2009 Smolt Trap Results

Lummi Indian Business Council
Lummi Natural Resources
Harvest Management Division

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Executive Summary

The data obtained during 2009 from the Lummi screwtrap indicated that 206,231 wild-origin zero-age Chinook, 401,559 wild-origin yearling coho, and wild-origin 31,663 steelhead smolts outmigrated past the trap site. Compared to outmigration estimates for recent years, the wild-origin zero-age Chinook outmigration estimate for 2009 is an intermediate value, while the yearling coho outmigration estimate for 2009 is the second lowest on record. No comparisons to previous years could be made for steelhead smolts due to methodological problems. Absolute production estimates could not be determined for other species. However, the relative abundance of chum smolts was the lowest recorded to-date. In total, 23 species of finfish and invertebrates were captured during the 2009 season.

Handling mortality rates from trap operations were typically negligible for most species encountered. However, the highest mortality rates were 0.7% for chum smolts, and 0.5% for wild-origin zero-age Chinook smolts handled during sampling. These mortality figures include smolts that were probably dead on arrival, smolts that were found in the gut of other fish, and smolts that died due to trauma caused by debris or handling.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

Lummi Natural Resources has operated a rotary-screw smolt trap (Trap) in the lower mainstem of the Nooksack River at Hovander Park near Ferndale since 1994. The goals of the Trap sampling program are to develop accurate estimates of the annual production of outmigrating wild-origin salmon fry and smolts. The emphasis is to quantify wild Chinook fry production for the endangered North Fork and South Fork stocks, but secondary objectives include stock assessment for other native salmonids such as coho, chum, pink, sockeye, steelhead, cutthroat, and bull trout.

A rotary-screw smolt trap is a barge-mounted sampling device that has a cone-shaped entrance that is lowered into the top of the water column and which faces upstream. The force of the flowing water continuously turns the cone, and internal vanes direct any fish that enter the trap into a screened holding area, known as the live box, where they can be caught using dip nets to be processed by the attending field crew.

Rotary-screw traps only sample a small proportion of the water column when they are being used and it is therefore not possible to count every fish that passes the trap site. As a result, the data for most species can only be analyzed to ascertain differences in the relative catch rates over time. However, if the catch efficiency of the trap can be quantified it is possible to extrapolate the trap catches to estimate the total number of fish passing by the trap site.

Data analyses of catch data from the Lummi screwtrap have been previously conducted from 2002 to 2008 (Dolphin 2008) to enumerate Chinook fry and coho yearling outmigrants passing downstream past the Trap site. The 2009 season was the fifth year since trap operations began in 1994 that virtually 100% of hatchery-released age-zero Chinook were marked and could be reliably separated from wild-origin Chinook.

This year a total of 1,054,500 zero-age Chinook were released upstream from the Trap site. Of these, it is estimated that only 4,038 released Chinook were externally unmarked, which represents just 0.38% of the total. The remainder either had the adipose fin clipped, or a coded wire tag implanted, or both.

This report considers data collected from December 2008 through to October 7, 2009 and aims to report the results of the 2009 sampling season, summarize the main findings, and compare these results to previous data (where available) for Chinook fry (age 0+) and Coho smolts (age 1+).

2.0 Methods

2.1 Field Methods

The full methodology for the operation of the smolt trap is not provided in this report but interested readers are referred to Conrad & MacKay (2000) for a full description of the site, sampling apparatus, and field protocols. Sets conducted since 2002 are also stratified according to daylight status. Dawn sets occur during the 2 hours following the morning civil twilight. Dusk sets take place during the 2-hours prior to evening civil twilight. Day sets begin at the end of the Dawn period and end at the start of the Duck period. Night sets take place after the Dusk period and prior to the Dawn period.

2.2 Trap Operating Schedule

From 1994 through 2002 the Trap was operated so as to achieve one 6-hour set every 2 – 3 days during the main outmigration time window for zero-age Chinook (approximately May – June). The specific timing of these sets was determined randomly. Outside of the main time window for Chinook outmigration, the Trap was operated much less frequently. Over time, the number of months during which the Trap was operated increased as zero-age Chinook were discovered to be present outside of the limits that were previously thought to define the outmigration period for zero-age Chinook. Starting in 1999, some additional nighttime effort was added to the schedule to supplement the sampling program.

In 2002, the operating schedule for the Trap was reviewed. To provide additional information about diurnal patterns in catch rate, a series of 24-hour sampling efforts were initiated in addition to the existing sampling schedule. Each of these time periods was subdivided into 2-hour sets.

At the end of the 2002 season, a 3-level nested Analysis of Variance (ANOVA) was conducted to determine whether between-month, between-week, between-day, or within-day differences in set timing best explained the variance in catch rate (Dolphin 2002). The ANOVA results indicated that most of the variability was best explained by between-week differences in set timing. Using the procedure outlined in Sokal & Rohlf (1981) for optimizing sample design based on the variances calculated for each level of nested ANOVAs, a table of relative sampling efficiencies was calculated for the possible sampling schedule permutations that could occur using 2-hour sets. The table of relative sampling efficiencies is presented in Table 2.1, and all values shown are relative to a sampling schedule of 6 hours sampled every 48 hours (the primary schedule used from 1994-2002 sampling).

The outcome of the operating schedule review was that, from the 2003 season onward, a net increase in overall effort was desirable, particularly during the peak outmigration window for zero-age Chinook outmigrants. Additionally, fishing effort was divided into 2-hour sets and stratified according to daylight conditions: twilight (dawn and dusk), day, and night. Because there appeared to be useful within-day correlations between catch rates based on daylight conditions, and the highest variance in catch rates occurred at the within-week time scale, it was preferred to distribute the available effort so as to have fewer sets taking place on more days, rather than having more sets taking place on fewer days.

Table 2.1. Relative efficiency of potential sampling schedules for sampling zero-age Chinook outmigrants

	Nº of 2-3 hour Samples taken per day											
	1	2	3	4	5	6	7	8	9	10	11	12
7 days per week	71%	138%	200%	259%	314%	367%	416%	463%	507%	550%	590%	628%
6 days per week	61%	118%	171%	222%	269%	314%	357%	397%	435%	471%	505%	538%
5 days per week	51%	98%	143%	185%	224%	262%	297%	331%	362%	393%	421%	449%
4 days per week	41%	79%	114%	148%	180%	209%	238%	265%	290%	314%	337%	359%
Every other day	35%	69%	100%	129%	157%	183%	208%	231%	254%	275%	295%	314%
3 days per week	30%	59%	86%	111%	135%	157%	178%	198%	217%	236%	253%	269%
2 days per week	20%	39%	57%	74%	90%	105%	119%	132%	145%	157%	168%	179%
One day per week	10%	20%	29%	37%	45%	52%	59%	66%	72%	79%	84%	90%

Figure 2.1 shows the total number of hours fished by the Trap versus sampling season, as well as the total number of hours fished during the main zero-age Chinook outmigration window (May and June) versus sampling season. Overall, Trap effort subsequent to the review has increased by 62% compared to the three years prior to the review, and Trap effort during the critical May/June months has increased by 105%.

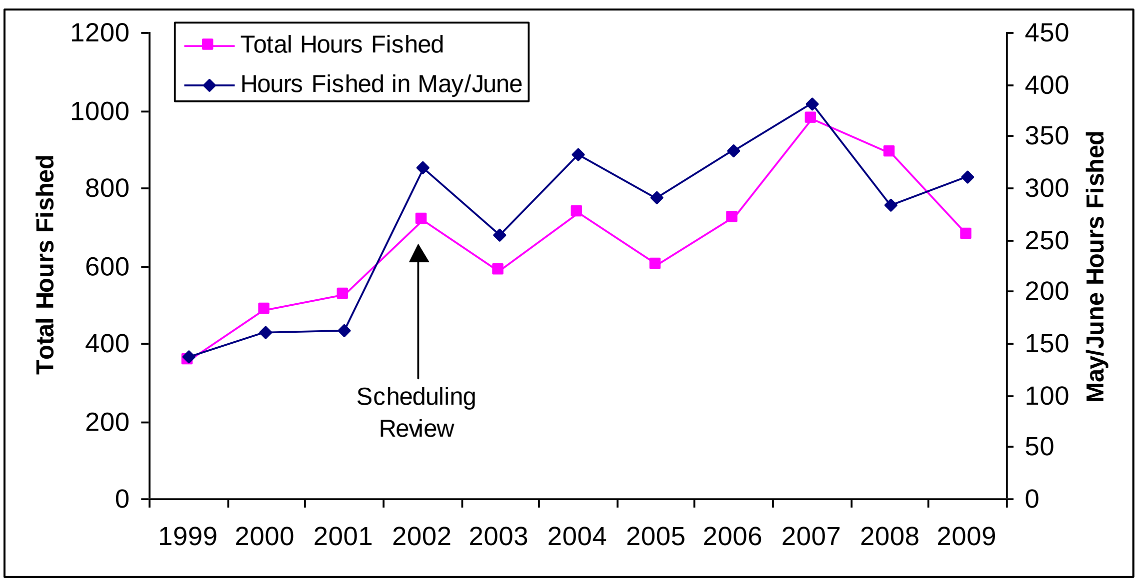
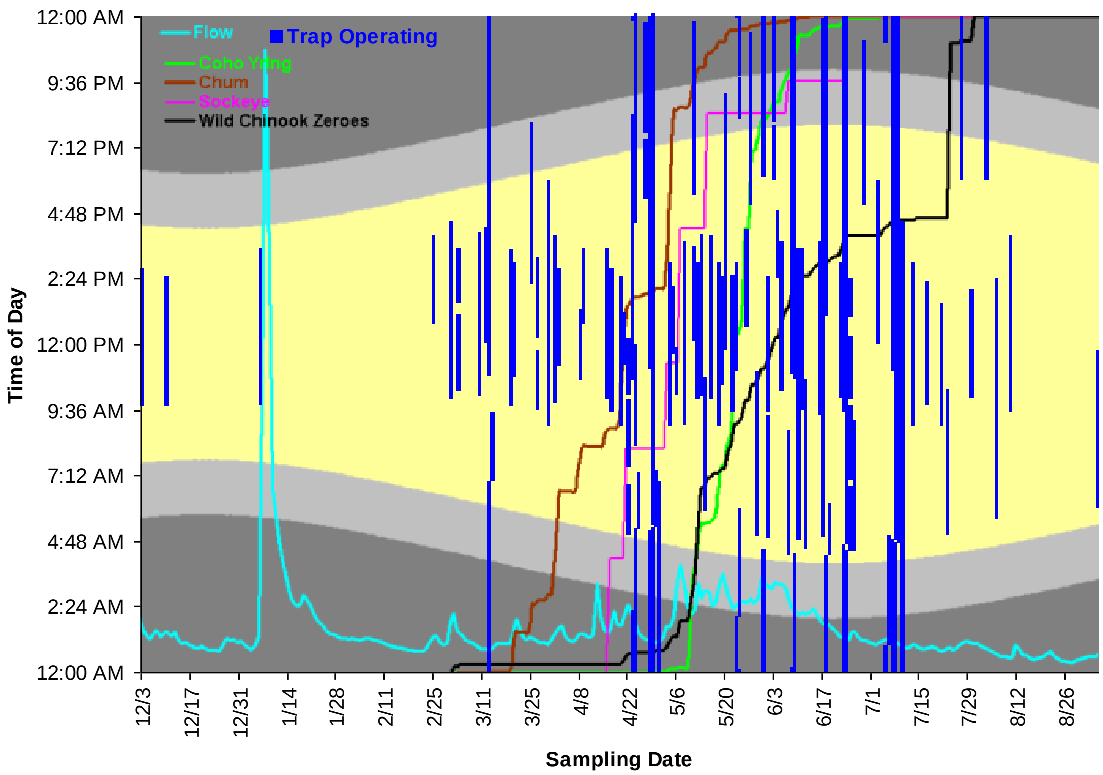


Figure 2.1. Comparison of Trap Effort Versus Sampling Season

In the 2009 season the screwtrap was operated from December 3, 2008 through to September 4, 2009, although sampling intensity was highest from April through July (Figure 2.2). The average monthly relative efficiency of the 2009 sampling schedule is shown in Figure 2.3. In total, the Trap was operated on 88 days during the 2009 season.



Trap operating hours (dark blue) in 2009 superimposed on a background of daylight (yellow area), twilight (light gray area), and night (dark gray area), relative river flow at Ferndale (light blue line),and cumulative catch curves for unmarked Chinook zero-age smolts (black line), coho yearling smolts (green line), chum fry (brown line), and sockeye salmon fry (pink line).

Figure 2.2. Trap Operating Hours During the 2009 Season

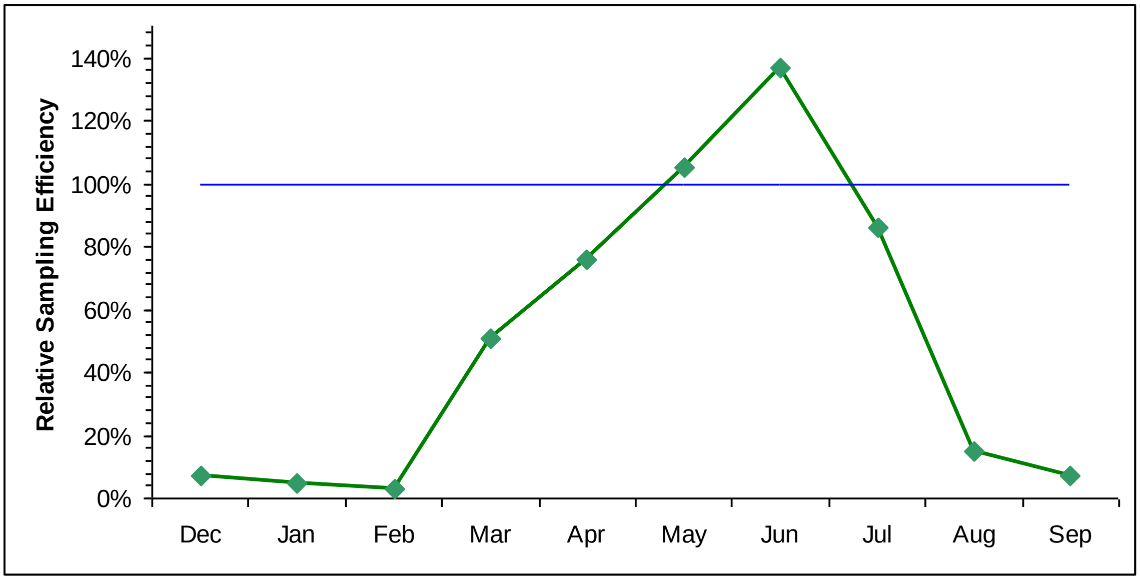


Figure 2.3. Relative Sampling Efficiency of Trap Schedule During the 2009 Season

2.3 Data Analysis Methods

2.3.1 Constructing Time Series

It is not possible to operate the Trap continuously throughout the year due to logistical constraints. As a consequence, there are gaps in the season when no catch rate data is available. To fill these gaps, linear interpolation is used to determine the missing values using the results from the nearest dates for which data is available.

The method used to achieve a complete time-series of catch rate data has two stages (Figure 2.4).

Catch Rates With Gaps in Sequence

	Day1	Day2	Day3	Day4	Day5
Dawn	9	-	-	-	-
Day	5	-	15	-	1
Dusk	-	-	6	-	0
Night	-	-	12	-	-

A. ➔Extrapolate Within Day

	Day1	Day2	Day3	Day4	Day5
Dawn	9	-	11	-	1
Day	5	-	15	-	1
Dusk	6	-	6	-	0
Night	8	-	12	-	2

B. ➔Interpolate Between Days

	Day1	Day2	Day3	Day4	Day5
Dawn	9	10	11	6	1
Day	5	10	15	8	1
Dusk	6	6	6	3	0
Night	8	10	12	7	2

Figure 2.4. Hypothetical Example Showing Time Series Generation Process

In the first stage, the catch rate results are extrapolated to predict the catch rates for daylight strata that were not sampled during a calendar date when the Trap was in operation. To achieve this, a linear regression is calculated for paired catch rate data from sets that were conducted during different daylight strata but within the same 24 hour time period, and the slope of the regression is used to predict the catch rates for the unsampled portions of days (Figure 2.4 A).

The second stage is to estimate the catch rates for days when the Trap was not in operation at all (Figure 2.4 B). To achieve this, the catch rates for each daylight stratum are linearly interpolated between the dates when the trap was in operation.

To determine the average catch rate estimate for each calendar date, the estimated catch rates for each daylight stratum on that date are averaged. The method used to average the catch rates weights the final result by the proportion of time represented by each daylight condition on that date (Figure 2.5). This ensures that for days during the middle of summer when the photoperiod is longest, the daytime catch rates are weighted more heavily than during the spring when the photoperiod is much shorter. Dawn and Dusk are each assumed to always be 2 hours long.

→Calculate Weighted Average					
	Day1	**Day2**	**Day3**	**Day4**	**Day5**
Photoperiod	10	10.2	10.4	10.6	10.8
Average*	**6.9**	**9.7**	**12.5**	**6.9**	**1.4**
	Weighting Used				
Dawn	0.08	0.08	0.08	0.08	0.08
Day	0.33	0.34	0.35	0.36	0.37
Dusk	0.08	0.08	0.08	0.08	0.08
Night	0.50	0.49	0.48	0.48	0.47

Figure 2.5. Calculating Average Daily Catch Rate Weighted by Photoperiod for Data Shown in Figure 2.4

2.3.2 Estimating Trap Efficiency

Trap catch efficiency (CE) is the percentage of fish passing by the Trap site that are caught in the Trap. The catch efficiency of the Trap is assumed to vary according to environmental conditions such as the clarity of water and river flow, as well as according to differences amongst fish such as size and behavior. Environmental conditions and the size and behavior of fishes can vary over time, which means that the catch efficiency of the Trap would ideally be measured over short time periods during which environmental conditions are relatively constant.

Direct measures of Trap CE were made in 2002 and 2003 using groups of 700 - 1000 marked hatchery-origin Chinook or chum smolts that were released into the thalweg of the river approximately one mile upstream from the Trap site (Michael McKay, Unpublished Data). Following the release of each group, the Trap was fished continuously for 24-hours and the total number of marked fish recovered during that time was determined. All fish from the marked groups were assumed to have moved downstream at the end of 24-hours after release. The measured recapture rates from these catch efficiency trials ranged from 0.13% to 5.62%. However the observed relationships between the catch efficiency of the trap and water clarity (Figure 2.6) and with river flow (Figure 2.7) were found to be too variable to be used to predict catch efficiency using these factors.

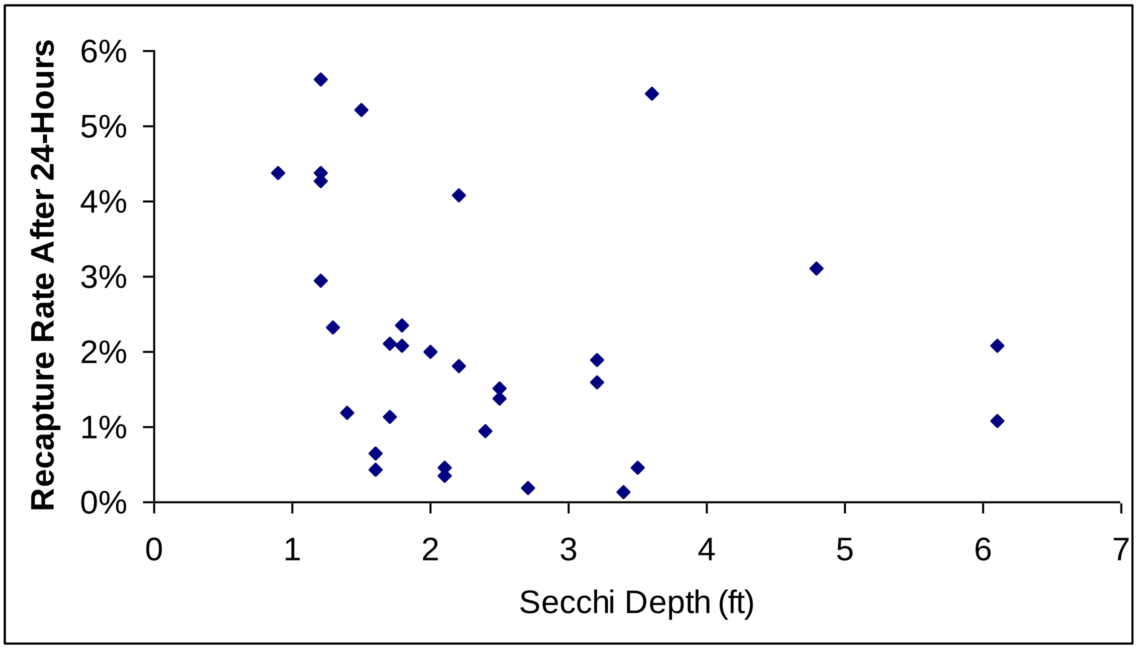


Figure 2.6. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus Water Clarity (Secchi-Depth)

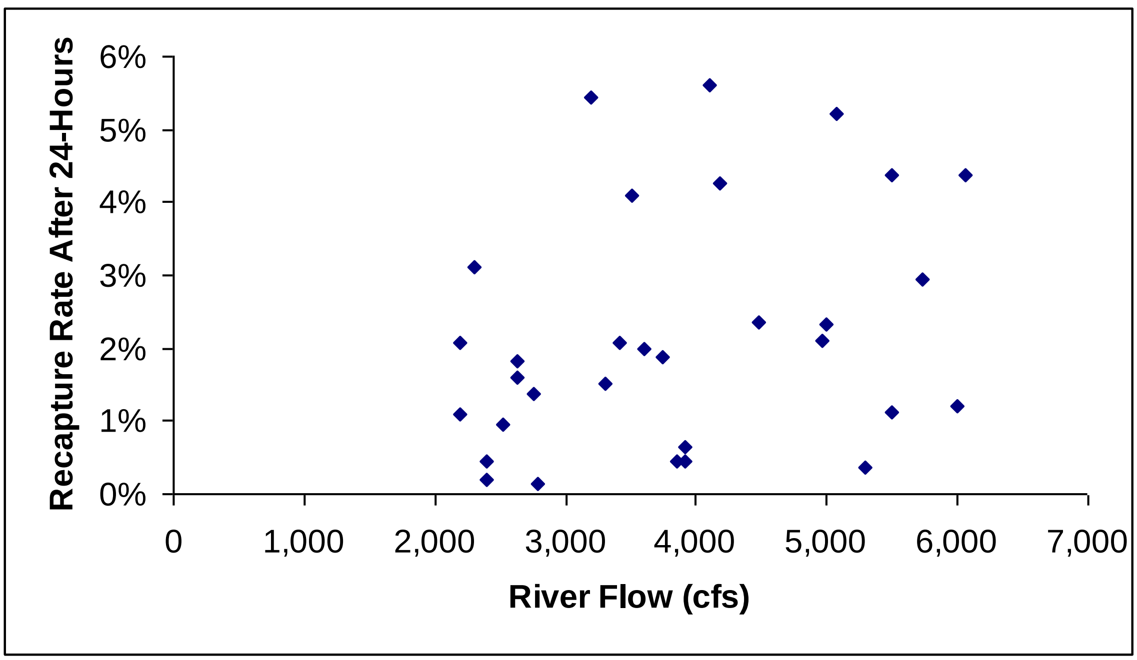


Figure 2.7. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus River Flow

Further catch efficiency trials were abandoned because the catch efficiency results from the trials did not appear to provide reliable predictive relationships based on environmental conditions, and also because newly released and highly stressed hatchery-origin fry probably do not behave similarly to wild-origin fish or hatchery-origin fry that have become accustomed to riverine conditions over a longer period of time.

Although the short-term trials using recently released fry were deemed to be unsuccessful at documenting real-time relationships between catch efficiency and environmental parameters, the presence of large groups of marked hatchery-origin fry in the river allows estimates to be made of the average catch efficiency for each season that the Trap is fished.

