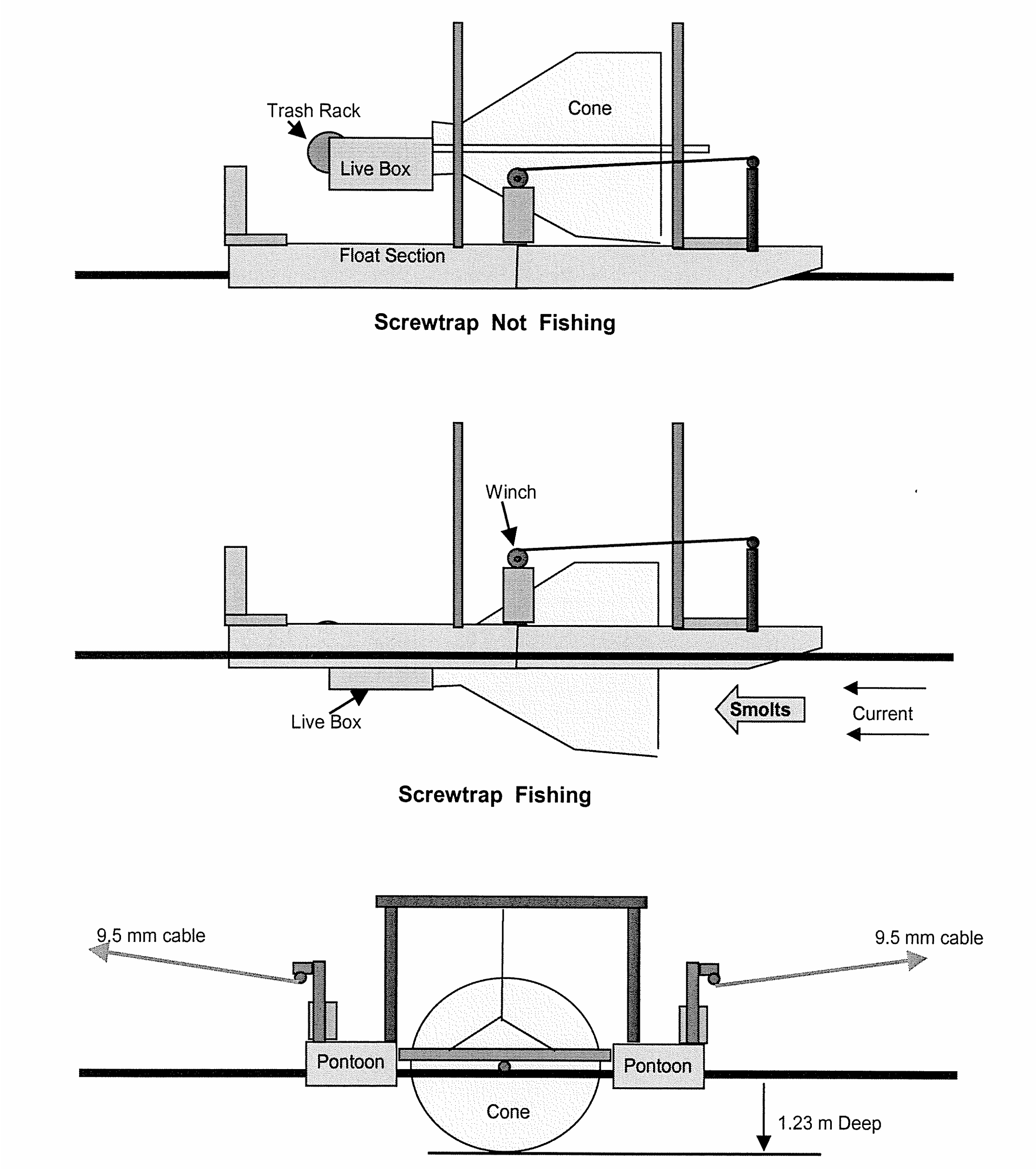


Figure 4. Schematic diagrams of the modified rotary screwtrap, designed by E.G. Solutions Inc., which was operated in the lower Nooksack River during the smolt out-migration study, 1994-1998.

overhead slightly upstream of the trap. A snatch block attached to the trap with a bow bridle runs free on this cable crossing the river. Using this configuration, the trap can be positioned anywhere in the river channel. There is generally less than three meters of movement in the up or downstream direction when sampling during most flows.

An aluminum skiff with a six horsepower motor is used to transport the crew between the deployed trap and the stream bank.

An emergency quick-release fitting is installed on the right bank so that both cables can be released from the shore in an emergency. This allows the trap to swing to the sand bar side of the channel where the river is less swift and river debris is less abundant.

Fish entering the mouth of the screwtrap can not escape because of internal vanes in the cone which block their passage as the cone of the trap rotates with the current. These vanes act as an Archimedes screw and force fish to the small end of the cone and into the live box. The rotating cone also drives a shaft connected to a rotating trash rack which is attached to the rear of the live box (Figure 4). This rack automatically removed much of the floating debris from the downstream end of the live box.

Screwtrap Operation

Prior to the start of a set, the screwtrap is positioned near the thalweg using the hand-winches. The frame securing the cone and live box assembly is then lowered using small hand winches. The "start time" is noted on a field form when the shaft first contacts the surface of the water. A sample of our data form is included in Appendix H.

At the start of each set we record the shaft rotational speed and the secchi depth of the water. The secchi depth is a measure of vertical water transparency. This measurement is taken by lowering a 21 cm diameter limnological secchi disk attached to a pole into the water until it is not visible. The distance from the water's surface to the disk is then recorded. A headlamp is used when taking secchi depth measurements during hours of darkness.

Other information recorded at the start of each set include water color, water temperature, type and amount of river debris, wind condition, and sky condition.

When river debris and/or catches are abundant, the crew remains on the trap for the duration of the set to continuously process the catch and to remove sticks, logs, and other debris from the cone and live box as needed. Occasionally a stick or log gets stuck in the trap opening; the cone end is then raised temporarily to remove the obstruction while leaving the live box in the river. The time is noted so that this temporary interruption in sampling can be subtracted from the overall set time.

Prior to the end of each set, another secchi depth measurement is taken. The frame, cone, and live box assembly is raised at an angle so that the water depth in the live box is approximately 0.5 m. The time when the shaft leaves the water surface marks the end of the set which is then recorded on the data form.

Catch Processing

Before processing the catch, all accumulated debris is removed from the live box. Salmon are dipped out of the live box and either (1) individually identified to species, examined for the presence of an adipose fin clip[4], and counted or (2) collected in a five-gallon plastic bucket for further processing. Some releases of hatchery-reared chinook salmon smolts upstream of the screwtrap are marked with an adipose fin clip (see Hatchery Releases section) so we examine each chinook salmon smolt for this mark. The adipose fin status of all chinook salmon smolts caught is usually determined. However, smolts are sometimes tallied without determining the adipose fin status to prevent handling mortalities when catches are high (for example, following a hatchery release upriver of the screwtrap) or due to problems caused by debris entering the trap and live box.

Individuals placed in the five-gallon bucket are removed in smaller groups of 5-10 individuals at at time and placed immediately into a small tub containing an anesthetic solution. Normally the first 20 individuals of each salmonid species are placed in the anesthetic solution. After the anesthetic takes effect, a fork length measurement is made and recorded from all species. Beginning in 1997, a DNA tissue sample was taken from some chinook salmon in this sample by removing the posterior (distal) margin of the dorsal caudal fin lobe with surgical scissors. All DNA tissue samples are stored in a 20% ethyl alcohol solution. The DNA tissue samples are for a pilot project to examine the feasibility of using microsatellite DNA analysis to identify the stock of origin of out-migrating smolts from the Nooksack River (Shaklee and Young 1999).

The anesthetic solution used is a 80-130 mg/l concentration of “Tricaine-S” brand tricaine methanesulfonate commonly known as “MS-222”. This is the dosage recommended by the manufacturer (Western Chemicals Inc.). Small adjustments to the MS-222 concentration are made so that anesthetized fish recover in fresh water in 3-5 minutes. This adjustment in dose is made using non-critical species whenever possible. Anesthetized fish are immediately placed in a recovery tank after processing and allowed to fully recover prior to release back into the river. Observed mortalities during sampling are rare and typically occur only during periods of heavy debris in the river. All mortalities are recorded.

All catch data are recorded for each set on weather-proof forms.

Environmental Data Collected

Weather and river conditions which might affect the efficiency of the screwtrap in capturing out-migrating smolts are recorded at the beginning of each set. Mean hourly river discharge volume, in cfs, and river stage are recorded at the USGS gauging station located approximately 1.7 km upstream of the trap (Figure 3). All flow data are taken from tables of mean daily flow produced by the USGS. River turbidity measurements are taken 0.8 km

[4] Fish with an adipose fin clip are subsequently referred to as adclipped fish.

above the screwtrap at the PUD #1[5] water intake facility using a Hach Surface Scatter #6 continuous monitoring device. Measurements are recorded by PUD staff on a daily log six to nine times per day. We averaged these measurements for each day for our analyses. The values are recorded in nephelometer turbidity units (ntus).

Screwtrap Effort and Annual Sampling Designs

From 1995 to 1998 the screwtrap was operated during the period 1 April through 31 July. In 1994, the trap was operated from 25 April through 14 July. The trap was operational in mid-March in 1996 and 1997. However, during these two years combined we were only able to operate the screwtrap a total of four days during the mid-March through 1 April period because river flows were too high to operate the trap safely. Cost factors limit the total number of hours the screwtrap is operated each year.

We refer to a set by the screwtrap as the discrete period of trap operation during which effort and catch are recorded. A set begins when the cone of the trap is lowered into the water and begins actively fishing and ends when the cone of the trap is lifted from the water. In 1994 and 1995, the screwtrap was generally operated on three or four consecutive weekdays each week. During these years, the trap was typically operated from four to six hours on a sample day primarily during daylight hours (between 0900 and 1500 hours).

In 1996, each day of the week was divided into six, four-hour time blocks beginning at 0000 on Sunday. This resulted in 42 possible four-hour sampling blocks each week. We then determined the total number of sets (four-hour sample blocks) we wanted to conduct each week based upon our sampling objectives and the timing of the out-migration of each species (determined from the 1994 and 1995 sampling). Four-hour sample periods were then randomly selected without replacement from the 42 available each week until the target sample size was obtained.

In 1997 and 1998, each day was divided into four, six-hour blocks. The possible starting times for a set on a sample day were 0000, 0600, 1200, or 1800 hours. We tried to sample every other day throughout the period that the trap was operated in 1997 and 1998. On each designated sample day, we randomly selected one of the six-hour blocks to sample.

There were occasional deviations from the sampling schedule due to high water flows (the most frequent cause) or when the gear was damaged by floating debris. Infrequently a set was canceled or delayed due to human factors. No mechanical breakdowns of the screwtrap, except those caused by debris damage, were experienced.

[5] Public Utility District #1 of Whatcom County, Ferndale, WA.

Hatchery Releases

Each year there were releases of hatchery-reared chinook salmon juveniles into the Nooksack River system. Most juvenile chinook salmon released into the Nooksack River system were reared at Kendall Creek Hatchery, which is operated by the Washington Department of Fish and Wildlife (WDFW). Two chinook salmon stocks have been reared at this site: the Green River Hatchery fall stock and the early-timed, North Fork (of the Nooksack) native spring stock.

It was not possible to identify all hatchery-origin smolts in the catches because they often did not have a visible mark (e.g., an adipose fin clip) and they had overlapping fork lengths with the native fish. As a result, we could not identify native spring chinook salmon in the catches. We hope the microsatellite DNA analysis technique will allow us to estimate stock composition and, ultimately, allow us to estimate the annual production of native chinook salmon smolts for both the North Fork and South Fork Nooksack stocks in the future.

Most spring chinook salmon were released directly from Kendall Creek Hatchery located approximately 67 km upstream of the screwtrap on the Nooksack River North Fork. Additional release sites for spring chinook salmon included the following acclimation ponds on the North Fork: Excelsior Tributary, Excelsior Side Channel, Deadhorse Creek Pond, and the Kidney Creek Pond (Figure 1). These sites are from 90 to 96 km above the trap site.

Releases of non-native, fall chinook salmon of Green River origin have been made into the Nooksack River since the late 1800s. Large numbers of these fall chinook salmon have been released at Kendall Creek Hatchery in the past several decades to enhance the commercial fishery in the river and in Bellingham Bay. In recent years, the number of fall chinook salmon released has been reduced and their release site has been moved from the Kendall Creek facility to locations further downriver to avoid interactions with the two native stocks of spring chinook salmon (North Fork Nooksack and South Fork Nooksack spring chinook stocks). This eliminated hatchery-origin fall chinook salmon from the screwtrap catches in 1997 and 1998 as these fish were released 5.4 km below the trap. In 1996, the fall chinook salmon were released 1.8 km above the trap (at Ferndale Ramp). In 1994, fall chinook salmon were released at Nugent’s Corner (49 km above the trap site). Age-zero fall chinook salmon were also released at this site in 1995.

During the years encompassed by this report, 1994 through 1998, the annual releases of fall chinook salmon were reduced from a peak of 5.5 million fish in 1994 to 124,046 fish in 1998. All releases of fall chinook salmon were age-zero fish. The native spring chinook salmon releases varied during this period from a low of 188,600 fish in 1996 to a high of 1,865,550 fish in 1998. Native spring chinook salmon releases were primarily age-zero fish but have also included yearling releases. Yearling spring chinook salmon releases have ranged from 185,962 fish in 1998 to 347,540 fish in 1995.

Analyses of Chinook Salmon Smolt Catch-and-Effort Data

Several analyses of the chinook salmon catch data from the screwtrap were conducted. Because the length of fishing time varied from set to set, catch data were converted to catch per hour fished (CPUE) for summaries by set, by day, and by statistical week[6] to facilitate comparisons among weeks within a year and among years.

Chinook salmon smolts with adipose fin clips were released above the screwtrap during each year the trap was operated. Catches of chinook salmon smolts with and without adipose fins were compiled separately. This was done because all adclipped fish are of hatchery origin while fish with adipose fins are often a mixture of both hatchery and native ("wild") fish. Because we sometimes tallied fish, and the adipose fin status of tallied fish was not determined, it was necessary to allocate tallied fish to one of the adipose fin status groups. This was done by allocating the tallied fish to each group in proportion to their abundance in the sampled fish (whose adipose fin status was determined) from the same set. If the number of sampled fish was less than 10, we then used the samples from the set or sets closest in time to the set being allocated. At least 10 sampled fish were used for these proportional allocations; for most allocations 20 or more sampled fish were used. All allocations to each group were rounded to the nearest whole fish.

Daily and Weekly Chinook Salmon CPUE and Percentage of Adclipped Fish:

We compiled both daily and weekly estimates of the CPUE of out-migrating chinook salmon smolts. CPUE was calculated separately for smolts with adipose fins, adclipped smolts, and total chinook smolt catch. We also calculated and plotted the percent of the chinook salmon smolt catch with adclips as an indicator of the relative contribution of hatchery-reared chinook smolts to the catches. Daily total CPUE values were plotted to examine trends in abundance within a year. To emphasize trends in the data, we linearly interpolated values for CPUE and percent adclipped between sample days when there were three or fewer consecutive days without sampling (i.e., screwtrap operation). No interpolation of values was done when there were four or more consecutive days without trap operation. We also plotted the mean hourly river discharge for each day on the daily CPUE and percent adclipped graphs so that we could visually examine the relationship between peak flow events and the CPUE of chinook salmon smolts.

Weekly CPUE values were plotted because they removed some of the large variations seen in the daily data and were more informative when comparing trends among years. Statistical weeks were defined to begin on Sunday at 0000 and end on Saturday at 2400. Weekly CPUE was calculated as the sum of the total catch of chinook salmon smolts by all sets during a statistical week divided by the total hours of screwtrap effort during the same statistical week. CPUE was calculated separately for adclipped and non-adclipped fish.

[6] See Appendix Table 1 for a definition of the statistical week and correspondence between date and statistical week.

Correlation Between River Discharge and CPUE:

We suspected that the out-migration of chinook salmon smolts may be influenced by river flow, particularly peak flow events. Specifically, we thought there may be a significantly higher rate of out-migration during periods of peak river discharge. Both the linear (Pearson's r) and nonparametric (Spearman's rho) correlation coefficients (Conover 1980) between total CPUE for a sample day and the mean hourly river discharge for that day (measured in cfs) were calculated and examined for significance. Sets with a CPUE of zero (i.e., no chinook smolts were caught during the set) were potentially a problem because a CPUE of zero could result from either the influence of an environmental parameter (such as flow) decreasing the ability of the screwtrap to capture smolts to a very low level (and hence a catch of zero) or could occur because there were no chinook smolts available for capture during the time period the trap was operated. Because we could not determine which was the case, we calculated the correlation coefficients with zero CPUE sets both included and excluded from the data set. Also, the CPUE of some sets was obviously influenced by the release of large numbers of hatchery-reared fish immediately above the screwtrap at the Ferndale Ramp (1.8 km above the trap). We omitted the data for these days from the analyses because the CPUE of these sets was heavily influenced by the hatchery release. Hatchery chinook salmon smolts were released at this site only in 1996. The correlation data were plotted for comparisons among years.

Differences Between Daytime and Nighttime CPUE:

Other researchers have found that catches of out-migrating chinook salmon smolts are sometimes different between daylight and nighttime hours (Roper and Scarnecchia 1996; Seiler et al. 1998). Unfortunately, we did not have the resources to conduct a designed experiment to test this hypothesis. Therefore, we examined the existing CPUE data for out-migrating chinook salmon smolts to determine if there was evidence of a difference between daytime and nighttime catch rates by the screwtrap. Only sets conducted in 1996, 1997, and 1998 were used for these analyses since these were the only years during which randomized starting times were assigned to sets. We classified each set during these years as either a daytime set or a nighttime set. If more than one-half of the set time occurred during the hours of civil twilight then the set was classified as a daytime set. If more than one-half of the set time occurred outside the hours of civil twilight then the set was classified as a nighttime set. Civil twilight is defined as the period of time when illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished. Before and after civil twilight, artificial illumination is normally required to carry on ordinary outdoor activities. Times for civil twilight at Bellingham, WA were obtained from the U. S. Naval Observatory webpage (http://aa.usno.navy.mil/AA/).

The CPUE of daytime and nighttime sets was compared each year using the nonparametric Mann-Whitney test (Conover 1980). A nonparametric test was used because CPUE data are ratios and ratios are usually not normally distributed. Similar to the previous correlation analysis, we omitted the data from the days when the CPUE of the sets was influenced by the release of hatchery chinook salmon smolts at the Ferndale Ramp (which occurred only in 1996). The CPUE of these sets was more a function of the timing of the hatchery release and not the time of day of the set. Total CPUE, calculated from combining the catch of both adclipped and non-adclipped chinook smolts, was used for these analyses. Like the correlation analyses, these analyses were conducted with zero catch sets included and excluded from the data. The frequency of zero catch sets in daytime and nighttime sets was compared each year using the χ^2 test statistic and Fisher's exact test (Conover 1980).

Results

Screwtrap Effort

Screwtrap effort (hours of sampling) ranged from 258.1 hours in 1994 to 476.5 hours in 1996 (Table 1). The average number of hours the screwtrap was fished each sample day was fairly consistent from year to year ranging from 5.9 to 6.8 hours. As indicated by the coefficients of variation and as shown in Figure 5, daily sample effort (the number of hours the trap was fished on a sample day) was more consistent during the last two years of sampling (1997 and 1998) than in the first three years of the study.

Table 1. Summary of annual effort (number of hours and days fished) for the screwtrap operated in the Nooksack River, 1994-1998.

YEAR:	1994	1995	1996	1997	1998
Total hours of effort:	258.09	371.38	476.52	320.00	354.37
Number of days sampled	41	55	76	54	59
Mean daily effort (hrs)	6.3	6.8	6.3	5.9	6.0
Standard Deviation	2.3	3.7	3.0	1.8	1.2
Coef. of Variation[a]	36.8%	54.7%	47.7%	29.5%	19.9%
First Day of Sampling	25-Apr	31-Mar	25-Mar	17-Mar	3-Apr
Last Day of Sampling	18-Jul	27-Jul	14-Aug	30-Jul	24-Jul

[a] The coefficient of variation = (standard deviation/mean) x 100%.

Hatchery Releases

A detailed summary of the releases of hatchery-reared chinook salmon juveniles into the Nooksack River for the years 1994 through 1998 is presented in Appendix Table 2. Table 2 summarizes the annual releases of hatchery yearling and age-zero, spring and fall chinook salmon above the screwtrap. These fish were available to capture by the screwtrap during their out-migration. The numbers of yearling spring chinook released were relatively constant during the last three years of the study (1996-1998). The numbers of age-zero spring chinook released above the trap greatly increased during the same time period. No age-zero fall chinook were released above the trap in 1997 or 1998.

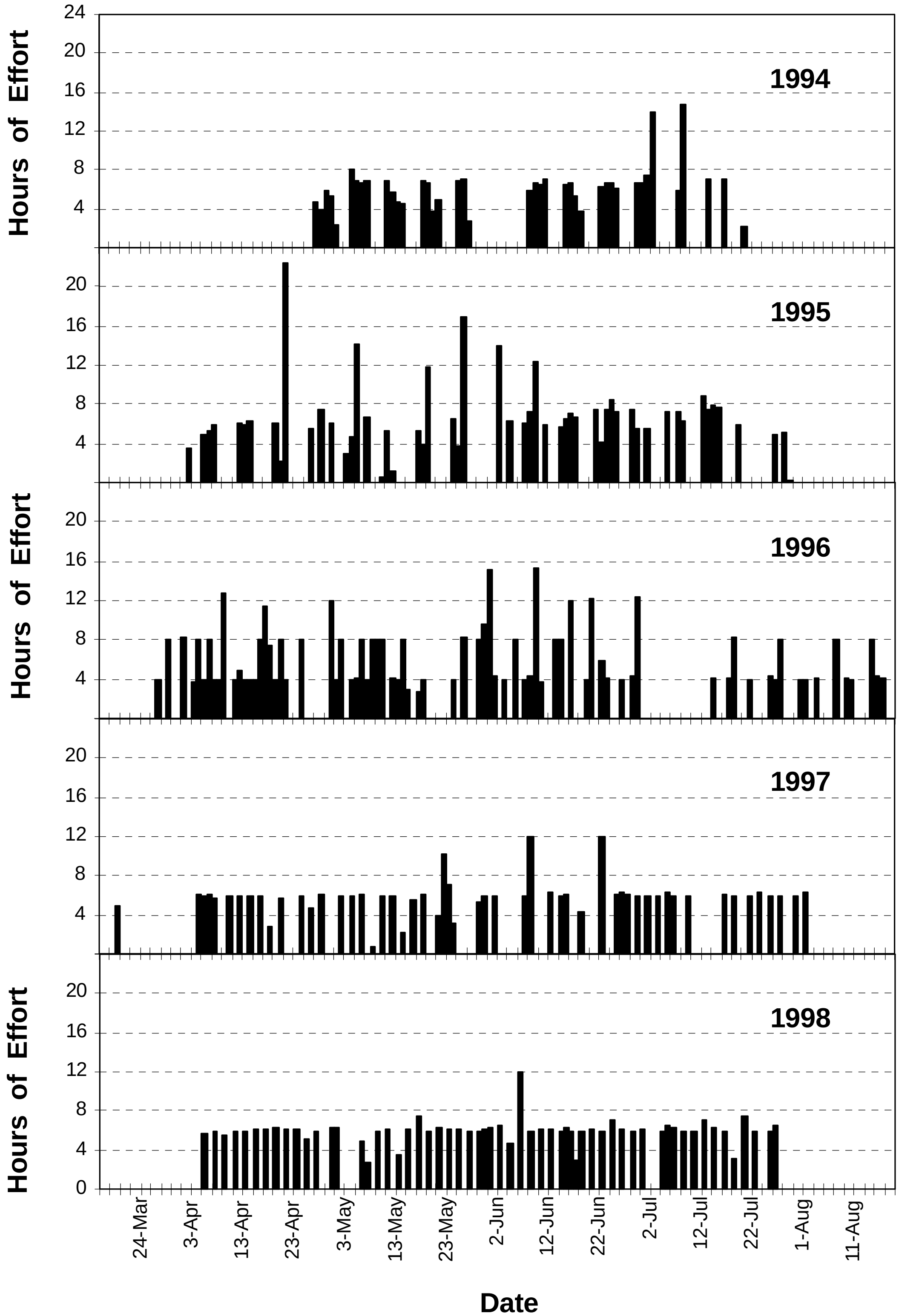


Figure 5. Daily hours of sampling effort for the screwtrap operated in the Nooksack River, by year, 1994 through 1998.

Table 2. Summary of the annual releases of hatchery-reared yearling and age-zero, spring and fall chinook salmon above the screwtrap operated on the Nooksack River, 1994-1998.

	Yearling Spring		Age-Zero Spring		Age-Zero Fall	
Year of Release	Number Released	Percent Adclipped	Number Released	Percent Adclipped	Number Released	Percent Adclipped
1994	292,300	47.8%	1,299,035	44.8%	3,596,702	0.0%
1995	347,540	100.0%	193,145	100.0%	4,229,705	0.0%
1996	185,962	98.7%	2,638	100.0%	3,108,560	0.0%
1997	187,765	100.0%	755,453	23.8%	0	
1998	187,636	80.8%	1,677,914	12.1%	0	

Analyses of Chinook Salmon Smolt Catch-and-Effort Data

A summary of the trap sampling effort and catch of juvenile chinook salmon for each screwtrap set and other pertinent set information is provided for the years 1994, 1995, 1996, 1997, and 1998 in Appendix Tables 3, 4, 5, 6, and 7, respectively.

Daily Chinook Salmon CPUE and Percentage of Adclipped Fish:

This section will briefly discuss the daily trends in CPUE on a year-by-year basis. We will identify sample days whose CPUE was influenced by upstream releases of hatchery-reared chinook salmon smolts.

1994: Figure 6 summarizes the daily CPUE, percent of catch with adclips, and river flow data during the period of screwtrap operation in 1994. There was a release of 292,300 yearling fish from Kendall Creek Hatchery in early April, before the screwtrap was operational, of which 48% were adclipped (Table 2 and Appendix Table 2). This release was probably responsible for the high percentage of adclipped fish caught (although in low numbers) by the trap from late April though mid-May. There was a seasonal high CPUE of chinook salmon smolts (185 fish caught per hour) on 13 June and a smaller peak on 15 June (119 fish per hour); more than 20% of these fish were adclipped. These peaks were probably influenced by the large releases of age-zero smolts in upriver ponds on 23-25 May (Appendix Table 2). During the period from 6 June to 23 June, about 20% to 35% of the daily chinook salmon catch was composed of adclipped smolts. There was a secondary peak in CPUE on 14 July. Adclipped fish composed about 20% of this catch.

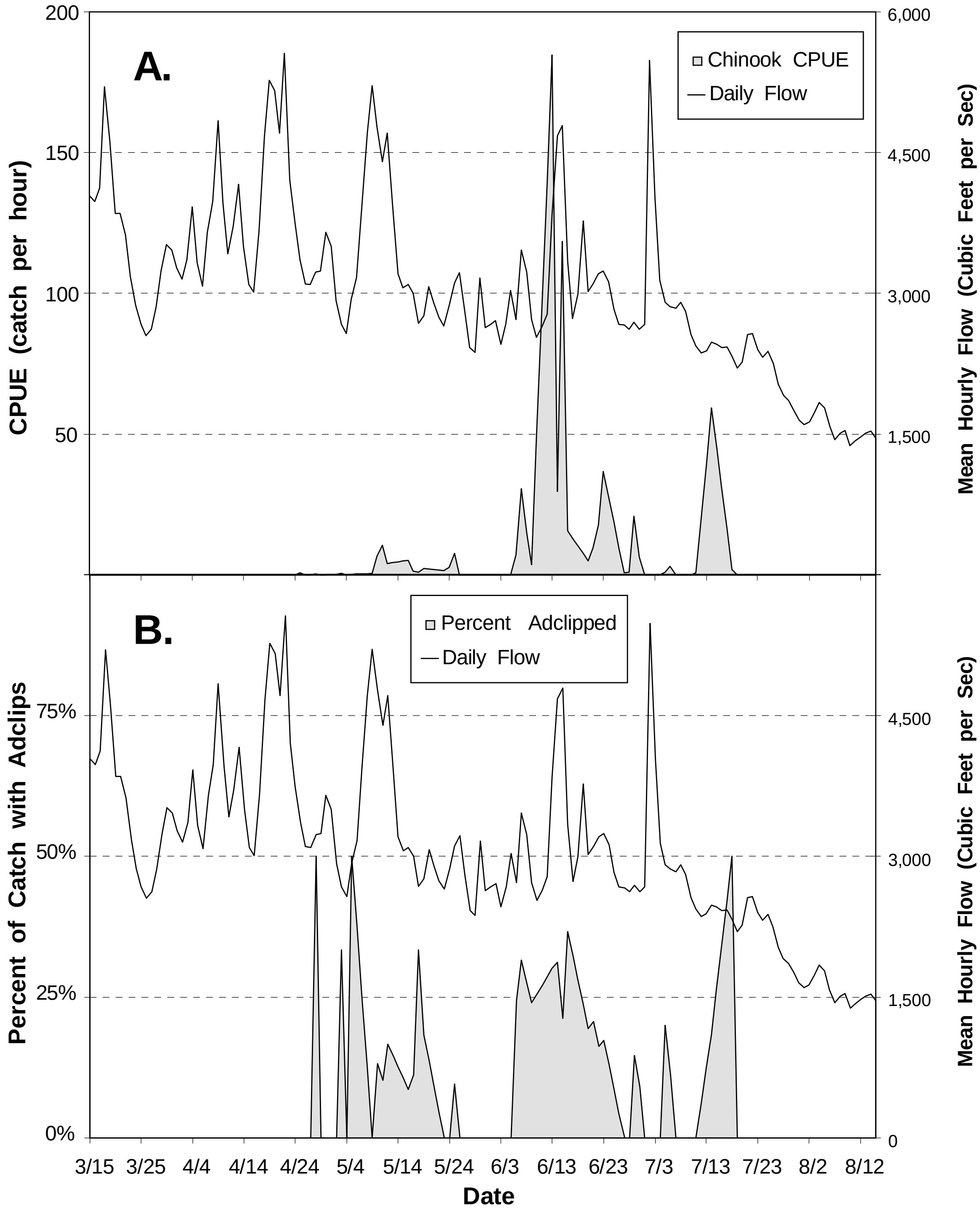


Figure 6. Plot of (A) daily catch per unit effort (CPUE) of out-migrating chinook salmon smolts by the screwtrap and (B) percent of chinook salmon catch with an adipose fin clip compared to mean hourly flow of the Nooksack River during the period March 15 through August 15, 1994.

1995: Figure 7 summarizes the daily CPUE, percent of catch with adclips, and river flow data during the period of screwtrap operation in 1995. There was a release of about one million age-zero fish at Nugent's Corner on 30 March (Appendix Table 2) and this release was probably responsible for the peaks in CPUE in early April (5-11 April). The percentage of adclipped chinook salmon smolts in the catch was low (<5%) until mid-May (15-17 May); these fish were from the release of 347,540 adclipped spring yearlings on 1 April at Kendall Creek Hatchery (the only release of adclipped fish prior to 15 May). Adclipped fish continued to compose from 10% to 86% of the chinook catch through 6 June. There was a seasonal high CPUE of chinook salmon smolts (123 fish caught per hour) on 3 July; none of these fish were adclipped. There was a second smaller peak in CPUE on 10 July. Many of the fish in these peaks were probably from a release of more than three million age-zero fall chinook salmon from Kendall Creek Hatchery on 14 June.

1996: Figure 8 summarizes the daily CPUE, percent of catch with adclips, and river flow data during the period of screwtrap operation in 1996. There was a high percentage of adclipped fish in most catches during the first half of April. The only release of adclipped chinook salmon smolts prior to this period was the release of 183,545 spring yearlings from Kendall Creek Hatchery on 1 April (Appendix Table 2). There was a CPUE peak of 202 fish per hour on 6 April. This peak coincided with a release of almost 700,000 age-zero fall chinook salmon at the Ferndale Ramp, 1.8 km above the trap, on 4 April. There was a seasonal high CPUE for chinook salmon smolts of 463 fish/hour on 5 June. Again, this peak coincided with a release of more than two million age-zero fall chinook salmon at the Ferndale Ramp on 3 June.

1997: Figure 9 summarizes the daily CPUE, percent of catch with adclips, and river flow data during the period of screwtrap operation in 1997. There was a release of 187,765 yearling fish, all adclipped, from Kendall Creek Hatchery on 1 April (Table 2 and Appendix Table 2). This release was probably responsible for the high percentage of adclipped fish caught and minor peak in CPUE on 2-4 April. There were three secondary peaks in CPUE of chinook salmon smolts during May. These peaks were probably associated with the upstream releases of age-zero spring chinook smolts on 25 April and 18-19 May, respectively (Appendix Table 2). There was a seasonal high CPUE for chinook salmon smolts of 90 fish/hour on June 12. The majority (68%) of these fish were adclipped. Most of these fish were probably from the release of 180,014 adclipped, age-zero spring chinook salmon from Kendall Creek Hatchery on 1 June. There were relatively high contributions (≥ 20%) of adclipped chinook to the catches during the period 6 June through 3 July.

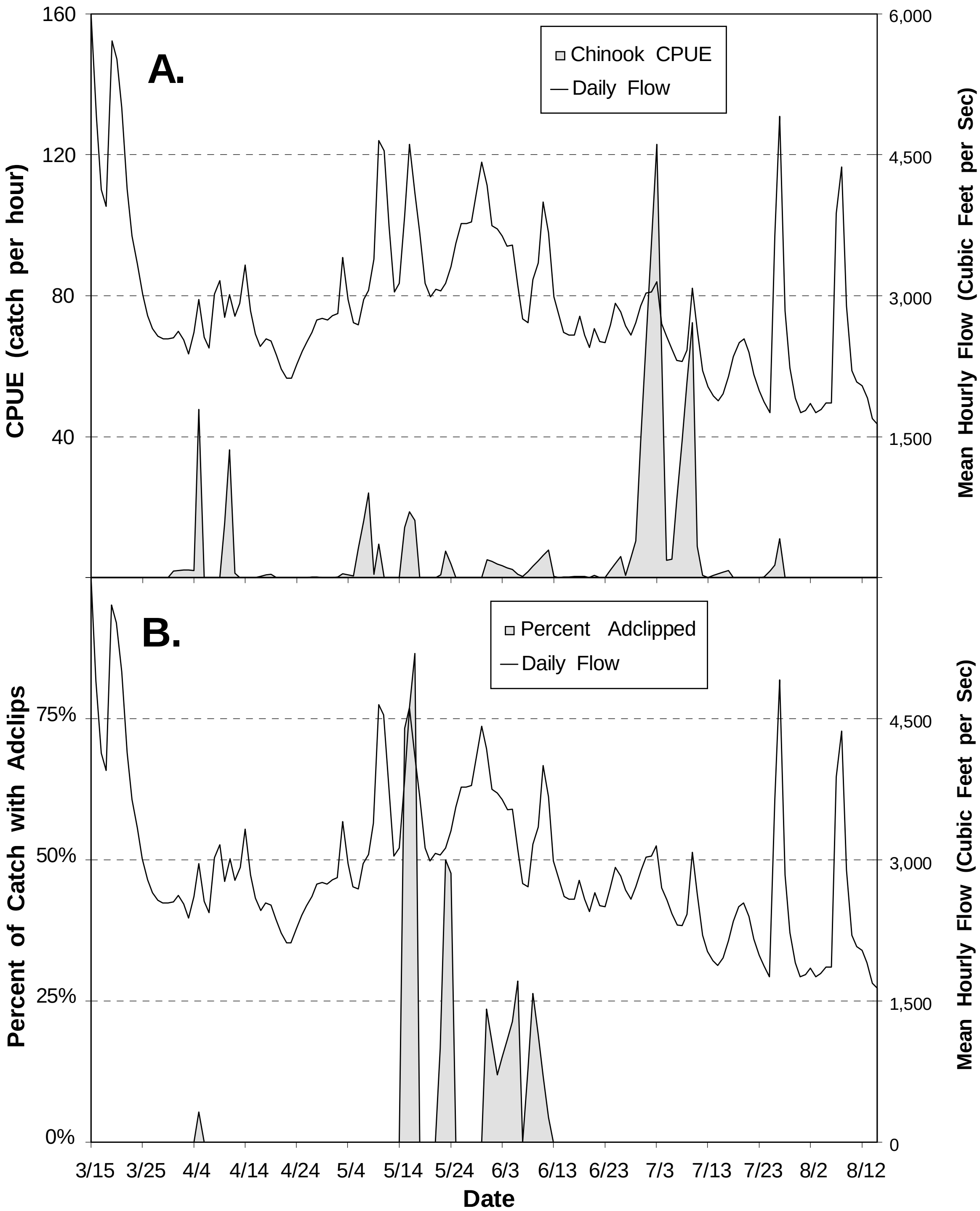


Figure 7. Plot of (A) daily catch per unit effort (CPUE) of out-migrating chinook salmon smolts by the screwtrap and (B) percent of chinook salmon catch with an adipose fin clip compared to mean hourly flow of the Nooksack River during the period March 15 through August 15, 1995.

