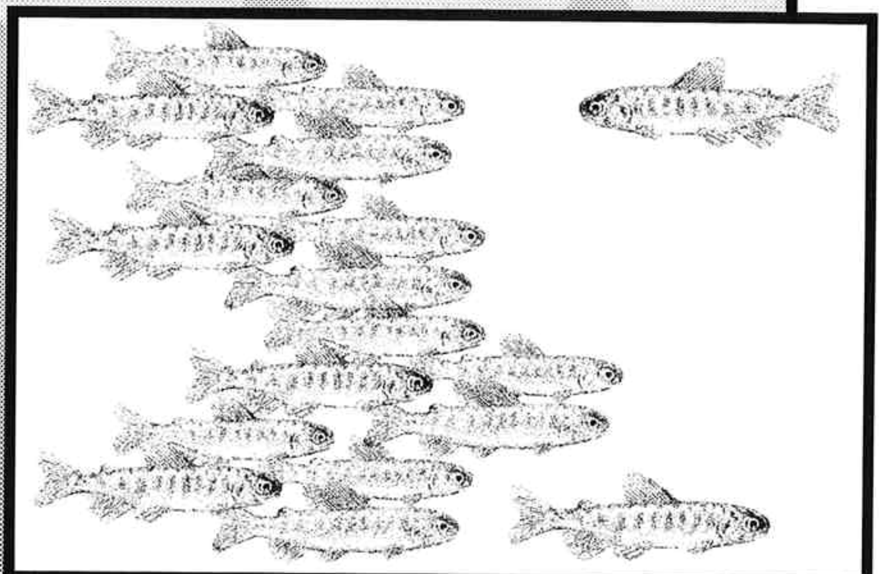
STATE OF WASHINGTON May 2002

2001 Skagit River Wild 0+ Chinook Production Evaluation Annual Report



by Dave Seiler, Steve Neuhauser and Lori Kishimoto

Washington Department of
FISH AND WILDLIFE
Fish Program
Science Division

Annual Report Number: FPA02-11

STATE OF WASHINGTON
DEPARTMENT OF FISH & WILDLIFE

Annual Report

2001 Skagit River Wild 0+ Chinook Production Evaluation

Funded by Seattle City Light

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Acknowledgments

Evaluation of the wild 0+ chinook production from the Skagit River in 2001 was made possible with funding from Seattle City Light. This fifth year of such support, combined with funds from the Dingle-Johnson/Wallop-Breaux program and matched with Washington Department of Fish & Wildlife funds, enabled the *Wild Salmon Production Evaluation* unit to trap downstream migrants in the lower Skagit River from mid-January through July.

We appreciate the contributions of a number individuals who provided logistical support: Sherman and Pat Courier, adjacent property owners, for providing drinking water and utility access at the site, and over-winter trap storage; Burlington Northern continued to allow us to anchor the traps to their railroad bridge.

The success of this project relies on the hard work of a number of dedicated permanent and temporary WDFW personnel. Scientific Technicians, Mat Gillum, Steve Meyer, Jason Eisenhauer, Pat Morrisson, and Paul Lorenz, worked long hours operating and maintaining the traps, and enumerating and sampling catches. Unit biologists Mike Ackley and Pete Topping provided valuable logistical support during trap installation and removal, Mark Hino developed the computer database and analyzed much of the trap data contained in this report, and Laurie Peterson helped with editing and final compilation of this report.

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Introduction

Skagit River chinook returns (spring and summer/fall combined) have steadily declined over the last fifty years (PSSSRG 1992, 1997). In 1994, the Joint Chinook Technical Committee of the Pacific Salmon Commission designated the status of these stocks as "Not Rebuilding." To address this poor stock status, resource managers formed the Skagit River Chinook work group in 1995. Composed of state, tribal, and federal fish biologists, this group recommends and coordinates restoration and monitoring programs. A major goal of this work group is to determine the limiting factors for chinook. Necessary data for this purpose include an indicator-stock tagging program, habitat inventory, annual adult escapement estimation, and wild juvenile chinook assessment. The juvenile production evaluation is a vital link in this process because it provides a direct measure of freshwater survival.

Seattle City Light (operators of several dams on the Skagit River), through a 1991 fisheries settlement agreement with WDFW, the Skagit tribes (Skagit System Cooperative or SSC) and federal agencies – National Marine Fisheries Service (NMFS), US Fish & Wildlife Service (USFWS), US Forest Service (USFS) and National Park Service(NPS) – created the Skagit Non-Flow Plan Coordinating Committee (NCC). The NCC is responsible for funding several non-flow fisheries programs including the "Chinook Research Program." Beginning in 1997, this program provided funding to conduct chinook studies. This report documents our 2001 downstream migrant trapping project in the Skagit River which, with funding from the NCC, we expanded to continue estimating wild 0+ chinook production.

Understanding the major sources of interannual variation in run size is critical to improving harvest and habitat management. Quantifying anadromous salmonid populations as seaward migrants near saltwater entry is the most direct assessment of stock performance in freshwater because the variation resulting from marine survival and harvest are precluded. Relating smolt production to adult spawners over a number of broods empirically determines the watershed's natural production potential (provided escapement and environmental conditions are sufficient), its stock/recruit function if escapements are less than that required to achieve maximum production, and enables identification of the major density-independent source(s) of interannual variation in freshwater survival. To accomplish these and other fish management objectives, the WDFW implemented a long-term research program directed at measuring wild salmon production in terms of smolts and adults in selected watersheds, beginning in 1976 (Seiler *et al.* 1981). In 1981, this program, which was directed primarily at coho salmon, was expanded to include additional large watersheds (Seiler *et al.* 1984).

In 1990, we initiated downstream migrant trapping in the Skagit River system to quantify wild coho smolt production to, among other objectives, resolve a discrepancy in escapement estimates (Conrad *et al* 1997). This program, which in 2001 was in its twelfth year, involves trapping and marking wild coho smolts emigrating from a lower river tributary, Mannser Creek (R.M. 35), and sampling a portion of the entire population via floating traps in the lower mainstem (R.M. 17, Burlington Northern railroad bridge).

In past years we evaluated returns of coho adults coded-wire tagged as smolts at the gulper in Baker Lake. The upstream migrant trap below the dam provided a reliable accounting of all salmon returning to this system. Applying the marine survival estimated from the tag-based estimates of harvest and escapement to respective estimates of total system wild coho smolt production yielded estimates of adult recruits, escapement, and harvest for the entire Skagit River system (Seiler *et al.*1995). Technical support for this program was eliminated beginning in Spring 2000 and continued through 2001, suspending this portion of the Skagit coho production and survival evaluation. This work resumed in 2002.

Although our trapping in the mainstem was originally directed at coho smolts, we identify and enumerate all fish captured. For the first seven years of this study (1990-1996), season total 0+ chinook catches in the one scoop trap varied six-fold, from 1,700 to 10,500 chinook. (As of 1993, we have simultaneously operated both a scoop and a screw trap.) In addition to abundance, these catch totals are influenced by fishing effort (the time fished on each date and for the season), migration timing relative to the interval we trapped, and instantaneous trap efficiency. Many such variables as discharge, water velocity, turbidity, debris, channel configuration, trap placement, and fish size combine to affect both instantaneous and season average trap efficiency.

Preliminary expansion of these 0+ chinook catches, based on the season average recapture rates of wild coho and several other assumptions held consistent between years, has yielded chinook production estimates that range from 0.5 to 6.5 million. The accuracy and precision of these estimates is presently incalculable because the assumptions remain unverified. We believe, however, that these estimates reflect the abundance of wild 0+ chinook production from these broods, at least in a relative sense. We base this contention upon the significant negative correlation between the freshwater survival estimates and the severity of flow during the period that the eggs were incubating in the gravel. The survival rates in this relationship are the ratio of total 0+ chinook emigrants estimated past the traps to the potential egg deposition. System total egg deposition is simply the product of the estimated total adult chinook escapement, an assumed sex ratio and a fecundity of 5,500 eggs/female (Pete Castle pers. comm.). This relationship indicates that overall egg-to-migrant survival for Skagit River chinook has varied over ten-fold within just the first seven broods, almost entirely as a function of flow during egg incubation.

In 1997, we began trapping in mid-February and continued into September. This first season of extended trapping produced our first insight into the migration timing. Over the season, we estimated a total of 2.4 million 0+ chinook, of which about one third emigrated before April.

Measuring the biological attributes of outmigration timing and size contributes to our understanding of juvenile chinook freshwater life history. This information is useful for flow management (dams and other flow controls), habitat protection, and designing hatchery programs to minimize hatchery/wild interactions.

We estimate coho smolt production from the Skagit River with the mark and recapture strategy that we developed and have used successfully in a number of large watersheds throughout the state over many years. This method involves the following components:

1. Trapping all the wild coho smolts emigrating from selected tributaries;
2. Identifying each of these smolts with an external mark; and

3. Capturing a portion of the smolt population migrating through the lower mainstem and examining each fish for the mark.

This design produces relatively precise and (we believe) unbiased production estimates, because a temporally- representative portion of the coho population is marked via 100% trapping at an upstream tributary. Therefore, trapping in the mainstem does not have to be continuous or even representative with respect to timing (*Seber* 1982). We explicitly developed this design to avoid the requirement of estimating gear efficiency.

Because of the early life history characteristics of chinook in freshwater, estimating their smolt production with the same statistical precision we achieve for coho smolts is not possible. Chinook originate in discrete portions of the mainstem, and subsequently rear for variable intervals in various reaches. Therefore, the methodology we use with coho, capturing and identifying a representative portion of the entire population, is not feasible for chinook. Each component likely has different survival patterns that result from the complex interactions of a number of factors: their parent's spawning timing and distribution; genetically-programed juvenile rearing strategies; and the flow and habitat conditions each brood and sub-population within it encounters. In a system as wide as the lower Skagit River, the migration pathways selected may also vary between sub-populations, which would affect capture rates. The susceptibility of migrants to capture also varies as a function of flow and environmental conditions in effect at the trap and upstream of it.

Operating downstream migrant traps over an extended period in the dynamic environment of the lower mainstem of a large river is challenging when conditions are optimal. During the spring runoff, however, as flows and debris levels exceed some threshold, it becomes impossible. Above a certain discharge, capture efficiency is generally some negative function of flow. When the traps are inoperable, however, it is zero. For these periods, migration has to be estimated by interpolation. Such estimates are biased if smolt migration rates are affected by flow changes, which we believe they are.

Sources of Variation Affecting Wild 0+ Chinook Estimates

Given the foregoing problems, estimating wild juvenile 0+ chinook production from the trapping data we have collected in the lower Skagit River involves a number of assumptions. Accuracy of the resultant estimates are a direct function of the veracity of these assumptions. Each assumption deals with the uncertainty resulting from the following five major sources of variation we have identified.

1. **Trap efficiency**. Expanding catches to estimate wild 0+ chinook production requires estimates of instantaneous gear efficiency, ideally as a function of some measurable variable such as discharge.

2. **Day vs night trap efficiency**. Trap efficiency may be influenced by light. For example, it may be lower during the daylight than at night.

   We have operated the traps primarily at night because catch rates, especially for coho and to a lesser extent chinook, are higher at night than during the daylight. Estimating instantaneous trap efficiency during the daylight hours, however, is probably not possible because it would require that a sufficient and known number of marked wild chinook pass the traps within a single daylight period. The traps fish only the top 4 ft of the water column, and the depth at our site is 20-30 ft, depending on discharge. If, as a function of increasing light intensity, juvenile chinook migrate at greater depth and/or their ability to avoid the trap increases, then trap efficiency during daylight hours would be lower. The behavior of juvenile chinook and the biases imposed by releasing marked fish immediately upstream of the traps precludes estimating instantaneous efficiency within such a limited time interval as a single daylight period. Catches during daylight hours appear to be positively affected by turbidity. If true, this results from either increased migration rate and/or an increase in trap efficiency because avoidance is reduced.

3. **Day vs. night migration**. Efficiency-based estimates rely on trapping either continuously or randomly throughout the time strata that migration is estimated. We developed our experimental design for estimating coho production to avoid the requirement of continuous trapping in the mainstem. Therefore, trapping in previous years was conducted almost entirely at night.

4. **Migration interval**. Skagit River 0+ chinook emigrate over a wider season than coho smolts. Chinook begin their downstream migration in January or earlier, and continue through the summer. In the first four years, we operated the traps only over the coho smolt migration period, early-April through mid-June. Beginning in 1994, and continuing through 1996, we extended trapping longer, as late as mid-July. In 1997, we began trapping in mid-February and continued into September. To better define the early portion of the migration period, in 1998 and 1999, we began trapping in mid-January and extended trapping into September. In 1999 and 2000 we attempted to assess late migration by operating the traps intermittently during October.

5. **Incidence of hatchery-produced fish**. Prior to 1994, releases of hatchery-produced 0+ chinook in the Skagit River were unmarked. Consequently, our estimates of wild chinook production for the first four years rely on an assumption for the number of hatchery-produced fingerlings we caught. Estimating both components of the migration relies on assumptions of how many hatchery fish survived to pass the trap during the interval trapped. Beginning with the 1993 brood, (released in 1994) all hatchery-produced zero age chinook released into the Skagit River have been marked with an adipose fin-clip (ad-mark) and coded-wire tagged.

Study Plan for 2001

The study plan for the 2001 trapping season was directed at continuing to improve the estimates of Skagit River chinook production through achieving a better understanding of the sources of variation. In addition to continuing our analysis of the chinook and coho trapping data collected over the previous eleven years, the 2001 work plan included the following six operational elements.

1. **Trapping season**. A critical uncertainty in estimating Skagit River wild 0+ chinook production is their emigration timing. In 2001 we began trapping in mid-January and

continued through July. Migration was in progress at a low level when trapping began and essentially over in mid-July.

2. **Nightly trap operation**. The scoop and screw traps were operated nightly throughout the season, with the exception of five nights when the traps did not operate due to high flows, debris and damaged gear.

3. **Daytime trap operation**. Daytime trapping occurred every third day. We enumerated catches shortly after dawn and around dusk to enable us to separate day and night catches.

4. **Wild coho marking**. In 1999 and 2000, we assessed differences in recapture rates of coho marked in the upper river with those marked in the lower watershed by using two different marks. Coho smolts marked and released by the NPS and the WDFW Habitat Program, were marked with a left ventral fin-clip (LV-mark) used in past years. Smolts captured at Mannser Creek in the lower river were right ventral fin-clip (RV-marked) by our trapping personnel. During the two-year evaluation we discovered significant differences in recapture rates between the two mark groups. Smolts released high in the river were recovered at lower rates than those released from Mannser Creek in the lower watershed. We attributed this difference to the longer migration distance for coho originating from the upper tributaries, which likely increased in-river mortality due to predation. Inclusion of the upper-river marked smolts in the coho production calculations biased the estimate high. Therefore, we discontinued marking fish in the upper watershed in Spring 2001. Smolts that were RV-marked at Mannser Creek provided the basis for the coho smolt production estimate.

5. **Trap efficiency**. In addition to the marked wild coho released from the Mannser Creek tributary trap and the groups of ad-marked/coded-wire tagged hatchery chinook fingerlings released from the three production facilities (Countyline Ponds, Red Creek and Skagit Hatchery), we marked and released four groups of hatchery chinook above the trap to serve as calibration groups.

6. **Measuring visibility**. To better understand the influence of water clarity on migration behavior, we measured visibility each day over the 1999, 2000, and 2001 spring seasons. Visibility data will be correlated with flow and fish catch data.

Methods

Trapping Gear and Operation

We use two trap types: a floating inclined-plane screen trap (scoop trap) (Seiler *et al.* 1981) and a screw trap (Busack *et al* 1991). Both traps are contained in steel pontoon barges, outfitted with two five-ton, bow-mounted anchor winches loaded with up to 600 ft of ⅜-inch aircraft cable. Overall, the scoop trap barge measures 13-ft x 44-ft, while the screw trap barge is 15-ft x 30-ft. The inclined-screen of the scoop trap is 6-ft wide, and we fish it only 3.5-ft deep to maintain an oblique angle to the flow. We have found that the angle formed by the 16 ft-long screen, set 3.5-ft deep at the entrance, precludes impinging even such small migrants as pink and chum fry, as there is sufficient sweep across the surface relative to the flow through it. At this depth, the scoop trap screens a rectangular cross-sectional area of 21-ft^2. The 8-ft diameter screw trap screens a cross-sectional area of 25-ft^2, in the shape of a semi-circle.

The traps are placed in the lower Skagit River at R.M. 17 (**Figure 1**). With the permission of Burlington Northern, we attach the four anchor lines to the bridge support structures. The traps are positioned side by side in the zone of highest water velocity, which is just south of the southernmost pier, approximately 70-ft from the south bank. Velocity at this site varies as a function of discharge. At low flows it averages around 5 fps, and increases to around 9 fps at high flows.

The traps were fished every night and every third day unless flows and associated debris loads were excessive. All captured fish were enumerated by species and age and examined for appropriate external marks. Samples of wild chinook were measured (fork length) over the season.

Environmental Parameters

Flow is the dominant factor affecting downstream migrant trapping operations in any system. This is particularly true in the lower Skagit River due to the quantity of large woody debris this system transports during rising and high flows. Mean daily flow data was provided by the USGS gauge, located at Mount Vernon. We also measured water temperature and turbidity daily using a standard secchi disk, which we compared with turbidity data from the City of Mount Vernon Water Treatment plant (Anacortes), located just below the trap site at R.M.16.

Estimating Migration

Estimating migration for any period, whether a short time interval or an entire season, requires a catch and an estimate of capture rate or trap efficiency. Catch is the product of abundance and capture rate (Equation #1). As our objective is to estimate abundance, and catch is simply a count within a time period, estimating capture rate is the primary challenge. We directed our analysis of the catch data at correlating day and night catch rates with flow and visibility data. These correlations were examined to correlate projections of 24-hour catches of wild 0+ chinook and selected groups of marked fish to the standard of continuous trapping. Relating the projected numbers of marked fish recovered to the numbers released provides estimates of capture rates.

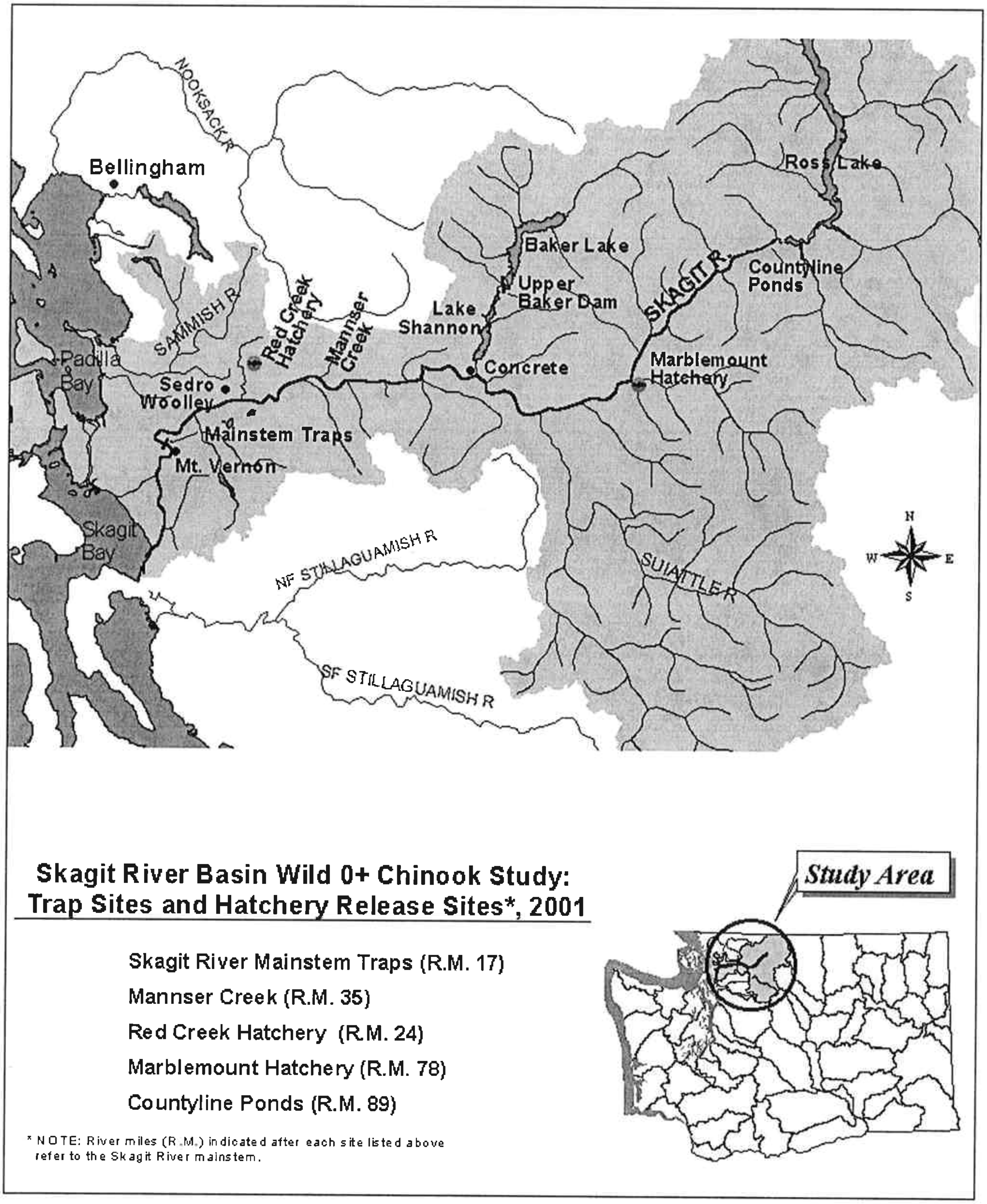


Figure 1. Map of tributary and mainstem trap sites and hatchery release sites, Skagit River chinook production evaluation, 2001.

Equation #1: Basic formulas

$$C = Me \qquad M = \frac{C}{e}$$

where: M = migrants
C = catch
e = trap efficiency

To assess catch rates of wild coho smolts and wild and hatchery 0+ chinook for light and dark periods, we selected sunrise and sunset as the strata breaks. For each trap, we sorted through the trapping interval database to select daytime fishing periods which were preceded and followed by night fishing intervals. Catch rates from the nights before and after the day fished were averaged to account for changing migration rates. Catch data were standardized by time fished in each interval and expressed as fish/hour rates. The ratio of day catch rate to night catch rate (d:n) was used to indicate relative catch rates as a function of daylight (Equation #2). We also computed season average day:night (d:n) catch ratios (Equation #3).

Equation #2: Comparing day catch rates to night catch rates:

$$R_i = C_{h_{di}} \frac{h_{ni-1} + h_{ni}}{C_{ni-1} + C_{ni}}$$

where: i = 24-hour period (from sunrise to sunrise)
R_i = ratio of day to night catch rates for period i
$C_{h(di)}$ = catch/hour during daylight for period i
C_{ni-1} = catch during night before period i
C_{ni} = catch during night for period i
h_{ni-1} = hours fished the night before period i
h_{ni} = hours fished during the night for period i

Equation #3: Season average ratio of day:night catch rates

$$\bar{R} = \frac{\Sigma R_i}{n}$$

where: n = total number of comparisons over the season

Catch data was expanded to the standard of continuous trapping. To estimate catches for the several contiguous nights that the screw trap did not fish during the summer, we expanded catches in the scoop trap with the ratio of scoop to screw trap catches before and after the outage. Catches during the daylight intervals that we did not fish were estimated from night catches and the d:n ratio correlations with the environmental parameter that best explained variation in d:n catch ratios.

Trap Efficiency

An estimate of instantaneous capture rate for both day and night intervals as a function of flow would be optimal. As discussed above, however, this may not be feasible with chinook. We had three primary indicators of trap efficiency in 2001: recaptures of the wild coho marked at the tributary trap over the season; recaptures of the four groups of fin-marked hatchery chinook that we released one mile upstream of the mainstem traps; and recoveries of the hatchery chinook fingerlings released from Skagit Hatchery, Countyline Ponds, Red Creek Hatchery. While the hatchery chinook are the same species and age, because they may behave differently than wild fish, their capture rate may not represent that of wild chinook. In addition, because the mortality and residualism of hatchery chinook between release and passing the trap is unknown, but probably significant, the resultant unadjusted estimates of capture rate are biased low. While wild coho are a different species, age, and somewhat larger size, because they are actively migrating smolts released over an extended period, their recaptures may actually represent season average trap efficiency for wild chinook better than the hatchery chinook groups.

To project recapture rates for both hatchery chinook and the marked wild coho to the standard of continuous trapping, we expanded mark recoveries with the process described above. Recaptures of ad-marked chinook were complicated by the release of three different groups/stocks with the same external mark. Following release of the chinook from Countyline Ponds and Red Creek Hatchery on May 12, we systematically sacrificed a sample of ad-marked 0+ chinook over the rest of the migration to recover tags and thereby estimate catches of each group.

Egg-to-Migrant Survival

When we expanded our trapping season in 1997, we began to examine survival from egg deposition to migration.

Equation #4: Egg-to-migrant survival for brood year i, $\hat{S}_i$, was calculated by:

$$\hat{S} = \frac{\hat{M}_{i+1}}{\hat{R}_{si}\hat{E}_i\hat{F}_i}$$

where:

$\hat{M}_{i+1}$ = estimated age-0+ chinook migration in year *i*+1

$\hat{R}_{si}$ = estimated proportion of females in chinook spawning population in year *i*

$\hat{E}_i$ = estimated chinook escapement in year *i*

$\hat{F}_i$ = estimated chinook fecundity in year *i*

To estimate $\hat{R}$ and $\hat{F}$, we assumed females comprised 45% of the adult escapement, and assumed a fecundity of 5,500 eggs/female (pers.comm. Pete Castle, WDFW).

Results

Trap Operation and Flow

The traps were installed on January 15. Trapping began on the night of January 16, and ended on July 30. Over this 195-day season, we operated the scoop trap every night with the exception of five nights. Trap operation on these nights was interrupted due to personnel emergencies, high flows and debris. We also fished the scoop trap throughout the daytime on 56 days, usually at a frequency of every third day. In total, we fished this trap 2,701 hours out of a possible 4,680 hours, 57.8% of the total season. The screw trap fished on nearly the same schedule, although for slightly more hours. In total, the screw trap fished 2,712 hours, 57.9% of the total season (**Table 1**).

Flows were very low throughout the 2001 season, with daily averages ranging from 6,000 to 27,000 cfs. In May, flows increased from around 8,000 cfs to exceed 15,000 cfs for the remainder of the trapping period (**Figure 2**).

