2010 Smolt Trap Results

Lummi Indian Business Council
Lummi Natural Resources
Harvest Management Division

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Executive Summary

In total, 13 species of finfish and invertebrates were captured during the 2010 season.

The data obtained during 2010 from the Lummi screwtrap indicated that 114,236 wild-origin zero-age Chinook outmigrated past the trap site. Compared to outmigration estimates for recent years, the wild-origin zero-age Chinook outmigration estimate for 2010 is the third lowest to date.

No meaningful production estimate could be ascertained for coho due to damage to the trap that prevented sampling during the most critical time for coho outmigration.

Unusually low recapture/detection rates for steelhead smolts indicate that the estimate of steelhead production made using the 2010 data may be unreliable. Estimates derived using the two methods diverged too greatly from each other to have confidence in the results. Overall the relative abundance of steelhead smolts was roughly twice as high compared to 2009, given the amount of sampling conducted in each year.

Absolute production estimates could not be determined for other species due to the lack of marked hatchery fish to use for mark-recapture analysis. However, the relative abundance of chum smolts continued the pattern seen in previous years whereby one high abundance years is followed by 3 low-abundance years. The 2010 season represented the second low abundance year in this cycle.

Handling mortality rates from trap operations were typically negligible for most species encountered. However, the highest mortality rates were 2.3% for hatchery-origin coho smolts, and 0.8% for hatchery-origin zero-age Chinook smolts. For wild-origin smolts, 0.2% of zero-age Chinook and 0.6% of coho yearlings handled during sampling were mortalities. 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.

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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 with the opening facing 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 2009 (Dolphin 2010) to enumerate Chinook fry and coho yearling outmigrants passing downstream past the Trap site. The 2010 season was the sixth 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 report considers data collected from December 2009 through to September 2010 and aims to report the results of the 2010 sampling season, summarize the main findings, and compare these results to previous data (where available).

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, the available effort was distributed 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 68% compared to the three years prior to the review, and Trap effort during the critical May/June months has increased by 107%.

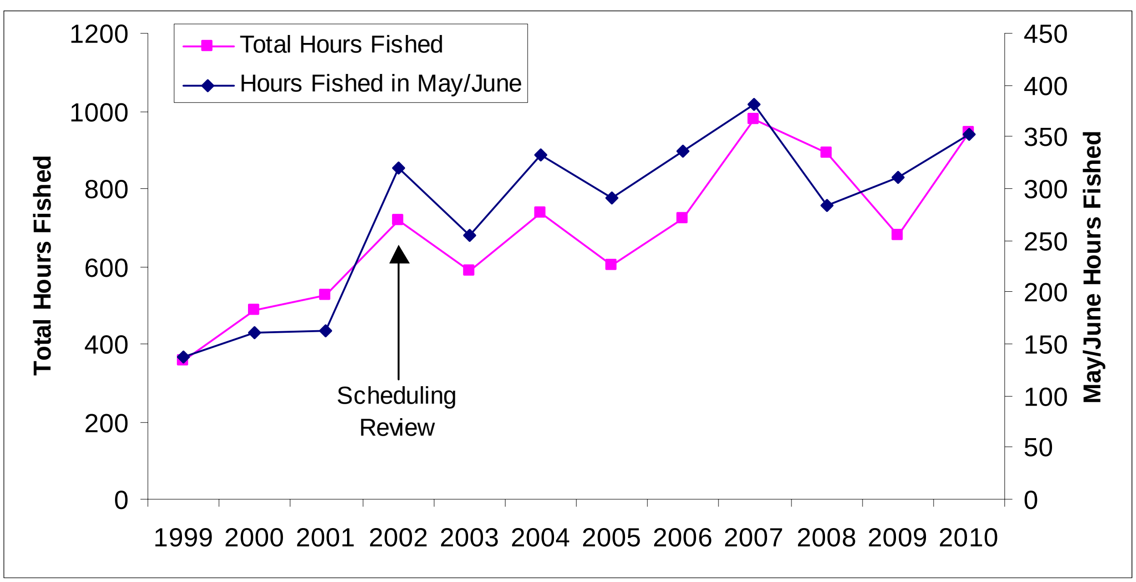
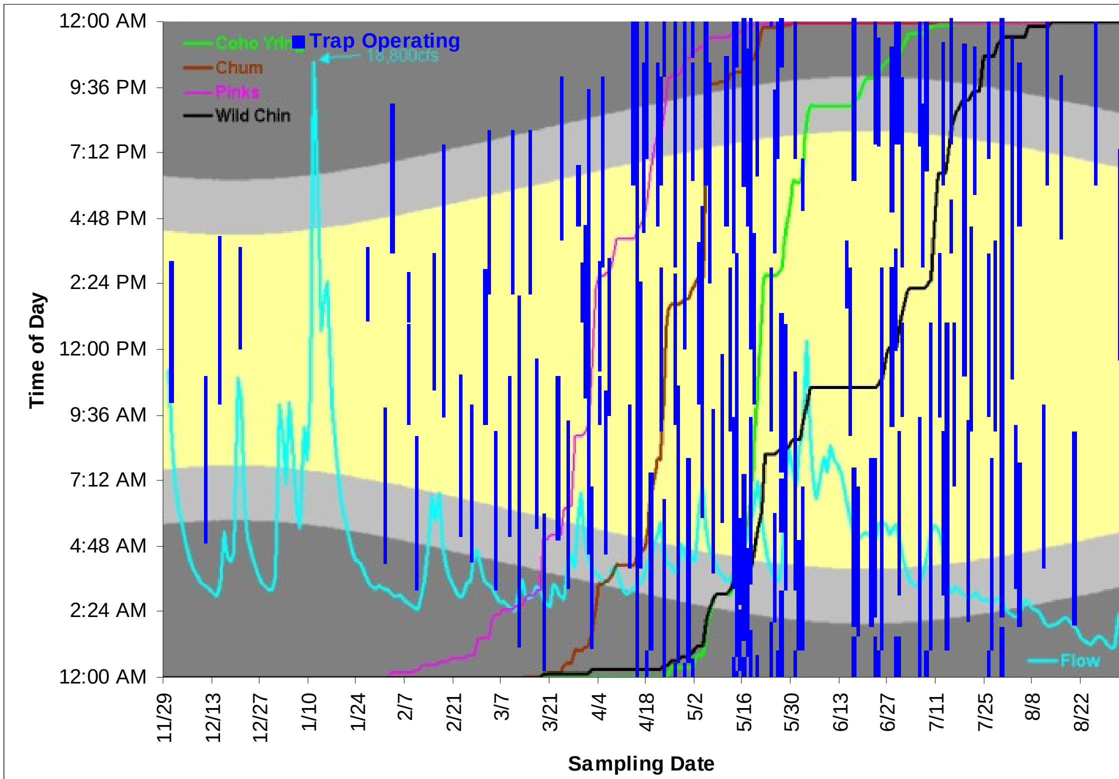


Figure 2.1. Comparison of Trap Effort Versus Sampling Season

In the 2010 season the screwtrap was operated from December 1, 2009 through to September 2, 2010, although sampling intensity was highest from April through July (Figure 2.2). Unfortunately, the screwtrap was damaged during a flow event and was unable to be fished from June 3, 2010 to June 14, 2010. The average monthly relative efficiency of the 2010 sampling schedule is shown in Figure 2.3. In total, the Trap was operated on 111 days during the 2010 season.



Trap operating hours (dark blue) in 2010 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 pink salmon fry (pink line).

Figure 2.2. Trap Operating Hours During the 2010 Season

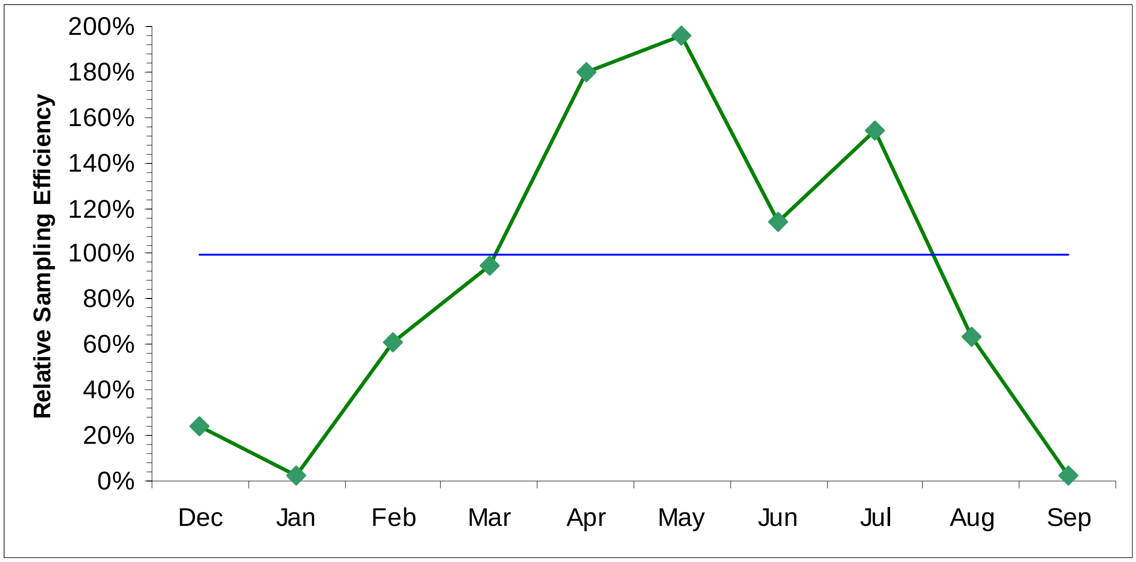


Figure 2.3. Relative Sampling Efficiency of Trap Schedule During the 2010 Season

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.

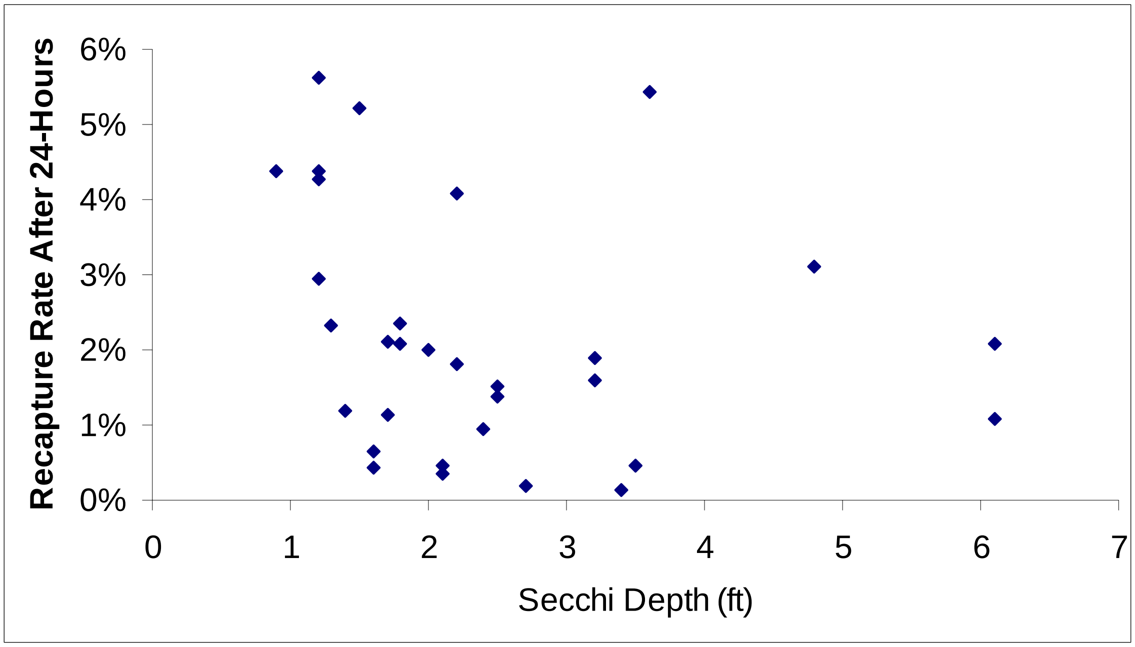


Figure 2.6. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus Water Clarity (Secchi-Depth)

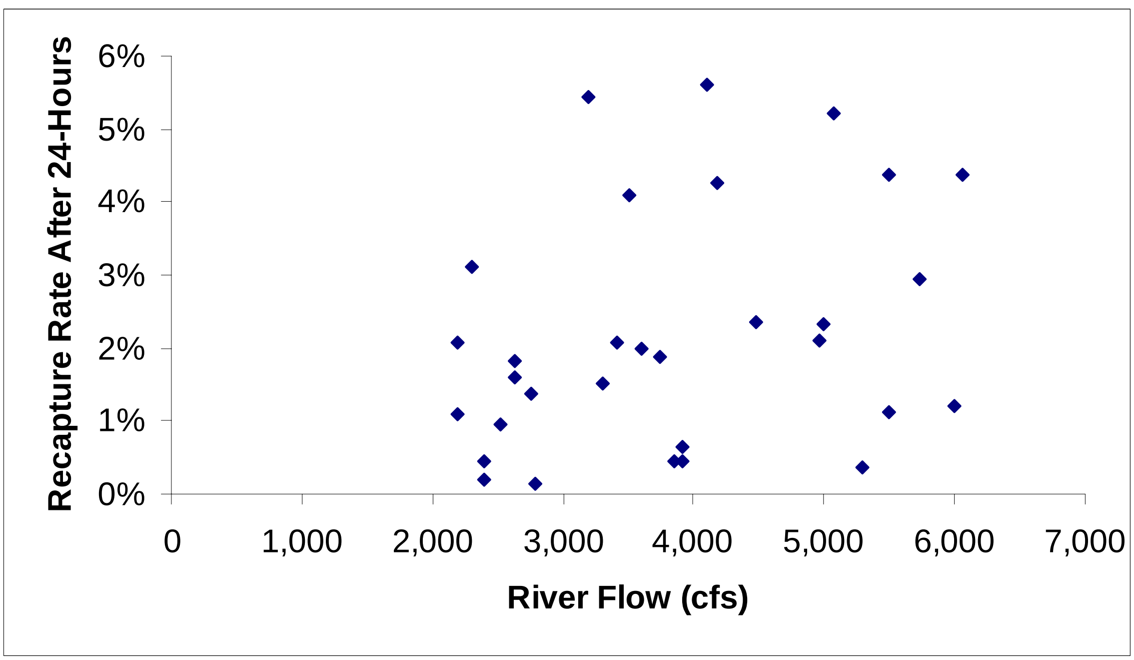


Figure 2.7. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus River Flow

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%

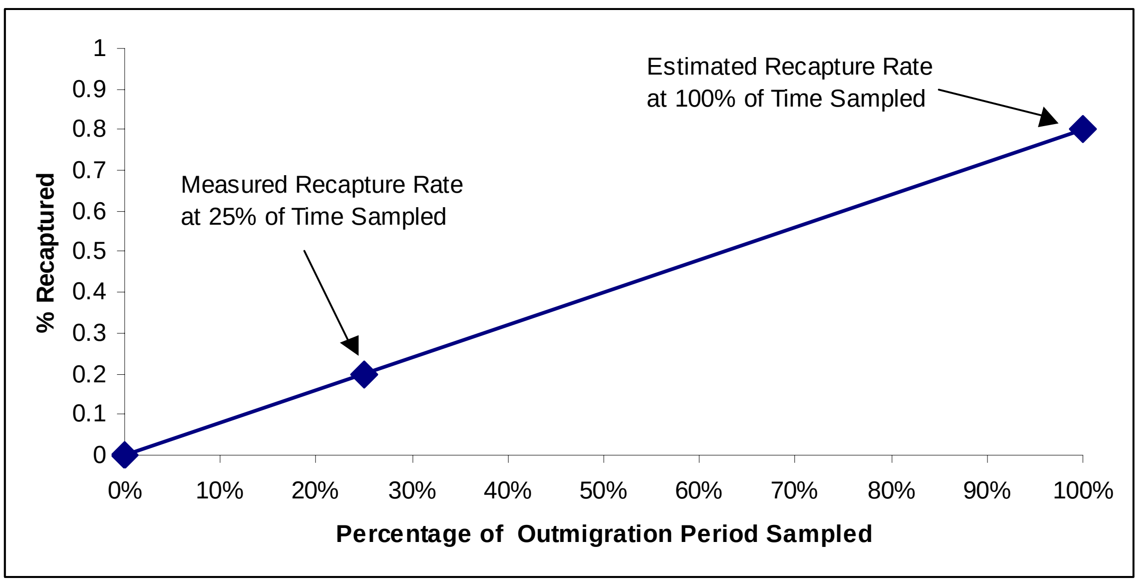


Figure 2.8. Hypothetical Example of Estimating Seasonal Trap Catch Efficiency

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

Table 3.1 and Figure 3.1 shows that the total number of hatchery-origin zero-age Chinook released upstream from the Trap was 1,273,378 smolts. Of this total, 99.6% (1,268,825 smolts) were externally marked, and 0.4% (4,553 smolts) were 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 2010 and the last release was on June 11 2010.