The number of marked fish that are caught in the Trap each year is a function of both the catch efficiency of the Trap and the amount of time that the trap is actually fishing while marked fish are passing by the Trap site. The outmigration period is assumed to begin when the first marked fish is caught in the Trap and to end when the last marked fish is caught in the trap. By calculating the proportion of the outmigration period that the Trap was actively sampling, it is possible to extrapolate from the number of marked fish that were caught in the Trap to determine what the recapture rate would have been had the Trap been fishing continuously for the entire period of time. This extrapolation assumes that the number of marked fish caught has a linear relationship with the proportion of time that was sampled, and also that no marked fish would have been caught if no sampling effort had been made during that time. For example, Figure 2.8 shows the assumed relationship between recapture rate and the percentage of the outmigration period sampled based on a hypothetical season where the recapture rate of marked fish released into the river was 0.2% and 25% of the outmigration period was actively fished. In this scenario, the seasonal catch efficiency would be calculated as:
0.2% / (25% / 100%) = 0.8%

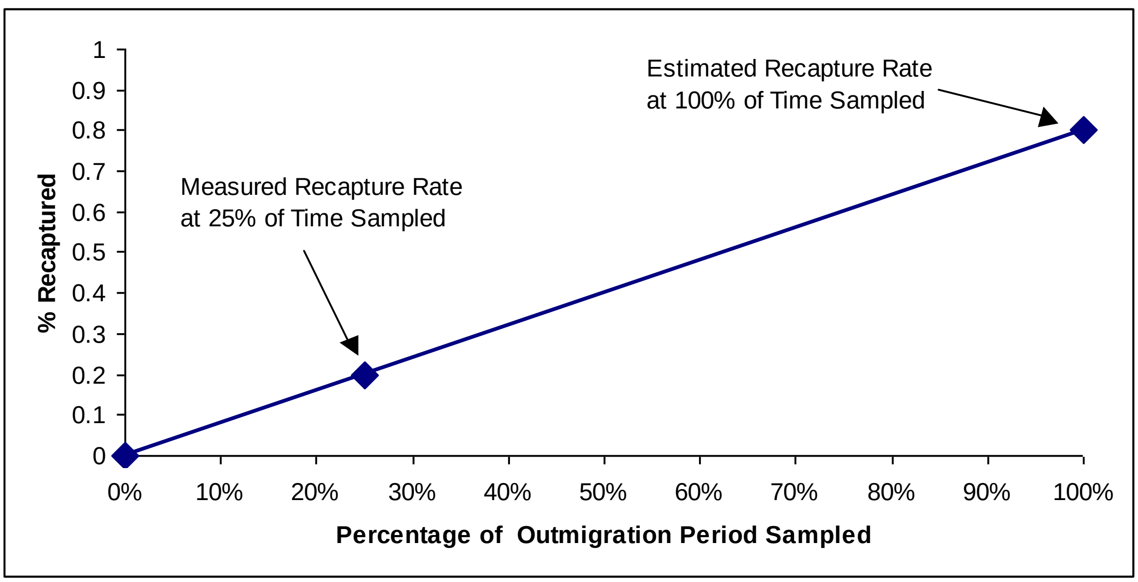


Figure 2.8. Hypothetical Example of Estimating Seasonal Trap Catch Efficiency

After multiple seasons of sampling effort, the overall average catch efficiency for the Trap can be calculated by averaging the seasonal catch efficiency estimates.

Seasonal estimates of catch efficiency cannot be directly related to environmental factors, such as water clarity or flow, because these vary over much shorter time scales. As a result, the catch efficiency for any particular set cannot be altered to reflect environmental conditions present for that set. This limitation means that a significant bias may be present when converting catch rates to outmigration rates if the seasonal catch efficiency differs significantly from the actual catch rate on days where high catch rates are observed.

2.3.3 Production Estimates

Wherever possible, the estimated number of smolts that outmigrate each year is calculated using two methods: a Peterson Mark-Recapture model and a time-series/catch efficiency based model.

Peterson (Mark-Recapture) Model

The Peterson mark-recapture model (Ricker 1975) is calculated using the equation:

$$N = \frac{(M+1)(C+1)}{R+1}$$

Where N represents the total number of fish passing the Trap site; M represents the total number of marked fish released upstream from the Trap; C represents the total number of fish caught by the trap; and R represents the total number of marked fish caught in the trap.

This estimate has a variance that can be estimated using the equation:

$$\mathrm{var}(N) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)(R+1)(R+2)}$$

This model assumes that:

1. The population is closed (N is constant)
2. All individuals have the same probability of capture;
3. Marked fish have the same catchability as unmarked fish
4. Each fish has an equal chance of being caught
5. Marked fish do not lose their marks before recapture
6. All marks are detected on recapture

It is likely that the closed population assumption is not valid because some marked fish released upstream from the smolt trap may die before reaching the trap site, or otherwise not outmigrate during the sampling season. However, mark-recapture models that do not assume closed populations (e.g., Jolly-Seber) require multiple sampling events to be conducted for the population. In this application, the multiple sample requirement would mean that a minimum of 2 additional smolt traps would also need to be operated in the mainstem of the Nooksack River, which is not logistically feasible given current program resources.

Time Series/Constant Catch Efficiency (CCE) Model

The CCE model uses an estimate of the average Trap catch efficiency, calculated by averaging the seasonal catch efficiency estimates for several years, in combination with the interpolated time series of catch rates to estimate the total number of marked and unmarked fish outmigrating past the Trap each day. The daily production estimates are summed to produce the yearly production estimates. The resulting estimates for marked and unmarked fish are both scaled to ensure that the number of marked fish matches the number of marked fish that were released.

2.3.4 Index of Abundance

For some groups of fishes there is no suitable catch efficiency data to allow observed catch rates to be extrapolated to absolute numbers of fish outmigrating past the Trap site. In these circumstances an alternative metric, the Index of Abundance, is calculated to permit between-year comparisons to be made. The Index of Abundance is calculated by summing the average daily catch rates for the relevant group of fishes that were derived from the interpolated time series described in section 2.3.1 of this report. Although this metric does not allow absolute numbers of fish to be determined, it does provide the ability to compare the relative catch rates of fishes between years while allowing for differences in the quantity of sample effort between years. However, because the sampling schedule is designed to be optimal for zero-age Chinook, this metric is vulnerable to distortion caused by comparatively long interpolation intervals for species that outmigrate during periods when the Trap sample effort is comparatively infrequent.

3.0 Chinook Salmon

3.1 Hatchery Release Summary

As shown in Table 3.1 and Figure 3.1, the total number of hatchery-origin zero-age Chinook released upstream from the Trap was 1,054,500 smolts. Of this total, 99.6% (1,050,462 smolts) were externally marked, and 0.4% (4,038 smolts) were estimated to be externally unmarked based on clipping error and coded wire tag (CWT) error rates reported by the hatcheries. The earliest release date was on April 15 2009 and the last release was on June 5 2009.

Table 3.1. Upstream Hatchery Releases of Zero-Age Chinook in 2009

Release Date	Source Hatchery	Location	Marked Chinook Released			Unmarked Chinook Released*	Total Marked Chinook Released	Grand Total Released
			Ad.Clip Only	Ad.Clip & CWT	CWT Only			
4/15/09	Kendall	Kendall Creek	55,832			168	55,832	56,000
5/4/09	Kendall	Kendall Creek	78,526			474	78,526	79,000
5/7/09	Kendall	North Fork Nooksack	5,459	52,970	53,283	88	111,712	111,800
5/12/09	Kendall	Middle Fork	213,280			1,720	213,280	215,000
5/13/09	Kendall	North Fork Nooksack	6,340	57,093	58,464	103	121,897	122,000
5/14/09	Kendall	North Fork Nooksack	7,827	61,056	66,690	127	135,573	135,700
5/26/09	Kendall	Kendall Creek	34,755			245	34,755	35,000
6/5/2009	Lummi Bay	Bertrand Creek	298,887			1,113	298,887	300,000
		Totals	700,906	171,119	178,437	4,038	1,050,462	1,054,500

* Based on reported clipping and CWT error rates

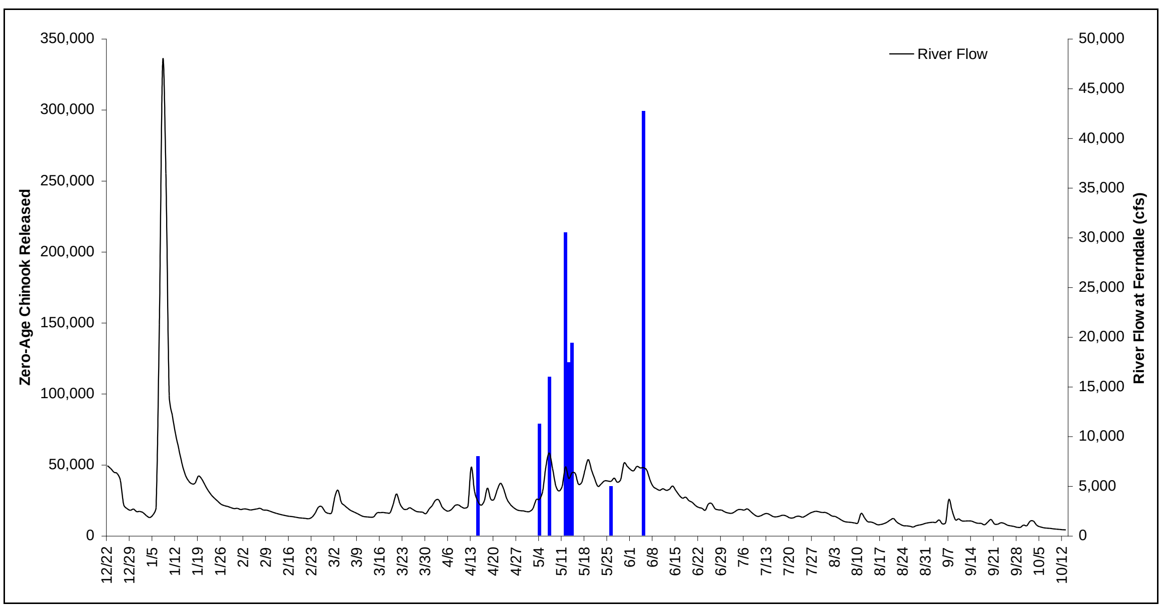


Figure 3.1. Timing and Magnitude of Hatchery Releases of Marked Zero-Age Chinook

3.2 Chinook Catch Totals

The 2009 catch of Chinook outmigrants is shown in Table 3.2 along with the totals for previous sampling years, and showing the total number of hours that the Trap was fished in each year. Prior to 2005, most of the hatchery-origin Chinook smolts were unmarked. From 2005 on, almost all hatchery-released Chinook have been marked either by an adipose fin clip, a coded wire tag, or both of these.

In 2009, the overall catch of unmarked zero-age Chinook was intermediate compared to the previous years, but the number of yearling Chinook outmigrants was the highest to date.

Table 3.2. Catch Totals for Chinook Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	% of Hatchery Chinook Zeroes Released Marked
	Marked	Unmarked	Marked	Unmarked		
2009	5,151	853	0	87	678.1	99.6%
2008	5,851	1,323	0	2	890.6	99.3%
2007	3,688	365	0	23	980.1	99.7%
2006	4,215	1,299	0	24	724.2	99.4%
2005	3,618	885	0	18	601.6	100.0%
2004	2,524	2,444	0	53	738.56	76.8%
2003	2120	5708	0	9	588.76	80.9%
2002	1429	8594	0	66	721.38	35.3%
2001	378	7013	0	19	526.31	12.1%
2000	1567	9080	0	56	487.94	9.4%
1999	76	3973	0	N/R	356	7.6%

Table 3.3 and Table 3.4 shows the correlation coefficients and the slopes for the relationships between observed catch rates of zero-age and yearling Chinook from sets conducted during different daylight conditions within 24 hours, based on Trap data collected from 2005 to 2009. Nocturnal catch rates for zero-age Chinook appear to be approximately 50% higher than daytime catch rates, but no clear trend exists for yearling Chinook.

Table 3.3. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Zero-Age Chinook During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		0.72	0.27	0.47		0.79*	0.36	0.78*
Night	0.79*		0.49	0.38	0.95		0.350	0.74*
Dawn	0.36	0.350		0.68	1.00	0.54		0.68*
Day	0.78*	0.74*	0.68*		1.42	1.55	0.75	
	* Indicates a Statistically Significant Correlation							

Table 3.4. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Yearling Chinook During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		0.22	0.00	0.20		0.41*	N/A	0.49*
Night	0.41*		0.00	0.06	0.88		0.04	0.11
Dawn	N/A	0.04		0.19	1.00	0.00		0.42*
Day	0.49*	0.11	0.42*		1.34	0.45	0.99	
	* Indicates a Statistically Significant Correlation							

3.3 Chinook Smolt Sizes

The average daily fork length of Chinook smolts that were measured at the Trap are shown in Figure 3.2 (grouped by life stage and mark types). Overall, unmarked zero-age Chinook caught in 2009 had an average fork length of 71.2 millimeters and marked zero-age Chinook had an average fork length of 82.1 millimeters.

In general, unmarked zero-age smolts were smaller than marked smolts caught on the same date. There was a strong linear relationship between the fork lengths of unmarked zero-age Chinook smolts versus date. However, the fork lengths of marked smolts appeared to be relatively constant during the first few weeks following release. This may indicate that hatchery-origin smolts have a period of acclimation during which they do not grow significantly. The lengths of marked and unmarked zero-age smolts appeared to exhibit similar rates of increase from the beginning of June onward.

Smolts that were presumed to be yearlings were considerably larger than either marked or unmarked zero-age smolts caught on the same date. Wild-origin yearling Chinook caught in 2009 had an average size of 104.33 millimeters.

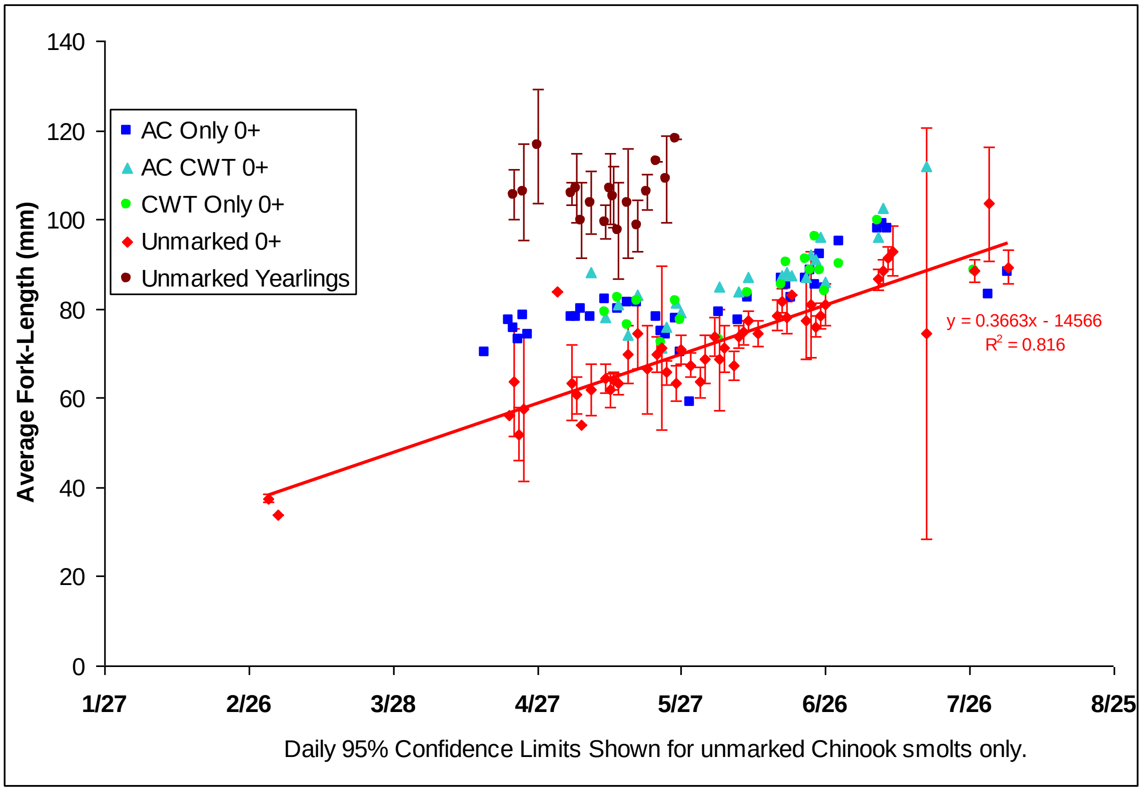


Figure 3.2. Average Daily Fork Lengths for Chinook Smolts Caught During 2009

3.4 Chinook Seasonal Outmigration Timing

The timing of outmigration for unmarked wild smolts in 2009 was within the range observed during previous years (Figure 3.3).

The first unmarked zero-age Chinook smolt was caught in late February and the last unmarked zero-age smolt was caught in early August. In the 2009 sampling season, 90% of unmarked zero-age Chinook outmigrated between May 4th and July 26th, and the 50th percentile occurred on June 22nd. The start of the main outmigration period was delayed by approximately 2 weeks for zero-age smolts, and by approximately 6 weeks for yearling smolts compared to long-term average dates. The median outmigration date was approximately 3 weeks later than average for zero-age Chinook and 11 days later than average for yearling Chinook. The end of the main outmigration period for both zero-age and yearling smolts was within a week of the long-term average dates.

The long-term average for zero-age Chinook outmigration dates excludes the results from the 2006 season due to a lengthy gap in sampling effort early in that season, which required a long period of interpolation based on a single unusually high cpue result that may have significantly skewed the results for that season.

The timing of outmigration for yearling Chinook smolts was relatively late and comparatively brief compared to the patterns observed for most previous years (Figure 3.4). In the 2009 sampling season, 90% of yearlings outmigrated between April 22nd and May 19th, with the 50th percentile date occurring on May 5th. This compares to the long-term average, which indicate that typically 90% of yearlings outmigrate between March 6 and May 10th.

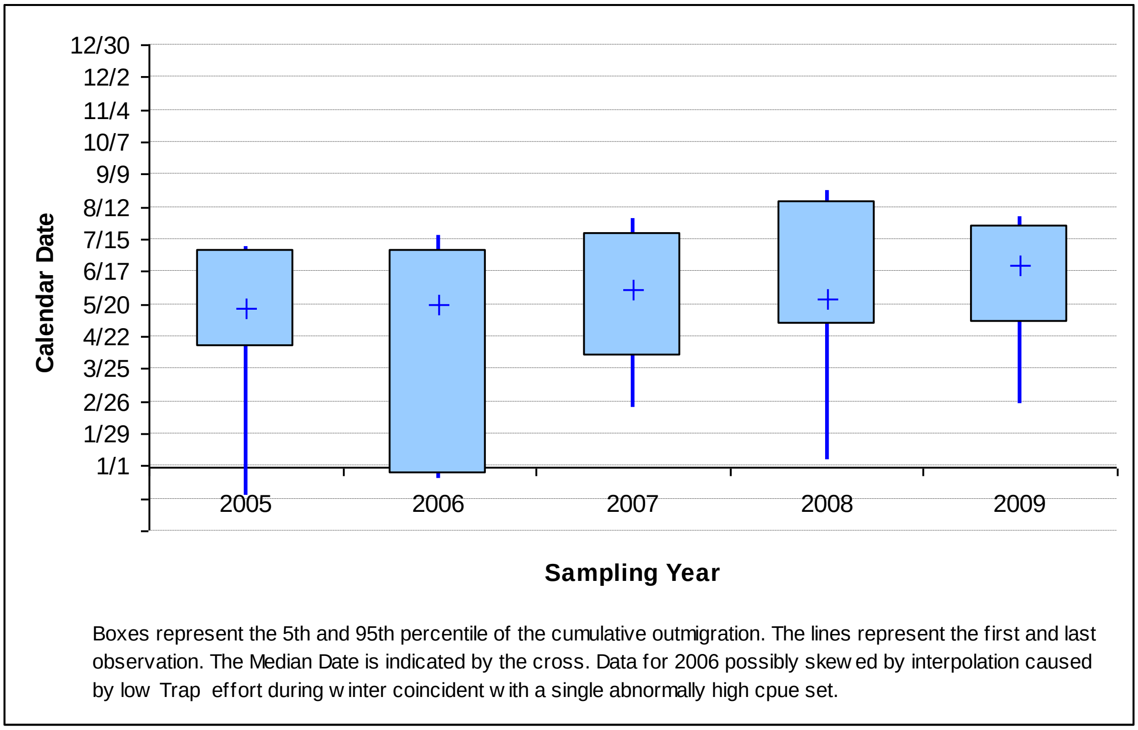


Figure 3.3. Outmigration timing for Unmarked Zero-Age Chinook smolts from 2005 to 2009

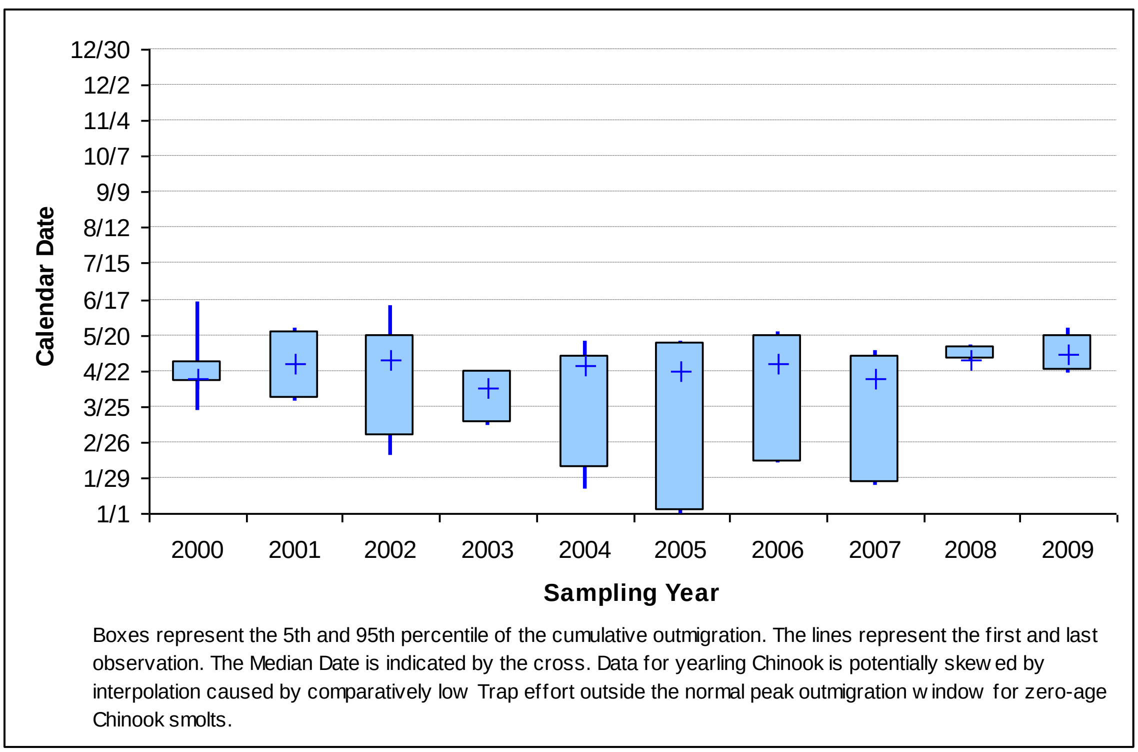


Figure 3.4. Outmigration timing for Unmarked Yearling Chinook smolts from 2000 to 2009

3.5 Zero-Age Chinook Outmigrants

3.5.1 CPUE Time Series for Zero-Age Chinook

Figure 3.5 shows the time series of interpolated hourly catch rates for zero-age Chinook throughout the season.

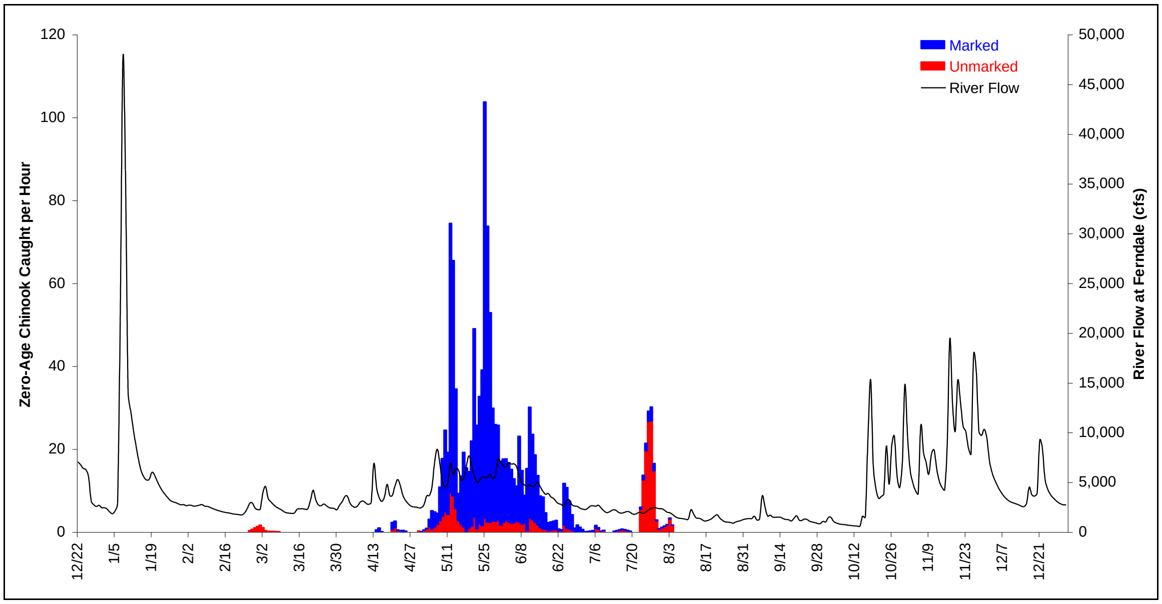


Figure 3.5. Interpolated Catch Per Hour of Zero-Age Chinook Smolts by Date and Mark Status

Aside from a small outmigration event at the beginning of March, unmarked zero-age Chinook began to be caught regularly from the beginning of May through mid-June 2009. From mid-June onwards very few unmarked Chinook were caught until the end of July when another discreet pulse of unmarked Chinook occurred. The highest catch rate of unmarked zero-age Chinook occurred on July 27, 2009.