Juvenile Chinook Catches

Chinook fry were moving downstream when we began trapping in mid-January. Catch rates remained low through January, with an average catch rate of just 1.3 chinook fry/hour over the first three days of trapping for both scoop and screw traps. By the end of January, catch rates increased, to average around 7 zero-age chinook/hour. The highest average catch rates of wild chinook over a night, 308 and 379 fish/hour in the scoop and screw traps, respectively, occurred on the night of March 19. Over the remaining season, wild 0+ chinook catch rates fluctuated but generally declined beginning in late-March with a brief increase in mid-May. In early-July, catches were less than 20 chinook/night, and dropped to less than 10 fish/night by mid-July. By the last month of the trapping season, wild chinook catch rates averaged less than 2 fish/hour.

Day-to-day variation in wild chinook catch rates was nearly identical between traps. The scoop trap, however, consistently out-fished the screw trap (**Figure 3**). For the season through August 1, the scoop and screw traps captured wild 0+ chinook at average rates of 20.3 and 14.8 fry/hour fished, respectively. These rates are simply the ratio of total catches to the total hours fished for each trap.

Over the season, we captured 94,906 wild and 3,021 hatchery 0+ chinook (**Table 2**). The hatchery 0+ chinook catch does not include the numbers of fin-marked chinook that we released above the trap on four dates to estimate trap efficiency. Also notable was the low number of wild coho captured (6,935 smolts). This catch is the lowest on record while both traps operated, 391 fewer fish than the previous low, 7,326 smolts in 1993. We caught only 76 yearling hatchery chinook, our second lowest catch since trapping began, from the 144,124 ad-marked/coded-wire tagged yearling chinook released from Skagit Hatchery on April 14.

Table 1. Record of downstream migrant trap operations, Skagit River, all years.

Year	Gear Type	TRAPPING INTERVAL[a]										
		Date		Season Total Days	Number of Days Fished					Hours		
					Nighttime		Daytime		Trap Out			
		Start	End		Full	Partial	Full	Partial		Total	Trapped	Percent Fished
1990[b]	Scr/Scp	04/13	06/19	66	50	1	5	10	11	1,602.5	590.5	36.8%
1991	Scoop	04/08	06/20	73	72	1	4	18	0	1,741.5	858.0	49.3%
1992	Scoop	04/10	06/21	72	65		3	5	7	1,717.0	667.0	38.8%
1993	Scoop	04/11	06/07	57	53	2	0	8	2	1,355.5	539.5	39.8%
	Screw	04/22	06/07	46	32	0	4	5	14	1,095.0	366.5	33.5%
1994	Scoop	04/09	06/29	81	78	3	5	4	0	1,931.0	828.0	42.9%
	Screw	04/09	06/29	81	78	1	10	6	2	1,931.0	917.0	47.5%
1995	Scoop	03/25	07/15	112	112	0	5	8	0	2,724.0	1,189.0	43.6%
	Screw	03/25	07/17	114	110	2	8	8	2	2,729.5	1,207.0	44.2%
1996	Scoop	04/12	07/18	97	95	0	6	28	2	2,321.5	1,110.5	47.8%
	Screw	04/12	07/18	97	91	3	7	25	3	2,321.5	1,112.0	47.9%
1997	Scoop	02/14	09/10	208	182	9	58	26	17	4,996.0	2,719.0	54.4%
	Screw	02/14	09/10	208	174	11	56	21	23	4,996.0	2,667.0	53.4%
1998	Scoop	01/18	09/11	236	231	0	85	3	5	5,640.0	3,599.0	63.8%
	Screw	01/18	09/11	236	188	0	69	1	48	5,640.0	2,992.0	53.0%
1999	Scoop	01/16	09/06	234	223	0	72	3	11	5,595.3	3,326.9	59.5%
	Screw	01/16	09/06	234	215	0	70	1	19	5,594.8	2,353.2	42.1%
2000	Scoop	01/15	08/18	216	205	0	62	0	11	5,206.0	3,042.1	58.6%
	Screw	01/15	10/27	286	209	0	65	0	77	6,860.5	3,116.1	45.6%
2001	Scoop	01/16	07/30	195	191	1	57	3	4	4,648.7	2,701.2	58.1%
	Screw	01/16	07/30	195	184	6	53	6	5	4,648.7	2,712.8	58.4%

[a] Trapping intervals are defined as follows: "full nighttime" is from dusk to dawn; "partial nighttime" is a sub-interval of the time between dusk and dawn "Full daytime" is from dawn to dusk; and "partial daytime" is a sub-interval of time between dawn and dusk.

[b] In 1990, we initially started trapping with a screw trap, but because of mechanical problems, replaced it with a scoop trap on May 7.

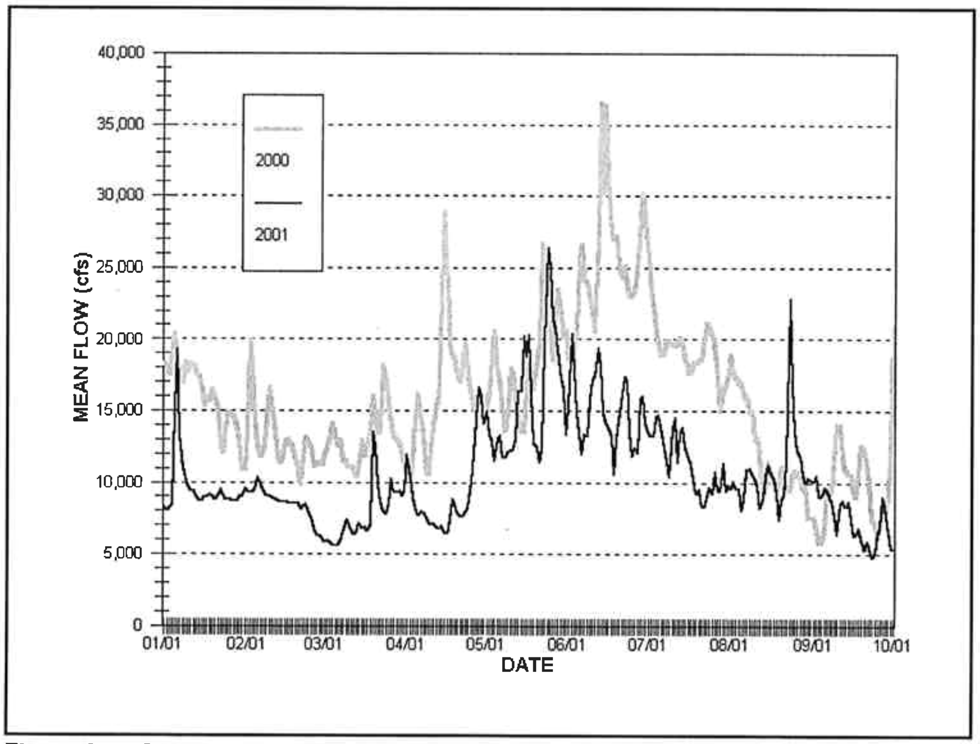


Figure 2. Comparison of daily mean flows in 2000 and 2001, Skagit River near Mount Vernon (USGS data), January through September.

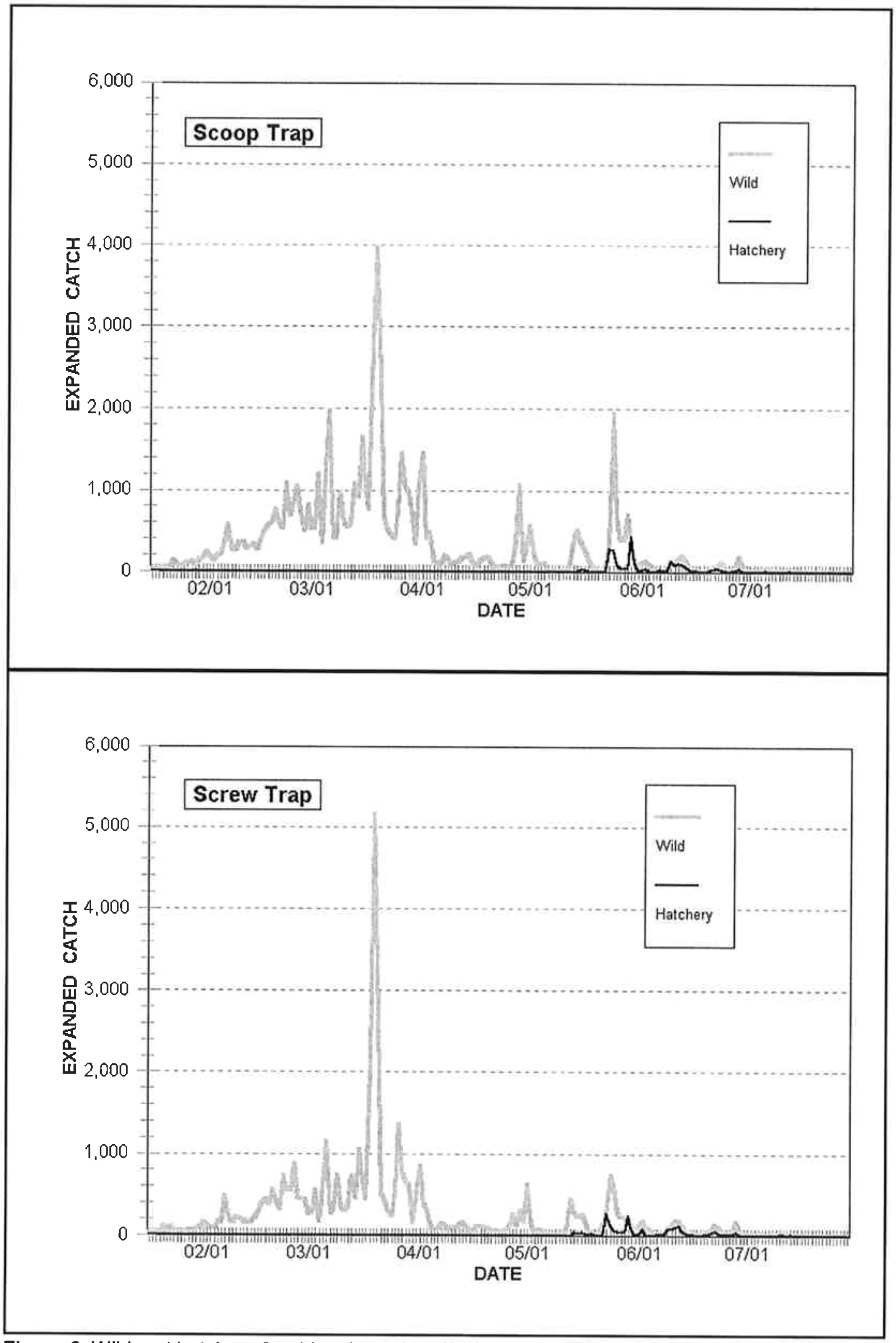


Figure 3. Wild and hatchery 0+ chinook catches (24-hour expansion), Skagit River mainstem traps 2001.

Table 2. Downstream migrant salmonids captured in the Skagit River mainstem scoop and screw traps, all years.

Species/age	1990 Scoop	1991 Scoop	1992 Scoop	1993		1994		1995		1996		1997		1998		1999		2000		2001	
				Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw	Scoop	Screw
Coho 1+ Wild	10,204	6,904	8,620	3,636	3,690	10,767	10,211	8,861	8,824	11,520	9,134	6,437	5,975	13,879	9,076	4,904	3,314	13,449	14,861	2,581	4,354
Coho 1+ Hatchery	234	382	596	[a]714	[a]723	1,880	1,873	4,800	5,274	973	1,208	334	362	623	1,028	673	635	624	946	103	398
Coho 0+	48	22	64	79	4	57	5	204	57	246	50	364	220	1,216	409	744	311	115	27	2,604	871
Chinook 1+ Wild	[b]45	[b]1,132	[b]299	[b]3,567	[b]262	308	212	184	112	80	32	46	52	876	350	198	87	129	105	32	26
Chinook 1+ Hatchery								1,754	570	415	117	376	249	24	12	201	41	511	360	26	50
Chinook 0+ Wild	[c]8,528	[d]1,706	[e]8,812	[f]7,463	[f]3,415	9,721	4,743	10,536	5,767	2,834	1,731	26,798	20,780	33,698	20,001	55,254	41,492	23,289	14,944	54,762	40,180
Chinook 0+ Hatchery						2,320	1,098	6,083	2,022	4,165	2,888	1,163	684	5,837	2,127	3,449	2,213	2,554	2,152	1,667	1,354
Sockeye 1+	2	21	2	32	16	106	45	31	17	36	56	59	48	111	84	72	23	9	11	5	1
Chum 0+	617	48,505	3,081	66,790	13,939	5,113	7,689	66,139	55,824	10,578	5,384	38,243	39,174	37,162	18,498	172,774	108,730	39,608	40,234	133,890	105,200
Pink 0+	697	0	18,682	0	0	48,532	22,952	0	0	27,482	9,778	9	17	338,520	102,338	476	265	207,530	198,015	2,644	1,350
Steelhead 1+ Wild	198	301	332	304	663	601	1,297	532	1,184	364	778	319	531	389	1,100	99	334	95	597	32	317
Steelhead 1+ Hatchery	223	66	124	658	2,381	670	3,107	1,282	4,579	751	1,751	982	2,401	446	2,325	122	511	75	736	23	465
Steelhead adult	0	0	0	0	0	0	0	4	1	1	0	3	4	1	3	11	1	1	2	0	0
Cutthroat 1+	117	60	153	45	91	198	437	107	263	165	332	58	89	98	401	30	150	51	248	11	318
Cutthroat adult	0	0	0	0	0	0	0	1	0	0	2	2	13	2	5	4	0	0	7	0	0
Dolly Varden	130	112	132	76	74	197	255	189	179	142	102	65	77	153	206	101	98	109	138	20	125
Trout parr	N/A	N/A	N/A	12	7	47	69	56	47	110	68	40	61	90	83	42	57	116	155	86	123

[a] Estimated by proportion of total catch.
[b] Includes both hatchery and wild.
[c] 1989 brood released from Clark Creek = 1,728,100: Fall = 1,170,800 Samish stock + 236,600 Clark Creek stock, released on June 8, 1990; and Summer = 73,800 + 246,900 Clark Creek stock released on June 28, 1990.
[d] Clark Creek stock released on June 18, 1991: 1,144,500 Fall and 111,120 Summer.
[e] Clark Creek stock: 786,100 Fall, released February 25, 1992; 483,280 Summer, released April 20, 1992; and 120,000 released May 21, 1992.
[f] Clark Creek stock: 1,588,800 Fall released in February 1993, and 250,000 Fall released on March 16, 1993; and 160,000 Summer released on May 16, 1993.

Day:Night Catch Ratios

We compared wild 0+ chinook catch rates during daylight hours to respective nighttime catch rates for the scoop and screw traps on 56 days (**Tables 3a-b**). Day:night catch rate ratios (d:n ratios) varied from 0% to over 133% in the scoop trap, and up to 217% in the screw trap. For the season, mean d:n catch rate ratios were 35% and 45% for the scoop and screw traps, respectively. These rates are similar to the rates observed in the past seasons.

On the dates that we computed d:n ratios at the traps, flows ranged approximately three-fold (6,300 - 17,400 cfs). Regression analysis determined that flow explained very little of the variation in d:n ratios in the scoop trap and screw traps, 1.8% and 5.3%, respectively (**Figure 4**). Given the atypically consistent low, moderate flows which dominated much of the early portion of the season, visibility was a more influential variable, explaining about 27% of the variation (**Figure 5**).

Analysis of d:n ratios for hatchery chinook was limited by release timing and low abundance to the mid-May through July period (**Tables 4a and 4b**). In both traps, hatchery 0+ chinook were consistently caught at lower rates during the daylight relative to respective nights than wild chinook evaluated over the same period. Overall, d:n ratios for hatchery chinook averaged 10% and 15% in the scoop and screw traps, respectively. These rates were about one-half those measured for wild chinook in both traps, which averaged 19% in the scoop trap and 32% in the screw trap over the same period. As with wild chinook, relating d:n ratios for hatchery chinook to flow indicated weak, positive correlations; hatchery 0+ chinook d:n ratios correlated with flow explained around 18% of the variation in the scoop trap and 13% in the screw trap (**Figure 6a**). Wild 0+ chinook d:n ratios in this same period showed no significant (95%) correlations with flow (R^2 = 26% and 18% for the scoop and screw traps, respectively) (**Figure 6b**). Day:night ratios for both hatchery and wild chinook appeared to vary in a similar manner (**Figure 7**). Flows increased just prior to the hatchery releases, which began on May 12. Before late-April, flows averaged around 8,400 cfs and thereafter increased to average around 14,000 cfs through the end of the season. Approximately 85% of the wild 0+ chinook had emigrated before the hatchery releases began.

Day:night catch ratios for wild coho smolts during the migration period (April through June) averaged 7% and 13% in the scoop and screw traps about one-fourth of the rates estimated for wild 0+ chinook (**Table 5a-b**). Flows on the days coho d:n ratios were assessed varied nearly three-fold (6,400 to 17,400 cfs) and averaged 12,000 cfs, but explained none of the variation in d:n ratios (**Figure 8**). The relationship between flow and d:n ratios in years when flows were considerably higher indicate that relatively few coho would be captured during the daytime at flows less than 20,000 cfs. Our finding in 2001 is consistent with our results in 1998 and 1999, when flows were also low, and matches our experience in other previous years whenever flows averaged less than 20,000 cfs.

Table 3a. Catch/hour rates of wild 0+ chinook during day and night periods, Skagit River scoop trap, 2001.

NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates Begin	Dates End	Hours Fished	Catch	Catch/ Hour	Date	Time Begin	Time End	Hours Fished	Catch	Catch/ Hour	Diff (D-N)	Ratio (D/N)	Secchi (cm)	Flow (cfs)
01/22	01/24	30.42	166	5.46	01/23	8.33	17.25	8.92	34	3.81	-1.64	69.87%	90	9,070
01/25	01/27	30.08	166	5.52	01/26	8.67	17.25	8.58	9	1.05	-4.47	19.00%	195	8,780
01/28	01/30	28.83	163	5.65	01/29	8.67	17.50	8.83	25	2.83	-2.82	50.06%	228	9,010
01/31	02/02	28.42	386	13.58	02/01	8.67	17.67	9.00	20	2.22	-11.36	16.36%	185	9,400
02/03	02/05	27.83	328	11.78	02/04	8.67	17.50	8.83	39	4.42	-7.37	37.47%	165	9,550
02/06	02/08	28.50	728	25.54	02/07	8.33	18.00	9.67	52	5.38	-20.16	21.06%	165	9,420
02/09	02/11	28.75	635	22.09	02/10	8.17	17.58	9.42	39	4.14	-17.95	18.75%	230	8,950
02/12	02/14	28.58	552	19.31	02/13	8.67	17.75	9.08	60	6.61	-12.71	34.20%	170	8,680
02/15	02/17	27.50	757	27.53	02/16	8.33	18.00	9.67	106	10.97	-16.56	39.84%	105	8,620
02/18	02/20	27.33	1,132	41.41	02/19	8.25	18.00	9.75	156	16.00	-25.41	38.63%	95	8,560
02/21	02/23	27.17	1,171	43.10	02/22	8.17	18.33	10.17	364	35.80	-7.30	83.06%	85	8,350
02/24	02/26	27.42	1,468	53.54	02/25	8.25	18.17	9.92	337	33.98	-19.56	63.47%	70	7,480
02/27	03/01	26.67	1,045	39.19	02/28	7.17	18.17	11.00	184	16.73	-22.46	42.69%	125	6,290
03/01	03/03	26.67	927	34.76	03/02	8.17	18.17	10.00	34	3.40	-31.36	9.78%	295	5,940
03/04	03/06	27.17	1,493	54.96	03/05	8.50	18.00	9.50	17	1.79	-53.17	3.26%	325	5,629
03/07	03/09	25.83	633	24.50	03/08	8.17	18.50	10.33	7	0.68	-23.83	2.76%	340	6,490
03/10	03/12	25.00	1,010	40.40	03/11	8.00	18.75	10.75	9	0.84	-39.56	2.07%	270	6,580
03/13	03/15	26.58	1,784	67.11	03/14	9.75	18.75	9.00	77	8.56	-58.55	12.75%	260	7,100
03/16	03/18	24.00	1,648	68.67	03/17	7.00	18.50	11.50	23	2.00	-66.67	2.91%	190	7,060
03/19	03/21	21.00	4,154	197.81	03/20	6.33	20.00	13.67	2,017	147.59	-50.22	74.61%	60	12,500
03/22	03/24	23.75	803	33.81	03/23	7.00	18.75	11.75	91	7.74	-26.07	22.91%	250	8,020
03/25	03/27	22.42	1,178	52.55	03/26	7.00	18.67	11.67	816	69.94	17.39	133.10%	185	10,200
03/28	03/30	23.00	1,236	53.74	03/29	6.58	18.50	11.92	231	19.38	-34.35	36.07%	120	9,400
03/31	04/02	23.08	1,609	69.70	04/01	9.50	18.75	9.25	575	62.16	-7.54	89.18%		11,900
04/03	04/05	21.33	495	23.20	04/04	7.25	20.00	12.75	42	3.29	-19.91	14.20%	245	8,169
04/06	04/08	20.92	249	11.90	04/07	7.50	20.50	13.00	15	1.15	-10.75	9.69%	175	7,890
04/09	04/11	20.25	171	8.44	04/10	7.25	20.50	13.25	12	0.91	-7.54	10.72%	300	7,060
04/12	04/14	20.58	301	14.62	04/13	6.67	20.25	13.58	30	2.21	-12.41	15.10%	300	6,810
04/15	04/17	19.50	157	8.05	04/16	6.75	20.50	13.75	3	0.22	-7.83	2.71%	295	6,430
04/19	04/21	19.75	228	11.54	04/20	6.75	21.00	14.25	62	4.35	-7.19	37.69%	275	7,860
04/22	04/24	19.42	102	5.25	04/23	6.50	20.00	13.50	10	0.74	-4.51	14.10%	290	7,960
04/25	04/27	19.75	124	6.28	04/26	6.50	19.50	13.00	16	1.23	-5.05	19.60%	135	12,100
04/30	05/02	15.92	426	26.76	05/01	5.50	20.50	15.00	343	22.87	-3.90	85.44%	96	14,900
05/03	05/05	17.75	139	7.83	05/04	6.00	20.25	14.25	0	0.00	-7.83	0.00%	170	11,500
05/06	05/08	17.33	9	0.52	05/07	6.00	20.83	14.83	0	0.00	-0.52	0.00%	175	11,700
05/09	05/11	18.25	30	1.64	05/10	5.75	21.00	15.25	7	0.46	-1.18	27.92%		12,200
05/12	05/14	17.17	274	15.96	05/13	6.00	20.50	14.50	181	12.48	-3.48	78.21%		16,300
05/20	05/22	15.50	29	1.87	05/21	5.75	21.50	15.75	4	0.25	-1.62	13.57%	220	11,400
05/30	06/01	13.83	141	10.19	05/31	6.25	21.00	14.75	5	0.34	-9.85	3.33%	110	15,300
06/02	06/04	15.33	172	11.22	06/03	5.25	21.25	16.00	28	1.75	-9.47	15.60%	100	14,800
06/06	06/08	15.00	22	1.47	06/07	5.83	21.25	15.42	1	0.06	-1.40	4.42%	222	13,200
06/09	06/11	14.83	207	13.96	06/10	5.42	21.50	16.08	20	1.24	-12.71	8.91%	115	17,400
06/14	06/16	14.83	38	2.56	06/15	5.50	21.83	16.33	14	0.86	-1.70	33.46%	210	13,900
06/19	06/21	16.58	51	3.08	06/20	5.50	21.58	16.08	6	0.37	-2.70	12.13%	240	16,200
06/22	06/24	14.50	108	7.45	06/23	5.17	21.78	16.62	68	4.09	-3.36	54.94%	115	13,600
06/25	06/27	13.83	52	3.76	06/26	4.83	21.67	16.83	12	0.71	-3.05	18.96%	235	12,100
06/28	06/30	14.45	174	12.04	06/29	5.17	21.58	16.42	2	0.12	-11.92	1.01%	240	14,199
07/01	07/03	15.33	36	2.35	07/02	6.00	21.50	15.50	4	0.26	-2.09	10.99%	180	13,200
07/05	07/07	14.67	52	3.55	07/06	5.25	21.75	16.50	8	0.48	-3.06	13.68%	80	13,400
07/08	07/10	15.33	42	2.74	07/09	5.50	21.67	16.17	0	0.00	-2.74	0.00%	150	10,400
07/11	07/13	14.58	49	3.36	07/12	5.42	21.75	16.33	6	0.37	-2.99	10.93%	100	11,400
07/14	07/16	15.67	13	0.83	07/15	5.58	21.25	15.67	4	0.26	-0.57	30.77%	125	12,500
07/17	07/19	15.00	7	0.47	07/18	5.58	21.58	16.00	0	0.00	-0.47	0.00%	200	10,200
07/20	07/22	16.00	5	0.31	07/21	5.67	21.33	15.67	1	0.06	-0.25	20.43%	285	8,260
07/23	07/25	15.67	7	0.45	07/24	5.58	21.92	16.33	2	0.12	-0.32	27.41%	170	9,670
07/26	07/28	15.83	5	0.32	07/27	6.00	21.50	15.50	0	0.00	-0.32	0.00%	120	9,540
Season Total		1,170.70	29,087	24.85				727.03	6,228	8.57	-16.28	34.48%		
Season Avg											-12.61	27.14%	186	10,259
Median											-7.45	17.56%	180	9,480

Table 3b. Catch/hour rates of wild 0+ chinook during day and night periods, Skagit River screw trap, 2001.

NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates		Hours	Catch	Catch/	Date	Time		Hours	Catch	Catch/	Diff	Ratio	Secchi	Flow
Begin	End	Fished		Hour		Begin	End	Fished		Hour	(D-N)	(D/N)	(cm)	(cfs)
01/22	01/24	30.50	136	4.46	01/23	8.50	17.50	9.00	31	3.44	-1.01	77.25%	90	9,070
01/25	01/27	30.25	88	2.91	01/26	8.50	17.25	8.75	10	1.14	-1.77	39.29%	195	8,780
01/28	01/30	29.00	106	3.66	01/29	8.50	17.50	9.00	21	2.33	-1.32	63.84%	228	9,010
01/31	02/02	28.75	242	8.42	02/01	8.50	17.50	9.00	19	2.11	-6.31	25.08%	185	9,400
02/03	02/05	27.83	195	7.01	02/04	8.75	17.67	8.92	57	6.39	-0.61	91.24%	165	9,550
02/06	02/08	28.58	577	20.19	02/07	8.17	18.00	9.83	54	5.49	-14.70	27.20%	165	9,420
02/09	02/11	28.92	374	12.93	02/10	8.08	17.67	9.58	30	3.13	-9.80	24.20%	230	8,950
02/12	02/14	28.50	242	8.49	02/13	9.00	18.00	9.00	49	5.44	-3.05	64.12%	170	8,680
02/15	02/17	27.50	532	19.35	02/16	8.17	18.00	9.83	95	9.66	-9.68	49.94%	105	8,620
02/18	02/20	27.42	745	27.17	02/19	8.00	18.00	10.00	144	14.40	-12.77	52.99%	95	8,560
02/21	02/23	27.67	701	25.34	02/22	8.25	18.17	9.92	292	29.45	4.11	116.21%	85	8,350
02/24	02/26	27.42	1,070	39.03	02/25	8.25	18.25	10.00	258	25.80	-13.23	66.11%	70	7,480
02/27	03/01	26.58	644	24.23	02/28	7.25	18.33	11.08	164	14.80	-9.43	61.08%	125	6,290
03/01	03/04	27.67	689	24.90	03/02	8.33	18.00	9.67	17	1.76	-23.14	7.06%	295	5,940
03/04	03/06	26.83	722	26.91	03/05	8.00	18.17	10.17	7	0.69	-26.22	2.56%	325	5,629
03/07	03/09	25.50	467	18.31	03/08	7.50	18.50	11.00	7	0.64	-17.68	3.47%	340	6,490
03/10	03/12	25.00	536	21.44	03/11	8.00	18.75	10.75	15	1.40	-20.04	6.51%	270	6,580
03/13	03/15	24.98	984	39.39	03/14	7.50	18.50	11.00	76	6.91	-32.48	17.54%	260	7,100
03/16	03/18	24.00	952	39.67	03/17	7.00	18.50	11.50	24	2.09	-37.58	5.26%	190	7,060
03/19	03/21	24.00	5,543	230.96	03/20	6.25	18.25	12.00	2,049	170.75	-60.21	73.93%	60	12,500
03/22	03/24	23.83	562	23.58	03/23	7.00	18.75	11.75	92	7.83	-15.75	33.20%	250	8,020
03/25	03/27	23.50	980	41.70	03/26	7.00	18.75	11.75	782	66.55	24.85	159.59%	185	10,200
03/28	03/30	22.92	814	35.52	03/29	6.50	18.67	12.17	295	24.25	-11.27	68.26%	120	9,400
03/31	04/02	19.25	691	35.90	04/01	7.50	20.50	13.00	500	38.46	2.57	107.15%		11,900
04/03	04/05	22.00	294	13.36	04/04	7.17	20.00	12.83	48	3.74	-9.62	27.99%	245	8,169
04/06	04/08	21.92	196	8.94	04/07	7.50	19.50	12.00	9	0.75	-8.19	8.39%	175	7,890
04/09	04/11	20.25	157	7.75	04/10	7.25	20.50	13.25	8	0.60	-7.15	7.79%	300	7,060
04/12	04/14	20.25	246	12.15	04/13	6.75	20.33	13.58	18	1.33	-10.82	10.91%	300	6,810
04/15	04/17	19.50	99	5.08	04/16	6.75	20.50	13.75	3	0.22	-4.86	4.30%	295	6,430
04/19	04/21	20.25	130	6.42	04/20	6.75	20.75	14.00	38	2.71	-3.71	42.28%	275	7,860
04/22	04/24	19.67	93	4.73	04/23	6.50	20.25	13.75	8	0.58	-4.15	12.30%	290	7,960
04/25	04/27	19.58	122	6.23	04/26	6.67	20.00	13.33	46	3.45	-2.78	55.38%	135	12,100
04/30	05/02	16.25	382	23.51	05/01	5.50	20.50	15.00	324	21.60	-1.91	91.88%	96	14,900
05/03	05/05	18.00	97	5.39	05/04	6.00	20.00	14.00	2	0.14	-5.25	2.65%	170	11,500
05/06	05/08	17.58	12	0.68	05/07	6.33	21.00	14.67	2	0.14	-0.55	19.98%	175	11,700
05/09	05/11	18.00	20	1.11	05/10	5.83	21.08	15.25	8	0.52	-0.59	47.21%		12,200
05/12	05/14	17.33	177	10.21	05/13	10.50	21.00	10.50	233	22.19	11.98	217.31%		16,300
05/20	05/22	15.83	33	2.08	05/21	5.83	21.42	15.58	6	0.39	-1.70	18.47%	220	11,400
05/30	06/01	14.50	102	7.03	05/31	6.50	21.50	15.00	13	0.87	-6.17	12.32%	110	15,300
06/02	06/04	15.25	185	12.13	06/03	5.50	21.33	15.83	40	2.53	-9.60	20.83%	100	14,800
06/06	06/08	15.42	21	1.36	06/07	5.92	21.08	15.17	1	0.07	-1.30	4.84%	222	13,200
06/09	06/11	15.00	160	10.67	06/10	5.75	21.67	15.92	36	2.26	-8.40	21.20%	115	17,400
06/14	06/16	15.17	34	2.24	06/15	5.67	22.00	16.33	22	1.35	-0.89	60.08%	210	13,900
06/19	06/21	16.75	27	1.61	06/20	5.42	21.50	16.08	18	1.12	-0.49	69.43%	240	16,200
06/22	06/24	14.97	152	10.16	06/23	5.33	21.67	16.33	41	2.51	-7.65	24.72%	115	13,600
06/25	06/27	14.25	53	3.72	06/26	5.17	21.67	16.50	5	0.30	-3.42	8.15%	235	12,100
06/28	06/30	14.85	141	9.49	06/29	5.33	21.75	16.42	6	0.37	-9.13	3.85%	240	14,199
07/01	07/03	15.75	38	2.41	07/02	6.00	21.58	15.58	0	0.00	-2.41	0.00%	180	13,200
07/05	07/07	15.08	38	2.52	07/06	5.58	21.67	16.08	3	0.19	-2.33	7.40%	80	13,400
07/08	07/10	15.58	36	2.31	07/09	5.50	21.50	16.00	7	0.44	-1.87	18.94%	150	10,400
07/11	07/13	14.58	33	2.26	07/12	5.33	21.92	16.58	9	0.54	-1.72	23.98%	100	11,400
07/14	07/16	15.00	20	1.33	07/15	5.33	21.50	16.17	3	0.19	-1.15	13.92%	125	12,500
07/17	07/19	15.17	10	0.66	07/18	5.50	21.50	16.00	2	0.13	-0.53	18.96%	200	10,200
07/20	07/22	16.00	2	0.12	07/21	5.58	21.25	15.67	0	0.00	-0.12	0.00%	285	8,260
07/23	07/25	15.42	6	0.39	07/24	5.50	21.83	16.33	3	0.18	-0.21	47.19%	170	9,670
07/26	07/28	16.58	5	0.30	07/27	5.75	21.33	15.58	1	0.06	-0.24	21.28%	120	9,540
Season Total		1,178.13	21,713	18.43				727.75	6,051	8.31	-10.12	45.11%		
Season Avg											-7.20	39.05%	186	10,259
Median											-3.93	24.09%	180	9,480

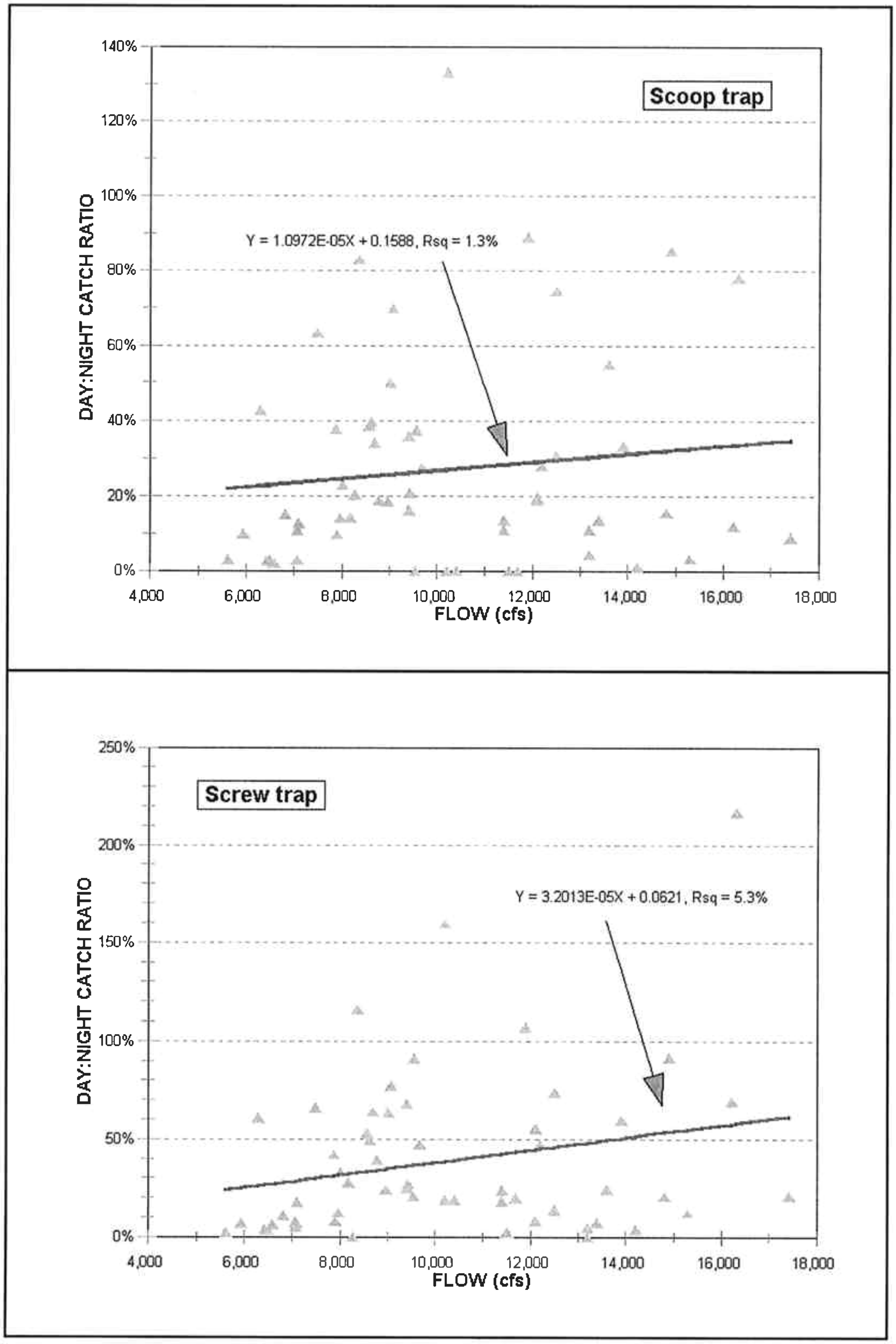


Figure 4. Day:night catch rate ratios for 0+ wild chinook and daily mean flow, Skagit River mainstem traps, January through July 2001.

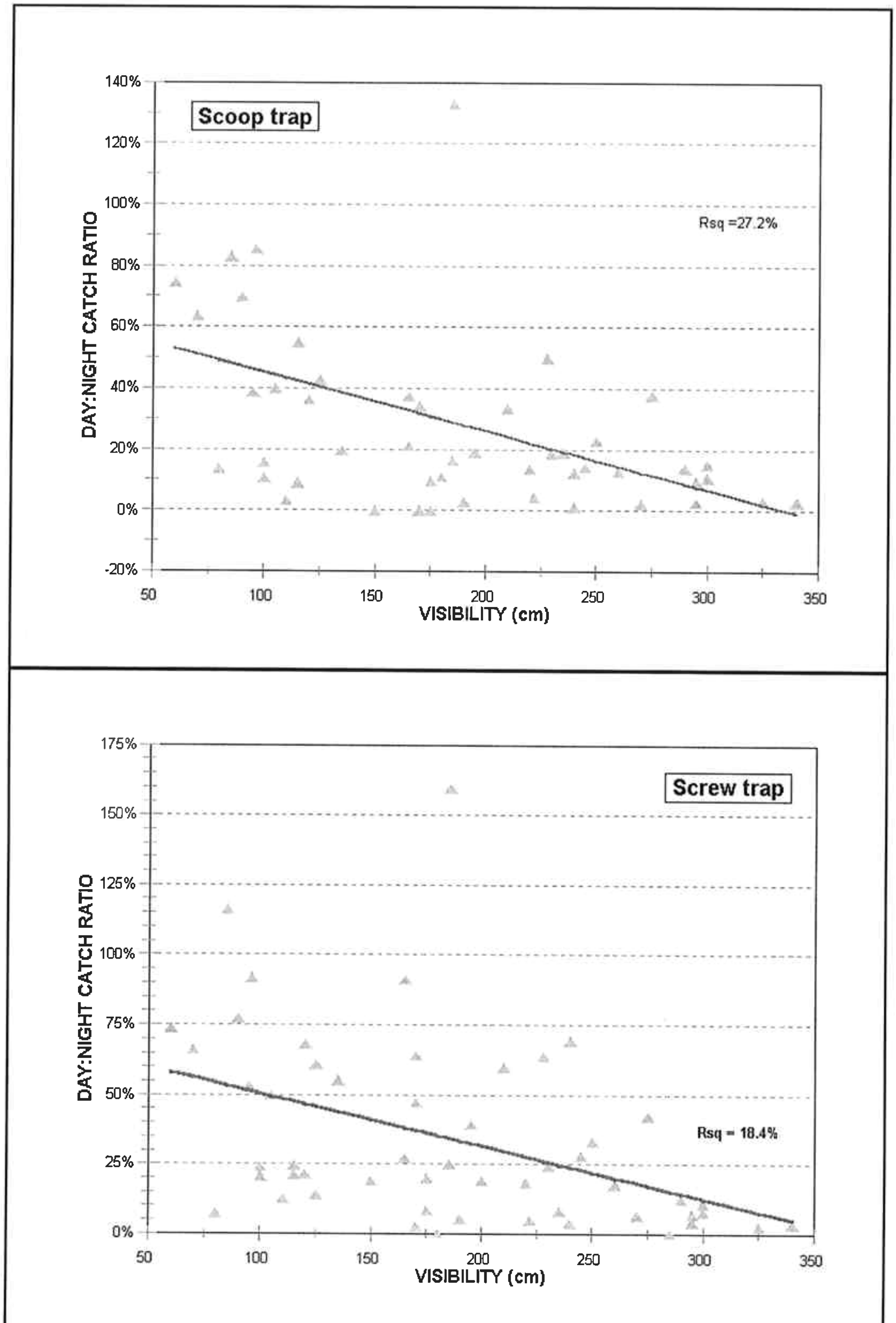


Figure 5. Day:night wild 0+ chinook catch rate ratios and visibility, Skagit River mainstem traps, 2001.

Table 4a. Catch/hour rates of hatchery 0+ chinook during day and night periods, Skagit River scoop trap, 2001.

NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates		Hours	Catch	Catch/	Date	Time		Hours	Catch	Catch/	Diff	Ratio	Secchi	Flow
Begin	End	Fished		Hour		Begin	End	Fished		Hour	(D-N)	(D/N)	(cm)	(cfs)
05/12	05/14	17.17	5	0.29	05/13	6.00	20.50	14.50	2	0.14	-0.15	47.36%		16,300
05/20	05/22	15.50	2	0.13	05/21	5.75	21.50	15.75	0	0.00	-0.13	0.00%	220	11,400
05/30	06/01	13.83	49	3.54	05/31	6.25	21.00	14.75	0	0.00	-3.54	0.00%	110	15,300
06/02	06/04	15.33	36	2.35	06/03	5.25	21.25	16.00	8	0.50	-1.85	21.30%	100	14,800
06/06	06/08	15.00	26	1.73	06/07	5.83	21.25	15.42	0	0.00	-1.73	0.00%	222	13,200
06/09	06/11	14.83	179	12.07	06/10	5.42	21.50	16.08	10	0.62	-11.45	5.15%	115	17,400
06/14	06/16	14.83	17	1.15	06/15	5.50	21.83	16.33	1	0.06	-1.08	5.34%	210	13,900
06/19	06/21	16.58	20	1.21	06/20	5.50	21.58	16.08	4	0.25	-0.96	20.62%	240	16,200
06/22	06/24	14.50	43	2.97	06/23	5.17	21.78	16.62	11	0.66	-2.30	22.32%	115	13,600
06/25	06/27	13.83	14	1.01	06/26	4.83	21.67	16.83	3	0.18	-0.83	17.61%	235	12,100
06/28	06/30	14.45	39	2.70	06/29	5.17	21.58	16.42	0	0.00	-2.70	0.00%	240	14,199
07/01	07/03	15.33	6	0.39	07/02	6.00	21.50	15.50	0	0.00	-0.39	0.00%	180	13,200
07/05	07/07	14.67	8	0.55	07/06	5.25	21.75	16.50	1	0.06	-0.48	11.11%	80	13,400
07/08	07/10	15.33	8	0.52	07/09	5.50	21.67	16.17	0	0.00	-0.52	0.00%	150	10,400
07/11	07/13	14.58	10	0.69	07/12	5.42	21.75	16.33	1	0.06	-0.62	8.93%	100	11,400
07/14	07/16	15.67	1	0.06	07/15	5.58	21.25	15.67	0	0.00	-0.06	0.00%	125	12,500
Season Total		241.45	463	1.92				254.95	41	0.16	-1.76	8.39%		
Season Avg											-1.80	9.98%	163	13,706
Median											-0.90	5.25%	150	13,500

Table 4b. Catch/hour rates of hatchery 0+ chinook during day and night periods, Skagit River screw trap, 2001

NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates		Hours	Catch	Catch/	Date	Time		Hours	Catch	Catch/	Diff	Ratio	Secchi	Flow
Begin	End	Fished		Hour		Begin	End	Fished		Hour	(D-N)	(D/N)	(cm)	(cfs)
05/12	05/14	17.33	2	0.12	05/13	10.50	21.00	10.50	1	0.10	-0.02	82.54%		16,300
05/20	05/22	15.83	2	0.13	05/21	5.83	21.42	15.58	0	0.00	-0.13	0.00%	220	11,400
05/30	06/01	14.50	26	1.79	05/31	6.50	21.50	15.00	0	0.00	-1.79	0.00%	110	15,300
06/02	06/04	15.25	63	4.13	06/03	5.50	21.33	15.83	3	0.19	-3.94	4.59%	100	14,800
06/06	06/08	15.42	23	1.49	06/07	5.92	21.08	15.17	1	0.07	-1.43	4.42%	222	13,200
06/09	06/11	15.00	107	7.13	06/10	5.75	21.67	15.92	29	1.82	-5.31	25.54%	115	17,400
06/14	06/16	15.17	18	1.19	06/15	5.67	22.00	16.33	5	0.31	-0.88	25.79%	210	13,900
06/19	06/21	16.75	13	0.78	06/20	5.42	21.50	16.08	3	0.19	-0.59	24.03%	240	16,200
06/22	06/24	14.97	47	3.14	06/23	5.33	21.67	16.33	10	0.61	-2.53	19.50%	115	13,600
06/25	06/27	14.25	14	0.98	06/26	5.17	21.67	16.50	0	0.00	-0.98	0.00%	235	12,100
06/28	06/30	14.85	34	2.29	06/29	5.33	21.75	16.42	0	0.00	-2.29	0.00%	240	14,199
07/01	07/03	15.75	7	0.44	07/02	6.00	21.58	15.58	0	0.00	-0.44	0.00%	180	13,200
07/05	07/07	15.08	6	0.40	07/06	5.58	21.67	16.08	0	0.00	-0.40	0.00%	80	13,400
07/08	07/10	15.58	7	0.45	07/09	5.50	21.50	16.00	2	0.13	-0.32	27.83%	150	10,400
07/11	07/13	14.58	5	0.34	07/12	5.33	21.92	16.58	2	0.12	-0.22	35.18%	100	11,400
07/14	07/16	15.00	2	0.13	07/15	5.33	21.50	16.17	0	0.00	-0.13	0.00%	125	12,500
07/17	07/19	15.17	1	0.07	07/18	5.50	21.50	16.00	0	0.00	-0.07	0.00%	200	10,200
07/20	07/22	16.00	0	0.00	07/21	5.58	21.25	15.67	0	0.00	0.00	0.00%	285	8,260
07/23	07/25	15.42	0	0.00	07/24	5.50	21.83	16.33	0	0.00	0.00	0.00%	170	9,670
07/26	07/28	16.58	0	0.00	07/27	5.75	21.33	15.58	0	0.00	0.00	0.00%	120	9,540
Season Total		308.48	377	1.22				313.67	56	0.18	-1.04	14.61%		
Season Avg											-1.26	14.67%	165	13,500
Median											-0.59	4.42%	165	13,400

Note: Night catches = 0 (shaded) are not included in the analysis.

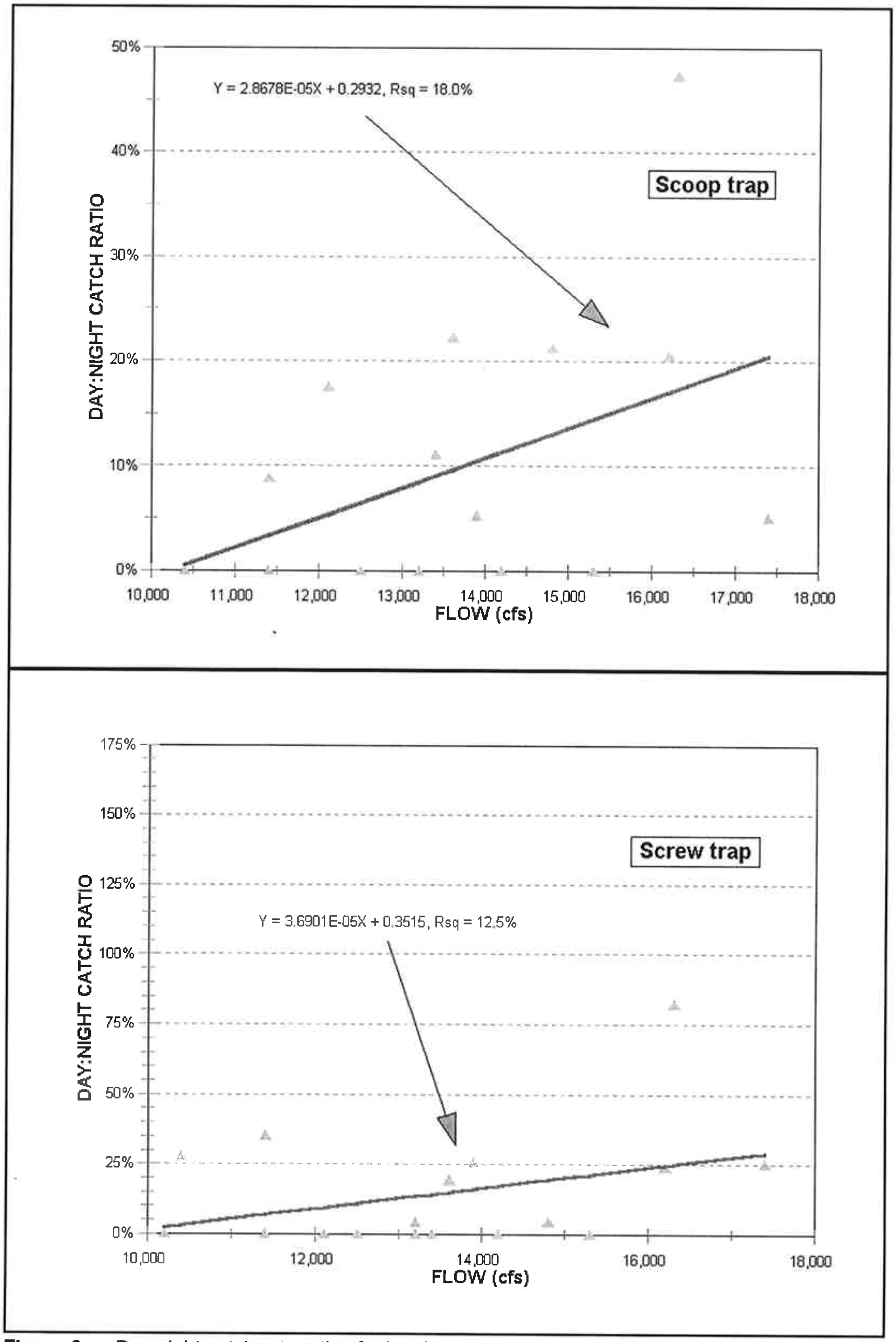
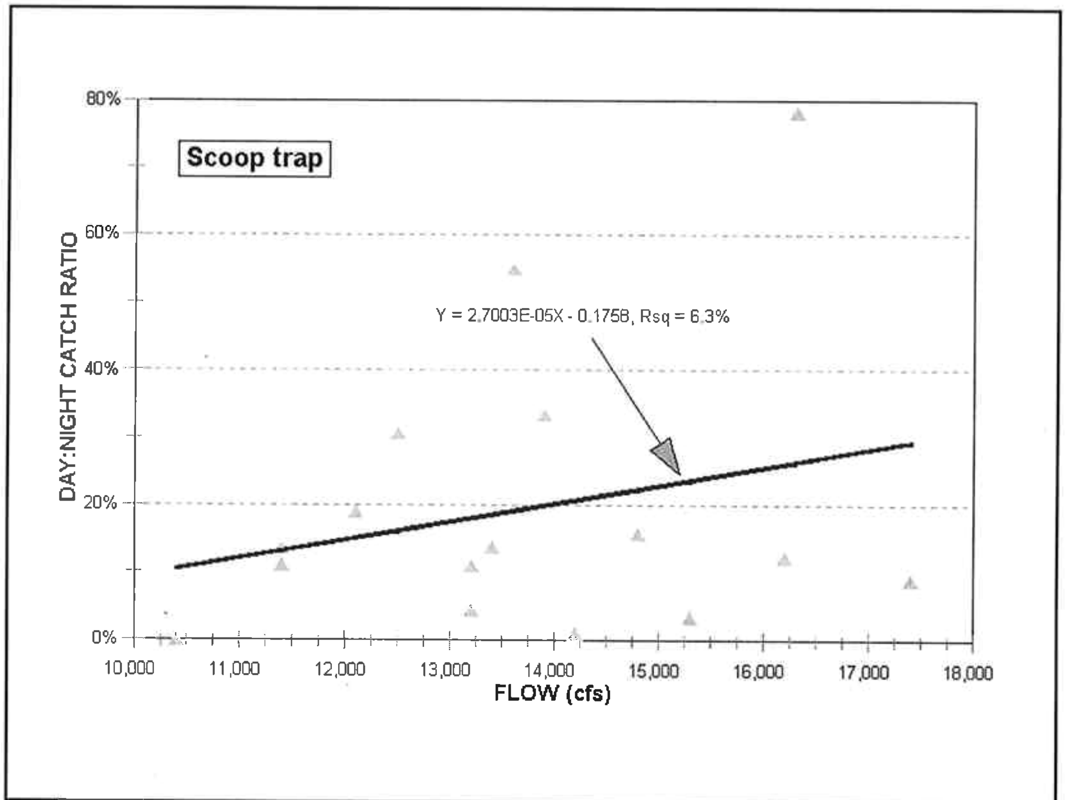


Figure 6a. Day:night catch rate ratios for hatchery 0+ chinook and daily mean flow, Skagit River mainstem traps, 2001.