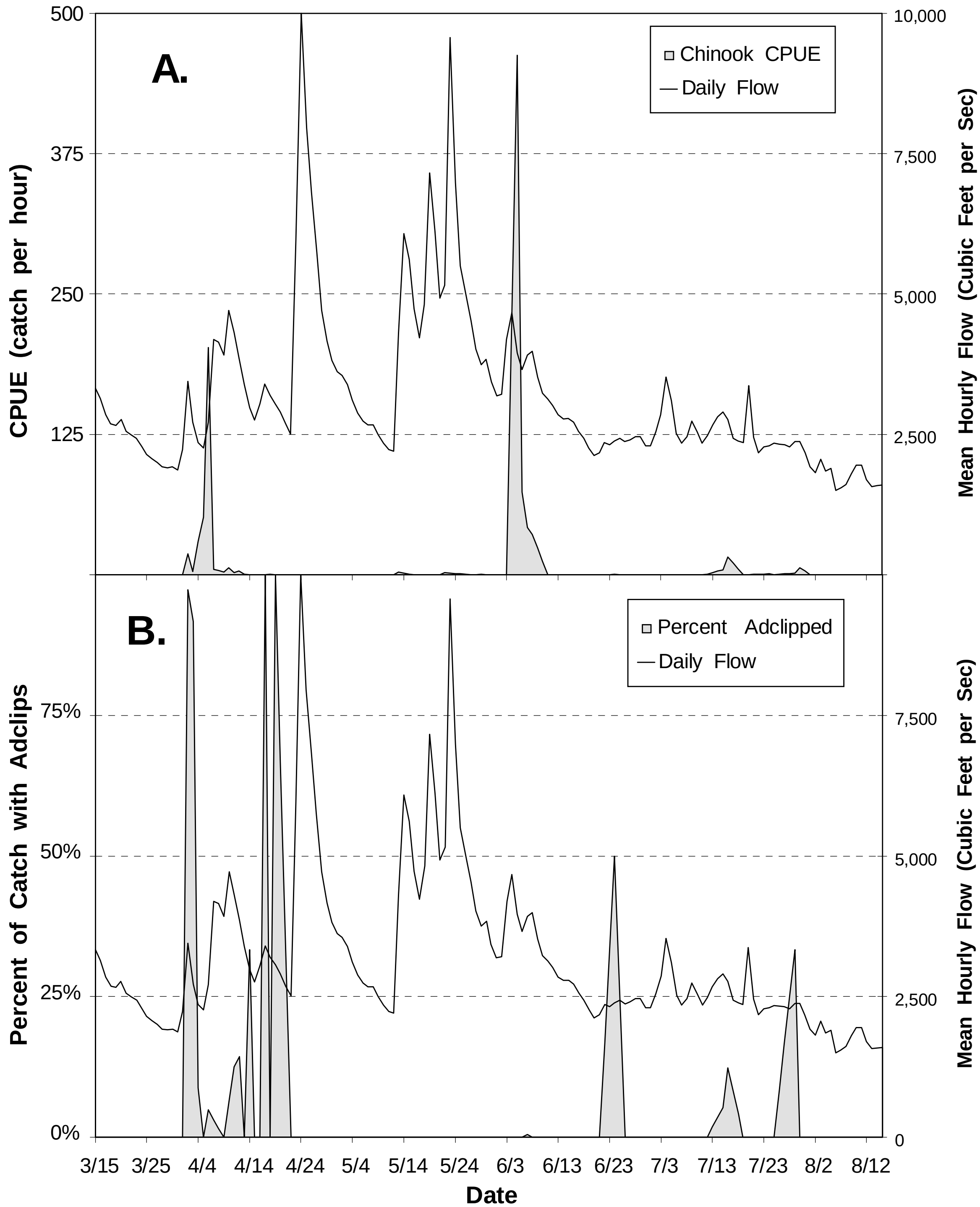


Figure 8. Plot of (A) daily catch per unit effort (CPUE) of out-migrating chinook salmon smolts by the screwtrap and (B) percent of chinook salmon catch with an adipose fin clip compared to mean hourly flow of the Nooksack River during the period March 15 through August 15, 1996.

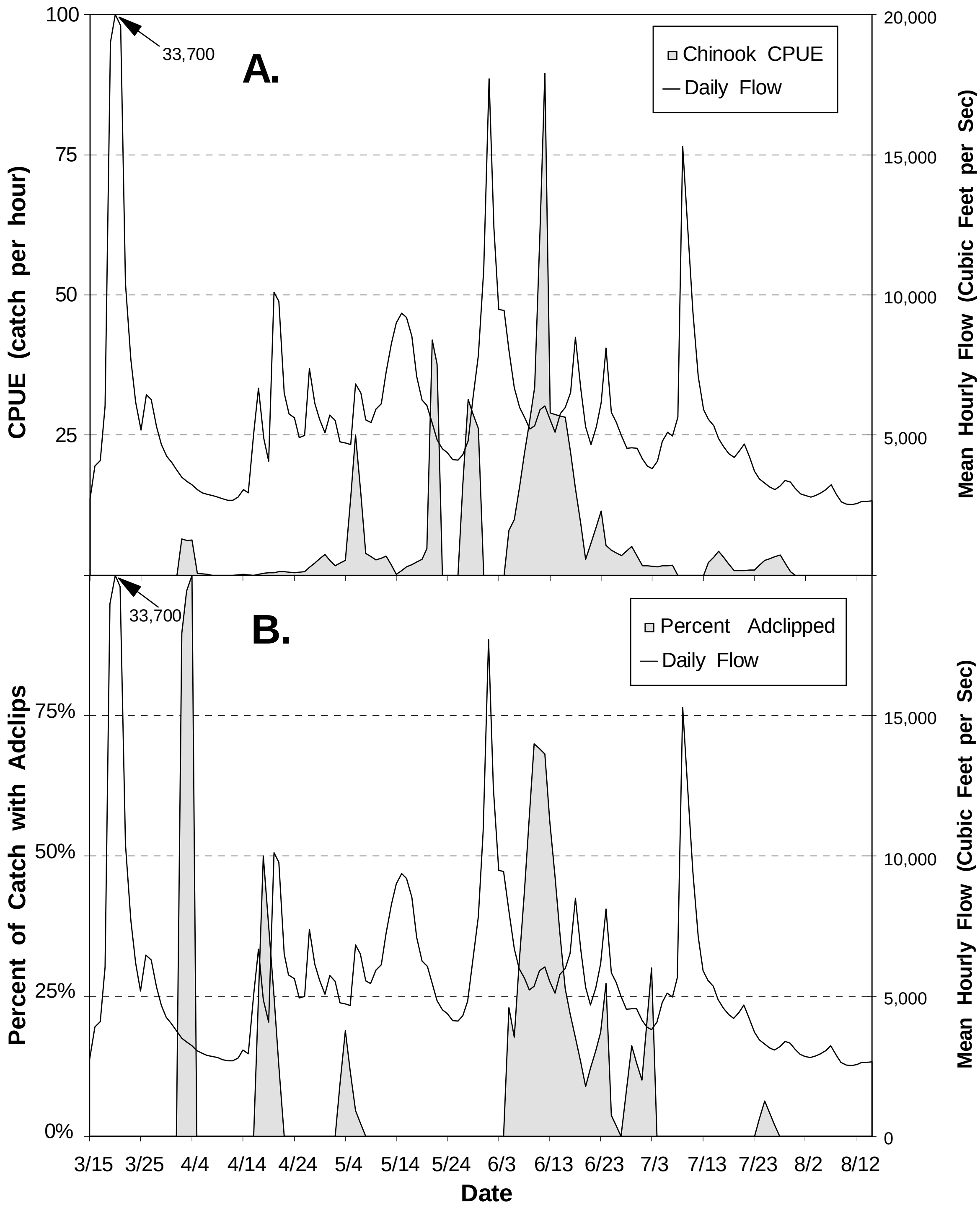


Figure 9. Plot of (A) daily catch per unit effort (CPUE) of out-migrating chinook salmon smolts by the screwtrap and (B) percent of chinook salmon catch with an adipose fin clip compared to mean hourly flow of the Nooksack River during the period March 15 through August 15, 1997.

1998: Figure 10 summarizes the daily CPUE, percent of catch with adclips, and river flow data during the period of screwtrap operation in 1998. There was a series of five sharp increases in CPUE of chinook salmon smolts beginning in late April and continuing through mid-June. These peaks were probably influenced by the numerous releases (nine separate releases) of age-zero spring chinook salmon smolts which occurred from mid-April through late May, 60 or more km above the trap (Appendix Table 2). Adclipped fish composed more than 10% of the daily catch for the first (23 April) and last (16 June) peaks. This was probably a result of the upstream releases of adclipped spring smolts on 1 April and 12 June, respectively (Appendix Table 2).

Summary: We examined the previous set of graphs for obvious occurrences of peak chinook smolt CPUE with peak flow events. In 1994, the seasonal peak in CPUE of chinook salmon smolts on 13 June preceded a peak flow event, but there was a secondary CPUE peak two days later that coincided with this same peak flow event. The two highest peak CPUE values in 1995 coincided with peaks in flow, however, these peaks in flow were of lesser magnitude than many during the season. The two CPUE peaks in 1996 were the direct result of the release of large numbers of hatchery smolts at the Ferndale Ramp, 1.8 km above the trap. The peak CPUE values observed in 1997 did not seem to directly coincide with any flow events. Two of the CPUE peaks in 1998 (the first and third) closely coincided with peak flow events. There is no clear visual evidence in these graphs of a strong link between peak CPUE values and peak discharge events.

Weekly Chinook Salmon CPUE:

The starting and ending dates for the statistical weeks each year are defined in Appendix Table 1. Figure 11 presents a summary of CPUE of non-adclipped and adclipped chinook smolts by the screwtrap, and the number of hours the screwtrap was operated, for each statistical week during the years 1994 through 1998. A discussion of each year follows. A discussion of common patterns observed over the five-year period ends this section.

1994: There were two peaks in CPUE for both groups of fish (non-adclipped and adclipped). The largest peak for both groups occurred during statistical week 24 in mid-June (12 to 18 June). The second, smaller peak occurred during statistical week 28 in mid-July (10 to 16 July). The CPUE of non-adclipped fish was greater in both cases. The first peak is probably related to the large releases of age-zero spring chinook smolts in upriver ponds during 23-25 May; 1.3 million fish were released of which 45% were adipose fin clipped. The CPUE peak in July was probably influenced by the release of 2.5 million age-zero, fall chinook from Kendall Creek Hatchery on 15 June. None of these fish were adipose fin clipped so these fish were not responsible for the second peak in CPUE of adclipped fish. The origin of these adclipped fish is uncertain.

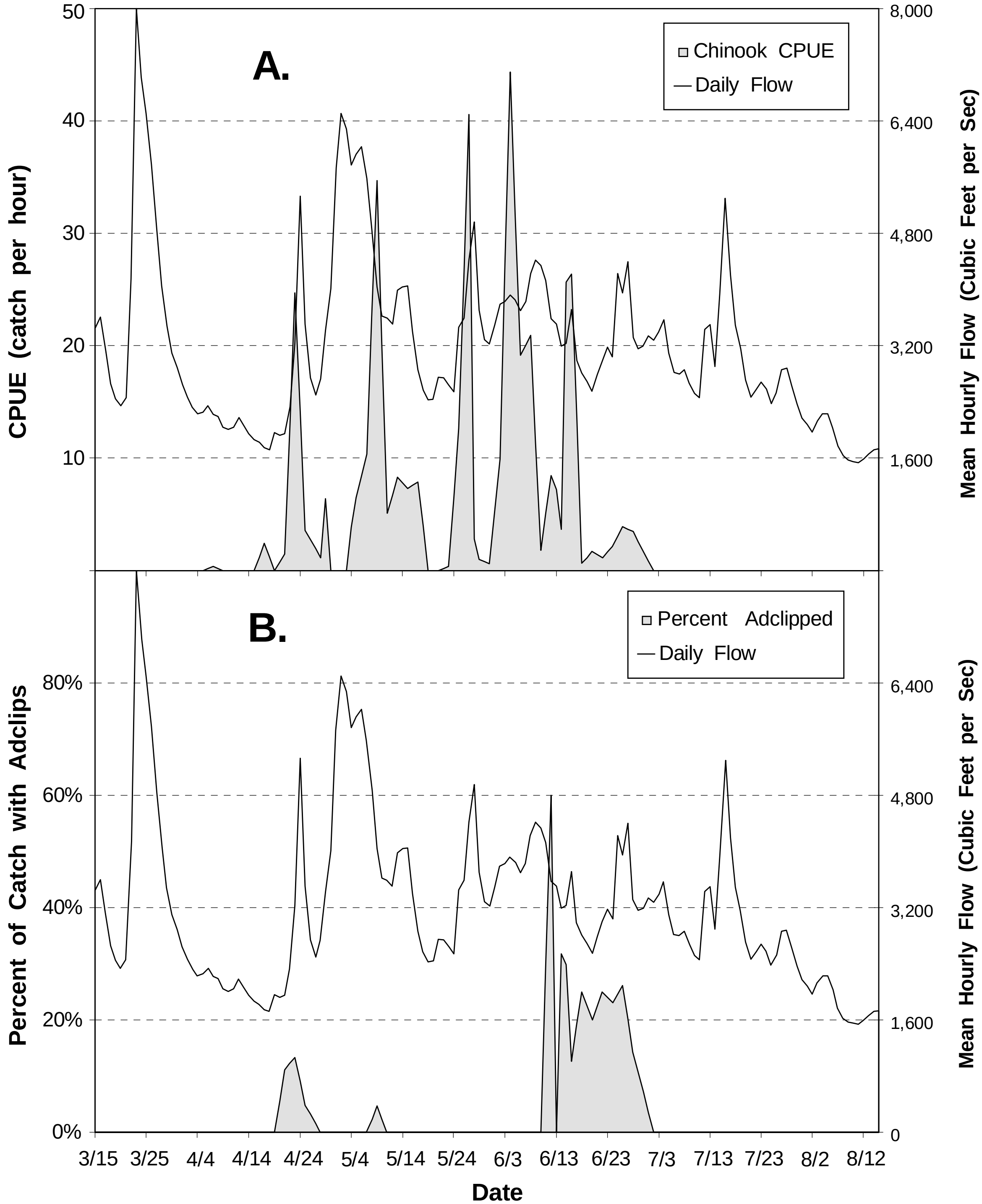


Figure 10. Plot of (A) daily catch per unit effort (CPUE) of out-migrating chinook salmon smolts by the screwtrap and (B) percent of chinook salmon catch with an adipose fin clip compared to mean hourly flow of the Nooksack River during the period March 15 through August 15, 1998.

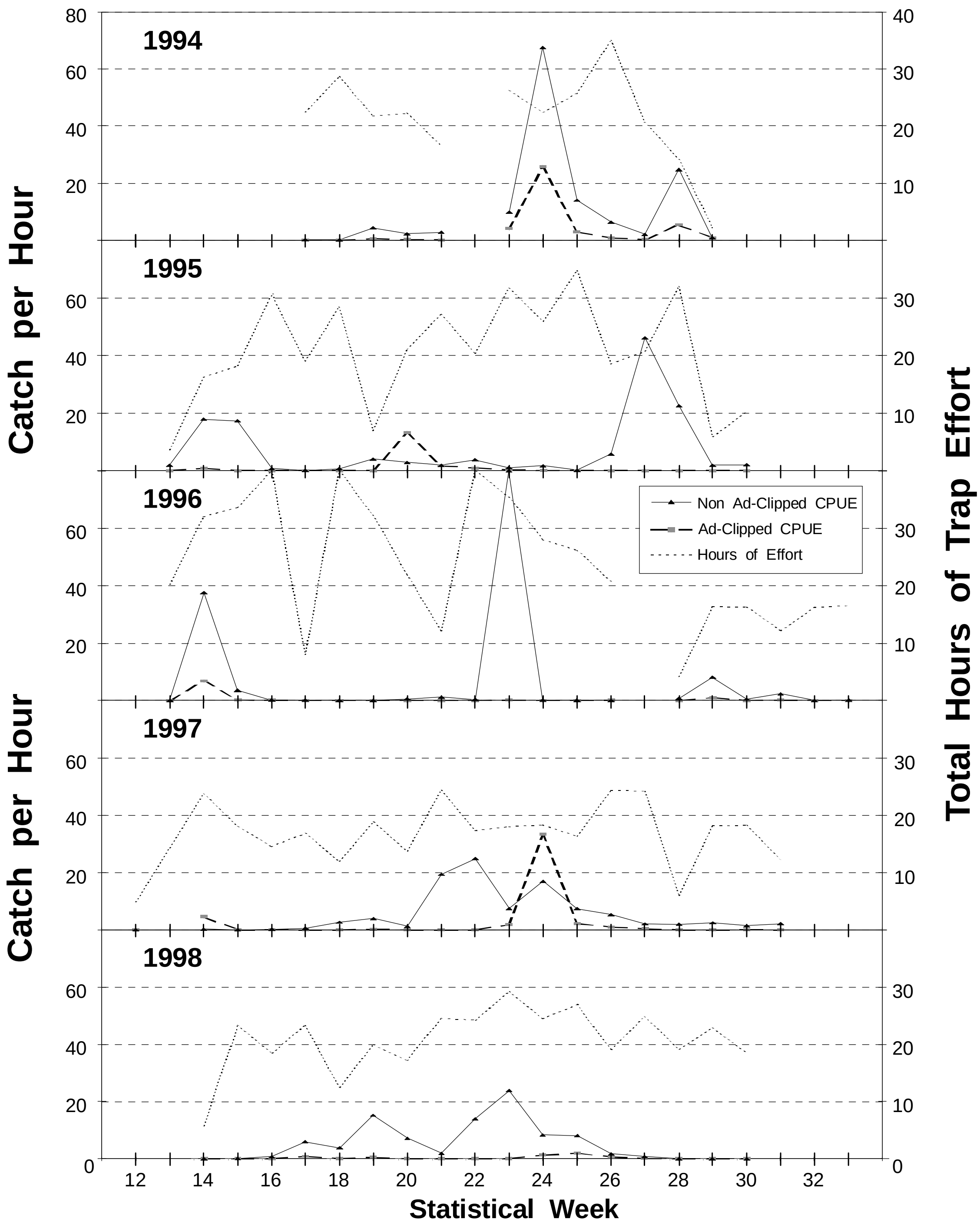


Figure 11. Summary of CPUE (catch per hour) of chinook salmon smolts during each statistical week by the Nooksack screwtrap for the years 1994 through 1998. CPUE of adclipped and non-adclipped fish is shown separately in addition to total number of hours of trap effort for the statistical week.

1995: There were two prominent peaks in CPUE for non-adclipped fish. The first, smaller peak occurred during statistical weeks 14 and 15 in early and mid April (2 to 15 April). The second, larger peak occurred during statistical weeks 27 and 28 in early and mid July (2 to 15 July). The first peak in non-adclipped CPUE is probably related to the large release of unmarked, age-zero fall chinook smolts 49 km above the trap on 30 March; more than 1.0 million fish were released. The peak non-adclipped CPUE in July was probably influenced by the release of 3.1 million age-zero fall chinook from Kendall Creek Hatchery on 14 June. There was only a single pronounced peak in CPUE of adclipped chinook smolts. This peak occurred during statistical week 20 in mid-May (14 through 20 May). These adclipped fish were probably from the release of 347,540 adclipped yearling smolts at Kendall Creek Hatchery on 1 April. There was also a large release of adclipped, age-zero smolts (178,069 fish) at Kendall Creek Hatchery on 15 May. However, it is unlikely these fish traveled the 66 km distance to the trap in time to contribute to this peak.

1996: There were two prominent peaks in CPUE for non-adclipped fish. The first, smaller peak occurred during statistical week 14 in early April. The second, larger peak occurred during statistical week 23 in early June (2 to 8 June). The first peak in non-adclipped CPUE was a result of the large release of unmarked, age-zero fall chinook smolts at the Ferndale Ramp, 1.8 km above the trap, on 4 April; about 700,000 fish were released. The peak non-adclipped CPUE in June was a result of the second large release of unmarked, age-zero fall chinook smolts at the Ferndale Ramp on 3 June; about 2.4 million fish were released. There was only a single pronounced peak in CPUE of adclipped chinook smolts. This peak occurred during statistical week 14 in early April (31 March through 6 April). These adclipped fish were probably from the release of 183,545 adclipped yearling smolts from Kendall Creek Hatchery on 1 April. This was the only large release of adclipped chinook salmon smolts into the Nooksack River in 1996.

1997: In 1997 there was a single prolonged period of relatively high CPUE for non-adclipped fish and a single peak for adclipped chinook smolts. The period of high CPUE began in statistical week 21 (18 to 24 May) and continued for five weeks through statistical week 26 (22 to 28 June). This period of elevated CPUE of non-adclipped chinook smolts cannot be attributed to any specific release but was probably influenced by the release of about 450,000 unmarked, age-zero spring chinook smolts into upriver ponds (90 to 96 km above the trap) between 25 April and 29 May. The single pronounced peak in CPUE of adclipped chinook smolts occurred during statistical week 24. These adclipped fish were probably from the release of 180,014 adclipped age-zero smolts from Kendall Creek Hatchery on 1 June. The only other large release of adclipped chinook salmon smolts into the Nooksack River in 1997 was 187,765 yearling spring chinook smolts from Kendall Creek Hatchery on 1 April. It is unlikely that these fish were still out-migrating from the system in early June and contributed to this peak in CPUE.

1998: There were two peaks in CPUE for non-adclipped chinook smolts in 1998. The first, smaller peak occurred during statistical week 19 in early May (3 to 9 May). The second, larger peak occurred during statistical week 23 in early June (31 May to 6 June). There were no single, large releases of hatchery-reared juvenile chinook salmon into the Nooksack system in 1998. Instead, there were numerous smaller releases; between 15 April and 30 May about

1.2 million age-zero spring chinook were released at sites from 66 to 96 km above the trap site. There were two releases of adclipped chinook smolts into the system in 1998. There was a release of 151,516 adclipped yearling spring chinook smolts from Kendall Creek Hatchery on 1 April and a release of 202,802 adclipped age-zero spring chinook from Kendall Creek Hatchery on 12 June. There was never a prominent peak in CPUE for adclipped chinook smolts in 1998. Adclipped chinook smolts were present in most screwtrap sets from 12 through 28 June (Figure 10), however, the catches were not large.

Summary: For the five years of data examined, all occurrences of weekly CPUE values of about 20 or more chinook salmon smolts per hour can be attributed to releases of hatchery fish into the Nooksack River system above the trap. *This seems to indicate that the out-migration of native chinook salmon smolts occurs at very low levels and does not produce prominent peaks in CPUE which can be directly associated with native fish.* Also, there may be a "flushing" phenomena associated with the hatchery fish relative to the native fish that we cannot detect. That is, when there is a large pulse of out-migrating, hatchery fish moving down river the native fish might join this migration where they cannot be distinguished from the non-adclipped hatchery fish in the catches. There does appear to be a constant low level of out-migration of chinook salmon smolts from at least early April through late July. Until there are methods that can better estimate the stock composition of the non-adclipped catch of chinook salmon smolts, we cannot determine the out-migration timing of the native stocks.

Correlation Between River Discharge and CPUE:

The correlations between total CPUE for a sample day and the mean hourly river discharge for that day (measured in cfs), and their significance, are summarized for each year in Table 3. Seven days of data were omitted in 1996 due to the obvious influence of the release of hatchery smolts at the Ferndale Ramp on CPUE. The correlation coefficients were generally higher when the sets with zero catch were included in the analysis, but only marginally so. For Pearson's r, the only significant correlations ($P \leq 0.05$) were those which included zero-catch sets in the data for 1994 and 1998. At least one of the nonparametric correlations coefficients was significant each year and in three years (1994, 1995, 1998) both were significant (zero-catch sets included and zero-catch sets excluded). Considering both coefficients (Pearson's and Spearman's) together, we interpret the results to indicate that higher CPUE values <u>generally</u> occur with higher peak flow values, but the relationship is not strictly linear. Inspection of the plots of these data demonstrates this (Figure 12). While CPUE values generally increase as flow increases, and there are fewer zero-catch sets at higher flows, the highest CPUE values often occur during intermediate flows.

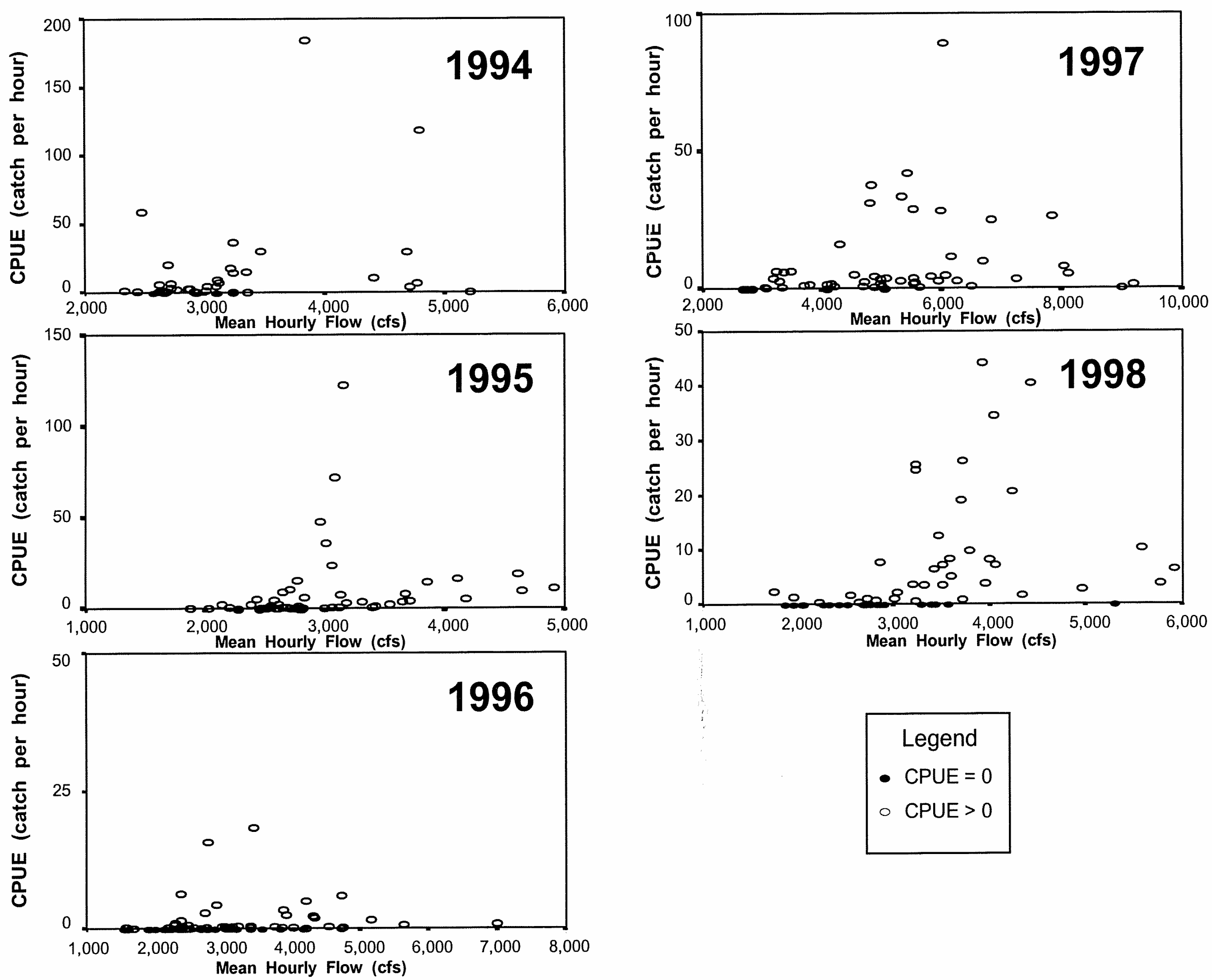


Figure 12. Plots of mean hourly river flow versus daily CPUE of chinook salmon smolts for the screwtrap in the Nooksack River, by year.

Table 3. Summary of Pearson's r and Spearman's rho correlation coefficients between mean hourly river flow (in cfs) for a sample day and CPUE of chinook salmon smolts by the screwtrap for the sample day.

	Includes	Pearson's r			Spearman's rho		
	0-Catch	Correl-	Sample	Signifi-	Correl-	Sample	Signifi-
Year	Sets	ation	Size	cance[a]	ation	Size	cance[a]
1994	Yes	**0.319**	41	0.042	**0.311**	41	0.048
	No	0.312	37	0.060	**0.353**	37	0.032
1995	Yes	0.191	55	0.163	**0.583**	55	0.000
	No	0.175	51	0.220	**0.585**	51	0.000
1996	Yes	0.138	69	0.260	**0.445**	69	0.000
	No	0.049	46	0.748	0.262	46	0.078
1997	Yes	0.198	54	0.151	**0.382**	54	0.004
	No	0.149	49	0.305	0.251	49	0.082
1998	Yes	**0.359**	57	0.006	**0.624**	57	0.000
	No	0.250	37	0.136	**0.536**	37	0.001

[a] Coefficients which are significant ($P \leq 0.05$) are in bold.

Differences Between Daytime and Nighttime CPUE:

Data from 1996, 1997, and 1998 were examined for differences between daytime and nighttime CPUE values for the screwtrap. Because the time of sampling during these years was randomized across the entire day, we assume that over the entire sample season consistent differences in CPUE between daytime and nighttime sets would become evident. There were no significant differences (all $P > 0.54$) in the rate of occurrence of zero-catch sets (sets where no chinook salmon smolts were caught) between daytime and nighttime sets during the three years (Table 4). Although there were fewer sets made during the nighttime period each year, the nighttime sets are represented roughly in proportion to the number of nighttime hours during the period 1 April through 31 July[7]. Unfortunately, because of the relatively small number of sets used in these tests, they could only detect differences in the rate of occurrence of zero-catch sets of 30% to 40% or more with power ≥ 80% (Peterman 1990).

[7] About 70% of the hours during this period fall during civil twilight.

Table 4. Comparison of the rate of occurrence for zero-catch sets between daytime and nighttime sets, and results of Fisher's exact test comparing the rates, for the screwtrap operated on the Nooksack River.

Year	Time of Day	Number of Sets Catch = 0	Catch > 0	Total	Percent w/ 0 catch	Significance χ^2 test (P)
1996	Day	40	42	82	48.8%	
	Night	14	20	34	41.2%	0.541 NS[a]
1997	Day	5	42	47	10.6%	
	Night	0	14	14	0.0%	0.580 NS
1998	Day	17	31	48	35.4%	
	Night	5	7	12	41.7%	0.744 NS

[a] NS = not significant, $P > 0.05$.

Mann-Whitney tests were used to compare the mean rank of the CPUE values for the sets in each category (daytime or nighttime). Data from thirteen sets were omitted in 1996 due to the obvious influence of the release of hatchery-reared smolts at the Ferndale Ramp on CPUE. CPUE values of daytime and nighttime sets were compared including and excluding zero-catch sets. The results are summarized in Table 5. Mean CPUE of chinook salmon smolts for nighttime sets was nearly twice that of daytime sets in 1997. However, in 1998 daytime sets had a higher CPUE than nighttime sets. In 1996 the CPUE values for the two groups were about the same. There were no significant differences between mean ranks of the CPUE values for daytime and nighttime sets, however (all $P > 0.23$). Because of the small number of sets used in these tests, and the variability of the data, these tests could only detect differences in the mean rank of CPUE between the groups of four or more times with power ≥ 80% (e.g., a mean CPUE of 0.6 fish per hour compared to a CPUE of 2.4 fish per hour).

Summary: There is no strong evidence that there is a difference in CPUE of out-migrating chinook salmon smolts between daytime and nighttime sets. In one year nighttime sets had a greater mean CPUE than daytime sets, in one year the CPUE for the two groups was about the same, and in one year daytime sets had a greater mean CPUE than nighttime sets. The data used for these analyses were sufficient for detecting only very large differences between the groups with adequate power (power ≥ 80%). The mean CPUE of one group would need to have been four or more times greater than the other group to be detected with power ≥ 80%. Because of the limitations of these data, a definite conclusion as to whether there are differences in CPUE between daytime and nighttime sets is not warranted. Given this, future sample designs should continue to sample daytime and nighttime hours in proportion to their frequency of occurrence, i. e., there should be no stratification. If a more definitive answer is needed for this question, experiments designed to examine the issue should be used.

Table 5. Comparison of CPUE of chinook salmon smolts by daytime and nighttime sets, and results of the Mann-Whitney test comparing the groups, for the screwtrap operated on the Nooksack River.

Year	Time of Day	Mean CPUE	Standard Error	Sample Size	Significance of Test (P)
		Data includes zero-catch sets			
1996	Day	1.182	0.417	82	
	Night	1.285	0.806	34	0.837 NS[a]
1997	Day	7.323	1.512	47	
	Night	15.476	7.481	14	0.289 NS
1998	Day	7.421	1.895	48	
	Night	4.199	2.199	12	0.346 NS
		Data excludes zero-catch sets			
1996	Day	2.308	0.780	42	
	Night	2.184	1.347	20	0.270 NS
1997	Day	8.195	1.643	42	
	Night	15.476	7.481	14	0.609 NS
1998	Day	11.490	2.674	31	
	Night	7.198	3.406	7	0.234 NS

[a] NS = not significant, $P > 0.05$.

Estimation of Screwtrap Capture Efficiency

Experiments were conducted in 1995, 1996, 1997, and 1998 to estimate the capture efficiency of the screwtrap for out-migrating chinook salmon smolts. We define capture efficiency as the percentage of the chinook salmon smolts migrating downstream past the trap during any period of time that are captured by the screwtrap. Previous research has shown that the efficiency of traps in capturing out-migrating salmon smolts can be affected by: velocity of the water moving past a trap (Seiler et al. 1995; Roper and Scarnecchia 1996); time of day, i.e. day or night (Seiler et al. 1995); size of the fish (Seiler et al. 1995; Roper and Scarnecchia 1996); species, life stage (Thedinga et al. 1994); and origin of the fish, hatchery or wild (Roper and Scarnecchia 1996); as well as river stage and trap placement within the channel (Thedinga et al. 1994). In addition, we examined the clarity of the water as a possible influencing factor.

Methods

Capture-efficiency trials were conducted by releasing a known number of marked, hatchery-reared chinook salmon smolts upstream of the trap site and then enumerating the number of these marked smolts recaptured at the trap. Marked smolts were released in two groups so that we could examine whether smolts were mixing across the river channel prior to being exposed to capture by the screwtrap. Each release group was split into approximately equal numbers. The upper lobe of the caudal fin of one group was clipped and the lower lobe of the caudal fin was clipped on the other group. The two groups were then released from opposite banks of the Nooksack River. In addition to the caudal fin clip, all fish used in the capture-efficiency trials were marked with Bismark brown to aid in the identification of marked fish. Fish were dyed following methods similar to previous studies (Goldsmith 1993; Rawson 1984).

All chinook salmon used in the capture-efficiency trials came from Kendall Creek Hatchery. Age-zero fish were used in every trial. In 1995 and 1996, the age-zero chinook salmon smolts used in the trials were of Green River Fall stock origin. In 1997 and 1998, the age-zero chinook salmon smolts used in the trials were of North Fork Nooksack spring stock origin. Fall chinook salmon smolts were used in the earlier years due to the lack of surplus native spring chinook salmon smolts. Generally these smolts were fin clipped one or two weeks prior to being used in the capture-efficiency trials. Fork length measurements were taken from fish released in 10 of the 14 capture-efficiency trial release groups used from 1995 through 1998. These measurements were taken from approximately 100 fish while they remained anesthetized during the clipping operation. We chose not to measure fish immediately before the experiment to minimize handling stress and to reduce mortalities prior to and during the release.