The longest gap in the Trap sampling schedule during the main outmigration period of unmarked Chinook was 3 days and the average gap between sampling events was 1 day. However, there were two longer sampling gaps of 5 days and 6 days that occurred in early April.

Marked hatchery-origin Chinook outmigrants were first noted in the catch on April 15 2009 and the last marked Chinook was caught on August 5, 2009. The majority of marked Chinook outmigrated between the second week of May and the end of June. The highest catch rate of marked Chinook occurred on May 27, which was approximately 2 weeks after the majority of marked hatchery Chinook were released (May 12 – 14) in the North and Middle forks of the Nooksack River.

The longest gap in sampling during the outmigration period of marked Chinook was 3 days and the average gap between sampling events was 0.8 days.

3.5.2 Zero-Age Chinook Production Estimates in the 2009 Season

Peterson Estimate for Zero-Age Chinook

In the 2009 sampling year, 1,050,462 externally marked zero-age Chinook were released upstream from the Trap site. Of this total, 5,151 were recaptured at the Trap, and a further 853 unmarked zero-age Chinook smolts were also caught (total = 6,004 smolts). The Peterson estimate of total zero-age Chinook passing the Trap site in 2009 is 1,224,385 smolts.

The difference between the Peterson estimate for total smolts and the number of hatchery-origin smolts released in 2009 is assumed to represent the wild-origin production estimate. Total hatchery releases in 2009 were 1,054,500 smolts (includes 4,038 unmarked smolts). For the 2009 sampling season, the Peterson-derived estimate of wild-origin zero-age Chinook is **169,885** smolts. As shown in Figure 3.6, the production estimate for wild-origin zero-age Chinook in 2009 is an intermediate quantity compared to production estimates for previous years.

Note that total production estimates using this model prior to the Trap schedule review were highly variable, and for two of those years were significantly below the known size of the hatchery releases (2000 and 2002). Production estimates subsequent to the Trap schedule review at the end of the 2002 season have not produced estimates lower than the known quantity of hatchery-origin smolts released, and appear to be much more stable.

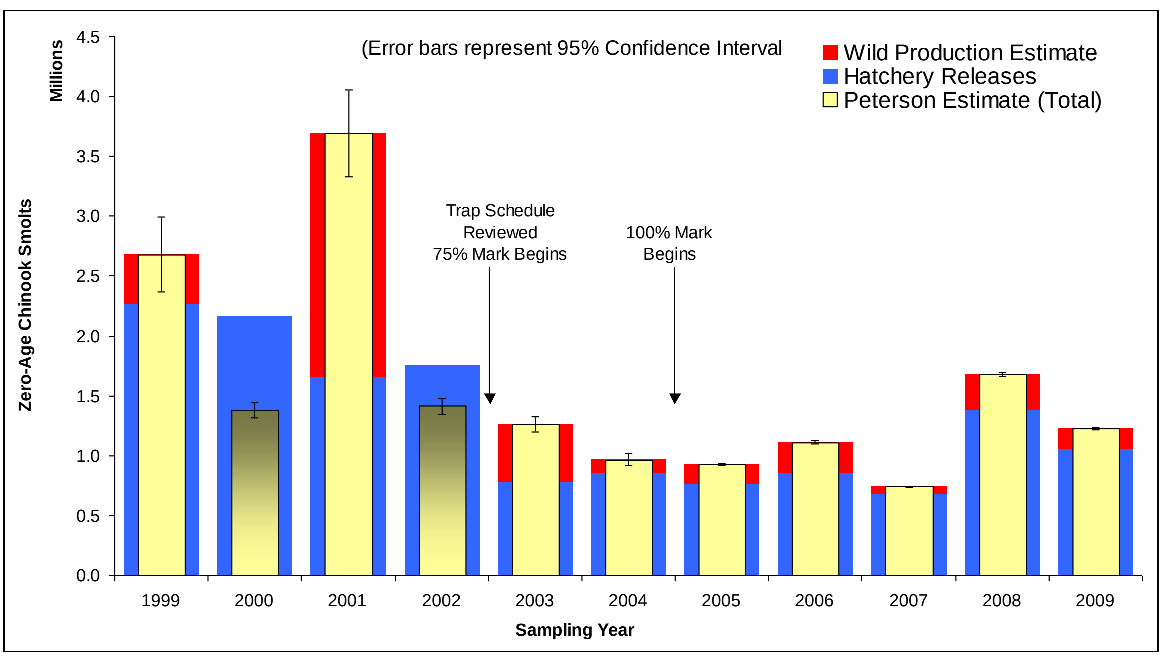


Figure 3.6. Peterson Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Zero-Age Chinook

In the 2009 season, the Trap recaptured 0.49% of the marked Chinook smolts that were released upstream. The Trap was fishing 25.23% of the time that marked Chinook smolts were outmigrating past the Trap site. Assuming that the number of marked smolts recaptured by the Trap would increase linearly with the amount of time fished during this period, then the 2009 season catch efficiency is estimated to have been 1.94% (Figure 3.7). This value is slightly lower than the average seasonal catch efficiency of 2.38%, for the seasons from 1999 to 2009. However, the 2009 seasonal catch efficiency estimate is almost identical to the estimates for the 2006, 2007, and 2008 sampling years (Figure 3.8). The estimate for the 2000 sampling season (10.56%) is excluded as an outlier.

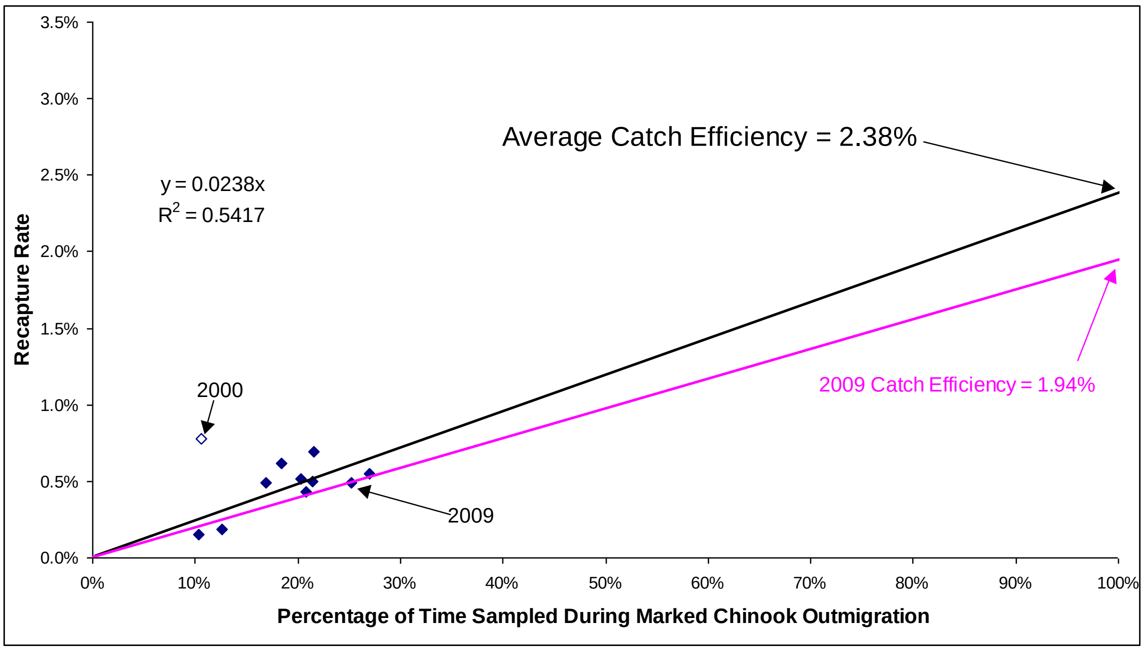


Figure 3.7. Seasonal Trap Catch Efficiency Estimates for Marked Zero-Age Chinook

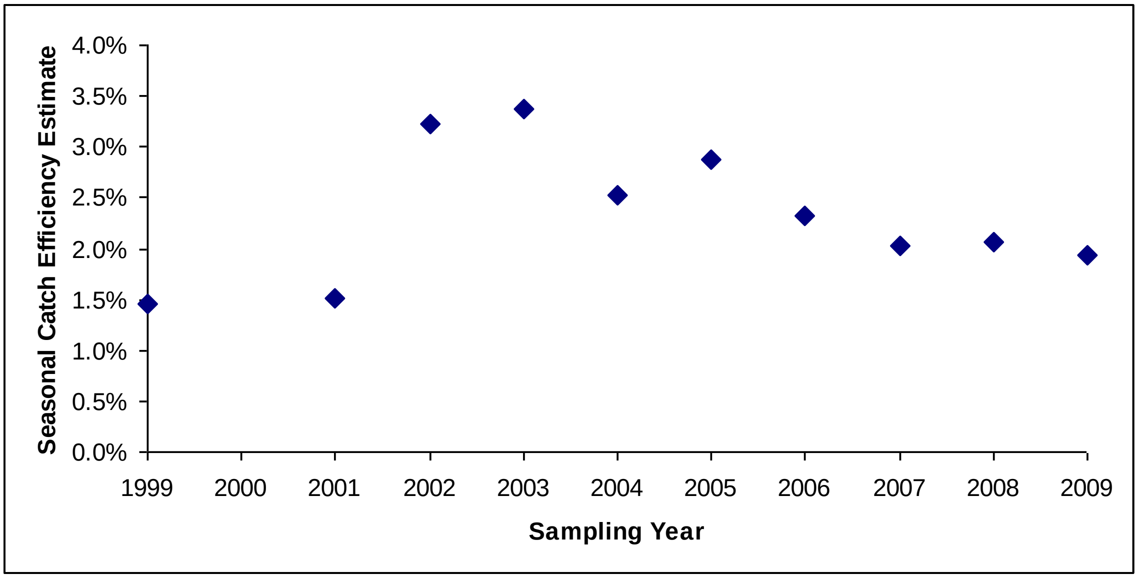


Figure 3.8. Comparison of Seasonal Catch Efficiency Estimates for Chinook over Time

The estimated number of marked and unmarked smolts passing the trap site per day is shown in Figure 3.9. These numbers were derived by using the average seasonal catch efficiency estimate to convert the time series of hourly catch rates shown in Figure 3.5 and multiplying by 24 hours per day.

The total number of smolts estimated to have outmigrated in 2009 was 1,304,195 Zero-age Chinook. This total includes 1,056,226 marked smolts and 247,970 unmarked smolts. The estimate for marked smolts is 0.5% higher than the number of marked smolts released. Assuming that the same is true for unmarked smolts, and removing 4,038 unmarked hatchery-origin smolts from the result, then the CCE-derived wild production estimate for zero-age Chinook is **242,579** smolts.

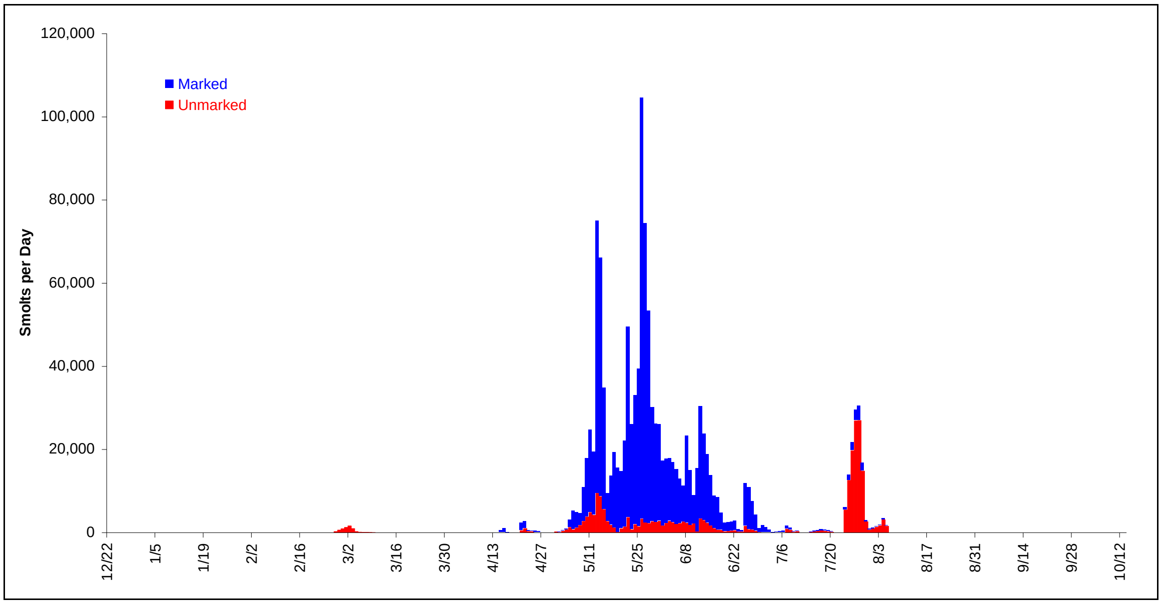


Figure 3.9. Daily Production Estimates for Zero-Age Chinook in 2009

Subsequent to the review of the Trap schedule at the end of the 2002 season, CCE-derived wild-production estimates have ranged from as low as 10,431 smolts in the 2004 sampling season, to as high as 849,771 smolts in the 2003 sampling season. Compared to estimates for previous years, the estimate of 242,579 wild-origin Chinook smolts in 2009 was lower than the average outmigration of 306, 275 smolts.

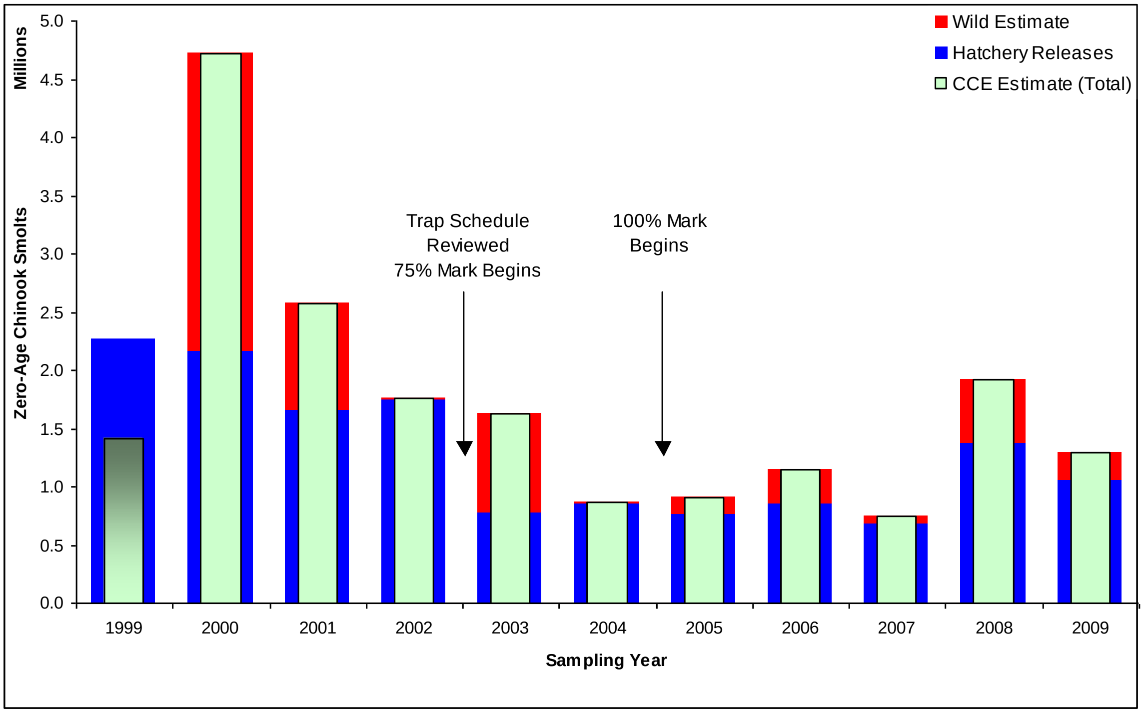


Figure 3.10. CCE Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

Prior to the Trap schedule review, the results for the CCE-model are highly variable, and clearly underestimated the total number of zero-age Chinook in the 1999 season. Accordingly, estimates for these years are not included in evaluations regarding the magnitude of an ‘average’ outmigration.

3.5.3 Between-Year Comparisons for Zero-Age Chinook

The average of the 2 production estimates for wild-origin zero-age Chinook in the 2009 season is **206,231** wild-origin zero-age Chinook smolts.

Both the Peterson and CCE production estimates have produced generally similar results for zero-age Chinook subsequent to the end of the 2002 sampling season (Figure 3.11).

Prior to this time, the Peterson model appeared to provide a more realistic result for the 1999 sampling season, but the CCE model performed somewhat better than the Peterson model in the 2000 and 2002 seasons. Given the large variation between the two estimates for the 2001 season, the wild production estimates for the 1999 to 2002 seasons should be treated with caution.

It is likely that the improvement in the performance of both models subsequent to 2002 is the result of two main factors. The first of these factors is the large increase in the proportion of hatchery-origin smolts that were externally marked, beginning with the 2003 season and improving even further from 2005 onwards. The second factor is likely to have been the result of the scheduling review process, which resulted in additional effort as well as changing the distribution and timing of sets throughout the season.

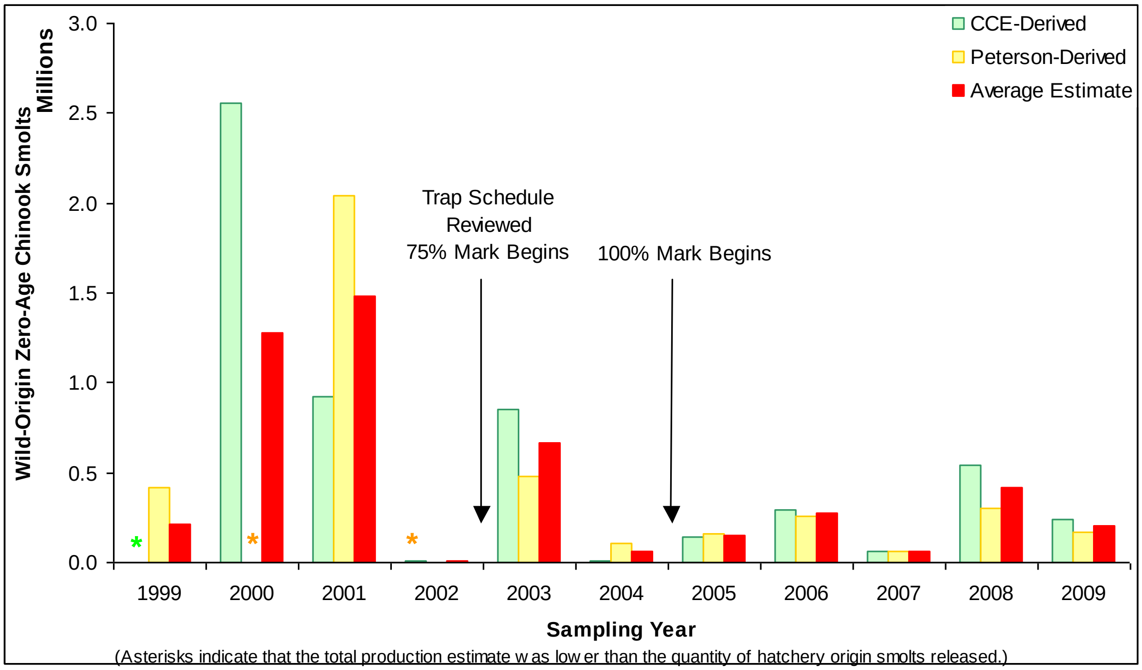


Figure 3.11. Comparison of Wild-Origin Zero-Age Chinook Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

3.6 Yearling Chinook Outmigrants

3.6.1 CPUE Time Series for Yearling Chinook

In total, 87 yearling Chinook were caught between April 22 and May 26, 2009. Figure 3.12 shows the time series of interpolated hourly catch rates for yearling Chinook smolts throughout the 2009 season. The highest observed catch rate for yearling Chinook was 3.8 smolts per hour, which was recorded on May 6, 2009.

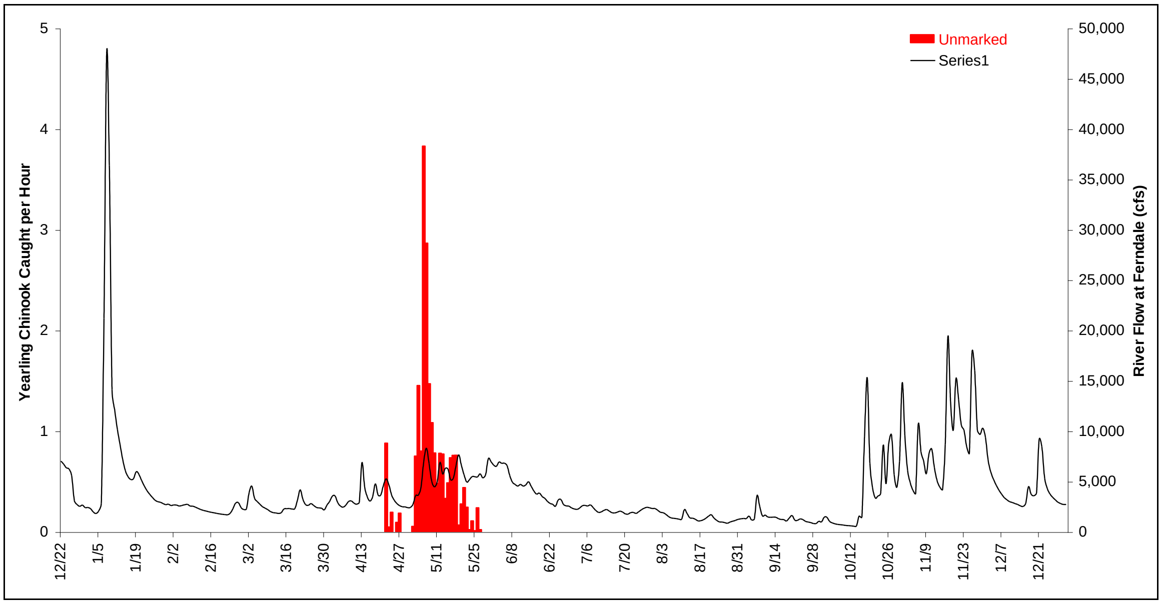


Figure 3.12. Interpolated Catch Per Hour of Yearling Chinook Smolts by Date

3.6.2 Between-Year Comparisons for Yearling Chinook CPUE

Yearling Chinook smolts that outmigrated during the 2009 sampling season are the offspring of adult Chinook that spawned during the summer and fall of 2007 (Brood Year [BY] 2007). The Index of Abundance for yearling Chinook during the 2009 sampling season has a value of 21. This is the second highest Index of Abundance value to date, and is approximately 2.8 times higher than the average Index of Abundance value for the preceding 9 years. Figure 3.13 shows the annual Index of Abundance value for yearling Chinook based on their relevant brood year, along with the production estimate for zero-age Chinook produced during the same brood year but which outmigrated one year earlier than the yearlings. Yearling Chinook that were produced in BY 2008 will not outmigrate until the 2010 sampling season.

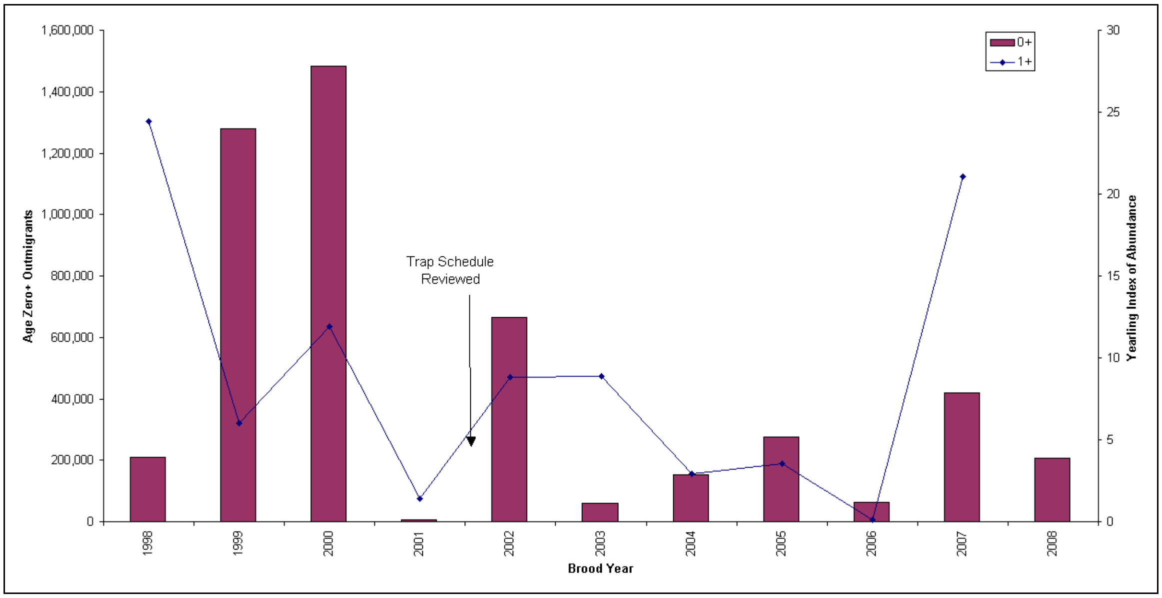


Figure 3.13. Comparison of Relative Zero-Age Production Estimates and Yearling Outmigrant Index of Abundance Based on Brood Year

Because no yearling Chinook are released from hatcheries it has not been possible to empirically measure the catch efficiency of the Trap for Chinook of this size. As a consequence, no valid production estimates can be made. Hypothetically, if the catch efficiency of the Trap for yearling Chinook were the same as the average catch efficiency of the Trap for yearling coho, then the CCE Production estimate for yearling Chinook in 2009 (BY 2007) would be approximately 55,938 smolts.