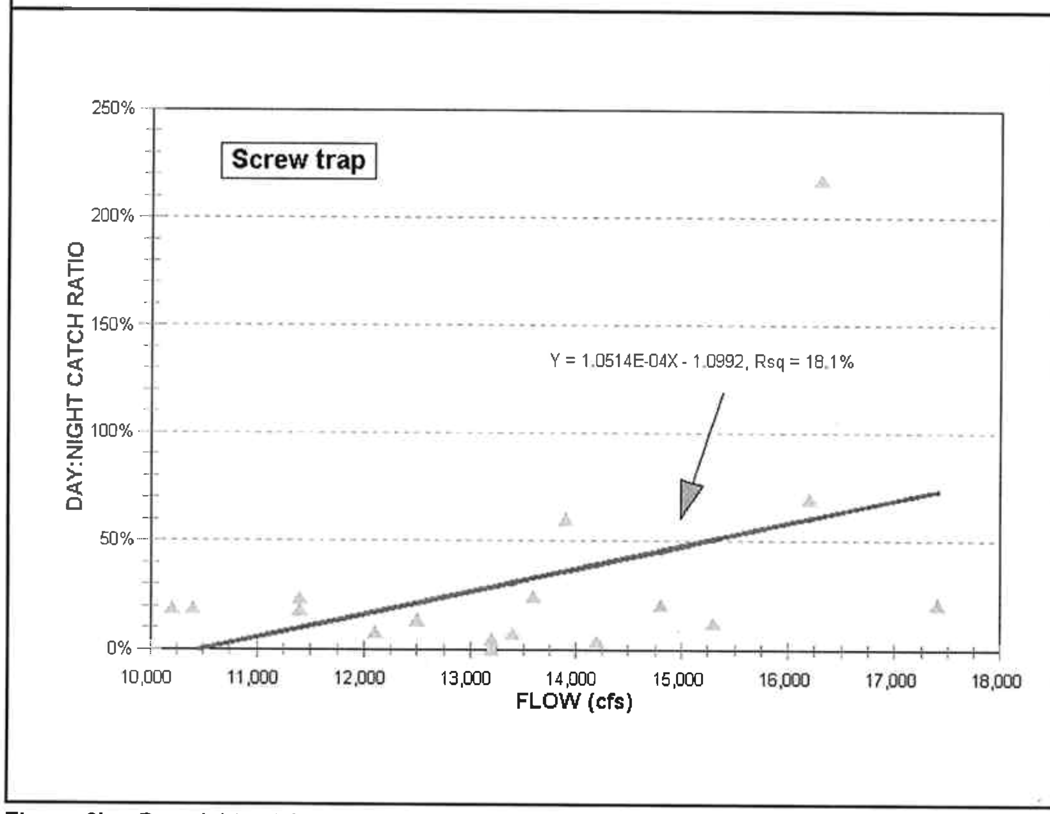


Figure 6b. Day:night catch rate ratios for wild 0+ chinook and daily mean flow , during the hatchery 0+ chinook migration period (May through July), Skagit River mainstem traps, 2001.

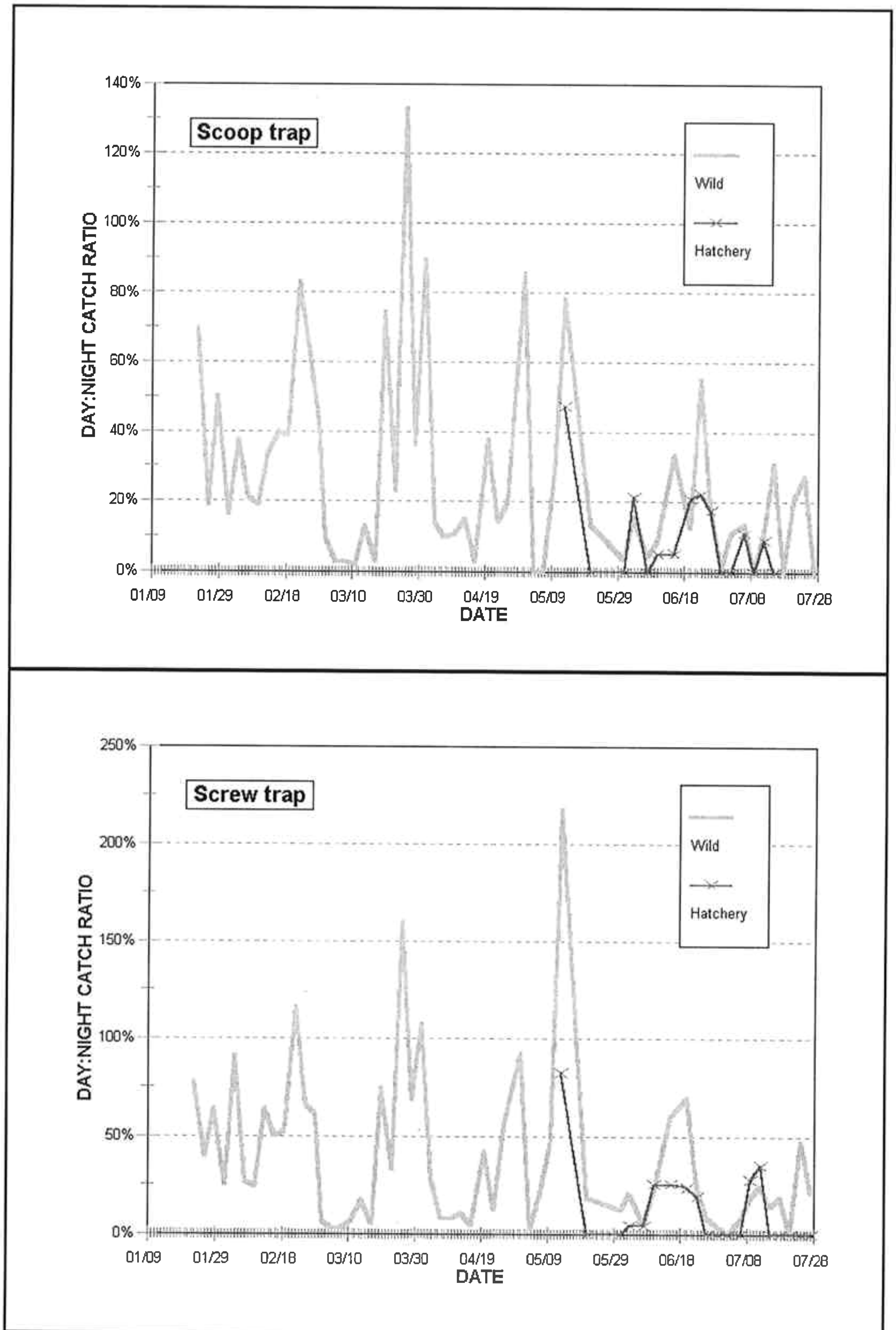


Figure 7. Comparison of day:night catch rate ratios for wild and hatchery 0+ chinook, Skagit River mainstem traps, 2001.

Table 5a. Catch/hour rates of wild coho smolts during day and night periods, Skagit River scoop trap, 2001.

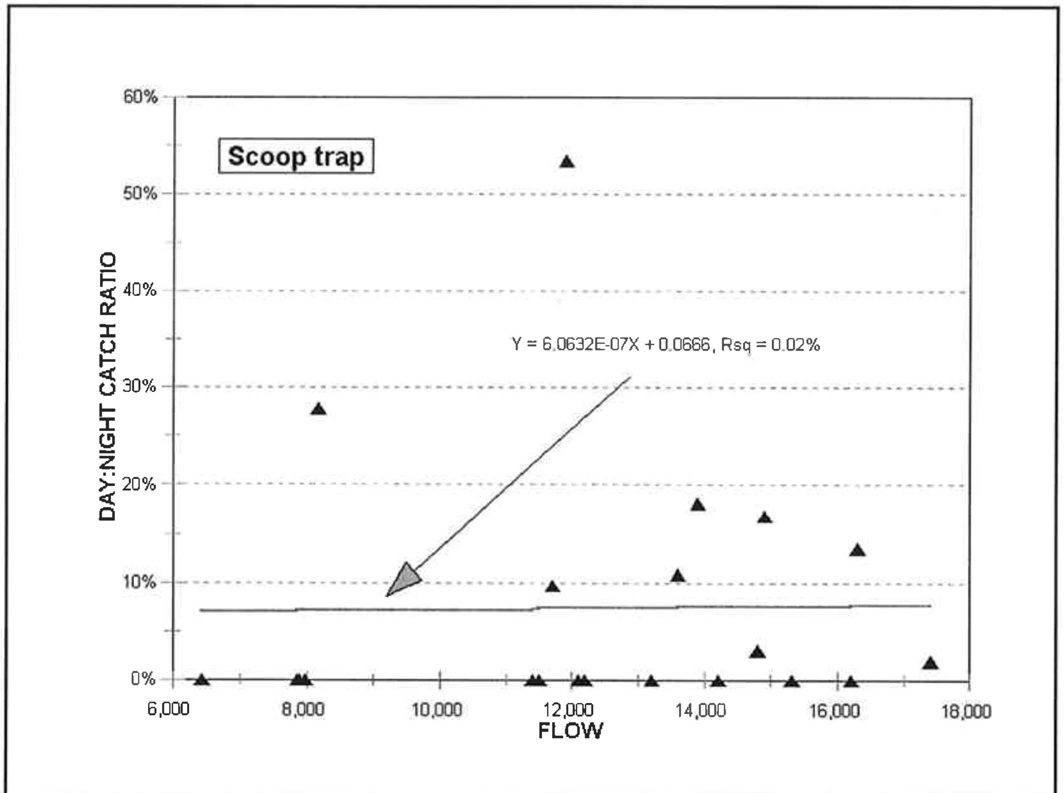
NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates		Hours	Catch	Catch/	Date	Time		Hours	Catch	Catch/	Diff	Ratio	Secchi	Flow
Begin	End	Fished		Hour		Begin	End	Fished		Hour	(D-N)	(D/N)	(cm)	(cfs)
01/22	01/24	30.42	0	0.00	01/23	8.33	17.25	8.92	0	0.00	0.00	0.00%	90	9,070
01/25	01/27	30.08	0	0.00	01/26	8.67	17.25	8.58	0	0.00	0.00	0.00%	195	8,780
01/28	01/30	28.83	0	0.00	01/29	8.67	17.50	8.83	0	0.00	0.00	0.00%	228	9,010
01/31	02/02	28.42	1	0.04	02/01	8.67	17.67	9.00	0	0.00	-0.04	0.00%	185	9,400
02/03	02/05	27.83	0	0.00	02/04	8.67	17.50	8.83	0	0.00	0.00	0.00%	165	9,550
02/06	02/08	28.50	0	0.00	02/07	8.33	18.00	9.67	0	0.00	0.00	0.00%	165	9,420
02/09	02/11	28.75	0	0.00	02/10	8.17	17.58	9.42	0	0.00	0.00	0.00%	230	8,950
02/12	02/14	28.58	0	0.00	02/13	8.67	17.75	9.08	0	0.00	0.00	0.00%	170	8,680
02/15	02/17	27.50	0	0.00	02/16	8.33	18.00	9.67	0	0.00	0.00	0.00%	105	8,620
02/18	02/20	27.33	0	0.00	02/19	8.25	18.00	9.75	0	0.00	0.00	0.00%	95	8,560
02/21	02/23	27.17	0	0.00	02/22	8.17	18.33	10.17	0	0.00	0.00	0.00%	85	8,350
02/24	02/26	27.42	2	0.07	02/25	8.25	18.17	9.92	0	0.00	-0.07	0.00%	70	7,480
02/27	03/01	26.67	0	0.00	02/28	7.17	18.17	11.00	0	0.00	0.00	0.00%	125	6,290
03/01	03/04	26.67	0	0.00	03/02	8.17	18.17	10.00	0	0.00	0.00	0.00%	295	5,940
03/04	03/06	27.17	0	0.00	03/05	8.50	18.00	9.50	0	0.00	0.00	0.00%	325	5,629
03/07	03/09	25.83	0	0.00	03/08	8.17	18.50	10.33	0	0.00	0.00	0.00%	340	6,490
03/10	03/12	25.00	1	0.04	03/11	8.00	18.75	10.75	0	0.00	-0.04	0.00%	270	6,580
03/13	03/15	26.58	0	0.00	03/14	9.75	18.75	9.00	0	0.00	0.00	0.00%	260	7,100
03/16	03/18	24.00	2	0.08	03/17	7.00	18.50	11.50	0	0.00	-0.08	0.00%	190	7,060
03/19	03/21	21.00	9	0.43	03/20	6.33	20.00	13.67	0	0.00	-0.43	0.00%	60	12,500
03/22	03/24	23.75	7	0.29	03/23	7.00	18.75	11.75	0	0.00	-0.29	0.00%	250	8,020
03/25	03/27	22.42	2	0.09	03/26	7.00	18.67	11.67	0	0.00	-0.09	0.00%	185	10,200
03/28	03/30	23.00	13	0.57	03/29	6.58	18.50	11.92	0	0.00	-0.57	0.00%	120	9,400
03/31	04/02	23.08	14	0.61	04/01	9.50	18.75	9.25	3	0.32	-0.28	53.47%		11,900
04/03	04/05	21.33	6	0.28	04/04	7.25	20.00	12.75	1	0.08	-0.20	27.89%	245	8,169
04/06	04/08	20.92	8	0.38	04/07	7.50	20.50	13.00	0	0.00	-0.38	0.00%	175	7,890
04/09	04/11	20.25	0	0.00	04/10	7.25	20.50	13.25	0	0.00	0.00	0.00%	300	7,060
04/12	04/14	20.58	0	0.00	04/13	6.67	20.25	13.58	0	0.00	0.00	0.00%	300	6,810
04/15	04/17	19.50	2	0.10	04/16	6.75	20.50	13.75	0	0.00	-0.10	0.00%	295	6,430
04/19	04/21	19.75	3	0.15	04/20	6.75	21.00	14.25	0	0.00	-0.15	0.00%	275	7,860
04/22	04/24	19.42	6	0.31	04/23	6.50	20.00	13.50	0	0.00	-0.31	0.00%	290	7,960
04/25	04/27	19.75	6	0.30	04/26	6.50	19.50	13.00	0	0.00	-0.30	0.00%	135	12,100
04/30	05/02	15.92	157	9.86	05/01	5.50	20.50	15.00	25	1.67	-8.20	16.90%	96	14,900
05/03	05/05	17.75	128	7.21	05/04	6.00	20.25	14.25	0	0.00	-7.21	0.00%	170	11,500
05/06	05/08	17.33	24	1.38	05/07	6.00	20.83	14.83	2	0.13	-1.25	9.74%	175	11,700
05/09	05/11	18.25	84	4.60	05/10	5.75	21.00	15.25	0	0.00	-4.60	0.00%		12,200
05/12	05/14	17.17	350	20.39	05/13	6.00	20.50	14.50	40	2.76	-17.63	13.53%		16,300
05/20	05/22	15.50	29	1.87	05/21	5.75	21.50	15.75	0	0.00	-1.87	0.00%	220	11,400
05/30	06/01	13.83	41	2.96	05/31	6.25	21.00	14.75	0	0.00	-2.96	0.00%	110	15,300
06/02	06/04	15.33	62	4.04	06/03	5.25	21.25	16.00	2	0.13	-3.92	3.09%	100	14,800
06/06	06/08	15.00	9	0.60	06/07	5.83	21.25	15.42	0	0.00	-0.60	0.00%	222	13,200
06/09	06/11	14.83	47	3.17	06/10	5.42	21.50	16.08	1	0.06	-3.11	1.96%	115	17,400
06/14	06/16	14.83	5	0.34	06/15	5.50	21.83	16.33	1	0.06	-0.28	18.16%	210	13,900
06/19	06/21	16.58	8	0.48	06/20	5.50	21.58	16.08	0	0.00	-0.48	0.00%	240	16,200
06/22	06/24	14.50	8	0.55	06/23	5.17	21.78	16.62	1	0.06	-0.49	10.91%	115	13,600
06/25	06/27	13.83	0	0.00	06/26	4.83	21.67	16.83	0	0.00	0.00	0.00%	235	12,100
06/28	06/30	14.45	2	0.14	06/29	5.17	21.58	16.42	0	0.00	-0.14	0.00%	240	14,199
07/01	07/03	15.33	0	0.00	07/02	6.00	21.50	15.50	0	0.00	0.00	0.00%	180	13,200
07/05	07/07	14.67	2	0.14	07/06	5.25	21.75	16.50	0	0.00	-0.14	0.00%	80	13,400
07/08	07/10	15.33	0	0.00	07/09	5.50	21.67	16.17	0	0.00	0.00	0.00%	150	10,400
07/11	07/13	14.58	0	0.00	07/12	5.42	21.75	16.33	0	0.00	0.00	0.00%	100	11,400
07/14	07/16	15.67	0	0.00	07/15	5.58	21.25	15.67	0	0.00	0.00	0.00%	125	12,500
07/17	07/19	15.00	0	0.00	07/18	5.58	21.58	16.00	0	0.00	0.00	0.00%	200	10,200
07/20	07/22	16.00	0	0.00	07/21	5.67	21.33	15.67	0	0.00	0.00	0.00%	285	8,260
07/23	07/25	15.67	0	0.00	07/24	5.58	21.92	16.33	0	0.00	0.00	0.00%	170	9,670
07/26	07/28	15.83	0	0.00	07/27	6.00	21.50	15.50	0	0.00	0.00	0.00%	120	9,540
Season Total		1,170.70	1,038	0.89				727.03	76	0.10	-0.78	11.79%	186	10,259
Migr-Period		365.03	999	2.74				306.78	76	0.25	-2.49	9.05%		
Average (Period-only)											-2.59	7.41%	190	12,329
Median (Period-only)											-0.49	0.00%	193	12,200

Note: Only the non-zero night catch of the coho migration period (April through June, shaded) was used in the analysis.

Table 5b. Catch/hour rates of wild coho smolts during day and night periods, Skagit River screw trap, 2001.

NIGHTTIME					DAYTIME						DAY:NIGHT			
Dates		Hours	Catch	Catch/	Date	Time		Hours	Catch	Catch/	Diff	Ratio	Secchi	Flow
Begin	End	Fished		Hour		Begin	End	Fished		Hour	(D-N)	(D/N)	(Cm)	(Cfs)
01/22	01/24	30.50	0	0.00	01/23	8.50	17.50	9.00	0	0.00	0.00	0.00%	90	9,070
01/25	01/27	30.25	0	0.00	01/26	8.50	17.25	8.75	0	0.00	0.00	0.00%	195	8,780
01/28	01/30	29.00	0	0.00	01/29	8.50	17.50	9.00	0	0.00	0.00	0.00%	228	9,010
01/31	02/02	28.75	0	0.00	02/01	8.50	17.50	9.00	0	0.00	0.00	0.00%	185	9,400
02/03	02/05	27.83	1	0.04	02/04	8.75	17.67	8.92	0	0.00	-0.04	0.00%	165	9,550
02/06	02/08	28.58	1	0.03	02/07	8.17	18.00	9.83	0	0.00	-0.03	0.00%	165	9,420
02/09	02/11	28.92	3	0.10	02/10	8.08	17.67	9.58	0	0.00	-0.10	0.00%	230	8,950
02/12	02/14	28.50	1	0.04	02/13	9.00	18.00	9.00	0	0.00	-0.04	0.00%	170	8,680
02/15	02/17	27.50	0	0.00	02/16	8.17	18.00	9.83	0	0.00	0.00	0.00%	105	8,620
02/18	02/20	27.42	0	0.00	02/19	8.00	18.00	10.00	0	0.00	0.00	0.00%	95	8,560
02/21	02/23	27.67	1	0.04	02/22	8.25	18.17	9.92	0	0.00	-0.04	0.00%	85	8,350
02/24	02/26	27.42	0	0.00	02/25	8.25	18.25	10.00	0	0.00	0.00	0.00%	70	7,480
02/27	03/01	26.58	0	0.00	02/28	7.25	18.33	11.08	0	0.00	0.00	0.00%	125	6,290
03/01	03/03	27.00	0	0.00	03/02	8.33	18.00	9.67	0	0.00	0.00	0.00%	295	5,940
03/04	03/06	26.83	0	0.00	03/05	8.00	18.17	10.17	0	0.00	0.00	0.00%	325	5,629
03/07	03/09	25.50	0	0.00	03/08	7.50	18.50	11.00	0	0.00	0.00	0.00%	340	6,490
03/10	03/12	25.00	1	0.04	03/11	8.00	18.75	10.75	0	0.00	-0.04	0.00%	270	6,580
03/13	03/15	24.98	0	0.00	03/14	7.50	18.50	11.00	0	0.00	0.00	0.00%	260	7,100
03/16	03/18	24.00	1	0.04	03/17	7.00	18.50	11.50	0	0.00	-0.04	0.00%	190	7,060
03/19	03/21	24.00	21	0.88	03/20	6.25	18.25	12.00	3	0.25	-0.63	28.57%	60	12,500
03/22	03/24	23.83	6	0.25	03/23	7.00	18.75	11.75	0	0.00	-0.25	0.00%	250	8,020
03/25	03/27	23.50	8	0.34	03/26	7.00	18.75	11.75	0	0.00	-0.34	0.00%	185	10,200
03/28	03/30	22.92	11	0.48	03/29	6.50	18.67	12.17	1	0.08	-0.40	17.12%	120	9,400
03/31	04/02	19.25	11	0.57	04/01	7.50	20.50	13.00	0	0.00	-0.57	0.00%		11,900
04/03	04/05	22.00	6	0.27	04/04	7.17	20.00	12.83	0	0.00	-0.27	0.00%	245	8,169
04/06	04/08	21.92	3	0.14	04/07	7.50	19.50	12.00	0	0.00	-0.14	0.00%	175	7,890
04/09	04/11	20.25	0	0.00	04/10	7.25	20.50	13.25	0	0.00	0.00	0.00%	300	7,060
04/12	04/14	20.25	2	0.10	04/13	6.75	20.33	13.58	0	0.00	-0.10	0.00%	300	6,810
04/15	04/17	19.50	0	0.00	04/16	6.75	20.50	13.75	0	0.00	0.00	0.00%	295	6,430
04/19	04/21	20.25	1	0.05	04/20	6.75	20.75	14.00	1	0.07	0.02	144.64%	275	7,860
04/22	04/24	19.67	7	0.36	04/23	6.50	20.25	13.75	0	0.00	-0.36	0.00%	290	7,960
04/25	04/27	19.58	23	1.17	04/26	6.67	20.00	13.33	0	0.00	-1.17	0.00%	135	12,100
05/01	05/02	16.25	418	25.72	05/01	5.50	20.50	15.00	23	1.53	-24.19	5.96%	96	14,900
05/03	05/05	18.00	205	11.39	05/04	6.00	20.00	14.00	1	0.07	-11.32	0.63%	170	11,500
05/06	05/08	17.58	69	3.92	05/07	6.33	21.00	14.67	2	0.14	-3.79	3.47%	175	11,700
05/09	05/11	18.00	143	7.94	05/10	5.83	21.08	15.25	1	0.07	-7.88	0.83%		12,200
05/12	05/14	17.33	467	26.94	05/13	10.50	21.00	10.50	176	16.76	-10.18	62.21%		16,300
05/20	05/22	15.83	84	5.31	05/21	5.83	21.42	15.58	3	0.19	-5.11	3.63%	220	11,400
05/30	06/01	14.50	46	3.17	05/31	6.50	21.50	15.00	0	0.00	-3.17	0.00%	110	15,300
06/02	06/04	15.25	106	6.95	06/03	5.50	21.33	15.83	7	0.44	-6.51	6.36%	100	14,800
06/06	06/08	15.42	26	1.69	06/07	5.92	21.08	15.17	2	0.13	-1.55	7.82%	222	13,200
06/09	06/11	15.00	59	3.93	06/10	5.75	21.67	15.92	8	0.50	-3.43	12.78%	115	17,400
06/14	06/16	15.17	19	1.25	06/15	5.67	22.00	16.33	2	0.12	-1.13	9.77%	210	13,900
06/19	06/21	16.75	9	0.54	06/20	5.42	21.50	16.08	0	0.00	-0.54	0.00%	240	16,200
06/22	06/24	14.97	7	0.47	06/23	5.33	21.67	16.33	0	0.00	-0.47	0.00%	115	13,600
06/25	06/27	14.25	5	0.35	06/26	5.17	21.67	16.50	0	0.00	-0.35	0.00%	235	12,100
06/28	06/30	14.85	0	0.00	06/29	5.33	21.75	16.42	0	0.00	0.00	0.00%	240	14,199
07/01	07/03	15.75	0	0.00	07/02	6.00	21.58	15.58	0	0.00	0.00	0.00%	180	13,200
07/05	07/07	15.08	1	0.07	07/06	5.58	21.67	16.08	0	0.00	-0.07	0.00%	80	13,400
07/08	07/10	15.58	0	0.00	07/09	5.50	21.50	16.00	0	0.00	0.00	0.00%	150	10,400
07/11	07/13	14.58	0	0.00	07/12	5.33	21.92	16.58	0	0.00	0.00	0.00%	100	11,400
07/14	07/16	15.00	1	0.07	07/15	5.33	21.50	16.17	0	0.00	-0.07	0.00%	125	12,500
07/17	07/19	15.17	1	0.07	07/18	5.50	21.50	16.00	0	0.00	-0.07	0.00%	200	10,200
07/20	07/22	16.00	0	0.00	07/21	5.58	21.25	15.67	0	0.00	0.00	0.00%	285	8,260
07/23	07/25	15.42	0	0.00	07/24	5.50	21.83	16.33	0	0.00	0.00	0.00%	170	9,670
07/26	07/28	16.58	0	0.00	07/27	5.75	21.33	15.58	0	0.00	0.00	0.00%	120	9,540
Season Total		1,177.47	1,774	1.51				727.75	230	0.32	-1.19	20.98%	186	10,259
Migr-Period		347.97	1,705	4.90				291.67	226	0.77	-4.13	15.81%		
Average (Period-only)											-4.08	12.91%	190	12,264
Median (Period-only)											-1.36	0.73%	193	12,150

Note: Only the non-zero night catch of the coho migration period (April through June, shaded) was used in the analysis.