Approximately one to two hours prior to the anticipated release time (depending if the holding site was the Kendall Hatchery or the Lummi Mamoya Pond facility), the caudal-fin clipped fish were transferred to a fish tote containing hatchery water. The two groups of clipped fish were separated by a net barrier within the tote. The tote was oxygenated while the fish were transported to the release site. Prior to leaving the hatchery, Bismark brown stain was added to the water at the manufacturer's recommended concentration of one gram for every 15 gallons of water. When the marked fish arrived at the lower river release site they had been exposed to the stain for approximately 45 to 60 minutes. The two groups of marked fish (one with the upper caudal fin clip and one with the lower caudal fin clip) were then transferred from the tote to separate 30-gallon plastic garbage cans filled with river water which were located in a skiff. The skiff then traveled 0.8 km upstream of the screwtrap site to release the fish for the first five trials in 1995. Subsequent releases were made 1.8 km above the trap. At the release location, the skiff went to a point in the river near the thalweg and slowly moved toward one bank of the stream while fish were spilled into the river from the garbage can. For the second group, the skiff returned to the thalweg and fish were spilled overboard while crossing to the opposite bank. The purpose of this procedure was to distribute each marked group across both sides of the river cross-section.

We deviated somewhat from this procedure for the second capture-efficiency trial conducted in 1996. Fish were released directly from floating net pens located on either bank of the river. This may have caused delayed migration and/or orientation to the stream margin, both of which would reduce recoveries at the trap during the sampling period. In the second, third, and fourth capture-efficiency trials in 1996, the fish were allowed to acclimate to river conditions following transport from the hatchery facility and prior to release by holding them in net pens for a period of six to sixteen hours prior to transfer to the skiff for release.

In all but the first trial, the screwtrap was in operation before the release of the marked fish. For the first trial, the trap was not fished until 20 minutes after the fish were released. The screwtrap was always operated for at least 10 consecutive hours after the release of the marked fish. Recoveries at the trap were recorded by their fin clip status (upper caudal fin clip, lower caudal fin clip, no clip). Clipped fish were identified by their yellow-gold color resulting from the Bismark brown stain. Following anesthetization with MS-222, all juvenile chinook salmon caught in the trap during the capture-efficiency trial were measured for fork length. This measurement provided an opportunity to closely examine the caudal fin of every fish to detect the presence of an upper or lower caudal fin clip.

Several assumptions are required for the capture-efficiency experiments and the estimates derived from them. They are:

1. All marked (caudal fin clipped) chinook salmon smolts were identified in the screwtrap catches.
2. All marked smolts migrated downstream after release and were available for capture by the trap during the period of continuous trap operation after their release (there was no prolonged residence time of the marked fish in the river above the trap).
3. There was no mortality of marked smolts before they migrated past the trap.

Data Analysis

Analyses were conducted to determine if some of these assumptions were supported by the data. We hypothesized that if the marked smolts were distributing themselves across the river channel similarly to the naturally-migrating fish, then an equal proportion of the right bank and left bank releases would be captured by the screwtrap. A significant difference between the recapture proportions of the right bank and left bank releases may indicate that the marked fish were not distributing themselves in the naturally out-migrating population and were staying oriented to the bank nearest their point of release. The χ^2 statistic and Fisher's exact test (Conover 1980) were used to compare the right bank and left bank recapture numbers, relative to the numbers released at each bank, for each experiment.

The time required for the marked fish to migrate downstream and pass the trap site was examined by constructing a recapture profile for each release. The recapture profile plots the cumulative percentage of the total recoveries of marked fish from each release, for each time the trap was checked, against the number of hours from the time of release. Average time to first recovery and average time between the last recapture and the end of screwtrap operation were calculated, also. These were used to help determine if recaptures may have been missed because trap effort during a particular capture-efficiency trial was too short.

Several environmental parameters were measured and their correlation with capture efficiency examined. The details on how these data were collected are described in the first section of this report. The environmental parameters were:

1. Secchi depth in m.
2. River discharge in cfs.
3. River turbidity measured in ntus.

The relationships between capture efficiency and the three environmental parameters were examined using both linear and nonlinear regression. The environmental parameters were the independent (explanatory) $\boldsymbol{X}$ variables and capture efficiency ($\boldsymbol{\theta}$) was the single, dependent $\boldsymbol{Y}$ variable. Several models were evaluated to determine which best fit the data. The regression models evaluated for each environmental parameter were:

1. a linear model: $\boldsymbol{\theta} = \boldsymbol{\alpha} \bullet \boldsymbol{X} + \boldsymbol{\beta}$.
2. a logarithmic model: $\boldsymbol{\theta} = \boldsymbol{\alpha} \bullet \mathrm{LN}(\boldsymbol{X}) + \boldsymbol{\beta}$.
3. an inverse model: $\boldsymbol{\theta} = \boldsymbol{\alpha} \bullet (1/\boldsymbol{X}) + \boldsymbol{\beta}$.
4. a quadratic model: $\boldsymbol{\theta} = (\boldsymbol{\alpha}_1 \bullet \boldsymbol{X}) + (\boldsymbol{\alpha}_2 \bullet \boldsymbol{X}^2) + \boldsymbol{\beta}$.
5. a power model: $\boldsymbol{\theta} = \boldsymbol{\beta} \bullet \boldsymbol{X}^{\boldsymbol{\alpha}}$.
6. an exponential model: $\boldsymbol{\theta} = \boldsymbol{\beta} \bullet e^{\boldsymbol{\alpha X}}$.

Where $\boldsymbol{\theta}$ is capture efficiency and $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ represent the slope and intercept parameters, respectively, in the typical regression model. All models except the quadratic model were two-parameter models and had identical degrees of freedom. Parameters of the regression models, including standard errors and significance levels, were estimated using the linear and nonlinear regression routines in the SPSS statistical computing package (Norusis 1994).

The fit of each regression model to the data was assessed using the coefficient of multiple determination (r^2) and residual mean square error (MSE) statistics (Draper and Smith 1981). The r^2 statistic is a measure of the amount of variation about the mean of the dependent variable explained by the fitted equation. The residual MSE is the calculated as $\sum$(observed $\boldsymbol{Y}$ - predicted $\boldsymbol{Y}$)^2 divided by the residual degrees of freedom. The model with the highest r^2 statistic and the lowest MSE value is generally considered superior (i.e., considered the "best fit") when comparing models based on the same data set (Draper and Smith 1981).

Some previous research has found differences in trap capture efficiencies between trap effort during daylight hours compared to trap effort during nighttime hours (Seiler et al. 1995). We examined our capture efficiency estimates for evidence of this phenomenon. The 14 capture-efficiency trials were classified as either daytime or nighttime trials depending upon whether the majority of the first 10 hours after release of the marked smolts was in light or dark. The hours of sunrise and sunset each day, and the timing of civil twilight, were used to determine the light level for each hour (light or dark). A significant difference between these two groups in the dependent variable (capture efficiency) could be due to differences between the groups in one of the independent variables (environmental parameters), if the independent variable has a significant influence on capture efficiency. Analysis of variance with a covariate (Milliken and Johnson 1995) was used to address this problem. Analysis of variance with a covariate (ANOVAWC) is used to test for differences between group means of a dependent variable controlling for the effect of a concomitant variable (usually called a covariate). The covariate must be a continuous variable whose effects are linear. The effect of the covariate is controlled for by adjusting the means of the dependent variable to account for the difference between the two groups in the covariate (Milliken and Johnson 1995). Therefore, the possible confounding effects on the dependent variable, due to differences in the distributions of the covariate for the two groups, are removed. ANOVAWC was used to test for a difference in mean capture efficiency between daytime and nighttime trials. The model with the most significant environmental parameter (independent variable) identified following the procedures in the previous paragraph was used as the covariate. The ANOVAWC was conducted following the procedures described in Milliken and Johnson (1995). Two important requirements of ANOVA tests are that all groups compared come from normally distributed populations with equal variances (homogenous variance assumption). While most ANOVA procedures are robust to departures from normality they can be sensitive to violations of the homogeneous variance assumption (Milliken and Johnson 1992). Levene's test for homogeneity of variances (Milliken and Johnson 1992) was used to test the data for this assumption.

Because one goal of this project is to eventually estimate the total out-migration of chinook salmon smolts from the Nooksack River, it is important that the smolts used in the capture-efficiency trials are representative of those in the out-migrating population. For most of the capture-efficiency trials, we collected length information from a random sample of the smolts to be released. We calculated mean and median fork lengths, standard error of the mean, and coefficient of variation for each group of these fish. Box-and-whiskers plots were used to display their fork length distributions.

Results

Trap Capture Efficiency Effort and Recovery Summary

The date, time, hours of screwtrap operation, and release location of marked fish for the 14 capture-efficiency trials conducted from 1995 through 1998 are summarized in Appendix Table 8. The hours of continuous operation of the screwtrap after the release of the marked chinook salmon smolts above the trap ranged from 10.4 to 24.7 hours (mean: 15.3 hours). The time between release and the first recapture of a marked chinook salmon smolt at the screwtrap was recorded for eight of the capture-efficiency trials (Appendix Table 9). The average time to the first recovery was 29.5 minutes for these trials (range 13 to 37 minutes). In nine of the 14 trials, all marked fish recovered were caught within the first four hours after release (Appendix Table 10). For these nine trials, the screwtrap was operated for at least ten hours (range 10 to 21 hours) after the last recovery without any additional recoveries. The recapture profiles for all but the first capture-efficiency experiment were very similar (Appendix Figure 1). The recaptures for the first trial occurred over a more extended period of time in comparison to the 13 other trials.

Using the Bismark brown as a secondary mark increased our effectiveness in detecting marked fish, especially during the first part of a sampling period. We don't know how long the stain remained visually detectable. In 1995, there were about 18 hours between the release and recovery of the last smolts during the first capture-efficiency trial and these fish were still visibly colored. It is possible that reliance on the stain mark could have negatively affected our effectiveness during the later part of an experiment if the stain faded sufficiently to avoid detection. The stain was especially useful in determining the time that the first marked fish was captured during days when water clarity allowed observation of the live box while the trap was in operation. This helped to alert crews of the onset of recoveries.

Examination of the occasional mortalities which occurred while transporting the fish from the hatchery facility indicated that the caudal fin clip remained identifiable, even when fish had some fungus growth and abrasion of the lower lobe due to hatchery rearing.

Capture Efficiency Estimates

The releases of marked chinook salmon smolts ranged from 732 to 1,993 fish for the 14 capture-efficiency trials (Table 6). Marked smolts were recaptured at the screwtrap during every capture-efficiency trial. The total number of marked fish recaptured ranged from 2 to 72 fish. Estimated capture efficiencies ranged from 0.14% to 5.62% (Table 6). In four of the 14 trials, there was a significant difference in the recovery rate between the right and left bank releases of marked fish (Table 6). There was no trend apparent in these four trials of one bank consistently having a higher recapture rate than the other.

Table 6. Summary of the release and recapture data for the capture-efficiency trials conducted from 1995 through 1998.

Trial Code	Release Date	Right Bank Rel.	Right Bank Recap.	Left Bank Rel.	Left Bank Recap.	Test[a] Signif.	Totals Rel.	Totals Recap.	Capture Eff. (θ)	95% Confidence Interval
95(1)	18-Apr-95	995	4	998	15	**0.019**	1,993	19	0.953%	0.527% - 1.380%
95(2)	2-May-95	986	25	984	16	0.206	1,970	41	2.081%	1.451% - 2.712%
95(3)	16-May-95	564	50	628	17	**0.000**	1,192	67	5.621%	4.313% - 6.929%
95(4)	23-May-95	981	14	952	15	0.853	1,933	29	1.500%	0.958% - 2.042%
95(5)	31-May-95	468	28	468	12	**0.014**	936	40	4.274%	2.977% - 5.570%
95(6)	7-Jun-95	451	7	281	3	0.749	732	10	1.366%	0.525% - 2.208%
96(1)	28-May-96	799	0	800	7	**0.015**	1,599	7	0.438%	0.114% - 0.761%
96(2)	7-Jun-96	789	6	785	4	0.753	1,574	10	0.635%	0.243% - 1.028%
96(3)	14-Jun-96	777	1	709	1	1.000	1,486	2	0.135%	-0.052% - 0.321%
96(4)	17-Jun-96	782	1	764	2	0.620	1,546	3	0.194%	-0.025% - 0.413%
96(5)	27-Jun-96	784	4	785	3	0.726	1,569	7	0.446%	0.116% - 0.776%
97	20-May-97	826	35	819	37	0.810	1,645	72	4.377%	3.388% - 5.366%
98(1)	28-May-98	899	20	899	18	0.870	1,798	38	2.113%	1.448% - 2.778%
98(2)	4-Jun-98	893	3	896	5	0.726	1,789	8	0.447%	0.138% - 0.756%

[a] Significance of Fisher's exact test of equal marked fish recapture rates for the right and left bank releases. Significant tests ($P < 0.05$) are in bold.

Relationship Between Environmental Parameters and Capture Efficiency

The relationships between capture efficiency and the three environmental parameters examined are shown in Figure 13. The data are summarized in Appendix Table 11. Capture efficiency clearly declined as secchi depth increased (Figure 13A) which indicates that as the water clarity increased capture efficiency decreased. There is a positive correlation between river discharge and capture efficiency (Figure 13B); generally, as flow increases so does capture efficiency. There is a similar positive correlation between river turbidity and capture efficiency (Figure 13C). This reflects the same inverse relationship with water clarity as secchi depth, as water clarity decreases capture efficiency increases.

The model which best explained the variability in capture efficiency was the inverse model with secchi depth (Table 7). This model has the highest r^2 value (84.1%) and the lowest residual MSE. The models with the three highest r^2 values (and three lowest residual MSE values) were models using secchi depth as the independent (***X***) variable. None of the models with river discharge as the independent variable explained more than 43% of the variability in capture efficiency. The highest r^2 value for the models using turbidity as the independent variable was less than the lowest r^2 value for the models using secchi depth as the independent variable. Clearly, secchi depth measured at the screwtrap explains more of the variability in capture efficiency than the other two environmental variables.

Based on the r^2 and MSE statistics, we selected the inverse model using secchi depth as the "best" model for predicting the capture efficiency of the screwtrap. The parameter estimates, their standard errors, and the significance of the parameters for this model are summarized in Table 8. Both model parameters (slope and intercept) are highly significant ($P < 0.01$). The fit of this model to the observed data is shown in Figure 14. We conclude that the strong relationship between secchi depth at the trap and capture efficiency indicates that it is not appropriate to characterize capture efficiency with a single mean value.

Table 7. Fit of different regression models, as measured by r^2 and the residual mean square error (MSE), for the relationship between the three environmental parameters examined (independent ***X*** variables) and capture efficiency (dependent ***Y*** variable).

Parameter:	Secchi Depth		River Discharge		Turbidity	
Model	r^2	MSE x 10^5	r^2	MSE x 10^5	r^2	MSE x 10^5
Linear	65.4%	11.75	42.3%	19.59	47.8%	17.72
Logarithmic	77.5%	7.63	41.5%	19.86	53.8%	15.69
Inverse	84.1%	5.41	38.8%	20.78	48.0%	17.74
Quadratic	81.2%	6.98	42.4%	21.34	63.8%	13.39
Power	65.3%	50,584.20	38.7%	89,524.80	54.1%	67,030.05
Exponential	65.4%	50,589.80	37.3%	91,548.37	45.3%	79,828.13

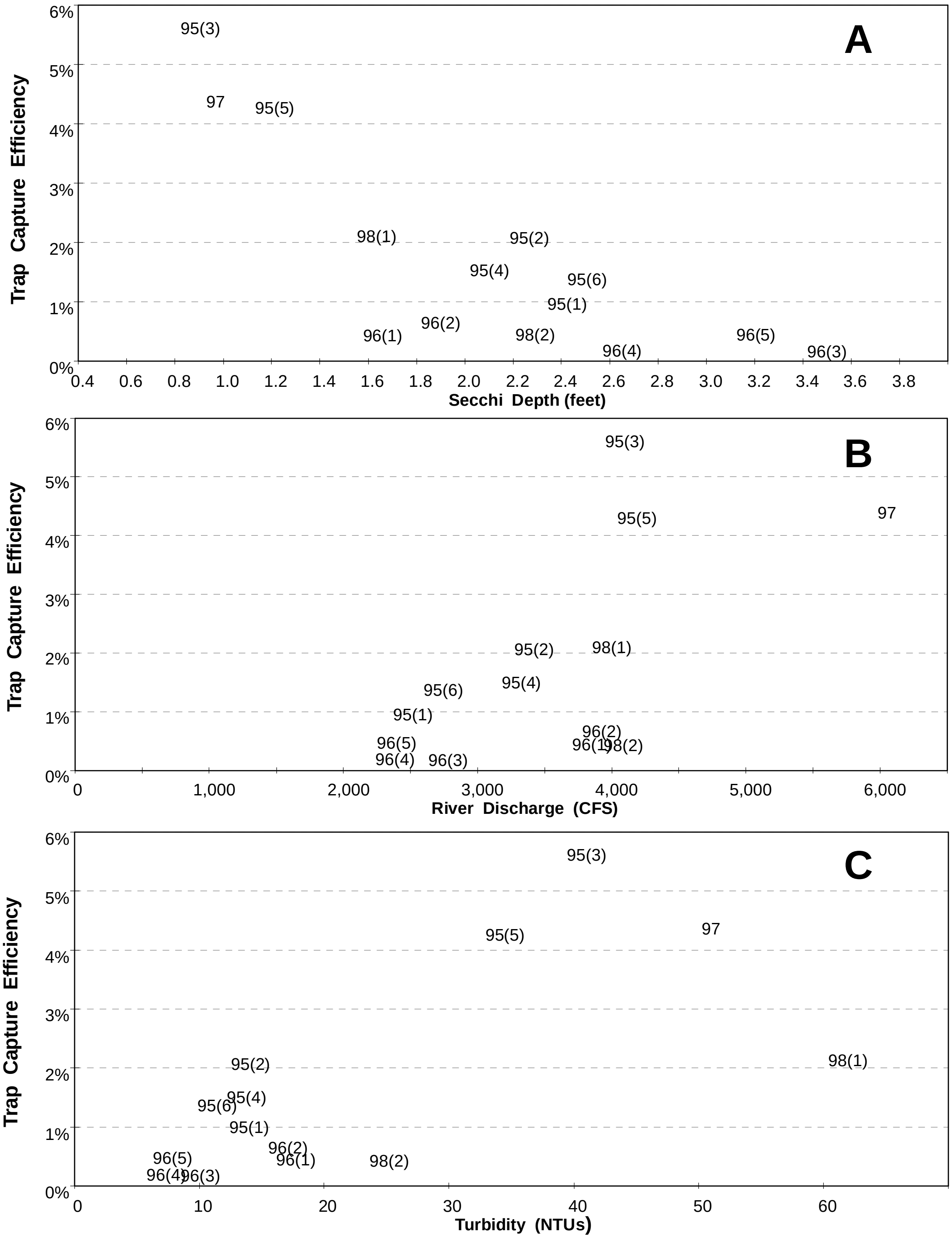


Figure 13. Plots of (A) secchi depth (ft) measured at the screwtrap, (B) river discharge (cfs), and (C) river turbidity (ntus) versus the estimated capture efficiency of the screwtrap for chinook salmon smolts for the 14 trials conducted from 1995 through 1998. Data points labeled by year and trial number (see Appendix Table 8).

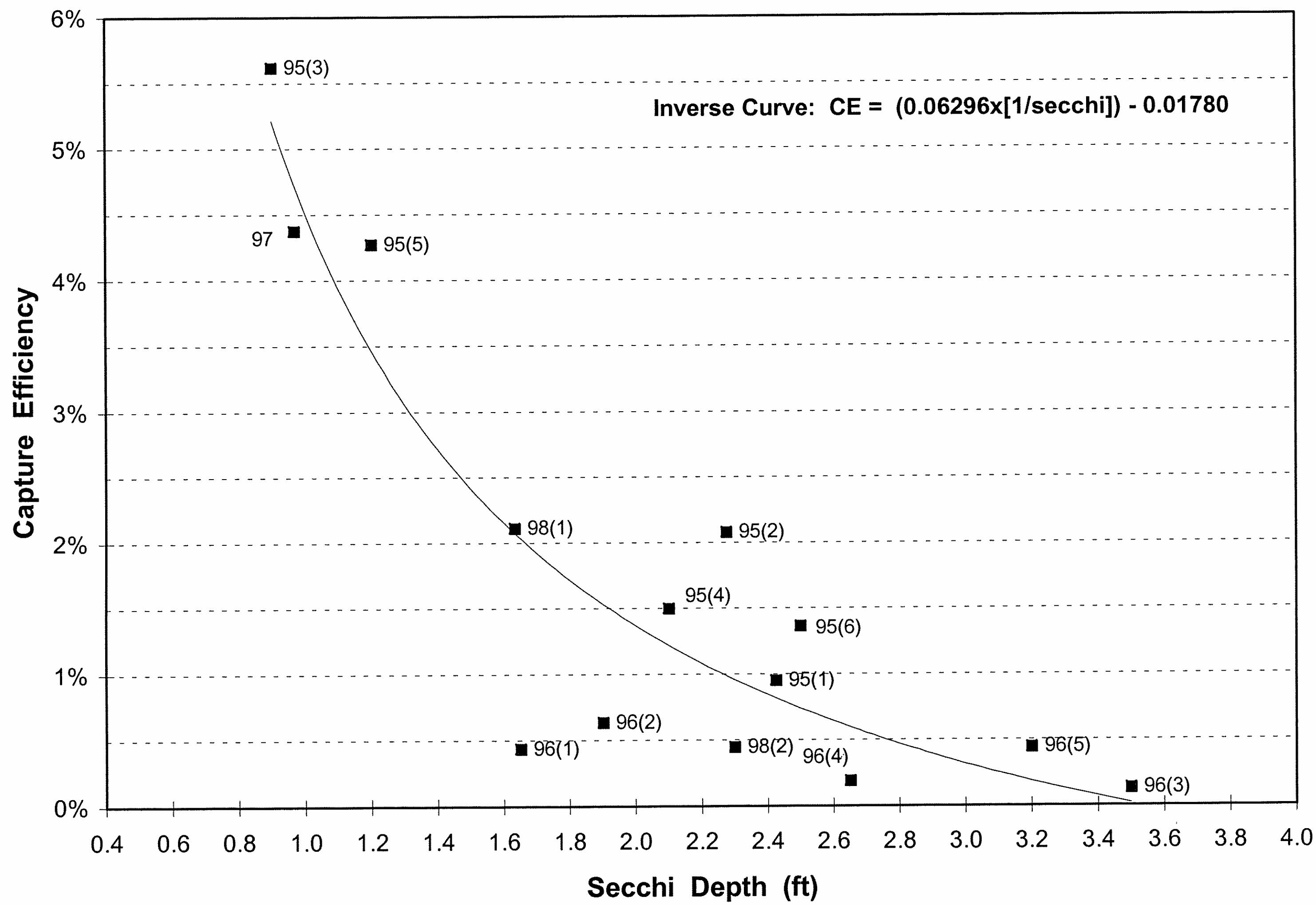


Figure 14. Plot of secchi depth at the screwtrap versus estimated capture efficiency, and the fit of the curve for the inverse secchi model, for the capture-efficiency trials conducted using hatchery-reared chinook salmon smolts, 1995-1998. Data points labeled by year and trial number (see Appendix Table 8).

Table 8. Parameter estimates, their standard errors, significance of the parameters, and 95% confidence interval for the linear regression model of inverse secchi depth (***X***) and capture efficiency (***Y***).

Model Parameter	Estimated Coefficient	Standard Error	Signifi-cance	95% Confidence Interval		
Intercept	-0.01780	0.00486	0.003	-0.02839	-	-0.00721
Slope	0.06296	0.00792	0.000	0.04572	-	0.08021

Comparison of Capture Efficiencies Between Daytime and Nighttime Trials

Based on the previous conclusion, it was necessary to use inverse secchi depth as a covariate in the comparison of mean capture efficiencies of daytime and nighttime trials. Following the procedures of Milliken and Johnson (1995), the results of the analysis of covariance with secchi depth as a covariate indicated that:

- Inverse secchi depth was a significant ($P < 0.01$) covariate and must be included in the analysis model.
- There was not a significant difference ($P = 0.74$) in the response (capture efficiency) to the covariate between daytime and nighttime trials. Therefore, the interaction effect could be removed from the model.
- Controlling for secchi depth, there was not a significant difference in capture efficiency between daytime and nighttime trials ($P = 0.27$).

Levene's test for the equality of group variances between the treatments (daytime and nighttime trials) was not significant for any of the tests (all $P > 0.15$) indicating that ANOVAWC was an appropriate procedure for the analysis. The power of these tests was low (less than 0.20) due to the variability of the data and the small sample size.

Length Analyses

Length information for the smolts used in the capture-efficiency trials was collected from 10 groups of fish; one of these groups was used in two different trials. The number of days between when the length measurements were made and when the marked fish were released varied from 0 to 25 days. This makes direct comparisons of smolt length compositions from the capture-efficiency trials to the length data of chinook smolts captured during normal operation of the trap difficult because of the unknown growth that occurred between the time of measurement and the time of release. Length data from the groups of capture-efficiency smolts which were measured are summarized in Appendix Table 12. Mean lengths of chinook salmon smolts used in the capture-efficiency trials ranged from 55.1 mm (SE = 1.43) to 88.0 mm (SE=0.77). Box-and-whiskers plots comparing the length data of the smolts used in the capture-efficiency experiments to that of fish captured during normal operation of the screwtrap are presented in the next section of this report.

Discussion

We chose to use all the capture efficiency estimates for our examination of the relationship between environmental parameters and capture efficiency. The following factors may have introduced error into our estimates of capture efficiency.

1. The screwtrap was not operating for relatively brief periods of time when marked smolts may have been passing the trap. If additional marked smolts had been captured during these periods, then we have underestimated capture efficiency. This possibly affected trial 95(1) (when the trap was not operated until 30 minutes after the release of the marked smolts) and trials 95(1), 95(2), and 95(3) when debris in the trap required that it be stopped periodically for cleaning (Appendix Table 8).
2. Fungus on the caudal fin may have obscured the caudal fin clips and caused some clips to be missed. This possibly affected trial 95(6). This would cause capture efficiency to be underestimated. Any smolts with clipped caudal fins that were missed when the trap catch was examined would result in an underestimate of capture efficiency.
3. Diseased or stressed smolts used for the capture-efficiency trials may have been more or less susceptible to capture by the screwtrap than "normal" fish. If diseased or stressed fish out-migrate immediately after release, but are unable to avoid capture as well as healthy fish because of a weakened condition, then capture efficiency will be overestimated. If diseased or stressed fish either die immediately after release or are disoriented and do not out-migrate within the same time period as "normal" fish (i.e., they out-migrate after the trial has ended) then capture efficiency will be underestimated. This possibly affected trial 95(6).
4. Water visibility could affect migratory timing. For example, when water clarity is high (high secchi disk measurements), some fish in the release group may orient to wood or other substrates on the river bottom or river margins, causing a delay in downstream migration beyond our sampling period. This would result in an underestimate of capture efficiency.

Although we acknowledge that the capture-efficiency estimates of some trials may have been affected by these factors:

- We do not believe there was sufficient evidence (statistical or otherwise) to identify the data from any capture-efficiency trial as an outlier and therefore exclude that data from the analysis.
- We believe the effects of these factors on the capture-efficiency estimates are relatively small and not sufficient to mask or change the underlying relationship that we have identified between capture efficiency and secchi depth.

There is a considerable variation in the capture-efficiency estimates for secchi depths between 1.60 and 2.80 ft (Figure 14). We suggest that at the extremes of water clarity, water clarity is the primary factor affecting capture efficiency. When water clarity is very poor (reflected by secchi depths less than 1.5 ft) then the capture efficiency of the screwtrap is high, and when water clarity is very high (reflected by secchi depths greater than 3.0 ft) then the capture efficiency of the screwtrap is low. At moderate secchi depths (between 1.5 and 3.0 ft) there are possibly additional factors influencing capture efficiency which we have not yet identified.

We examined the capture-efficiency estimates for the trials with secchi depths in the moderate range (between 1.60 and 2.80 ft) more closely. Six of the eight capture-efficiency trials in this range have length data for the smolts used in the trial. We found a strong negative correlation ($r = -0.772$, $P = 0.072$) between the capture efficiency estimates and the median length for the chinook salmon smolts used in the trap capture-efficiency trials (Figure 15). There is not sufficient data at this time to determine whether this relationship is truly significant and meaningful or an artifact of the small sample size. From a biological viewpoint, this relationship supports the hypothesis that larger smolts are stronger swimmers than smaller smolts and are better able to avoid capture by the screwtrap than smaller fish. If this hypothesis is true, under similar environmental conditions, the screwtrap is less efficient at capturing larger smolts compared to smaller smolts. More data need to be collected to better examine this relationship.

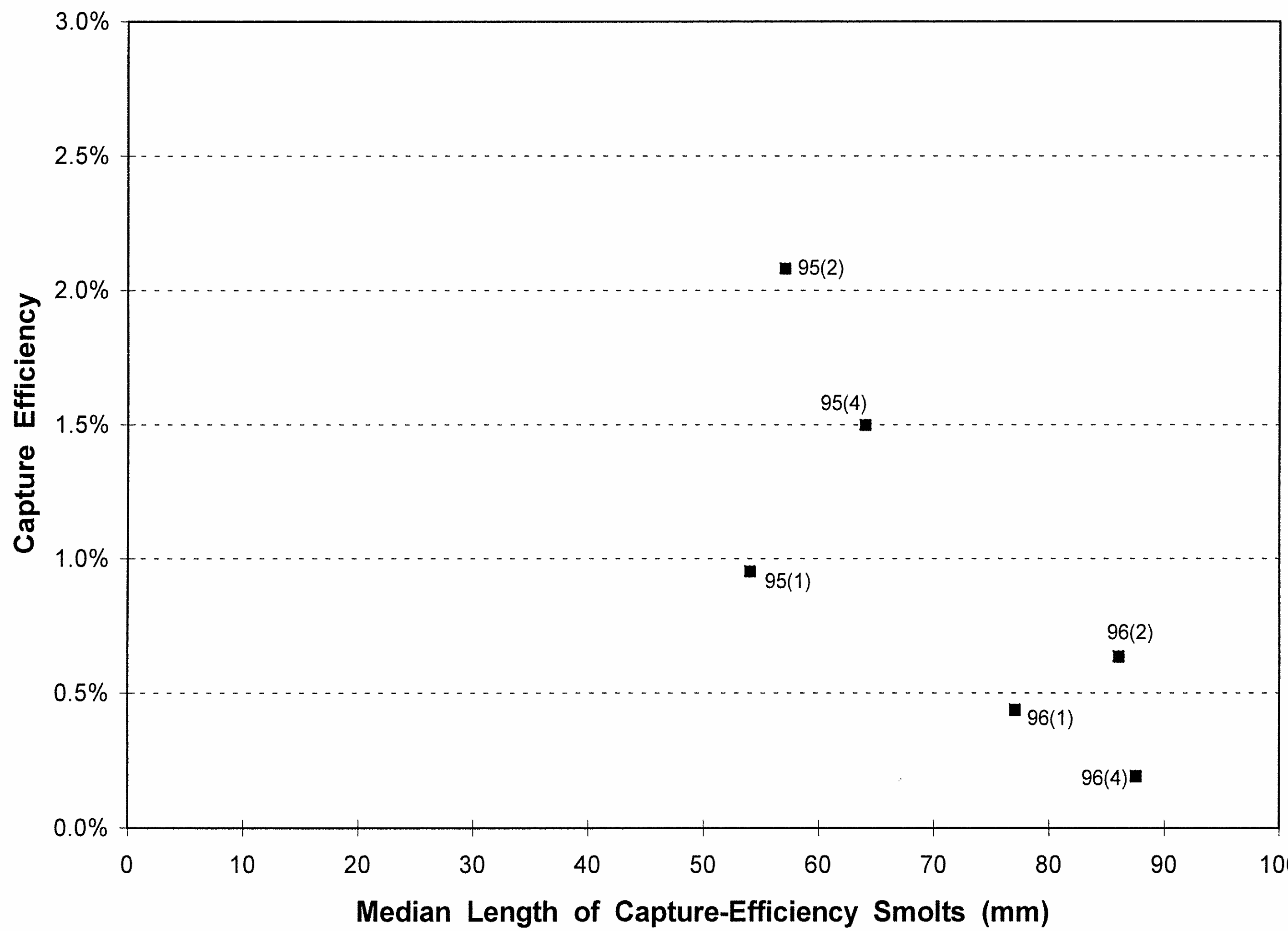


Figure 15. Plot of the median length (mm) of chinook salmon smolts used in the capture-efficiency trials versus estimated capture efficiency, for the trials with secchi depths between 1.65 and 2.80 ft.

Analysis of Fork Length Data

Length data were collected from chinook salmon smolts captured at the trap and from those hatchery-reared smolts used in the capture-efficiency trials. The analyses that follow examine these length data. However, the interpretation of these data must be approached cautiously because:

1. The lengths of fish captured during a set by the screwtrap were not collected from a random sample. Usually, the lengths of the first 20 chinook salmon smolts caught were measured and these lengths may not be representative of the fish caught during the entire set.
2. There was no attempt to weight the length samples to reflect the total number of chinook salmon smolts in the catch. A sample of 20 lengths was taken whether the total catch was 40 chinook salmon smolts or 400 chinook smolts. For catches of 20 or fewer chinook smolts, the lengths of all fish caught were usually measured.

Therefore the mean lengths, graphical summaries of the data, and other summary statistics reported here may not be representative of the larger population of all fish captured. Because the number of chinook smolts measured for length from most sets was small, we accumulated the length data for a statistical week and present length summaries by statistical week. Since there was no weighting of samples to reflect the number of fish in the catch by a set, the summary data for a statistical week may not be representative of the lengths of the chinook smolts caught during the week.

Methods

We graphically summarized the data using both box-and-whiskers plots and length frequency histograms. The box-and-whisker plots show the median length, the central 50% of the distribution of the data (the "box"), the lowest and highest lengths not considered outliers (the box "whiskers"), and lengths considered outliers (Norusis 1994). Lengths more than 1.5 box lengths from the edge of the box were classified as outliers. Length summaries were presented for adclipped and non-adclipped chinook smolts separately in the plots. In addition, means and standard errors for the lengths by statistical week were calculated for each group (adclipped and non-adclipped) separately.

We were interested in identifying by their length yearling chinook salmon smolts in the catches, if possible. Length frequency histograms were used to identify fish which were much larger than the majority of chinook smolts measured. We tentatively classified these fish as yearling (age-1) smolts. Length data were grouped by two time periods for these length frequency histograms: statistical weeks 13 through 21, late March through late May, and statistical weeks 22 through 33, late May through August (Appendix Table 1). We divided the data into these two periods because we observed that typically most of the yearling-sized smolts were caught before 1 June and relatively few were caught after that date.

We also wanted to compare fork length data among the years. To facilitate this comparison, we defined four temporal strata based upon statistical weeks (Appendix Table 1):

1. Statistical weeks 12 through 17 (roughly March and April);
2. Statistical weeks 18 through 21 (roughly May);
3. Statistical weeks 22 through 26 (roughly June);
4. Statistical weeks 27 through 33 (roughly July and early August).

We then plotted the mean lengths of adclipped and non-adclipped chinook smolts during these time strata separately for each of the five years.

Finally, we used box-and-whiskers plots to compare the fork length data for the hatchery-reared chinook salmon smolts used in the capture-efficiency trials to those of chinook smolts captured by the screwtrap during approximately the same time periods as the capture-efficiency trials.

Results

Length data summaries are discussed below by year. The box-and-whiskers plots summarizing lengths of sampled chinook salmon smolts by statistical week are presented first. This is followed by the length frequency distribution analysis to examine the possible contribution of yearling chinook smolts to the catches. Finally, there is a comparison of the length distributions of the smolts used in the capture-efficiency trials to those captured by the screwtrap.

Length Data Summarized by Statistical Week

1994:

The box-and-whiskers plots summarizing the length data collected from catches during each statistical week sampled in 1994 are shown in Figure 16. In general, the median fork length of non-adclipped chinook salmon smolts increased throughout the sampling period. Early in the sampling period (statistical weeks 19 through 21), the lengths of the adclipped chinook smolts were generally larger than the lengths of the non-adclipped smolts. After week 21, the lengths of the two groups were more similar. Most of the lengths classified as outliers belonged to non-adclipped fish. Mean lengths of non-adclipped chinook smolts ranged from 66.6 mm during week 19 to 88.3 mm during week 28 (Appendix Table 13). Adclipped chinook smolts ranged in mean length (for weeks where 10 or more fish were measured) from 76.6 mm during week 23 to 87.5 mm during week 24 (Appendix Table 13).

1995:

The box-and-whiskers plots summarizing the length data collected from catches during each statistical week sampled in 1995 are shown in Figure 17. In general, the median fork length of non-adclipped chinook salmon smolts increased throughout the sampling period. Most of the length data were from non-adclipped chinook smolts; there were only six weeks with length data for adclipped smolts. Statistical weeks 20 through 23 all had sample sizes of ten or more fish for both non-adclipped and adclipped chinook smolts. The adclipped smolts had slightly larger median lengths than the non-adclipped fish. Most of the lengths classified as outliers belonged to non-adclipped fish. Mean lengths of non-adclipped chinook smolts (for weeks where 10 or more fish were measured) ranged from 54.5 mm during week 15 to 88.9 mm during week 29 (Appendix Table 14). Adclipped chinook smolts ranged in mean length from 75.9 mm during week 20 to 83.7 mm during week 23 (Appendix Table 14).