3.7 Chinook Discussion

The results for the Trap in the 2009 sampling season suggest that, relative to the previous 5 years, the production of wild-origin Chinook smolts from the Nooksack River was moderately successful for zero-age smolts in BY 2008, and surprisingly successful for BY 2007 yearlings. Analyses of data from previous years have suggested the possibility of a link between high river flows during October/November and the number of zero-age smolts outmigrating the following year. Scouring of Chinook redds during these flow events may be the causal mechanism underlying the apparent relationship. The flow conditions during egg incubation for BY 2008 were moderate compared to flows during the fall of other years: in particular 1998, 2003, 2004, and 2006 had potentially damaging flow events that may have adversely impacted Chinook redds. The maximal daily river flow during October/November 2008 was 17,100 cubic feet per second (cfs) at the Ferndale gage (Table 3.5), which occurred in mid-November. However, the largest flow event during the period of time considered in this report occurred in early January of 2009 (47,500 cfs). The fact that such a large event did not appear to adversely impact the production of Chinook smolts is consistent with the theory that redd scour may be a limiting factor for Chinook production, rather than flushing emergent Chinook fry out to sea.

Table 3.5 Comparison of Maximum Daily River Flow at Ferndale by Month and Year to Production Estimates for Zero-Age Chinook and Annual Index of Abundance Values for Yearling Chinook

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Max Jan	23,200	10,300	14,300	4,890	7,640	24,100	13,900	11,700	29,000	16,000	17,700	5,860	47,500
Max Feb	8,470	5,680	9,500	5,160	2,900	27,500	8,210	6,700	5,480	9,510	8,710	4,320	2,890
Max Mar	33,700	8,160	7,180	5,860	5,810	5,760	16,200	6,970	6,400	2,850	23,700	5,090	4,550
Max Apr	10,100	5,730	5,730	13,800	5,100	15,700	7,740	4,040	10,400	5,340	11,800	4,320	6,870
May May	17,700	6,500	10,000	8,390	7,140	9,860	6,150	6,580	5,290	8,850	5,860	15,300	8,310
Max Jun	12,400	4,420	10,600	13,300	7,150	13,100	5,270	5,740	3,070	8,550	7,980	10,100	6,940
Max Jul	15,300	5,300	8,450	4,720	3,190	5,729	2,990	2,970	6,970	4,010	6,570	10,300	2,670
Max Aug	3,230	2,230	6,090	3,600	9,860	2,280	1,940	9,920	1,840	1,730	1,990	10,700	2,220
Max Sep	7,470	1,340	3,350	4,950	2,690	2,490	1,640	9,580	10,600	1,600	2,020	3,600	3,610
Max Oct	13,000	3,560	16,600	9,990	8,790	1,880	32,300	6,340	11,900	2,020	9,610	4,960	15,300
Max Nov	7,700	16,600	19,800	3,290	17,700	13,700	25,400	31,100	7,350	31,800	8,810	17,100	19,400
Max Dec	12,600	21,100	19,100	4,260	19,300	11,100	6,620	22,400	15,900	12,300	19,700	7,080	9,190
		Brood Year											
Wild Production Estimate (0+ Chinook Numbers)			208,723	1,278,838	1,482,803	4,987	666,424	59,216	151,832	275,975	63,088	420,194	206,231
			Zero-Age Migrants										
Yearling Chinook Ind. of Abund.				24.5 Yearling Migrants	6.0	11.9	1.4	8.8	8.9	2.9	3.5	0.1	21.0

Aside from BY 2003, the abundance of outmigrating zero-age and yearling Chinook smolts from each year class have generally followed similar trends subsequent to the Trap schedule review conducted at the end of the 2002 sampling season. This suggests that the number of smolts that remain in the river to outmigrate as yearlings may be directly related to the number of fry that survive the egg incubation period to become fry. The alternative hypothesis, that the number of yearlings is related to the carrying capacity of the river environment, is inconsistent with the pattern seen over the past 5 years. By contrast, trends between zero-age and yearling smolts do not appear to correlate well prior to the Trap schedule review. This is most likely the result of having a lower sampling effort and a suboptimal sampling strategy in place prior to the review, as well as the much lower mark rate of hatchery-origin Chinook prior to the 2003 sampling season.

The seemingly anomalous index of abundance value for yearling Chinook that outmigrated during the 2005 sampling season can be traced to a period of almost a week during early April when no sampling effort occurred, followed by a single very-short set that captured one yearling. The combination of a relatively high catch rate immediately following an extended break in effort resulted in interpolated estimates of daily catch rates for several days that may have over estimated the true catch rate. The trap schedule is optimized for sampling zero-age smolts, which appear to exhibit different outmigration timing to yearlings. Large gaps in the sampling schedule outside of the main outmigration window for zero-age Chinook are likely to present a data interpretation challenge for any groups of fish that exhibit different outmigration timing from zero-age Chinook.

4.0 Coho

4.1 Hatchery Release Summary

As shown in Table 4.1 and in Figure 4.1 the total number of hatchery-origin yearling coho released upstream from the Trap was 1,342,960 smolts. Of this total, 95.6% (1,284,383 smolts) were externally marked with adipose fin clips, and 4.3% (58,259 smolts) were estimated to be externally unmarked based on the clipping error reported by the hatcheries. The earliest release date was on May 8 2009 and the last release was on May 28 2009.

Because hatchery-released coho usually exhibit a very brief outmigration period the number of coho yearlings that can be caught can overwhelm the ability of the Trap crew to process the catch. As a consequence, the crew responds to large influxes by not scanning each coho for coded wire tags to reduce the amount of time required to process the catch. Unfortunately, this means that coho that are not adipose clipped but that do have a coded wire tag cannot be reliably distinguished from wild-origin smolts and for the purposes of this report are considered to be externally unmarked. (This issue does not apply to Chinook as all Chinook caught at the trap are always scanned for coded wire tags.)

Table 4.1 Upstream Hatchery Releases of Yearling Coho in 2009

Release Date	Source Hatchery	Location	Marked Coho Released		Unmarked Coho Released		Total
			AC Only	AC & CWT	CWT Only	No AC * No CWT	
5/8/09	Kendall	Kendall Cr.	216,972	46,319	46,319	351	**309,961**
5/22/09	Skookum	Skookum Cr.	247,009			2,802	**249,811**
5/23/09	Skookum	Skookum Cr.	209,134			2,373	**211,507**
5/24/09	Skookum	Skookum Cr.	200,929			2,280	**203,209**
5/25/09	Skookum	Skookum Cr.	176,700			2,005	**178,705**
5/26/09	Skookum	Skookum Cr.	83,804			951	**84,755**
5/27/09	Skookum	Skookum Cr.	81,356			923	**82,279**
5/28/09	Skookum	Skookum Cr.	22,479			255	**22,734**
		Totals	**1,238,383**	**46,319**	**46,319**	**11,940**	**1,342,960**

* Based on reported clipping and tagging error rates

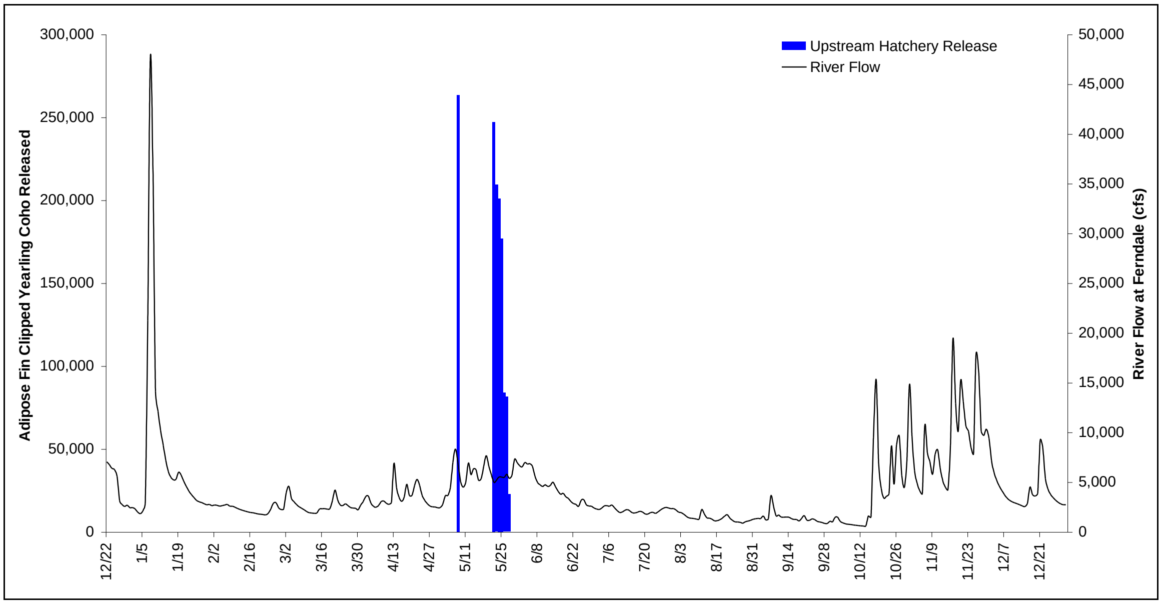


Figure 4.1. Timing and Magnitude of Hatchery Releases of Marked Yearling Coho

4.2 Coho Catch Totals

The 2009 catch of coho outmigrants is shown in Table 4.2 along with the totals for previous sampling years, and showing the total number of hours that the Trap was fished in each year. Prior to 2000, most of the hatchery-origin coho were unmarked. From 2000 on, almost all hatchery-released coho have been marked either by an adipose fin clip, a coded wire tag, or both of these. The number of marked yearling coho caught in the Trap during the 2009 season was the highest on record, and exceeded the previous highest total by 41%. The overall catch of unmarked yearling coho was the third-highest total since the 2000 sampling season.

Table 4.2. Catch Totals for Coho Outmigrants by Year

Sampling	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	% Marked in Released Hatchery Coho
Year	Marked	Unmarked	Marked	Unmarked		
2009	0	10	4,975	1,800	678.1	99.1%
2008	0	18	2,163	694	890.6	94.7%
2007	0	4	1,981	1,633	980.1	90.5%
2006	0	26	2,465	1,919	724.2	89.9%
2005	0	8	1,801	1,687	601.6	96.2%
2004	0	27	1,284	1,614	738.56	96.1%
2003	0	70	2,761	1,295	588.76	96.5%
2002	0	56	3,519	2,462	721.38	93.9%
2001	N/R	N/R	2,136	1,810	526.31	100.0%
2000	N/R	N/R	1,774	1,163	487.94	95.6%
1999	N/R	N/R	76	11,433	356	12.0%

Table 4.3 and Table 4.4 shows the correlation coefficients and the slopes for the relationships between observed catch rates of zero-age and yearling coho from sets conducted during different daylight conditions within 24 hours, based on Trap data collected from 2005 to 2009. Nighttime catch rates of yearling coho tend to be approximately 3 times as high as daytime catch rates, which is consistent with published descriptions of a strongly nocturnal migratory behavior for coho (e.g., Mehan and Siniff, 1962).

Table 4.3. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Zero-Age Coho During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		0.00	1.00	0.70		0.01	N/A	0.93*
Night	0.01		1.00	0.00	0.00		N/A	0.01
Dawn	N/A	N/A		0.15	1.00	0.00		0.57*
Day	0.93*	0.01	0.57*		1.25	0.00	2.19	
	* Indicates a Statistically Significant Correlation (p<0.05)							

Table 4.4. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Yearling Coho During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		2.49	0.84	0.38		0.83*	0.83*	0.78*
Night	0.83*		0.34	0.18	0.29		0.88*	0.70*
Dawn	0.83*	0.88*		0.48	0.87	2.36		0.82*
Day	0.78*	0.70*	0.82*		1.65	3.04	1.45	
	* Indicates a Statistically Significant Correlation (p<0.05)							

4.3 Coho Smolt Sizes

The average daily fork lengths of coho smolts that were measured at the Trap are shown in Figure 4.2 (grouped by life stage and mark status). Unmarked coho yearlings caught in 2009 had an average fork length of 102.8 millimeters. Marked hatchery-origin coho yearlings had an average fork length of 124.9 millimeters. Unmarked zero-age coho had an average fork length of 47.6 millimeters.

In general, unmarked yearling smolts were smaller than marked yearling smolts caught on the same date. There was no clear relationship between the fork lengths of yearling coho smolts versus date, while the size of zero-age coho generally increased over time.

The lengths of unmarked zero-age smolts appeared to remain constant until May, when an increase in size was observable. However, relatively few zero-age coho smolts were encountered during sampling.

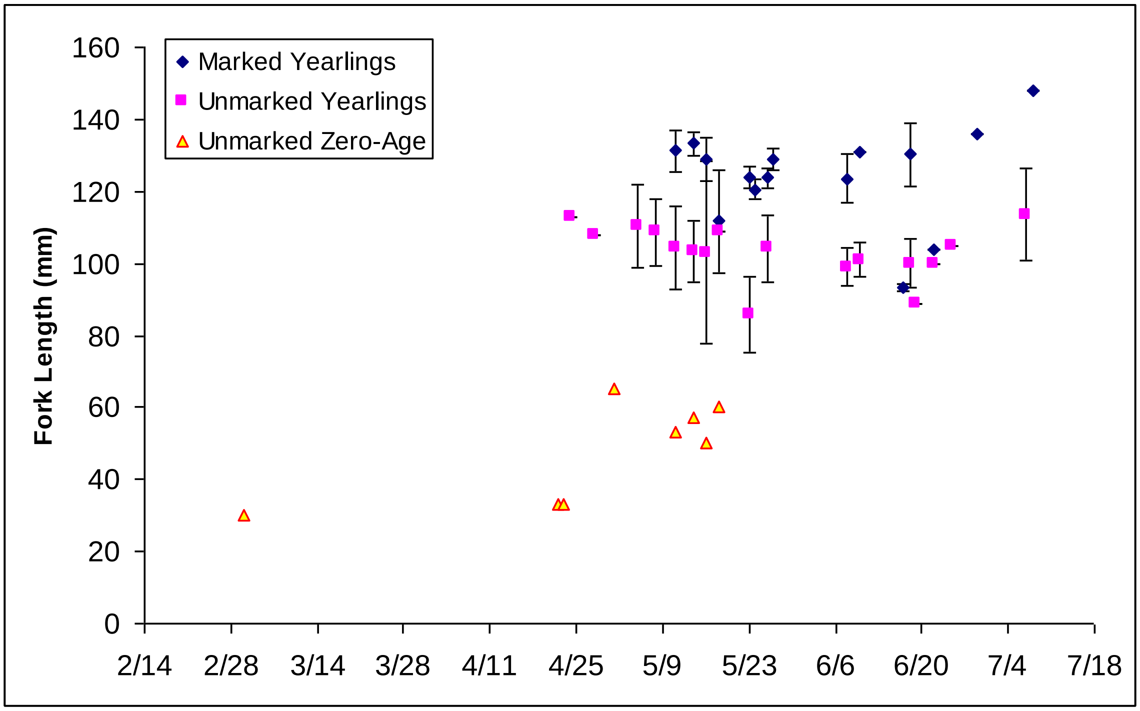
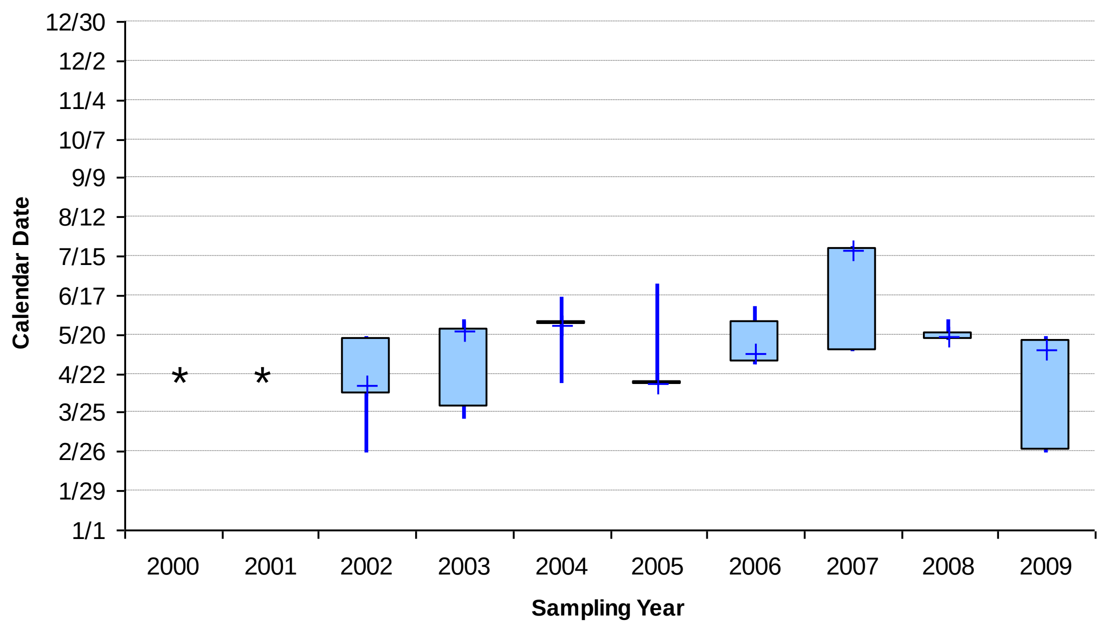


Figure 4.2. Average Daily Fork Lengths for Coho Smolts Caught During 2009

4.4 Coho Seasonal Outmigration Timing

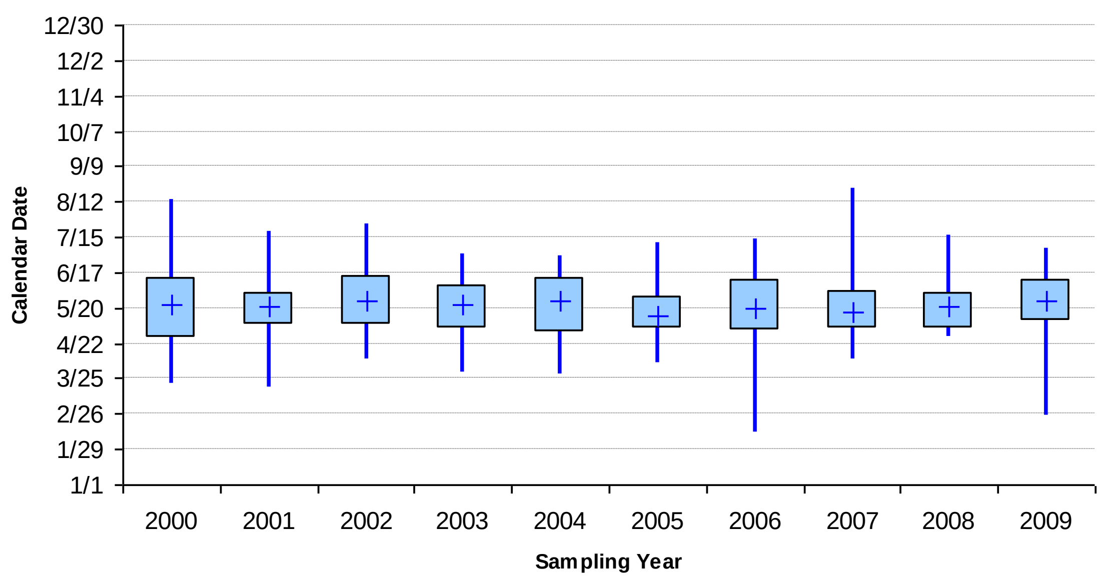
The timing of outmigration for zero-age coho smolts is highly variable from year to year (Figure 4.3). The lack of a defined outmigration window suggests that these zero-age smolts are not deliberately outmigrating but instead are inadvertently moving downstream either in search of suitable habitat, or as a consequence of flow events.

Yearling coho smolts have a much more consistent outmigration window, which has a median outmigration date that has varied by less than one week over the past 10 seasons, and which has an average duration of 34 days during which 90% of yearling coho outmigrate. In 2009, the median outmigration date was May 25. The first yearling coho was caught on March 25 2009 and the last was caught on July 19, 2009. The 5th and 95th percentile dates were May 3 2009, and June 6 2009, respectively.



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for zero-age coho is potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts. Zero-age coho not identified in catch for the 2000 and 2001 seasons.

Figure 4.3. Outmigration timing for Unmarked Zero-Age Coho smolts from 2002 to 2009



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for yearling Coho is potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts.

Figure 4.4. Outmigration timing for Unmarked Yearling Coho smolts from 2000 to 2009

4.5 Zero-Age Coho Outmigrants

Very few zero-age coho smolts are caught in the Trap in most years (Table 4.2).

4.5.1 CPUE Time Series for Zero-Age Coho

In the 2009 season, only 10 zero-age coho smolts were caught. These individuals were generally caught from March through May, and usually were coincident with small increases in flow (Figure 4.5). It is assumed that this handful of smolts was flushed from upstream habitats by the increase in water velocities.

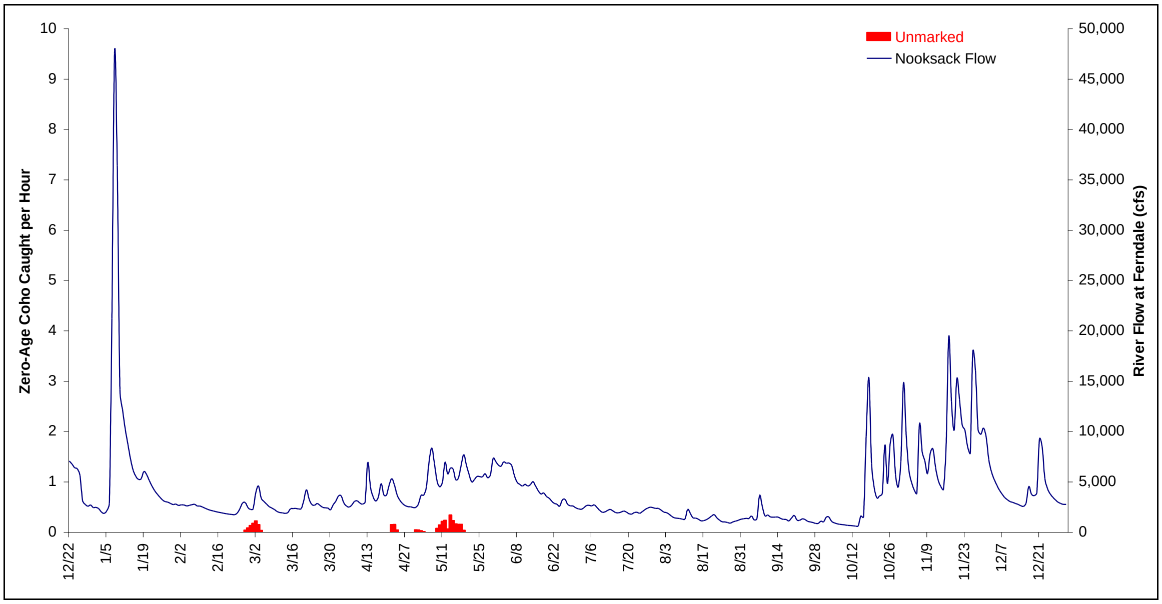


Figure 4.5. Interpolated Catch Per Hour of Zero-Age Coho Smolts by Date Versus Flow

4.5.2 Between-Year Comparisons for Zero-Age Coho CPUE

Because the number of zero-age coho smolts caught in the Trap are usually very low, and also because it is thought that these few 'outmigrants' are not part of a deliberate migration strategy, no attempts have been made to use the catch data for this life stage to ascertain between-year differences in abundance for coho.

4.6 Yearling Coho Outmigrants

Most coho smolts that are caught in the Trap are yearlings and generally catches are dominated by hatchery-origin marked smolts (Table 4.2).