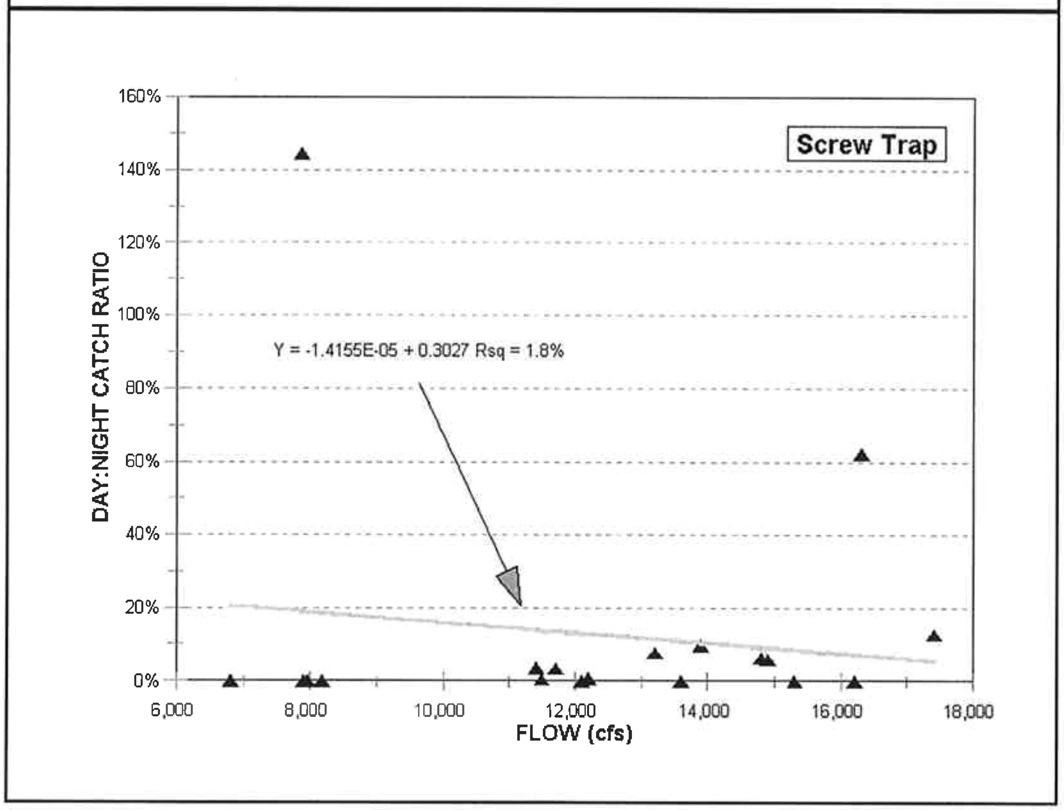


Figure 8. Day:night catch ratios for wild coho smolts during the migration period (April through June), Skagit River mainstem traps, 2001.

Visibility

Over the season, secchi disk values ranged from 45 to 340 cm. Day-to-day variation rarely exceeded a factor of two. Monthly averages ranged from a low of 138 cm in February to a high of 231 cm in March (**Table 6**). Over the season, flow explained only 26% of the daily variation in visibility (**Figure 9**). However, when compared monthly, flow correlation values ranged from a low of 21% (July) to a high of 73% (May) (**Table 6**).

Table 6. Summary of flow (USGS) and visibility data measured at the Skagit River mainstem traps at Mt. Vernon, 2001.

Interval	FLOW (cfs)			VISIBILITY (cm)				R^2
	Min	Max	Avg	N	Min	Max	Avg	
January	7,910	19,300	9,644	11	90	300	208	26.6%
February	5,750	10,200	8,314	26	70	230	138	29.0%
March	5,540	13,400	7,867	31	50	340	231	58.2%
April	6,340	16,500	9,103	27	65	310	223	71.4%
May	11,300	26,300	15,703	21	45	225	139	72.5%
June	10,600	20,400	14,830	29	95	240	180	24.1%
July	8,200	14,600	11,190	28	80	285	160	21.1%
All	5,629	26,300	11,062	173	45	340	183	26.4%

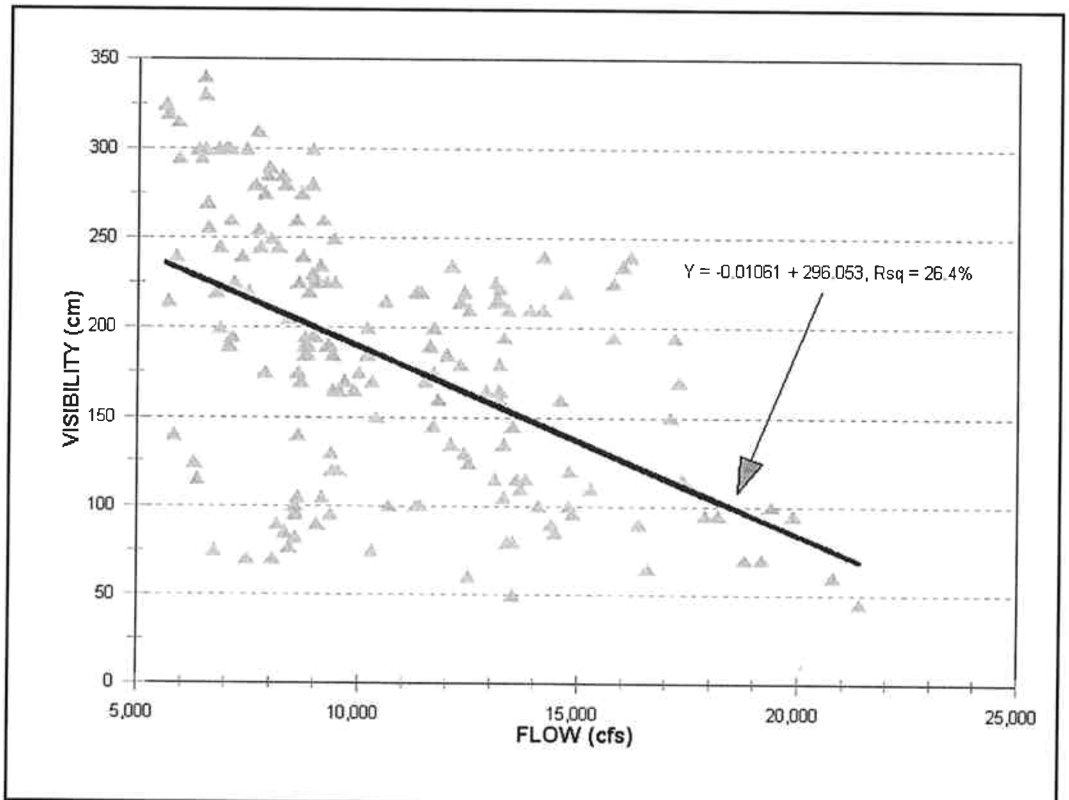


Figure 9. Visibility correlated with flow, Skagit River near Mt Vernon, 2001.

We correlated day:night catch ratios for wild 0+ chinook with the daily visibility data through June, and found that daytime migration rates were significantly correlated with visibility (**Figure 5**). This finding is consistent with correlations of d:n ratios and visibility in previous years. Visibility data explained 27% of the variation through June, and 18% over the entire season, in the wild chinook d:n ratios for both the scoop and screw traps, a stronger relationship than with flow.

We also compared average daily turbidity data recorded at the City of Mt. Vernon, Anacortes Water Treatment Plant. These readings agreed with the secchi readings taken daily at the traps, although not perfectly ($R^2 = 63\%$). Our secchi data represents one value at a specific point in time, rather than a composite over a 24-hour period.

Wild Coho Smolt Production Evaluation

In Spring 1999, we initiated a new marking procedure, that incorporated two different marks: one to identify coho smolts from the upper basin tributaries (left ventral-mark), and another (right ventral-mark) to indentify fish from Mannser Creek, in the lower basin. In 1999, only 0.34% of the left ventral-mark (LV-mark) group was captured, compared to 1.24% of the right-ventral (RV-mark) group, a four-fold difference. During Spring 2000, we recovered 1.8% of the coho smolts marked at the lower tributary (RV-marks), and 0.9% of the upper tributary LV-marks, a two-fold difference. Although this discrepancy was only half that observed in 1999, these rates indicate a substantial difference between the release groups. While we expect some mortality occurs between marking at the tributary traps and passing the mainstem traps, we doubt that in-river mortality on wild coho smolts is as high as 50%-75%.

In Spring 2001, we stopped marking smolts from upper basin tributaries, given the low recovery rates observed in 1999 and 2000. Smolts that were RV-marked at Mannser Creek, provided the basis for the coho smolt estimate. Relating the season catch of 47 RV-marked smolts from Mannser Creek to the total catch of 6,935 wild smolts estimates the mark incidence at 0.7%. Application of this rate to the 7,013 smolts marked and released at Mannser Creek estimates system production at 1,013,523 wild coho smolts (**Table 7**).

Capture Rate Indicators

Wild Coho Smolts

Projecting catches of right ventral-marked (RV) wild coho smolts to continuous 24-hour trapping on the basis of day:night catch ratios using the season median rate for the scoop and screw traps, estimates that we would have caught 7 and 13 additional marked coho (67 total projected RV-marked smolts) in the scoop and screw traps, respectively. Relating this total projected RV-marked catch to the 7,013 RV-marked smolts released from the Mannser Creek trap, estimates combined scoop and screw trap capture rates for the season at 1%. This estimate assumes that all of the RV-marked wild coho smolts survived and passed the mainstem traps during the season. This is the lowest coho recapture rate we have documented at the Skagit River. We believe that the extreme low flows through most of April contributed to decreased trapping efficiency in Spring 2001.

Table 7. Estimation of wild coho smolt production, Skagit River, 2001.		
	Number	**Formula**
Total mainstem trap catches	7,436	
Skagit Hatchery/ Lake Shannon[a]	-501	
Wild coho captured (c)	**6,935**	$N = \frac{(m+1)(c+1)}{(r+1)}$
RVs recaptured (r)	47	
RVs released (m)	7,013	
Total production (N)	**1,013,523**	
Variance (Var)	2.07e+10	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)}$
Standard deviation (sd)	143,793	
Coefficient of Var (CV)	14.19%	$CV = sd \div N$
Confidence interval (CI)	281,833	$CI = \pm 1.96(sd)$
Estimated coho smolt production	1,013,523	
Upper CI (95%)	1,295,356	
Lower CI (95%)	731,690	

[a] Hatchery ad-marked and unmarked smolt total from counts obtained by visual identification at trapping.

Fin-marked Hatchery 0+ Chinook

We released four groups of hatchery chinook (10,176 total) with three different fin-mark types (adipose fin-clip only, ad/upper caudal-clip, and ad/lower caudal-clip) on four different evenings, May 9, May 30, June 6 and June 19. Recoveries of the four calibration groups occurred primarily on the first night after the releases, but extended over two to three-day periods. We operated the traps continuously, both day and night, over 36 hours after each release. Recapture rates for the calibration groups ranged from 1.1% to 2.7%, and averaged 1.9% (**Table 8**).

Table 8. Overall recapture rates and proportion of total recoveries during the first 24-hours after release of four fin-marked hatchery 0+ chinook calibration groups, Skagit River mainstem traps, 2001.

Mark Group	Release			Number Recaptured						Recap Rate	% First 24-hrs
				First 24-hours			Total				
	Date	Number	Avg Daily Flow	Scoop	Screw	Total	Scoop	Screw	Total		
Ad-CWT	May 09	2,600	12,100	30	22	52	31	23	54	2.1%	96%
Ad-CWT/UC	May 30	2,567	16,500	14	10	24	14	13	27	1.1%	89%
Ad-CWT/LC	June 06	2,495	12,000	22	25	47	22	25	47	1.9%	100%
Ad-CWT/UC	June 19	2,514	13,100	28	39	67	29	39	68	2.7%	99%
Total		10,176		94	96	190	96	100	196	1.9%	

Hatchery 0+ Chinook Production Groups

Over the season, we caught a total of 3,020 adipose fin-marked (ad-marked) hatchery 0+ chinook in the mainstem traps, 1,667 in the scoop trap and 1,353 in the screw trap. These totals do not include recoveries from the four calibration groups that we released on May 9, May 30, June 6 and June 19.

Three releases of ad-marked and coded-wire tagged (ad-CWT) hatchery chinook fingerlings occurred in Spring 2001 (**Table 9, Figure 1**):

- May 12, the volitional release of 162,132 fall chinook from Red Creek Hatchery (R.M. 24);
- May 13 the release of 206,257 summer chinook from Countyline Ponds (R.M. 89); and
- June 4, 270,079 spring chinook released from the Skagit Hatchery (R.M. 78).

Estimating our catch of these release groups required recovering tags. On May 12, we began sampling hatchery smolts for tag recovery. Over the season, we sacrificed 556 ad-marked chinook and recovered 551 tags, which we used to estimate the proportions of Countyline Ponds summers, Skagit Hatchery springs, and Red Creek fall chinook in our total hatchery catch. (**Table 10**).

Applying daily tag recovery results to the sum of actual and projected catches of hatchery chinook estimates 1,985 Red Creek Hatchery fall 0+ chinook , 991 Countyline Ponds summer 0+ chinook and 1,389 Skagit Hatchery spring 0+ chinook (**Table 11**). Relating these projected catches to respective numbers released, yields capture rates of 1.2% for falls and 0.5% for summers and springs. As these rates are simply the ratio of estimated recoveries to estimated release, they are biased low by mortality and residualism.

Table 9. Various groups of marked salmon smolts released into the Skagit River and numbers recovered at the mainstem traps, 2001.

Group	Stock	Species/ Age	Mark Type	RELEASE		Recapture Dates	ACTUAL CATCH			CAPTURE RATE		
				Date	Number		Scoop	Screw	Total	Scoop	Screw	Total
	Wild	Coho 1+	RV	March-June	7,013	May - June	20	27	47	0.3%	0.4%	0.7%
	Hatchery	Coho 1+	Ad-CWT	May 21, 2001	251,900	May 23 - July 5	103	389	492	0.0%	0.2%	0.2%
Calibration Groups	Hatchery/spring	Chinook 0+	Ad-cwt[a]	May 09, 2001	2,600	May 09 - 12	31	23	54	1.2%	0.9%	2.1%
Calibration Groups	Hatchery/spring	Chinook 0+	Ad-UC[a]	May 30, 2001	2,567	May 30 - June 2	14	13	27	0.5%	0.5%	1.1%
Calibration Groups	Hatchery/spring	Chinook 0+	Ad-LC[a]	June 06, 2001	2,495	June 06 - 10	22	25	47	0.9%	1.0%	1.9%
Calibration Groups	Hatchery/spring	Chinook 0+	Ad-UC[a]	June 19, 2001	2,514	June 19	29	39	68	1.2%	1.6%	2.7%
Hatchery Releases	Red Creek Hatchery/ fall	Chinook 0+	Ad-CWT	May 12, 2001	162,132	May 12 - July 10	n/a	n/a	1,363	n/a	n/a	0.8%
Hatchery Releases	Countyline Ponds/ summer	Chinook 0+	Ad-CWT	May 13-20, 2001	206,257	May 13 - July 12	n/a	n/a	605	n/a	n/a	0.3%
Hatchery Releases	Skagit Hatchery/spring	Chinook 0+	Ad-CWT	June 04, 2001	270,079	June 7 - July 19	n/a	n/a	1,052	n/a	n/a	0.4%
	Hatchery/spring	Chinook 1+	Ad-CWT	March 06-13, 2000	291,540	April 25 - May 15	26	50	76	0.0%	0.0%	0.0%

[a] Mark groups used for trap efficiency tests; not included in hatchery migration estimate.

Table 10. Breakdown of CWT recoveries from ad-marked chinook sacrificed at the Skagit River mainstem traps, 2001.

Date	NUMBER SAMPLED[a]			RESULTS		Marblemount - springs				Red Cr - falls		Countyline - summers	
	Screw	Scoop	Total	No tags	Tags	63-07/68	63-06/66	Total	Percent	21-29/50	Percent	21-01/68	Percent
05/23/01	29	29	58	0	58	0	0	0	0.0%	36	62.1%	22	37.9%
05/24/01	11	21	32	0	32	0	0	0	0.0%	24	75.0%	8	25.0%
05/25/01	3	7	10	0	10	0	0	0	0.0%	4	40.0%	6	60.0%
05/26/01	11	9	20	0	20	0	0	0	0.0%	3	15.0%	17	85.0%
05/27/01	6	7	13	1	12	0	0	0	0.0%	4	33.3%	8	66.7%
05/28/01	5	5	10	1	9	0	0	0	0.0%	1	11.1%	8	88.9%
05/29/01	24	37	61	1	60	0	0	0	0.0%	59	98.3%	1	1.7%
05/30/01	21	49	70	1	69	0	0	0	0.0%	64	92.8%	5	7.2%
05/31/01	5	8	13	0	13	0	0	0	0.0%	8	61.5%	5	38.5%
06/01/01	0	2	2	0	2	0	0	0	0.0%	1	50.0%	1	50.0%
06/02/01	15	3	18	0	18	0	0	0	0.0%	16	88.9%	2	11.1%
06/03/01	1	7	8	0	8	0	0	0	0.0%	6	75.0%	2	25.0%
06/04/01	0	3	3	0	3	0	0	0	0.0%	2	66.7%	1	33.3%
06/05/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
06/06/01	1	0	1	0	1	0	0	0	0.0%	0	0.0%	1	100.0%
06/07/01	2	2	4	0	4	0	2	2	50.0%	2	50.0%	0	0.0%
06/08/01	2	1	3	0	3	0	2	2	66.7%	0	0.0%	1	33.3%
06/09/01	3	2	5	0	5	1	4	5	100.0%	0	0.0%	0	0.0%
06/10/01	15	16	31	0	31	1	28	29	93.5%	0	0.0%	2	6.5%
06/11/01	10	15	25	0	25	0	25	25	100.0%	0	0.0%	0	0.0%
06/12/01	15	12	27	0	27	2	22	24	88.9%	2	7.4%	1	3.7%
06/13/01	13	14	27	0	27	0	20	20	74.1%	3	11.1%	4	14.8%
06/14/01	5	8	13	0	13	0	11	11	84.6%	0	0.0%	2	15.4%
06/15/01	3	3	6	0	6	0	4	4	66.7%	1	16.7%	1	16.7%
06/16/01	2	1	3	0	3	0	2	2	66.7%	0	0.0%	1	33.3%
06/17/01	1	1	2	0	2	0	2	2	100.0%	0	0.0%	0	0.0%
06/18/01	0	2	2	0	2	0	1	1	50.0%	0	0.0%	1	50.0%
06/19/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
06/20/01	3	1	4	0	4	1	3	4	100.0%	0	0.0%	0	0.0%
06/21/01	1	3	4	0	4	1	3	4	100.0%	0	0.0%	0	0.0%
06/22/01	6	6	12	0	12	0	10	10	83.3%	0	0.0%	2	16.7%
06/23/01	8	8	16	0	16	0	7	7	43.8%	1	6.3%	8	50.0%
06/24/01	3	2	5	0	5	1	2	3	60.0%	0	0.0%	2	40.0%
06/25/01	1	2	3	0	3	0	2	2	66.7%	0	0.0%	1	33.3%
06/26/01	1	1	2	0	2	0	1	1	50.0%	0	0.0%	1	50.0%
06/27/01	2	2	4	0	4	0	2	2	50.0%	0	0.0%	2	50.0%
06/28/01	1	2	3	0	3	0	3	3	100.0%	0	0.0%	0	0.0%
06/29/01	6	7	13	0	13	1	6	7	53.8%	1	7.7%	5	38.5%
06/30/01	1	1	2	0	2	0	0	0	0.0%	0	0.0%	2	100.0%
07/01/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/02/01	1	1	2	0	2	0	1	1	50.0%	0	0.0%	1	50.0%
07/03/01	1	1	2	0	2	0	0	0	0.0%	0	0.0%	2	100.0%
07/04/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/05/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/06/01	0	2	2	0	2	0	2	2	100.0%	0	0.0%	0	0.0%
07/07/01	0	1	1	0	1	0	1	1	100.0%	0	0.0%	0	0.0%
07/08/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/09/01	1	1	2	0	2	0	2	2	100.0%	0	0.0%	0	0.0%
07/10/01	1	1	2	0	2	0	1	1	50.0%	1	50.0%	0	0.0%
07/11/01	2	0	2	0	2	0	0	0	0.0%	0	0.0%	2	100.0%
07/12/01	0	2	2	0	2	0	1	1	50.0%	0	0.0%	1	50.0%
07/13/01	1	2	3	0	3	0	3	3	100.0%	0	0.0%	0	0.0%
07/14/01	1	0	1	0	1	0	1	1	100.0%	0	0.0%	0	0.0%
07/15/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/16/01	0	0	0	0	0	0	0	0	0.0%	0	0.0%	0	0.0%
07/17/01	1	0	1	0	1	0	1	1	100.0%	0	0.0%	0	0.0%
Total	**245**	**310**	**555[b]**	**4[c]**	**551**	**8**	**175**	**183**	**33.2%**	**239**	**43.4%**	**129**	**23.4%**

[a] Includes 4 poorly-labeled heads which were allocated by data and timing (shaded).
[b] Does not include 1 lost tag (sampled May 29).
[c] "No Tags" were not allocated.

Table 11. Projected hatchery 0+ chinook catches, by tag group, Skagit River mainstem traps, 2001.

Group/age	Tag Code	Number Released	Recovery Period	Projected 24-hr Catch[b]	Catch Rate
Red Creek Hatchery/fall	21-29/50	162,132	May 12 - July 10	1,985	1.2%
Countyline Ponds/summer	21-01/68	206,257	May 13 - July 12	991	0.5%
Marblemount Hatchery/spring (Skagit Hatchery)	Pooled[a]	270,079	June 07 - July 19	1,389	0.5%
	Total	638,468	May 12 - July 12	4,365	0.7%

[a] Tag codes 63-07/68 and 63-06/66.
[b] Estimated by applying the proportion of the tagged groups in the total hatchery catch (**Table 10**), by day, to the projected 24-hour catch.

Wild & Hatchery 0+ Chinook Production Estimates

Catch Projection

Expansion of catch rates for the intervals not fished estimate an additional 10,945 and 8,092 wild 0+ chinook would have been captured in the scoop and screw traps, respectively (**Table 12**). Combined with the actual catches (54,762 and 40,180 fry, respectively), these projections estimate that, had we fished continuously from January 15, through July 30, we would have caught 114,000 wild 0+ chinook in the two traps. Actual catches represent 83% of the total projected catches.

Expanding actual catch rates for the intervals not fished following release of the hatchery production groups, estimates an additional 1,345 0+ hatchery chinook would have been captured in the scoop and screw traps (**Table 12**). Actual catches represent 70% of the total projected hatchery catch.

Table 12. Summary of actual and projected wild and hatchery 0+ chinook catches in the Skagit River mainstem traps, 2001.

Group	Scoop Trap			Screw Trap			Total		
	Actual	Projected	Total	Actual	Projected	Total	Actual	Projected	Total
Wild	54,762	10,945	65,707	40,180	8,092	48,272	94,942	19,037	113,979
Hatchery	1,667	698	2,365	1,353	647	2,000	3,020	1,345	4,365

Production

We selected a value of 1.9% to represent season average trap efficiency. This rate is the average of the four 0+ chinook calibration groups that we released upstream of the mainstem traps in 2001 (**Table 8**). Expansion of the projected season catch in both traps by this rate yields a system production estimate of approximately 6 million zero-age chinook (**Figure 10**).
Applying this same rate to the projected hatchery catch yields a combined estimate of 230,000 0+ chinook. Relating this estimate to the 627,000 chinook released, estimates in-river mortality above Mt. Vernon at 63%.

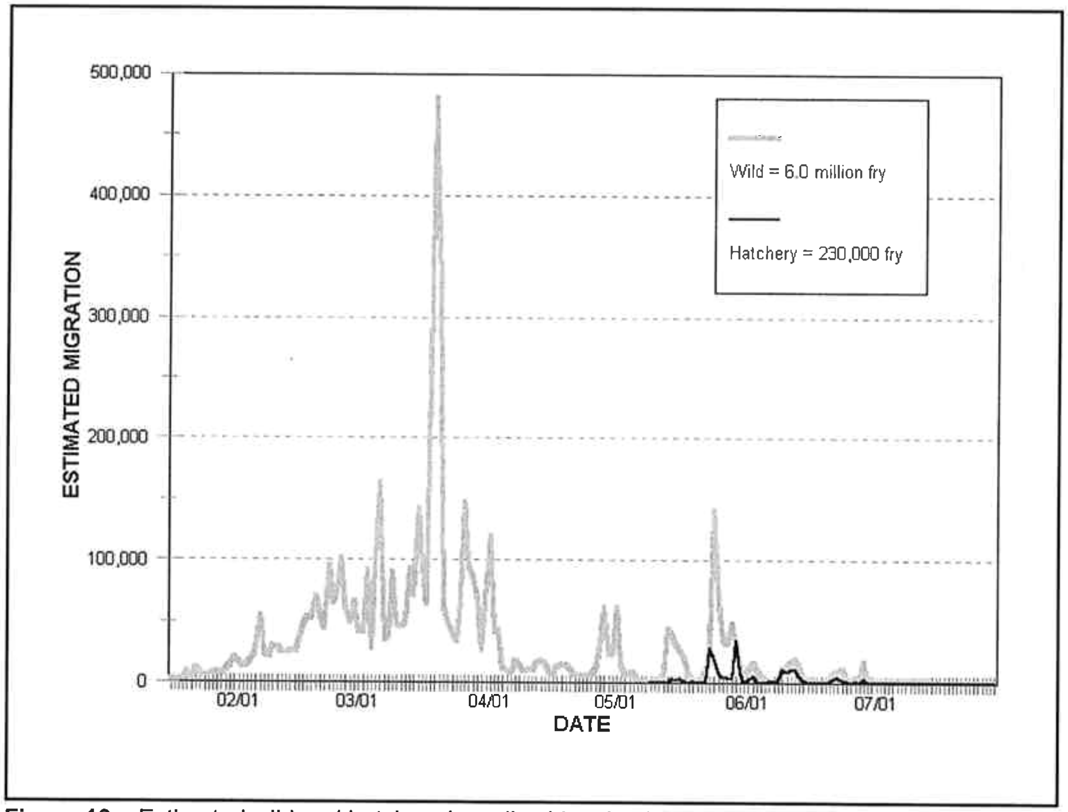


Figure 10. Estimated wild and hatchery juvenile chinook migration, Skagit River 2001.