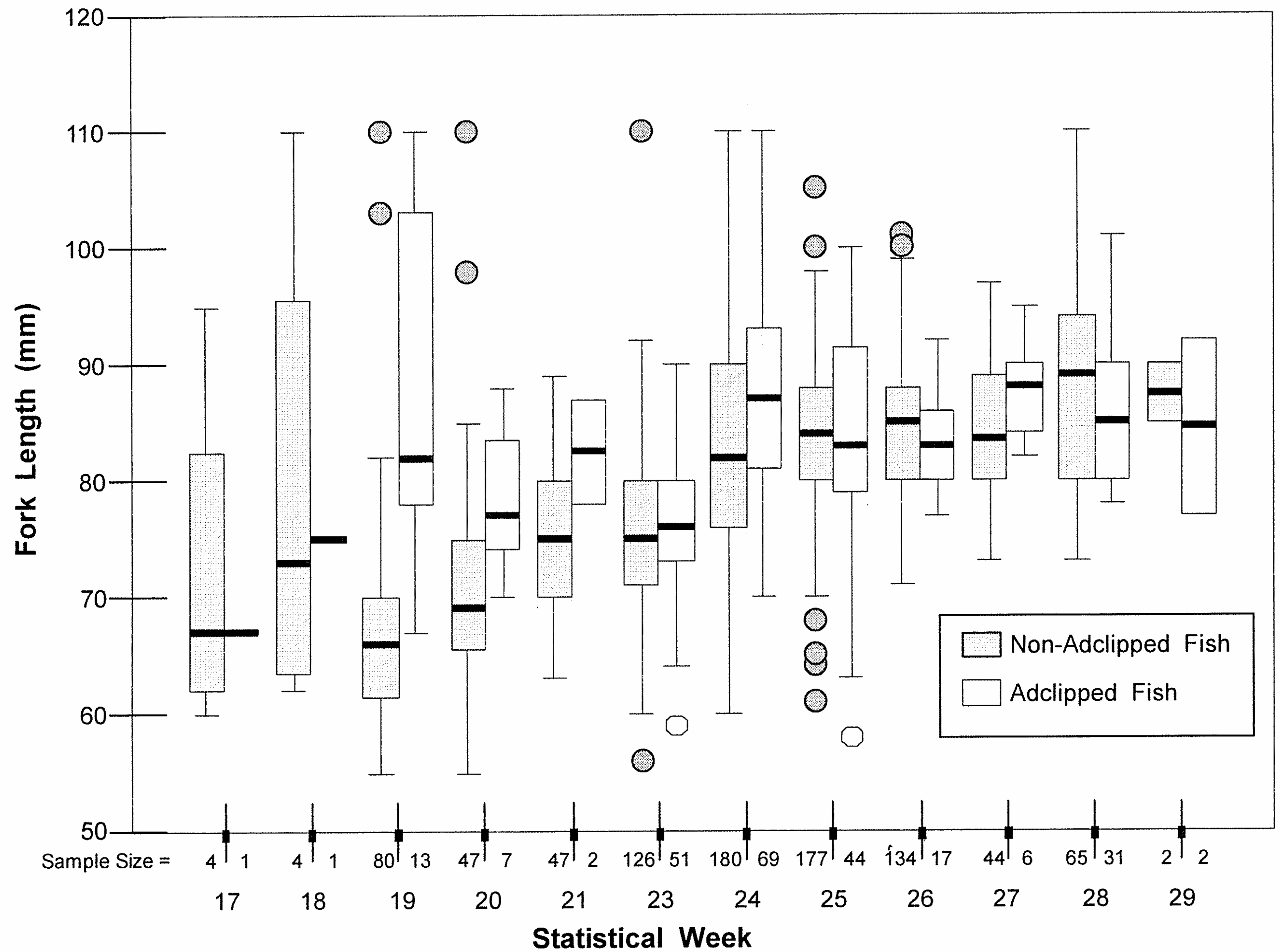


Figure 16. Box plots summarizing length data, by statistical week, collected from chinook salmon smolts caught by the screwtrap operated in the Nooksack River, 1994. Box plots show median length (heavy solid line), the central 50% of the data (box encloses 25th and 75th percentiles), and the lowest and highest lengths not considered outliers (box whiskers). Lengths more than 1.5 box lengths from the edge of the box are considered outliers (o).

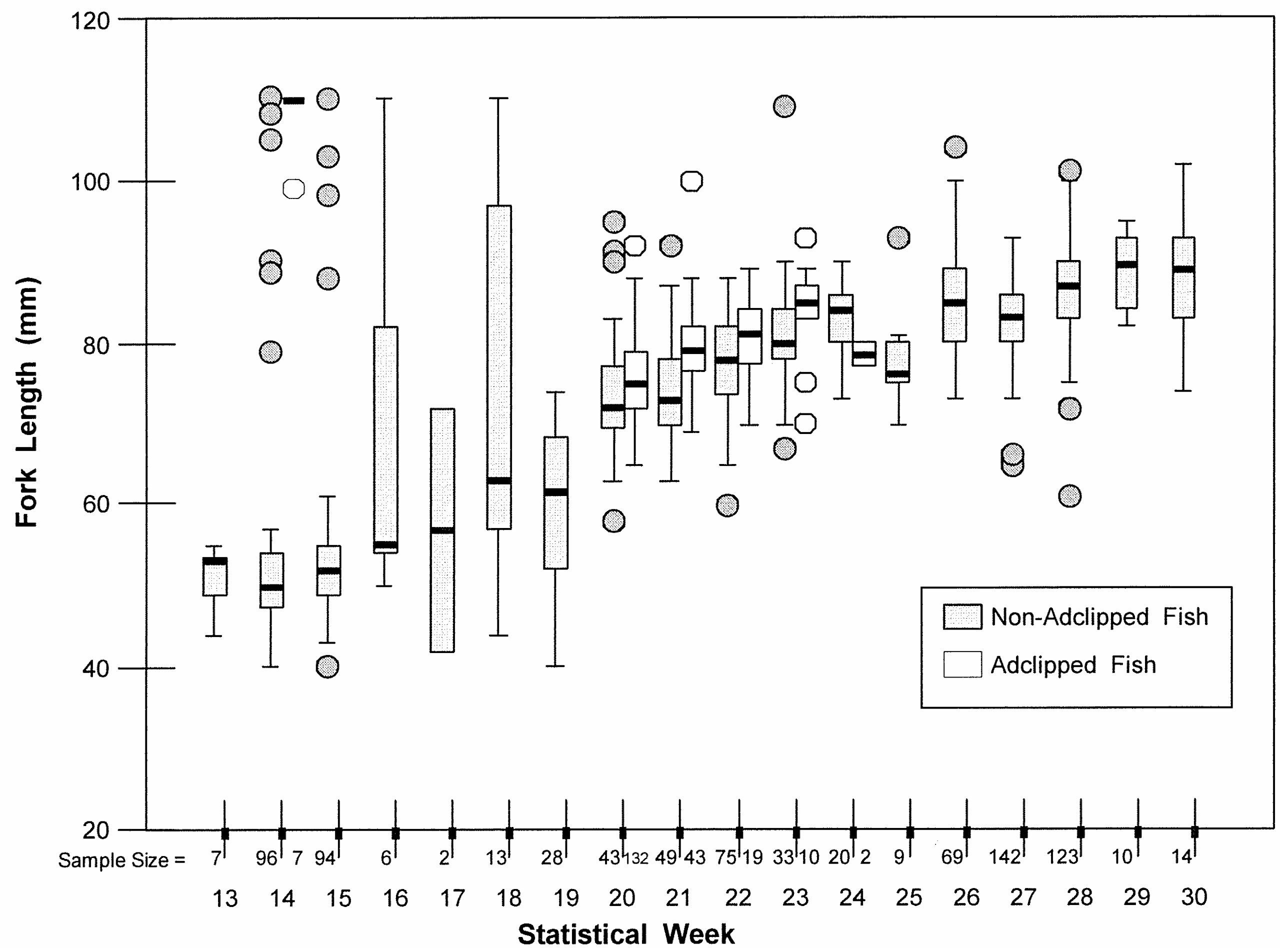


Figure 17. Box plots summarizing length data, by statistical week, collected from chinook salmon smolts caught by the screwtrap operated in the Nooksack River, 1995. Box plots show median length (heavy solid line), the central 50% of the data (box encloses 25th and 75th percentiles), and the lowest and highest lengths not considered outliers (box whiskers). Lengths more than 1.5 box lengths from the edge of the box are considered outliers (o).

1996:

The box-and-whiskers plots summarizing the length data collected from catches during each statistical week sampled in 1996 are shown in Figure 18. There was not a clear increase in the median fork length throughout the sample period as in the two previous years. This was probably due to the smaller sample sizes (less than 10 fish measured) for many of the statistical weeks during 1996 compared to 1994 and 1995. Most of the length data were from non-adclipped chinook salmon smolts; there was only one week with length data for adclipped smolts where more than 10 fish were measured. The median length for this sample of adclipped fish during week 14 was the largest observed during the season for either group. Most of the lengths classified as outliers belonged to non-adclipped fish. Mean lengths of non-adclipped chinook smolts (for weeks where 10 or more fish were measured) ranged from 59.3 mm during week 15 to 90.1 mm during week 29 (Appendix Table 15). The mean length of adclipped chinook smolts during week 14 (the only week where 10 or more fish were measured) was 187.1 mm (Appendix Table 15). This was the largest mean length observed for adclipped fish sampled during any statistical week in the five years of smolt trapping.

1997:

The box-and-whiskers plots summarizing the length data collected from catches during each statistical week sampled in 1997 are shown in Figure 19. Similarly to 1996, there was not a clear increase in median fork length throughout the sample period. All sample sizes for non-adclipped smolts after week 17 were greater than 10 fish. Most of the lengths classified as outliers belonged to non-adclipped fish. Mean lengths of non-adclipped chinook smolts (for weeks where 10 or more fish were measured) ranged from 79.4 mm during week 19 to 103.6 mm during week 18 (Appendix Table 16). This was the largest mean length observed for non-adclipped smolts sampled during any statistical week in the five years of smolt trapping. There were only three samples of adclipped smolts where 10 or more fish were measured. Adclipped chinook smolts ranged in mean length from 83.2 mm during week 23 to 138.6 mm during week 14 (Appendix Table 16).

1998:

The box-and-whiskers plots summarizing the length data collected from catches during each statistical week sampled in 1998 are shown in Figure 20. In general, the median fork length of non-adclipped chinook salmon smolts increased throughout the sampling period. Most of the lengths classified as outliers belonged to non-adclipped fish. Mean lengths of non-adclipped chinook smolts (for weeks where 10 or more fish were measured) ranged from 66.9 mm during week 19 to 85.6 mm during week 25 (Appendix Table 17). There were only two weeks where 10 or more adclipped smolts were measured, statistical weeks 24 and 25.

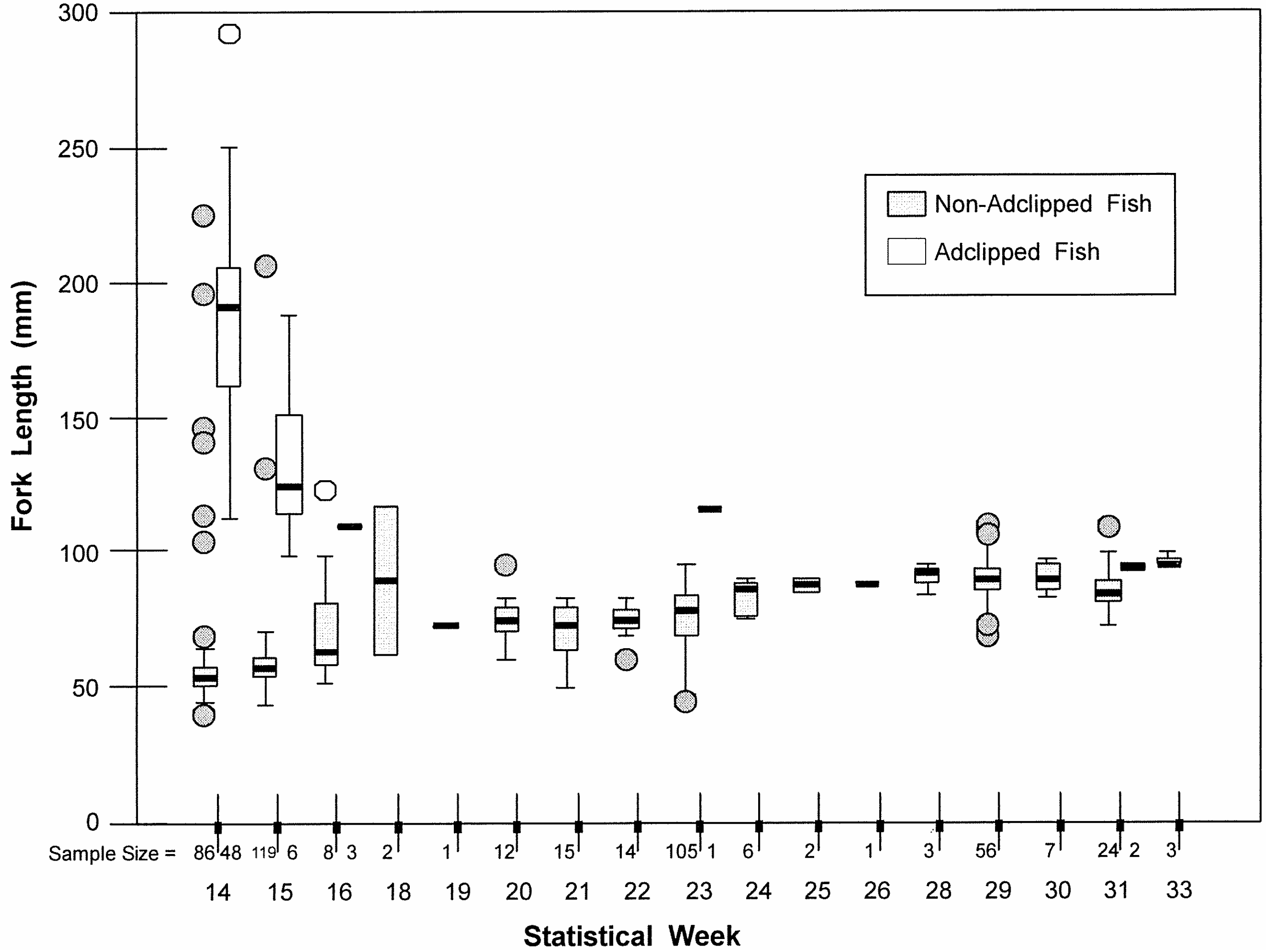


Figure 18. Box plots summarizing length data, by statistical week, collected from chinook salmon smolts caught by the screwtrap operated in the Nooksack River, 1996. Box plots show median length (heavy solid line), the central 50% of the data (box encloses 25th and 75th percentiles), and the lowest and highest lengths not considered outliers (box whiskers). Lengths more than 1.5 box lengths from the edge of the box are considered outliers (o).

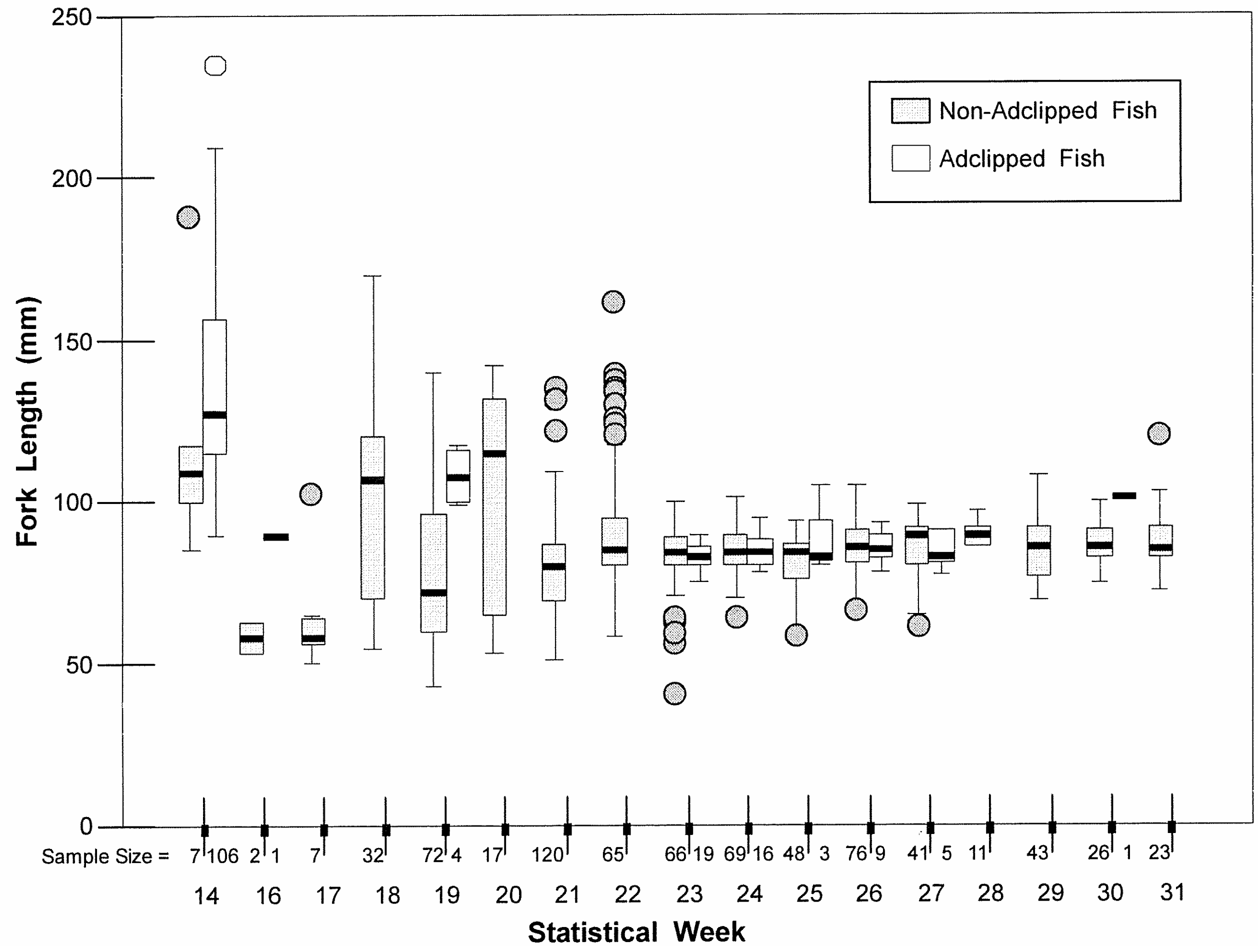


Figure 19. Box plots summarizing length data, by statistical week, collected from chinook salmon smolts caught by the screwtrap operated in the Nooksack River, 1997. Box plots show median length (heavy solid line), the central 50% of the data (box encloses 25th and 75th percentiles), and the lowest and highest lengths not considered outliers (box whiskers). Lengths more than 1.5 box lengths from the edge of the box are considered outliers (o).

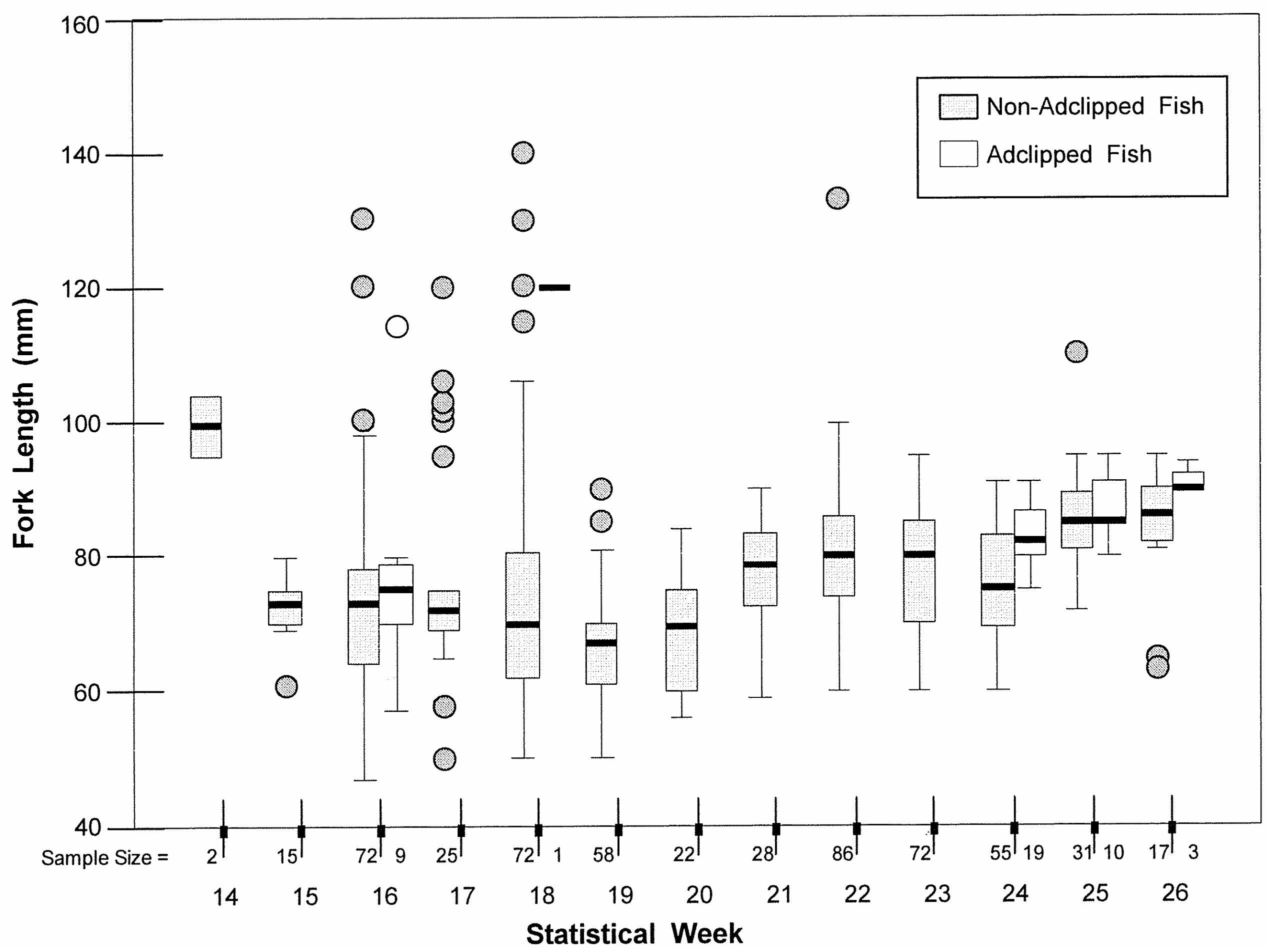


Figure 20. Box plots summarizing length data, by statistical week, collected from chinook salmon smolts caught by the screwtrap operated in the Nooksack River, 1998. Box plots show median length (heavy solid line), the central 50% of the data (box encloses 25th and 75th percentiles), and the lowest and highest lengths not considered outliers (box whiskers). Lengths more than 1.5 box lengths from the edge of the box are considered outliers (o).

Length Frequency Distributions

Figures 21 through 25 present the length frequency distributions of chinook salmon smolts sampled at the screwtrap for the two sample periods defined (statistical weeks 13 through 21 and statistical weeks 22 through 33) for each year sampled. We examined the length frequency distributions across all five years to help us establish rough guidelines for classifying smolts as yearlings from their lengths. We acknowledge that without scale data to verify our assumptions, this is a very imprecise method of estimating the contribution of yearling smolts to the catches. We view this more as an index of the contribution of yearlings to the catches than an absolute estimate of numbers. We wanted to simplify the procedure as much as possible, therefore we established length guidelines for each period that were identical across years. Fish greater than the defined length breakpoints were considered yearlings. We selected 92 mm as the breakpoint between age-zero and yearling chinook smolts during the first period (statistical weeks 13 through 21) and 102 mm as the breakpoint for the second period (statistical weeks 22 through 33). These breakpoint lengths are indicated in Figures 21 through 25 by vertical dotted lines.

1994:

About 140,000 adclipped yearling smolts were released at Kendall Creek Hatchery on 1 April, 1994 (Appendix Table 2). The only other adclipped chinook salmon smolts released into the Nooksack River in 1994 were age-zero smolts released on 24 and 25 May (statistical week 21). All adclipped chinook salmon smolts caught during the first sample period (statistical weeks 13 through 21) must have been from the 1 April release and were therefore yearlings. The length frequency distribution of the adclipped fish measured greatly overlapped that of the non-adclipped fish (Figure 21). The majority of the adclipped fish measured were less than 92 mm in length. About 3% (6 out of 182) of the non-adclipped chinook smolts measured had lengths greater than 92 mm during the first sample period. About 17% (4 out of 24) of the adclipped chinook smolts measured had lengths greater than 92 mm.

During the second time period (statistical weeks 22 through 33), non-adclipped and adclipped chinook salmon smolts had similar length distributions (Figure 21). All adclipped chinook smolts released into the Nooksack River during this period were age-zero. About 2% (14 out of 728) of the non-adclipped chinook smolts measured had lengths greater than 102 mm during the second period. About 3% (7 out of 220) of the adclipped chinook smolts measured during the second period had lengths greater than 102 mm.

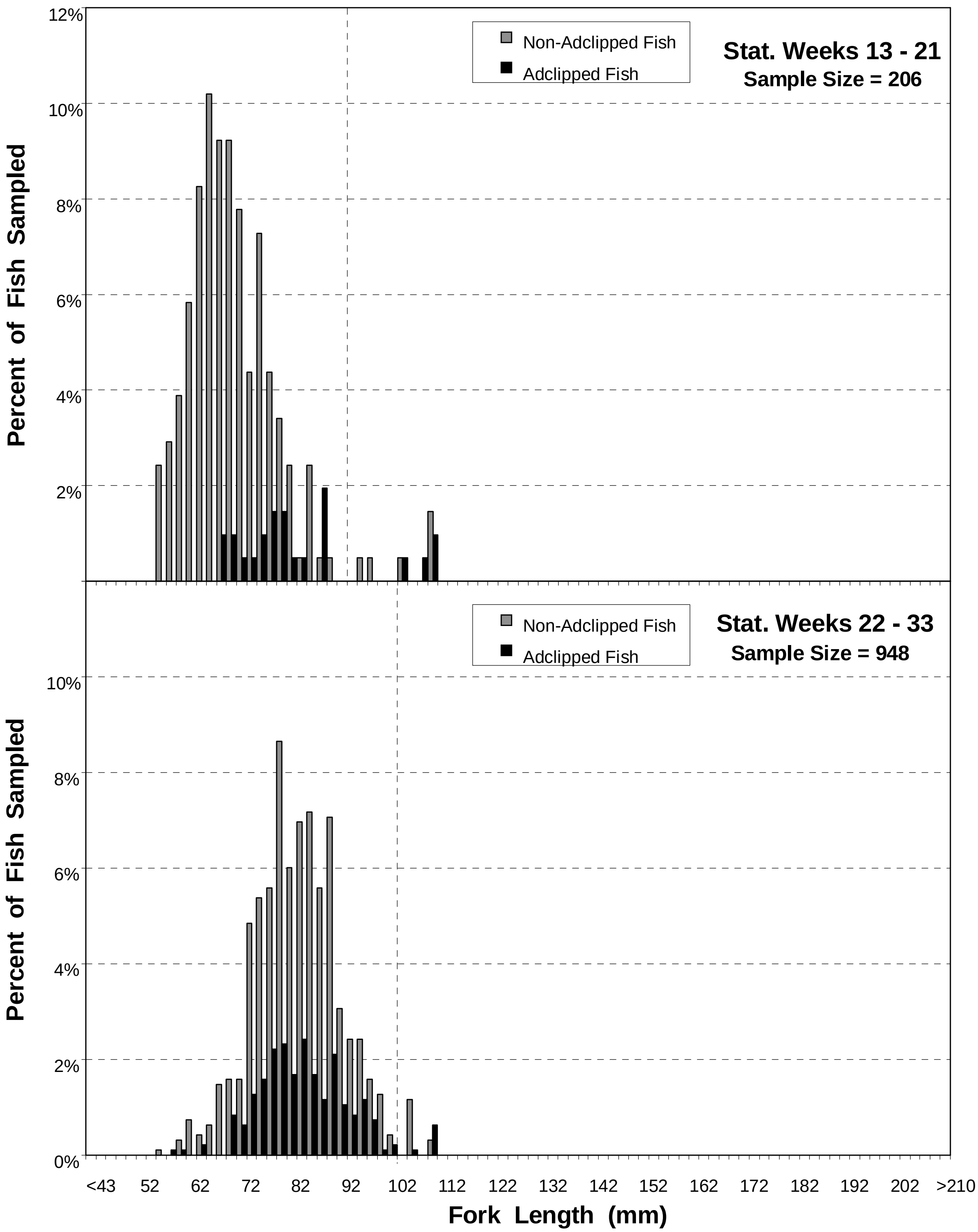


Figure 21. Length frequency histograms comparing fork lengths of non-adclipped and adclipped chinook salmon smolts sampled at the screwtrap during statistical weeks 13-21 (pooled) and statistical weeks 22-33 (pooled), 1994 data.

1995:

About 348,000 adclipped yearling smolts were released at Kendall Creek Hatchery on 1 April, 1995 (Appendix Table 2). There was a large release of about 178,000 adclipped, age-zero smolts from Kendall Creek Hatchery on 15 May (statistical week 20). Large numbers of adclipped chinook smolts were not caught until statistical weeks 20 and 21 (Figure 17). We believe that the majority of the adclipped chinook smolts measured during the first time period were yearling fish. The non-adclipped fish measured during the first period (statistical weeks 13 through 21) had a bimodal length distribution with peaks at the 50-52 mm and 72-74 mm ranges (Figure 22). The length frequency distribution of the adclipped fish (thought to be primarily yearling fish) greatly overlapped that of the second peak of the non-adclipped fish. About 6% (19 out of 338) of the non-adclipped chinook smolts measured had lengths greater than 92 mm during the first time period. About 4% (7 out of 182) of the adclipped chinook smolts measured during the first time period had lengths greater than 92 mm.

During the second time period (statistical weeks 22 through 33), non-adclipped and adclipped chinook salmon smolts had similar length distributions (Figure 22). Less than 1% (2 out of 495) of the non-adclipped chinook smolts measured had lengths greater than 102 mm and none of the adclipped smolts had lengths greater than 102 mm.

1996:

About 184,000 adclipped yearling smolts were released at Kendall Creek Hatchery on 1 April, 1996 (Appendix Table 2). Except for a small release of adclipped age-zero chinook smolts from Kendall Creek Hatchery on 21 June, this was the only release of adclipped chinook salmon smolts into the Nooksack River in 1996. All adclipped chinook smolts caught during the first sample period (statistical weeks 13 through 21) were from the 1 April release and all were greater than 92 mm in length (Figure 23). About 5% of the non-adclipped chinook smolts measured had lengths in the range of the adclipped smolts.

Only three adclipped chinook salmon smolts were measured during the second time period (statistical weeks 22 through 33); two smolts had lengths less than 102 mm and one was greater than 102 mm in length. About 2% (5 out of 221) of the non-adclipped chinook smolts measured had lengths greater than 102 mm during the second period.

1997:

The length frequency distributions for 1997 resembled those of 1996. About 188,000 adclipped yearling smolts were released at Kendall Creek Hatchery on 1 April, 1997 (Appendix Table 2). There was a release of about 180,000 age-zero, adclipped chinook smolts from Kendall Creek Hatchery on 1 June. All adclipped chinook smolts caught during the first sample period (statistical weeks 13 through 21) were from the 1 April release; all but four of the adclipped smolts measured were greater than 92 mm in length (Figure 24). About 26% (66 out of 257) of the non-adclipped chinook smolts measured had lengths greater than 92 mm during the first time period.

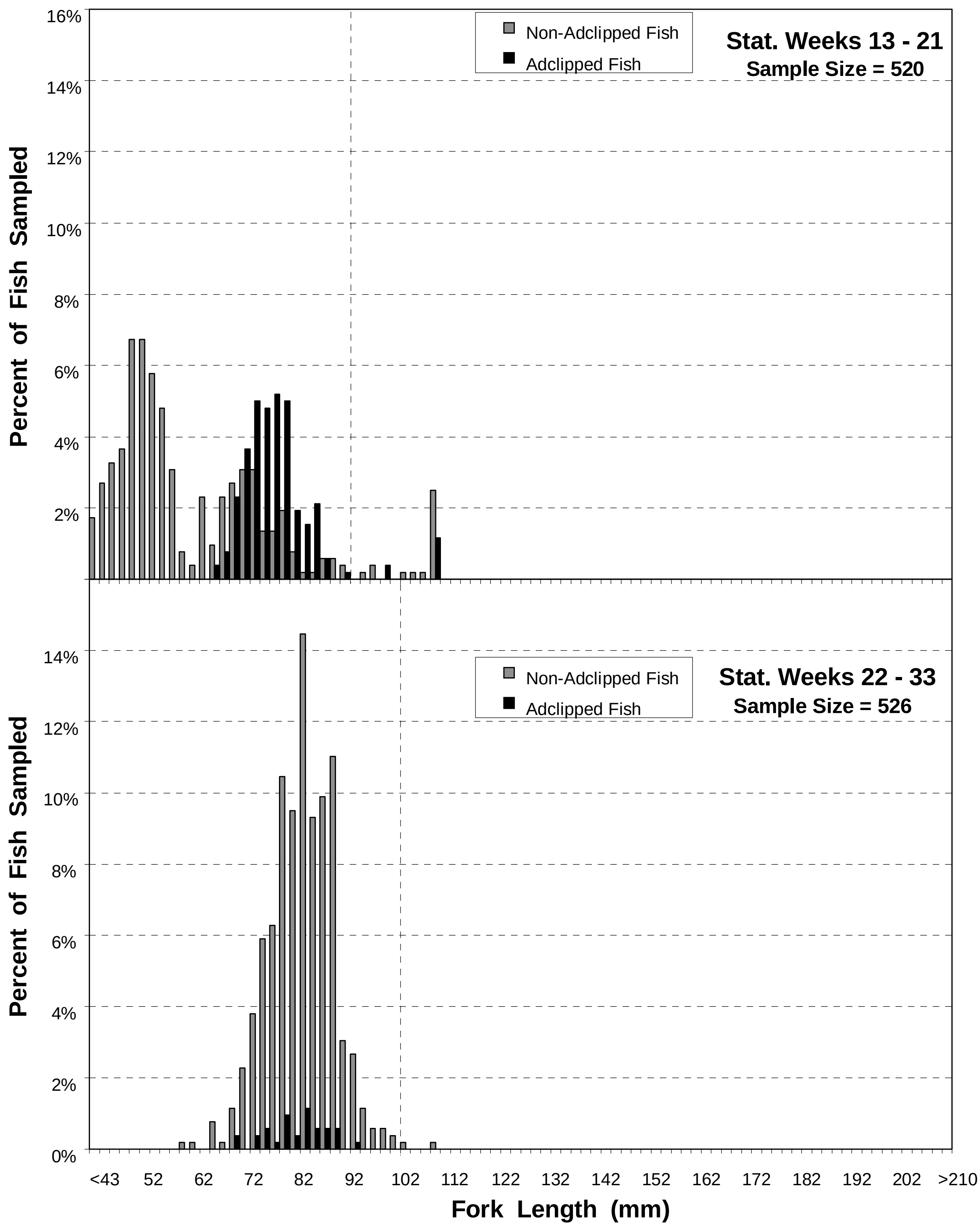


Figure 22. Length frequency histograms comparing fork lengths of non-adclipped and adclipped chinook salmon smolts sampled at the screwtrap during statistical weeks 13-21 (pooled) and statistical weeks 22-33 (pooled), 1995 data.