Table 3.1. Upstream Hatchery Releases of Zero-Age Chinook in 2010

Release Date	Source Hatchery	Release Location	Externally Marked			Externally Unmarked*	Total Marked Chinook Released	Total All Chinook Released
			AC & CWT	AC only	CWT Only			
4/15/2010	Kendall	Kendall Creek	0	55,278	0	222	55,278	55,500
5/3/2010	Kendall	Kendall Creek	0	55,068	0	332	55,068	55,400
5/12/2010	Kendall	Middle Fork	0	220,668	0	1,332	220,668	222,000
5/13/2010	Kendall	North Fork Nooksack	65,747	13,539	66,510	259	145,796	146,055
5/18/2010	Kendall	North Fork Nooksack	64,994	17,996	66,503	301	149,493	149,794
5/25/2010	Kendall	Kendall Creek	0	51,244	0	206	51,244	51,450
5/25/2010	Kendall	North Fork Nooksack	64,994	10,454	66,503	228	141,951	142,179
6/11/2010	Lummi Bay	Bertrand Creek	0	449,327	0	1,673	449,327	451,000
		Total Released	195,735	873,574	199,516	4,553*	1,268,825	1,273,378

* Based on reported clippling and tagging error rates

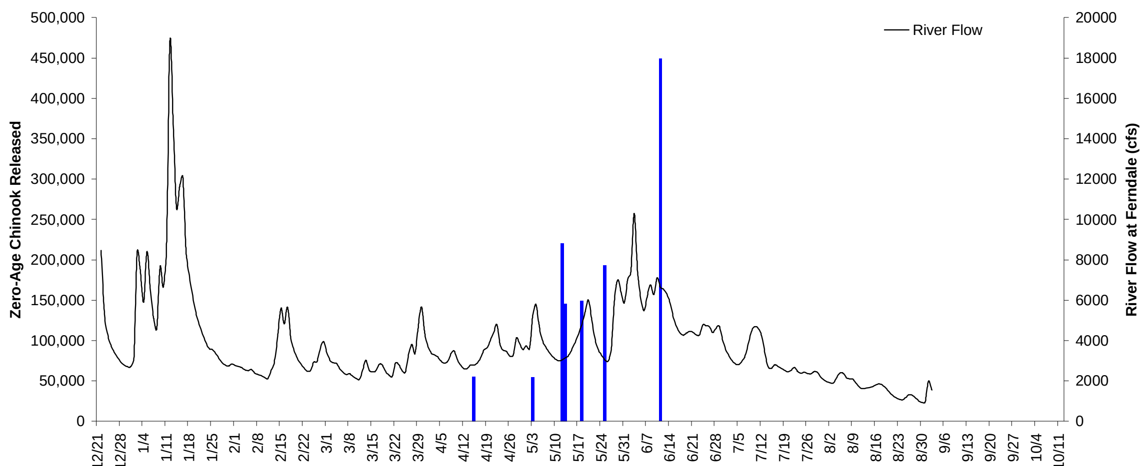


Figure 3.1. Timing and Magnitude of Hatchery Releases of Marked Zero-Age Chinook

3.2 Chinook Catch Totals

The 2010 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, significant numbers of the hatchery-origin Chinook smolts were externally unmarked when released. From 2005 on, almost all hatchery-released Chinook have been externally marked either by an adipose fin clip, a coded wire tag, or both of these.

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		
2010	**4,794**	**502**	**0**	**51**	943.7	99.6%
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	2,120	5,708	0	9	588.76	80.9%
2002	1,429	8,594	0	66	721.38	35.3%
2001	378	7,013	0	19	526.31	12.1%
2000	1,567	9,080	0	56	487.94	9.4%
1999	76	3,973	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 2010. 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		0.92	0.24	0.50		0.795*	0.428*	0.747*
Night	0.795*		0.43	0.38	0.75		0.25	0.737*
Dawn	0.428*	0.25		0.69	1.34	0.27		0.688*
Day	0.747*	0.737*	0.688*		1.23	1.57	0.74	
	* Indicates a Statistically Significant Correlation (p<0.05)							

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	0.17		0.396*	-0.04	0.522*
Night	0.396*		0.00	0.05	0.79		-0.03	0.10
Dawn	-0.04	-0.03		0.20	0.00	0.00		0.424*
Day	0.522*	0.10	0.424*		1.71	0.43	0.98	
	* Indicates a Statistically Significant Correlation (p<0.05)							

3.3 Chinook Smolt Sizes

The average daily fork lengths 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 2010 had an average fork length of 78.6 millimeters and marked zero-age Chinook had an average fork length of 82.7 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 middle of May onward.

Smolts that were considerably larger than either marked or unmarked zero-age smolts caught on the same date were presumed to be yearlings. Wild-origin yearling Chinook caught in 2010 had an average size of 106.2 millimeters.

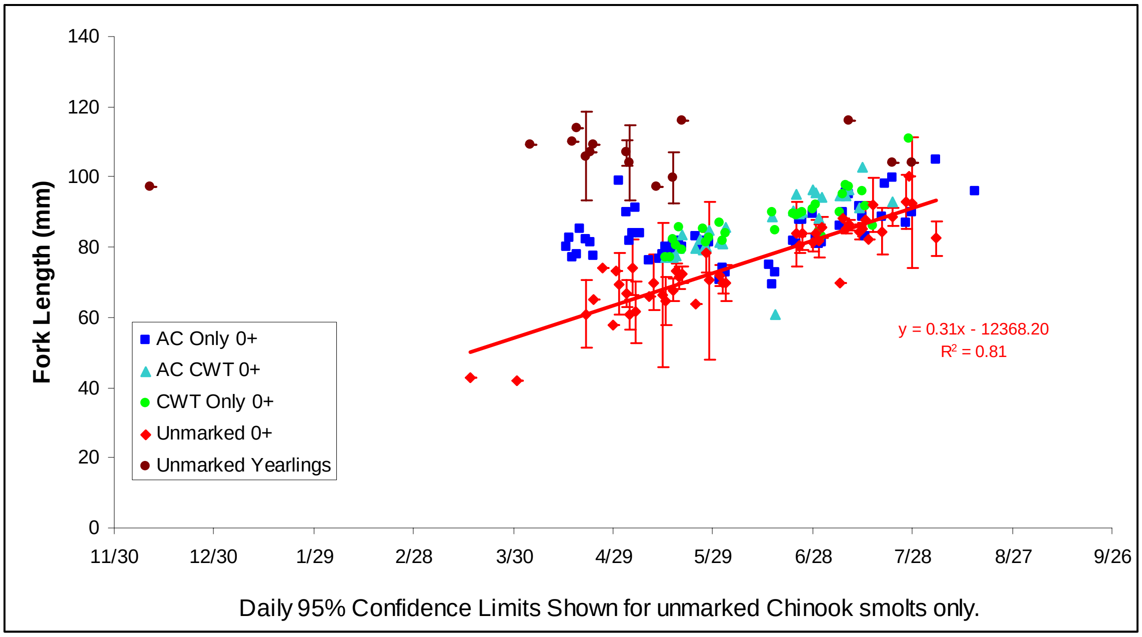


Figure 3.2. Average Daily Fork Lengths for Chinook Smolts Caught During 2010

3.4 Chinook Seasonal Outmigration Timing

The timing of outmigration for unmarked wild smolts in 2010 was within the range observed during previous years (Figure 3.3) and was very similar to the 2009 outmigration window.

The first unmarked zero-age Chinook smolt was caught in mid-March and the last unmarked zero-age smolt was caught in mid-August. In the 2010 sampling season, 90% of unmarked zero-age Chinook outmigrated between April 30th and July 23rd, and the 50th percentile occurred on June 23rd. The start of the main outmigration period was delayed by approximately one week for zero-age smolts. The median outmigration date was almost 3 weeks later than average. The end of the main outmigration period for zero-age smolts was within a week of the long-term average date.

The long-term average date for zero-age Chinook outmigration timing excludes the results from the 2006 season due to a lengthy gap in sampling effort. That gap resulted in a long period of interpolation immediately following a single unusually high CPUE result that may have significantly skewed the results for that season.

The outmigration of yearling Chinook smolts started very early in the 2010 season, with one yearling Chinook smolt being caught on December 9, 2009. Due to the relatively low number of yearling smolts caught, and the long interpolation intervals at that time of year, this outlier had the effect of strongly skewing the start of the main outmigration window very early compared with previous years (Figure 3.4). In the 2010 sampling season, 90% of yearlings outmigrated between December 9th and May 19th, with the 50th percentile date occurring on May 1st. This compares to the long-term average dates, which indicate that typically 90% of yearlings outmigrate between February 27 and May 15th. However, if this early outlier were removed from consideration, the main outmigration window for yearling Chinook smolts would have started in early April.

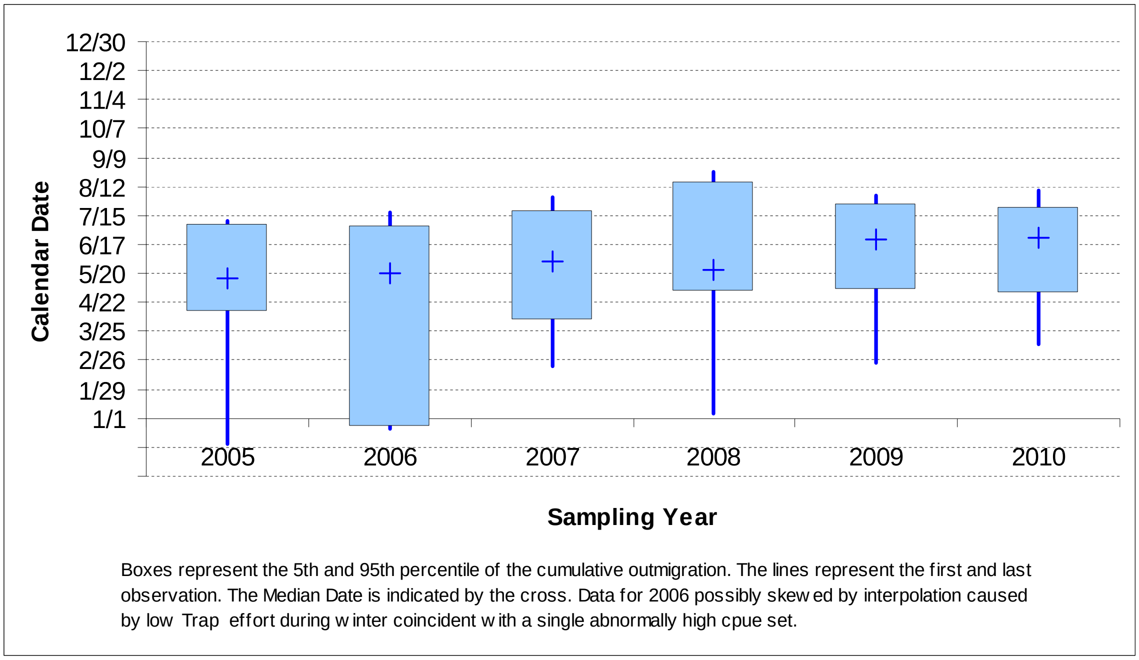


Figure 3.3. Outmigration timing for Unmarked Zero-Age Chinook smolts from 2005 to 2010

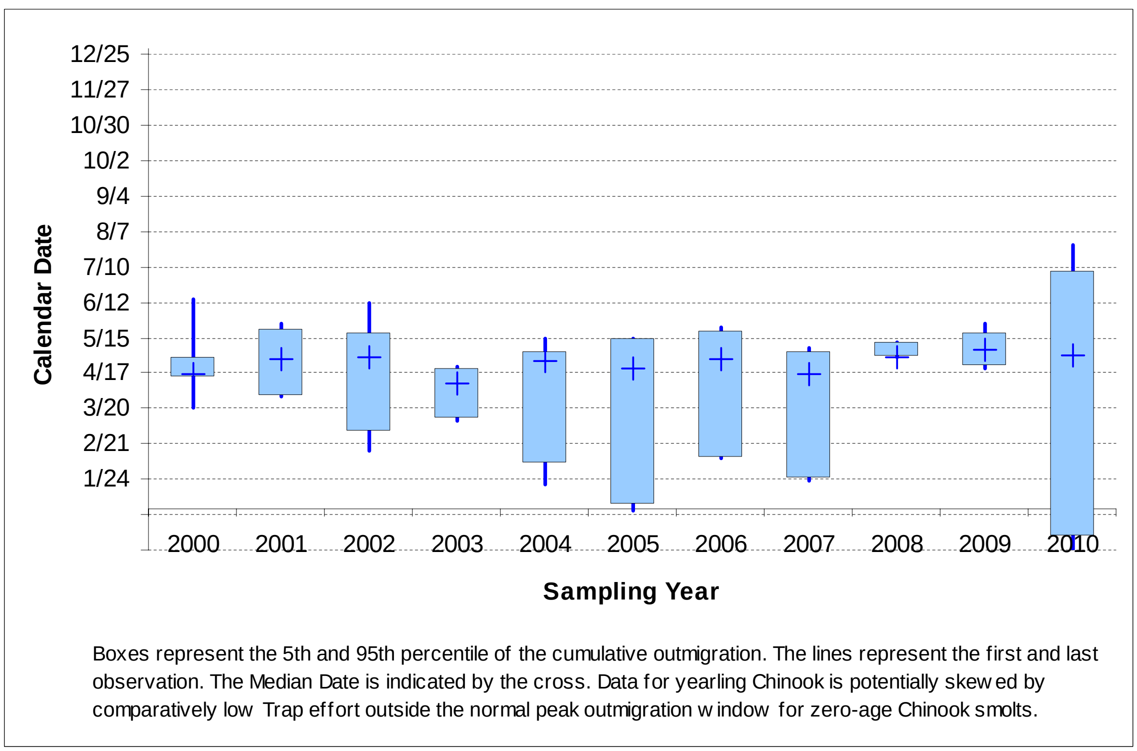


Figure 3.4. Outmigration timing for Unmarked Yearling Chinook smolts from 2000 to 2010

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.

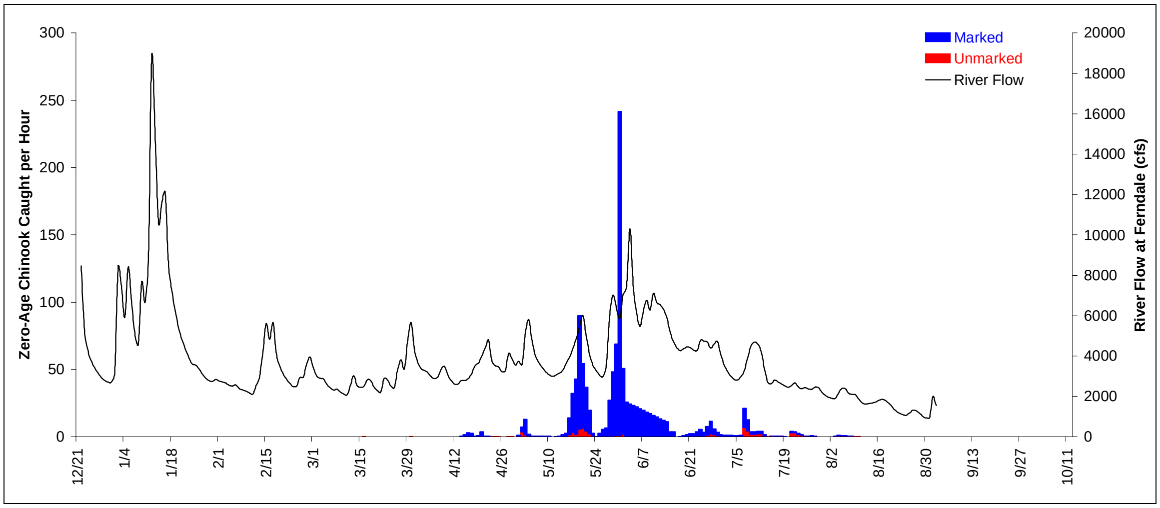


Figure 3.5. Interpolated Catch Per Hour of Zero-Age Chinook Smolts by Date and Mark Status

Unmarked zero-age Chinook began to be caught regularly from the beginning of May through mid-July 2010. Unfortunately, the trap was not operation in early June, which created a very long interpolation interval right in the middle of the peak outmigration window. From mid-June onwards a steady trickle of a few unmarked Chinook were caught until the outmigration finished in early August. The highest catch rate of unmarked zero-age Chinook occurred on July 7, 2010.