4.6.1 CPUE Time Series for Yearling Coho

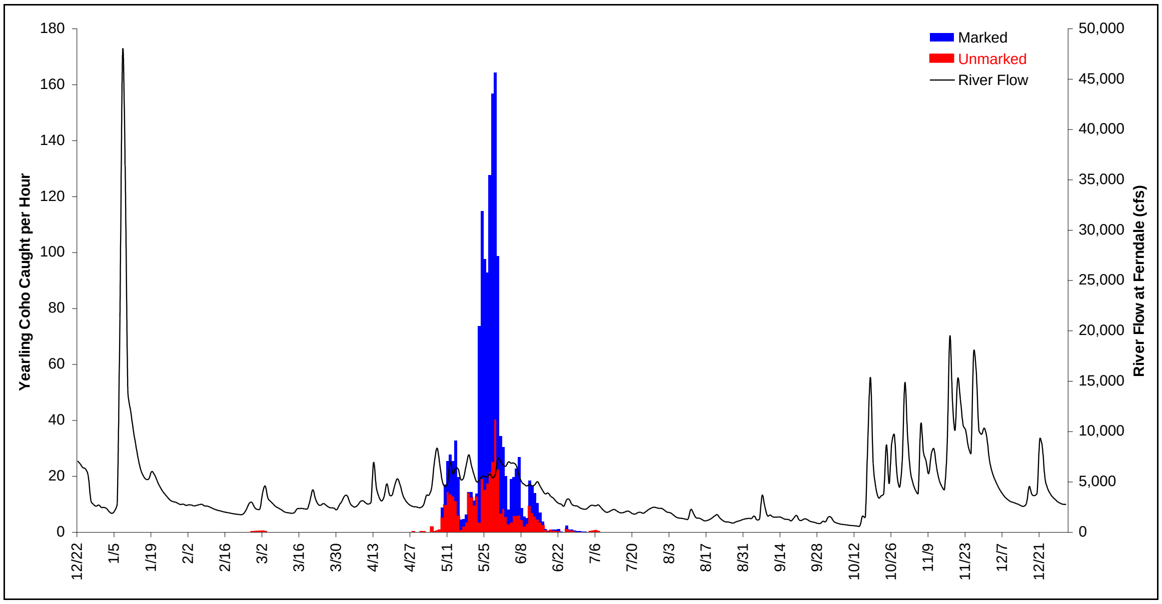


Figure 4.6. Interpolated Catch Per Hour of Yearling Coho Smolts by Date Versus Flow

In 2009 unmarked yearling coho began to be caught regularly from the end of the first week of May through to mid-June. The first unmarked yearling coho was caught on March 1 and the last was caught on July 6, 2009. In the 2009 season the highest catch rate of unmarked yearling coho (40.1 smolts per hour) occurred on May 29 2009.

Marked hatchery-origin coho outmigrants were first caught on May 9 and the last was caught on July 8. The majority of marked coho outmigrated between the second week of May and the middle of June. The highest catch rate of marked coho (131 smolts per hour) occurred on May 28 2009, which was also the last day of release from the Skookum hatchery.

4.6.2 Production Estimates for Yearling Coho in the 2009 Season

Peterson Estimate for Yearling Coho

In the 2009 sampling year, 1,284,702 externally marked (adipose fin clipped) yearling coho were released upstream from the Trap site. Of this total, 4,975 were recaptured at the Trap, and a further 1,800 unmarked yearling coho smolts were also caught (total = 6,775 smolts). The Peterson estimate of total yearling coho passing the Trap site in 2009 is 1,749,519 smolts.

The difference between the Peterson estimate for total smolts and the number of hatchery-origin smolts released in 2009 is assumed to represent the wild-origin production estimate. Total hatchery releases in 2009 were 1,342,960 smolts (includes 58,258 unclipped smolts). For the 2009 sampling season, the Peterson-derived estimate of wild-origin yearling coho is 406,559 smolts (Figure 4.7).

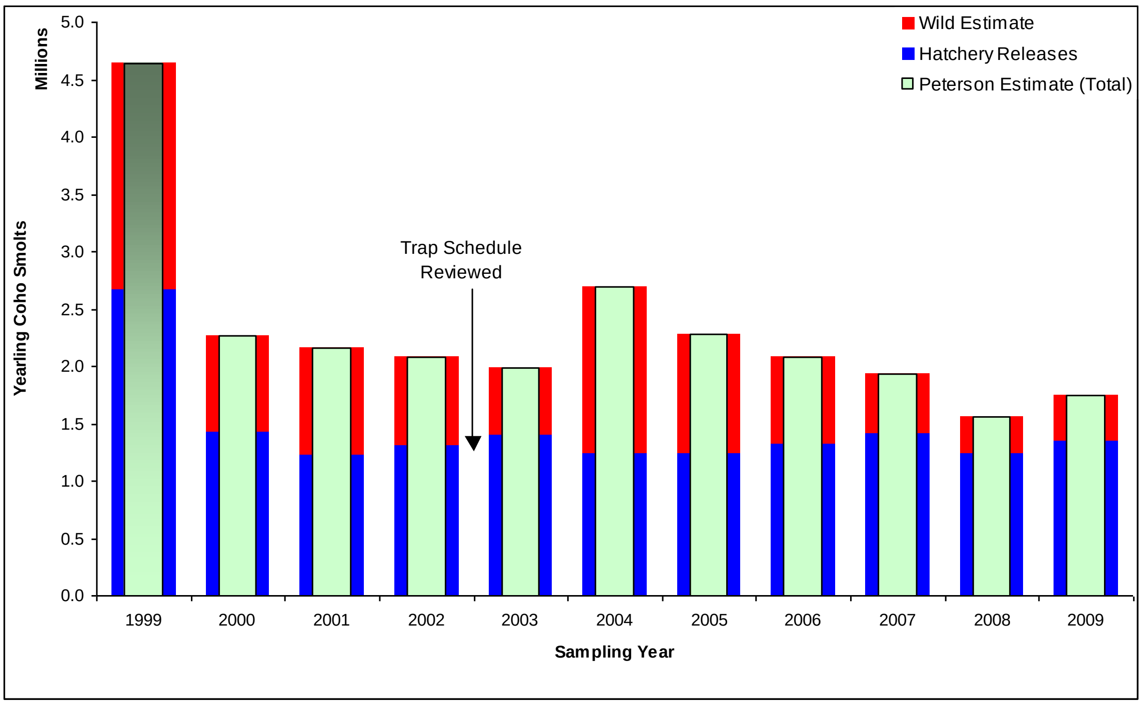


Figure 4.7. Peterson Estimates for Yearling Coho Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Yearling Coho

During the 2009 season the Trap recaptured 0.401% of the clipped coho smolts that were released upstream. During the time period when clipped coho smolts were outmigrating, the Trap was fishing 23.77% of the time. Assuming that the number of marked smolts recaptured by the Trap would increase linearly with the amount of time fished during this period, then the 2009 season catch efficiency is estimated to have been 1.57% (Figure 4.8). This value is considerably higher than the average seasonal catch efficiency of 0.99% but was approximately the same as the seasonal catch efficiency that was calculated for the 2001 sampling season (Figure 4.9).

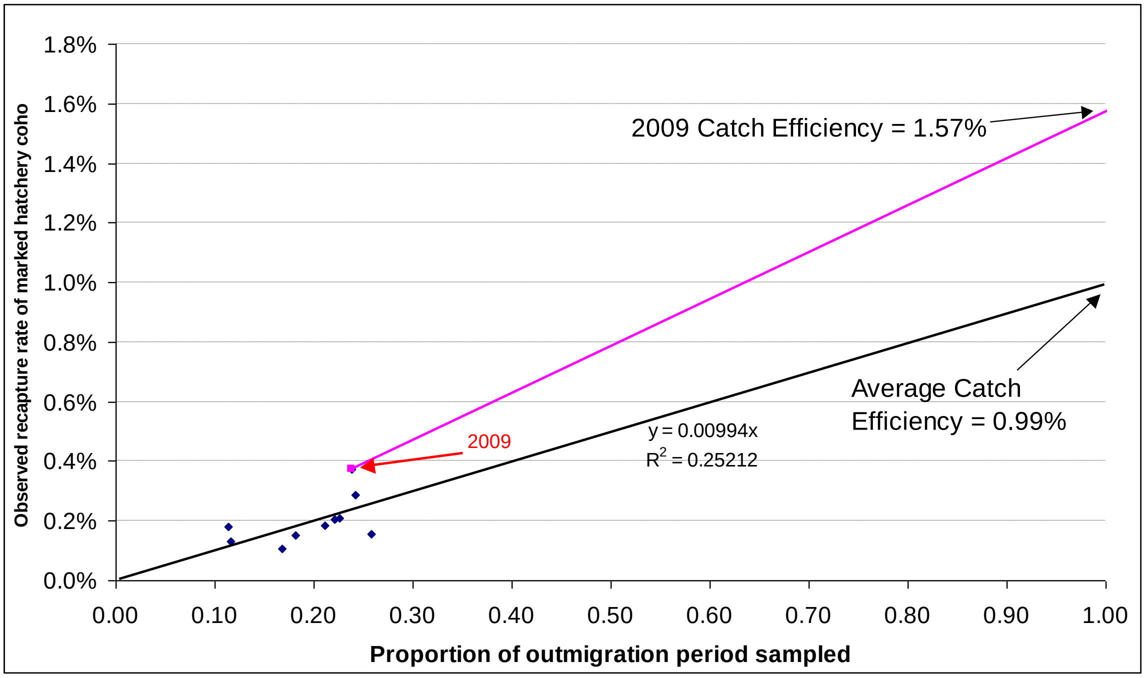


Figure 4.8. Comparison of Production Estimates for Yearling Coho

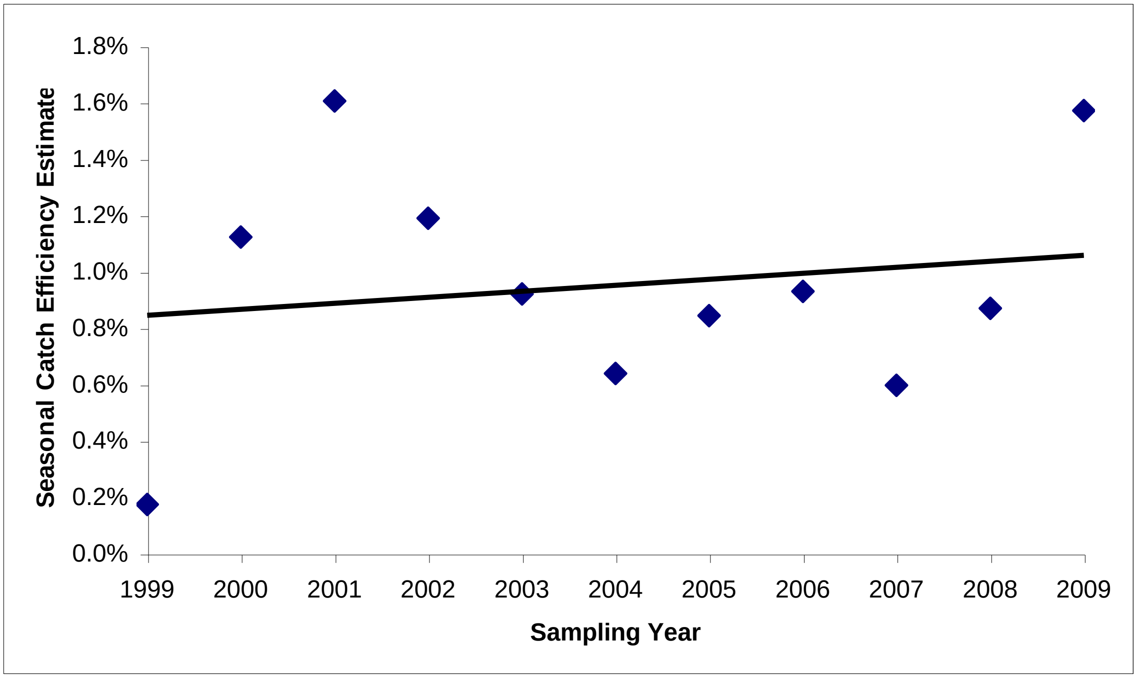


Figure 4.9. Comparison of Seasonal Catch Efficiency Estimates for Coho over Time

Using the average seasonal catch efficiency estimate of 0.99% to convert the time series of hourly catch rates shown in Figure 4.6, the total number of marked smolts estimated was 2.529 million, which was approximately 97% higher than the known number of marked smolts released. This large over-estimate is primarily a consequence of a large disparity between the seasonal catch efficiency for the 2009 season and the average catch efficiency for all seasons. If the 2009 season catch efficiency were used instead, the estimate would only exceed the known release by 24%. The daily production estimates for marked and unmarked smolts, after the known bias has been removed, are shown in Figure 4.10. After deducting unclipped hatchery-origin smolts, the final estimate of wild-origin yearling coho outmigrating in 2009 was estimated to be 396,085 smolts.

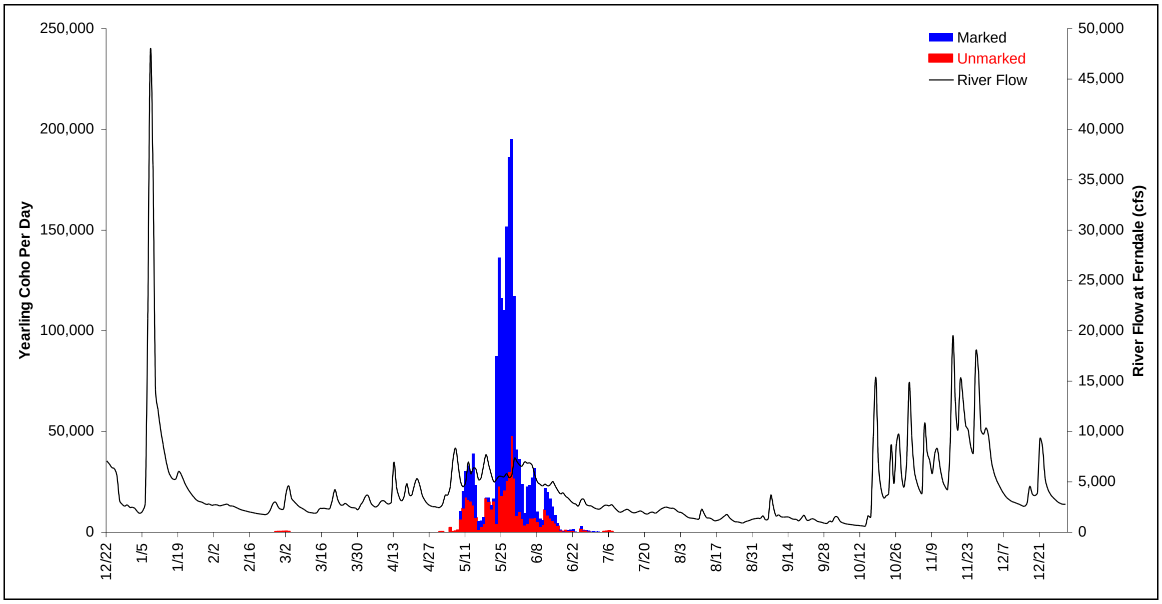


Figure 4.10. Daily Production Estimates for Yearling Coho in 2009

4.6.3 Between-Year Comparisons for Yearling Coho Production Estimates

Both the Peterson and CCE production estimates have produced generally similar results for yearling coho since the 2000 sampling season. Comparable results for 1999 are not available because the field crews did not distinguish between zero-age and yearling coho in that field season.

The average of the two different production estimates for wild-origin yearling coho in the 2009 season is **401,559** smolts. This is the second lowest estimate of wild origin yearling coho to date. Only the 2008 season had a lower estimate for the total wild production of yearling coho. It is tempting to suggest that the unusually high catch efficiency of the Trap in 2009 may somehow explain this low abundance estimate. However, the magnitude of the known bias was quantified and allowances were made to correct for it. It is possible that the catch efficiency of the Trap for unmarked yearling coho was lower than that for marked yearling coho due to potential differences in their respective outmigration timing. However, Figure 4.6 shows that both marked and unmarked smolts outmigrated at essentially the same time of year. Given that the production of wild-origin coho yearlings was also low in 2008, when the catch efficiency for marked coho was more typical (Figure 4.9), this suggests that the low final production estimate for 2009 likely has some other cause.

Based on the results for the 2008 and 2009 seasons, it seems probable that the number of returning adult coho from brood years 2006 and 2007 will be lower than average unless favorable ocean conditions offset the low production of smolts from the Nooksack River.

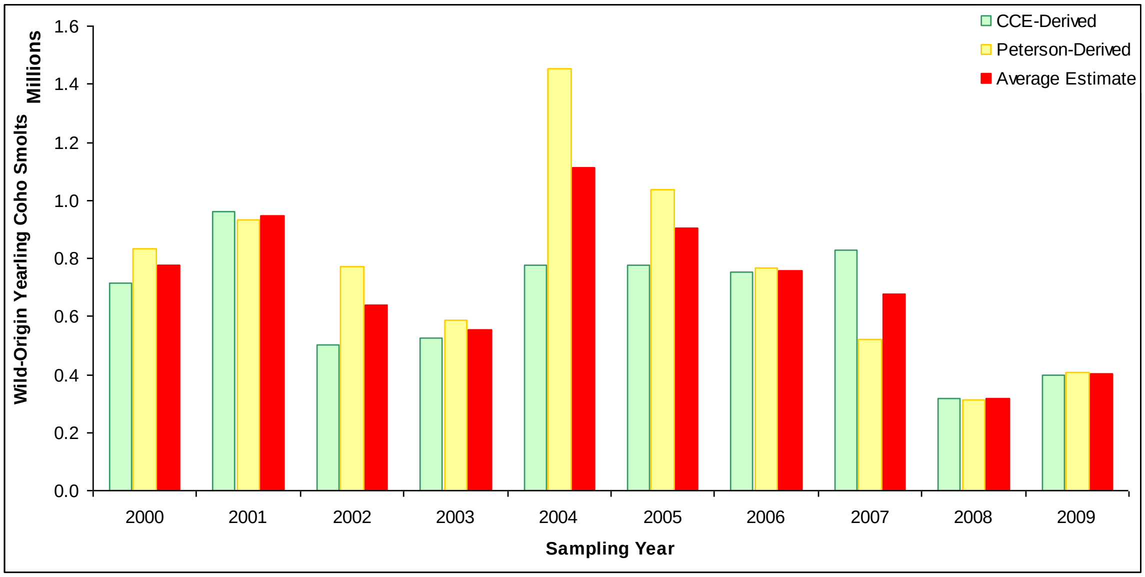


Figure 4.11. Comparison of Wild-Origin Yearling Coho Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

4.7 Coho Discussion

Coho salmon caught in the Trap are almost invariably yearling smolts with only a handful of zero-age smolts present in the catch. The high variation in the timing of capture for zero-age coho indicates that these smolts are likely not outmigrating from the river deliberately but are more likely to be redistributing downstream involuntarily as a result of physical processes (sudden increases in flow), or from competitive pressures from other fish occupying more favorable upstream habitats.

Yearling coho appear to outmigrate in a very well defined time period that, on average, typically varies by less than a week between years.

The estimates of the production of wild yearling coho in 2008 and 2009 were the lowest to date. There does not appear to be any clear explanation for this. Flows during the fall of 2006 and 2007 were not unusually severe compared to flows during the previous few years indicating that mechanisms such as scour or flushing of fry are likely not a causal factor. The largest daily flow during the time period considered in this report occurred in January 2009, which might explain a reduction in yearling coho migrants in 2009, but obviously cannot explain the low estimate for 2008. It would be interesting to compare these results to spawner escapement estimates for coho salmon to see whether there is a relationship between smolt production and the number of spawning adults.

The unusually high catch efficiency for coho yearlings in 2009 is something of a mystery. River flows during May and June were within the range of flows previously seen during other seasons so it unlikely to be related to unusual flow conditions. If changes in channel morphology or trap position were responsible then you might also expect to see increased catch efficiencies for other species, such as Chinook. However, the catch efficiencies for zero-age Chinook were normal in the 2009 season (Figure 3.8). Coho salmon are generally thought to outmigrate more often during nighttime hours, and the relationship between daytime and nighttime catch rates shown in Table 4.4 indicates that this observation is also true for the Nooksack River. If there had been a substantial increase in the amount of nighttime effort during the outmigration period for coho, then that might explain the unusually high seasonal catch efficiency. However, the relative proportion of nighttime sampling effort during that time period was approximately 20%, which was actually marginally lower than the average for the previous 5 seasons (22.5%). So differences in the diurnal timing of effort do not seem likely to be the cause.

The most likely factor that could explain the high catch efficiency was the low water clarity during May 2009, which was the lowest on record (Figure 4.12). However, the water clarity in May 2008 was only marginally higher than in 2009 and the catch efficiency for yearling coho in 2008 was relatively normal which would not be expected if water clarity was responsible for catch efficiency. Also, the water clarity in the other high-efficiency sampling season (2001) was relatively normal, so even if water clarity could explain the unusually high efficiency for yearling coho in 2009, it obviously does not explain it for the 2001 season.

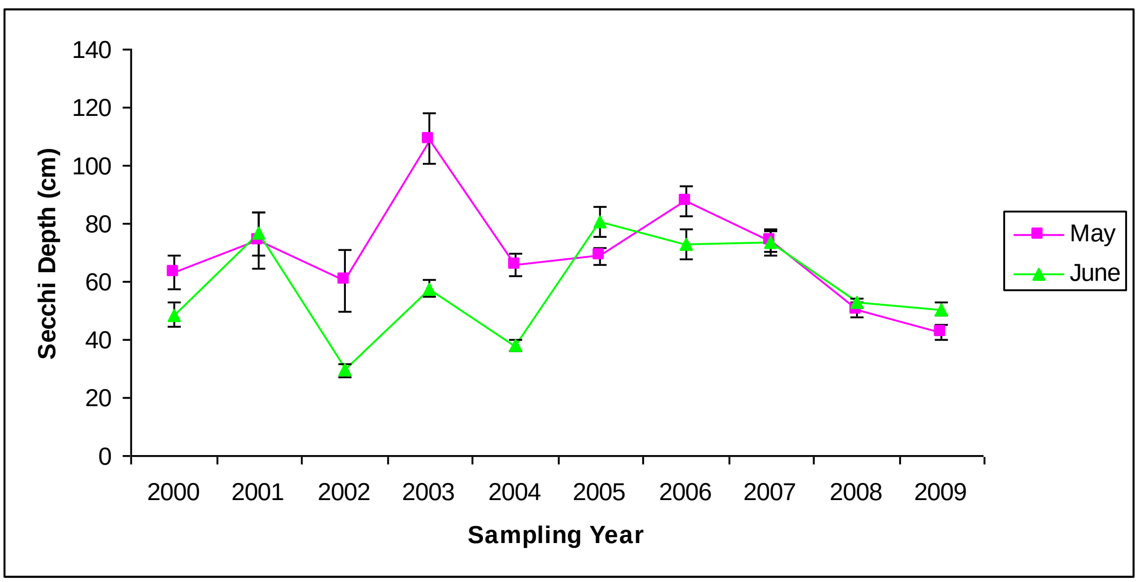


Figure 4.12. Comparison of Average Secchi Depth Readings in May and June by Sampling Season

5.0 Chum Salmon

5.1 Hatchery Release Summary

There are no known releases of chum salmon from hatcheries.

5.2 Chum Catch Totals

The 2009 catch of chum outmigrants is shown in Table 5.1 along with the totals for previous sampling years, and showing the total number of hours that the Trap was fished in each year. The index of abundance score for the 2009 season was the lowest in the period of record.

Table 5.1. Catch Totals for Chum Outmigrants by Year

Sampling	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance (Unmarked)
Year	Marked	Unmarked	Marked	Unmarked		
2009	0	2,072	0	0	678.1	726.3
2008	0	22,576	0	0	890.6	5,456.6
2007	0	8,089	0	0	980.1	1,324.7
2006	0	4,608	0	0	724.2	1,292.3
2005	0	3,222	0	0	601.6	925.6
2004	0	41,398	0	0	738.56	9,329.3
2003	0	8,180	0	0	588.76	2,452.2
2002	0	5,052	0	0	721.38	1,139.0
2001	0	4,489	0	0	526.31	1,352.7
2000	0	34,330	0	0	487.94	14,220.5

Table 5.2 shows the correlation coefficients and the slopes for the relationships between observed catch rates of zero-age chum from sets conducted during different daylight conditions within 24 hours, based on Trap data collected from 2005 to 2009. Generally, sets occurring during daytime and dawn tend to produce the highest catch rates of chum salmon at the Trap. However, this pattern can vary from year to year. For example, in 2003 the nighttime and dawn sets tended to produce the highest catch rates of chum. In 2009, the highest catch rates occurred during daytime sets only (Figure 5.1).