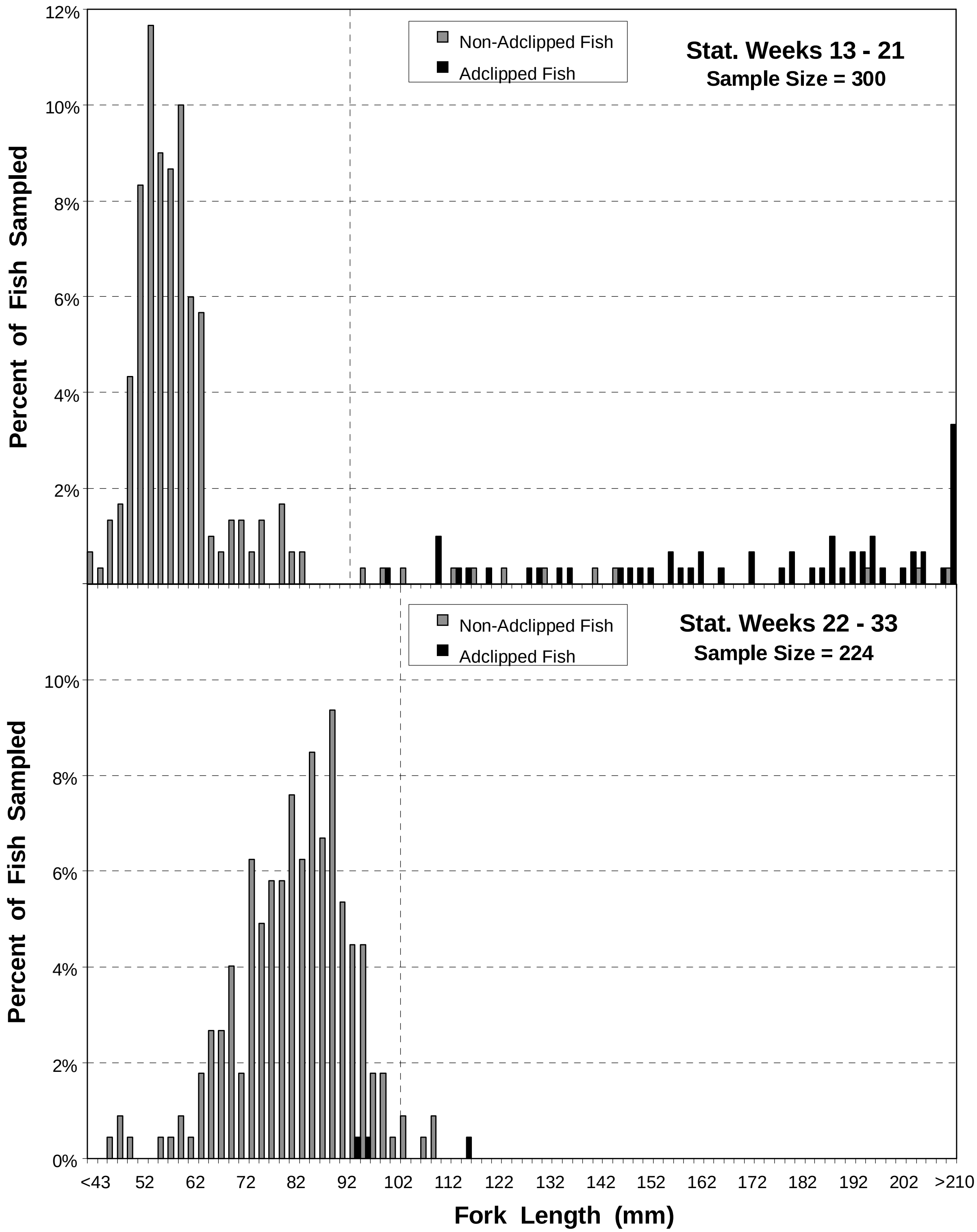


Figure 23. Length frequency histograms comparing fork lengths of non-adclipped and adclipped chinook salmon smolts sampled at the screwtrap during statistical weeks 13-21 (pooled) and statistical weeks 22-33 (pooled), 1996 data.

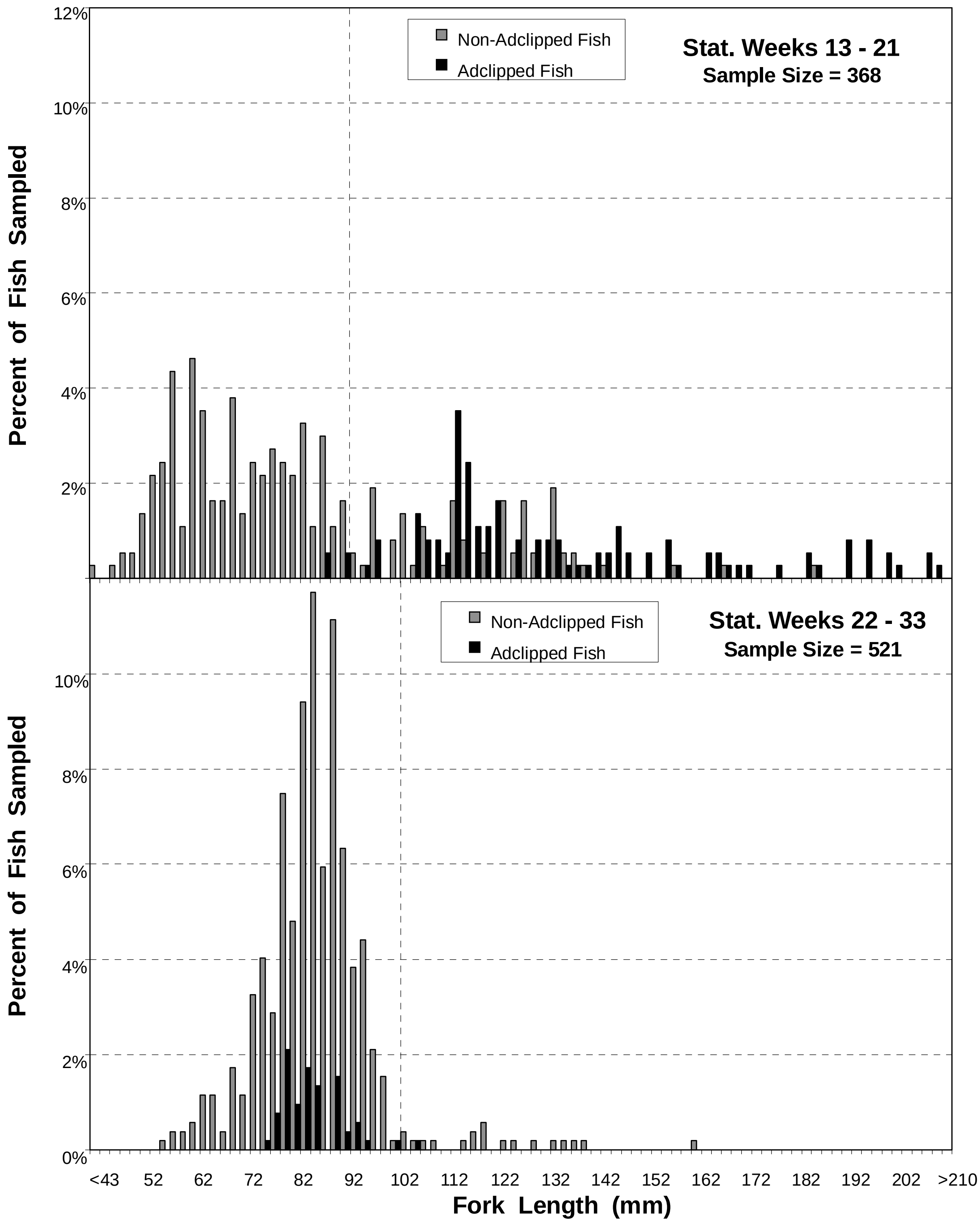


Figure 24. Length frequency histograms comparing fork lengths of non-adclipped and adclipped chinook salmon smolts sampled at the screwtrap during statistical weeks 13-21 (pooled) and statistical weeks 22-33 (pooled), 1997 data.

During the second time period (statistical weeks 22 through 33), non-adclipped and adclipped chinook salmon smolts had similar length distributions (Figure 24). All adclipped chinook smolts released into the Nooksack River during this period were age-zero. About 4% (19 out of 468) of the non-adclipped chinook smolts measured had lengths greater than 102 mm during the second period. Only one of the adclipped chinook smolts measured during the second period had a length greater than 102 mm.

1998:

The length frequency distributions in 1998 were similar to those in 1994 and 1995. About 152,000 adclipped yearling smolts were released at Kendall Creek Hatchery on 1 April, 1998 (Appendix Table 2). The only other adclipped chinook salmon smolts released into the Nooksack River in 1998 were age-zero smolts released from Kendall Creek Hatchery on 12 June (statistical week 21). All adclipped chinook smolts caught during the first sample period (statistical weeks 13 through 21) must have been from the 1 April release and were therefore yearlings. Only ten adclipped smolts were measured during the first period and their lengths ranged from 57 mm to 120 mm (Figure 25). About 9% (27 out of 294) of the non-adclipped chinook smolts measured had lengths greater than 92 mm during the first time period.

During the second time period (statistical weeks 22 through 33), non-adclipped and adclipped chinook salmon smolts had similar length distributions (Figure 25). All adclipped chinook smolts released into the Nooksack River during this period were age-zero. Less than 1% (2 out of 261) of the non-adclipped chinook smolts measured had lengths greater than 102 mm during the second period. None of the adclipped chinook smolts measured in the second time period had lengths greater than 102 mm.

Summary:

The previous analyses demonstrate the difficulty in using only fork length to determine whether a chinook salmon smolt is age-0 or age-1. During three of the study years (1994, 1995, and 1998), the length distributions of adclipped fish that were almost certainly age-1 fish overlapped the distribution of the non-adclipped fish during the first time period. In 1996 and 1997, the adclipped yearlings measured in the first time period were in general much larger than the majority of the non-adclipped chinook smolts measured.

During the second time period, an argument could be made that the majority of the fish in the right-hand tail of the length frequency distributions for 1994, 1995, 1996, and 1998 are large age-0 chinook smolts and not age-1 fish. Only in 1997 is there a sufficient spread between the center of the distribution and the larger fish to argue strongly that these larger fish are yearlings.

Because of these problems, and the problems with non-random sampling discussed at the beginning of this section, we do not feel that the age composition of the catches can be reliably estimated based upon lengths. Therefore, we will not pursue this any further in this document. We recommend that scale samples be collected in the future so that the length-age relationship can be better determined.

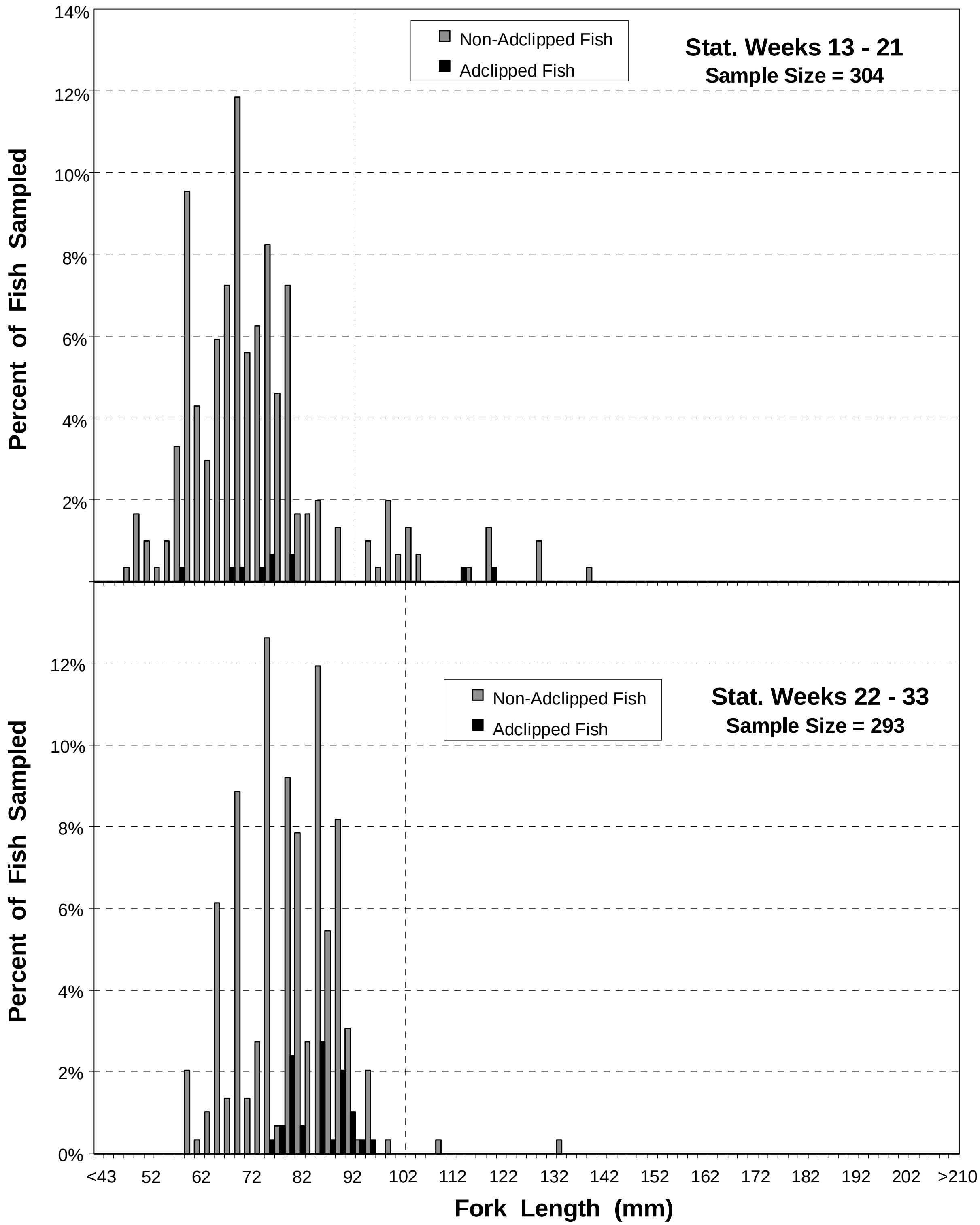


Figure 25. Length frequency histograms comparing fork lengths of non-adclipped and adclipped chinook salmon smolts sampled at the screwtrap during statistical weeks 13-21 (pooled) and statistical weeks 22-33 (pooled), 1998 data.

Comparison of Mean Lengths Among Years

Figure 26 compares the mean fork lengths by year for non-adclipped (A) and adclipped (B) chinook salmon smolts measured during each of the four defined temporal strata. The increase in the mean lengths of non-adclipped smolts during the sampling season was generally similar for all years except 1997. In 1997, the mean lengths fluctuated between about 84 and 86 mm throughout sampling. The mean lengths of measured fish for the first temporal stratum (statistical weeks 12 through 17) varied widely ranging from 55.5 mm in 1995 to 86.3 mm in 1997. Except for 1997, the mean lengths of measured fish for the second temporal stratum (statistical weeks 18 through 21) were within 5 mm of each other (Table 9). The mean lengths of measured fish for the third temporal stratum (statistical weeks 22 through 26) were within 6 mm of each other with the exception of 1997. The mean lengths of measured non-adclipped fish for the last temporal stratum (statistical weeks 27 through 33) were all within 5 mm of each other.

There is not the similarity among years for the mean lengths of the adclipped chinook salmon smolts (Figure 26B). There are no clear trends in the mean lengths evident but this may be due to the small sample sizes for many statistical weeks (Table 10).

Comparison of Capture-Efficiency Trial Smolt Lengths to Trap-Captured Smolt Lengths

Figures 27 through 30 compare the lengths of the hatchery-reared chinook salmon smolts used in the capture-efficiency experiments to non-adclipped and adclipped chinook smolts caught by the trap during the same approximate time period as the experiments.

1995:

Fork lengths were measured for a sample of smolts from four of the six trap capture-efficiency trials conducted in 1995 (Appendix Table 12). The trials with length data associated with them were conducted during statistical weeks 16, 18, 20, and 21. For three of the four trials, the length data were collected on the same day as the trial. There were four days between the time of the length measurements and the release of the fish for the fourth capture-efficiency trial. Length data for non-trial chinook smolts captured at the trap are displayed for statistical weeks 16, 18, 20, 21, and 22 (Figure 27). There were very few chinook smolts measured during weeks 16 through 19 so the non-adclipped smolt length data were pooled for those weeks and are displayed as week 19 data.

The length data for the first three capture-efficiency trials have a distribution similar to that for the combined weeks 16 through 19 data (Figure 27). The fork lengths of smolts used for the fourth trial in 1995 were generally smaller than the lengths of the non-adclipped and adclipped smolts measured from screwtrap catches during statistical weeks 20, 21, and 22 (Figure 27).

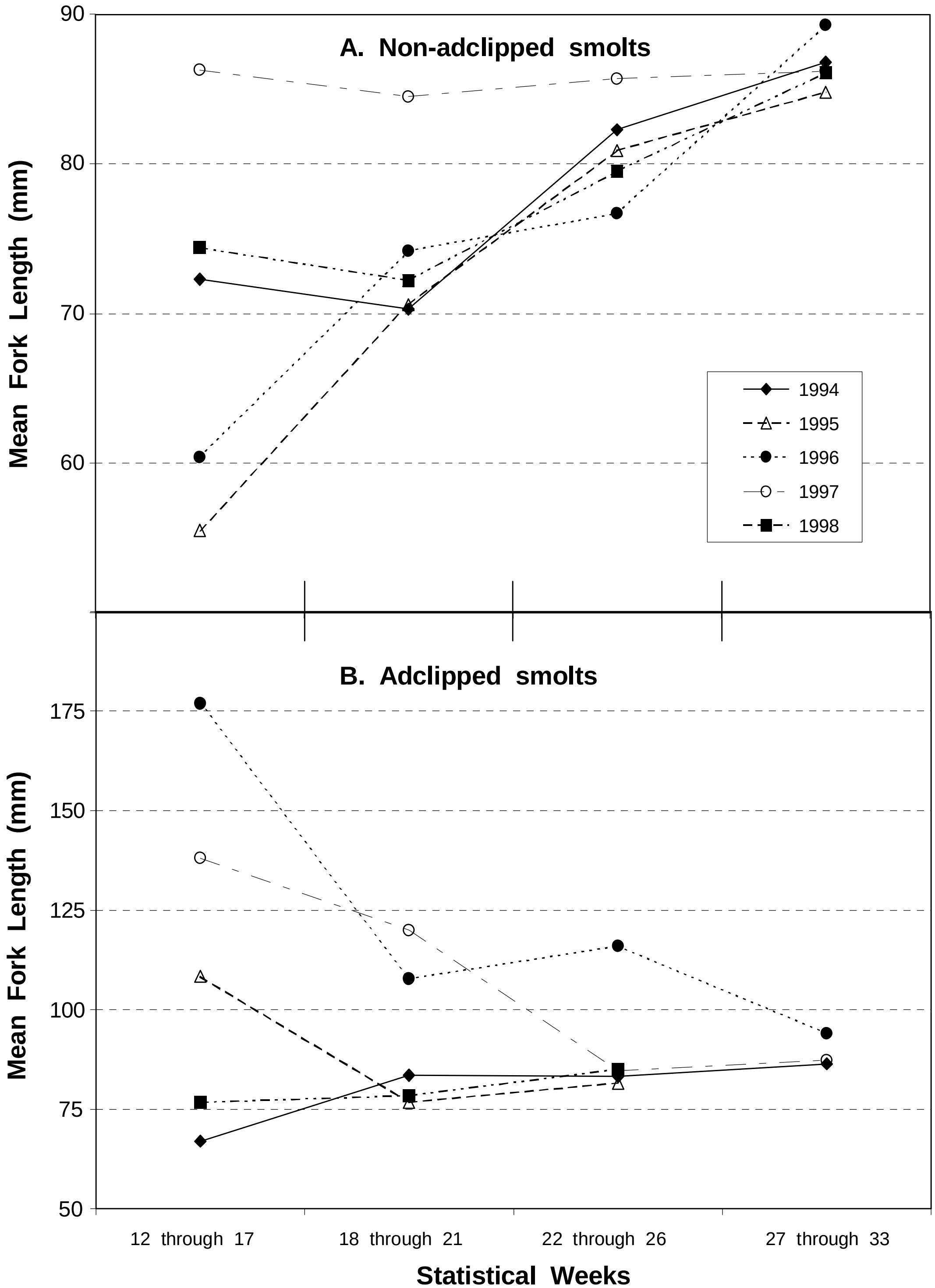


Figure 26. Mean fork lengths during four temporal periods (pooled statistical weeks), by year, for (A) non-adclipped and (B) adclipped chinook salmon smolts sampled at the screwtrap operated in the Nooksack River.

Table 9. Summary statistics for length data collected from non-adclipped chinook salmon smolts captured by the screwtrap in the Nooksack River, 1994-1998. Summarized by four temporal strata.

Year:	1994	1995	1996	1997	1998
Period 1: Statistical weeks 12 - 17					
Mean	72.3	55.5	60.4	86.3	74.4
Stand. Error[a]	7.86	1.11	1.53	9.09	1.38
Coef. Var.[b]	10.9%	2.0%	2.5%	10.5%	1.9%
Median	67.0	51.0	56.0	75.0	73.0
Sample Size	4	205	213	16	114
Period 2: Statistical weeks 18 - 21					
Mean	70.3	70.6	74.2	84.5	72.2
Stand. Error	0.71	1.03	2.26	1.61	1.07
Coef. Var.	1.0%	1.5%	3.0%	1.9%	1.5%
Median	69.0	71.0	74.0	80.0	70.0
Sample Size	178	133	30	241	180
Period 3: Statistical weeks 22 – 26					
Mean	82.3	80.9	76.7	85.7	79.5
Stand. Error	0.35	0.48	0.90	0.69	0.58
Coef. Var.	0.4%	0.6%	1.2%	0.8%	0.7%
Median	82.0	80.5	78.0	85.0	80.0
Sample Size	617	206	128	324	261
Period 4: Statistical weeks 27 - 33					
Mean	86.8	84.8	89.3	86.2	86.1
Stand. Error	0.74	0.34	0.81	0.74	0.29
Coef. Var.	0.9%	0.4%	0.9%	0.9%	0.3%
Median	86.0	85.0	89.0	87.0	86.0
Sample Size	111	289	93	144	637

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Table 10. Summary statistics for length data collected from adclipped chinook salmon smolts captured by the screwtrap in the Nooksack River, 1994-1998. Summarized by four temporal strata.

Year:	1994	1995	1996	1997	1998
Period 1: Statistical weeks 12 - 17					
Mean	67.0	108.4	176.9	138.1	76.8
Stand. Error[a]		1.57	5.15	3.05	5.20
Coef. Var.[b]		1.4%	2.9%	2.2%	6.8%
Median		110.0	186.0	127.0	75.0
Sample Size	1	7	57	107	9
Period 2: Statistical weeks 18 - 21					
Mean	83.6	76.8	107.8	120.0	78.4
Stand. Error	2.64	0.40	4.78		0.60
Coef. Var.	3.2%	0.5%	4.4%		0.8%
Median	80.0	76.0	107.5		77.0
Sample Size	23	175	4	1	203
Period 3: Statistical weeks 22 - 26					
Mean	83.3	81.6	116.0	84.7	85.1
Stand. Error	0.72	1.05		0.83	0.92
Coef. Var.	0.9%	1.3%		1.0%	1.1%
Median	82.0	83.0		84.0	85.0
Sample Size	181	31	1	47	32
Period 4: Statistical weeks 27 - 33					
Mean	86.4		94.0	87.3	
Stand. Error	1.03		1.00	3.56	
Coef. Var.	1.2%		1.1%	4.1%	
Median	85.0		94.0	87.0	
Sample Size	39	0	2	6	0

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

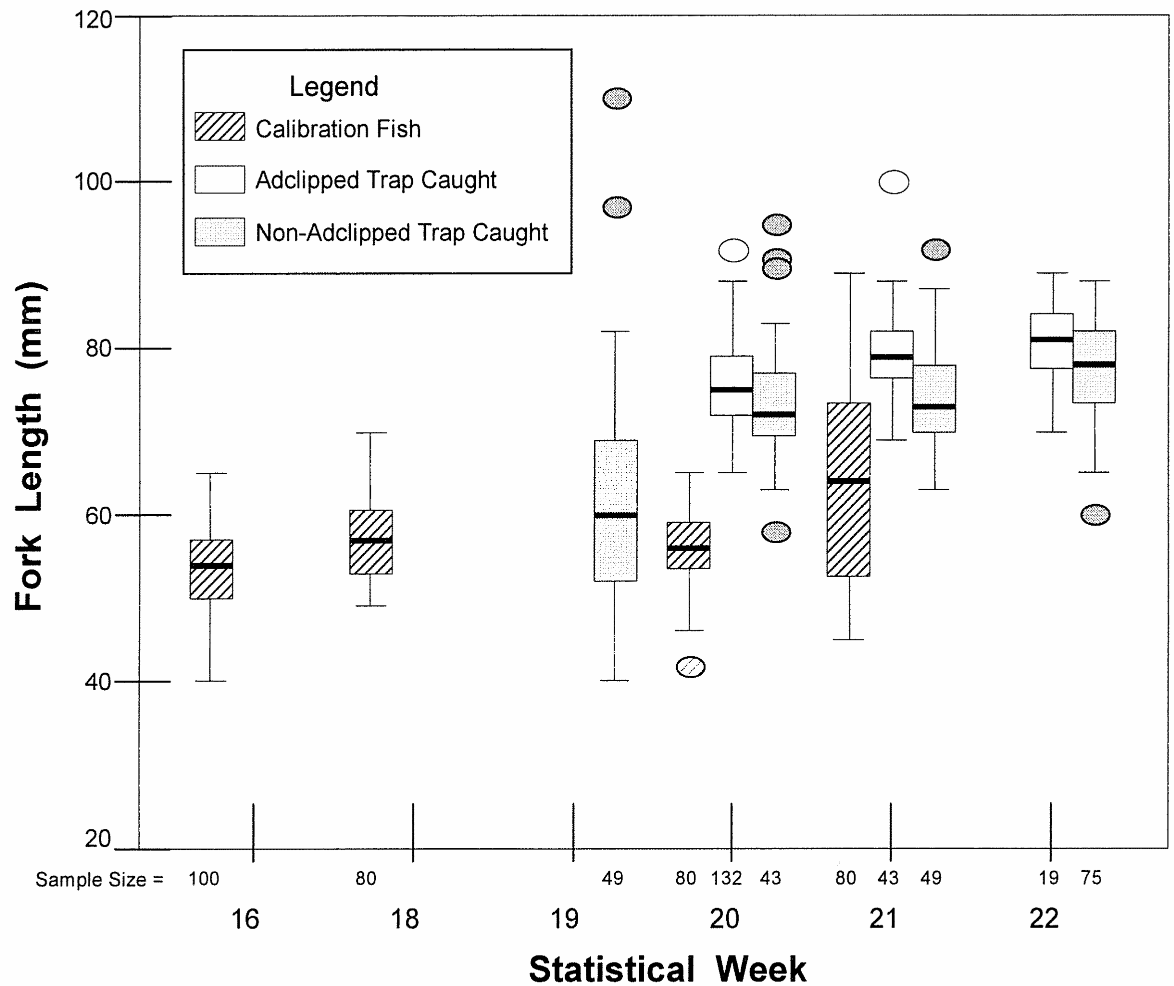


Figure 27. Box plots comparing length data from chinook salmon smolts used in trap capture-efficiency trials to length data from chinook smolts caught by the screwtrap, 1995. Week 19 data for non-adclipped smolts is pooled data from weeks 16 through 19.

1996:

Fork lengths were measured for a sample of smolts from four of the five capture-efficiency trials conducted in 1996 (Appendix Table 12). Smolts from the group of fish measured for the third trial were also used in the fourth trial. The capture-efficiency trials with length data associated with them were conducted during statistical weeks 22, 23, 24, and 26. For three of the four trials, the length data were collected within four days of the release of the fish for the trial. There were 19 days between the time of the length measurements and the release of the fish for the first trial. These fish were measured during statistical week 19 and released during week 22. Length data for non-trial chinook smolts captured at the trap are displayed for statistical weeks 19, 20, 21, 22, 23, 24, 26, and 28 (Figure 28). There were very few chinook smolts measured during weeks 24 through 28 so the non-adclipped smolt length data were pooled for those weeks and are displayed as week 28 data.

The length data for the first capture-efficiency trial (measured during week 19) are not very useful because these fish were used in a trial conducted almost three weeks later and would experience an unknown amount of growth between the time of measurement and release. The length data for the other three trials were roughly similar to that for the non-adclipped smolts measured during weeks 23 and 28 (Figure 28). The lengths of the smolts measured for the trials conducted during weeks 23 and 24 were somewhat larger than the non-adclipped chinook smolts measured from catches during week 23. There were no length data for adclipped smolts captured at the trap during this period.

1997:

There was only a single capture-efficiency experiment conducted in 1997. Fork lengths were measured for a sample of smolts for this trial (Appendix Table 12). There were 25 days between the time of the length measurements and the release of the fish for the trial. These fish were measured during statistical week 17 and released during week 21. Length data for non-trial chinook smolts captured at the trap are displayed for statistical weeks 18 through 22 (Figure 29).

The length data for this trial (measured during week 17) are not very useful because these fish were used in a trial conducted almost four weeks later and would experience an unknown amount of growth between the time of measurement and release.

There were not sufficient length data for adclipped smolts captured at the trap during this period for display. The distribution of the lengths of the smolts used in the trial, when measured, were on the lower end of the range of lengths observed for non-adclipped smolts measured from catches during weeks 18 through 22 (Figure 29).

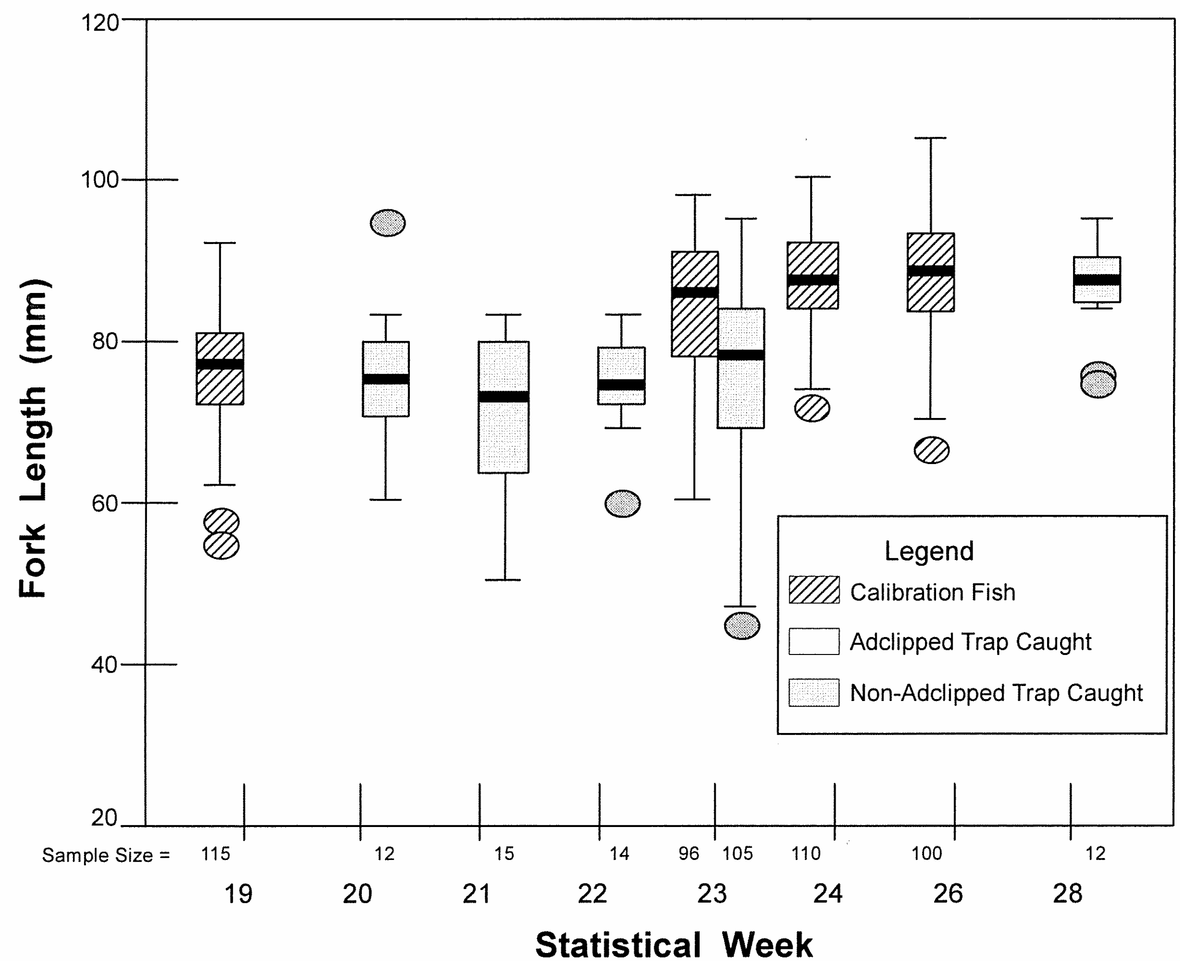


Figure 28. Box plots comparing length data from chinook salmon smolts used in trap capture-efficiency trials to length data from chinook smolts caught by the screwtrap, 1996. Week 28 data for non-adclipped smolts is pooled data from weeks 24 through 28.

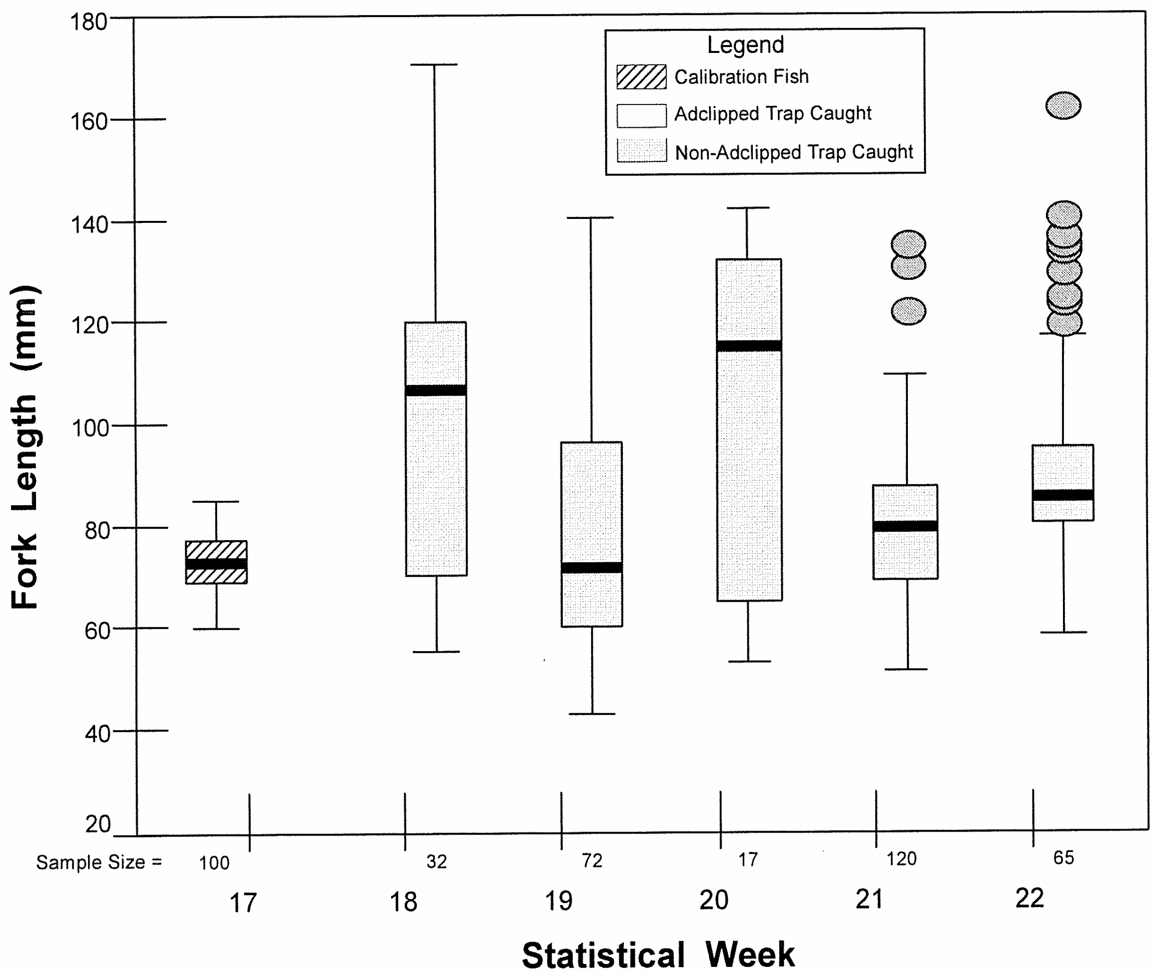


Figure 29. Box plots comparing length data from chinook salmon smolts used in trap capture-efficiency trials to length data from chinook smolts caught by the screwtrap, 1997.