Marked hatchery-origin Chinook outmigrants were first noted in the catch on April 15 2010 and the last marked Chinook was caught on August 16, 2010. The majority of marked Chinook outmigrated between mid- May and the end of June. The highest catch rate of marked Chinook occurred on May 31, 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.

3.5.2 Zero-Age Chinook Production Estimates in the 2010 Season

Peterson Estimate for Zero-Age Chinook

In the 2010 sampling year, 1,268,825 externally marked zero-age Chinook were released upstream from the Trap site. Of this total, 4,794 were recaptured at the Trap, and a further 502 unmarked zero-age Chinook smolts were also caught (total = 5,296 smolts). The Peterson estimate of total zero-age Chinook passing the Trap site in 2010 is 1,401,662 smolts.

The difference between the Peterson estimate for total smolts and the number of hatchery-origin smolts released in 2010 is assumed to represent the wild-origin production estimate. Total hatchery releases in 2010 were 1,273,378 smolts (includes 4,553 unmarked smolts). For the 2010 sampling season, the Peterson-derived estimate of wild-origin zero-age Chinook is **128,284** smolts. As shown in Figure 3.6, the production estimate for wild-origin zero-age Chinook in 2010 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.

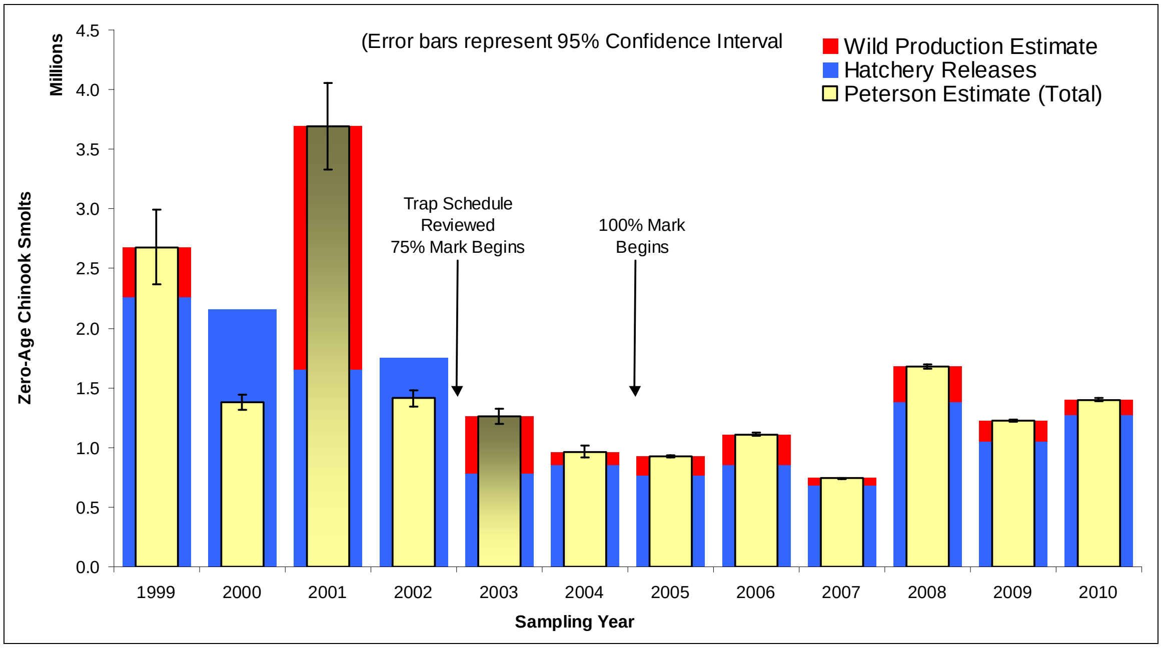


Figure 3.6. Peterson Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Zero-Age Chinook

In the 2010 season, the Trap recaptured 0.378% of the marked Chinook smolts that were released upstream. The Trap was fishing 23.73% 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 2010 season catch efficiency is estimated to have been 1.59% (Figure 3.7). This value is considerably lower than the average seasonal catch efficiency of 2.28%, for the seasons from 1999 to 2010 (Figure 3.8; Note that the estimate for the 2000 sampling season (10.56%) is excluded as an outlier). The lower than normal catch efficiency for the 2010 season is likely to be the result of the trap being non-operational for a prolonged period during the peak of the Chinook outmigration window. However, catch efficiencies for the past four seasons have all been lower than the longer-term average, so it is also possible that the catch efficiency of the Trap is declining over time.

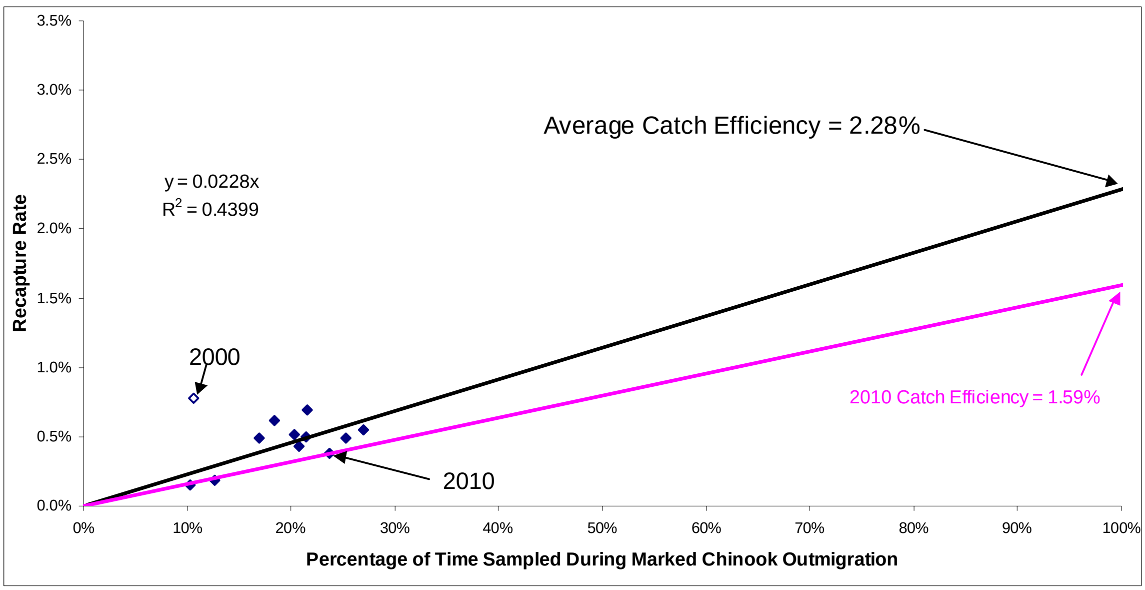


Figure 3.7. Seasonal Trap Catch Efficiency Estimates for Marked Zero-Age Chinook

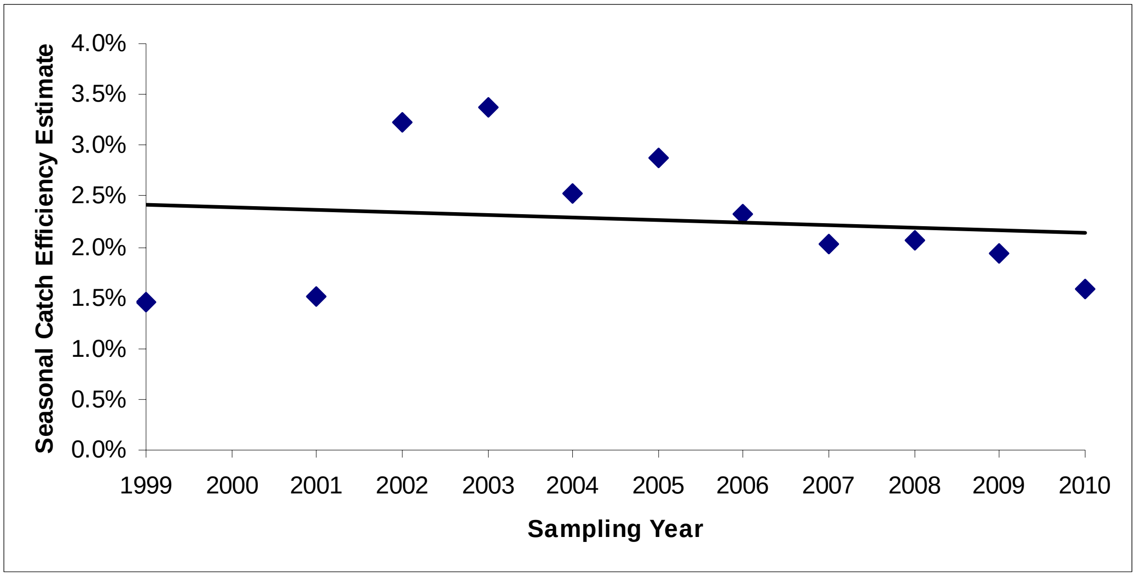


Figure 3.8. Comparison of Seasonal Catch Efficiency Estimates for Chinook over Time

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 (Figure 3.5) and multiplying by 24 hours per day.

The total number of smolts estimated to have outmigrated in 2010 was 1,228,047 Zero-age Chinook. This total includes 1,138173 marked smolts and 89,871 unmarked smolts. The estimate for marked smolts is 10.3% lower than the number of marked smolts that were released. Assuming that the same is true for unmarked smolts, and removing 4,553 unmarked hatchery-origin smolts from the result, then the CCE-derived wild production estimate for zero-age Chinook is **100,187** smolts.

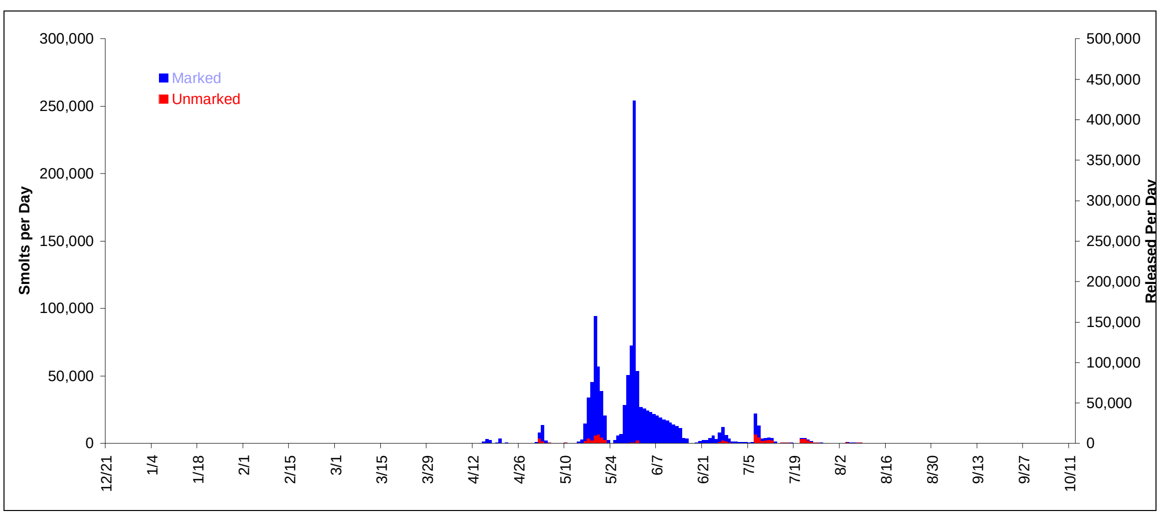


Figure 3.9. Daily Production Estimates for Zero-Age Chinook in 2010

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.

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 100,187 wild-origin Chinook smolts in 2010 was lower than the average outmigration of 280,514 smolts.

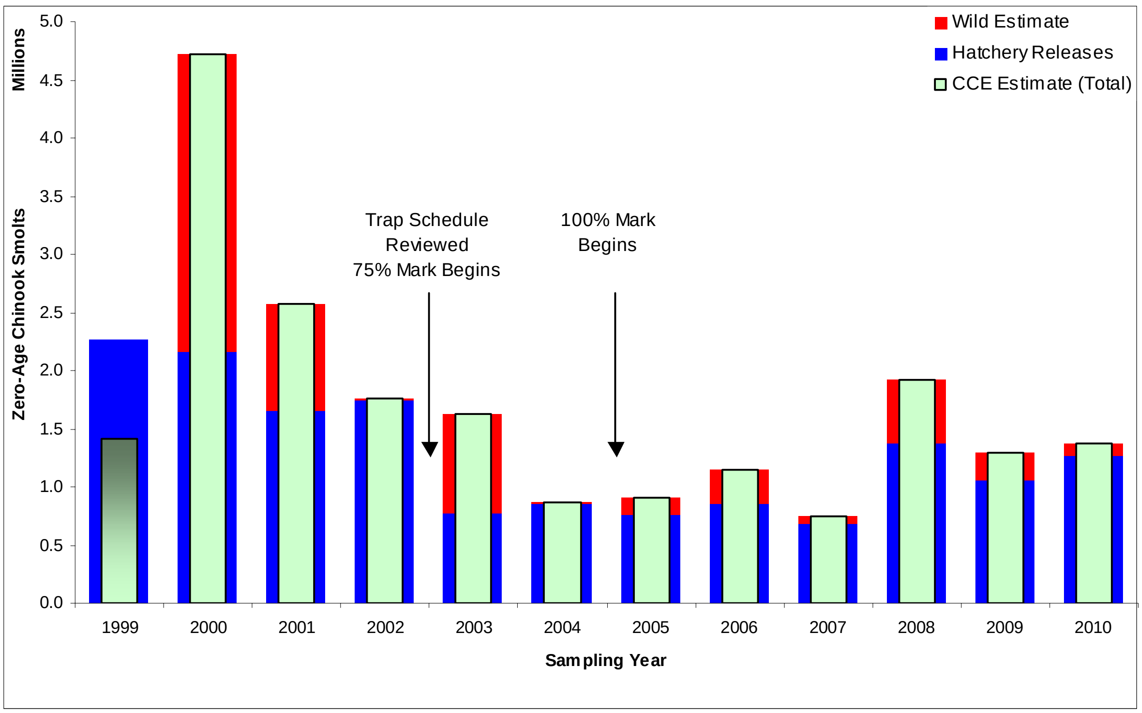


Figure 3.10. CCE Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

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 2010 season is **114,236** wild-origin zero-age Chinook smolts (Table 3.5).

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 more 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.