Migration Timing

Wild 0+ chinook were caught on the first night of trap operation, indicating that the migration was under way before we began trapping. The low initial catches, however, indicated that relatively few chinook fry had passed the trap before we started. Similarly, low catches in June and July indicated the chinook migration was virtually over when trapping ceased on July 30. While catch data exhibited considerable day-to-day variation, the months of February and March accounted for 71% of the season total migration (**Figure 11**). By March 19, we estimate that 50% of the migration had passed the mainstem traps. Over the five years we have trapped throughout the entire migration (1997 through 2001), the median migration date has ranged from March 10 (1999) to May 2 (1998), and the average on March 27 (**Figure 12**).

Ad-marked hatchery 0+ spring, summer and fall chinook were released at three sites in the Skagit River basin: Skagit Hatchery, Countyline acclimation ponds, and Red Creek Hatchery, respectively (**Table 9, Figure 1**). Hatchery migrants first entered catches within hours to four days after their release (**Figure 13**). In Spring 2001, the Red Creek fall chinook, released lowest in the watershed, had a median migration timing past the traps of 18 days. Countyline summer chinook, released highest in the watershed, had a median migration timing of 12 days. These two groups were released around the same date in mid-May, and both took around 60 days to emigrate from the basin. Skagit Hatchery spring chinook, which were released about three weeks later from Marblemount Hatchery (downstream of Countyline Ponds), had a mean migration timing of 6 days, and took only 43 days to migrate from the basin. Migration timing for hatchery 0+ chinook groups is potentially influenced by size, flow, release date and release site.

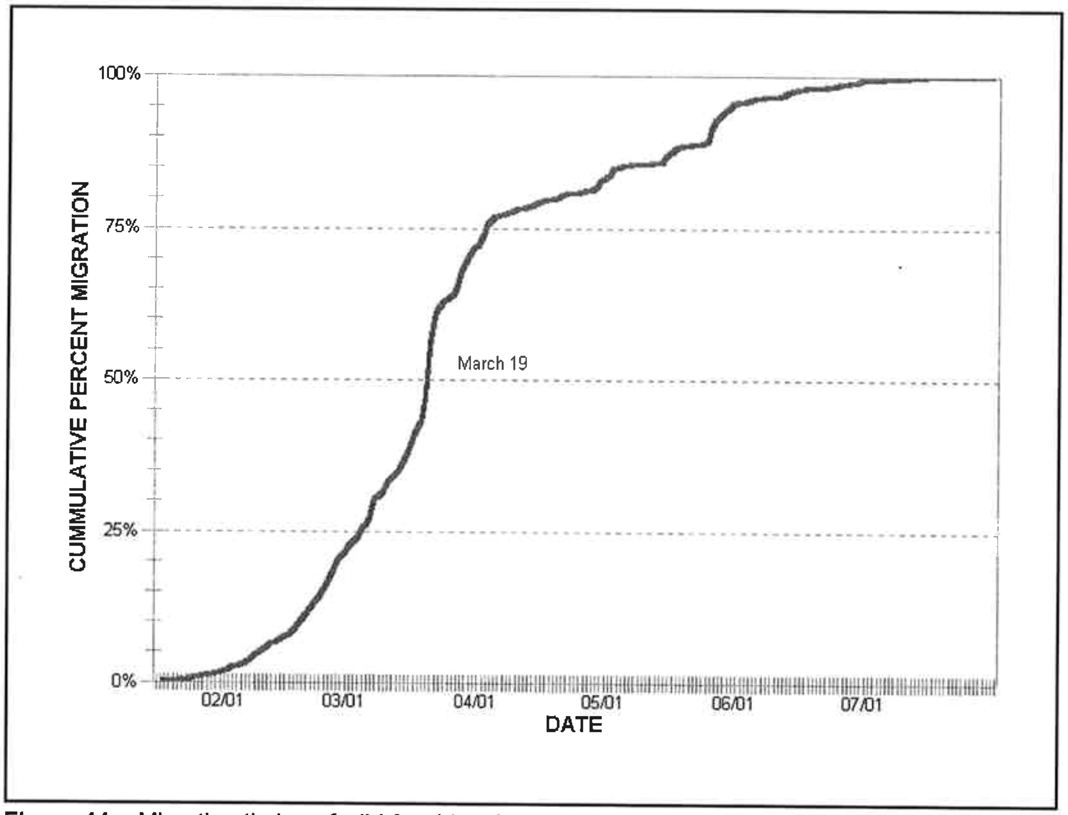


Figure 11. Migration timing of wild 0+ chinook past the Skagit River mainstem traps, 2001.

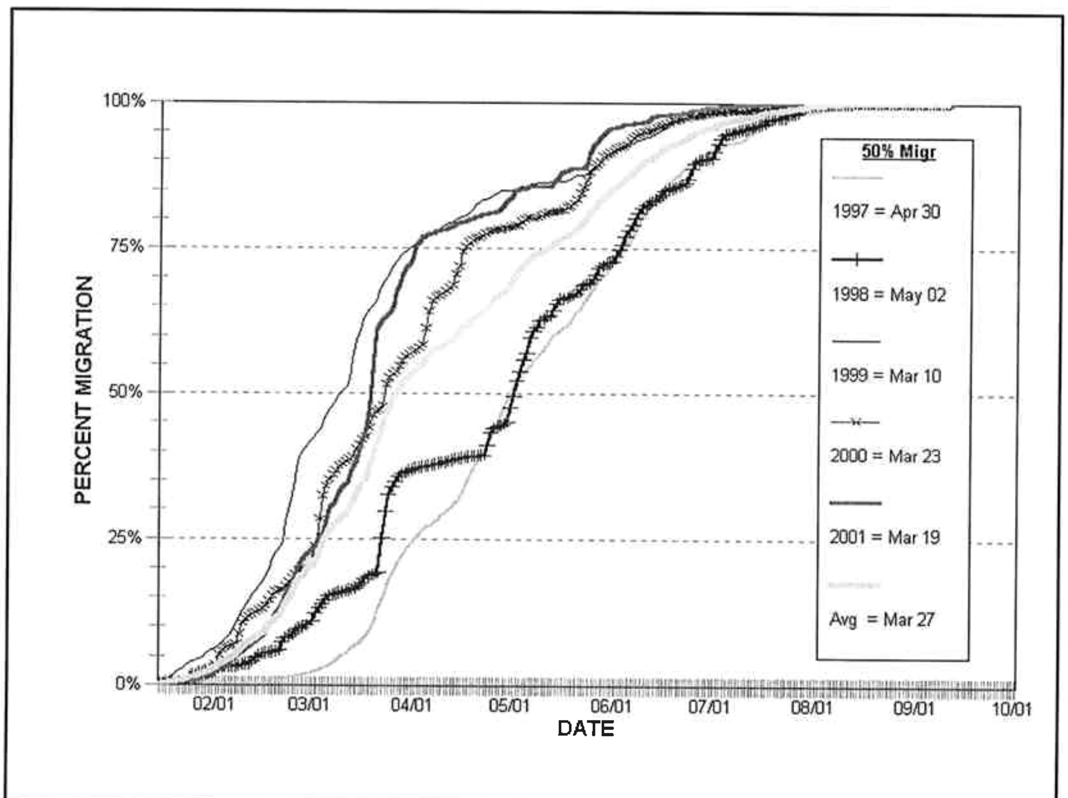


Figure 12. Wild 0+ chinook migration timing in past the Skagit River mainstem traps 1997-2001 and average migration over all years.

Wild 0+ Chinook Size

Over the season, wild 0+ chinook captured in the traps increased in size from less than 40 mm through the end of February, to around 80 mm by mid-July (**Table 13, Figure 14**). The lower end of the weekly size range did not exceed 40 mm until early-May, indicating protracted emergence and/or slow growth for a component of the population. Comparing mean chinook fork lengths from the scoop and screw trap catches by statistical week showed no significant difference at the 95% significance level (**Figure 15**).

Length Analysis and Size Selectivity

Low river flows decreased velocity at the trap site during Spring 2001. At lower velocities, larger smolts can avoid capture by swimming away from the trap entrance, and/or out of the traps. To assess this bias, we tested size (fork length) of RV-marked coho smolts captured in the scoop and screw traps with the RV-marked smolts released from the Mannser Creek trap. No significant differences were found (KS test, $\alpha = 0.05$). The length distributions of marked smolts recaptured also showed no statistical difference between the scoop and screw traps.

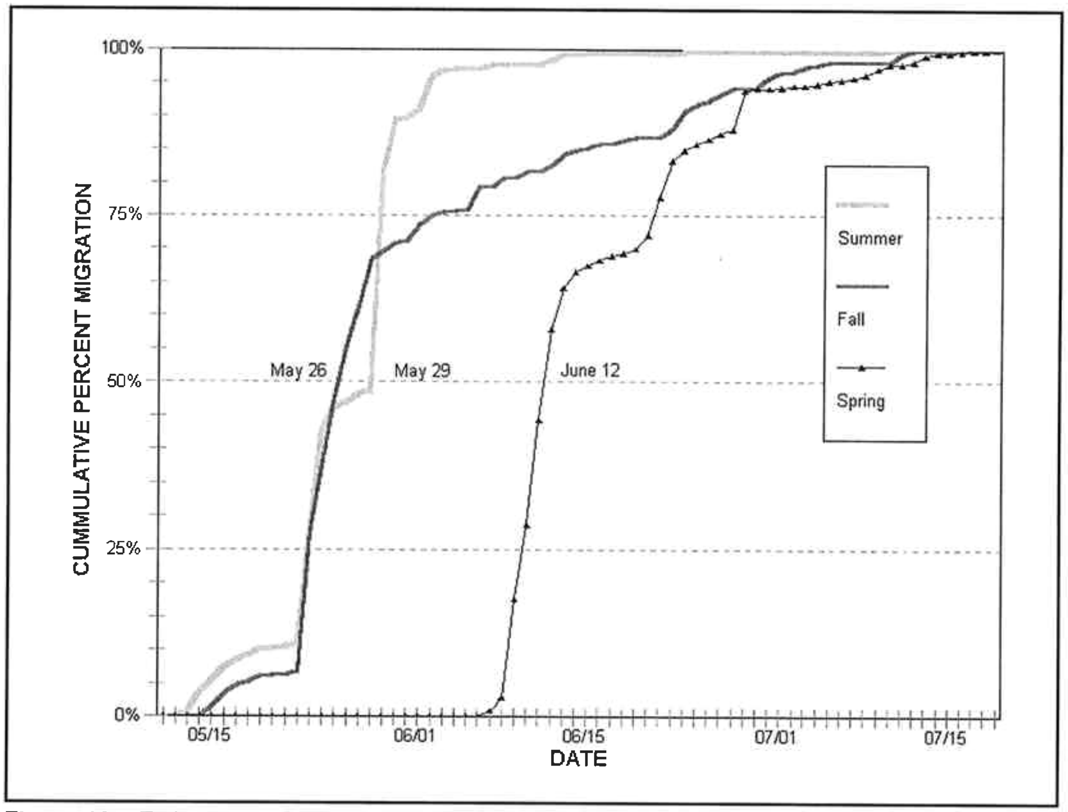


Figure 13. Estimated migration timing of three groups of hatchery 0+ chinook past the Skagit River mainstem traps, 2001.

Table 13. Mean fork length, standard deviation, range, sample size and catches of wild 0+ chinook in the Skagit River mainstem traps, 2001.

Statistical Week			Scoop Trap						Screw Trap					
Begin	End	No.	Mean	sd	Range Min	Range Max	n	Catch	Mean	sd	Range Min	Range Max	n	Catch
01/16/01	01/21/01	3	38.4	1.51	36	40	10	69	37.9	1.66	36	42	10	60
01/22/01	01/28/01	4	39.7	1.29	37	42	30	592	39.2	1.87	35	43	28	413
01/29/01	02/04/01	5	39.6	1.84	36	44	52	1,170	40.3	1.85	36	45	53	771
02/05/01	02/11/01	6	40.6	2.37	36	46	39	2,228	41.4	2.37	34	46	36	1,440
02/12/01	02/18/01	7	39.9	1.26	36	43	78	2,759	39.9	1.85	32	45	68	1,800
02/19/01	02/25/01	8	39.7	1.55	35	46	116	5,215	40.2	1.63	36	46	117	3,724
02/26/01	03/04/01	9	40.4	1.87	36	49	97	4,159	39.7	1.76	36	44	94	2,263
03/05/01	03/11/01	10	40.8	2.12	37	51	124	5,520	40.5	1.72	38	49	107	3,237
03/12/01	03/18/01	11	40.2	1.47	36	42	26	7,950	41.3	2.92	37	50	27	5,007
03/19/01	03/25/01	12	41.5	2.74	37	54	134	8,562	41.6	2.35	37	53	134	9,205
03/26/01	04/01/01	13	43.3	4.17	37	58	86	6,180	42.8	3.65	37	59	89	4,336
04/02/01	04/08/01	14	44.3	6.23	36	59	46	1,321	43.8	5.54	38	66	53	986
04/09/01	04/15/01	15	44.1	5.38	35	63	81	848	43.3	4.71	38	60	93	601
04/16/01	04/22/01	16	43.1	5.22	35	66	54	716	43.4	5.17	36	61	55	507
04/23/01	04/29/01	17	45.7	6.18	36	64	43	823	46.9	8.27	37	66	40	526
04/30/01	05/06/01	18	55.0	6.94	40	64	12	1,139	56.9	5.88	47	67	30	914
05/07/01	05/13/01	19					0	536					0	475
05/14/01	05/20/01	20	59.6	5.31	49	67	16	908	64.0	4.34	60	70	6	577
05/21/01	05/27/01	21	61.5	7.12	49	73	20	1,624	67.7	5.89	51	77	20	1,198
05/28/01	06/03/01	22	63.5	6.92	51	80	54	787	61.7	6.18	51	75	53	622
06/04/01	06/10/01	23	64.5	5.32	57	75	13	317	68.0	4.90	60	74	10	294
06/11/01	06/17/01	24	70.4	7.36	57	91	60	425	70.8	9.38	49	99	51	374
06/18/01	06/24/01	25	71.9	7.94	52	90	59	310	74.0	6.87	61	90	51	329
06/25/01	07/01/01	26	79.2	9.56	59	97	36	297	77.1	8.08	60	93	34	262
07/02/01	07/08/01	27					0	122					0	89
07/09/01	07/15/01	28	87.5	8.36	70	100	31	132	83.8	9.33	63	107	32	124
07/16/01	07/22/01	29	82.1	7.50	71	94	17	34	81.7	2.50	78	85	7	25
07/23/01	07/29/01	30					0	19					0	21
07/30/01		31					0	0					0	0
Season Total			N/A	N/A	35	100	1,334	54,762	N/A	N/A	32	107	1,298	40,180

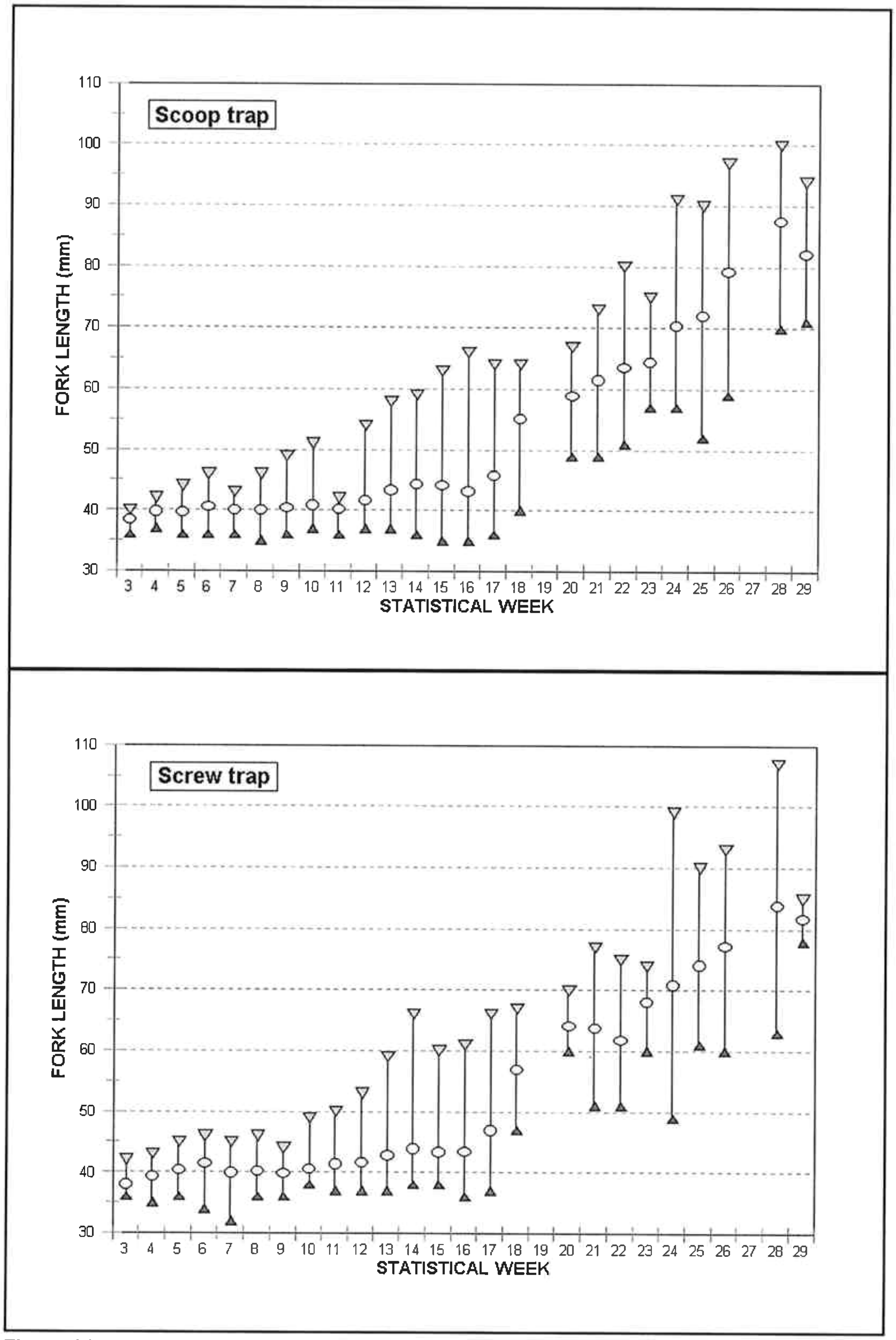


Figure 14. Weekly range and mean fork lengths, wild 0+ chinook, Skagit River 2001.

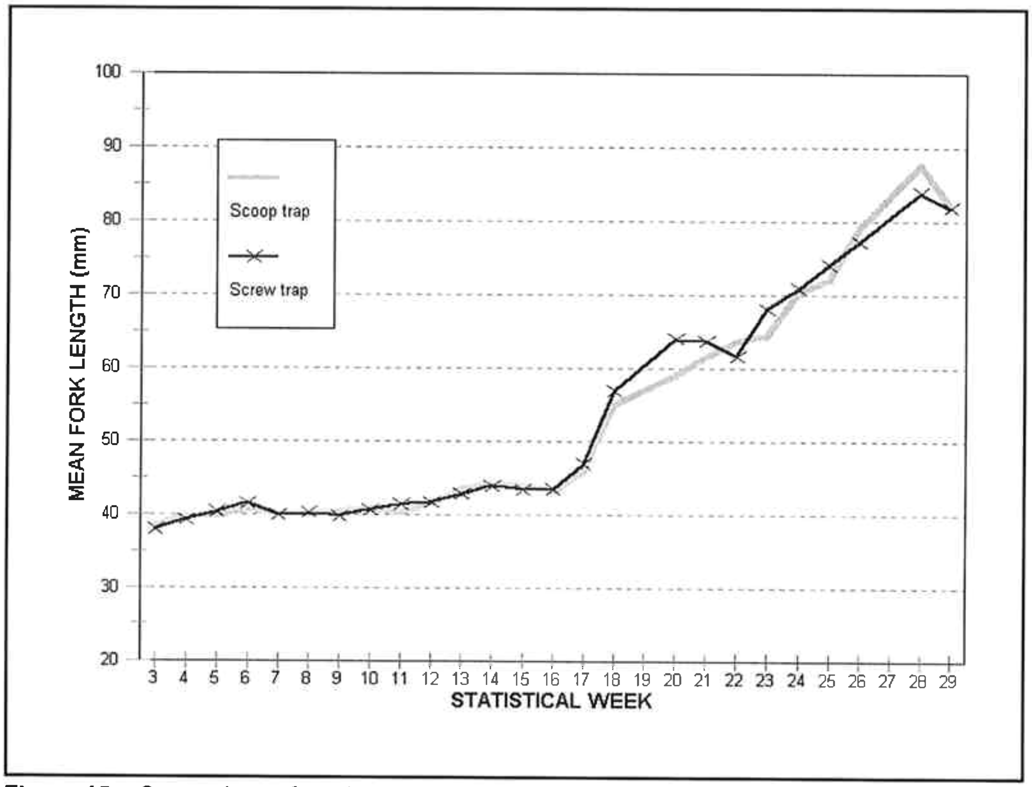


Figure 15. Comparison of weekly mean size, by trap, Skagit River 0+ chinook, 2001.

Egg-to-Migrant Survival

Relating our estimate of 6.0 million downstream-migrant chinook to a potential deposition of 44 million eggs, results in an average survival-to-migration of 13.5%. This estimate of potential egg deposition (P.E.D.) is the product of 8,078 females and a fecundity of 5,500 eggs/female (**Table 14**).

Table 14. Estimated freshwater survival (egg deposition-to-migration), by brood year, Skagit River wild 0+ chinook, (includes spring chinook).

Brood Year (i)	Migr Year (i+1)	Estimated Escapement[a]		PED @5,500[b] (million)	Wild Smolts (millions)	Survival to Migration	Winter High Flow	
		Total	Females (@45%)				cfs	Date
1989	1990	8,084	3,638	20.0	1.8	8.7%	88,200	12/05
1990	1991	18,303	8,236	45.3	0.5	1.2%	142,000	11/25
1991	1992	7,062	3,178	17.5	2.4	13.7%	40,100	02/01
1992	1993	8,334	3,750	20.6	3.0	14.4%	27,600	01/26
1993	1994	6,584	2,963	16.3	2.7	16.7%	32,100	12/11
1994	1995	6,019	2,709	14.9	1.5	10.2%	55,700	12/28
1995	1996	7,932	3,569	19.6	0.7	3.8%	132,000	11/30
1996	1997	11,664	5,249	28.9	4.5	15.6%	47,600	01/20
1997	1998	5,913	2,661	14.6	2.4	16.4%	32,800	12/17
1998	1999	15,695	7,063	38.8	6.4	16.5%	51,900	12/14
1999	2000	5,395	2,428	13.4	1.7	12.7%	76,000	11/13
2000	2001	17,951	8,078	44.4	6.0	13.5%	19,300	01/06

[a] Prior to the 1996 brood, estimates were based on trapping during the coho migration period (April -June). Full-season trapping commenced in 1997.
[b] Personal communication Pete Castle, WDFW.

Assumptions

Every estimate relies on assumptions. Although we know that trap efficiency varies over time, we assume it is a relatively constant fraction of smolt abundance. We presently have no flow-based correlation model to indicate its variation. Therefore, we selected a value based on the recapture rates of several groups of marked chinook to represent a season average rate. We made the following assumptions to estimate the numbers of wild 0+ chinook migrating from the Skagit River.

1. **Catch Expansion**. Because we fished at least one trap every night with the exception of five nights, expansion of catch up to the standard of continuous trap operation involved primarily estimating catch for the daytime periods that we did not fish.

2. **Trap Efficiency**. Estimating trap efficiency also involves the expansion for daytime catch for all marked fish categories used to indicate capture rates. Inherent in this approach is the assumption that trap efficiency during the daytime is identical to that during the night. Basic assumptions for every trap calibration group of marked fish include:
   a. The number passing the gear is known (survival from release to the trap is 100%);
   b. All marked fish captured are identified and enumerated;
   c. Marked hatchery chinook were captured at the same rate as wild chinook; and
   d. Instantaneous trap efficiency is not a function of light.

Discussion of Assumptions

Although direct assessment of the above assumptions is not possible, we have some intuition as to how important they are and in which direction some of them may be violated. These beliefs and their effects on our estimate of the 0+ chinook production from the Skagit River follows.

Assumption #1: Catch Projection

We have no reason to believe that the catch projections using expansions of the day/night ratios for the day light periods not fished are biased. We believe that the catch projection for the season is a reasonable estimate of the numbers of wild 0+ chinook that we would have caught in both traps had we fished continuously from mid-January to July 30.

Assumption #2a: 100% Survival of Calibration Fish

It is unlikely that all of the calibration fish in each group survived to pass the trap. However, for calibration tests involving the release of marked hatchery chinook, the short distance from the release site to the traps (about 1 mile), and condensed recovery time would support high survival to the traps. The recovery rate for chinook released from the upper river hatcheries was 0.7% for both Countyline Ponds and Skagit Hatchery, while the average of calibration groups was 1.9%. This difference indicates that about one-third of the hatchery production groups survived to pass the traps. The Red Creek release group, released in the lower river, was recovered at the highest rate (1.6%), indicating these fish survived at about two times the rate of the upper river releases. This result supports our theory that in-river survival is largely a function of distance; i.e. in a short distance relatively little mortality occurs. For this reason, to estimate wild 0+ chinook migration, we used the average capture rate of our calibration groups over the season (1.9%).