1998:

There were only two capture-efficiency experiments conducted in 1998. Fork lengths were measured for a sample of smolts from the first trial only (Appendix Table 12). There were 19 days between the time of the length measurements and the release of the fish for the first trial. These fish were measured during statistical week 19 and released during week 22. Length data for non-trial chinook smolts captured at the trap are displayed for statistical weeks 19 through 23 (Figure 30).

The length data for the first capture-efficiency trial (measured during week 19) are not very useful because these fish were used in a trial conducted almost three weeks later and would experience an unknown amount of growth between the time of measurement and release. There were not sufficient length data for adclipped smolts captured at the trap during this period for display. The distribution of the lengths of the smolts used in the trial, when measured, were similar to the range of lengths observed for non-adclipped smolts measured from catches during weeks 21 through 23 (Figure 30).

Summary:

The length distributions of the chinook salmon used for the capture-efficiency trials did not always correspond to those of the non-trial chinook smolts captured by the trap at the time of the experiment. Fish length was discussed as a possible factor affecting capture efficiency, especially for some water clarity conditions, in an earlier section of this report. However, we do not feel the differences in length distributions between the two groups (capture-efficiency trial and non-trial chinook smolts) were of sufficient magnitude to bias the estimates of capture-efficiency.

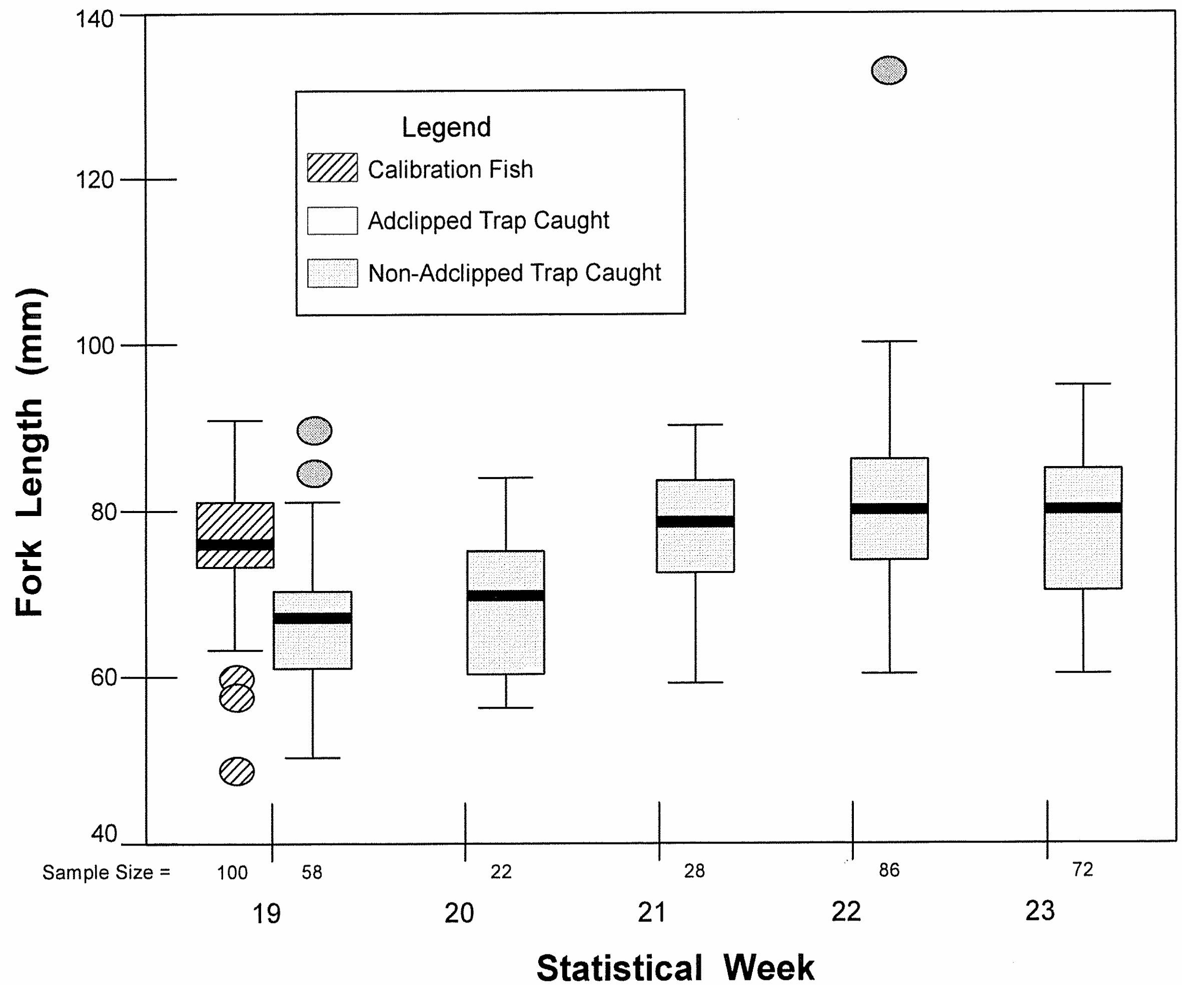


Figure 30. Box plots comparing length data from chinook salmon smolts used in trap capture-efficiency trials to length data from chinook smolts caught by the screwtrap, 1998.

Index of Relative Abundance

The feasibility of developing an annual index of the relative abundance of chinook salmon smolts out-migrating from the Nooksack River using the screwtrap catch and effort data is examined in this section. Several methods of estimating an index of relative abundance are explored. Indices are evaluated by comparing them to the numbers of hatchery-reared chinook salmon juveniles (both non-adclipped and adclipped fish) released in areas above the screwtrap. Indices for 1996, 1997, and 1998 are developed.

Methods

<u>Calculation of CPUE Indices</u>

Four indices of relative abundance were calculated using catch and effort data from 1996, 1997, and 1998. These were the only years that the screwtrap was operated following a random sampling schedule and provide the data most appropriate for developing an index. For each year, monthly indices were computed for April, May, June, and July. A combined May-June index was also computed each year as this was typically the period of peak out-migration for chinook salmon smolts from the Nooksack River (see Figure 11). The first index was:

Total CPUE index (TCPU): $$TCPU_i = \frac{\sum_{j=1}^{n_i} catch_{ij}}{\sum_{j=1}^{n_i} effort_{ij}} \qquad [1]$$

where $catch_{ij}$ = the number of chinook salmon smolts caught during screwtrap set j conducted in month i, $effort_{ij}$ = the effort (in hours) during screwtrap set j conducted in month i, and n_i = the number of screwtrap sets conducted in month i. This is equivalent to the ratio of the means of catch and effort for sets conducted during month i. The variance of TCPU was approximated using the formula for the ratio of the means of two random variables (Jessen 1978):

$$\hat{V}(TCPU_i) = (TCPU_i)^2 \left(\frac{1}{n_i}\right)\left[\left(\frac{s_{ci}^2}{\bar{c}_i^2}\right) + \left(\frac{s_{ei}^2}{\bar{e}_i^2}\right) - \left(2r\frac{s_{ci}s_{ei}}{\bar{c}_i\bar{e}_i}\right)\right] \qquad [2]$$

where n_i is defined above, s_{ci}^2 = the estimated variance of the catches for sets conducted during month i, $\bar{c}_i$ = the mean catch for sets conducted during month i, s_{ei}^2 = the estimated variance of the efforts for sets conducted during month i, $\bar{e}_i$ = the mean effort for sets conducted during month i, and r is the correlation between catch and effort for sets conducted during month i.

The second index was calculated as:

$$\text{Mean CPUE index (MCPU):} \quad MCPU_i = \frac{\sum_{j=1}^{n_i} CPUE_{ij}}{n_i} \qquad [3]$$

where $CPUE_{ij}$ = the CPUE for chinook salmon smolts caught during screwtrap set j conducted in month i. The variance of MCPU was estimated using the formula for the variance of a sample.

The first index essentially weights the CPUE value for each set by the total number of chinook smolts caught in the set while the second method gives equal weight to the CPUE value of each set, regardless of the number of chinook caught in the set.

The other two indices of abundance were based on estimates of the expanded catch of smolts. Expanded catch is the catch of each set expanded to account for the estimated capture efficiency of the trap at the time of the set. Capture efficiency was estimated using the secchi depth measured at the time of the set and the regression parameters relating capture efficiency to secchi depth from Table 8. Expanded catch was estimated by:

$$\text{Expanded catch } (xpcatch)\text{:} \quad xpcatch_{ij} = \frac{catch_{ij}}{(0.06296 / depth_{ij}) - 0.01780} \qquad [4]$$

where $depth_{ij}$ = the secchi depth measured at the screwtrap during set j conducted in month i. The estimated expanded catch was then used in the calculation of the other two indices. The first was:

$$\text{Total expanded CPUE index (TXCPU):} \quad TXCPU_i = \frac{\sum_{j=1}^{n_i} xpcatch_{ij}}{\sum_{j=1}^{n_i} effort_{ij}}. \qquad [5]$$

Finally, expanded CPUE (*XCPUE*) was calculated for each set by dividing the expanded catch for the set by its effort. The fourth index was then calculated as

$$\text{Mean expanded CPUE index (MXCPU):} \quad MXCPU_i = \frac{\sum_{j=1}^{n_i} XCPUE_{ij}}{n_i} \qquad [6]$$

where $XCPUE_{ij}$ is the expanded CPUE for set j conducted in month i.

The variances of both of these indices (TXCPU and MXCPU) were estimated using the same procedures as for TCPU and MCPU but using the expanded catch estimates in place of the observed catch values. The additional variation added by expanding the catch for trap efficiency was not accounted for in our analyses. Therefore, the variances of TXCPU and MXCPU reported are underestimates of the true variance of these parameters.

Evaluation of CPUE Indices

The large numbers of hatchery-reared chinook salmon smolts released upstream of the trap offered a unique opportunity to determine whether there was a relationship between CPUE and abundance, and to evaluate the performance of the four different CPUE indices. We assumed that the number of hatchery-reared juvenile chinook released above the trap during any specific time period would be related to the catch realized at the trap during the time those fish out-migrated. We totaled the number of hatchery-reared juvenile chinook released above the trap that were available to capture by the trap for each of the index months (April, May, June, and July). Releases made 80 or more km above the trap during the last eight days of a month were totaled with the releases in the next month. We assumed that the majority of the fish from such a release could not migrate past the trap during the eight remaining days in the month.

We then examined the correlation between each monthly CPUE index and the total number of hatchery-reared juveniles released above the trap during the month. This was done for both: (1) CPUE calculated using the catch of all juvenile chinook salmon out-migrants and the total number of hatchery-reared juvenile chinook released above the trap and (2) CPUE calculated using only the catch of adclipped juvenile chinook salmon out-migrants and the number of adclipped juvenile chinook released above the trap. Both linear (Pearson's r) and nonparametric (Spearman's rho) correlation coefficients (Conover 1980) were calculated and examined for significance. Visual inspections of plots of the relationships were used to identify data points that may have strongly influenced the correlations. These points were then omitted from the analysis and the correlations recalculated.

The premise of this evaluation of the indices is that there is a direct correspondence between the number of hatchery-reared juvenile chinook salmon released above the trap and the catch of chinook out-migrants realized at the trap. We feel that this is a valid assumption since our previous analyses (see the section: Screwtrap Effort and Chinook Salmon Smolt Catch Summary and Analyses) indicate that almost all major peaks in chinook CPUE observed during each year of the study can be related to a release of hatchery-reared fish above the trap. We hypothesize that there is a low level of out-migration for naturally-produced chinook salmon but the majority of the out-migration during most periods is dominated by hatchery releases. Therefore, there should be a high correlation between CPUE of chinook out-migrants at the trap and the number of hatchery-reared chinook released above the trap during most time periods.

Results

Release Data by Month and Monthly CPUE Indices

A summary of the releases of all hatchery-reared chinook salmon juveniles above the trap and each of the monthly CPUE indices is given in Appendix Table 18 for screwtrap data collected in 1996, 1997, and 1998. Appendix Table 19 summarizes the releases of all adclipped, hatchery-reared chinook salmon juveniles above the trap and each of the monthly CPUE indices calculated using only the catch of adclipped chinook. All releases of hatchery-reared chinook occurred 66 or more km above the trap except for two releases at the Ferndale Ramp (1.8 km above the trap) in 1996; there were 689,700 non-adclipped, age-zero chinook released in April and 2,418,860 non-adclipped, age-zero fish released in June at the Ferndale Ramp. There were four releases near the end of a month that were moved to the next month's total releases: the release of 96,530 age-zero chinook on 25 April 1997, the release of 96,470 age-zero fish on 29 May 1997, the release of 40,000 age-zero chinook on 22 April 1998, and the release of 35,000 age-zero chinook on 30 May 1998.

Evaluation of CPUE Indices

The indices were evaluated using: (1) total juvenile chinook salmon data for the total monthly releases and monthly CPUE indices and (2) only adclipped juvenile chinook salmon data for the monthly releases and monthly CPUE indices.

Indices Using Total Release and Catch Data:

The relationship between the monthly CPUE indices for all chinook out-migrants and the total number of hatchery-reared chinook salmon released each month upstream of the trap is shown for the 1996-1998 data collectively in Figure 31. The correlation coefficients for these data, and their significance, are summarized in Table 11.

Both correlation coefficients (r and ρ) were significant ($P < 0.02$) for the TCPU and MCPU indices (Table 11, data set 1). However, the June 1996 data point is far removed from the rest of the data and may be strongly influencing the relationships (Figure 31). Therefore, we removed this point and recalculated the correlations to examine the influence of this single point. Although the correlations decreased, both remained significant (Table 11 - data set 2 and Figure 32).

For the correlations calculated from the CPUE indices which used the expanded catch data (TXCPU and MXCPU), the Pearson r coefficients were not significant ($P > 0.39$) while the nonparametric Spearman ρ coefficients were significant (Table 11 - data set 1). An examination of Figure 31 explains this as the April 1996 data point appears to be an obvious outlier. There is a clear increase in the CPUE index with the number of fish released upstream for all data points but this one. This single point has a much greater effect on the Pearson coefficient than the Spearman coefficient. Removing this single point increases r

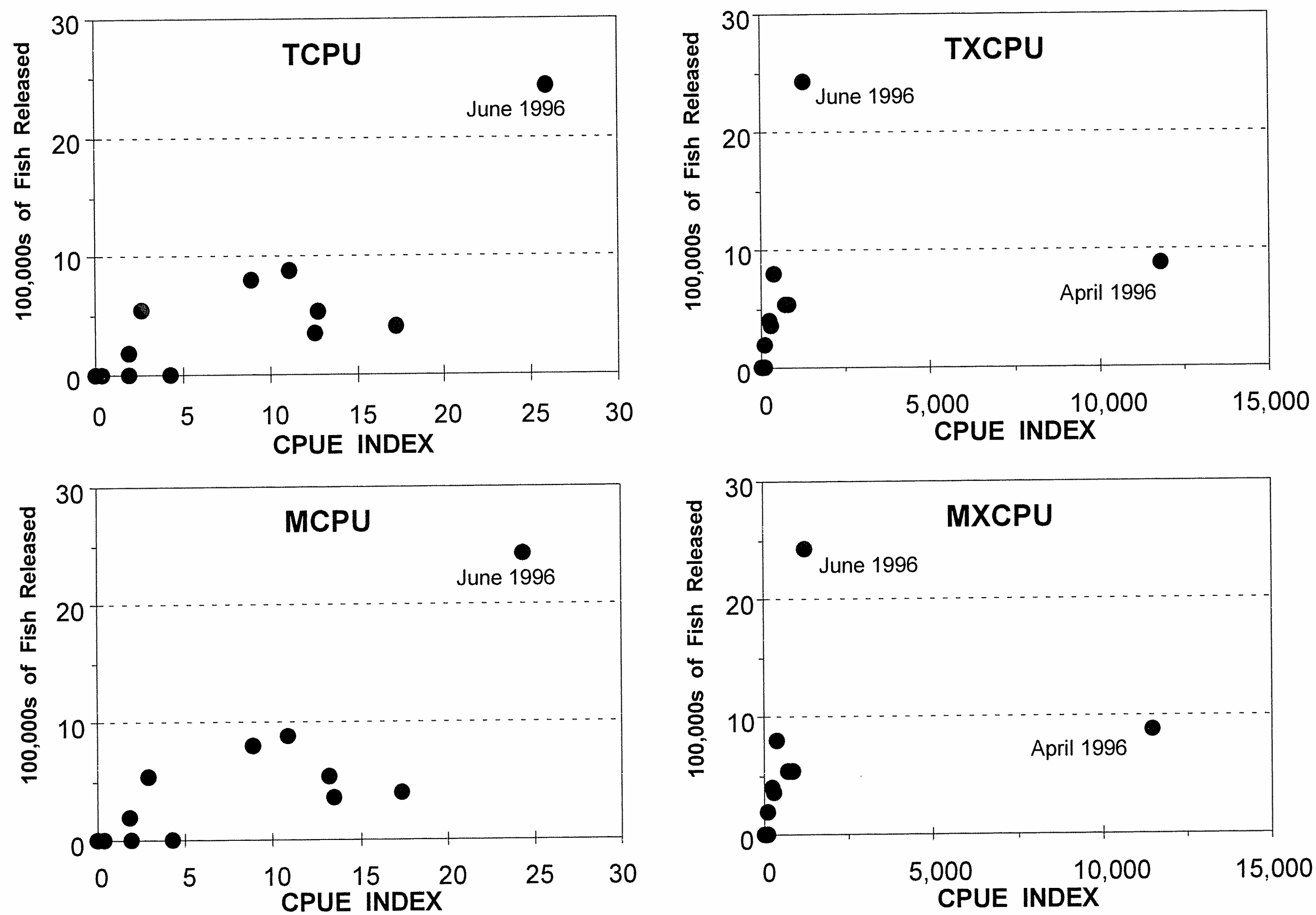


Figure 31. Plots showing the relationship between the four monthly CPUE indices and the number of hatchery-reared chinook salmon juveniles released above the trap site (1996-1998 data).

Table 11. Summary of Pearson's r and Spearman's rho (ρ) correlation coefficients between the total number of hatchery-reared chinook salmon juveniles released each month above the trap and each of the four monthly CPUE indices.

Data Set	Coeffi-cient	TCPU Corr.[a]	TCPU Sig.[b]	MCPU Corr.	MCPU Sig.	TXCPU Corr.	TXCPU Sig.	MXCPU Corr.	MXCPU Sig.
1. All 1996-1998	r	**0.82**	0.001	**0.79**	0.002	0.27	0.393	0.27	0.393
Data (n = 12)	ρ	**0.72**	0.008	**0.69**	0.014	**0.94**	0.000	**0.94**	0.000
2. All Data w/o June	r	**0.62**	0.043	**0.60**	0.049	0.60	0.051	**0.60**	0.050
1996 (n = 11)	ρ	**0.63**	0.037	0.59	0.056	**0.93**	0.000	**0.93**	0.000
3. All Data w/o April	r	**0.82**	0.002	**0.79**	0.004	**0.88**	0.000	**0.87**	0.000
1996 (n = 11)	ρ	**0.74**	0.009	**0.70**	0.016	**0.93**	0.000	**0.93**	0.000
4. All Data w/o April,	r	0.60	0.068	0.59	0.071	**0.77**	0.009	**0.76**	0.010
June 1996 (n = 10)	ρ	**0.66**	0.039	0.60	0.067	**0.91**	0.000	**0.91**	0.000

[a] Value of the correlation coefficient.

[b] Significance of correlation coefficient. Coefficients which are significant at $P \leq 0.05$ are in bold.

Table 12. Summary of Pearson's r and Spearman's rho (ρ) correlation coefficients between the number of adclipped, hatchery-reared chinook salmon juveniles released each month above the trap and each of the four monthly CPUE indices.

Data Set	Coef-ficient	TCPU Corr.[a]	TCPU Sig.[b]	MCPU Corr.	MCPU Sig.	TXCPU Corr.	TXCPU Sig.	MXCPU Corr.	MXCPU Sig.
1. All 1996-1998	r	0.53	0.077	0.54	0.073	**0.73**	0.007	**0.74**	0.006
Data (n = 12)	ρ	**0.73**	0.008	**0.73**	0.008	**0.88**	0.000	**0.88**	0.000
2. All Data w/o June	r	**0.85**	0.001	**0.88**	0.000	**0.71**	0.015	**0.72**	0.012
1997 (n = 11)	ρ	**0.70**	0.017	**0.70**	0.017	**0.89**	0.000	**0.89**	0.000
3. All Data w/o April	r	0.54	0.084	0.55	0.078	**0.89**	0.000	**0.90**	0.000
1996 (n = 11)	ρ	**0.70**	0.017	**0.70**	0.017	**0.89**	0.000	**0.89**	0.000
4. Data w/o April '96,	r	**0.83**	0.003	**0.86**	0.001	**0.91**	0.000	**0.90**	0.000
June '97 (n = 10)	ρ	0.62	0.054	0.62	0.054	**0.89**	0.001	**0.89**	0.001

[a] Value of the correlation coefficient.

[b] Significance of correlation coefficient. Coefficients which are significant at $P \leq 0.05$ are in bold.

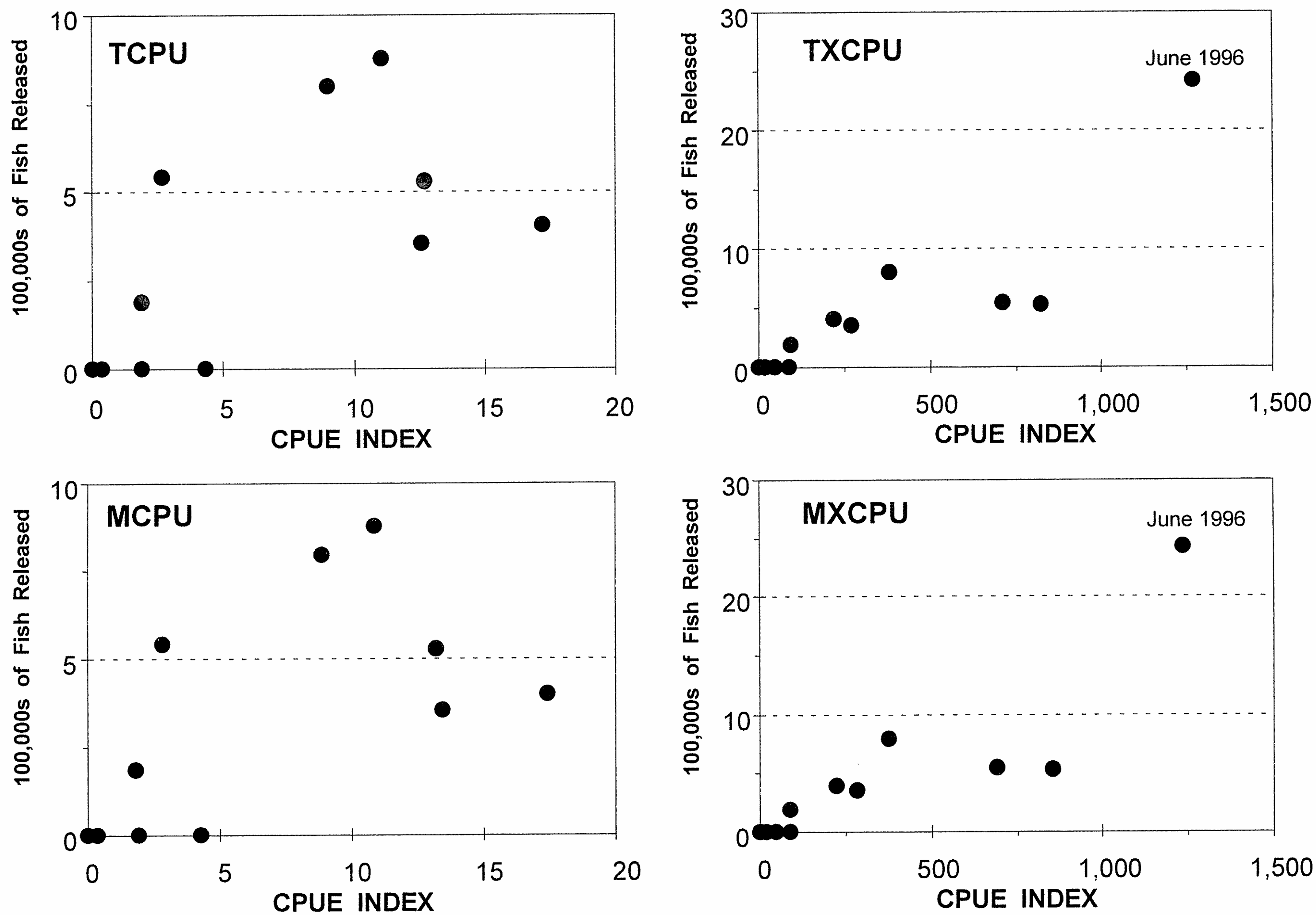


Figure 32. Plots showing the relationship between the four monthly CPUE indices and the number of hatchery-reared chinook salmon juveniles released above the trap site (influential points removed).

from 0.27 to 0.88 and 0.87 for TXCPU and MXCPU, respectively. Both coefficients become significant ($P < 0.01$) for both indices with the removal of this point, also (Table 11 - data set 3). There is virtually no change in the Spearman coefficients with the removal of this data point.

The April 1996 and June 1996 data points appear to be heavily influencing the correlations between the four CPUE indices and the number of chinook released above the trap. Both of these points were associated with releases of hatchery-reared juvenile chinook at the Ferndale Ramp, only 1.8 km above the trap. The releases for all other data points used in the correlation analyses occurred more than 66 km above the trap. The relationship between any CPUE index and the number of fish released above the trap may be different when the fish are released immediately above the trap compared to fish released far above the trap. Therefore, we omitted both the April and June 1996 data and recalculated the correlations for a comparison of indices. Using this reduced data set (Table 11 - data set 4), the two indices calculated using the expanded catch data (TXCPU and MXCPU) are both greater than the correlations calculated using the "raw" catch data (TCPU and MCPU). Both correlations for each of the expanded-catch indices are also significant ($P \leq 0.01$).

Indices Using Release and Catch Data for Adclipped Chinook Only:

The relationship between the monthly CPUE indices for adclipped chinook out-migrants and the number of adclipped, hatchery-reared chinook salmon released each month upstream of the trap is shown for the 1996-1998 data collectively in Figure 33. The correlation coefficients for these data, and their significance, are summarized in Table 12.

Both correlation coefficients were significant ($P < 0.01$) for the TXCPU and MXCPU indices (Table 12 - data set 1). However, only the Spearman coefficient was significant for TCPU and MCPU. The June 1997 data point is far removed from the rest of the data and may be strongly influencing the TCPU and MCPU relationships. Therefore, we removed this point and recalculated the correlations to examine its influence. The Pearson correlation coefficients increased greatly and both became significant (Table 12 - data set 2 and Figure 34). The correlations for the TXCPU and MXCPU indices remained virtually unchanged.

For the correlations calculated from the CPUE indices which used the expanded catch data (TXCPU and MXCPU), the April 1996 data point is far removed from the rest of the data and may be strongly influencing these relationships. Removing this point increased the Pearson correlation from about 0.70 to 0.90 but the correlations were significant ($P < 0.01$) for both data sets. It had little effect on the Spearman coefficient (Table 12 - data set 3).

There is no apparent explanation for why the values of TCPU and MCPU for June 1997 are much higher than expected. The April 1996 data point, while being a potential outlier, does not greatly effect the correlation coefficients. Both correlations (r and ρ) for each of the expanded-catch indices are significant ($P < 0.02$) in each of the data sets examined. It is interesting to note that all adclipped fish were released from the same location (Kendall Creek Hatchery, 66.6 km above the trap) during all three years.

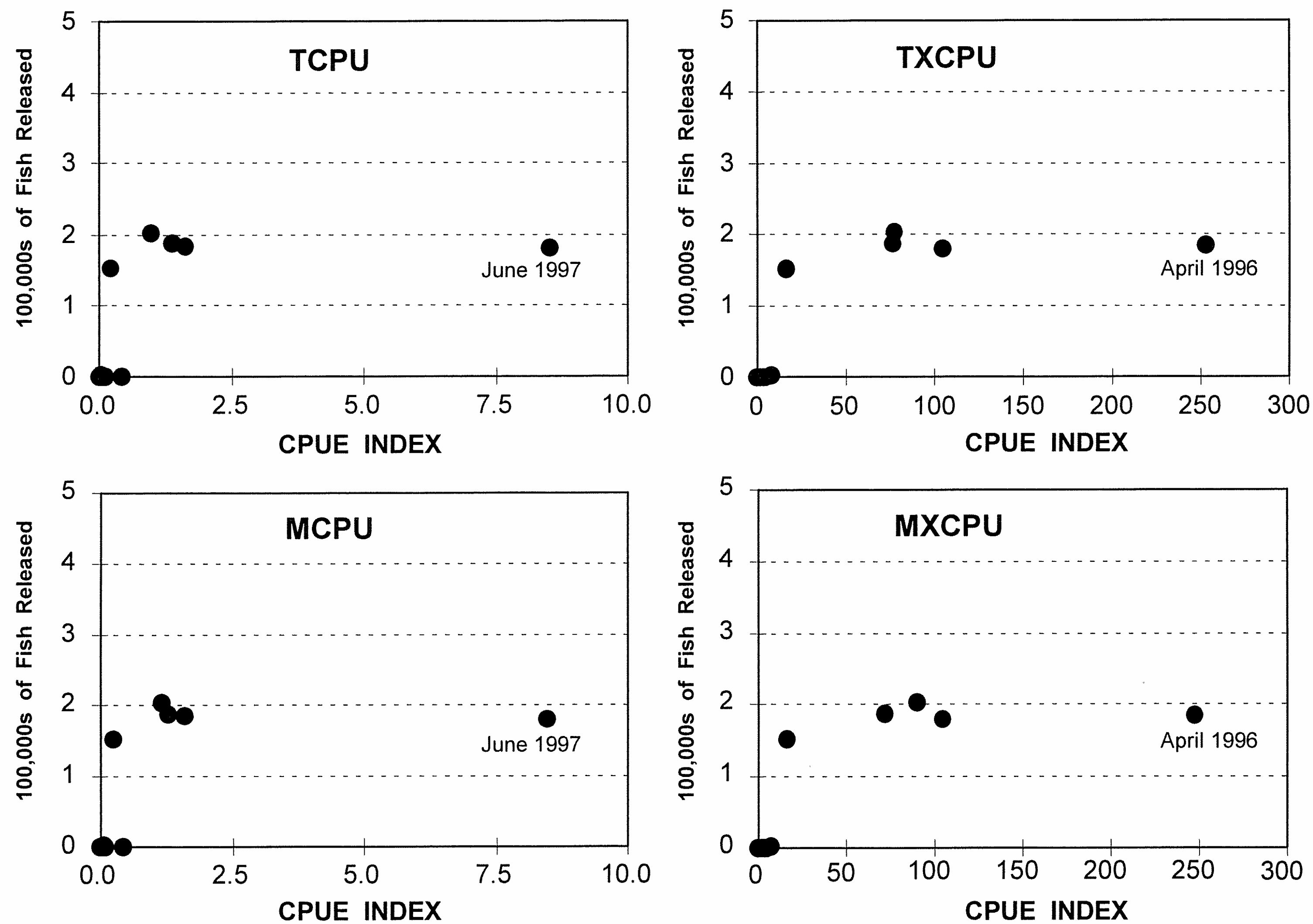


Figure 33. Plots showing the relationship between the four monthly CPUE indices and the number of adclipped, hatchery-reared chinook salmon juveniles released above the trap site.

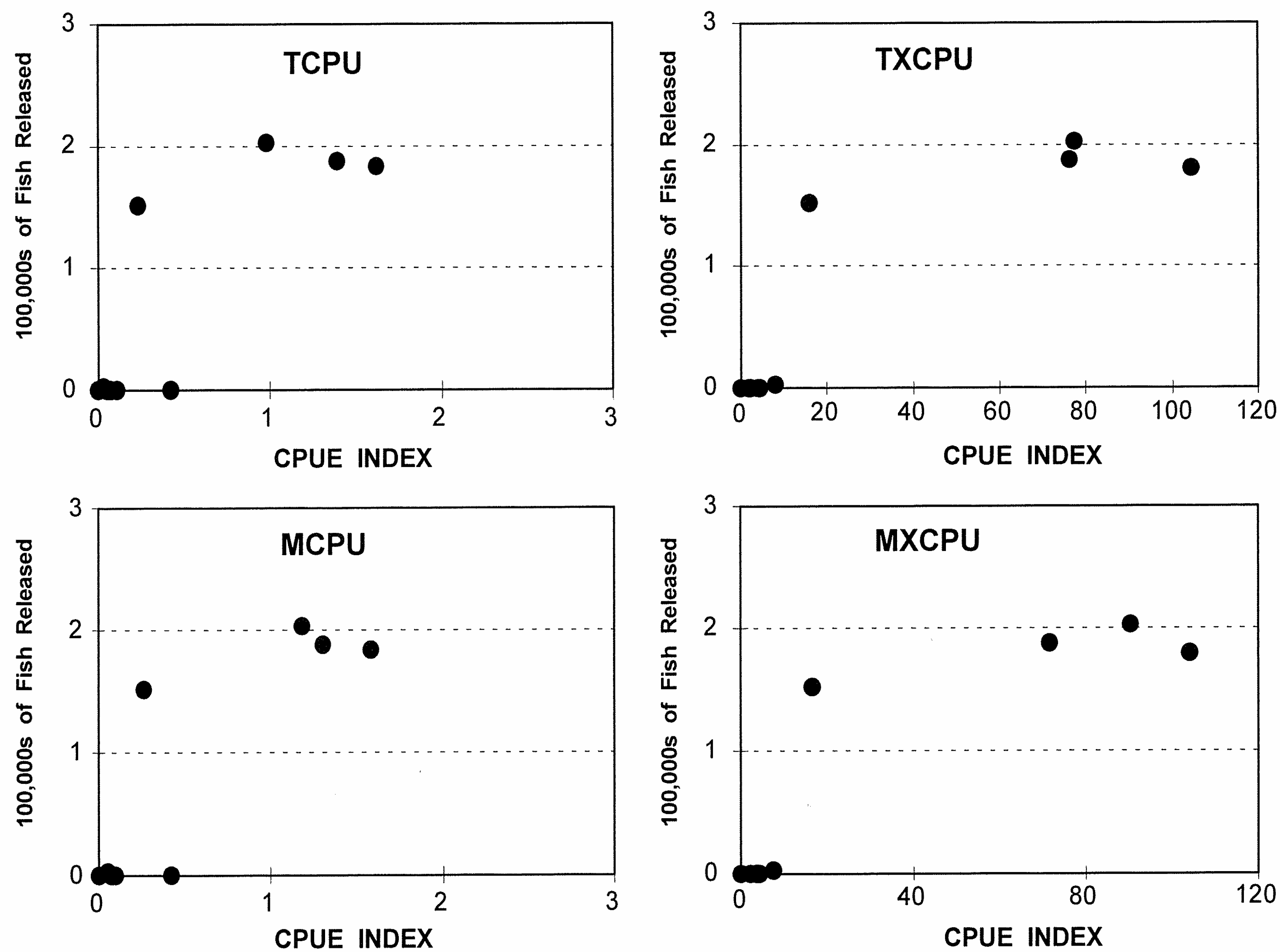


Figure 34. Plots showing the relationship between the four monthly CPUE indices and the number of adclipped, hatchery-reared chinook salmon juveniles released above the trap site (influential points removed).

Discussion and Recommendations

In many situations, researchers must assume that CPUE is proportional to abundance. Often there is no evidence to support this assumption. The release of hatchery-reared juvenile chinook salmon above the trap allowed us to examine this assumption for the Nooksack River screwtrap catch and effort data. The assumption that the CPUE of out-migrating chinook salmon juveniles at the screwtrap is proportional to the number of chinook out-migrating from the river is supported by the previous analyses. Therefore, in this section we will evaluate the four indices and determine which index is "best".

A single annual index is desirable rather than having multiple indices each year. Therefore, we examined using a combined May/June index as the annual index of abundance. Because there were only three data points, one for each year, we did not feel it was useful to calculate correlation coefficients for the May/June indices. Table 13 summarizes the annual estimates of the May/June index of abundance, including standard errors and coefficients of variation, for the four indices. We plotted each of the May/June indices against the number of hatchery-reared chinook released for both: (1) all fish caught and all fish released and (2) for adclipped fish caught and adclipped fish released, similar to the methods used in the previous analyses (Figure 35). The relationships between abundance and CPUE index for both indices based on expanded catch were generally more linear in appearance than those indices based upon "raw" catch for both sets of data.