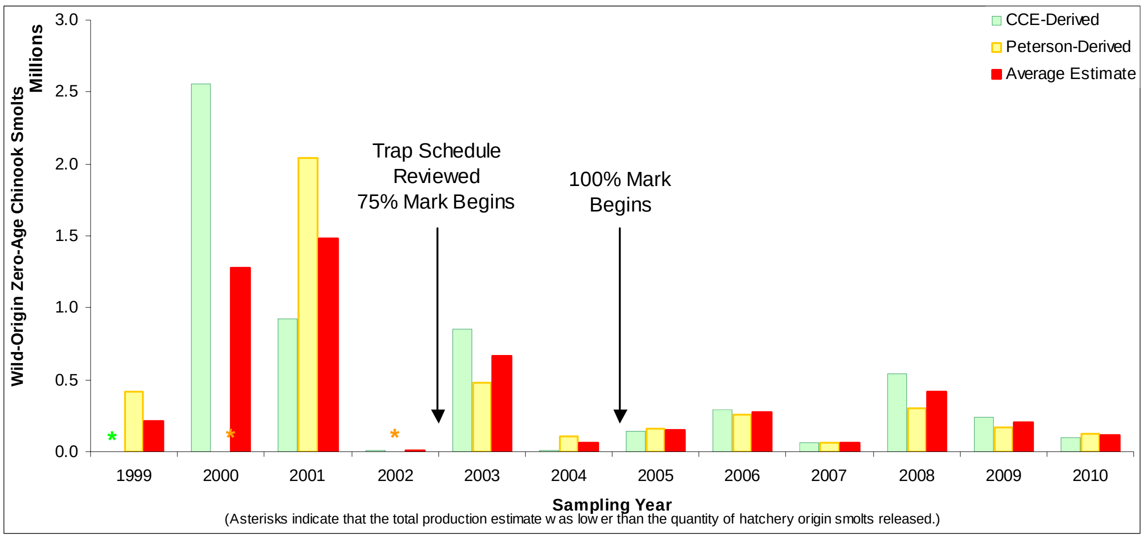


Figure 3.11. Comparison of Wild-Origin Zero-Age Chinook Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

Table 3.5. Production Estimates for Wild-Origin Zero-Age Chinook Smolts

Brood Year	Trap Year*	Average Estimate
2002	2003	666,424
2003	2004	59,216
2004	2005	151,832
2005	2006	275,975
2006	2007	63,088
2007	2008	420,194
2008	2009	206,231
2009	2010	114,236

Earlier estimates are considered to be too unreliable.

3.6 Yearling Chinook Outmigrants

3.6.1 CPUE Time Series for Yearling Chinook

In total, 51 yearling Chinook were caught between December 9, 2009 and July 28, 2010. 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 4.6 smolts per hour, which was recorded on May 3, 2010.

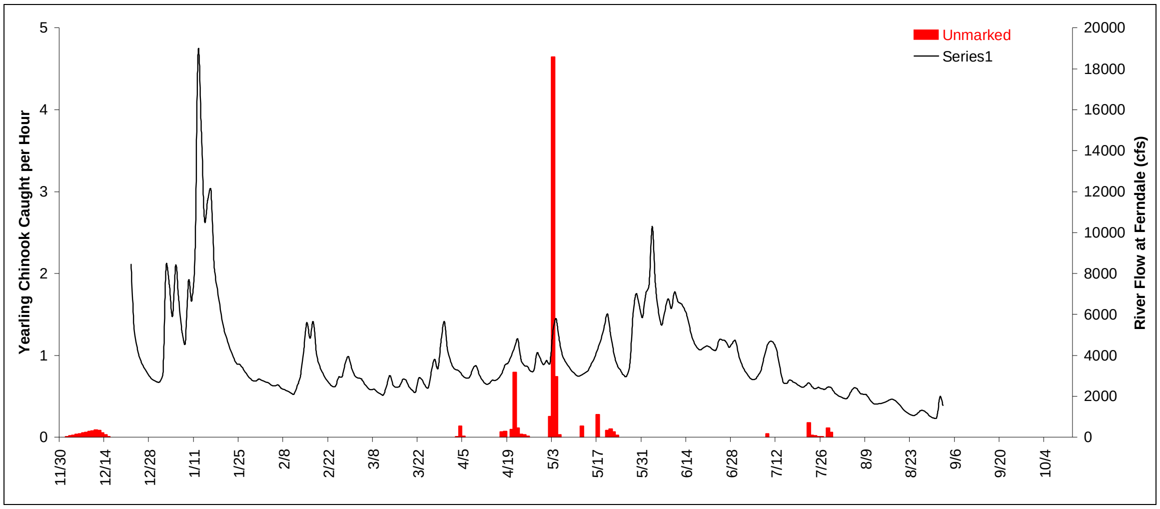


Figure 3.12. Interpolated Catch Per Hour of Yearling Chinook Smolts by Date

3.6.2 Between-Year Comparisons for Yearling Chinook CPUE

Yearling Chinook smolts that outmigrated during the 2010 sampling season are the offspring of adult Chinook that spawned during the summer and fall of 2008 (Brood Year [BY] 2008). The Index of Abundance for yearling Chinook during the 2010 sampling season has a value of 8.9. This is equal to the average Index of Abundance value for the period of record. 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 2009 will not outmigrate until the 2011 sampling season.

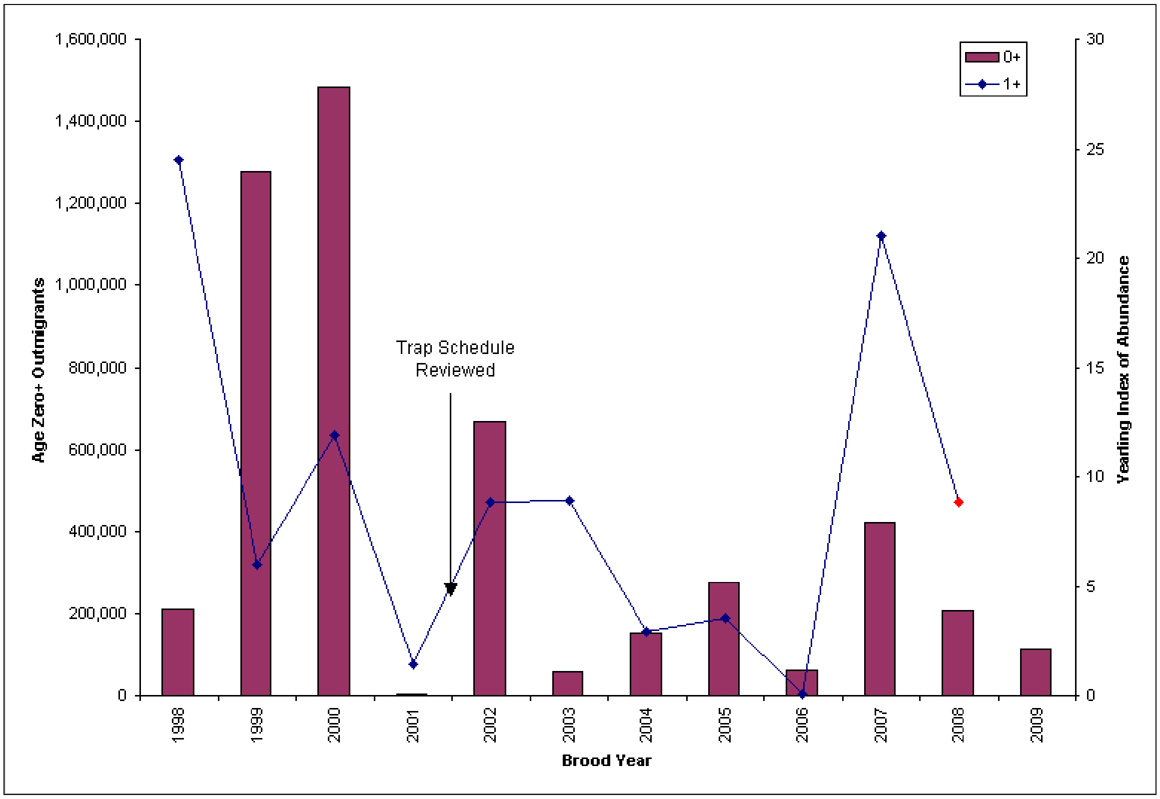


Figure 3.13. Comparison of Relative Zero-Age Production Estimates and Yearling Outmigrant Index of Abundance Based on Brood Year

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 2010 (BY 2008) would be approximately 23,554 smolts.

3.7 Chinook Discussion

The results for the Trap in the 2010 sampling season suggest that, relative to the previous 6 years, the production of wild-origin Chinook smolts was above-average for yearling smolts produced in BY 2008, and below-average for zero-age smolts produced in BY 2009.

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 slightly less severe than average compared to flows during the fall of other years, while the flows during egg incubation during BY 2009 were slightly worse than average (Table 3.6). These results are consistent with the hypothesis that river flows during egg incubation may be responsible for determining year class strength. The largest flow event during the period of record occurred in early January of 2009 (47,500 cfs). The fact that such a large event did not appear to strongly impact the production of zero-age Chinook smolts in 2009, or yearling smolts in 2010, 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 3.6 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	2010	2011
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**	**18,800**	**27,400**
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	5,660	7,820
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	5,660	
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	4,790	
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	7,050	
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	10,300	
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	4,700	
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	2,400	
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	9,750	
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**	5,900	
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**	10,000	
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	**31,700**	
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	114,236	?
Yearling Chinook Ind. of Abund.				24.5	6.0	11.9	1.4	8.8	8.9	2.9	3.5	0.1	21.0	8.9	?

Brood Year → Zero-Age Migrants → Yearling Migrants

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. 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 6 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 have 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 1,019,613 smolts. Coho smolts were released from June 4 through June 9, 2010 from the Skookum Creek hatchery. This is the first year that Kendall Creek hatchery has not released any coho smolts.

No data relating to clipping error rates were available at the time of writing and it is assumed that 100% of smolts were correctly clipped.

Because hatchery-released coho smolts 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.)

Release Date	Source Hatchery	Location	Marked Coho Released		Unmarked Coho Released		Total Coho Released
			AC Only	AC & CWT	CWT Only	No AC No CWT	
06/04/10	Skookum	Skookum Creek	54,221	2,487	0	0	56,708
06/05/10	Skookum	Skookum Creek	170,440	7,818	0	0	178,258
06/06/10	Skookum	Skookum Creek	389,800	17,880	0	0	407,680
06/07/10	Skookum	Skookum Creek	255,824	11,735	0	0	267,558
06/08/10	Skookum	Skookum Creek	41,970	1,925	0	0	43,896
06/09/10	Skookum	Skookum Creek	62,640	2,873	0	0	65,513
			974,895	44,718	0	0	1,019,613

Table 4.1 Upstream Hatchery Releases of Yearling Coho in 2010

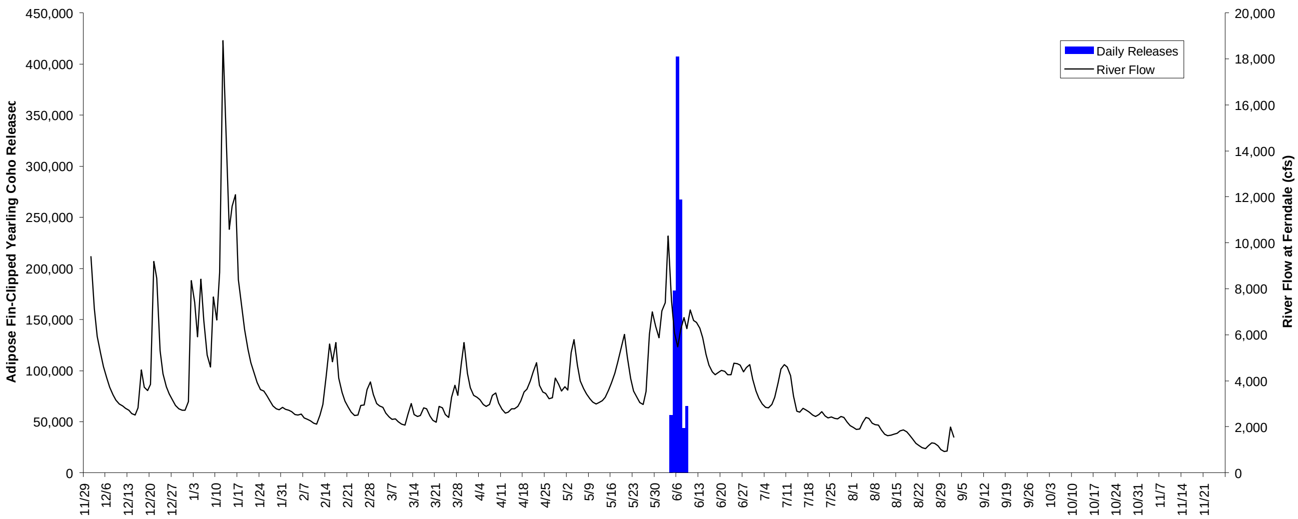


Figure 4.1. Timing and Magnitude of Hatchery Releases of Marked Yearling Coho

4.2 Coho Catch Totals

The 2010 catch of coho outmigrants is shown in Table 4.2 along with the totals for previous sampling years, and also 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 2010 season was the second lowest on record, and the lowest since the advent of large-scale adipose fin clipping. The overall catch of unmarked yearling coho was also the second lowest on record.

The reason for the very low catch total for coho smolts is explained by the timing of a prolonged and unplanned gap in sampling effort that occurred coincident with the release of hatchery coho and also during the main outmigration period for wild coho smolts. The gap in sampling lasted approximately 2 weeks and began within a day of the first official release of hatchery coho smolts. Previous work has indicated that hatchery coho smolts have an average residency period of c. 3 days. Thus it is likely that more than 90% of the hatchery smolts outmigrated while the trap was not operational.

Table 4.2. Catch Totals for Coho Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	% Marked in Released Hatchery Coho
	Marked	Unmarked	Marked	Unmarked		
2010	0	4	663	847	943.7	?
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%

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 2010 had an average fork length of 113.9 millimeters. Marked hatchery-origin coho yearlings had an average fork length of 108.7 millimeters. Unmarked zero-age coho had an average fork length of 51.3 millimeters.

In general, unmarked yearling smolts were in the same size range as 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 increase during the year. However, relatively few zero-age coho smolts were encountered during sampling.

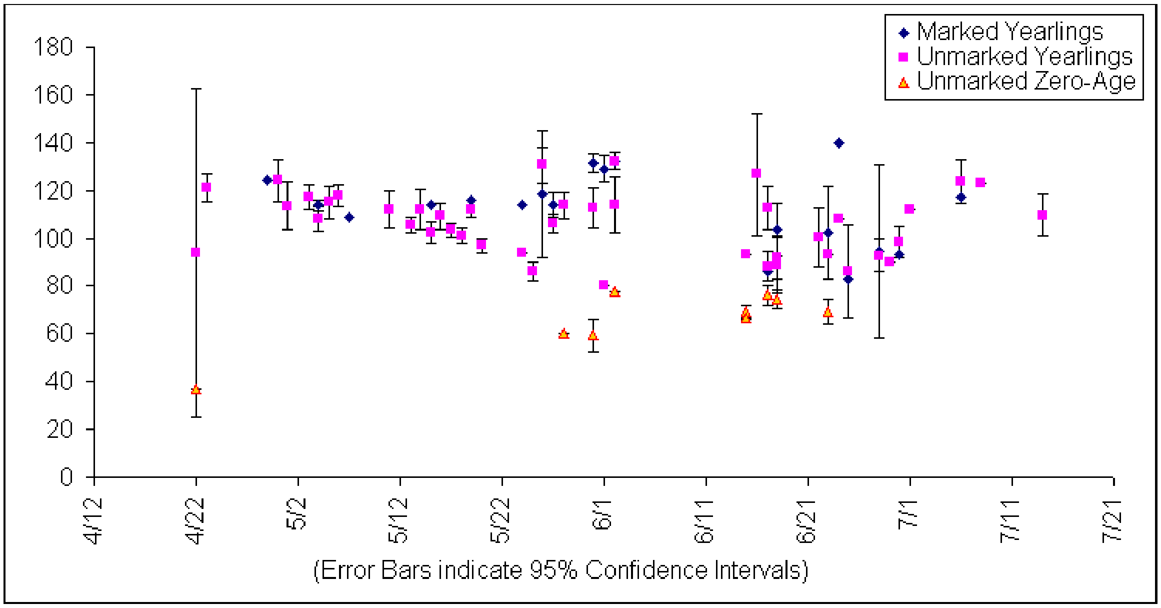


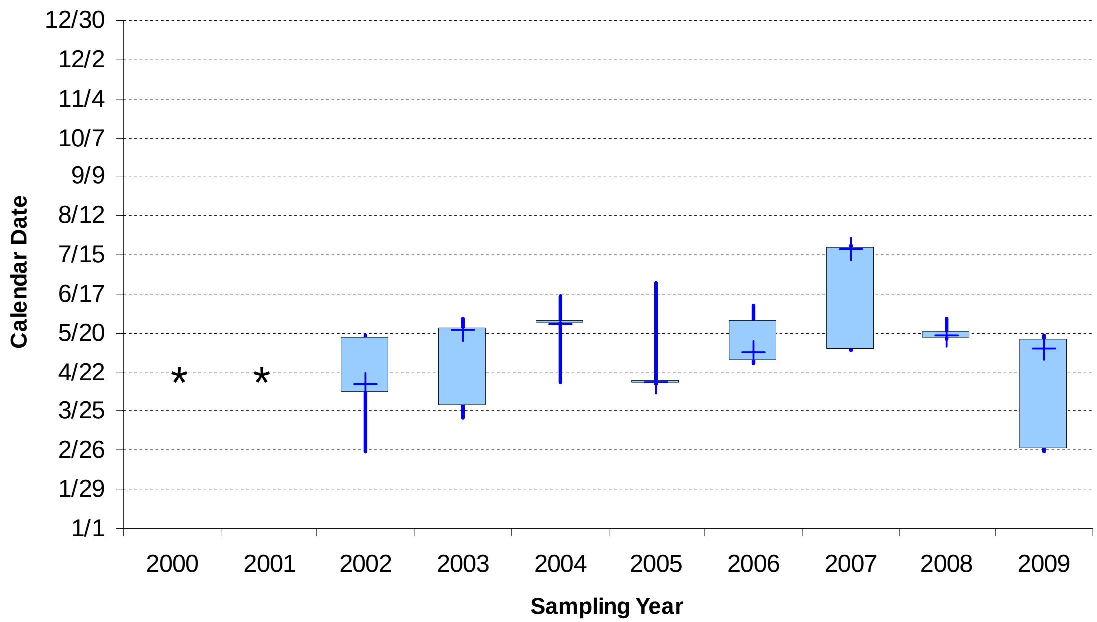
Figure 4.2. Average Daily Fork Lengths for Coho Smolts Caught During 2010

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.