Table 5.2. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Zero-Age Chum Salmon During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		1.21	1.92	0.83		0.907*	0.858*	0.856*
Night	0.907*		2.95	0.53	0.69		0.470*	0.204*
Dawn	0.858*	0.470		0.53	0.41	0.10		0.669*
Day	0.856*	0.204*	0.669*		0.92	0.14	0.90	
	* Indicates a Statistically Significant Correlation							

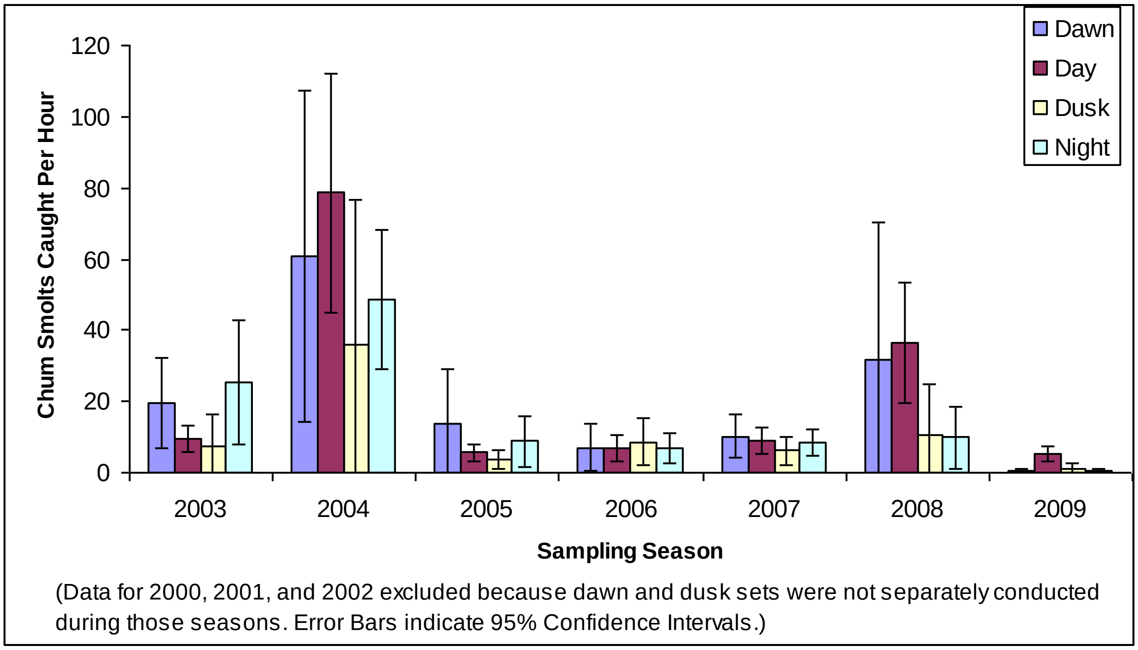


Figure 5.1. Comparison of Average Chum Catch Rates in April, by Daylight Stratum and Sampling Season.

5.3 Chum Smolt Sizes

The average daily fork lengths of chum smolts that were measured at the Trap are shown in Figure 5.2. In general, chum smolts outmigrated at an average size of 37.8 millimeters and no growth was evident over time for the majority of chum smolts. However, in early to mid-June, 4 chum were caught that were considerably larger than the rest (ranging from 50 mm to 66 mm fork length).

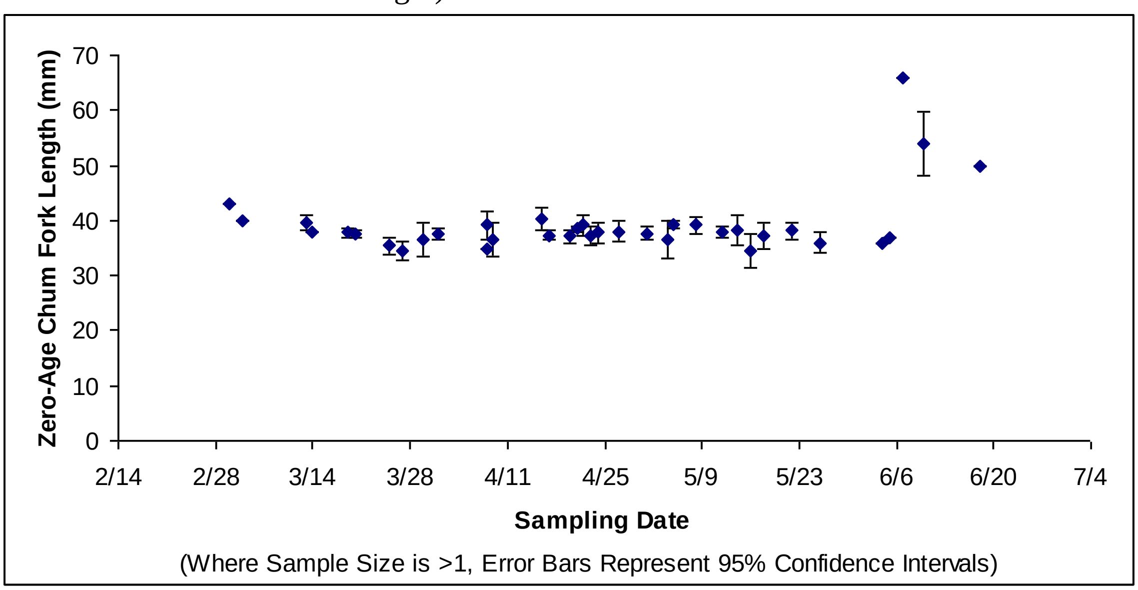
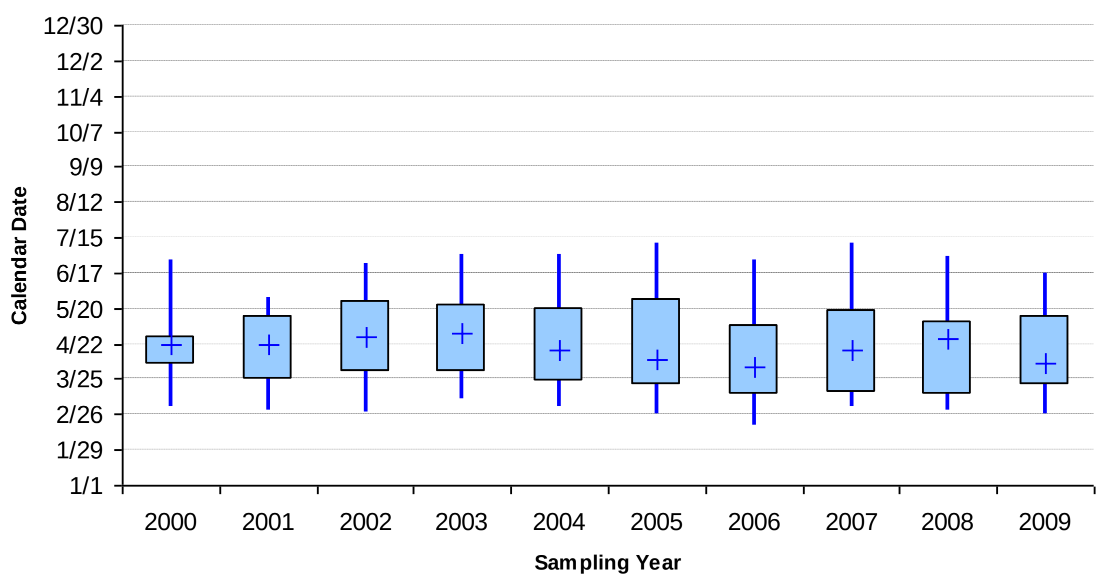


Figure 5.2. Average Daily Fork Lengths for Chum Smolts Caught During 2009

5.4 Chum Seasonal Outmigration Timing

Chum smolts have a somewhat variable outmigration window (Figure 5.3). The median outmigration date has varied by up to 28 days over the past 10 seasons; ranging from April 3rd in 2006 to May 1st in 2003. The main outmigration window has an average duration of 54 days during which 90% of chum smolts outmigrate, although this window was markedly shorter during the 2000 sampling season (23 days). It is possible that the low sampling effort during the first half of the chum outmigration window in most years is partially responsible for the high variability in the median outmigration date due to long interpolation intervals being present in the data during March and early April when the chum outmigration is underway.

In 2009, the median outmigration date was April 7. The first chum was caught on February 27 2009 and the last was caught on June 17 2009. The 5th and 95th percentile dates were March 19 2009, and May 13 2009, respectively.



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for zero-age chum smolts are potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts.

Figure 5.3. Comparison of Outmigration Window for Chum Smolts by Season

5.5 Zero-Age Chum Outmigrants

5.5.1 CPUE Time Series for Zero-Age Chum

The highest catch rate for chum smolts during the 2009 season was 54.9 smolts per hour, which occurred on April 21 (Figure 5.4). However, Trap effort during the first half of the chum outmigration was low compared to the effort during the second half of the chum outmigration, and it is possible that higher catch rates might have been observed had more effort occurred during March. The relatively long interpolation intervals present in the data during March are clearly visible in Figure 5.4 and this may have biased the estimate of the median outmigration date for 2009 to be too early.

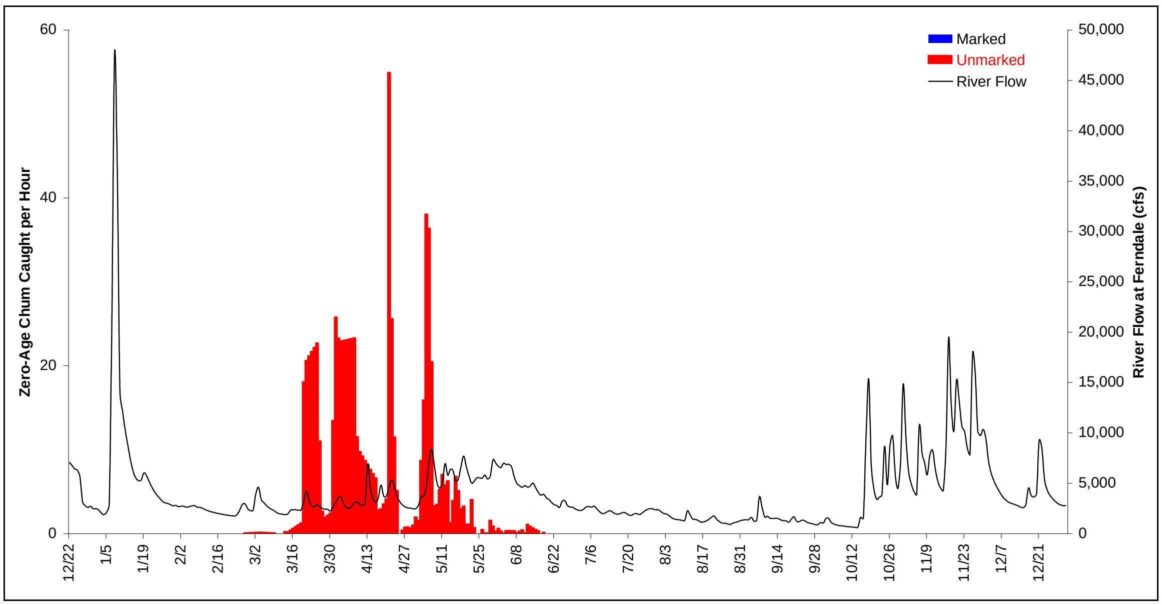


Figure 5.4. Interpolated Catch Per Hour of Zero-Age Chum Smolts by Date Versus Flow

5.5.2 Between-Year Comparisons for Zero-Age Chum CPUE

The index of abundance score calculated for each sampling season is shown in Figure 5.5. The most notable features are the comparatively much higher index of abundance scores for the 2000, 2004, and 2008 sampling seasons relative to the scores for the remaining years. This may be evidence that a particularly strong year class returned to spawn in 1999, 2003, and 2007 because the high index of abundance values do not appear to be related to river flows during egg incubation (Table 3.5). If this interpretation is correct, then a larger than average number of adult chum should return to spawn in 2011. However, the index of abundance for this strong year class appears to be trending downwards with each generation, which may suggest that the difference may not be as large as for previous generations. There does not appear to be much evidence that 5 year-old chum provide much spillover from one year-class to the next, although there may be some indication that 3 year-old chum from brood year 1999 may have increased production of fry in brood year 2002 that outmigrated in 2003.

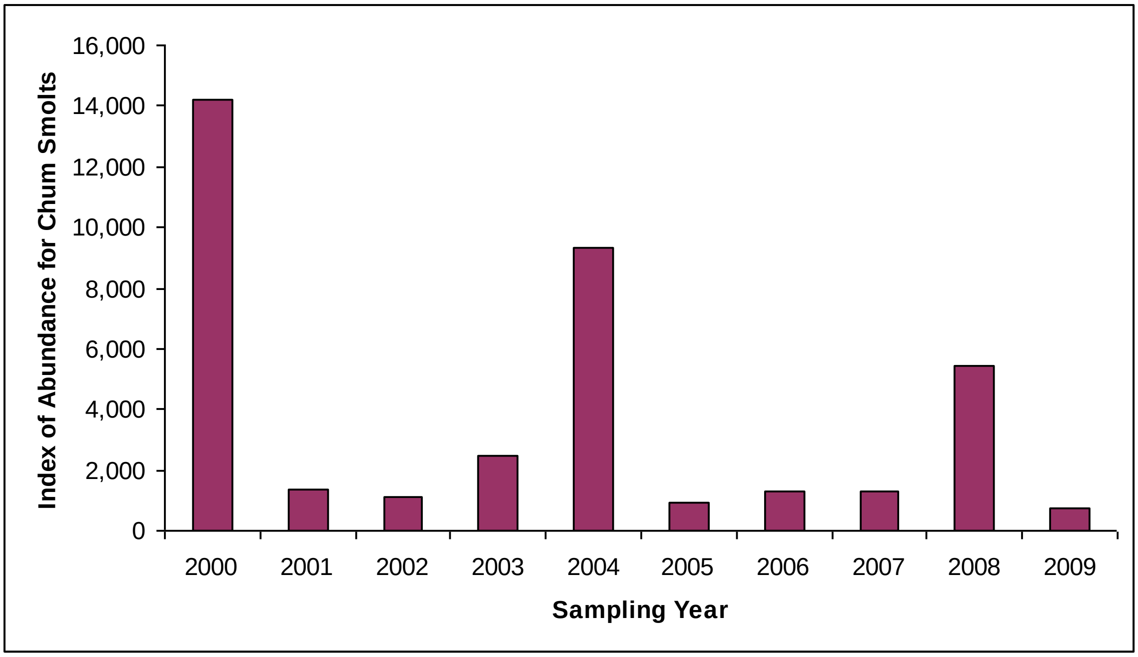


Figure 5.5. Comparison of the Index of Abundance for Chum Smolts by Sampling Year

5.6 Chum Discussion

Chum salmon outmigrate earlier than Chinook salmon smolts and, almost universally, do not appear to feed and grow in the freshwater environment. However, a very small number of chum salmon do appear to buck this trend and outmigrate at the end of the outmigration season at much larger sizes.

The number of chum smolts produced each year seems to be somewhat unrelated to the severity of flow events during the fall and winter. This may be the result of their tendency to spawn in tributaries rather than in the main forks of the Nooksack River, which may afford them protection from large flow events.

The presence of a strong year class seems to be the best explanation for the much higher index of abundance values and total catches of chum in the 2000, 2004, and 2008 sampling seasons. There does not appear to be an obvious reason for the apparent decline in the size of the index of abundance values in each successive generation for this year class. Incubation flows in 1999 were similar to those in 2008, and the only particular bad flow occurred during the 2003 incubation period. It would be interesting to determine whether the number of adult chum returning to spawn in 1999, 2003, and 2007 showed a similar pattern of reduction. If so, then this might suggest that ocean conditions and/or over-exploitation in chum fisheries may best explain the decline. It is a concern that the index of abundance for chum smolts in the 2009 season was the lowest to-date. However, the largest flow event that has been observed during the time period considered in this report occurred in early January of 2009, and this flow event may have been large enough to scour chum redds even in tributaries, or to flush emergent fry out of the system.

As a consequence of their early outmigration timing, the amount of Trap effort during the first half of the chum outmigration period is much more limited than it is during the second half of their outmigration. This pattern of effort is the result of the Trap being operated to focus primarily on zero-age Chinook smolts and due to logistical constraints.

6.0 Pink Salmon

Pink salmon in the Nooksack River generally return to spawn every-other year, with spawning occurring during odd-numbered years and outmigration of fry/smolts during the following even-numbered year. However, occasional strays from nearby river systems may produce a handful of pink salmon outmigrants during odd-numbered years.

6.1 Hatchery Release Summary

There are no known releases of pink salmon from hatcheries into the Nooksack River.

6.2 Pink Salmon Catch Totals

No pink salmon smolts were caught during Trap operations in the 2009 sampling season (Table 6.1).

Table 6.1. Catch Totals for Pink Salmon Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance
	Marked	Unmarked	Marked	Unmarked		
2009	0	0	0	0	678.1	0.0
2008	0	10,084	0	0	890.6	2,411.5
2007	0	0	0	0	980.1	0.0
2006	0	5,219	0	0	724.2	1,373.2
2005	0	0	0	0	601.6	0.0
2004	0	7,607	0	0	738.56	1,289.3
2003	0	16	0	0	588.76	9.4
2002	0	8,235	0	0	721.38	1,740.3
2001	0	23	0	0	526.31	5.9
2000	0	11,395	0	0	487.94	3,119.4

Pink salmon catch rates tend to be higher during dawn and day sets, and lowest during night sets (Table 6.2 and Figure 6.1).

Table 6.2. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Zero-Age Pink Salmon During Different Daylight Conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		0.75	1.22	1.15		0.645*	0.527*	0.706*
Night	0.645*		1.34	0.66	0.57		0.269*	0.360*
Dawn	0.527*	0.269		0.56	0.30	0.09		0.462*
Day	0.706*	0.360*	0.462*		0.46	0.22	0.44	
	* Indicates a Statistically Significant Correlation							

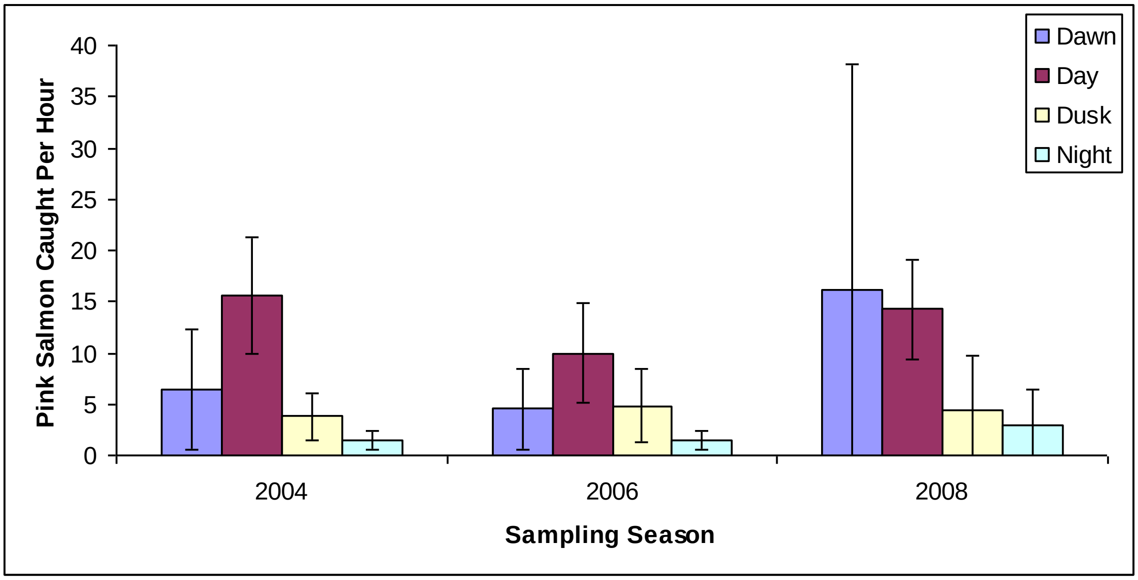


Figure 6.1. Comparison of Average Pink Salmon Catch Rates in March and April, by Daylight Stratum and Sampling Season.

6.3 Pink Salmon Smolt Sizes

No pink salmon smolts were caught and measured during the 2009 season.

6.4 Pink Salmon Seasonal Outmigration Timing

Pink salmon smolts have a somewhat variable outmigration window during even-numbered sampling years (Figure 6.2). Excluding odd-numbered sampling seasons, the median outmigration date has varied by up to 25 days, ranging from March 23rd in 2004 to April 17th in 2000. The main outmigration window has an average duration of 54 days during which 90% of pink salmon outmigrate.

It is possible that the low sampling effort during the pink salmon outmigration window is partially responsible for the high variability in the median outmigration date: due to long interpolation intervals being present in the data during March and April when the pink salmon outmigration is underway.

The low numbers of pink salmon caught during odd-numbered sampling years are primarily a consequence of the life cycle of pink salmon and the lack of a significant year class that spawns during even years in the Nooksack River. However, the fact that a few individuals have occasionally been caught during odd years indicates that there may be have been some strays from other river systems, or a residual population of even-year pink salmon may have been present. The very low number of pink salmon caught during the 2001 and 2003 seasons makes determining the outmigration window for these seasons very problematic. Accordingly, the outmigration periods for these seasons are not included with the results from even-numbered years.

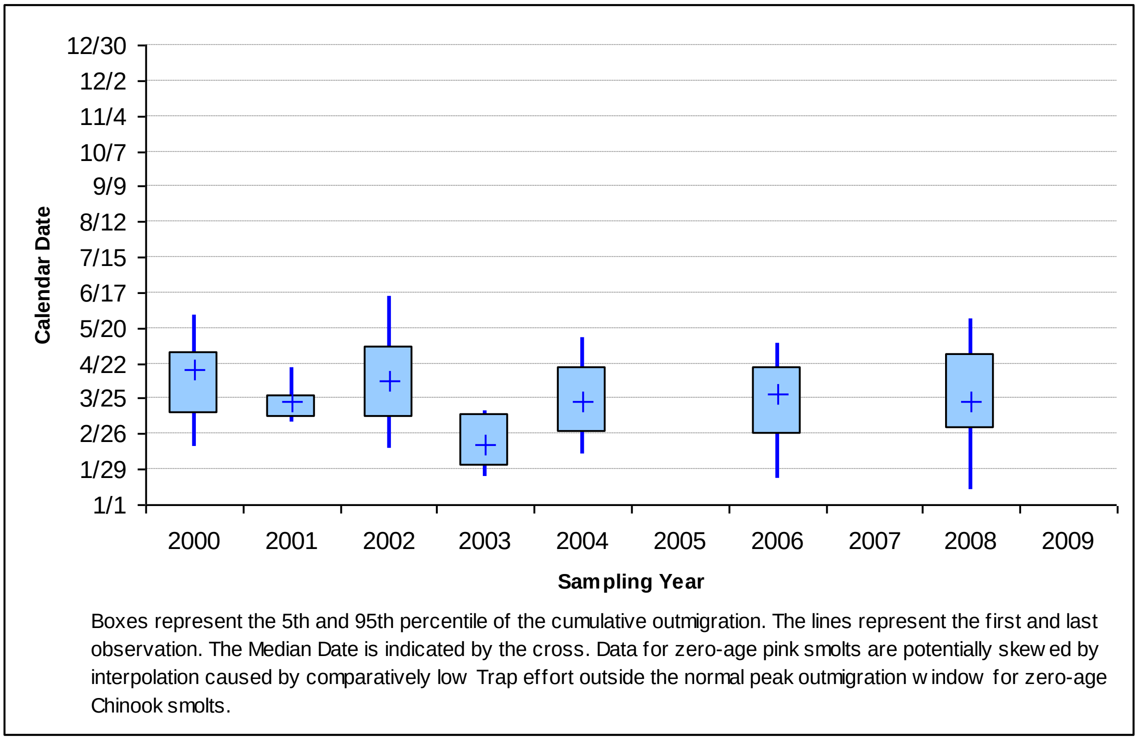


Figure 6.2. Comparison of Outmigration Window for Pink Salmon Smolts by Season

6.5 Zero-Age Pink Salmon Outmigrants

6.5.1 CPUE Time Series for Zero-Age Pink

No pink salmon smolts were caught during Trap operations in the 2009 sampling season.

6.5.2 Between-Year Comparisons for Zero-Age Pink Salmon CPUE

The index of abundance for pink salmon smolts has varied over time during even-numbered sampling years from a low value of 1,289 in 2004 to a high of 3,119 in 2000. The most recent year (2008) was the second highest value (2,411) calculated during the time period considered in this report.

The index of abundance score for pink salmon does not appear to be related to incubation river flows. For example, although the highest index of abundance score for pink salmon was for individuals outmigrating during the 2000 sampling season, the incubation flows for that year were worse than those experienced by smolts that outmigrated in 2006 and 2008 (Table 3.5). However, the incubation flows for pink salmon outmigrating in 2002 and 2004 were the worst experienced by pink salmon during the period considered in this report.