The correlations for the monthly indices based upon expanded catch were generally as high or higher than those for the indices base upon "raw" catch regardless of the data set examined (Tables 11 and 12). This, in conjunction with the more linear appearance of the abundance-CPUE relationship noted above for the combined May/June index using expanded catch, leads us to recommend the indices based upon expanded catch (TXCPU or MXCPU). We recommend that the combined May/June screwtrap catch data be used in developing an annual index of abundance. There is little to recommend one of the expanded catch based indices over the other at this time (Table 13). We recommend further evaluation of these two indices as additional data are collected in the future.

Table 13. Estimated May/June index of abundance, with standard error and coefficient of variation, using total catch data for out-migrating chinook salmon smolts in 1996, 1997, and 1998.

Index Year	Index Estimate	Standard Error[a]	Coefficient Of Variation
TCPU			
1996	12.87	8.05	62.5%
1997	14.93	3.65	24.4%
1998	10.92	2.61	23.9%
MCPU			
1996	13.07	7.15	54.7%
1997	15.08	3.41	22.6%
1998	11.11	2.55	22.9%
TXCPU			
1996	631.93	377.21	59.7%
1997	243.52	51.94	21.3%
1998	608.73	131.43	21.6%
MXCPU			
1996	663.66	344.34	51.9%
1997	259.35	54.57	21.0%
1998	623.66	130.37	20.9%

[a] Variance estimates for TXCPU and MXCPU do not include the additional variation introduced by estimating the catch expanded for trap capture efficiency.

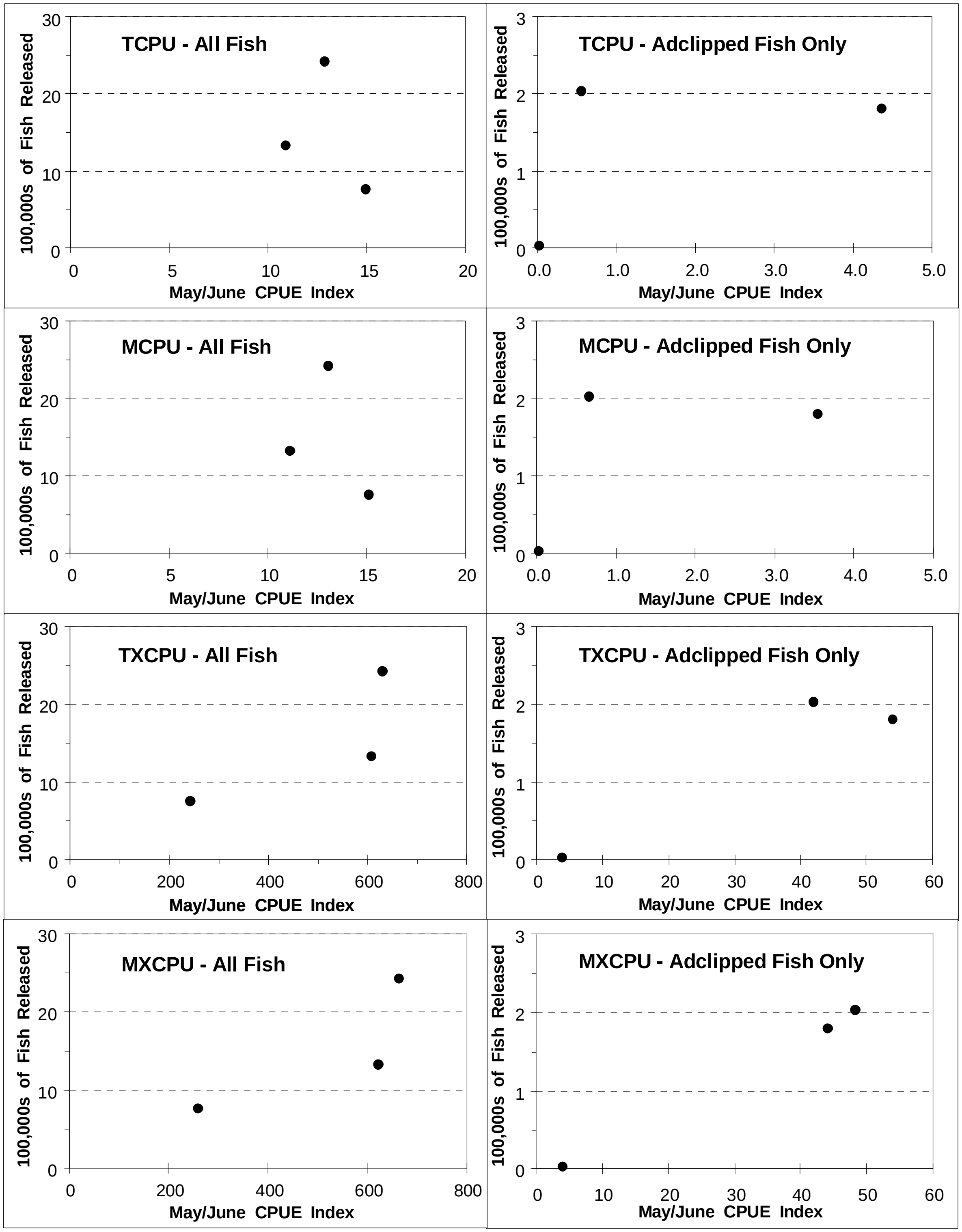


Figure 35. Plots showing the relationships between the four CPUE indices and the number of juvenile chinook salmon released above the trap calculated using May/June data only. Plots for all juvenile chinook salmon caught and released are on the left and for adclipped chinook juveniles caught and released are on the right.

Conclusions and Recommendations

The five years of trap operation have demonstrated the feasibility of using a screwtrap to sample the out-migration of chinook salmon juveniles from the Nooksack River. We have shown that chinook salmon out-migrants can be non-lethally captured by the trap and released alive after enumeration and biological sampling. Based upon our analyses of the data we have reached the following conclusions and recommendations.

Conclusions

1. Chinook salmon juveniles out-migrate from the Nooksack River from at least late March and early April through July.
2. The period of peak out-migration for naturally-produced chinook smolts cannot be identified in the current data set. The large releases of hatchery-reared chinook juveniles upstream of the trap overwhelm the naturally-produced chinook salmon smolts and do not allow them to be identified in the out-migration.
3. There is no evidence at this time, at this location, of diurnal patterns in the daily out-migration of chinook salmon juveniles. These fish apparently out-migrate throughout the day and do not consistently exhibit higher rates of catch related to any period of the day.
4. While high rates of river flow are sometimes associated with high catch rates of chinook smolts at the trap, flow is not the critical factor affecting catch rates.
5. There is a strong relationship between the clarity of the water (as measured by secchi depth) and the efficiency of the trap in capturing chinook salmon out-migrants. As the clarity of the water increases (secchi depth gets deeper), the efficiency of the trap in catching out-migrating chinook salmon juveniles decreases.
6. The size (length) of out-migrating chinook salmon juveniles may influence their susceptibility to capture by the trap, also. Currently, there are not sufficient data to determine whether this relationship is significant.
7. Length data alone are not sufficient to accurately estimate the proportion of yearling (age-1) chinook in the out-migration.
8. There is a significant and positive relationship between the number of chinook smolts migrating past the trap and catch per unit effort (CPUE). CPUE provides an index of the relative abundance of chinook salmon in the out-migration and can be used for comparisons within and between years.
9. The best index of abundance that we examined was based on CPUE calculated using the catch expanded for the capture efficiency of the trap estimated from secchi depth measured at the time of the set.

A long-range goal of this project is to estimate the annual production of chinook salmon smolts from the Nooksack River system. There are three major problems that must be addressed before total production estimates are possible:

- The feasibility of using CPUE data to estimate the total number of out-migrating chinook salmon during periods of trap operation and expanding these estimates to unsampled time periods must be examined;

- A method for differentiating naturally-produced chinook from hatchery-reared chinook must be developed if the natural smolt production in the Nooksack river system is to be estimated; and
- It must be determined if the relationship between capture efficiency of the screwtrap for hatchery-reared juvenile chinook and secchi depth measured at the trap estimated in this report is the same for naturally-produced juvenile chinook salmon.

These will require that additional resources be devoted to the project. If CPUE data are to be expanded to total production estimates, the frequency of sampling must be increased. Under the current sampling plan, only six out of every 48 hours (12.5% of the hours possible) are sampled on average. Precise estimates of total production will most likely require more hours of trap operation. Secondly, if a method of differentiating naturally-produced chinook from hatchery-reared chinook is developed it may require additional processing costs for the samples, especially if microsatellite DNA analysis is used. If all hatchery-reared chinook salmon are mass-marked with an adipose fin clip, DNA analysis is no longer needed for differentiating hatchery from natural chinook salmon smolts. This will allow the estimation of total river production by the natural stocks. However, DNA analysis will still be required to estimate the production by each of the natural chinook salmon stocks in the Nooksack River.

Also, because the naturally-produced smolts appear to be in very low abundance relative to the hatchery-reared fish, additional sampling effort (more hours of trap operation) will be required to collect sufficient numbers for precise estimates of the contribution of the naturally-produced fish to the total out-migration. Ideally, capture efficiency experiments should be conducted with naturally-produced fish. However it is unlikely that sufficient numbers could be collected and marked for a comparative experiment without unacceptable risks to the native stocks. Future experiments should attempt to use fish with fork lengths more similar to those captured in the screwtrap.

Recommendations

1. The trap should be operated following a random sampling schedule to provide unbiased estimates of CPUE.
2. All future length data collected at the screwtrap should be from a random sample of the captured chinook salmon. We recommend that a systematic sampling procedure be implemented for collecting fish lengths. For example, taking a length measurement from every fifth chinook smolt removed from the trap. This would ensure that mean lengths and other associated biological statistics are representative of the catch.
3. A random sample of scale samples with associated fish lengths should be collected. This will allow the length-age relationship of the out-migrating smolts to be established. This relationship can then be used to estimate the proportion of yearling (age-1) smolts in the out-migration and to estimate the catch statistics (CPUE, etc.) for this group separately. Estimating the age composition of the out-migrants will be important if brood year production is to be estimated in the future.

4. The feasibility of differentiating hatchery-reared and naturally-produced chinook smolts should be further examined. Both scale pattern and microsatellite DNA analysis options should be explored. Estimates of the production of naturally-produced chinook salmon smolts from the Nooksack River system will not be possible until there is a method of estimating (or identifying) the contribution of naturally-produced chinook salmon smolts to the trap catches. It is important that the samples for these techniques be collected in a random manner in proportion to their abundance.
5. Additional capture–efficiency experiments should be conducted each year. The length data for the fish used in the capture-efficiency trials should be collected so that the relationship between capture efficiency and fish length can be further examined. This requires that the lengths are measured shortly before the fish are released for the experiment (not two to three weeks prior to release).
6. Capture–efficiency experiments should be conducted using naturally-produced ("native") chinook salmon juveniles, if possible, to determine if the current capture-efficiency and secchi depth relationship is appropriate for these fish.
7. Estimates of the total production of chinook salmon out-migrants from the Nooksack River should be generated from the 1997 through 1999 data. Different methods of producing these estimates should be examined and compared. The variance of these estimates should be generated so the precision of the estimates under current sampling rates is known.

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Lummi Seaponds
Bob Hall

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APPENDICES

Appendix Table 1. Starting and ending dates of statistical weeks for the years 1994 through 1998. All statistical weeks begin on Sunday and end the following Saturday.

Statistical	1994		1995		1996		1997		1998	
Week	Start	End	Start	End	Start	End	Start	End	Start	End
12	03/20	03/26	03/19	03/25	03/17	03/23	03/16	03/22	03/15	03/21
13	03/27	04/02	03/26	04/01	03/24	03/30	03/23	03/29	03/22	03/28
14	04/03	04/09	04/02	04/08	03/31	04/06	03/30	04/05	03/29	04/04
15	04/10	04/16	04/09	04/15	04/07	04/13	04/06	04/12	04/05	04/11
16	04/17	04/23	04/16	04/22	04/14	04/20	04/13	04/19	04/12	04/18
17	04/24	04/30	04/23	04/29	04/21	04/27	04/20	04/26	04/19	04/25
18	05/01	05/07	04/30	05/06	04/28	05/04	04/27	05/03	04/26	05/02
19	05/08	05/14	05/07	05/13	05/05	05/11	05/04	05/10	05/03	05/09
20	05/15	05/21	05/14	05/20	05/12	05/18	05/11	05/17	05/10	05/16
21	05/22	05/28	05/21	05/27	05/19	05/25	05/18	05/24	05/17	05/23
22	05/29	06/04	05/28	06/03	05/26	06/01	05/25	05/31	05/24	05/30
23	06/05	06/11	06/04	06/10	06/02	06/08	06/01	06/07	05/31	06/06
24	06/12	06/18	06/11	06/17	06/09	06/15	06/08	06/14	06/07	06/13
25	06/19	06/25	06/18	06/24	06/16	06/22	06/15	06/21	06/14	06/20
26	06/26	07/02	06/25	07/01	06/23	06/29	06/22	06/28	06/21	06/27
27	07/03	07/09	07/02	07/08	06/30	07/06	06/29	07/05	06/28	07/04
28	07/10	07/16	07/09	07/15	07/07	07/13	07/06	07/12	07/05	07/11
29	07/17	07/23	07/16	07/22	07/14	07/20	07/13	07/19	07/12	07/18
30	07/24	07/30	07/23	07/29	07/21	07/27	07/20	07/26	07/19	07/25
31	07/31	08/06	07/30	08/05	07/28	08/03	07/27	08/02	07/26	08/01
32	08/07	08/13	08/06	08/12	08/04	08/10	08/03	08/09	08/02	08/08
33	08/14	08/20	08/13	08/19	08/11	08/17	08/10	08/16	08/09	08/15

Appendix Table 2. Details of annual releases of hatchery-reared chinook salmon into the Nooksack River, 1994-1998.

Release Date	Stock	Stock Origin	Age	Release Site	km to Trap	Otolith Mark	Number Adipose Fin Clips	Total Number Released
4/1/94	Spring	N. F. Nooksack	Yearling	Kendall Hatchery	66.6	No	139,738	292,300
4/4/94	Fall	Green River	Zero	Nugents Corner	49.6	No	0	1,056,000
5/23/94	Spring	N. F. Nooksack	Zero	Kidney Creek Pond	89.5	No	0	231,395
5/24/94	Spring	N. F. Nooksack	Zero	Excelsior Side Chan.	96.1	No	0	188,370
5/24/94	Spring	N. F. Nooksack	Zero	Deadhorse Pond	94.3	No	180,208	221,209
5/25/94	Spring	N. F. Nooksack	Zero	Deadhorse Pond	94.3	No	202,507	225,117
5/25/94	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	No	199,593	432,944
5/25/94	Fall	Green River	Zero	Mamoya Ponds	-7.1	No	0	2,000,000
6/15/94	Fall	Green River	Zero	Kendall Hatchery	66.6	No	0	1,552,902
6/15/94	Fall	Green River	Zero	Kendall Hatchery	66.6	No	0	987,800
3/30/95	Fall	Green River	Zero	Nugents Corner	49.6	No	0	1,008,090
4/1/95	Spring	N. F. Nooksack	Yearling	Kendall Hatchery	66.6	No	347,540	347,540
5/15/95	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	No	178,069	178,069
5/24/95	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	No	15,076	15,076
5/26/95	Fall	Green River	Zero	Mamoya Ponds	-7.1	No	52,600	2,085,072
6/7/95	Fall	Green River	Zero	Kendall Hatchery	66.6	No	0	138,390
6/14/95	Fall	Green River	Zero	Kendall Hatchery	66.6	No	0	3,083,225
4/1/96	Spring	N. F. Nooksack	Yearling	Kendall Hatchery	66.6	No	183,545	185,962
4/4/96	Fall	Green River	Zero	Ferndale Ramp	1.8	No		689,700
6/3/96	Fall	Green River	Zero	Ferndale Ramp	1.8	No		2,418,860
6/21/96	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	No	2,638	2,638

- continued -

Appendix Table 2. Details of annual releases of hatchery-reared chinook salmon into the Nooksack River, 1994-1998 (continued).

Release Date	Stock	Stock Origin	Age	Release Site	km to Trap	Otolith Mark	Number Adipose Fin Clips	Total Number Released
4/1/97	Spring	N. F. Nooksack	Yearling	Kendall Hatchery	66.6	Yes	187,765	187,765
4/25/97	Spring	N. F. Nooksack	Zero	Kidney Creek Pond	89.5	Yes		96,530
5/18/97	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes		45,600
5/19/97	Spring	N. F. Nooksack	Zero	Deadhorse Pond	94.3	Yes		211,831
5/29/97	Spring	N. F. Nooksack	Zero	Kidney Creek Pond	89.5	Yes		96,470
6/1/97	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	Yes	180,014	248,822
6/2/97	Fall	Green River	Zero	Below Trap	-5.5	No		1,143,200
6/8/97	Spring	N. F. Nooksack	Zero	Kidney Creek Pond	89.5	Yes		56,200
4/1/98	Spring	N. F. Nooksack	Yearling	Kendall Hatchery	66.6	Yes	151,516	187,636
4/15/98	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	Yes	0	352,601
4/22/98	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes	0	40,000
5/1/98	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes	0	40,000
5/11/98	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes	0	40,000
5/17/98	Spring	N. F. Nooksack	Zero	Excelsior Side Chan.	96.1	Yes	0	100,000
5/20/98	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes	0	40,000
5/20/98	Spring	N. F. Nooksack	Zero	Deadhorse Pond	94.3	Yes	0	339,073
5/20/98	Spring	N. F. Nooksack	Zero	Kidney Creek Pond	89.5	Yes	0	198,263
5/30/98	Spring	N. F. Nooksack	Zero	Excelsior Tributary	96.1	Yes	0	35,000
6/1/98	Fall	Green River	Zero	Below Trap	-5.5	No	0	124,046
6/2/98	Spring	N. F. Nooksack	Zero	Excelsior Side Chan.	96.1	Yes	0	122,978
6/12/98	Spring	N. F. Nooksack	Zero	Kendall Hatchery	66.6	Yes	202,802	369,999

Appendix Table 3. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1994.

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch: Adipose Fin Present	Chinook Smolt Catch: Adipose Fin Absent	Chinook Smolt Catch: Tally Count	Chinook Smolt Catch: Total Catch
1	17	4/25	10:15	0.50		1	0	0	1
2	17	4/25	11:00	4.25		2	0	0	2
3	17	4/26	10:53	4.02	2.0	0	0	0	0
4	17	4/27	8:50	5.92	2.0	0	0	0	0
5	17	4/28	10:16	5.40	1.5	1	1	0	2
6	17	4/29	9:10	2.33	1.5	0	0	0	0
7	18	5/2	8:30	8.00	2.0	1	0	0	1
8	18	5/3	8:44	6.98	2.5	2	1	0	3
9	18	5/4	8:50	6.70	2.8	0	0	0	0
10	18	5/5	8:44	6.97	2.8	1	1	0	2
11	19	5/9	8:54	6.95	1.1	3	0	0	3
12	19	5/10	8:30	4.00	1.2	27	5	0	32
13	19	5/10	13:55	1.67	1.0	6	0	0	6
14	19	5/11	18:07	2.38	1.3	35	3	0	38
15	19	5/11	21:30	2.25	1.2	9	2	0	11
16	19	5/12	18:45	2.00	1.2	8	0	0	8
17	19	5/12	21:30	2.50	1.2	7	3	0	10
18	20	5/16	8:47	3.87		16	2	0	18
19	20	5/16	13:00	2.92	2.7	16	1	0	17
20	20	5/17	8:37	3.72	3.2	4	1	0	5
21	20	5/17	12:37	3.00	2.8	4	0	0	4
22	20	5/18	19:04	1.85	3.7	0	0	0	0
23	20	5/18	21:30	1.92		2	1	0	3
24	20	5/19	18:00	2.95	3.2	1	0	0	1
25	20	5/19	21:30	2.00		8	2	0	10
26	21	5/23	9:00	2.95	4.2	5	0	0	5
27	21	5/23	11:57	3.92		5	0	0	5
28	21	5/24	8:25	3.58	3.4	0	0	0	0
29	21	5/24	12:15	3.45		19	0	0	19
30	21	5/25	12:37	2.72	2.7	19	2	0	21
31	23	6/6	9:32	3.47	2.8	11	9	0	20
32	23	6/6	13:30	2.42		20	1	0	21
33	23	6/7	8:25	4.00	1.7	13	6	95	114
34	23	6/7	13:12	2.63		24	11	54	89
35	23	6/8	8:42	3.63	1.3	25	13	0	38
36	23	6/8	12:45	2.95		16	5	39	60
37	23	6/9	8:30	3.83	3.2	11	3	0	14
38	23	6/9	12:30	3.25		8	3	0	11
39	24	6/13	8:28	4.53	1.8	247	106	0	353
40	24	6/13	13:30	1.92		0	0	838	838
41	24	6/14	8:16	3.78	1.0	89	45	0	134
42	24	6/14	12:45	2.92		48	17	0	65
43	24	6/15	8:30	2.75	1.0	375	116	0	491
44	24	6/15	12:16	2.65		129	20	0	149
45	24	6/16	8:30	3.83	1.7	38	22	0	60
46	25	6/20	9:25	2.92	2.4	12	2	0	14
47	25	6/20	12:05	3.40		13	4	0	17
48	25	6/21	8:19	3.75	2.6	14	1	0	15
49	25	6/21	12:23	2.87		36	12	0	48
50	25	6/22	8:15	3.83	2.3	18	1	0	19
51	25	6/22	12:20	2.78	2.4	80	18	0	98
52	25	6/23	8:36	3.67	2.1	71	5	0	76

- continued -

Appendix Table 3. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1994 (continued).

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch: Adipose Fin Present	Chinook Smolt Catch: Adipose Fin Absent	Chinook Smolt Catch: Tally Count	Chinook Smolt Catch: Total Catch
53	25	6/23	12:40	2.48		116	34	0	150
54	26	6/27	8:27	6.72	2.7	4	0	0	4
55	26	6/28	8:26	3.98	3.4	1	0	0	1
56	26	6/28	12:33	2.78		5	0	0	5
57	26	6/29	15:28	3.78	1.8	18	5	0	23
58	26	6/29	19:30	3.75		116	18	0	134
59	26	6/30	23:55	5.05	1.9	59	6	0	65
60	26	6/30	5:43	5.55	2.4	10	0	0	10
61	26	6/30	11:30	3.42		11	2	0	13
62	27	7/5	9:45	6.00	1.9	4	1	0	5
63	27	7/6	8:23	5.18	2.2	10	0	0	10
64	27	7/6	8:23	5.33	1.8	7	2	0	9
65	27	7/6	19:20	4.17	1.7	23	3	0	26
66	28	7/11	0:30	3.78	2.3	0	0	0	0
67	28	7/11	8:23	3.25	2.0	5	0	0	5
68	28	7/14	16:02	4.85	0.9	221	36	0	257
69	28	7/14	21:43	2.32	1.1	27	9	132	168
70	29	7/18	10:30	2.25	1.6	2	2	0	4
			TOTALS	258.09		2,139	563	1,158	3,860

Appendix Table 4. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1995.

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch Adipose Fin Present	Absent	Tally Count	Total Catch
1	13	3/31	1012	3.60	3.4	7	0	0	7
2	14	4/3	1105	2.73	3.2	3	0	0	3
3	14	4/3	1349	2.22		8	0	0	8
4	14	4/4	1021	2.98	3.1	2	0	0	2
5	14	4/4	1320	2.37		9	0	0	9
6	14	4/5	950	3.37	1.6	74	7	0	81
7	14	4/5	1312	2.55		23	1	178	202
8	15	4/10	931	3.00	2.5	21	0	30	51
9	15	4/10	1245	3.12		21	0	23	44
10	15	4/11	940	3.50	1.9	43	0	104	147
11	15	4/11	1330	2.38		42	0	24	66
12	15	4/12	912	2.55	2.1	6	0	0	6
13	15	4/12	1150	3.67		2	0	0	2
14	16	4/17	935	2.43	3.3	1	0	0	1
15	16	4/17	1201	3.58		1	0	0	1
16	16	4/18	2220	2.17	2.1	2	0	0	2
17	16	4/19	2430	2.00	2.1	5	0	0	5
18	16	4/19	230	2.00	1.9	2	0	0	2
19	16	4/19	430	2.00	2.7	2	0	0	2
20	16	4/19	630	2.00	2.5	3	0	0	3
21	16	4/19	830	0.92	2.5	2	0	0	2
22	16	4/19	1032	1.97	3.0	3	0	0	3
23	16	4/19	1230	2.17	2.6	1	0	0	1
24	16	4/19	1440	1.83	2.6	2	0	0	2
25	16	4/19	1630	2.08	2.8	0	0	0	0
26	16	4/19	1835	2.00	2.3	0	0	0	0
27	16	4/19	2035	1.75	2.0	1	0	0	1
28	16	4/19	2220	1.67	2.0	0	0	0	0
29	17	4/24	940	3.08	4.0	0	0	0	0
30	17	4/24	1250	2.33	4.0	0	0	0	0
31	17	4/26	915	3.50	3.4	1	0	0	1
32	17	4/26	1245	3.97		0	0	0	0
33	17	4/28	918	2.95	3.0	0	0	0	0
34	17	4/28	1234	3.18	2.9	1	0	0	1
35	18	5/1	935	1.08	3.3	0	0	0	0
36	18	5/1	1155	1.88	3.2	0	0	0	0
37	18	5/2	1910	4.67	3.1	1	0	0	1
38	18	5/3	2350	1.17	2.2	4	0	0	4
39	18	5/3	130	1.25	2.2	0	0	0	0
40	18	5/3	315	2.25	1.6	3	1	0	4
41	18	5/3	620	2.25	1.6	2	0	0	2
42	18	5/3	935	1.75	1.4	3	0	0	3
43	18	5/3	1150	4.42	1.3	4	0	0	4
44	18	5/3	1615	1.00	1.2	0	0	0	0
45	18	5/5	922	3.38	3.1	2	0	0	2
46	18	5/5	1300	3.33	2.8	1	0	0	1
47	19	5/8	945	0.50	2.7	12	0	0	12
48	19	5/9	912	2.05	2.1	0	0	0	0
49	19	5/9	1250	3.17	2.2	5	0	0	5
50	19	5/10	942	0.23		1	0	0	1
51	19	5/10	1035	1.03	1.2	11	0	0	11
52	20	5/15	945	3.00	2.0	9	23	0	32

- continued -

Appendix Table 4. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1995 (continued).

					Secchi	**Chinook Smolt Catch**			
Set	Stat.		Start	Effort	Depth	Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
53	20	5/15	1325	2.25	1.7	11	32	0	43
54	20	5/16	1937	3.97	0.9	15	56	3	74
55	20	5/17	2335	1.58	1.3	0	104	0	104
56	20	5/17	110	2.92	1.4	9	27	0	36
57	20	5/17	435	3.67	1.5	9	25	0	34
58	20	5/17	835	3.67	1.4	8	11	0	19
59	21	5/22	855	3.33	3.0	1	0	0	1
60	21	5/22	1225	3.17	3.1	4	1	0	5
61	21	5/23	1931	3.75	2.1	14	14	0	28
62	21	5/24	2316	1.98	1.9	1	0	0	1
63	21	5/24	115	2.12		1	0	0	1
64	21	5/24	322	1.72	2.4	2	0	0	2
65	21	5/24	505	2.25	2.4	2	2	0	4
66	21	5/24	720	3.92	2.4	3	5	0	8
67	21	5/24	1115	4.92	2.5	25	24	0	49
68	22	5/31	748	1.00	1.2	0	0	0	0
69	22	5/31	854	0.10		2	0	1	3
70	22	5/31	900	0.27		3	0	0	3
71	22	5/31	916	0.23		0	0	0	0
72	22	5/31	930	5.55	1.1	12	0	0	12
73	22	5/31	1503	6.87	1.5	46	7	1	54
74	22	6/2	912	4.25	1.8	13	0	0	13
75	22	6/2	1429	2.10	1.6	9	3	0	12
76	23	6/5	930	3.83	1.8	6	0	0	6
77	23	6/5	1320	2.28	1.7	5	3	0	8
78	23	6/6	908	3.37	2.3	1	1	0	2
79	23	6/6	1230	4.00	2.2	4	1	0	5
80	23	6/7	845	1.17	2.5	3	0	0	3
81	23	6/7	955	0.42		0	0	0	0
82	23	6/7	1020	0.50	2.5	0	0	0	0
83	23	6/7	1050	1.03		0	0	0	0
84	23	6/7	1152	1.67		0	0	0	0
85	23	6/7	1332	2.03	2.6	1	0	0	1
86	23	6/7	1534	2.60	2.8	0	0	0	0
87	23	6/7	1810	2.90		0	0	0	0
88	23	6/9	908	3.28	2.1	1	1	0	2
89	23	6/9	1240	2.62	1.9	13	4	0	17
90	24	6/12	905	2.72	1.7	26	0	0	26
91	24	6/12	1200	3.00	1.7	17	2	0	19
92	24	6/13	908	3.37	2.5	1	0	0	1
93	24	6/13	1230	3.08	2.5	1	0	0	1
94	24	6/14	835	3.50	2.5	0	0	0	0
95	24	6/14	1205	3.50	2.5	0	0	0	0
96	24	6/15	853	3.62	3.1	0	0	0	0
97	24	6/15	1230	3.13	3.0	1	0	0	1
98	25	6/19	858	3.37	2.5	1	0	0	1
99	25	6/19	1220	4.03	3.0	2	0	0	2
100	25	6/20	1220	4.13	3.6	0	0	0	0
101	25	6/21	858	4.03	3.3	3	0	0	3
102	25	6/21	1300	3.35		1	0	0	1
103	25	6/22	810	8.47	3.4	1	0	0	1
104	25	6/23	900	2.75	3.0	0	0	0	0

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Appendix Table 4. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1995 (continued).

					Secchi	**Chinook Smolt Catch**			
Set	Stat.		Start	Effort	Depth	Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
105	25	6/23	1145	4.58	2.6	1	0	0	1
106	26	6/26	831	5.02		27	0	0	27
107	26	6/26	1332	2.42		18	0	0	18
108	26	6/27	845	2.92		2	0	0	2
109	26	6/27	1140	2.67		2	0	0	2
110	26	6/29	940	3.17	2.0	25	0	0	25
111	26	6/29	1325	2.33	1.6	33	0	0	33
112	27	7/3	815	3.92	1.1	40	0	591	631
113	27	7/3	1247	3.32	1.0	40	0	219	259
114	27	7/5	820	3.63	1.7	17	0	0	17
115	27	7/5	1158	3.58	1.6	18	0	0	18
116	27	7/6	926	2.78	1.9	10	0	0	10
117	27	7/6	1213	3.53	1.9	23	0	0	23
118	28	7/10	736	4.68	1.2	40	0	202	242
119	28	7/10	1220	4.27	1.6	41	0	365	406
120	28	7/11	824	5.85	1.1	57	0	0	57
121	28	7/11	1429	1.63	1.1	10	0	0	10
122	28	7/12	825	3.62	1.7	4	0	0	4
123	28	7/12	1202	4.18	1.4	1	0	0	1
124	28	7/13	834	6.43	1.5	1	0	0	1
125	28	7/13	1500	1.33		0	0	0	0
126	29	7/17	908	5.12	1.7	7	0	0	7
127	29	7/17	1530	0.83	1.5	5	0	0	5
128	30	7/24	1045	4.87		1	0	0	1
129	30	7/26	914	2.47	0.3	1	0	0	1
130	30	7/26	1202	2.68	0.4	17	0	0	17
131	30	7/27	1004	0.18	0.3	2	0	0	2
			TOTALS	371.38		1,067	355	1,741	3,163

Appendix Table 5. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1996.

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch: Adipose Fin Present	Absent	Tally Count	Total Catch
1	13	3/25	12:02	4.00	3.0	0	0	0	0
2	13	3/27	7:46	4.18	3.3	0	0	0	0
3	13	3/27	20:10	3.88	3.5	0	0	0	0
4	13	3/30	4:10	4.00	3.5	0	0	0	0
5	13	3/30	12:00	4.17	4.0	0	0	0	0
6	14	4/1	4:14	3.78	2.9	0	0	0	0
7	14	4/2	8:12	4.08	0.9	4	127	0	131
8	14	4/2	12:27	4.08	0.8	0	20	0	20
9	14	4/3	4:10	4.00	1.5	1	11	0	12
10	14	4/4	15:59	4.00	3.2	20	3	135	158
11	14	4/4	20:20	4.03		20	0	62	82
12	14	4/5	8:00	4.03	3.5	20	0	186	206
13	14	4/6	16:00	4.00	3.2	20	1	788	809
14	15	4/7	23:57	4.67	1.1	42	0	1	43
15	15	4/7	12:07	4.02	0.9	9	0	0	9
16	15	4/7	16:10	4.03	0.7	12	2	0	14
17	15	4/9	12:00	4.02	1.6	10	0	0	10
18	15	4/10	4:27	3.70	1.2	24	1	0	25
19	15	4/10	8:43	1.22	1.1	4	1	0	5
20	15	4/11	4:00	4.00	0.9	7	1	0	8
21	15	4/12	16:00	4.00	1.6	12	2	0	14
22	15	4/13	20:00	4.00	2.4	2	0	0	2
23	16	4/14	4:03	4.00	2.1	1	1	0	2
24	16	4/14	20:00	4.08	2.2	1	0	0	1
25	16	4/15	0:16	4.07	3.1	1	0	0	1
26	16	4/15	16:15	3.53	3.3	0	0	0	0
27	16	4/15	20:04	3.85	3.3	1	0	0	1
28	16	4/16	0:05	3.82	3.1	0	0	0	0
29	16	4/16	4:14	3.70	2.9	1	0	0	1
30	16	4/17	4:10	4.03	1.3	0	1	0	1
31	16	4/18	4:15	4.00	1.7	2	0	0	2
32	16	4/18	12:00	4.00	1.6	2	0	0	2
33	16	4/19	16:40	4.00	1.7	0	1	0	1
34	17	4/22	0:03	4.00	2.8	1	0	0	1
35	17	4/22	4:03	4.00	3.3	0	0	0	0
36	18	4/28	12:10	4.00	1.2	0	0	0	0
37	18	4/28	16:17	4.00	1.5	1	0	0	1
38	18	4/28	20:23	4.05	1.5	0	0	0	0
39	18	4/29	4:30	4.00	1.4	0	0	0	0
40	18	4/30	0:30	4.08	1.9	0	0	0	0
41	18	4/30	16:00	4.00	1.9	0	0	0	0
42	18	5/2	11:59	4.00	2.0	0	0	0	0
43	18	5/3	8:05	4.13	1.8	0	0	0	0
44	18	5/4	0:26	3.97	1.7	0	0	0	0
45	18	5/4	16:05	4.00	2.5	1	0	0	1
46	19	5/5	20:05	4.00	3.2	0	0	0	0
47	19	5/6	0:12	4.08	2.7	0	0	0	0
48	19	5/6	7:58	4.00	2.9	0	0	0	0
49	19	5/7	8:00	4.00	2.9	0	0	0	0
50	19	5/7	0:00	3.97	2.6	0	0	0	0
51	19	5/8	12:09	4.13	1.9	0	0	0	0
52	19	5/8	16:45	4.00	1.8	1	0	0	1

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Appendix Table 5. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1996 (continued).