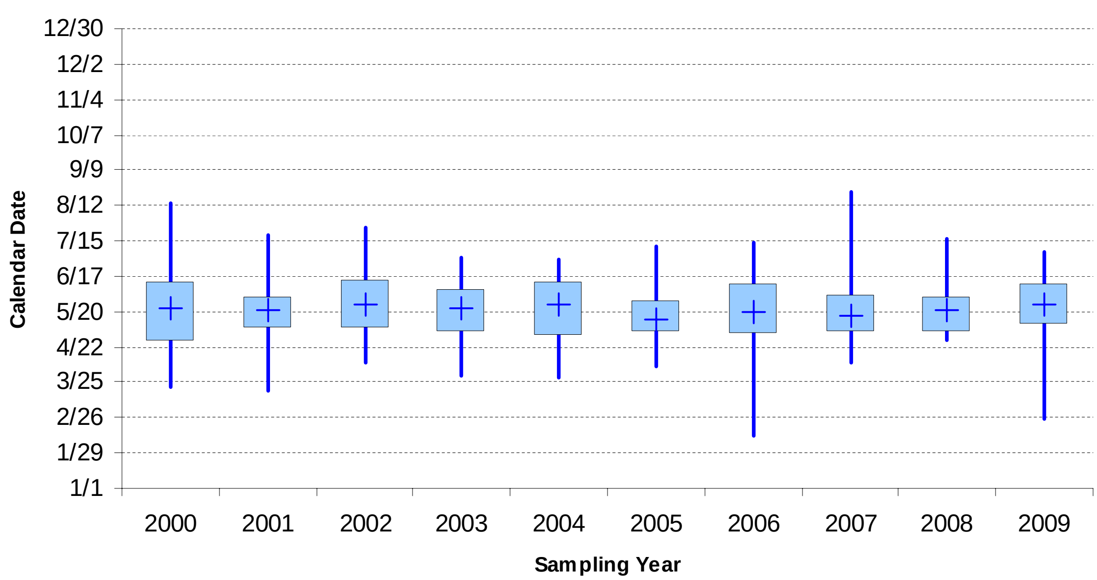
Yearling coho smolts have a much more consistent outmigration window, which has a median outmigration date that has varied by less than one week over the past 10 seasons, and which has an average duration of 34 days during which 90% of yearling coho outmigrate (Figure 4.4).

Because the trap was not operating during the majority of the typical outmigration period, no attempt is made here to calculate outmigration statistics for the 2010 sampling year.



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 skew ed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration w indow 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 skew ed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration w indow 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 2010 season, only 4 zero-age coho smolts were caught from late April to mid June. Because of the prolonged gap in sampling, no time series has been constructed for CPUE of zero-age coho in the 2010 sampling season.

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

Because there was no sampling effort during the critical outmigration period for coho yearlings, no attempt can be made to examine trends in CPUE for yearling coho for the 2010 sampling season.

4.6.2 Production Estimates for Yearling Coho in the 2010 Season

Peterson Estimate for Yearling Coho

In the 2010 sampling year, 1,019,613 externally marked (adipose fin clipped) yearling coho were released upstream from the Trap site. Of this total, 663 were recaptured at the Trap, and a further 847 unmarked yearling coho smolts were also caught (total = 1,510 smolts). It is mathematically possible to compute a Peterson mark-recapture estimate for yearling coho using these values as inputs. However, because the trap did not operate during the time that the majority of hatchery-origin coho were outmigrating, the resulting value would be completely meaningless. And because there are some differences in the outmigration timing of wild and hatchery-origin smolts, it is not reasonable to assume that the lack of sampling effort would impact both groups of coho yearlings equally. Accordingly, it is not possible to determine a production estimate for wild-origin coho yearlings for the 2010 sampling season.

The Peterson-derived estimate of wild-origin yearling coho for previous seasons is shown in (Figure 4.5).

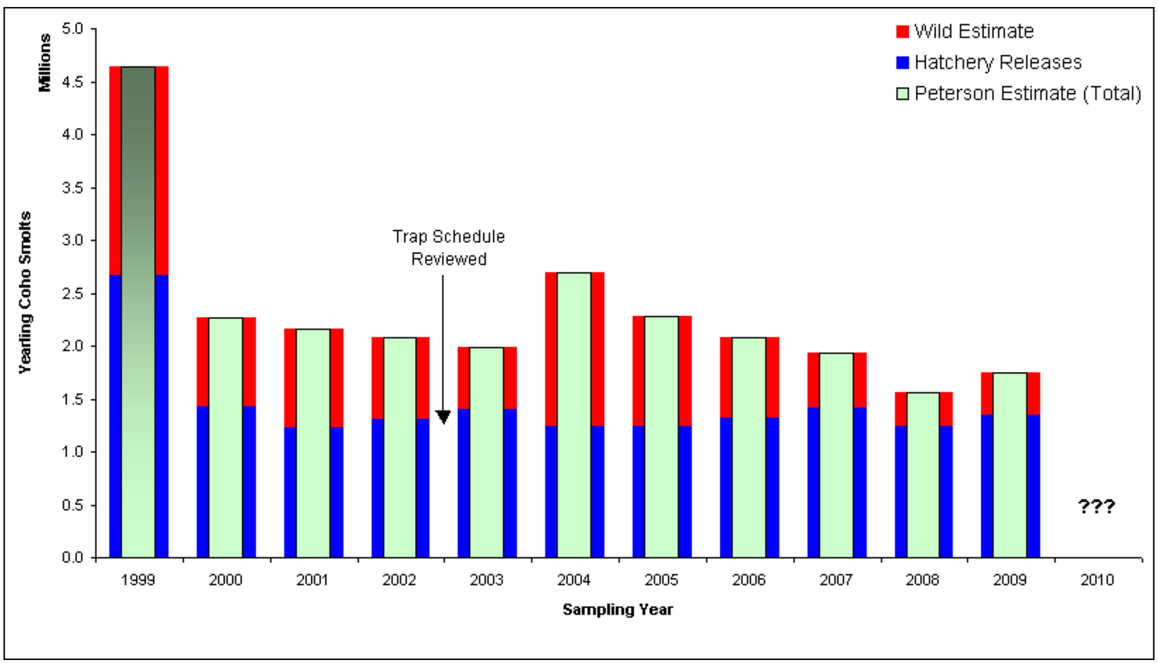


Figure 4.5. Peterson Estimates for Yearling Coho Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Yearling Coho

Because there was no sampling effort at all during the most critical 2-week period of the outmigration for hatchery smolts no meaningful analysis of the time series data of catch results for yearling coho can be made for the 2010 season.

4.6.3 Between-Year Comparisons for Yearling Coho Production Estimates

No production estimates were possible for yearling coho in the 2010 season because the smolt trap was not sampling during the critical outmigration window for coho yearlings.

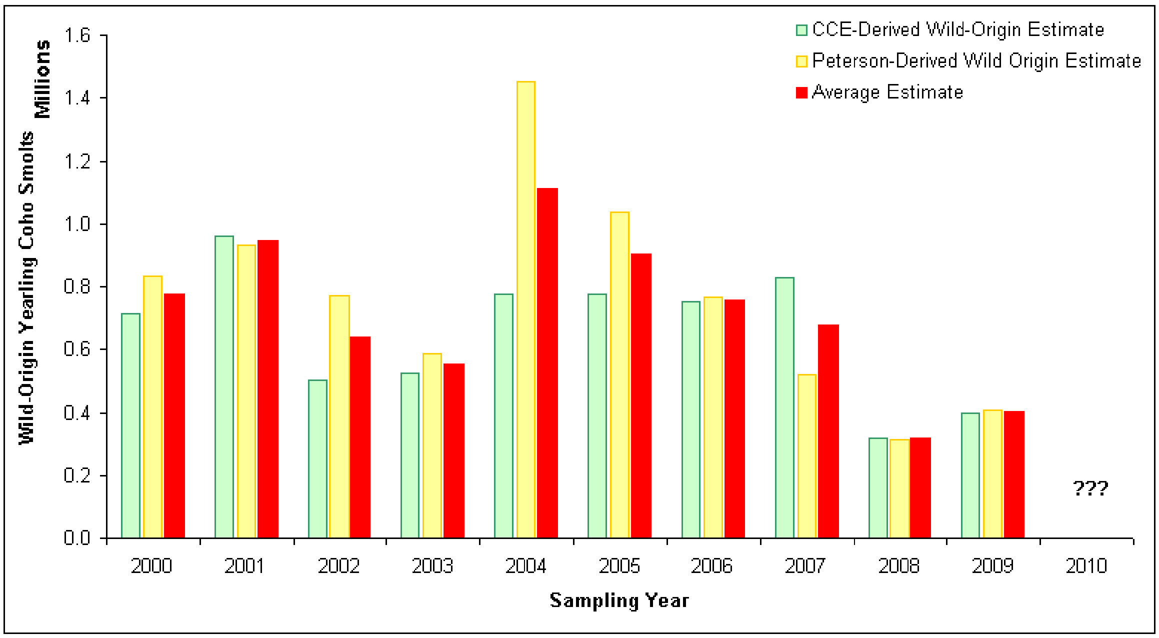


Figure 4.6. Comparison of Wild-Origin Yearling Coho Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

4.7 Coho Discussion

Yearling coho appear to outmigrate in a very well defined time period that, on average, typically varies by less than a week between years. Unfortunately, damage to the trap prevented sampling at the worst possible time for estimating coho production in 2010.

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 2010 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 2010 season was the fourth lowest in the period of record.

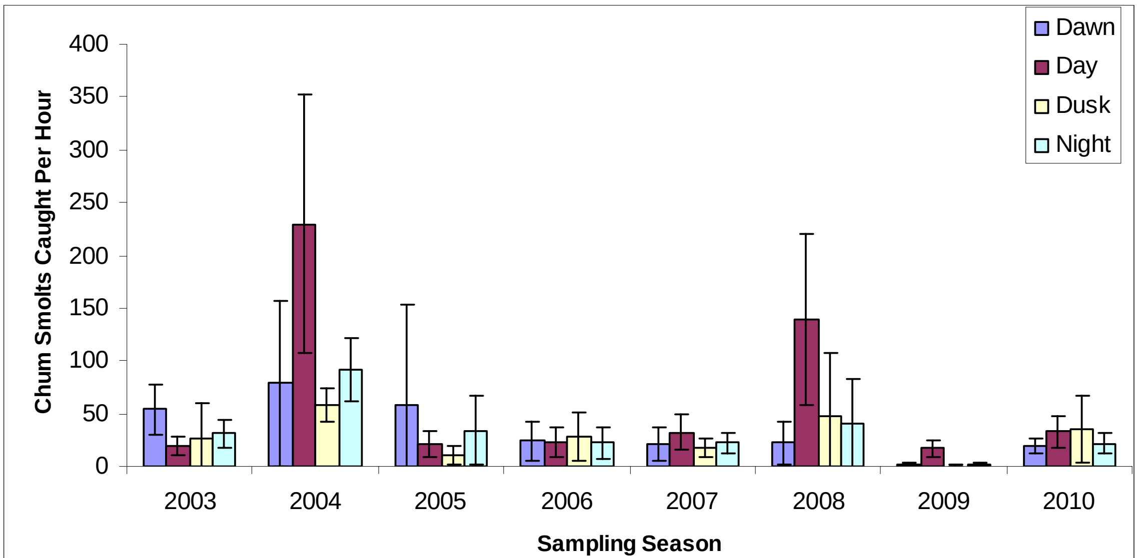
Table 5.1. Catch Totals for Chum Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance (Unmarked)
	Marked	Unmarked	Marked	Unmarked		
2010	**0**	**9,200**	**0**	**0**	943.7	**1,235**
2009	0	2,072	0	0	678.1	726
2008	0	22,576	0	0	890.6	5,457
2007	0	8,089	0	0	980.1	1,325
2006	0	4,608	0	0	724.2	1,292
2005	0	3,222	0	0	601.6	926
2004	0	41,398	0	0	738.56	9,329
2003	0	8,180	0	0	588.76	2,452
2002	0	5,052	0	0	721.38	1,139
2001	0	4,489	0	0	526.31	1,353
2000	0	34,330	0	0	487.94	14,220

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 2010. 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 2010, the highest catch rates occurred during daytime and dusk sets (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		1.22	0.64	1.17		0.897*	0.425*	0.853*
Night	0.897*		1.30	0.56	0.68		0.329	0.223*
Dawn	0.425*	0.329		0.54	0.40	0.13		0.664*
Day	0.853*	0.223*	0.664*		0.64	0.15	0.87	
	* Indicates a Statistically Significant Correlation							



(Data for 2000, 2001, and 2002 excluded because dawn and dusk sets were not separately conducted during those seasons. Error Bars indicate 95% Confidence Intervals.)

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 40.97 millimeters in 2010. However, later in the season there was more variability in sizes compared with earlier in the season, and several smolts larger than 60 mm were encountered. The largest individual chum caught in the screwtrap was 77 mm.

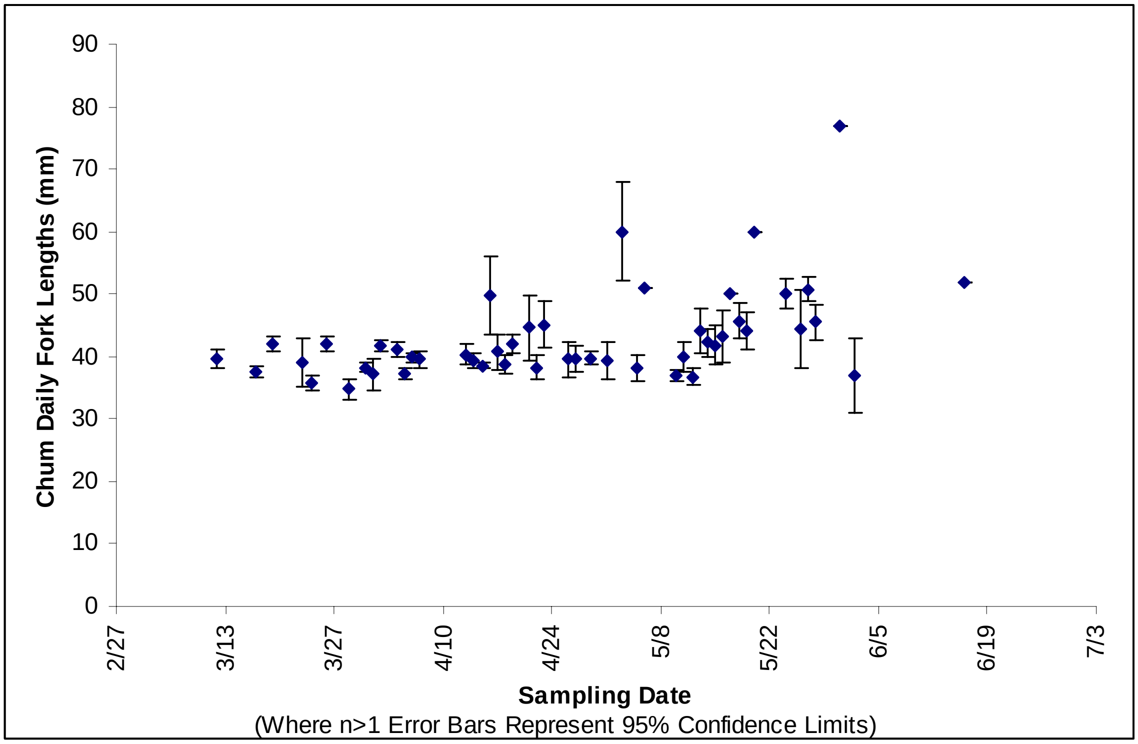


Figure 5.2. Average Daily Fork Lengths for Chum Smolts Caught During 2010

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 11 seasons; ranging from April 3rd in 2006 to May 1st in 2003. Overall, the average median date for the chum outmigration is April 18. 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 2010, the median outmigration date was April 19, which is within one calendar day of the long-term median date. The first chum was caught on March 5 2010 and the last was caught on July 8 2010. The 5th and 95th percentile dates were March 22 2010, and May 15 2010, respectively.