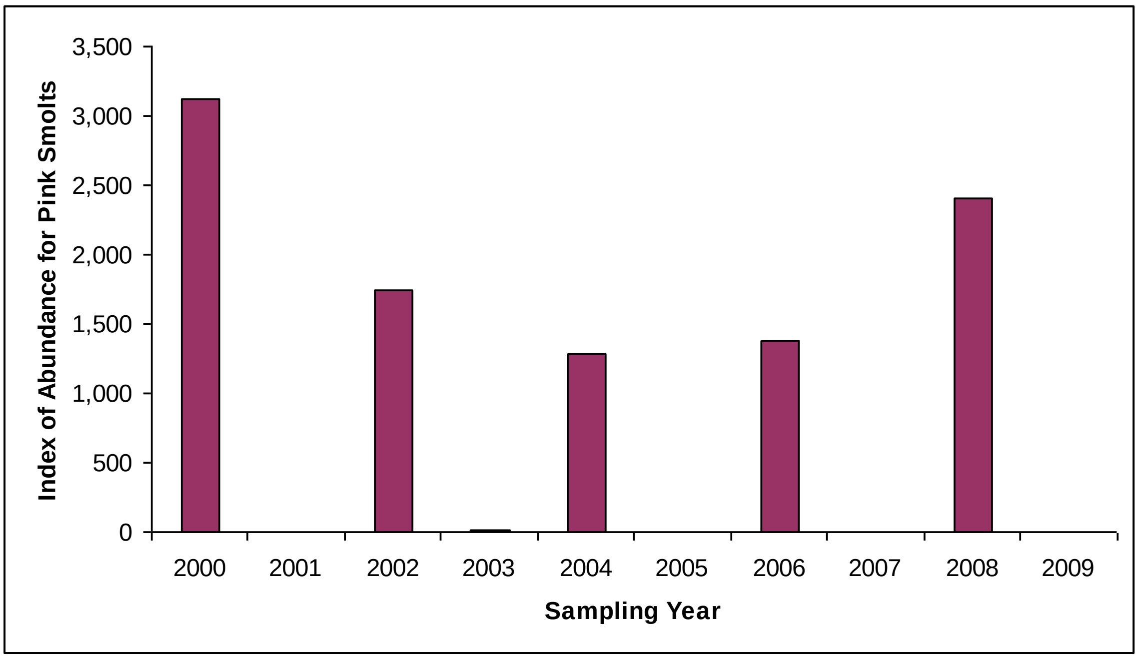


Figure 6.3. Comparison of the Index of Abundance for Pink Salmon by Sampling Year

6.6 Pink Salmon Discussion

Significant numbers of pink salmon are only present every two years. In even-numbered years, they are the first salmon species to outmigrate. In previous years, most pink salmon have not exhibited any significant growth during the outmigration season.

The number of pink salmon outmigrants does not appear to be closely linked to incubation flows. Assuming that the number of outmigrating chum salmon is related to the number of adult chum spawning, the number of pink salmon does not appear to be negatively impacted by interference from chum salmon either since the abundance of both chum and pink salmon was highest during brood year 1999. It may be that ocean survival and fishing may be more important for year class strength for pink salmon.

Because Trap effort is primarily focused on the later outmigration of Chinook smolts, there are longer gaps in the Trap schedule while pink salmon are outmigrating which necessitates longer interpolation intervals. Accordingly, outmigration timing and abundance statistics for this species are likely to be the most strongly skewed.

7.0 Sockeye Salmon

7.1 Hatchery Release Summary

There are no known releases of sockeye salmon into the Nooksack River from any hatchery.

7.2 Sockeye Salmon Catch Totals

Sockeye salmon are the least abundant salmon species encountered in the Trap catch. There were 16 sockeye salmon smolts caught during the 2009 sampling season, which is equal to the second highest previous catch (Table 7.1). Differences in sample effort and timing suggest that the 2009 index of abundance was marginally higher than that for the 2007 season.

Table 7.1. Catch Totals for Sockeye Salmon Outmigrants by Year

Sampling	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance (Unmarked)
Year	Marked	Unmarked	Marked	Unmarked		
2009	0	16	0	0	678.1	3.1
2008	0	1	0	0	890.6	0.2
2007	0	16	0	0	980.1	2.2
2006	0	1	0	0	724.2	0.6
2005	0	0	0	0	601.6	0.0
2004	0	0	0	0	738.56	0.0
2003	0	1	0	0	588.76	0.1
2002	0	4	0	0	721.38	0.6
2001	0	77	0	0	526.31	13.9
2000	0	0	0	0	487.94	0.0

There have been too few sockeye salmon caught to develop meaningful correlations between catch rates for sets conducted on the same day but under different daylight conditions (Table 7.2).

Table 7.2. Within-Day Correlation Coefficients (Green Cells) and Slopes of Relationships (Gray Cells) for Catch Rates of Zero-Age Sockeye Salmon During Different Daylight Conditions

Independent Variable	**Dependent Variables**							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		0.00	1.00	0.00		N/A	N/A	-0.016
Night	N/A		1.00	0.00	1.00		N/A	-0.012
Dawn	N/A	N/A		0.00	0.00	0.00		-0.017
Day	-0.016	-0.012	-0.017		0.00	0.00	0.00	
	* Indicates a Statistically Significant Correlation							

7.3 Sockeye Salmon Smolt Sizes

The smallest sockeye salmon that was caught in 2009 had a fork length of 37 mm, and the largest sockeye had a fork length of 68 mm (Figure 7.1). The average size of sockeye salmon was approximately 61 mm, which remained relatively constant throughout the season except for a much smaller individual that was caught in mid April and which may have been flushed out of the upper reaches of the river by a sudden increase in flow.

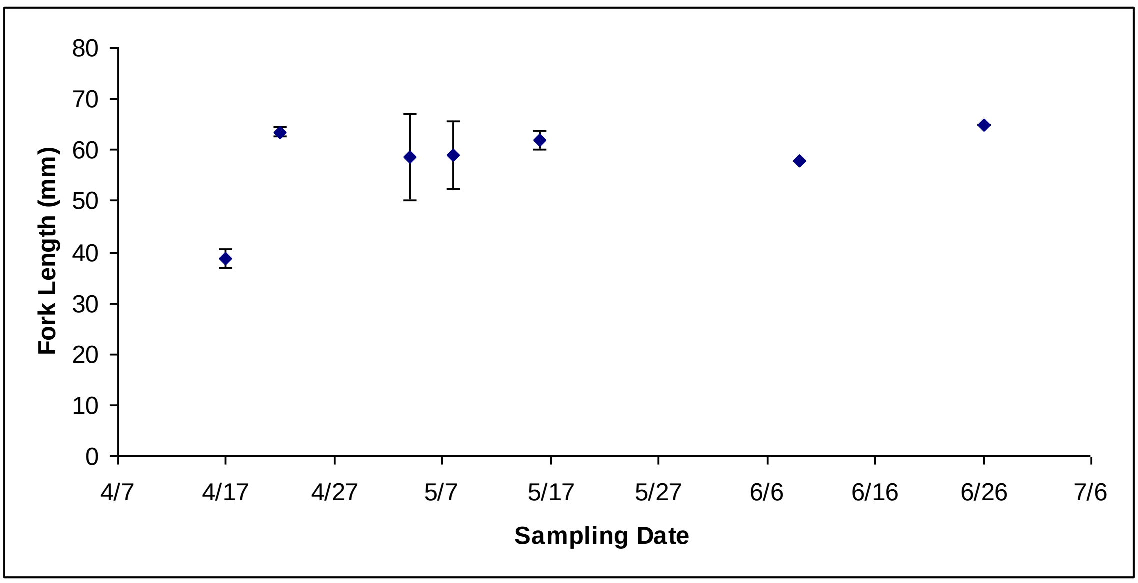
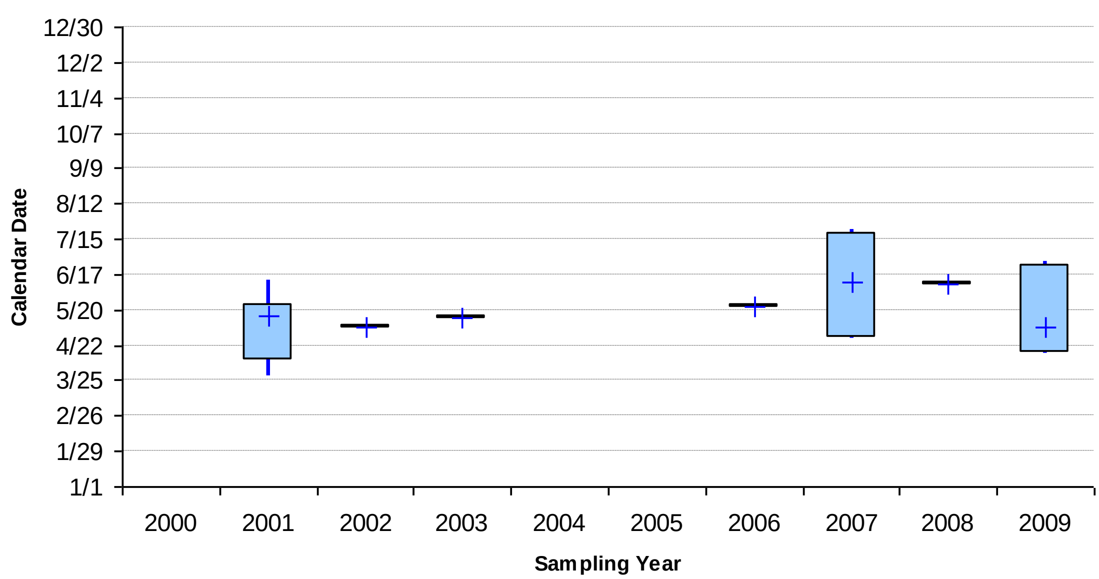


Figure 7.1. Average Daily Fork Lengths for Sockeye Salmon Smolts Caught During 2009

7.4 Sockeye Salmon Seasonal Outmigration Timing

The first sockeye salmon was captured on April 15, 2009. The last sockeye salmon was captured on June 8, 2009. In 2009, the median outmigration date was May 6, and 90% of the sockeye salmon smolts outmigrated between April 15th and June 25th.

The timing of the sockeye outmigration period has been relatively variable over time (Figure 7.2). Across all seasons, the median outmigration date for sockeye salmon is May 21, with the main window of outmigration typically occurring between May 6th and June 3rd, lasting approximately 36 days on average. However, the outmigration period for most years is exceptionally short. This is because the total catch of sockeye salmon smolts during those years was just 1 - 4 smolts. In years with only one smolt, the ranges indicated on Figure 7.2 are the result of interpolation during gaps in the trap schedule.



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for zero-age sockeye smolts are potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts.

Figure 7.2. Comparison of Outmigration Periods for Sockeye Salmon Smolts by Season

7.5 Zero-Age Sockeye Outmigrants

7.5.1 CPUE Time Series for Zero-Age Sockeye

The highest catch rate for sockeye salmon in 2009 was 0.36 smolts per hour, which occurred on May 8. Most encounters with sockeye salmon at the Trap occurred between mid April and mid May, although sockeye salmon were encountered periodically until the end of June.

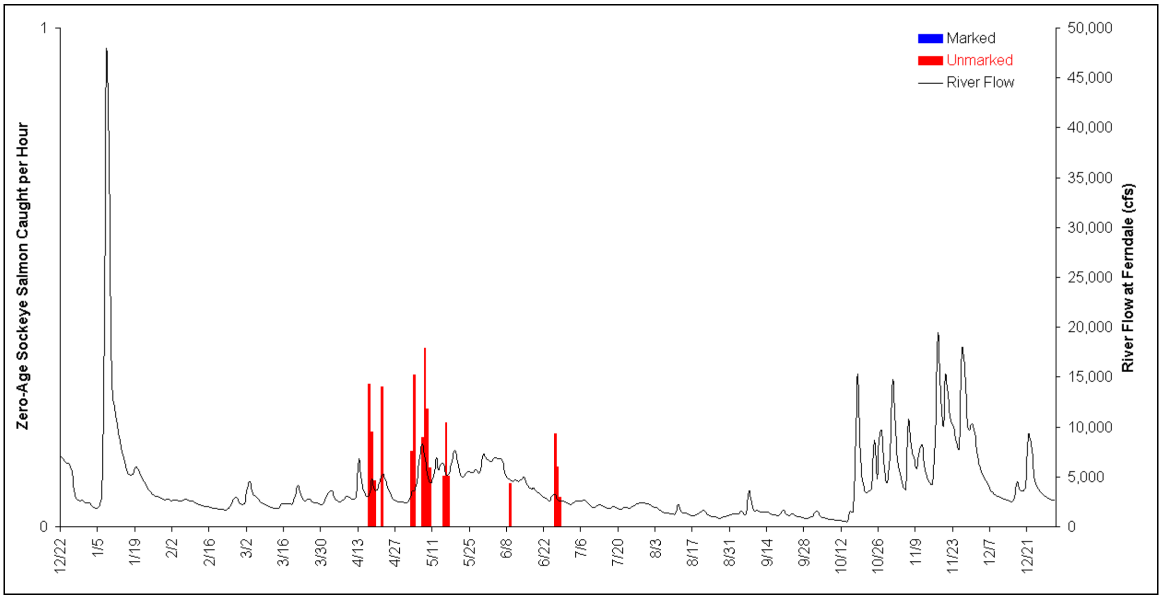


Figure 7.3. Interpolated Catch Per Hour of Zero-Age Sockeye Salmon Smolts by Date and Flow

7.5.2 Between-Year Comparisons for Zero-Age Sockeye CPUE

Sockeye salmon are present in the catch during most sampling years, but the total catch and index of abundance scores are orders of magnitude lower than for pink or chum salmon. The highest sockeye index of abundance value was calculated for the 2001 sampling season. The second highest index value was calculated for the 2009 season results, but this is still just 22% of the 2001 season score. It is likely that sockeye salmon produced in the Nooksack River are the offspring of strays from larger stocks of sockeye salmon in the Fraser River.

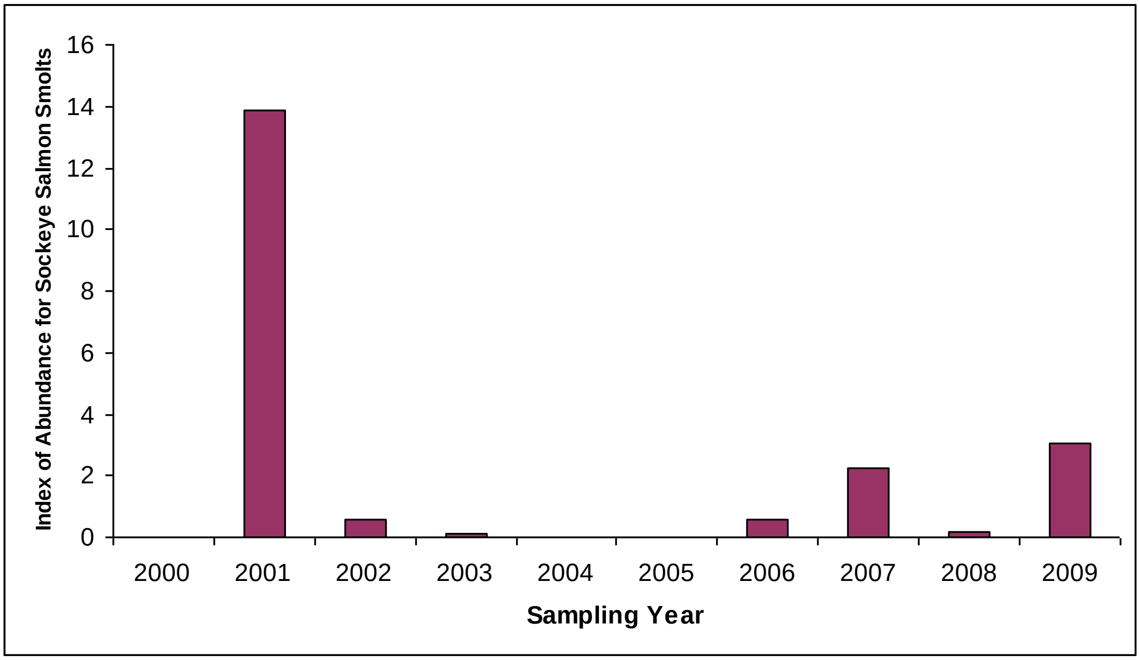


Figure 7.4. Comparison of the Index of Abundance for Sockeye Salmon by Sampling Year

7.6 Sockeye Discussion

Sockeye salmon smolts typically outmigrate during May until early June, which overlaps with the main outmigration window for zero-age Chinook. Accordingly, the timing of Trap effort should enable relatively good estimates to be made of the relative abundance and timing of sockeye outmigration.

Based on the limited size information available, it appears that sockeye salmon smolts may rear upstream from the Trap until they reach a size of approximately 60+ mm, unless they are flushed out of the river prematurely. Nonetheless, the very low abundance of sockeye salmon smolts probably indicates that these smolts are the offspring of individuals that have strayed from nearby river systems, rather than comprising a Nooksack River stock. The scarcity of suitable lacustrine environments in the Nooksack River watershed probably limits the potential for successful colonization by sockeye salmon.

8.0 Steelhead Trout

8.1 Hatchery Release Summary

The total number of hatchery-origin steelhead released upstream from the Trap in 2009 was 146,500 smolts (Table 8.1). Of this total, 100% were assumed to be externally marked by adipose fin clips (clipping error rates for 2009 were not available at the time this report was compiled). These fish were released from the Kendall Hatchery on May 18, 2009 into Kendall Creek.

Table 8.1. Upstream Hatchery Releases of Steelhead in 2009

Release Date	Source Hatchery	Location	Marked Steelhead Released			Unmarked Steelhead Released*	Total Marked Steelhead Released	Grand Total Released
			Ad.Clip Only	Ad.Clip & CWT	CWT Only			
5/18/2009	Kendall	Kendall Creek	146,500	0	0	0	146,500	146,500
5/19/2008	Kendall	Kendall Creek	163,180	0	0	820	163,180	164,000
5/23/2007	Kendall	Kendall Creek	158,000	0	0	2,000	158,000	160,000
5/2/2006	Kendall	Kendall Creek	162,525	0	0	2,475	162,525	165,000
5/2/2005	Kendall	Kendall Creek	136,741	0	0	4,960	136,741	141,700
5/3/2004	Kendall	Kendall Creek	126,975	0	0	25	126,975	127,000
5/3/2004	Kendall	Kendall Creek	9,998	0	0	2	9,998	10,000
5/1/2003	Kendall	Kendall Creek	157,440	0	0	2,560	157,440	160,000
5/1/2002	Kendall	Kendall Creek	34,800	0	0	0	34,800	34,800
5/2/2001	Kendall	Kendall Creek	30,500	0	0	0	30,500	30,500

* Based on reported clipping and CWT error rates

8.2 Steelhead Catch Totals

In total, 570 steelhead trout were caught in the 2009 season. Of these, 481 were recorded as having their adipose fin clipped, and 89 were recorded as unclipped (

Table 8.2). Unfortunately, because the emphasis of the screwtrap program is on Chinook and coho, many of the field crewmembers have not reliably examined steelhead smolts for the presence of clipped adipose fins in many of the previous seasons. Accordingly, the ability to differentiate between marked and unmarked smolts in the screwtrap data has been compromised and the yearly totals for each mark status are essentially meaningless unless combined together.

Table 8.2. Catch Totals for Steelhead Trout by Year

Sampling Year	Age Not Recorded		Hours Fished	Index of Abundance (Unmarked)	% Hatchery Released Marked
	Marked	Unmarked			
2009	481	89	678.1	24.5	100.0%
2008*	182	169	890.6		99.5%
2007*	55	125	980.1		98.8%
2006*	189	249	724.2		98.5%
2005*	91	122	601.6		96.5%
2004*	216	232	738.56		100.0%
2003*	21	103	588.76		100.0%
2002*	293	361	721.38		98.4%
2001*	70	307	526.31		100.0%
2000*	181	340	487.94		100.0%

* Field crews did not reliably examine steelhead for clipped adipose fins from 2000 to 2008

8.3 Steelhead Sizes

Overall, clipped steelhead trout that were caught in the Trap tended to be 22 millimeters bigger than unclipped steelhead trout, although the sizes of steelhead were highly variable and considerable overlap existed. Steelhead trout fork lengths ranged from 155 to 225 millimeters for clipped fish, and from 111 to 230 millimeters for unclipped fish. The 2 unclipped steelhead trout that were caught in January and October respectively were considerably smaller than most of the unclipped steelhead trout that were caught during the summer (111 and 118 millimeters respectively, versus an average summertime length of 177 millimeters).

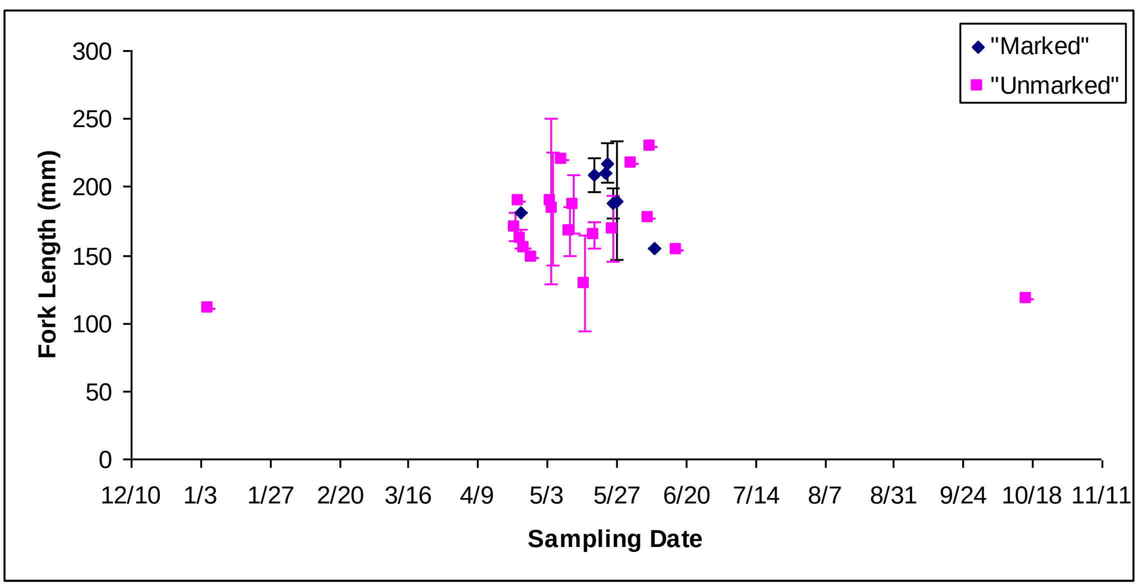
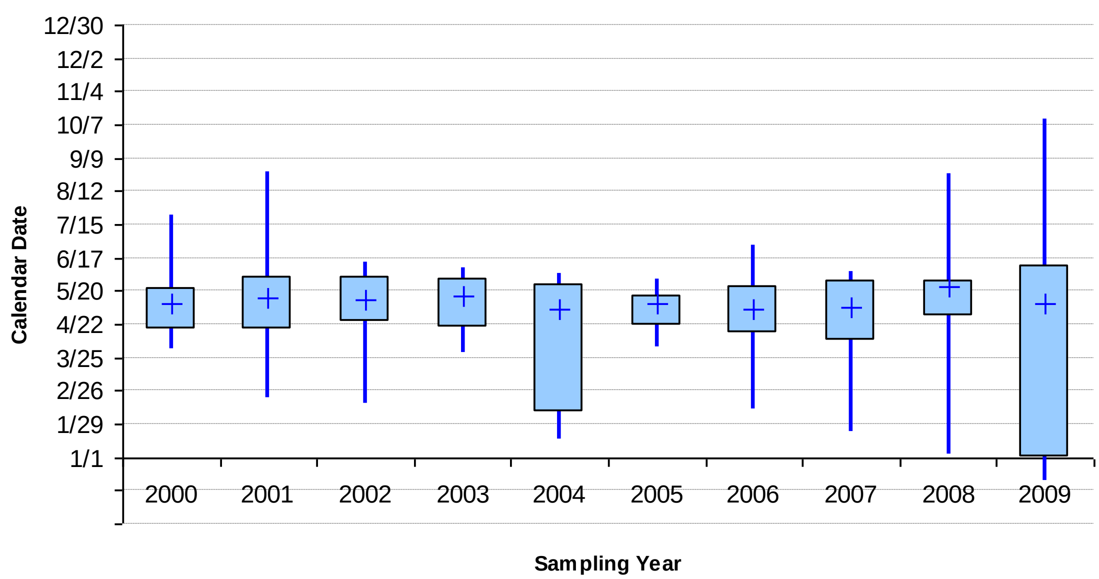


Figure 8.1. Average Daily Fork Lengths for Steelhead Outmigrants Caught During 2009

8.4 Steelhead Seasonal Outmigration Timing

The timing of steelhead outmigration in 2009 was strongly skewed by the existence of a long interpolation interval during January of 2009.