					Secchi	**Chinook Smolt Catch**			
Set	Stat.		Start	Effort	Depth	Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
53	19	5/10	20:15	4.12	4.0	0	0	0	0
54	20	5/11	20:00	4.00	3.0	0	0	0	0
55	20	5/12	0:02	4.15	3.1	2	0	0	2
56	20	5/12	4:15	3.97	0.9	0	0	0	0
57	20	5/13	12:15	2.95	1.5	7	0	0	7
58	20	5/15	13:34	2.85	1.0	2	0	0	2
59	20	5/16	8:10	4.00	1.5	1	0	0	1
60	21	5/22	12:05	3.92	1.4	7	0	0	7
61	21	5/24	12:20	4.00	0.6	4	0	0	4
62	21	5/24	16:25	4.18	1.1	4	0	0	4
63	22	5/27	0:00	4.00	1.7	1	0	0	1
64	22	5/27	16:10	4.00	1.8	2	0	0	2
65	22	5/28	14:22	1.63	1.6	1	0	0	1
66	22	5/28	16:00	2.00	1.7	0	0	0	0
67	22	5/28	18:00	2.00	1.7	0	0	0	0
68	22	5/28	20:00	2.00	1.6	1	0	0	1
69	22	5/28	22:00	2.00	1.2	1	0	0	1
70	22	5/29	0:00	4.00	1.2	2	0	0	2
71	22	5/29	4:00	4.10	1.8	2	0	0	2
72	22	5/29	8:06	6.95	1.9	3	0	0	3
73	22	5/30	3:58	4.25	1.4	1	0	0	1
74	22	6/1	0:00	3.95	2.3	0	0	0	0
75	23	6/3	0:00	4.00	2.7	1	0	0	1
76	23	6/3	4:00	4.00	2.7	0	0	0	0
77	23	6/5	20:14	4.00	1.6	20	0	1,830	1,850
78	23	6/6	9:00	4.37	1.8	0	0	323	323
79	23	6/7	4:41	1.45	1.9	194	0	0	194
80	23	6/7	6:09	1.93	1.8	58	0	0	58
81	23	6/7	8:06	1.97	1.8	23	1	37	61
82	23	6/7	10:05	1.98	1.6	21	0	69	90
83	23	6/7	12:05	3.92	1.4	0	0	105	105
84	23	6/7	16:08	4.02	1.4	137	0	0	137
85	23	6/8	4:15	3.78	1.3	0	0	136	136
86	24	6/11	16:00	4.12	3.0	1	0	0	1
87	24	6/11	20:07	4.03	2.5	2	0	0	2
88	24	6/12	8:00	4.00	3.1	2	0	0	2
89	24	6/12	12:05	4.00	2.8	1	0	0	1
90	24	6/14	8:06	2.00	3.5	0	0	0	0
91	24	6/14	10:06	1.90	3.4	0	0	0	0
92	24	6/14	12:02	1.97	3.5	0	0	0	0
93	24	6/14	14:00	2.05	3.2	0	0	0	0
94	24	6/14	16:06	4.00	3.6	0	0	0	0
95	25	6/17	20:00	2.00	3.3	0	0	0	0
96	25	6/17	22:00	1.95	2.0	1	0	0	1
97	25	6/18	23:57	2.22	2.5	1	0	0	1
98	25	6/18	2:10	2.00	2.5	0	0	0	0
99	25	6/18	4:10	4.00	2.5	0	0	0	0
100	25	6/18	8:10	4.00	3.6	0	0	0	0
101	25	6/20	16:07	5.83	3.8	0	0	0	0
102	25	6/21	8:30	4.17	3.8	0	0	0	0
103	26	6/24	20:00	4.00	3.8	1	1	0	2
104	26	6/26	8:13	4.33	3.8	0	0	0	0

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Appendix Table 5. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1996 (continued).

					Secchi	**Chinook Smolt Catch**			
Set	Stat.		Start	Effort	Depth	Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
105	26	6/27	4:07	2.22	3.2	0	0	0	0
106	26	6/27	6:20	2.00	3.8	0	0	0	0
107	26	6/27	8:20	2.00	3.8	0	0	0	0
108	26	6/27	10:20	2.00	3.8	0	0	0	0
109	26	6/27	12:20	4.20	3.8	0	0	0	0
110	28	7/12	0:30	4.17	3.1	3	0	0	3
111	29	7/15	4:00	4.17	1.5	18	1	0	19
112	29	7/16	0:00	4.17	0.4	18	3	89	110
113	29	7/16	16:05	4.00	0.8	20	0	0	20
114	29	7/19	8:17	4.00	1.6	1	0	0	1
115	30	7/23	20:00	4.25	1.5	3	0	0	3
116	30	7/24	20:07	4.00	1.3	4	0	0	4
117	30	7/25	8:12	4.00	1.6	0	0	0	0
118	30	7/25	16:15	4.00	1.1	1	0	0	1
119	31	7/29	12:04	4.00	1.0	4	2	0	6
120	31	7/30	16:07	4.00	0.7	26	0	0	26
121	31	8/1	8:15	4.20	1.4	0	0	0	0
122	32	8/5	11:53	4.00	2.7	0	0	0	0
123	32	8/5	15:53	4.00	2.2	0	0	0	0
124	32	8/7	0:08	4.20	2.2	0	0	0	0
125	32	8/8	20:05	4.00	1.8	0	0	0	0
126	33	8/12	4:13	4.07	1.2	1	0	0	1
127	33	8/12	11:47	4.08	1.2	0	0	0	0
128	33	8/13	19:45	4.25	1.3	1	0	0	1
129	33	8/14	4:08	4.15	1.3	1	0	0	1
			TOTALS	476.52		825	180	3,761	4,766

Appendix Table 6. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1997.

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch: Adipose Fin Present	Absent	Tally Count	Total Catch
1	12	3/17	11:57	4.82	1.1	0	0	0	0
2	14	4/2	12:05	6.03	1.9	4	35	0	39
3	14	4/3	18:04	6.00	1.9	1	36	0	37
4	14	4/4	0:06	6.07	1.4	0	37	1	38
5	14	4/5	22:57	5.67	2.3	2	0	0	2
6	15	4/8	11:52	6.00	2.8	0	0	0	0
7	15	4/10	7:45	6.00	3.0	0	0	0	0
8	15	4/12	10:50	6.00	3.6	0	0	0	0
9	16	4/14	11:55	6.00	1.4	1	0	0	1
10	16	4/16	6:20	2.85	1.7	0	0	0	0
11	16	4/18	10:45	5.67	0.8	1	1	0	2
12	17	4/22	12:00	6.00	0.6	1	0	3	4
13	17	4/24	17:44	4.77	0.9	2	0	0	2
14	17	4/26	11:55	6.08	1.2	4	0	0	4
15	18	4/30	0:05	5.95		22	0	0	22
16	18	5/2	6:02	5.97	1.1	10	0	0	10
17	19	5/4	11:52	6.17	1.5	13	3	0	16
18	19	5/6	5:57	0.88	0.9	21	1	0	22
19	19	5/8	12:05	5.92	1.0	23	0	0	23
20	19	5/10	23:56	5.82	1.1	15	0	1	16
21	20	5/12	18:06	2.07	0.7	7	0	0	7
22	20	5/14	12:25	5.58	0.4	1	0	0	1
23	20	5/16	10:05	6.08	0.4	9	0	0	9
24	21	5/19	11:07	3.95	0.8	11	0	0	11
25	21	5/20	12:04	2.05	0.8	15	0	0	15
26	21	5/20	14:12	2.05	0.8	1	0	0	1
27	21	5/20	16:15	2.25	1.2	15	0	0	15
28	21	5/20	18:30	1.92	0.9	0	0	10	10
29	21	5/20	20:25	2.00	1.2	7	0	1	8
30	21	5/21	22:25	4.00	0.9	27	0	53	80
31	21	5/21	2:25	3.08	0.8	0	0	217	217
32	21	5/22	12:10	3.08	1.2	44	0	72	116
33	22	5/27	12:45	5.33	1.5	21	0	65	86
34	22	5/28	12:00	6.00	1.1	29	0	159	188
35	22	5/30	6:00	6.00	0.4	29	0	128	157
36	23	6/5	14:00	6.00	0.4	28	8	12	48
37	23	6/6	6:00	6.00	0.5	20	2	54	76
38	23	6/6	12:00	6.00	0.5	18	9	16	43
39	24	6/10	17:45	6.25	0.8	23	54	133	210
40	24	6/12	0:00	6.00	0.5	29	62	446	537
41	24	6/13	18:00	6.08	0.8	17	22	137	176
42	25	6/16	6:35	4.33	0.8	20	7	95	122
43	25	6/20	6:00	6.17	0.6	14	2	3	19
44	25	6/20	12:10	5.83	0.7	14	1	0	15
45	26	6/23	12:00	6.08	0.8	18	4	48	70
46	26	6/24	11:45	6.25	0.4	17	6	10	33
47	26	6/25	12:10	6.08	0.7	21	1	5	27
48	26	6/27	0:05	5.92	0.9	21	0	0	21
49	27	6/29	0:00	6.00	1.1	17	3	11	31
50	27	7/1	12:00	6.00	1.2	9	1	0	10
51	27	7/3	0:00	6.25	1.3	6	3	1	10
52	27	7/4	12:00	6.00	1.3	9	0	0	9

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Appendix Table 6. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1997 (continued).

Set Number	Stat. Week	Date	Start Time	Effort (hours)	Secchi Depth (feet)	Chinook Smolt Catch: Adipose Fin Present	Chinook Smolt Catch: Adipose Fin Absent	Chinook Smolt Catch: Tally Count	Chinook Smolt Catch: Total Catch
53	28	7/7	0:01	5.98	0.7	11	0	0	11
54	29	7/14	18:00	6.17	0.5	14	0	0	14
55	29	7/16	0:00	6.00	0.8	24	0	2	26
56	29	7/19	18:00	6.00	0.5	5	0	0	5
57	30	7/21	6:00	6.25	0.5	5	0	0	5
58	30	7/23	0:00	6.00	0.8	6	0	0	6
59	30	7/25	18:00	6.00	1.2	15	1	0	16
60	31	7/28	10:00	6.00	1.7	19	0	3	22
61	31	7/30	12:30	6.25	1.0	4	0	0	4
			TOTALS	320.00		740	299	1,686	2,725

Appendix Table 7. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1998

Set	Stat.		Start	Effort	Secchi Depth	**Chinook Smolt Catch**			
						Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
1	14	4/3	10:15	5.75	4.0	0	0	0	0
2	15	4/5	12:05	5.92	4.5	0	0	0	0
3	15	4/7	18:05	5.50	4.8	2	0	0	2
4	15	4/9	0:05	5.92	4.0	0	0	0	0
5	15	4/11	6:00	6.00	4.0	0	0	0	0
6	16	4/13	18:23	6.10	4.0	0	0	0	0
7	16	4/15	0:07	6.08	4.0	0	0	0	0
8	16	4/17	6:00	6.28	4.0	15	0	0	15
9	17	4/19	11:52	6.08	4.0	0	0	0	0
10	17	4/21	0:02	6.17	4.0	8	1	0	9
11	17	4/23	18:09	5.18	1.3	46	7	75	128
12	17	4/25	6:21	5.90	1.5	19	1	1	21
13	18	4/28	9:56	6.22	3.6	7	0	0	7
14	18	4/29	0:15	6.25	4.0	20	0	20	40
15	19	5/4	12:05	4.92	0.9	19	0	0	19
16	19	5/5	17:03	2.78	0.8	18	0	0	18
17	19	5/7	6:00	6.00	1.1	25	0	37	62
18	19	5/9	12:00	6.17	1.4	20	1	193	214
19	20	5/11	8:03	3.52	2.4	18	0	0	18
20	20	5/13	18:06	6.15	1.3	20	0	31	51
21	20	5/15	6:00	7.50	1.5	20	0	35	55
22	21	5/17	12:00	6.00	2.0	20	0	27	47
23	21	5/19	6:05	6.35	4.7	0	0	0	0
24	21	5/21	18:00	6.17	3.2	0	0	0	0
25	21	5/23	11:57	6.05	3.2	2	0	0	2
26	22	5/25	18:00	6.00	1.5	10	0	66	76
27	22	5/27	6:05	5.92	1.3	10	0	230	240
28	22	5/28	17:40	6.08	1.6	2	0	15	17
29	22	5/29	23:45	6.25	1.7	6	0	0	6
30	23	5/31	12:00	6.58	4.9	4	0	0	4
31	23	6/2	11:50	4.63	2.1	46	0	0	46
32	23	6/4	9:00	6.00	2.3	20	0	101	121
33	23	6/4	15:00	6.00	1.7	20	0	391	411
34	23	6/6	0:00	6.00	1.7	20	0	95	115
35	24	6/8	0:05	6.17	1.2	21	0	108	129
36	24	6/10	18:26	6.15	1.8	11	0	0	11
37	24	6/12	18:05	5.92	2.2	20	30	0	50
38	24	6/13	10:16	6.23	2.5	20	0	25	45
39	25	6/14	6:00	6.00	2.3	14	6	2	22
40	25	6/15	13:00	3.00	1.9	14	6	57	77
41	25	6/16	9:00	6.00	1.9	138	20	0	158
42	25	6/18	12:15	6.02	2.8	3	1	0	4
43	25	6/20	12:00	6.00	2.5	8	2	0	10
44	26	6/22	0:09	7.10	2.1	6	2	0	8
45	26	6/24	17:55	6.08	2.3	10	3	0	13
46	26	6/26	6:05	5.92	1.5	15	5	3	23
47	27	6/28	11:55	6.08	1.8	17	3	1	21
48	27	7/2	12:00	6.00	1.2	0	0	0	0
49	27	7/3	6:05	6.42	0.5	0	0	0	0
50	27	7/4	12:04	6.35	0.4	0	0	0	0
51	28	7/6	18:00	6.00	1.1	0	0	0	0
52	28	7/8	0:00	6.00	1.1	0	0	0	0

- continued -

Appendix Table 7. Summary of the chinook salmon smolt catch data, by set, for the screwtrap operated in the Nooksack River, 1998 (continued).

					Secchi	**Chinook Smolt Catch**			
Set	Stat.		Start	Effort	Depth	Adipose Fin		Tally	Total
Number	Week	Date	Time	(hours)	(feet)	Present	Absent	Count	Catch
53	28	7/10	0:05	7.17	0.9	0	0	0	0
54	29	7/12	6:15	6.27	1.1	0	0	0	0
55	29	7/14	12:00	6.00	1.5	0	0	0	0
56	29	7/16	14:56	3.07	0.4	0	0	0	0
57	29	7/18	10:15	7.50	0.9	0	0	0	0
58	30	7/20	18:00	6.00	1.2	0	0	0	0
59	30	7/23	18:00	6.00	0.8	0	0	0	0
60	30	7/24	12:00	6.50	0.9	0	0	0	0
			TOTALS	354.37		714	88	1,513	2,315

Appendix Table 8. Summary of the date, time, and release location of hatchery-reared, caudal fin clipped chinook salmon smolts released for the capture-efficiency trials, and screwtrap effort, for capture-efficiency experiments conducted from 1995 through 1998.

Trial Code	Time of Release	Night Or Day[a]	Release Location	Release Method	Starting Date	Starting Time	Ending Date	Ending Time	Effort (hours)	Comments
95(1)	21:50	N	RM 5.8	Boat	18-Apr	22:20	19-Apr	24:00	24.55	Trap not fished for one 67 minute period.
95(2)	22:52	N	RM 5.8	Boat	2-May	22:52	3-May	17:15	15.05	Trap down for debris for total of 200 min.
95(3)	22:25	N	RM 5.8	Boat	16-May	22:25	17-May	12:15	13.00	Trap down for 50 min.
95(4)	22:02	N	RM 5.8	Boat	23-May	22:02	24-May	16:10	18.13	
95(5)	8:45	D	RM 5.8	Boat	31-May	8:45	31-May	21:55	13.17	
95(6)	9:36	D	RM 5.8	Boat	7-Jun	9:36	7-Jun	21:04	11.47	
96(1)	14:20	D	RM 6.1	Pen	28-May	14:22	29-May	15:03	24.72	
96(2)	4:34	D	RM 5.8	Boat	7-Jun	4:41	7-Jun	20:09	15.45	Trap down for 8 min.
96(3)	8:30	D	RM 5.8	Boat	14-Jun	8:30	14-Jun	20:06	11.52	Trap down for 5 min.
96(4)	20:14	N	RM 5.8	Boat	17-Jun	20:14	18-Jun	12:10	15.93	
96(5)	4:17	D	RM 5.8	Boat	27-Jun	4:17	27-Jun	16:32	12.25	
97	12:26	D	RM 6.0	Boat	20-May	12:26	21-May	5:30	17.07	Trap down for 5 min.
98(1)	18:15	N	RM 5.8	Boat	28-May	18:15	29-May	6:00	11.75	
98(2)	10:34	D	RM 5.8	Boat	4-Jun	10:34	4-Jun	21:00	10.43	
								Mean Effort:	15.32	
								Minimum Effort:	10.43	
								Maximum Effort:	24.72	
								Median Effort:	14.11	

[a] Day (D) or Night (N) indicates whether the majority of the recapture effort occurred during daytime (light) or nighttime (dark) hours.

Appendix Table 9. Number of chinook salmon smolts released from each bank for the capture-efficiency trials conducted from 1995 through 1998.

Trial Code[a]	Release Date	Smolt Type	Right Bank Release. Number	Mark	Left Bank Release Number	Mark	Minutes to 1st Recap.
95(1)	18-Apr	Fall	995	Up Clip	998	Bismark	
95(2)	2-May	Fall	986	Up Clip	984	Low Clip	
95(3)	16-May	Fall	564	Low Clip	628	Up Clip	
95(4)	23-May	Fall	981	Up Clip	952	Low Clip	22
95(5)	31-May	Fall	468	Up Clip	468	Low Clip	13
95(6)	7-Jun	Fall	451	Low Clip	281	Up Clip	
96(1)	28-May	Fall	799	Low Clip	800	Up Clip	
96(2)	7-Jun	Fall	789	Low Clip	785	Up Clip	32
96(3)	14-Jun	Fall	777	Low Clip	709	Up Clip	35
96(4)	17-Jun	Fall	782	Low Clip	764	Up Clip	37
96(5)	27-Jun	Fall	784	Low Clip	785	Up Clip	30
97	20-May	Spring	826	Low Clip	819	Up Clip	
98(1)	28-May	Spring	899	Low Clip	899	Up Clip	35
98(2)	4-Jun	Spring	893	Up Clip	896	Low Clip	32
						Mean:	29.5
						Standard Deviation:	8.1
						Coefficient of Variation:	27.4%
						Median:	32

[a] Trials coded by year (trial number for the year).

Appendix Table 10. Summary of the cumulative percent (Cum %) of total recaptures of marked chinook salmon smolts used for the capture-efficiency trials by number of hours from time of release (Time).

95(1)		95(2)		95(3)		95(4)		95(5)		95(6)		96(1)	
Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %
2.67	10.5%	0.97	70.7%	1.17	100.0%	1.23	100.0%	0.25	10.0%	0.73	100.0%	1.67	71.4%
4.67	31.6%	2.13	95.1%	2.75	100.0%	3.22	100.0%	0.52	75.0%	1.23	100.0%	3.67	100.0%
6.67	36.8%	3.88	97.6%	5.67	100.0%	5.33	100.0%	0.75	100.0%	2.27	100.0%	5.67	100.0%
8.67	42.1%	6.63	100.0%	9.83	100.0%	7.05	100.0%	6.30	100.0%	3.93	100.0%	7.67	100.0%
10.67	57.9%	9.72	100.0%	13.83	100.0%	9.30	100.0%	13.17	100.0%	5.97	100.0%	9.67	100.0%
11.58	68.4%	12.47	100.0%			13.22	100.0%			8.57	100.0%	13.67	100.0%
14.67	84.2%	17.38	100.0%			18.13	100.0%			11.47	100.0%	17.77	100.0%
16.83	84.2%	18.38	100.0%									24.72	100.0%
18.67	94.7%												
20.75	94.7%												
22.75	94.7%												
24.50	100.0%												
26.17	100.0%												

96(2)		96(3)		96(4)		96(5)		97		98(1)		98(2)	
Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %	Time	Cum %
1.57	100.0%	1.60	100.0%	1.77	66.7%	2.05	100.0%	1.68	87.5%	0.58	2.6%	0.53	12.5%
3.52	100.0%	3.50	100.0%	3.72	100.0%	4.05	100.0%	3.82	91.7%	1.00	63.2%	0.93	62.5%
5.50	100.0%	5.50	100.0%	5.93	100.0%	6.05	100.0%	6.07	94.4%	3.00	76.3%	2.93	87.5%
7.50	100.0%	7.55	100.0%	7.93	100.0%	8.05	100.0%	7.98	97.2%	5.50	100.0%	4.43	87.5%
11.43	100.0%	11.60	100.0%	11.93	100.0%	12.25	100.0%	9.98	98.6%	11.75	100.0%	10.43	100.0%
15.58	100.0%			15.93	100.0%			13.98	100.0%				
								17.07	100.0%				

Appendix Table 11. Values for environmental variables measured during each capture-efficiency trial.

Year	Trial Code	Number Released	Number Recaptured	Capture Efficiency	River Discharge (CFS)	Average Secchi (ft)	Turbidity (Ntus)
95	95(1)	1,993	19	0.953%	2,520	2.425	14.0
95	95(2)	1,970	41	2.081%	3,410	2.275	14.0
95	95(3)	1,192	67	5.621%	4,100	0.900	41.0
95	95(4)	1,933	29	1.500%	3,310	2.100	13.5
95	95(5)	936	40	4.274%	4,180	1.200	34.5
95	95(6)	732	10	1.366%	2,750	2.500	11.5
96	96(1)	1,599	7	0.438%	3,850	1.650	17.5
96	96(2)	1,574	10	0.635%	3,920	1.900	17.0
96	96(3)	1,486	2	0.135%	2,780	3.500	9.0
96	96(4)	1,546	3	0.194%	2,400	2.650	8.0
96	96(5)	1,569	7	0.446%	2,400	3.200	8.0
97	97	1,645	72	4.377%	6,060	0.967	51.0
98	98(1)	1,798	38	2.113%	4,000	1.633	62.0
98	98(2)	1,789	8	0.447%	4,000	2.300	25.0

Appendix Table 12. Summary of length data for chinook salmon smolts used in the capture-efficiency trials conducted from 1995 through 1998. All length measurements are in mm.

Trial Code	Total Released	Measure-ment Date	Release Date	**Mean Length Summary** Mean	SE	CV	Sample Size	Median	Minimum	Maximum
95(1)	1,993	18-Apr	18-Apr	53.29	0.53	10.0%	100	54.0	40	65
95(2)	1,970	2-May	2-May	56.93	0.49	7.7%	80	57.0	49	70
95(3)	1,192	16-May	16-May	56.16	0.48	7.7%	80	56.0	42	65
95(4)	1,933	19-May	23-May	64.16	1.35	18.8%	80	64.0	45	89
95(5)	936		31-May	no lengths taken						
95(6)	732		7-Jun	no lengths taken						
96(1)	1,599	9-May	28-May	76.10	0.66	9.3%	115	77.0	55	92
96(2)	1,574	4-Jun	7-Jun	84.29	0.88	10.3%	96	86.0	60	98
96(3)	1,486	10-Jun	14-Jun	87.62	0.60	7.2%	110	87.5	72	100
96(4)[a]	1,546	10-Jun	17-Jun							
96(5)	1,569	25-Jun	25-Jun	88.04	0.77	8.7%	100	88.5	67	105
97	1,645	25-Apr	20-May	72.54	0.52	7.2%	100	73.0	60	85
98(1)	1,798	8-May	28-May	76.62	0.69	9.0%	100	76.0	49	91
98(2)	1,789		4-Jun	no lengths taken						

[a] Fish measured and clipped on 10 June used in both 14 June and 17 June releases.

Appendix Table 13. Summary of fork length data by statistical week for chinook salmon smolts captured by the screwtrap and measured during 1994.

Statistical Week	Mean Length	Stand. Error[a]	Coef. Var.[b]	Median Length	Sample Size
Non-adclipped Smolts					
17	72.3	7.85	10.9%	67.0	4
18	79.5	10.99	13.8%	73.0	4
19	66.6	0.98	1.5%	66.0	80
20	71.0	1.36	1.9%	69.0	47
21	75.2	0.93	1.2%	75.0	47
23	75.9	0.70	0.9%	75.0	126
24	83.0	0.73	0.9%	82.0	180
25	84.0	0.55	0.7%	84.0	177
26	84.0	0.52	0.6%	85.0	134
27	84.6	0.87	1.0%	83.5	44
28	88.3	1.08	1.2%	89.0	65
29	87.5	2.50	2.9%	87.5	2
Statistical Week	Mean Length	Stand. Error	Coef. Var.	Median Length	Sample Size
Adclipped Smolts					
17	67.0				1
18	75.0				1
19	87.1	4.23	4.9%	82.0	13
20	78.6	2.62	3.3%	77.0	7
21	82.5	4.50	5.5%	82.5	2
23	76.6	0.85	1.1%	76.0	51
24	87.5	1.25	1.4%	87.0	69
25	84.4	1.39	1.6%	83.0	44
26	83.2	1.05	1.3%	83.0	17
27	87.8	1.89	2.2%	88.0	6
28	86.2	1.19	1.4%	85.0	31
29	84.5	7.50	8.9%	84.5	2

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Appendix Table 14. Summary of fork length data by statistical week for chinook salmon smolts captured by the screwtrap and measured during 1995.

Statistical Week	Mean Length	Stand. Error[a]	Coef. Var.[b]	Median Length	Sample Size
Non-adclipped Smolts					
13	51.0	1.60	3.1%	53.0	7
14	56.0	1.92	3.4%	50.0	96
15	54.5	1.25	2.3%	52.0	94
16	67.8	9.69	14.3%	55.0	6
17	57.0	15.00	26.3%	57.0	2
18	72.2	6.95	9.6%	63.0	13
19	59.9	1.83	3.1%	61.5	28
20	73.4	1.12	1.5%	72.0	43
21	73.8	0.92	1.2%	73.0	49
22	77.4	0.65	0.8%	78.0	75
23	81.0	1.32	1.6%	80.0	33
24	83.1	1.05	1.3%	84.0	20
25	77.8	2.26	2.9%	76.0	9
26	84.6	0.74	0.9%	85.0	69
27	82.8	0.42	0.5%	83.0	142
28	86.4	0.53	0.6%	87.0	123
29	88.9	1.52	1.7%	89.5	10
30	88.1	1.85	2.1%	89.0	14

Statistical Week	Mean Length	Stand. Error	Coef. Var.	Median Length	Sample Size
Adclipped Smolts					
13					
14	108.4	1.57	1.4%	110.0	7
15					
16					
17					
18					
19					
20	75.9	0.42	0.6%	75.0	132
21	79.6	0.85	1.1%	79.0	43
22	80.8	1.26	1.6%	81.0	19
23	83.7	2.12	2.5%	85.0	10
24	78.5	1.50	1.9%	78.5	2
25					
26					
27					
28					
29					
30					

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Appendix Table 15. Summary of fork length data by statistical week for chinook salmon smolts captured by the screwtrap and measured during 1996.

Statistical Week	Mean Length	Stand. Error[a]	Coef. Var.[b]	Median Length	Sample Size
Non-adclipped Smolts					
14	60.8	3.09	5.1%	54.0	86
15	59.3	1.45	2.4%	57.0	119
16	72.8	8.75	12.0%	63.0	8
18	89.5	27.50	30.7%	89.5	2
19	73.0				1
20	75.5	2.49	3.3%	75.0	12
21	71.3	2.66	3.7%	73.0	15
22	74.6	1.62	2.2%	74.5	14
23	76.3	1.03	1.3%	78.0	105
24	83.5	2.62	3.1%	86.0	6
25	87.5	2.50	2.9%	87.5	2
26	88.0				1
28	90.3	3.28	3.6%	92.0	3
29	90.1	1.05	1.2%	90.0	56
30	90.3	2.20	2.4%	90.0	7
31	86.1	1.63	1.9%	84.0	24
33	96.7	1.67	1.7%	95.0	3

Statistical Week	Mean Length	Stand. Error	Coef. Var.	Median Length	Sample Size
Adclipped Smolts					
14	187.1	4.66	2.5%	192.0	49
15	133.7	13.00	9.7%	124.5	6
16	109.7	0.33	0.3%	110.0	3
18					
19					
20					
21					
22					
23	116.0				1
24					
25					
26					
28					
29					
30					
31	94.0	1.00	1.1%	94.0	2
33					

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Appendix Table 16. Summary of fork length data by statistical week for chinook salmon smolts captured by the screwtrap and measured during 1997.

Statistical Week	Mean Length	Stand. Error[a]	Coef. Var.[b]	Median Length	Sample Size
Non-adclipped Smolts					
14	116.3	12.57	10.8%	109.0	7
16	58.0	5.00	8.6%	58.0	2
17	64.4	6.70	10.4%	58.0	7
18	103.6	5.29	5.1%	106.5	32
19	79.4	3.06	3.9%	71.5	72
20	100.7	8.20	8.1%	115.0	17
21	80.1	1.59	2.0%	79.5	120
22	92.8	2.55	2.7%	85.0	65
23	83.1	1.13	1.4%	84.0	66
24	84.2	0.91	1.1%	84.0	69
25	81.1	1.30	1.6%	84.0	48
26	86.3	0.89	1.0%	86.0	76
27	85.7	1.56	1.8%	89.0	41
28	89.7	1.20	1.3%	89.0	11
29	84.8	1.39	1.6%	86.0	43
30	86.4	1.35	1.6%	86.0	26
31	87.5	2.11	2.4%	85.0	23

Statistical Week	Mean Length	Stand. Error	Coef. Var.	Median Length	Sample Size
Adclipped Smolts					
14	138.6	3.04	2.2%	127.0	106
16	89.0				1
17					
18					
19	107.8	4.78	4.4%	107.5	4
20					
21					
22					
23	83.2	0.98	1.2%	83.0	19
24	84.9	1.35	1.6%	84.0	16
25	89.3	7.88	8.8%	83.0	3
26	85.8	1.74	2.0%	85.0	9
27	84.6	2.79	3.3%	83.0	5
28					
29					
30	101.0				1
31					

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Appendix Table 17. Summary of fork length data by statistical week for chinook salmon smolts captured by the screwtrap and measured during 1998.

Statistical Week	Mean Length	Stand. Error[a]	Coef. Var.[b]	Median Length	Sample Size
Non-adclipped Smolts					
14	99.5	4.50	4.5%	99.5	2
15	72.2	1.11	1.5%	73.0	15
16	73.1	1.75	2.4%	73.0	72
17	77.5	3.35	4.3%	72.0	25
18	75.6	2.29	3.0%	70.0	72
19	66.9	1.00	1.5%	67.0	58
20	69.0	1.82	2.6%	69.5	22
21	77.2	1.64	2.1%	78.5	28
22	79.9	1.10	1.4%	80.0	86
23	78.4	0.98	1.3%	80.0	72
24	75.3	1.16	1.5%	75.0	55
25	85.6	1.30	1.5%	85.0	31
26	84.3	2.10	2.5%	86.0	17

Statistical Week	Mean Length	Stand. Error	Coef. Var.	Median Length	Sample Size
Adclipped Smolts					
14					
15					
16	76.8	5.20	6.8%	75.0	9
17					
18	120.0				1
19					
20					
21					
22					
23					
24	83.2	1.10	1.3%	82.0	19
25	86.8	1.51	1.7%	85.0	10
26	91.3	1.33	1.5%	90.0	3

[a] Standard error of the mean.

[b] Coefficient of variation = standard error/mean length.

Appendix Table 18. Summary of the monthly releases of hatchery-reared chinook salmon juveniles above the trap and the four monthly CPUE indices calculated using all chinook out-migrant catch data for the years 1996-1998.

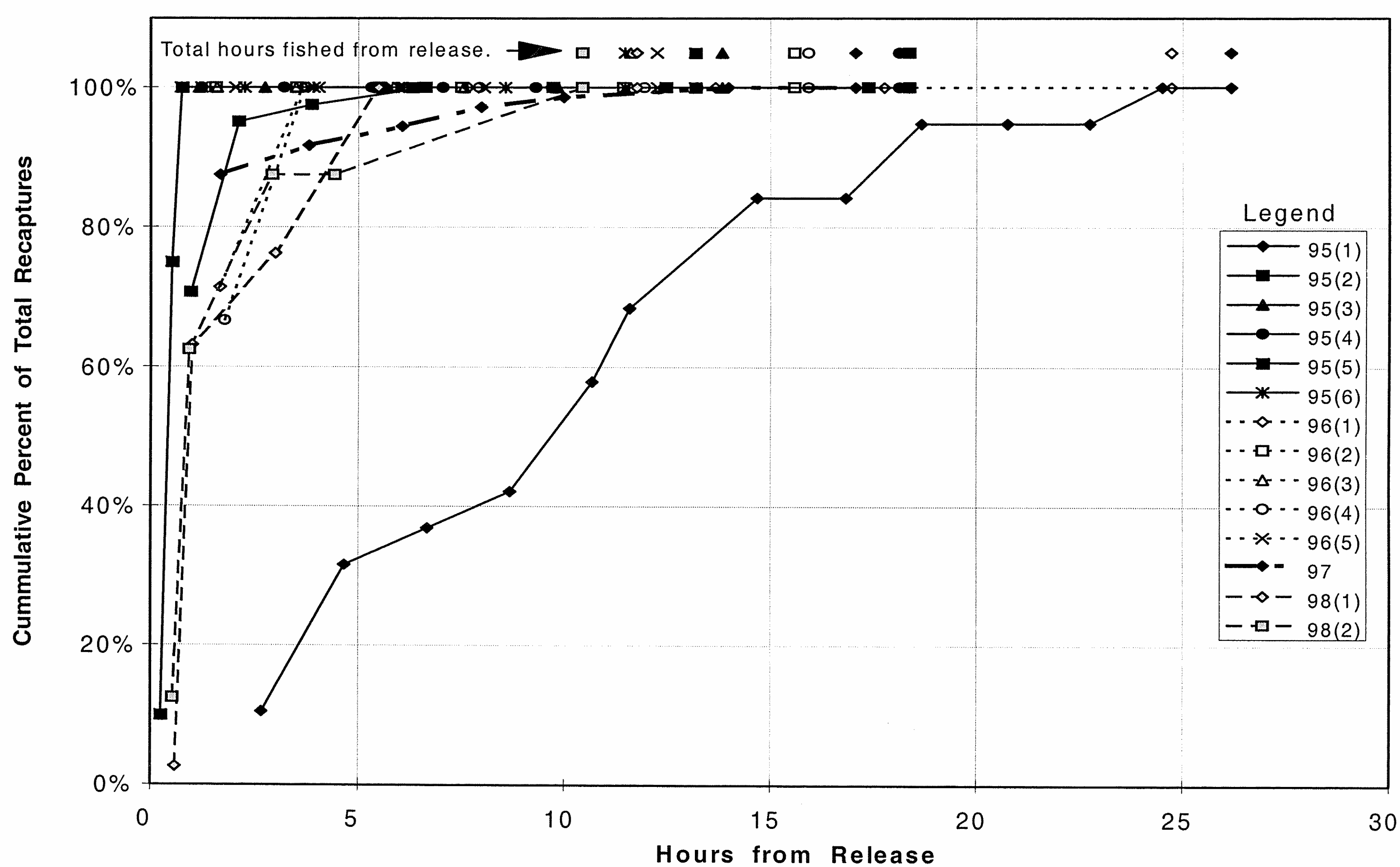
Month - Year	Number Released	Release Location[a]	Index of Abundance for All Chinook Caught TCPU	MCPU	TXCPU	MXCPU
April-96	875,662	1.8 (79%), 66.6 (21%)	11.09	10.86	11,792.90	11,479.03
May-96	0		0.36	0.38	20.67	20.43
June-96	2,421,498	1.8	25.93	24.35	1,269.85	1,235.43
July-96	0		4.31	4.26	87.52	86.30
April-97	187,765	66.6	1.91	1.80	92.54	87.11
May-97	353,961	89.5 - 96.1	12.57	13.46	269.48	285.06
June-97	401,492	66.6 – 89.5	17.21	17.40	218.43	222.62
July-97	0		1.89	1.90	48.05	48.35
April-98	540,237	66.6	2.66	2.86	711.25	690.95
May-98	797,336	89.5 – 96.1	8.97	8.86	381.26	377.68
June-98	527,977	66.6 – 96.1	12.73	13.22	820.48	855.16
July-98	0		0.00	0.00	0.00	0.00
May/June-96	2,421,498	1.8	12.87	13.07	631.93	663.66
May/June-97	755,453	66.6 – 96.1	14.93	15.08	243.52	259.35
May/June-98	1,325,313	66.6 – 96.1	10.92	11.11	608.73	623.66

[a] Release location in km above the trap.

Appendix Table 19. Summary of the monthly releases of hatchery-reared and adipose fin clipped chinook salmon juveniles above the trap and the four monthly CPUE indices calculated using adclipped chinook out-migrant catch data for the years 1996-1998.

Month -	Number	Release	Index of Abundance for Adclipped Chinook Only			
Year	Released	Location[a]	TCPU	MCPU	TXCPU	MXCPU
April-96	183,545	66.6	1.62	1.58	252.57	247.12
May-96	0		0.00	0.00	0.00	0.00
June-96	2,638	66.6	0.03	0.05	8.02	7.62
July-96	0		0.42	0.42	4.47	4.41
April-97	187,765	66.6	1.39	1.30	76.42	71.64
May-97	0		0.05	0.08	1.79	2.10
June-97	180,014	66.6	8.52	8.47	104.57	104.25
July-97	0		0.07	0.07	2.13	2.11
April-98	151,516	66.6	0.23	0.26	16.07	16.76
May-98	0		0.11	0.10	3.98	3.73
June-98	202,802	66.6	0.98	1.18	77.47	90.20
July-98	0		0.00	0.00	0.00	0.00
May/June-96	2,638	66.6	0.02	0.03	3.83	4.40
May/June-97	180,014	66.6	4.36	3.54	54.06	44.16
May/June-98	202,802	66.6	0.56	0.66	42.04	48.28

[a] Release location in km above the trap.



Appendix Figure 1. Recapture profile for each capture-efficiency trial showing the cumulative percent of total recaptures of marked chinook salmon smolts by hour after release.