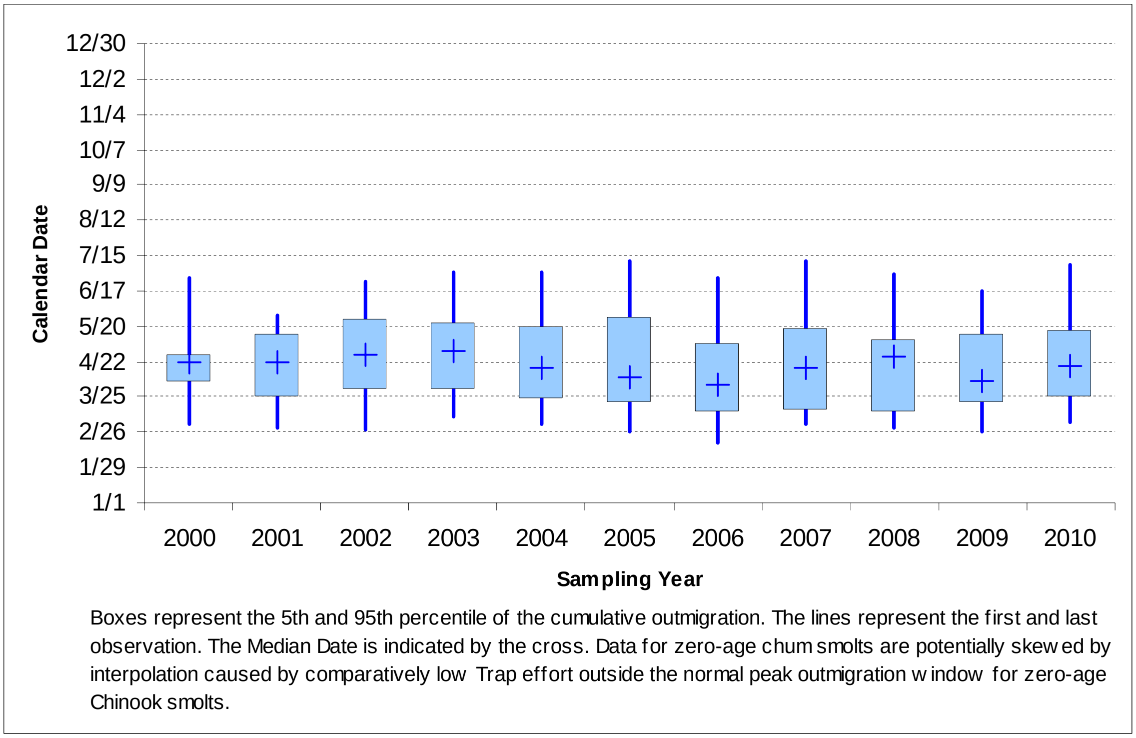


Figure 5.3. Comparison of Outmigration Window for Chum Smolts by Season

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 2010 season was 192 smolts per hour, which occurred on May 3 (Figure 5.4). Overall Trap sampling effort from March through May was relatively high compared to some previous years leading to reasonably short interpolation intervals. Consequently, the time-series of CPUE is probably a good representation of trends during the outmigration window for chum smolts.

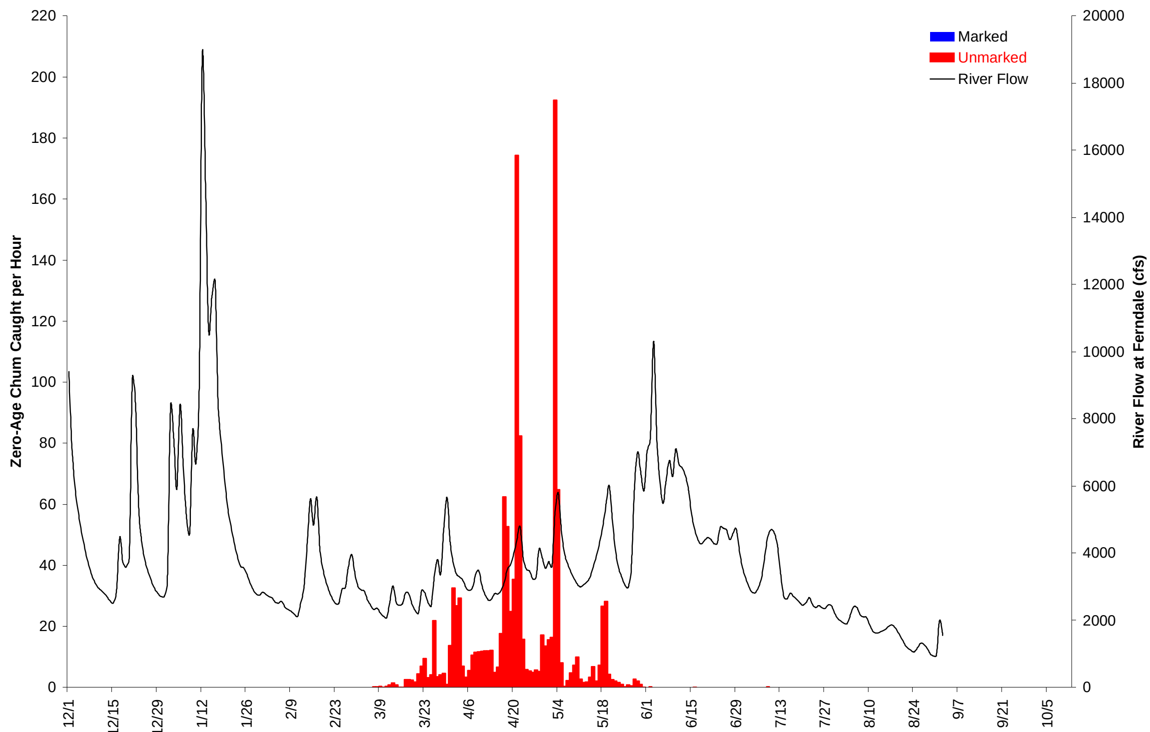


Figure 5.4. Interpolated Catch Per Hour of Zero-Age Chum Smolts by Date Versus Flow

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 3.6). If this interpretation is correct, then a larger than average number of adult chum should return to spawn in 2011, and producing a large outmigration of smolts in 2012. 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 has been the case with 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, which then outmigrated in 2003.

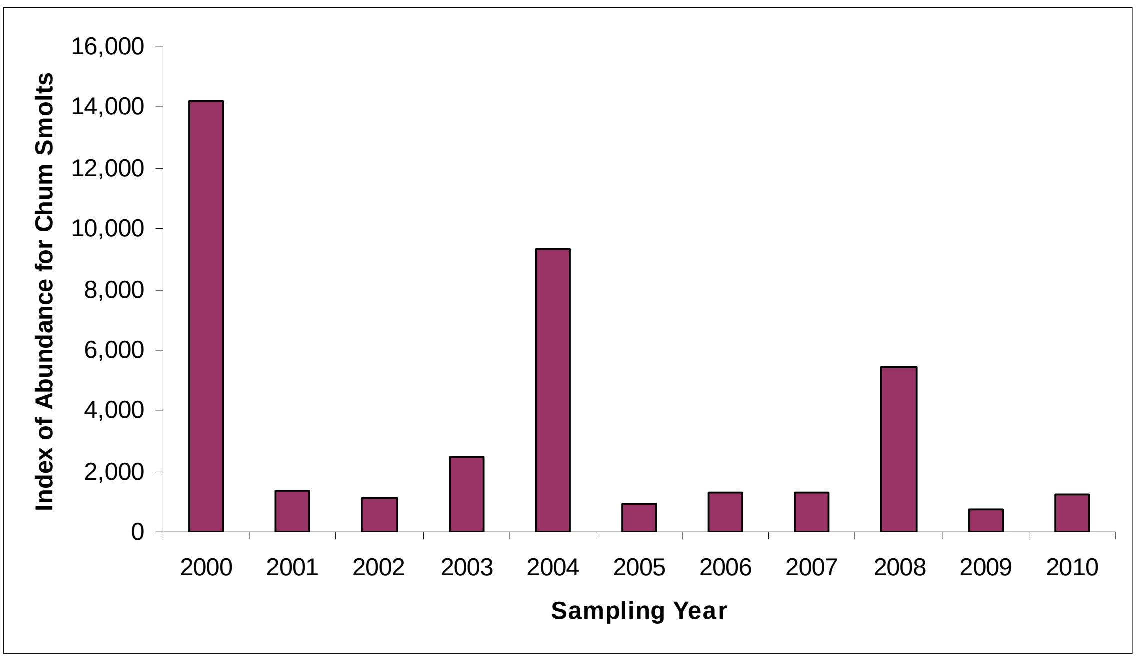


Figure 5.5. Comparison of the Index of Abundance for Chum Smolts by Sampling Year

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 larger-than-average 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.

The magnitude of the 2010 chum outmigration was within the range of results for previous seasons, but generally was at the mid to lower end of the spectrum. This result is consistent with previous expectations that there are 3 consecutive weak year classes, followed by one strong year class. The next strong outmigration event is likely to occur in 2012. The 2011chum outmigration event is likely to be comparable to the 2010 outmigration.

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	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance
Year	Marked	Unmarked	Marked	Unmarked		
2010	**0**	**5,966**	**0**	**0**	**943.7**	**998.6**
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 highest 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		0.81	2.30	1.21		0.649*	0.94*	0.582*
Night	0.649*		1.08	0.99	0.55		0.795*	0.411*
Dawn	0.94*	0.795*		0.59	0.39	0.61		0.459*
Day	0.582*	0.411*	0.459*		0.31	0.19	0.41	

* Indicates a Statistically Significant Correlation

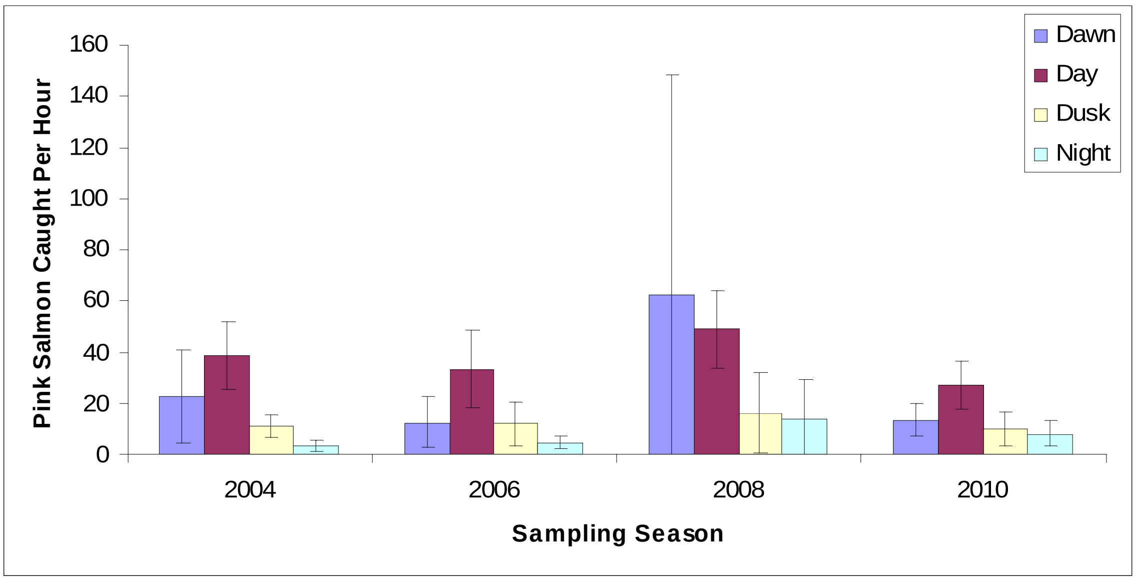


Figure 6.1. Comparison of Average Pink Salmon Catch Rates in March and April, by Daylight Stratum and Sampling Season.

6.3 Pink Salmon Smolt Sizes

The average daily fork lengths of pink smolts that were measured at the Trap are shown in Figure 6.2. In general, pink smolts outmigrated at a consistent average size of 31.98 millimeters in 2010. The largest individual chum caught in the screwtrap was 44 mm on May 3, 2010.

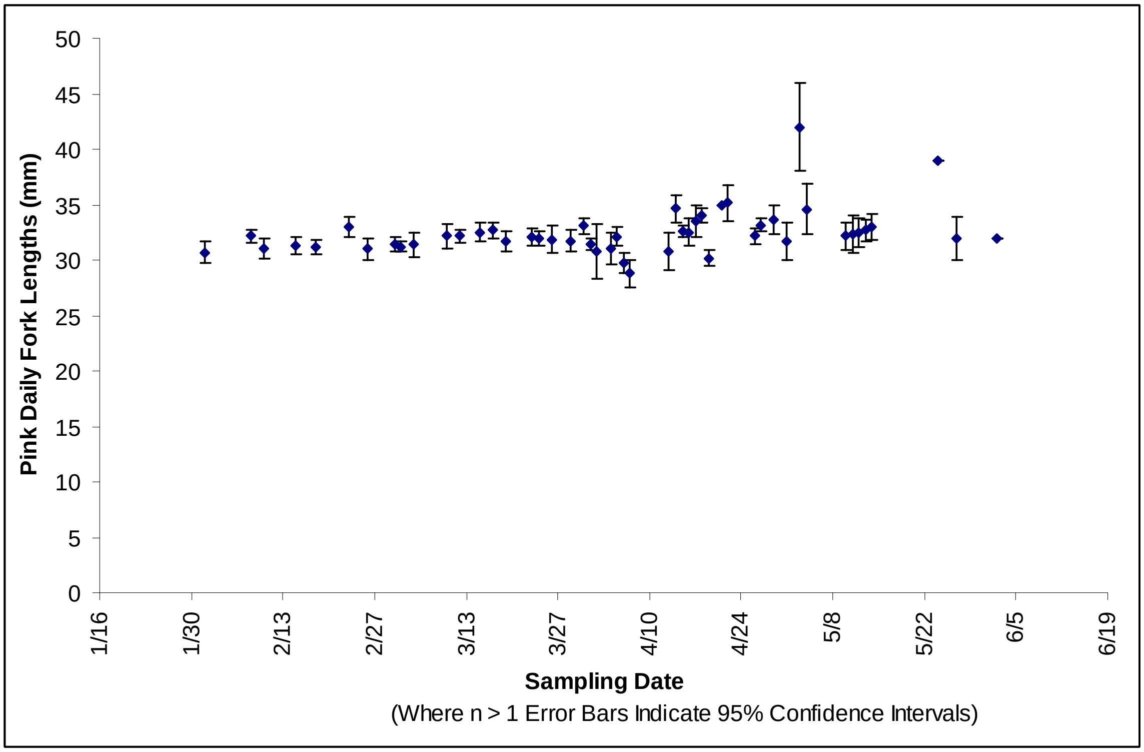


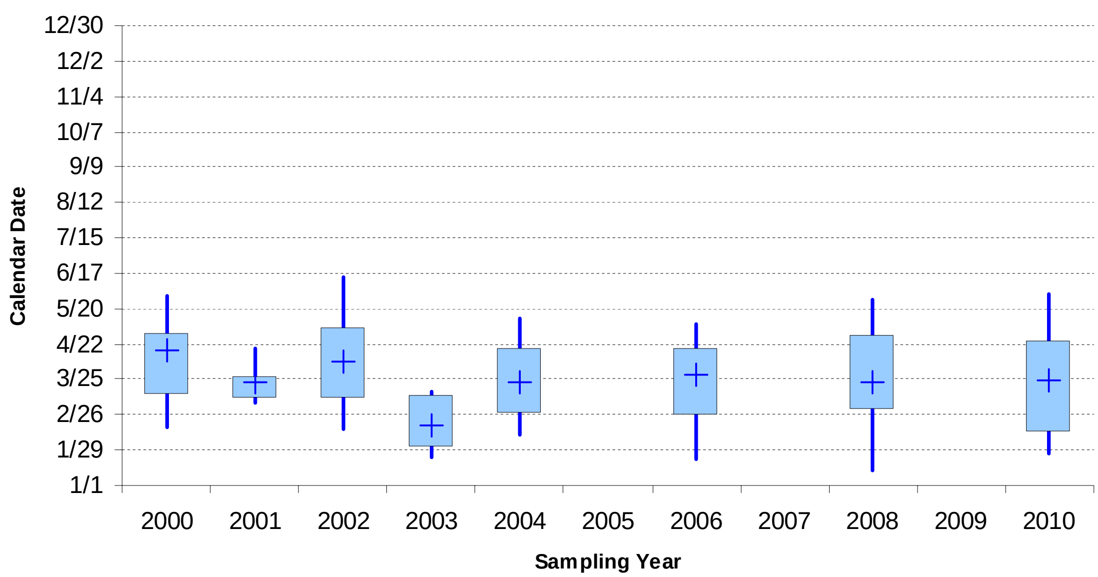
Figure 6.2. Average Daily Fork Lengths for Pink Smolts Caught During 2010

6.4 Pink Salmon Seasonal Outmigration Timing

Pink salmon smolts have a somewhat variable outmigration window during even-numbered sampling years (Figure 6.3). 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. Overall, the median outmigration date for pink salmon is March 31. The main outmigration window has an average duration of 57 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 intervals in sampling effort 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.