Assumption # 2b: Complete Identification/enumeration of All Marked Fish Captured

We are confident that virtually every marked fish captured was identified and recorded. The 2001 trap crew was comprised of trained scientific technicians. Consequently, we don't consider this potential bias to be significant.

Assumption # 2c: Marked Hatchery Chinook Were Captured at the Same Rate as Wild Chinook

The degree to which the hatchery chinook represent wild 0+ chinook is unknown. The similarity of d:n ratios over the season (**Figure 7**) provides some evidence that hatchery fish are responding to the river conditions in a manner similar to that of the wild chinook. Presently, we do not have any indication that hatchery produced 0+ chinook are caught at higher or lower rates than wild chinook.

Assumption #2d: Trap Efficiency Is Not Affected by Light

If this assumption is not correct, then it is likely that efficiency during the day is lower relative to the night rate; trap avoidance enhanced by daylight is the likely reason, if a difference exists. Another factor that would contribute to lower capture rates during the daylight could be any shifting in the migration path to deeper water as a function of light. In an attempt to measure trap efficiency during the day and night, in Spring 1999, we released the paired groups of hatchery chinook. As we expected, however, these fish did not pass the gear within their release strata (catches occurred primarily at night) so these tests provided no insight into this potential problem. If the hatchery calibration groups have the same diel migration behavior as wild fish, then different capture rates for day and night would not constitute a source of bias. Therefore, this assumption is really the same as #2b, for which we have little intuition.

Conclusion

As in previous years, we conclude that the critical assumption for producing unbiased estimates of wild 0+ chinook production is that hatchery fish represent their wild cohorts in every aspect that affects capture rate. Based on this assumption, we believe that the number of wild 0+ chinook passing the traps in the Skagit River in 2001 is around 6 million fish. If this estimate is biased, we believe that it is high, because it isn't likely that all of the marked chinook survived to pass the trap. Therefore, actual capture rate would be somewhat higher than the 1.9% indicated by the four calibration groups. If we were to use the average rate (2.2%) derived from all calibration groups released over the last five years, the migration estimate would be somewhat lower, at 5.2 million wild fish.

Discussion

Relatively moderate flows throughout the four seasons following 1997 have allowed almost continuous trapping. As a result, this fifth year of extended trapping provided another measure of the "shape" of the 0+ chinook migration from the Skagit River. Despite the differences in flow, timing of the out-migration estimates was very similar in 1997 and 1998. In 1999, 2000 and 2001, however, migration timing was somewhat earlier (**Figure 12**). The influence of flow on migration timing may become more evident by comparing results from subsequent seasons which include a wider range of flow patterns. It is important to remember, however, that these estimates are based on catch and the assumption of constant trap efficiency within each season.

Trap efficiency is the link between catch and production. The accuracy of all of our within-season estimates and interannual comparisons depend on the veracity of each season's estimate of this most critical parameter. In each year since 1998, we conducted several test releases in an attempt to improve our understanding of capture rates. Recovery rates of the fifteen calibration groups we have released over the years ranged from 0.7% to 3.5%, and averaged 2%. The more uniform recovery rates of the hatchery chinook groups released from the upper basin (Skagit Hatchery and Countyline Ponds) over these five years (0.7% to 1.7%) indicates that interannual variation in trap efficiency may be lower than indicated by the variation between small calibration groups.

In-river mortality, presumably due to predation, is a function of the distance traveled. In every year, recovery rates of the calibration groups released approximately one mile upstream of the traps has exceeded that of the production groups released further upstream. Therefore, release location is an important source of bias in using such groups to estimate capture rate. In addition, such other factors as release timing relative to flows, and fish size at release could explain some of the differences between the recovery rates for the hatchery production groups.

Improving our estimates of the 0+ chinook production from the Skagit River largely depends on calibrating the traps for a range of conditions. Instantaneous trap efficiency is not constant over the season; it varies as a function of flow, velocity, turbidity, light, water temperature (possibly), and fish size. Flow is undoubtedly the most important variable because it integrates other physical parameters which affect fish behavior and trap operation. At the trap site, velocity is a positive function of flow, as evidenced by the rotational speed of the screw trap. Even for a given discharge, however, velocity and flow vectors can be altered by both large woody debris upstream of the railroad bridge, and locally, at the trap site. Turbidity also appears to be an important parameter which affects the rate that chinook migrate during the day, their ability to avoid the gear, and, potentially, their vertical and lateral locations in the channel. Using hatchery fish to represent the responses of wild fish to the complex interactions of these variables with fish size, their physiological status, and the traps may present incalculable biases.

Over the previous eleven seasons, flow during egg incubation has explained most of the interannual variation in our estimates of egg-to-migrant survival rates (**Figure 16**). While the production in 2001 is somewhat lower than predicted by this relationship, we have lower confidence in the production estimated for the first seven broods. Estimates for these broods (1989 through 1995) were based on expanding estimated chinook migration during the coho trapping interval (April through June). To assess the veracity of these estimates, we will analyze migration timing relative to flow patterns and parent spawner densities.

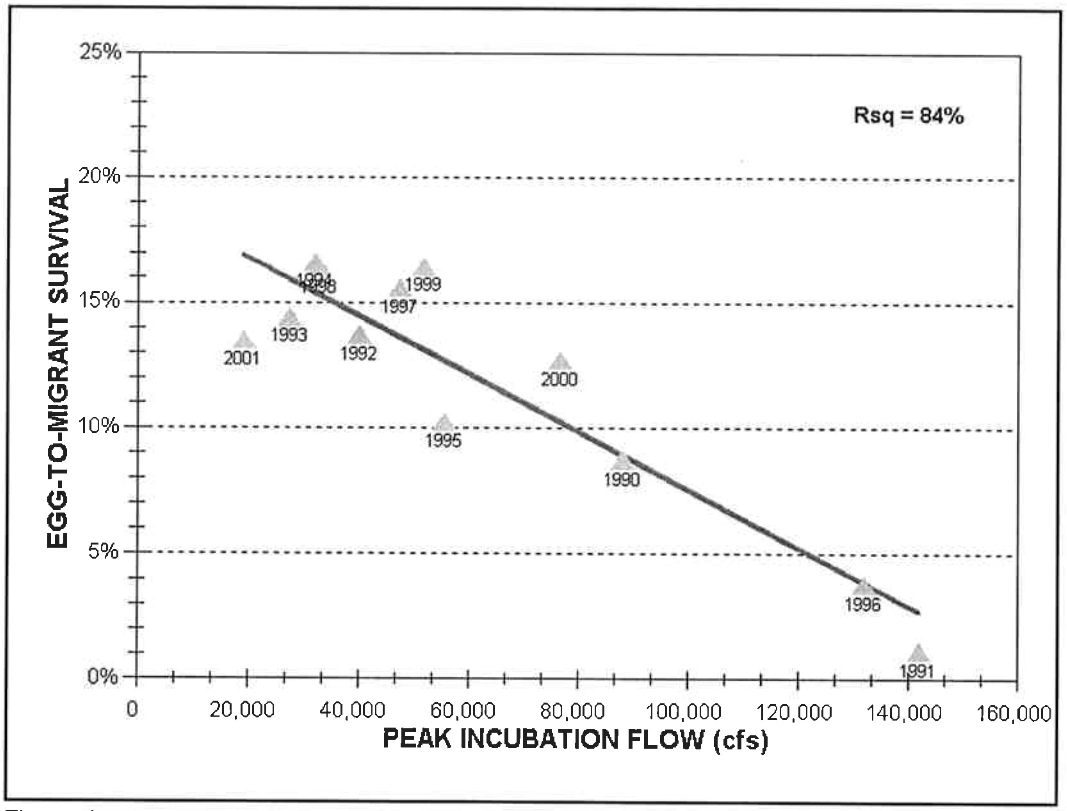


Figure 16. Egg-to-migrant survival estimates of wild 0+ chinook, migration years 1990-2001, Skagit River.

Statistical Review

In Winter 2000, Seattle City Light provided funding to assess the sources of variation affecting our wild chinook smolt production estimates from the Skagit River. We contracted with an independent biometrician to review the Spring 2000 data and provide recommendations to improve the precision of the outmigration estimate. This review (Appendix A) focused on our methods used to estimate wild 0+ chinook production and concluded with a work plan to investigate the implications of violating the assumptions of the estimator. The biometrician developed equations for calculating smolt abundance, bias, variance of the estimator (trap efficiency), an assessment of precision, and recommendations to improve estimates of trapping efficiency and thereby the overall production estimate. Recommendations to improve estimates of trap efficiency will be incorporated in the 2002 study plan.

Recommendations for 2001

The following recommendations, compiled from the past five years work, are listed so that we can assess the progress we made during the 2001 season. As noted in last year's report, these measures include actions that we may reasonably and cost-effectively implement within the current scope and funding level of our trapping program in the lower Skagit River.

1. Continue the extended season trapping over a sufficient span of years and flow conditions to gain an understanding of the interannual variation in migration timing.

2. Count catches at or near sunrise and sunset to increase the data base for Day:Night catch comparisons.

3. Measure turbidity and assess the correlation with flow.

4. Increase the numbers of release groups of marked hatchery 0+ chinook and continue to assess the feasibility of using these fish to calibrate the traps.

5. Engage a biometrician to optimize sampling design and analytical methods, assess assumptions, and compute variance estimates.

Progress in 2001

1. **Accomplished**. Aided by low to moderate flows, we trapped each night with the exception of five nights, from January 15 through July.

2. **Accomplished**. On most dates over the season, we counted catches at dusk and dawn.

3. **Accomplished**. We collected turbidity data throughout the 2001 season.

4. **Accomplished**. As documented in this report, we released four groups of marked chinook.

5. **Accomplished**. With funding from Seattle City Light, WDFW contracted a biometrician to review the basic assumptions and the associated production estimation methods.

Recommendations for 2002

Our study plan for the 2002 season includes continuing all of the above recommendations.

1. We will continue to collect turbidity data and assess the relationship of flow, visibility, and migration rates.

2. Increase the number of marked hatchery 0+ chinook release groups to assess recapture rates at various flow levels.

3. When possible, conduct paired releases of hatchery and wild fish to test the assumption of similar capture rates.

4. Conduct pilot 0+ chinook releases early in the season with dye marked chum, pink, and chinook fry to assess recapture rates for these fish.

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Appendix A

Review: 2000 Skagit River Wild 0+ Chinook Production Evaluation

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12 December 2001

Introduction

Logistical constraints create difficulties in estimating the production of salmonid smolts in large river systems. Variations in river conditions over time can change not only the migration pattern, but also potential recapture rates of tagged fish. Further, each species will have its own migration pattern varying in space, time, or both. Since 1990 the WDFW has been trapping migrating smolts in the Skagit River system in order to estimate wild coho abundance. In 1997, the effort was expanded to include the estimation of wild 0+ chinook production.

The Annual Report for the 2000 Skagit River Wild 0+ Chinook Production Evaluation describes the methods used for estimating production of wild 0+ chinook and wild coho smolts in the Skagit River. This review focuses on the methods used to estimate wild 0+ chinook production. Equations are presented first, followed by an estimator for the bias of the daily smolts abundance and a discussion on the assumptions used in estimating production. The review concludes with a work plan to further investigate the implications of violating the assumptions of the estimator.

Wild Chinook 0+ production estimators

In this section the equations used for calculating smolt abundance in the Lower Skagit River is reviewed, and an estimate of the bias is derived. Smolt abundance on the i^{th} day was estimated by,

$$\hat{M}_i = \frac{C_i}{\hat{\hat{e}}}, \qquad (1)$$

where, $\hat{M}_i$ = the number of chinook smolts on the i^{th} day,

C = the number of fish caught in the trap i^{th} day,

$\hat{\hat{e}}$ = trap efficiency.

Using replicate releases of tagged fish one mile upstream of the trap, efficiency, e for each release group was estimated by,

$$\hat{e}_i = \frac{r_i}{m_i}, \qquad (2)$$

where r_i = the number of marked fish recaptured in the trap from the i^{th} release group,

m_i = the number of marked fish in the i^{th} release group.

Overall trap efficiency, $\hat{\hat{e}}$, was estimated by,

$$\hat{\hat{e}} = \frac{\sum_{i=1}^{n} \hat{e}_i}{n}. \qquad (3)$$

where $\hat{e}_i$ = the recapture rate of the i^{th} release group

Traps were not in operation during daylight for most of the season, however daytime catch rates were estimated using a day/night (d:n) catch ratio estimated from the days the trap was in use. The ratio was calculated by,

$$R_i = \frac{C_{h(di)}}{\left(C_{n(i-1)} + C_{n(i)} \Big/ h_{(i-1)} + h_{n(i)} \right)}, \tag{4}$$

where, $C_{h(di)}$ = the day time catch rate per hour on the i^{th} day,

$C_{n(i)}$ = the night time catch on the i^{th} night,

$h_{n(i)}$ = the number of hours fished on the i^{th} night.

The average d:n catch ratio, $\bar{R}$, was estimated by

$$\hat{\bar{R}} = \frac{\sum_{i=1}^{n} R_i}{n}. \tag{5}$$

Thus the catch for the i^{th} day, when no fishing occurred during the day, was estimated by,

$$C_i = C_{n(i)} + \hat{\bar{R}} C_{n(i)} = C_{n(i)} \left(1 + \hat{\bar{R}} \right), \tag{6}$$

and was referred to as the expanding the catch to the "standard of continuous trapping"(pg. 8). The estimated out-migration, $\hat{M}_i$, (Eq. (1)) could then be re-written as,

$$\hat{M}_i = \frac{C_{n(i)} \left(1 + \hat{\bar{R}} \right)}{\hat{\bar{e}}}, \tag{7}$$

for the days when the trap was not in operation during the day, and

$$\hat{M}_j = \frac{C_{n(j)} + C_{d(j)}}{\hat{\bar{e}}}, \tag{8}$$

for the days when day time catches were available. The total abundance, M, is estimated from the sum of the estimates from Eqs. (7) and (8) across the season, or

$$\hat{M} = \sum_{i=1}^{l} \hat{M}_i + \sum_{j=1}^{k} \hat{M}_j. \tag{9}$$

No variances for the estimates are given in the report.

Bias of the abundance estimator

Daily variation in trap efficiency and the day/night catch ratio can bias out-migration estimates that are based on the seasonal averages of these quantities rather than values corresponding to each catch, i.e., C_i, Eqs. (7) and (8). The bias of the estimate on the i^{th} day is defined as,

$$Bias_i = \hat{M}_i - E(M_i), \tag{10}$$

where $Bias_i$ = the bias on the i^{th} day,

$E(M_i)$ = the expected value of the abundance on the i^{th} day, as estimated by

$$E(M_i) = \frac{C_{n(i)}(1+R_i)}{e_i},$$

Substituting the values for $E(M_i)$ and $\hat{M}_i$ (Eq. (7)) into Equation (10) gives a bias for the i^{th} day of

$$Bias_i = \frac{C_i\left[\left(e_i - \hat{\bar{e}}\right) + \left(e_i\hat{\bar{R}} - \hat{\bar{e}}R_i\right)\right]}{\hat{\bar{e}} \cdot e_i}. \qquad (11)$$

Differences between daily and average trap efficiency will have greater influence on the magnitude of the bias than differences between the daily and average day/night catch ratios. The plot of the bias versus daily trap efficiency, e_i and daily day/night catch ratios, R_i, is shown in **Figure 1** with $\hat{\bar{e}} = 0.031$ and $\hat{\bar{R}} = 0.3159$. The bias of the estimate of daily out-migration, M_i, increases in magnitude at a faster rate the further the difference between $\hat{\bar{e}}$ and e_i than the difference between R_i and $\hat{\bar{R}}$. The plots in **Figure 2** and **Figure 3** also supported this result. Further, **Figure 3** shows that biases caused by over or under estimation of R_i will be exacerbated when e_i is overestimated (i.e., $\hat{\bar{e}}$ is larger than the true value of e_i)

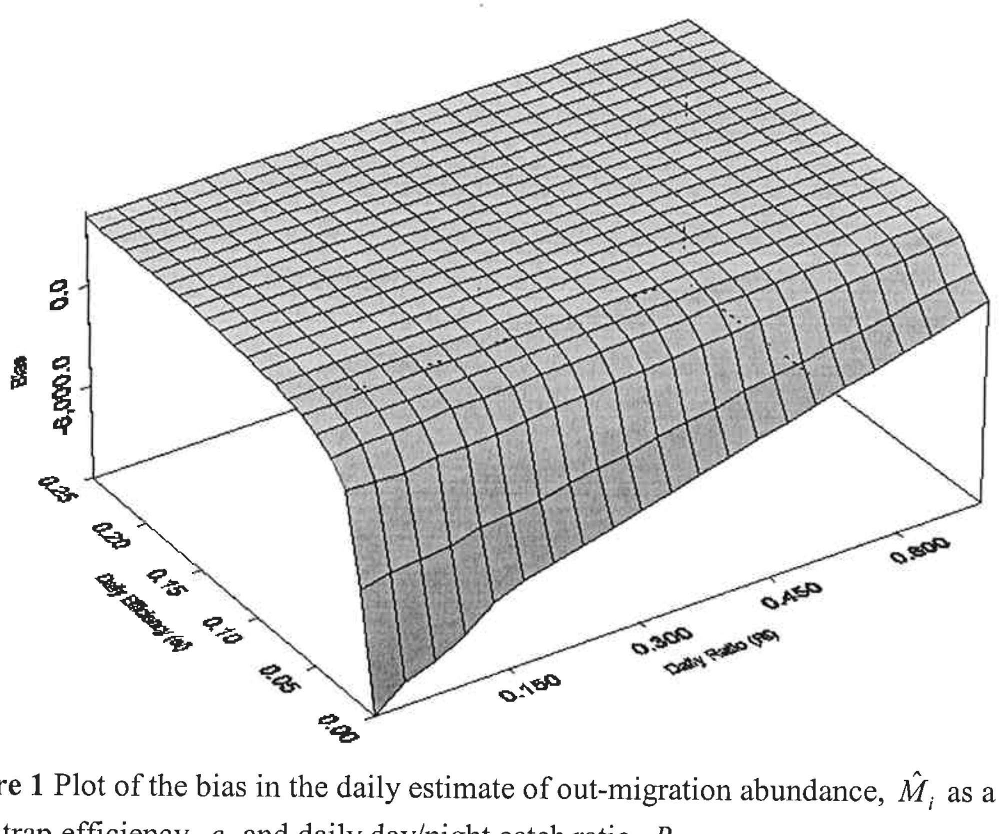

Figure 1 Plot of the bias in the daily estimate of out-migration abundance, $\hat{M}_i$ as a function of daily trap efficiency, e_i and daily day/night catch ratio, R_i.

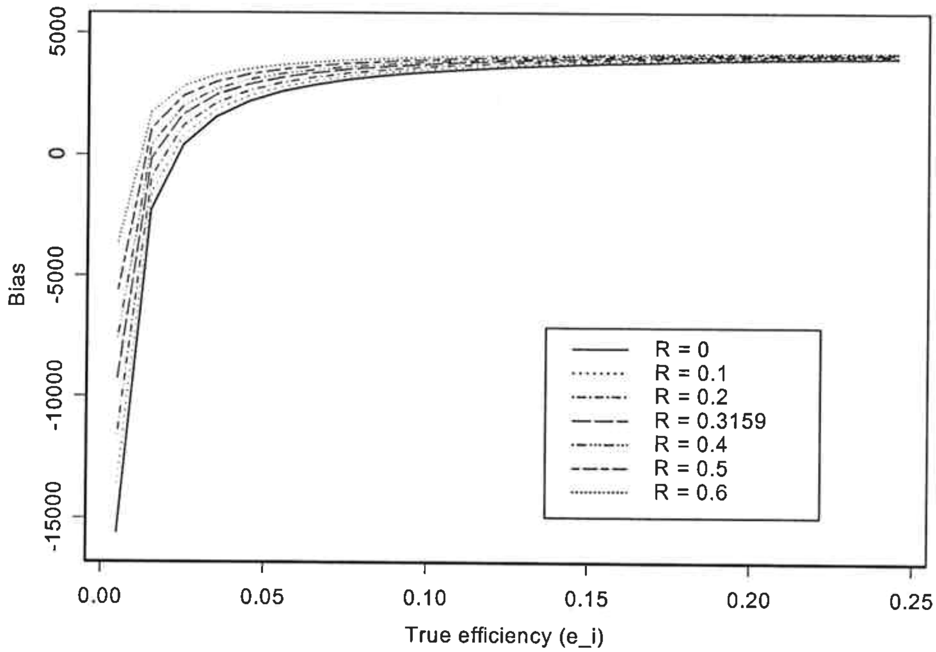

Figure 2 A plot of the bias as a function of efficiency, for several values of the day/night catch ratio for an estimated average efficiency of 0.03 ($\hat{\bar{e}} = 0.03$)

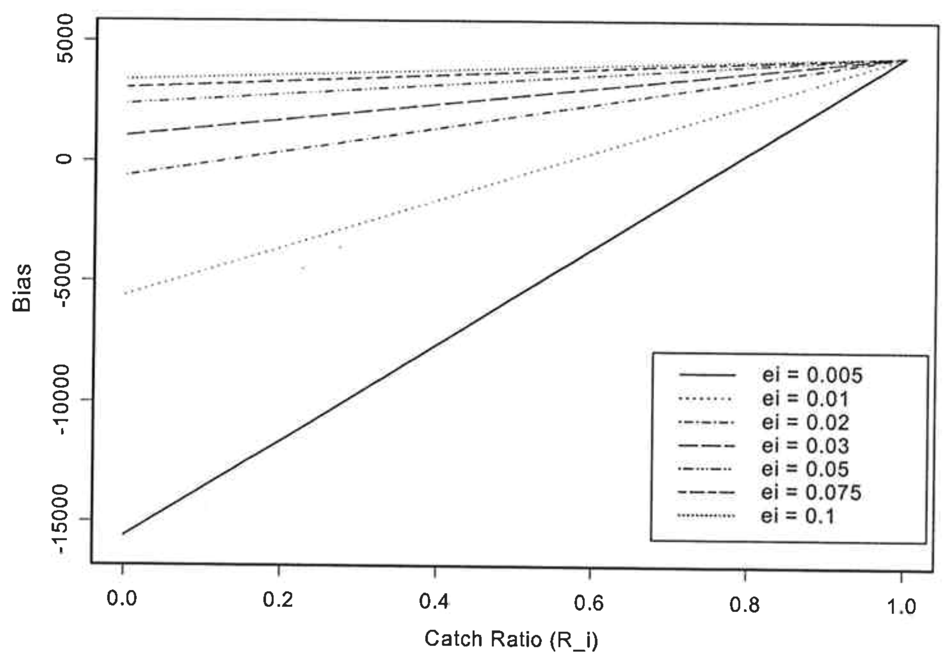

Figure 3 A plot of the bias as a function of the day/night catch ratio for several values of trap efficiency using the estimated average catch ratio. ($\hat{\bar{R}} = 0.3159$).

The second concern covers the calculation of the average trap efficiency, $\bar{e}$, and the average day/night catch ratio, $\bar{R}$. Using efficiency as an example, the average of a proportion, or a ratio, can be calculated as

$$\hat{\bar{e}} = \frac{\sum_{i=1}^{n} r_i}{\sum_{i=1}^{n} m_i}, \tag{12}$$

where r_i = the number of marked fish recaptured in the trap from the i^{th} release group,
m_i = the number of tagged fish in the i^{th} release group.

Average trap efficiency can be calculated using either Equation (3) or (12), depending on the homogeneity of recapture rates across release groups (e_i), which is easy to check using a goodness of fit test. If recapture rates are similar Equation (12) is appropriate, otherwise Equation (3) should be used. A chi-square test on the homogeneity, using a contingency table, concluded that the recapture rates for the 3 groups were not the same ($P < 0.10$), and thus, Eq. (3) is the better estimate of average trap efficiency than Eq. (12). Similarly, the day/night catch ratio varied widely throughout the out-migration season (**Figure 5** in the report). If a contingency table analysis showed that the day/night catches were not homogeneous throughout the season Eq. (5) would be the appropriate estimator for the average day/night catch ratio.

Variance of M for the abundance estimator

The 2000 report did not give an equation or an estimate of the variance of annual out-migration. Therefore, a variance derived here based on the abundance estimator in Eq. (9). The variance of annual out-migration can be written as,

$$Var\left(\hat{M}\right) = Var\left(\sum_{i=1}^{n} \hat{M}_i + \sum_{j=1}^{m} \hat{M}_j\right),$$

or,

$$Var\left(\hat{M}\right) = \sum_{i=1}^{n} Var\left(\hat{M}_i\right) + \sum_{j=1}^{m} Var\left(\hat{M}_j\right), \tag{13}$$

noting that the covariance between $\hat{M}_i$ and $\hat{M}_j$ is zero, the covariance between each days out-migration estimate is zero, i.e., $Cov\left(\hat{M}_i, \hat{M}_{i'}\right) = 0, \forall i \neq i'$. The variance of both $\hat{M}_i$ and $\hat{M}_j$ is approximated using the delta method. Details of the derivation of the variance and estimated variance are given in the appendix. The variance of total seasonal out-migration, $\hat{M}$ can be written in terms of the coefficients of variation (CV) of $C_i, \hat{\bar{R}}$, and, $\hat{\bar{e}}$ as,

$$\begin{aligned} Var\left(\hat{M}\right) = & \sum_{i=1}^{l} \hat{M}_i^2 \left(CV^2\left(C_i\right) + CV^2\left(1 + \hat{\bar{R}}\right) + CV^2\left(\hat{\bar{e}}\right)\right) \\ & + \sum_{j=1}^{k} \hat{M}_j^2 \left(CV^2\left(C_{n(j)} + C_{d(j)}\right) + CV^2\left(\hat{\bar{e}}\right)\right) \end{aligned}, \tag{14}$$

with estimated variance,

$$Var\left(\hat{M}\right)=\sum_{i=1}^{l}\hat{M}_i^2\left(\widehat{CV}^2\left(C_i\right)+\widehat{CV}^2\left(1+\hat{\bar{R}}\right)+\widehat{CV}^2\left(\hat{\bar{e}}\right)\right)$$
$$+\sum_{j=1}^{k}\hat{M}_j^2\left(\widehat{CV}^2\left(C_{n(j)}+C_{d(j)}\right)+\widehat{CV}^2\left(\hat{\bar{e}}\right)\right) \qquad (15)$$

Writing the variance in terms of the CVs in the variance equations simplifies the equation, and is useful when the relative precision of the parameters are known, or estimated even though the actual parameters values remain unknown. Re-writing the equation using the empirical variances of $C_i, \hat{\bar{R}}$, and, $\hat{\bar{e}}$ gives,

$$Var\left(\hat{M}\right)=\sum_{i=1}^{l}\hat{M}_i^2\left(\frac{\hat{M}_i\hat{\bar{e}}\left(1-\hat{\bar{e}}\right)}{C_i^2}+\frac{\sum_{r=1}^{m}\left(R_r-\bar{R}\right)^2}{m(m-1)\left(1+\hat{\bar{R}}\right)^2}+\frac{\sum_{i=1}^{n}\left(e_i-\hat{\bar{e}}\right)^2}{n(n-1)\left(\hat{\bar{e}}\right)^2}\right)$$
$$+\sum_{j=1}^{k}\hat{M}_j^2\left(\frac{\hat{M}_j\hat{\bar{e}}\left(1-\hat{\bar{e}}\right)}{\left(C_{n(j)}+C_{d(j)}\right)^2}+\frac{\sum_{i=1}^{n}\left(e_i-\hat{\bar{e}}\right)^2}{n(n-1)\left(\hat{\bar{e}}\right)^2}\right) \qquad (16)$$

Based on Eq. (16) it is apparent that the overall variance of out-migration will be reduced by using more tag release groups, n, to estimate seasonal trap efficiency $\hat{\bar{e}}$. Further, increases in trap, or capture efficiency ($\hat{\bar{e}}$) will increase the precision in abundance estimate by decreasing the binomial sampling variance of C_i and $\left(C_{j(d)}+C_{j(n)}\right)$.