Steelhead trout were caught from December 11 2008 to October 12, 2009. The median outmigration date was May 9, and 90% of the outmigration was estimated to have occurred between Jan 1 and June 10. This compares to the average median date of May 10, and the average 90% date range that begins on Mar 31 and ends on May 27.



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for steelhead outmigrants are potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts.

Figure 8.2. Comparison of Outmigration Periods for Steelhead Outmigrants by Season

8.5 Steelhead Outmigrants

8.5.1 CPUE Time Series for Steelhead

The highest catch rate for 'unclipped' steelhead trout in the 2009 season was 2.86 fish per hour, which occurred on April 22. The highest catch rate for 'clipped' steelhead trout was 23.7 fish per hour, which occurred on May 25.

Most encounters with steelhead trout occurred between late April and the start of June. However, a combination of long interpolation intervals and a fortuitous catch of a single steelhead in January meant that the temporal distribution was strongly skewed from late

December to early February. It is unlikely that the early period of sustained low catch rates shown in Figure 8.3 is realistic given the usual pattern seen during other years (Figure 8.2).

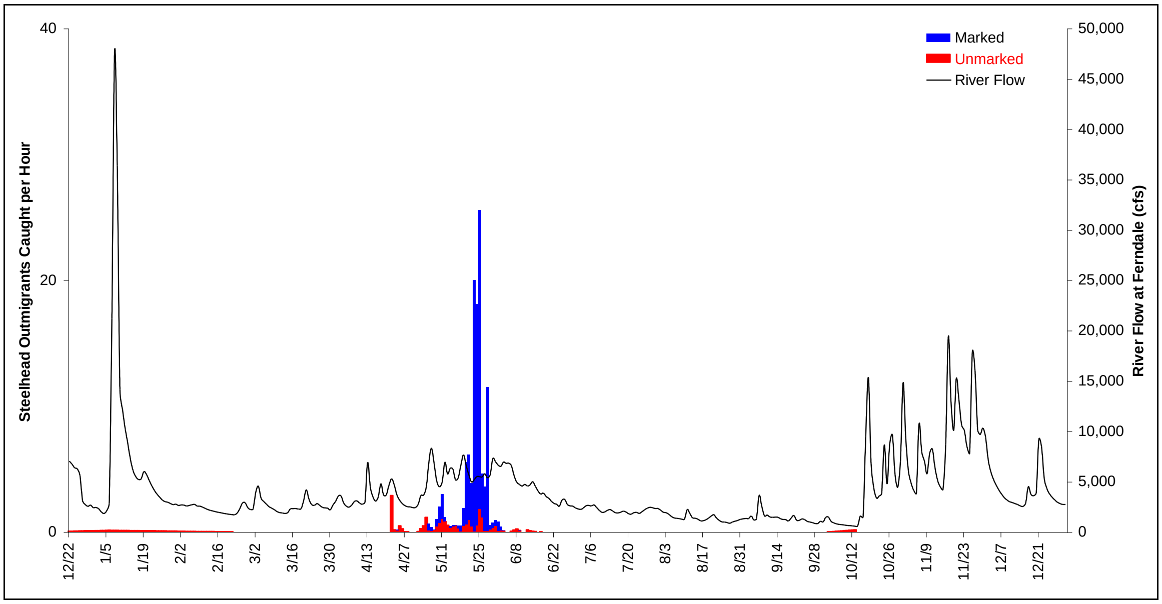


Figure 8.3. Interpolated Catch Per Hour of Steelhead Outmigrants by Date and Flow

8.6 Steelhead Production Estimates in the 2009 Season

8.6.1 Peterson Estimate for Steelhead

In the 2009 sampling year, 146,500 adipose fin clipped steelhead trout were released upstream from the Trap site. Assuming that all clipped steelhead were reliably detected in 2009, 481marked smolts were recaptured at the Trap, and a further 89 unclipped steelhead trout were also caught (total = 570). Based on these values, the Peterson estimate of total steelhead trout passing the Trap site in 2009 would be 173,552 fish.

The difference between the Peterson estimate for total steelhead trout and the number of hatchery-origin steelhead trout released is assumed to represent the wild-origin production estimate. Total hatchery releases in 2009 were 146,500 steelhead trout (Kendall hatchery reported a 0% clipping failure rate in 2009). Accordingly, the Peterson-derived estimate of wild-origin steelhead trout is **27,052** fish for the 2009 season.

8.6.2 CCE Estimate for Steelhead

During the 2009 season the Trap recaptured 0.33% of the clipped coho smolts that were released upstream. During the time period when clipped steelhead smolts were outmigrating, the Trap was fishing 23.01% of the time. Assuming that the number of marked smolts recaptured by the Trap would increase linearly with the amount of time fished during this period, then the 2009 season catch efficiency is estimated to have been 1.43%.

The estimated number of marked and unmarked steelhead smolts passing the trap site per day is shown in Figure 8.4. The daily estimates of the number of steelhead smolts was derived by using the 2009 seasonal catch efficiency estimate (1.43%) to convert the time series of hourly catch rates shown in Figure 8.3 and multiplying by 24 hours per day.

The total number of steelhead smolts estimated to have outmigrated in 2009 was 215,775. This total includes an estimated 172,951 marked smolts and 42,823 unmarked smolts. The estimate for marked smolts is 18% higher than the known number of marked steelhead smolts released. Assuming that the same is true for unmarked smolts, then the final CCE-derived wild production estimate for steelhead is **36,274** smolts.

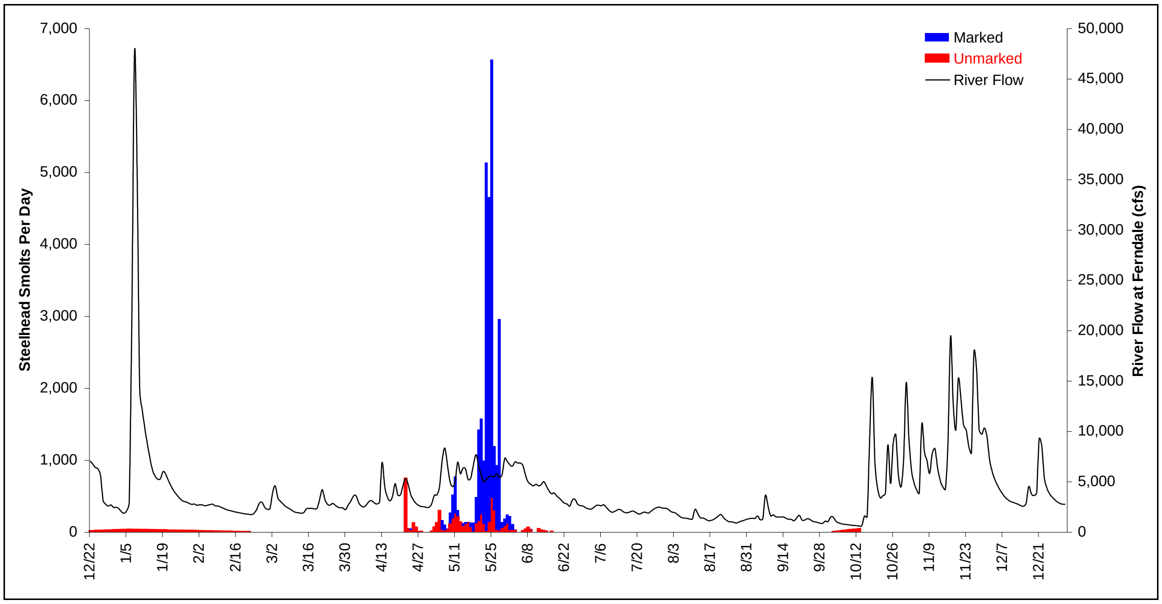


Figure 8.4. Daily Production Estimates for Steelhead Smolts in 2009

8.7 Between-Year Comparisons for Steelhead Production Estimates

Because marked steelheads were not reliably detected by the screwtrap crewmembers during previous seasons, no between-year comparisons can be made for wild-origin steelhead at this time.

8.8 Steelhead Discussion

The only known release of hatchery steelhead in 2009 occurred on May 18. However, the first clipped steelhead was detected at the trap on April 24, and more consistent numbers of marked steelhead were caught during the 2-week period immediately prior to the official release date. The origin of these marked smolts is uncertain but they are likely to represent a ‘leakage’ of hatchery steelhead smolts that are escaping confinement prior to the intended release date. Based on the CCE results, this pre-release group numbers approximately 1,440 smolts.

The screwtrap data for steelhead is of marginal utility due to the long-term failure of crewmembers to consistently examine all steelhead for clipped adipose fins. This issue precludes useful analysis of past results to detect temporal trends. It is hoped that this data will be collected more consistently for steelhead in future years. However, assuming that adipose fin clip detection was reliable in 2009, the average estimate of wild-origin steelhead production in 2009 was 31,663 smolts.

9.0 Other Species

In addition to the species discussed previously, several other species are periodically caught in the Trap. The complete list of organisms caught at the Trap from 2006 to 2009 is provided in Table 9.1.

Table 9.1. Organisms Present in Trap Catch Between 2006 and 2009

Salmonids	Total Count	Non Salmonid Fish	Total Count	Invertebrates	Total Count	Amphibians	Total Count
Bulltrout/Char	12	Bass	573	Crayfish	1	Tadpoles	4
Chinook	67,998	Dace	114				
Chum	134,284	Lamprey (eyes)	846				
Coho	40,462	Lamprey (no eyes)	150				
Cutthroat	177	Mountain Whitefish	11				
Pink	44,249	Pumpkin Seed	14				
Rainbow Trout	1	Sculpin	67				
Sockeye	118	Starry Flounder	2				
Steelhead	3,887	Stickleback	7,389				
Trout - Indeterminate	32	Sucker	1				

9.1 Catch Totals

The annual total catch and index of abundance for cutthroat trout, bull trout, lamprey (with eyes), Sticklebacks, and Sculpins are shown in Table 9.2. In 2009, the only other organisms caught in the Trap were 15 Lampreys (without eyes) and 1 Starry Flounder. (Note that prior to the 2006 field season, non-salmonid bycatch was not entered into the juvenile salmon database).

Table 9.2. Catch Totals and Index of Abundance by Year for Selected Species

Sampling	Cutthroat Trout		Bull Trout		Lamprey (eyes)		Sticklebacks		Sculpins		Hours Fished
Year	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	
2009	8	1.8	7	1.4	100	29.8	5,669	975.4	3	0.1	678.1
2008	5	0.2	0	0	109	23.7	169	23.7	4	0.5	890.6
2007	2	0.2	1	0	394	70.7	299	59.2	23	2.9	980.1
2006	19	4.8	4	0.5	238	75.7	1,250	763.7	37	14.2	724.2
2005	14	2.1	0	0	N/A	N/A	N/A	N/A	N/A	N/A	601.6
2004	13	2.3	0	0	N/A	N/A	N/A	N/A	N/A	N/A	738.56
2003	14	4.4	0	0	N/A	N/A	N/A	N/A	N/A	N/A	588.76
2002	31	6.7	0	0	N/A	N/A	N/A	N/A	N/A	N/A	721.38
2001	36	14.2	0	0	N/A	N/A	N/A	N/A	N/A	N/A	526.31
2000	35	12.3	0	0	N/A	N/A	N/A	N/A	N/A	N/A	487.94

10.0 Discussion

The results from the 2009 sampling season showed a mixture of trends in abundance for most species and life-stages of migratory fishes (Figure 10.1).

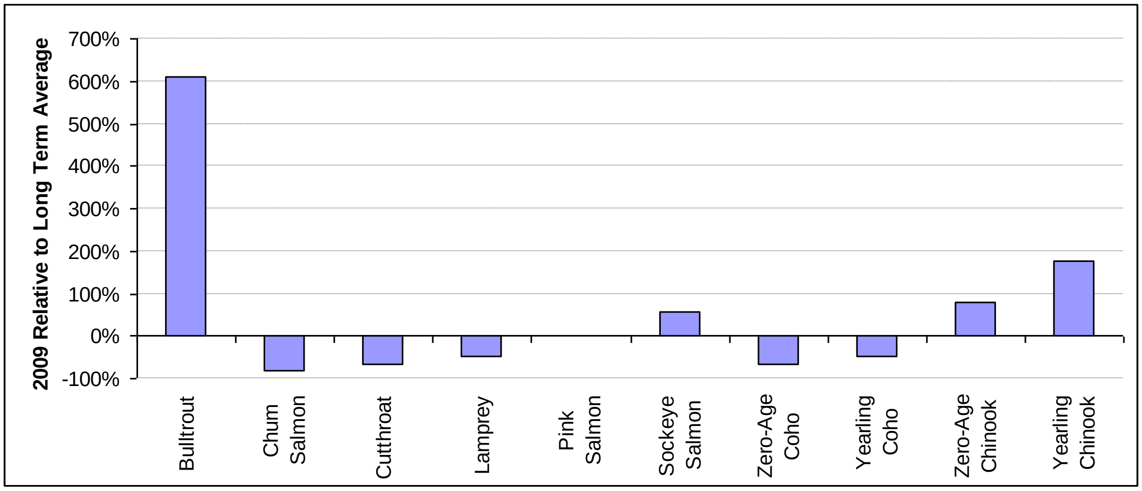


Figure 10.1. Comparison of 2009 Abundance Estimates Versus Multiple-Year Averages for Selected Fishes

The number of chum salmon outmigrants was estimated to be approximately 80% below the long-term average

Pink salmon were not caught in 2009 because the smolts of this species only outmigrate during even-numbered years.

The number of yearling Chinook outmigrants caught at the Trap in 2009 was approximately 180% higher than the average, which corresponds with a 110% higher-than-average outmigration of zero-age Chinook in the 2008 season.

The number of zero-age Chinook outmigrating in 2009 was approximately 10% below the long-term average (this average does not include estimates prior to 2002 due to differences in Trap operating schedules).

Sockeye salmon, bull trout, and cutthroat trout numbers were extremely low, but the numbers of bull trout and sockeye salmon caught in 2009 were higher than their respective long-term averages (by 610% and 50% respectively), while the number of cutthroat trout caught was 60% lower than average.

The number of lamprey outmigrating in 2009 was estimated to be 50% lower than the average from the preceding three seasons. (Comparable data obtained prior to the 2006 season is not currently accessible for non-salmonids.)

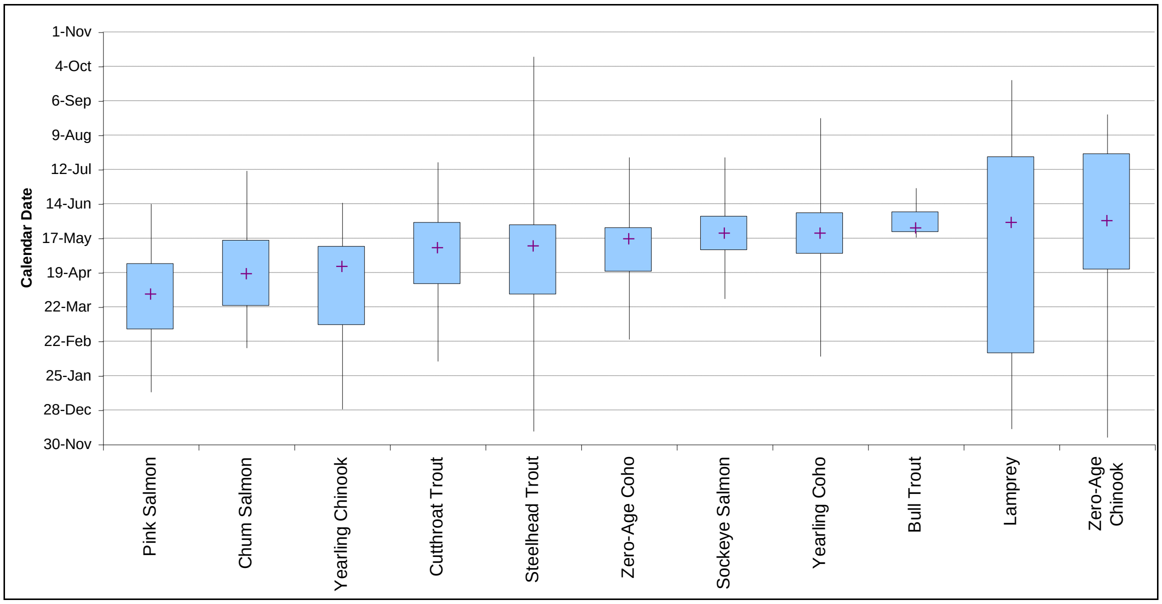


Figure 10.2. Comparison of Average Median (crosses) and 90% Outmigration Period Timing (boxes) for Selected Species with Minimum and Maximum Catch Dates Also Indicated (whiskers)

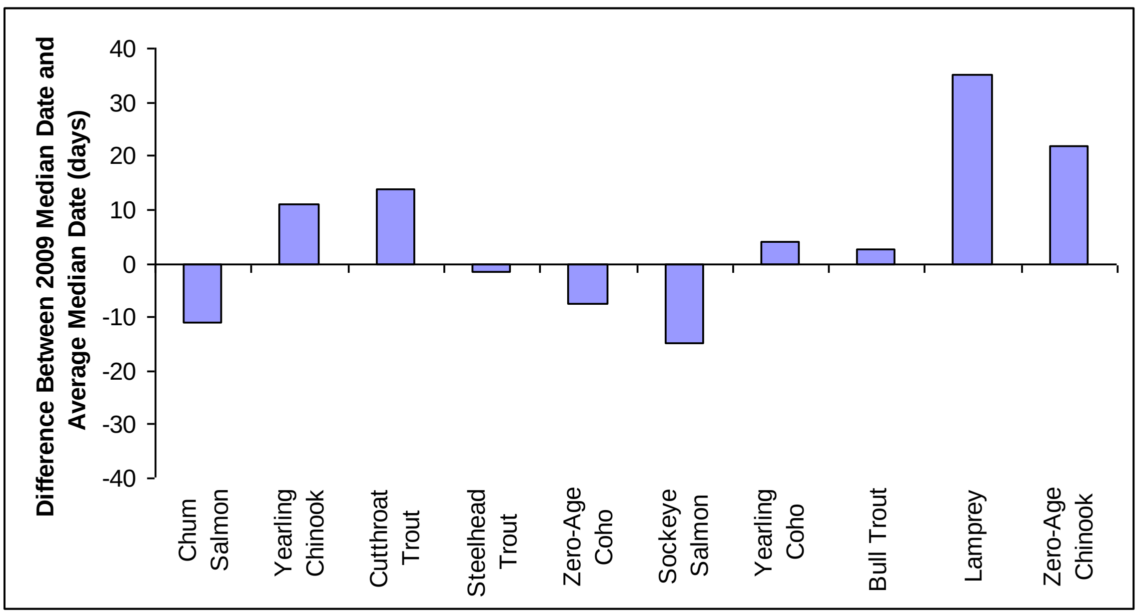


Figure 10.3. Comparison of Median Outmigration Dates in 2009 versus Average Median Dates (Negative values indicate that the 2009 median was early)

The ‘normal’ timing of outmigration and observed range of dates for several species is shown in Figure 10.2. The difference between the median outmigration date in 2009 versus the average median date is shown in Figure 10.3. Based on these data, it appears that the 2009 outmigration was somewhat later than usual for Chinook salmon and lamprey. In contrast, the timing of outmigration appeared to be somewhat earlier than usual for chum salmon. The timing of outmigration for yearling coho and steelhead in 2009 was within a week of the average outmigration date. Estimates of outmigration timing for zero-age coho salmon, cutthroat trout, bull trout, and sockeye salmon in 2009 are less dependable due to the comparatively much lower abundance of these species. Consequently, the observed differences between the median dates for these species are not likely to be particularly meaningful.

11.0 Sampling Mortality Rates

The Trap field protocol requires that any dead fishes removed from the Trap's live box are recorded as mortalities (Table 2.1). In some instances the cause of death can be ascribed to mechanical damage due to an excess of debris, or to accidental damage caused by handling, or that appear to be eaten after capture by other larger fishes that have also been caught ('Accidental Death'). However, in some cases, smolts appear to be already dead when caught in the Trap, and are simply corpses that are drifting downstream with the current (Dead on Arrival). In rare cases, some individuals may be deliberately sacrificed to obtain samples (cwt, DNA, otolith).

Table 11.1. Summary of Mortalities and Number of Fishes Handled at the Trap in the 2009 Season

Species_Name	Lifestage	Presumptive Origin	Accidental Death	Dead on Arrival	Sacrificed Intentionally	Total Handled	Mortality Rate
Bulltrout/Char	Not Recorded	Wild	0	0	0	7	0%
Chinook	Yearling	Wild	0	0	0	87	0%
Chinook	Zero-Age	Hatchery	14	0	0	5,151	0.3%
Chinook	Zero-Age	Wild	4	0	0	853	0.5%
Chum	Zero-Age	Wild	3	12	0	2,072	0.7%
Coho	Yearling	Hatchery	0	1	0	4,975	0%
Coho	Yearling	Wild	2	0	0	1,798	0.1%
Coho	Zero-Age	Wild	0	0	0	12	0%
Cutthroat	Not Recorded	Wild	0	0	0	8	0%
Lamprey (eyes)	Not Recorded	Wild	0	0	0	100	0%
Lamprey (no eyes)	Not Recorded	Wild	0	0	0	15	0%
Pink	Mature Adult	Wild	0	0	0	3	0%
Sculpin	Not Recorded	Wild	0	0	0	3	0%
Sockeye	Zero-Age	Wild	0	0	0	16	0%
Starry Flounder	Not Recorded	Wild	0	0	0	1	0%
Steelhead	Not Recorded	Hatchery	0	0	0	481	0%
Steelhead	Not Recorded	Wild	0	0	0	89	0%
Stickleback	Not Recorded	Wild	1	0	0	5,669	0%

In the 2009 sampling season, the mortality rate for most groups of fishes was relatively low. The highest mortality rate was for juvenile chum salmon where 0.7% of 2,072 fish were killed. However, most of these individuals were thought to be dead on arrival. Compared to mortality rates from the previous 3 years, the overall rate of mortalities in 2009 was below average for all groups except chum salmon.

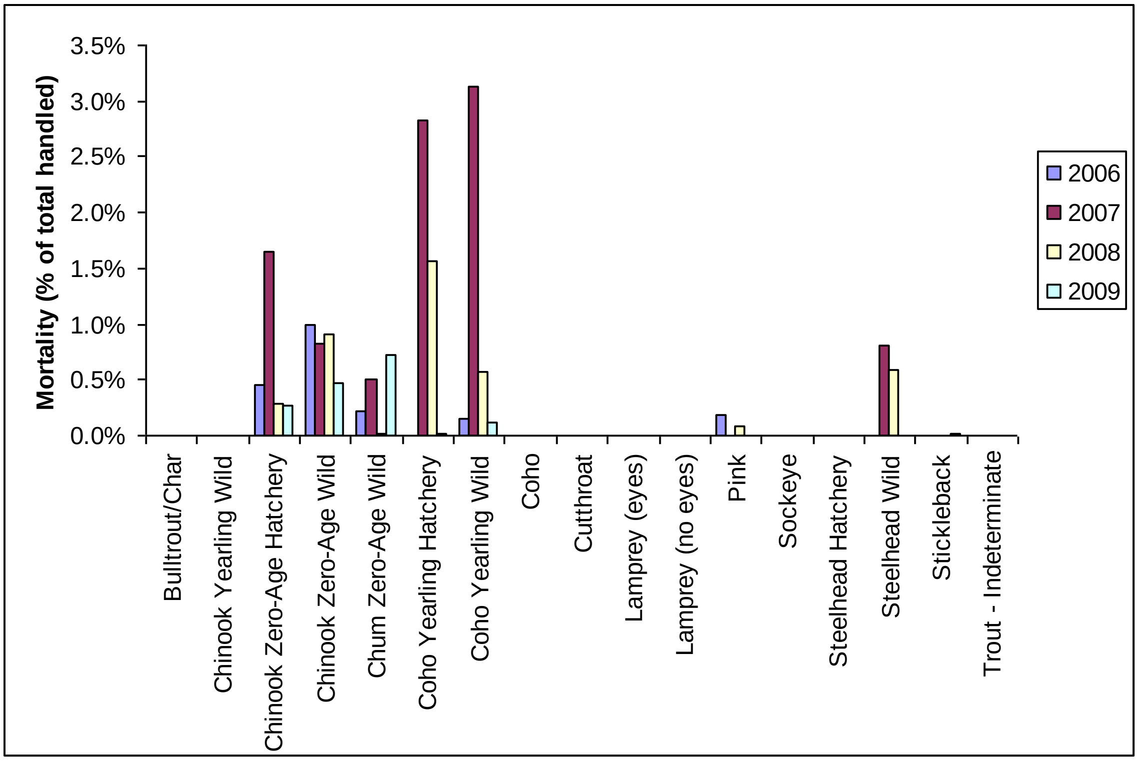


Figure 11.1. Comparison of Total Mortality Rates at the Trap by Sampling Year

12.0 References

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