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 pink smolts are potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts.

Figure 6.3. 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

The highest catch rate for pink smolts during the 2010 season was 87 smolts per hour, which occurred on March 26 (Figure 6.4).

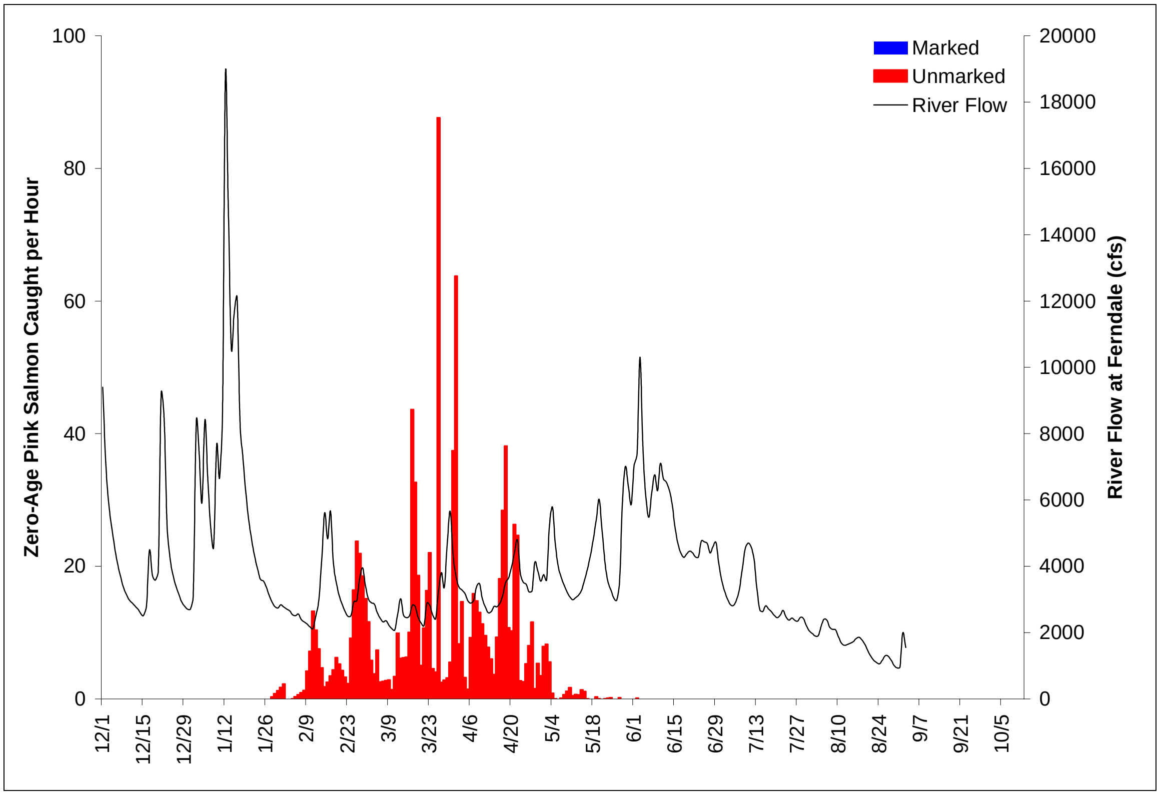


Figure 6.4. Interpolated Catch per Hour of Zero-Age Pink Smolts by Date Versus Flow

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 998 in 2010 to a high of 3,119 in 2000 (Table 6.1). Consequently, the 2010 outmigration estimate for pink salmon smolts is the lowest calculated during the time period considered in this report.

The index of abundance score for pink salmon does not appear to be strongly related to river flows during the egg incubation period. 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, and closely comparable to incubation flows for the 2010 outmigrants (lowest index of abundance) (Table 3.6).

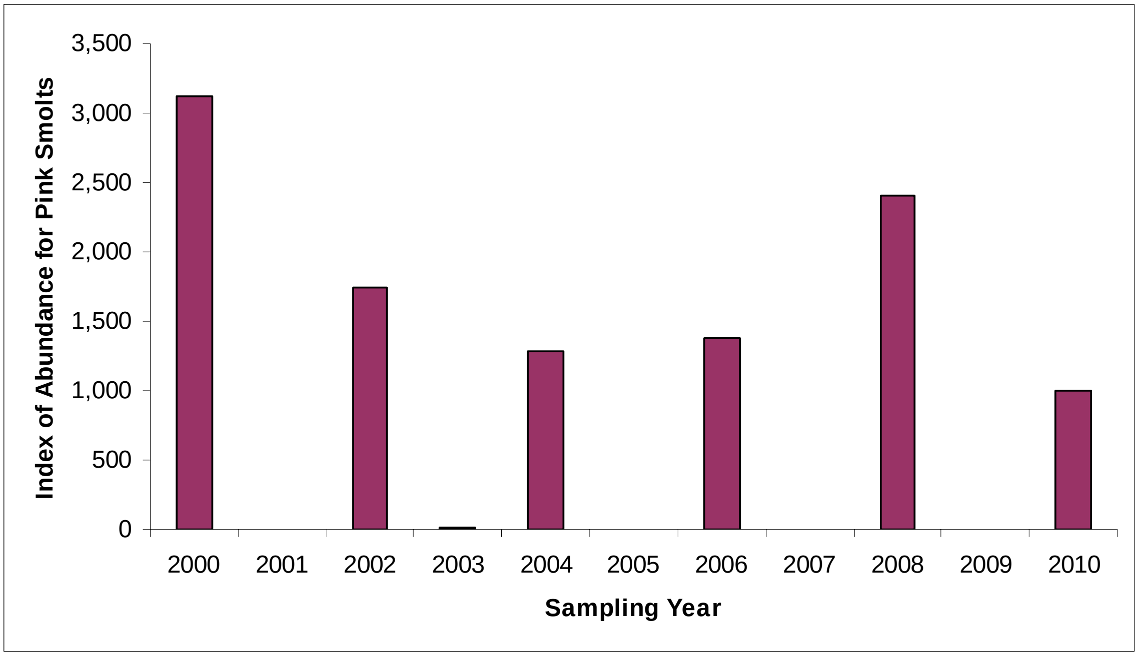


Figure 6.5. Comparison of the Index of Abundance for Pink Salmon by Sampling Year

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, and they are the smallest of the salmonids when they move downstream as most seem to exhibit little growth in freshwater.

The number of pink salmon outmigrants does not appear to be closely linked to incubation flows. It may be that ocean survival and fishing may be a very important factor in 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 when pink salmon are outmigrating. This pattern necessitates longer interpolation intervals for pink salmon that may not be particularly representative. Accordingly, outmigration timing and abundance statistics for this species are likely to be the most strongly skewed of the salmonids considered in this report.

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 only 2 sockeye salmon smolts caught during the 2010 sampling season, (Table 7.1).

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		
2010	**0**	**2**	**0**	**0**	**943.7**	**0.1**
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	738.6	0.0
2003	0	1	0	0	588.8	0.1
2002	0	4	0	0	721.4	0.6
2001	0	77	0	0	526.3	13.9
2000	0	0	0	0	487.9	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	0.00	0.00		N/A	-0.037	-0.018
Night	N/A		1.00	0.00	1.00		N/A	-0.010
Dawn	-0.037	N/A		0.00	0.00	0.00		-0.014
Day	-0.018	-0.010	-0.014		0.00	0.00	0.00	
	* Indicates a Statistically Significant Correlation							

7.3 Sockeye Salmon Smolt Sizes

The two sockeye salmon smolts caught in 2010 had fork lengths of 56 and 57 mm, and were caught on June 23 and June 25 respectively.

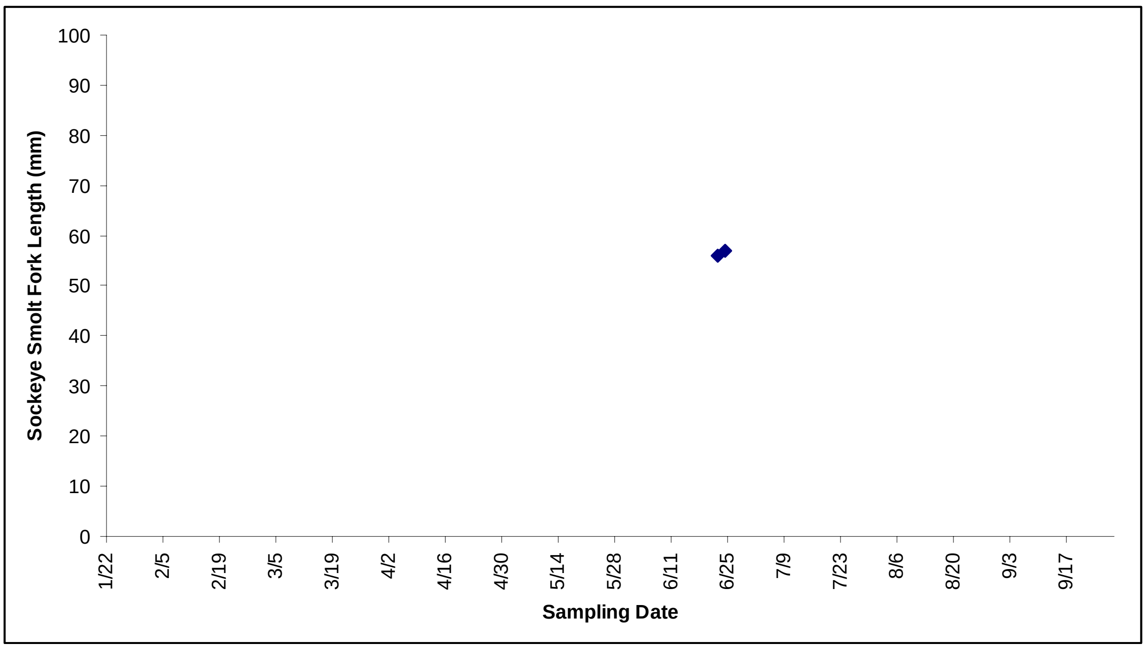
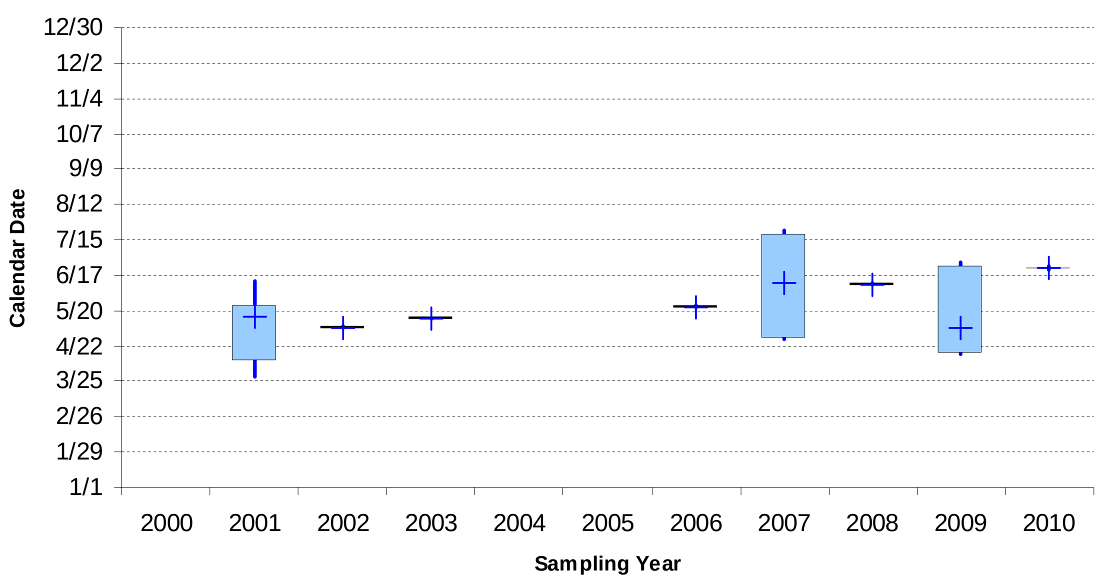


Figure 7.1. Average Daily Fork Lengths for Sockeye Salmon Smolts Caught During 2010

7.4 Sockeye Salmon Seasonal Outmigration Timing

Two sockeye salmon smolts were caught from June 23 to June 25, 2010. This is the latest average outmigration timing calculated for the period considered in this report. However, the very low numbers of sockeye smolts encountered in 2010 probably means that the timing out outmigration for 2010 is fairly unreliable.

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 25, with the main window of outmigration typically occurring between May 12 and June 6, lasting approximately 25 days on average. However, the outmigration period calculated 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 2010 was 0.07 smolts per hour, which occurred on June 25 (Figure 7.3).