Assumptions

A number of assumptions are required to attain unbiased estimates of smolt production, as estimated by Eqs. (7) and (8). How well the assumptions are met will determine the reliability of the estimates. The most important assumption is that the trap efficiency is obtained over a random sample of days. In the absence of a flow based correlation between flow and catch rates, or continuous release and recapture of tagged fish, trap efficiency was estimated using 3 release groups using Eq. (3). Other assumptions specific to this study are:

1) The day/night catch expansion was an unbiased estimate of the number of fish caught had the traps been fished continuously;
2) Expansion of the number of marked fish using the day/night catch ratio was an unbiased estimate r of the number of marked fish that would have been caught had the trap been fished every night (additional assumption for wild coho estimates);
3) Trap efficiency during the day was the same as night time;
4) Marked hatchery chinook are captured at the same rate as wild 0+ chinook.

In addition, the basic assumptions used for the mark release groups to estimate trap efficiency were:

5) Survival from release to the trap was 100%;
6) All marked fish are identified and correctly enumerated
7) Fish do not loose their marks
8) All fish in the mark release groups out-migrate i.e., do not residualize in the area of release.

The assumptions, the effect on out-migration estimates, and suggestions on how to test the validity of each are outlined below from most to least important.

Although an appropriate estimator was used for the average of trap efficiency based on the release groups, the degree to which the assumption reasonably models the system will depend on the representativeness of the release groups with regard to river conditions and the behavior of the fish. Three release groups of hatchery fish, all in May, is probably not representative of the wild chinook out-migrating in the months January to April. A greater number of mark-release groups across the entire season would help in addressing this point. The only way to adequately assess the difference in behavior between wild and hatchery chinook is through replicate releases of the two groups under the same in-river conditions.

The assumption that the catch expansion (Eq. (6)) is an unbiased estimate of the number of fish that would have been caught under continuous trapping does not seem unreasonable. The number data points used to calculate R, and more importantly, the variety of conditions under which the values were observed is adequate to provide an unbiased estimate of R. The assumption that trap efficiency would not be affected by light is difficult to measure (assumption 5). Although releasing marked fish upstream of the trap during the day would give an estimate of daytime trap efficiency, unless in-river conditions during the day release are comparable to night, comparisons would not help in addressing this issue. It was mentioned that daytime mark releases were conducted in 1999, but the fish did not pass the gear during the day. I would agree that if the release groups did have the same migration patterns as other fish, then the assumption would not bias the results greatly. Assumptions 5-7 seem reasonable with regard to the chinook release groups.

Concerns that would be best addressed in the field are;

1. Estimating a more precise and unbiased trap efficiency by releasing more tag groups over a wider range of in-river conditions throughout the migration season;
2. If possible, releasing groups of marked wild 0+ chinook to evaluate the capture rate of wild fish with regard to hatchery fish (or to estimate recapture estimates of wild fish directly);
3. If possible, include estimates of in-river survival for wild coho.

The following two analyses address the issue of increasing the precision of out-migration estimates, and assessing the differences in trap efficiency between wild and hatchery fish.

Assessing precision goals using flow/efficiency relationships

Based on the estimator of annual out-migration, Eq. (9), the variance, Eq (16), and data provided by the Department of Fisheries for the 2000 out-migration, annual out-migration of Wild Chinook 0+ ($\hat{M}$) is 1,507,808 fish, with a standard error of 34,453 fish $\left(SE\left(\hat{M}\right)=34453\right)$, giving a $CV = 2.28\%$. The estimated out-migration value is within the 1.3 and 2.0 million estimate given in the report.

The apparent precision of the estimate of $\hat{M}$ is due mostly to the small sampling variance of $\hat{\bar{e}}$, and it illustrates two potential problems associated with estimation of trap efficiency. Trap efficiency releases were not conducted over the entire out-migration season, with a wide range of in river conditions, but rather within a one-month period of somewhat similar flow conditions. Thus the variance $\hat{\bar{e}}$ is likely under estimated and may perhaps be biased. Unfortunately the direction and magnitude of the bias is inestimable. However, using in river flow conditions at the time the trap efficiencies were estimated, and data on mark-recapture rates from the 1999 out-migration season in addition to 2000 efficiencies, a variance can be estimated for the purpose of sample size and power calculations.

The number of recaptures per mark release group was regressed against flow conditions for using the tag released from both 1999 and 2000. The variance of average trap efficiency can be written in terms of the processes effecting the variability in recapture rates that are flow, measurement error and natural variability. Using the sums of square errors from the regression, the variance of $\hat{\bar{e}}$ can be written as,

$$Var\left(\hat{\bar{e}}\right)=\frac{Var\left(\hat{e}\right)}{n}=\frac{1}{n}\left(MSR+\overline{Var\left(\hat{e}_i\left|e_i\right.\right)}+\sigma_{e_i}^2\right) \qquad (17)$$

where MSR = the regression error,

$\overline{Var\left(\hat{e}_i\left|e_i\right.\right)}$ = the average measurement error and,

$\sigma_{e_i}^2$ = process error (natural variability) of trap efficiency.

The average measurement error is estimated using the variance of a proportion as

$$\frac{\sum_{i=1}^{n}\frac{e_i\left(1-e_i\right)}{f_i}}{n},$$

where f_i = the number of fish released in the ith group, and,

n = the number of release groups.

Natural variability, or process error, is estimated from the MSE of the regression as and the average measurement error as,

$$\sigma_{e_i}^2 = MSE-\frac{\sum_{i=1}^{n}\frac{e_i\left(1-e_i\right)}{f_i}}{n}$$

Holding the number of fish released in each group constant, the expression for the variance used in sample size calculations is,

$$Var\left(\hat{\bar{e}}\right)=\left(1-\frac{n}{N}\right)\frac{1}{n}\left(MSR+\frac{\sum_{i=1}^{n}e_i\left(1-e_i\right)}{n\cdot f}+\sigma_{e_i}^2\right). \quad (18)$$

The finite population correction $\left(1-\frac{n}{N}\right)$ is used because only a fraction of the days out of the total out-migration season will be sampled. Precision estimates were calculated in terms of the CV of $\hat{\bar{e}}$, where average trap efficiency was calculated as the arithmetic mean of efficiencies estimated from the 1999 and 2000 data.

Values of the CV for were calculated for the replicate release numbers (n) ranging from 2 to 25, and five different release sizes (f) (**Table 1**). The size of each release was held constant across all releases. The values in **Table 2** are the relative error rates associated with 90% confidence interval. The values are interpreted to mean that the difference between seasonal average efficiency, $\bar{e}$, and the estimated efficiency, $\hat{\bar{e}}$, will be within $1.96\cdot CV\left(\hat{\bar{e}}\right)$, 90% of the time. For example, with 10 releases of 500 fish, difference between true efficiency, and the estimated efficiency, $\bar{e}-\hat{\bar{e}}$ will be within 60% of $\hat{\bar{e}}$, 90% of the time. Relative error rates were also calculated for seasonal out-migration estimates (**Table 3**) using the same numbers and sizes of releases as those in **Table 2**. In either case, the number of releases has a greater effect on precision than the size of the releases.

The calculations presented here assume that estimates of trap efficiency are an unbiased estimate of seasonal efficiency, and address the precision of the estimates. Unbiased estimates can only be obtained if the releases occur over a random and representative subset of in-river conditions.

Table 1. The coefficients of variation (CV) for estimates of the average trap efficiency $\hat{\bar{e}}$ based on the size of each release group, and the number of groups released.

$CV\left(\hat{e}\right)$ Trap Efficiency		Number of tagged fish per release group				
		500	1000	1500	2000	2500
Number of release groups	2	0.7829	0.7318	0.7139	0.7048	0.6993
	3	0.6103	0.5816	0.5717	0.5666	0.5636
	5	0.4529	0.4392	0.4345	0.4322	0.4308
	10	0.3069	0.302	0.3003	0.2995	0.299
	15	0.2449	0.2423	0.2414	0.2409	0.2407
	20	0.2083	0.2066	0.2061	0.2058	0.2056
	25	0.1834	0.1822	0.1818	0.1816	0.1814

Table 2. Relative error rates of average trap efficiency associated with a 90% confidence interval.

Error (90%)		Number of fish per release				
		500	1000	1500	2000	2500
Number of release groups	2	1.5345	1.4343	1.3992	1.3814	1.3706
	3	1.1962	1.1399	1.1205	1.1105	1.1047
	5	0.8877	0.8608	0.8516	0.8471	0.8444
	10	0.6015	0.5919	0.5886	0.5870	0.5860
	15	0.4800	0.4749	0.4731	0.4722	0.4718
	20	0.4083	0.4049	0.4040	0.4034	0.4030
	25	0.3595	0.3571	0.3563	0.3559	0.3555

Table 3. Relative error rates of estimates of total seasonal out-migration associated with a 90% confidence interval.

Error (95%)		Number of fish per release				
		500	1000	1500	2000	2500
Number of release groups	2	0.1510	0.1412	0.1378	0.1360	0.1350
	3	0.1179	0.1124	0.1105	0.1095	0.1089
	5	0.0877	0.0851	0.0842	0.0837	0.0835
	10	0.0598	0.0589	0.0586	0.0584	0.0583
	15	0.0480	0.0475	0.0474	0.0473	0.0472
	20	0.0412	0.0408	0.0407	0.0407	0.0406
	25	0.0365	0.0363	0.0362	0.0361	0.0361

Power calculation for comparing trap efficiencies between wild and hatchery fish

Out-migration estimates of wild chinook rely on the assumption that wild fish are caught at the rates similar to those of hatchery fish. If trap efficiencies based on hatchery fish over or underestimate the rate at which wild fish are caught, then out-migration estimates will be biased. In absence wild releases to estimate efficiency, the direction of the bias is inestimable. Hence, this assumption can only be tested in the field. Paired releases of wild and hatchery fish, done on the same day, would be the best way to test the assumptions of similar trap efficiencies. Conduction the efficiency experiments on the same day would minimize the impact of varying in-river conditions.

The power calculations presented in this section are designed to address the question of magnitude of the difference one would expect to detect given the inherent variability in estimating trap efficiency. The probability of detecting a difference of concern is dependent upon the magnitude of the difference between capture rates of wild and hatchery chinook, and the variance of capture rates. Underestimation of capture rates would lead to an overestimate of seasonal out-migration; the calculations of power were based on efficiency estimates of hatchery chinook being below the value of wild fish. If wild fish are recaptured at a rate of twice that of hatchery fish, and efficiencies based on hatchery releases, estimates of out-migration of wild chinook would be 2x the actual value.

Because efficiency estimates are calculated as the arithmetic mean of replicate trap efficiency release groups, power calculations were based on the formula,

$$\phi_{(1,2(n-1))} = \frac{1}{\sqrt{2}} \frac{\left|\hat{\bar{e}}_{hatchery} - \hat{\bar{e}}_{wild}\right|}{\sqrt{Var\left(\hat{\bar{e}}_{hatchery}\right) + Var\left(\hat{\bar{e}}_{wild}\right)}}, \qquad (19)$$

where $\hat{\bar{e}}_{hatchery}$ = average trap efficiency for hatchery fish,

$\hat{\bar{e}}_{wild}$ = average trap efficiency of wild fish,

$Var\left(\hat{\bar{e}}_{hatchery}\right)$ = the variance of $\hat{\bar{e}}_{hatchery}$, as estimated in Eq. (18)

$Var\left(\hat{\bar{e}}_{wild}\right)$ = the variance of $\hat{\bar{e}}_{wild}$,

The daily variations in trap efficiency due to in-river conditions, and the process error, as estimated by MSR and $\sigma^2_{e_i}$ respectively for hatchery fish, are assumed to be the same for wild fish. Thus, variance of $\hat{\bar{e}}_{wild}$ is estimated by

$$Var\left(\hat{\bar{e}}_{wild}\right) = \left(1 - \frac{n}{N}\right)\frac{1}{n}\left(MSR + \frac{\sum_{i=1}^{n} e_{i(wild)}\left(1 - e_{i(wild)}\right)}{n \cdot f} + \sigma^2_{e_i} \right). \qquad (20)$$

The difference between the variances is attributable to the measurement error, $\frac{\sum_{i=1}^{n} e_{i(wild)}\left(1 - e_{i(wild)}\right)}{n \cdot f}$, which is a function of trap efficiency. Because overestimation of wild chinook would be less desirable than overestimation, values of $\hat{\bar{e}}_{wild} = 2 \cdot \hat{\bar{e}}_{hatchery}$ and $\hat{\bar{e}}_{wild} = 1.5 \cdot \hat{\bar{e}}_{hatchery}$ were used in the power calculations. The values in **Table 4** and **Table 5** are the probabilities of detecting a wild fish recapture rates of 2 and 1.5 times higher than hatchery fish, if such differences existed. Basing wild out-migration estimates on hatchery recapture rates with these differences would over estimate true out-migration by 100% and 67%, respectively. As seen with the previous analysis, increasing the number of replicate releases increases power significantly more than increasing the size of the releases.

Recommendations for estimating wild chinook 0+ out-migration

All recommendations for this study involve improving estimates of trap efficiency, both in terms of reducing bias and increasing precision, both of which will improve estimates of annual out-migration. The recommendations are:

1) Conduct efficiency releases through out the year to obtain estimates of capture rates that are representative of the entire out-migration season;
2) Conduct paired releases of hatchery and wild fish to test the assumption of similar capture rates;
3) Increase the number of efficiency releases.

The sample size and power calculation tables provide a guideline for choosing the number of releases. Logistics will most likely have a greater effect on determining the number of releases.

Other aspects influencing, and confounding, estimates of trap efficiency are the effects of size of the fish, survival and residualization. Residualization and survival are a problem when marked fish do not migrate immediately, or do not survive between release and recapture. The presence of either one will underestimate trap efficiency. Unfortunately, these parameters are confounded and difficult to estimate. The effect of fish size on capture rates in the traps could be simulated through comparing the fish to neutrally buoyant objects, the comparing the capture rates in the same way and those of wild and hatchery fish.

Table 4. The probability of detecting a wild fish recapture rate that is twice that of hatchery fish, for several number of paired releases, and release sizes.

Power estimates for $\hat{\hat{e}}_{wild} = 2 \cdot \hat{\hat{e}}_{hatchery}$, $\alpha = 0.10$					
	Number of fish released per group				
Number of release groups	500	1000	1500	2000	2500
2	0.5667	0.5879	0.5966	0.6014	0.6044
3	0.6115	0.6352	0.6443	0.6491	0.6520
5	0.7291	0.7494	0.7565	0.7602	0.7626
10	0.9070	0.9155	0.9182	0.9197	0.9205
15	0.9715	0.9743	0.9752	0.9757	0.9760
20	0.9921	0.9929	0.9932	0.9933	0.9934
25	0.9980	0.9982	0.9983	0.9983	0.9983

Table 5 The probability of detecting a wild fish recapture rate that is 1.5 times that of hatchery fish, for several number of paired releases, and release sizes.

Power estimates for $\hat{\hat{e}}_{wild} = 1.5 \cdot \hat{\hat{e}}_{hatchery}$, $\alpha = 0.10$					
	Number of fish released per group				
Number of release groups	500	1000	1500	2000	2500
2	0.4787	0.4846	0.4871	0.4884	0.4892
3	0.4616	0.4692	0.4720	0.4736	0.4745
5	0.4921	0.5005	0.5035	0.5051	0.5061
10	0.6013	0.6090	0.6117	0.6131	0.6139
15	0.6981	0.7040	0.7063	0.7072	0.7082
20	0.7757	0.7806	0.7826	0.7834	0.7838
25	0.8370	0.8408	0.8421	0.8428	0.8431

Appendix – Derivation of Variance estimators for Wild Chinook

The variance of out-migration abundance of Wild Chinook 0+ was based on Eq. (13), where $\hat{M}_i$ is estimated by Eq. (7) and $\hat{M}_j$ by Eq. (8). The variance of $\hat{M}_i$ is approximated by the delta method, and written as,

$$Var\left(\sum_{i=1}^{l}\hat{M}_i\right) \square \sum_{i=1}^{l}\left(Var\left(C_{i(n)}\right)\left(\frac{\partial M_i}{\partial C_{i(n)}}\right)^2_{|E(C,\bar{R},\bar{e})} Var\left(\hat{\bar{R}}\right)\left(\frac{\partial M_i}{\partial \bar{R}}\right)^2_{|E(C,\bar{R},\bar{e})} + Var\left(\hat{\bar{e}}\right)\left(\frac{\partial M_i}{\partial \bar{e}}\right)^2_{|E(C,\bar{R},\bar{e})} \right.$$
$$+2Cov\left(C_{i(n)},\bar{e}\right)\left(\frac{\partial M_i}{\partial C_{i(n)}}\cdot\frac{\partial M_i}{\partial \bar{e}}\right)_{|E(C,\bar{R},\bar{e})} + 2Cov\left(C_{i(n)},\bar{R}\right)\left(\frac{\partial M_i}{\partial C_{i(n)}}\cdot\frac{\partial M_i}{\partial \bar{R}}\right)_{|E(C,\bar{R},\bar{e})} \qquad ,(21)$$
$$\left. +2Cov\left(\bar{R},\bar{e}\right)\left(\frac{\partial M_i}{\partial \bar{R}}\cdot\frac{\partial M_i}{\partial \bar{e}}\right)_{|E(\bar{R},\bar{e})}\right)$$

and the variance of $\hat{M}_j$ is,

$$Var\left(\sum_{j=1}^{m}\hat{M}_j\right) \square \sum_{j=1}^{m}\left(Var\left(C_{j(n)}\right)\left(\frac{\partial M_j}{\partial C_{j(n)}}\right)^2_{|E\left(C_{j(n)},C_{j(d)},\bar{e}\right)} + Var\left(C_{j(d)}\right)\left(\frac{\partial M_j}{\partial C_{j(d)}}\right)^2_{|E\left(C_{j(n)},C_{j(d)},\bar{e}\right)} \right.$$
$$+Var\left(\hat{\bar{e}}\right)\left(\frac{\partial M_j}{\partial \hat{\bar{e}}}\right)^2_{|E\left(C_{j(n)},C_{j(d)},\bar{e}\right)} + 2Cov\left(C_{j(n)},\hat{\bar{e}}\right)\left(\frac{\partial M_j}{\partial C_{j(n)}}\cdot\frac{\partial M_j}{\partial \bar{e}}\right)_{|E\left(C_{j(n)},C_{j(d)},\bar{e}\right)} \qquad . \qquad (22)$$
$$\left. +2Cov\left(C_{j(d)},\hat{\bar{e}}\right)\left(\frac{\partial M_j}{\partial C_{j(n)}}\cdot\frac{\partial M_j}{\partial \hat{\bar{e}}}\right)_{|E\left(C_{j(n)},C_{j(d)},\bar{e}\right)}\right)$$

Assuming that the daily catches are independent, then the covariance between day and night catches, and the day/night catch ratio, $\bar{R}$ is 0, i.e., $Cov\left(C_{i(n)},\bar{R}\right)=0$, and $Cov\left(C_{j(d)},C_{j(n)}\right)=0$. Also, because the day/night catch ratio was estimated independently of efficiency, $Cov\left(\bar{R},\bar{e}\right)=0$.

Substituting in the first derivatives from Eqs. (7), and the parameter estimates for the expected values into the above variance expression for M_i (Eqs. (21)), and using the parameter estimates for the expected values yields,

$$Var\left(\sum_{i=1}^{l}\hat{M}_i\right) \square \sum_{i=1}^{l}\left(Var\left(C_i\right)\left(\frac{\left(1+\bar{R}\right)}{\bar{e}}\right)^2 + Var\left(\hat{\bar{R}}\right)\left(\frac{C_i}{\bar{e}}\right)^2 + Var\left(\hat{\bar{e}}\right)\left(\frac{C_i\left(1+\bar{R}\right)}{\bar{e}^2}\right)^2\right).$$

The variance can be simplified by noting through the following manipulation,

$$Var\left(\sum_{i=1}^{l}\hat{M}_i\right) \approx \sum_{i=1}^{l}\left(\frac{Var(C_i)}{C_i}\left(\frac{C_i\left(1+\hat{\bar{R}}\right)}{\hat{\bar{e}}}\right)^2 + \frac{Var\left(\hat{\bar{R}}\right)}{\left(1+\hat{\bar{R}}\right)}\left(\frac{C_i\left(1+\hat{\bar{R}}\right)}{\hat{\bar{e}}}\right)^2 + \frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}}\left(\frac{C_i\left(1+\hat{\bar{R}}\right)}{\hat{\bar{e}}}\right)^2\right) \text{ and}$$

using Eq. (7) gives,

$$Var\left(\sum_{i=1}^{l}\hat{M}_i\right) \approx \sum_{i=1}^{l}\hat{M}_i^2\left(CV^2(C_i)+CV^2\left(1+\hat{\bar{R}}\right)+CV^2\left(\hat{\bar{e}}\right)\right), \tag{23}$$

where the CV is the coefficient of variation, estimated by,

$$CV(x)=\frac{\sqrt{Var(x)}}{x}.$$

The variance of $\hat{M}_j$ is,

$$Var\left(\sum_{j=1}^{k}\hat{M}_j\right) \approx \sum_{j=1}^{k}\left(\frac{Var\left(C_{n(j)}\right)}{\hat{\bar{e}}^2}+\frac{Var\left(C_{d(j)}\right)}{\hat{\bar{e}}^2}+\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^4}\right). \tag{24}$$

Noting that $Cov\left(C_{j(d)},C_{j(n)}\right)=0$, then $Var\left(C_{n(j)}+C_{d(j)}\right)=Var\left(C_{n(j)}\right)+Var\left(C_{d(j)}\right)$, thus Eq. (24) can be re-written as,

$$Var\left(\sum_{j=1}^{k}\hat{M}_j\right) \approx \sum_{j=1}^{k}\left(\frac{Var\left(C_{n(j)}+C_{d(j)}\right)}{\left(C_{n(j)}+C_{d(j)}\right)^2}\cdot\frac{\left(C_{n(j)}+C_{d(j)}\right)^2}{\hat{\bar{e}}^2}+\frac{Var\left(\hat{\bar{e}}\right)\left(C_{n(j)}+C_{d(j)}\right)^2}{\hat{\bar{e}}^4}\right),$$

or,

$$Var\left(\sum_{j=1}^{k}\hat{M}_j\right) \approx \sum_{j=1}^{k}\hat{M}_j^2\left(CV^2\left(C_{n(j)}+C_{d(j)}\right)+CV^2\left(\hat{\bar{e}}\right)\right). \tag{25}$$

The variance of total seasonal out-migration, $\hat{M}$ is,

$$\begin{aligned}Var\left(\hat{M}\right)=&\sum_{i=1}^{l}\hat{M}_i^2\left(CV^2(C_i)+CV^2\left(1+\hat{\bar{R}}\right)+CV^2\left(\hat{\bar{e}}\right)\right)\\&+\sum_{j=1}^{k}\hat{M}_j^2\left(CV^2\left(C_{n(j)}+C_{d(j)}\right)+CV^2\left(\hat{\bar{e}}\right)\right)\end{aligned}, \tag{26}$$

with estimated variance,

$$\begin{aligned}Var\left(\hat{M}\right)=&\sum_{i=1}^{l}\hat{M}_i^2\left(\widehat{CV}^2(C_i)+\widehat{CV}^2\left(1+\hat{\bar{R}}\right)+\widehat{CV}^2\left(\hat{\bar{e}}\right)\right)\\&+\sum_{j=1}^{k}\hat{M}_j^2\left(\widehat{CV}^2\left(C_{n(j)}+C_{d(j)}\right)+\widehat{CV}^2\left(\hat{\bar{e}}\right)\right)\end{aligned}. \tag{27}$$

The coefficient of variation for $\hat{\bar{R}}$ and $\hat{\bar{e}}$ can be estimated using the empirical variance of the estimates, or $\hat{V}ar\left(\hat{\bar{R}}\right)=\frac{\sum_{i=1}^{n}\left(R_i-\bar{R}\right)^2}{n(n-1)}$, and $\hat{V}ar\left(\hat{\bar{e}}\right)=\frac{\sum_{i=1}^{n}\left(e_i-\hat{\bar{e}}\right)^2}{n(n-1)}$. The CV of both C_i and $\left(C_{j(d)}+C_{j(n)}\right)$ are estimated using the binomial sampling variance, written as, $Var\left(C_i\right)=\hat{M}_i\hat{\bar{e}}\left(1-\hat{\bar{e}}\right)$, and $Var\left(C_{j(d)}+C_{j(n)}\right)=\hat{M}_j\hat{\bar{e}}\left(1-\hat{\bar{e}}\right)$, where $\hat{M}_j$ is the out-migration estimate for the j^{th} day.

This program receives Federal financial assistance from the U.S. Fish and Wildlife Service Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972. The U.S. Department of the Interior and its bureaus prohibit discrimination on the bases of race, color, national origin, age, disability and sex (in educational programs). If you believe that you have been discriminated against in any program, activity or facility, please write to:

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