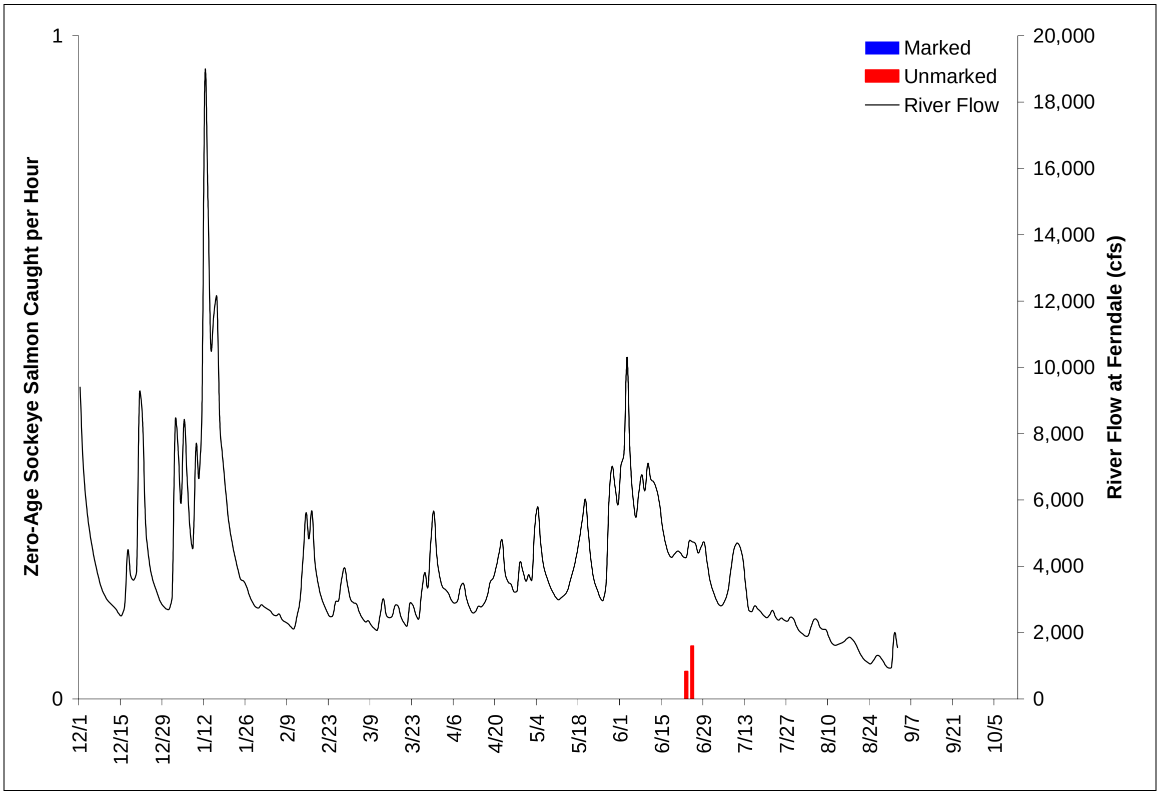


Figure 7.3. Interpolated Catch Per Hour of Zero-Age Sockeye Salmon Smolts by Date and Flow

7.5.2 Between-Year Comparisons for Zero-Age Sockeye CPUE

Sockeye salmon are usually 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 index of abundance value for sockeye smolts was calculated for the 2001 sampling season (Figure 7.4). The second and third highest sockeye index scores were for the 2009 and 2007 outmigration seasons. Index scores for the remaining seasons, including 2010, border upon negligible.

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.

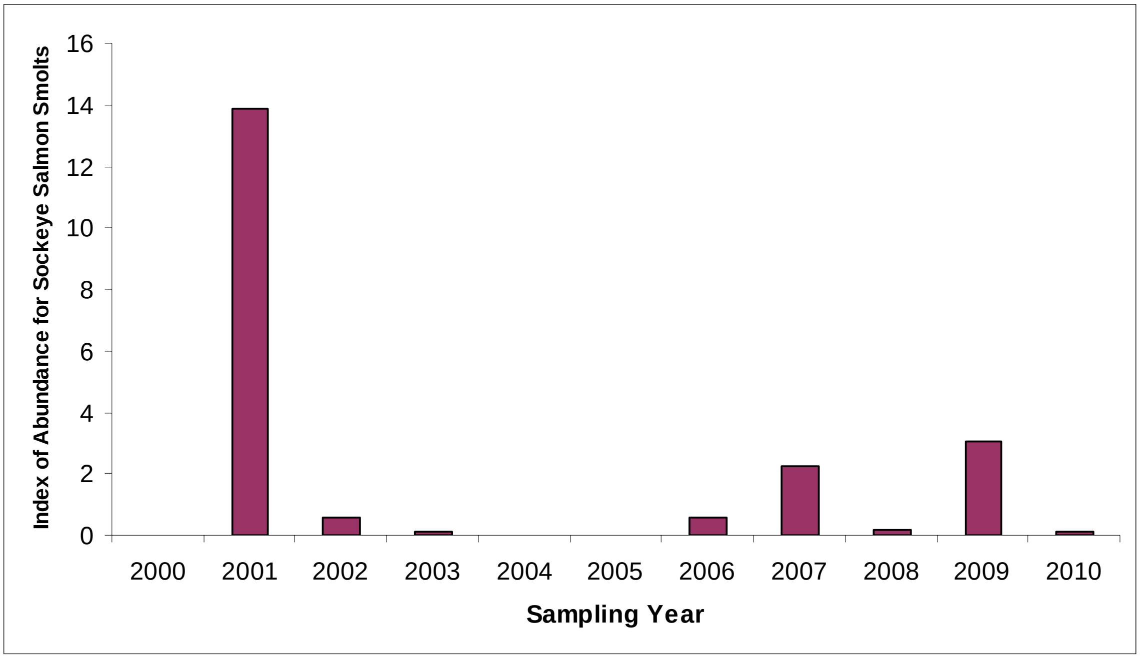


Figure 7.4. Comparison of the Index of Abundance for Sockeye Salmon by Sampling Year

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. Since the Trap effort is optimized for this time period, the Trap results should enable relatively good estimates to be made of the relative abundance of sockeye smolts and the timing of sockeye outmigration. However, in 2010, the Trap was unable to be fished for a long period of time earlier during the usual outmigration window for sockeye smolts and it is conceivable that the timing of the 2010 outmigration was skewed by this situation.

Based on the limited size information available in previous years, 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

8.1 Hatchery Release Summary

The total number of hatchery-origin steelhead released upstream from the Trap in 2010 was 106,200 smolts (Table 8.1). Of this total, 105,563 were externally marked with a clipped adipose fin, and 637 were not externally marked due to clipping error. These fish were released from the Kendall Hatchery on May 12, 2010 into Kendall Creek.

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			
5/12/2010	Kendall	Kendall Creek	**105,563**	**0**	**0**	**637**	105,563	106,200
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

Table 8.1. Upstream Hatchery Releases of Steelhead since 2001

8.2 Steelhead Catch Totals

In total, 277 steelhead trout were caught in the 2010 season. Of these, 92 were recorded as having their adipose fin clipped, and 185 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 sometimes not reliably examined steelhead smolts for the presence of clipped adipose fins. 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 meaningless unless combined together.

Table 8.2. Catch Totals for Steelhead by Year

Sampling Year	Age Not Recorded		Hours Fished	Index of Abundance (Unmarked)	% Hatchery Released Marked
	Marked	Unmarked			
2010	92	185	943.7	52.3	99.40%
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 that were caught in the Trap had an average size that was 25 millimeters bigger than unclipped steelhead trout, although the sizes of steelhead were highly variable and considerable overlap existed between the two groups. Steelhead fork lengths ranged from 87 to 232 millimeters for clipped fish, and from 25 to 235 millimeters for unclipped fish.

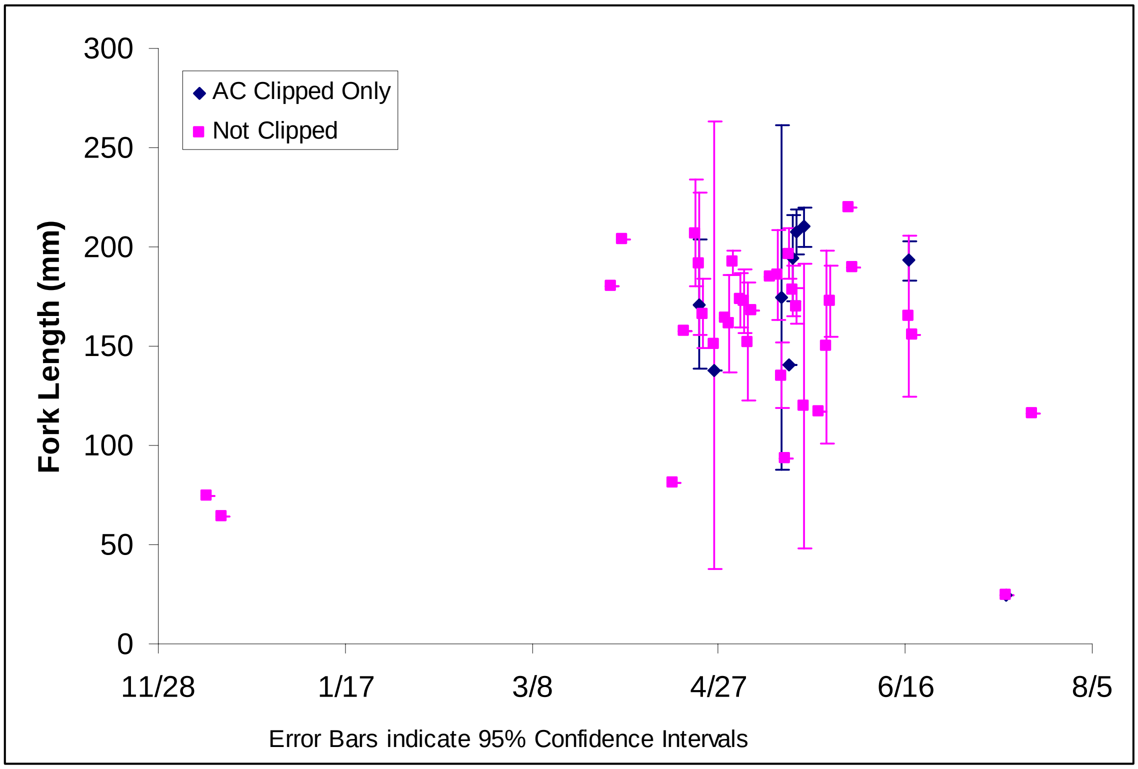
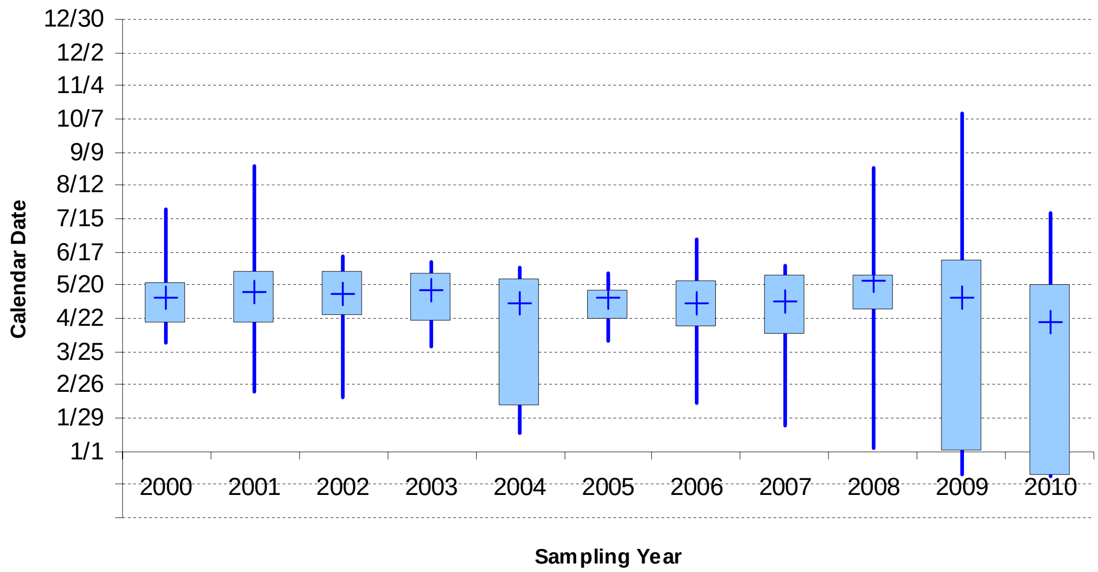


Figure 8.1. Average Daily Fork Lengths for Steelhead Outmigrants Caught During 2010

8.4 Steelhead Seasonal Outmigration Timing

The timing of steelhead outmigration in 2010 was strongly skewed by the existence of a long interpolation interval in December 2009, and also potentially by underestimating steelhead outmigrants during a long gap in sampling in June 2010.

Steelhead smolts were caught from December 2, 2009 to July 19, 2010. The median outmigration date was April 19, and 90% of the outmigration was estimated to have occurred between December 10 and May 21. This appears to be somewhat earlier than usual, and compares to the long-term average median date of May 8, and the long-term average 90% date range that begins on Mar 21 and ends on May 27. However, because the data are strongly skewed by long gaps in sampling during December, this early timing is almost certainly an artifact caused by the sampling schedule rather than a true shift in timing. If the December data were excluded, the median outmigration date would be May 15, and the 90% outmigration window would begin on April 16 and end on May 24, which is a much more typical timing for steelhead outmigration.



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 2010 season was 3.78 fish per hour, which occurred on May 20. The highest catch rate for 'clipped' steelhead trout was 4.9 fish per hour, which occurred on May 18.

Most encounters with steelhead trout occurred between late April and the start of June. However, a combination of a long interpolation interval and atypical catches of steelhead in December meant that the abundance of steelhead was strongly exaggerated from late December to mid January. It is unlikely that the early period of sustained early catch rates shown in Figure 8.3 is realistic given the usual pattern seen during most other years (Figure 8.2). This issue was also a problem during the analysis of the steelhead outmigration for the 2009 season

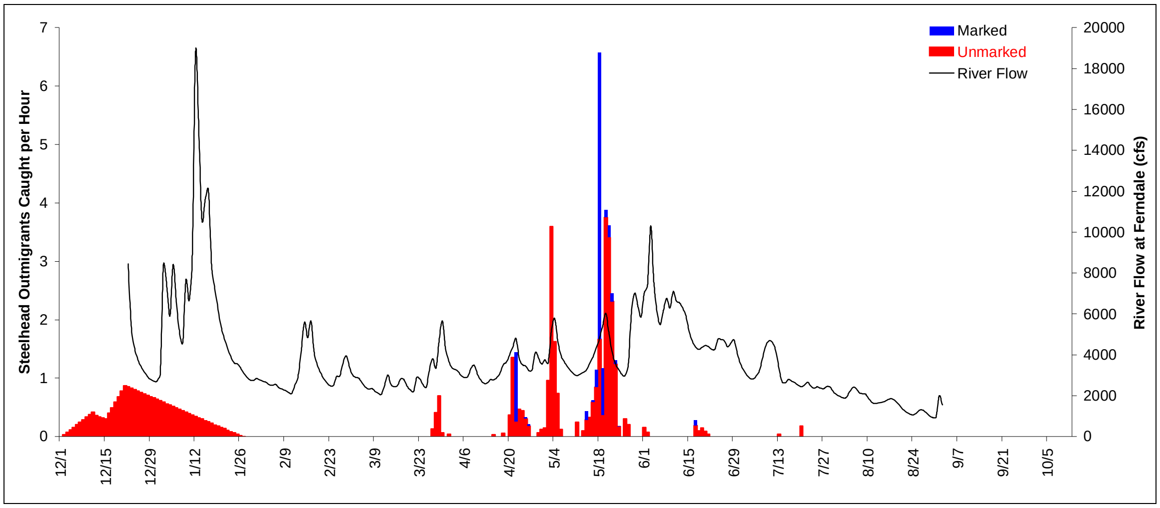


Figure 8.3. Interpolated Catch Per Hour of Steelhead Outmigrants by Date and Flow

8.6 Steelhead Production Estimates in the 2010 Season

8.6.1 Peterson Estimate for Steelhead

In the 2010 sampling year, 105,563 adipose fin clipped steelhead smolts were released upstream from the Trap site. *Assuming that all clipped steelhead were reliably detected* in 2010, 92 marked smolts were recaptured at the Trap, and a further 185 unclipped steelhead smolts were also caught (total = 277). Based on these values, the Peterson estimate of total steelhead passing the Trap site in 2010 would be 315,557 smolts.

The difference between the Peterson estimate for total steelhead and the number of hatchery-origin steelhead trout released is assumed to represent the wild-origin production estimate. Total hatchery releases in 2010 were 106,200 steelhead smolts (this includes 637 unclipped smolts). Accordingly, the Peterson-derived estimate of wild-origin steelhead trout is **209,357** fish for the 2010 season.

8.6.2 CCE Estimate for Steelhead

During the 2010 season the Trap recaptured 0.09% of the clipped steelhead smolts that were released upstream. During the time period when clipped steelhead smolts were outmigrating, the Trap was fishing 23.82% of the time. Assuming that the number of marked smolts recaptured by the Trap increases linearly with the amount of time fished during this period, then the 2010 season catch efficiency is estimated to have been 0.34%.

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 2010 seasonal catch efficiency estimate (0.34%) 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 estimated to have outmigrated in 2010 was 425,842 smolts. This total includes an estimated 56,611 marked smolts and 369,235 unmarked smolts. The estimate for marked smolts is 49% lower than the number of marked steelhead smolts that were released. Assuming that the same is true for unmarked smolts, then the final CCE-derived wild production estimate for steelhead is **687,245** smolts.

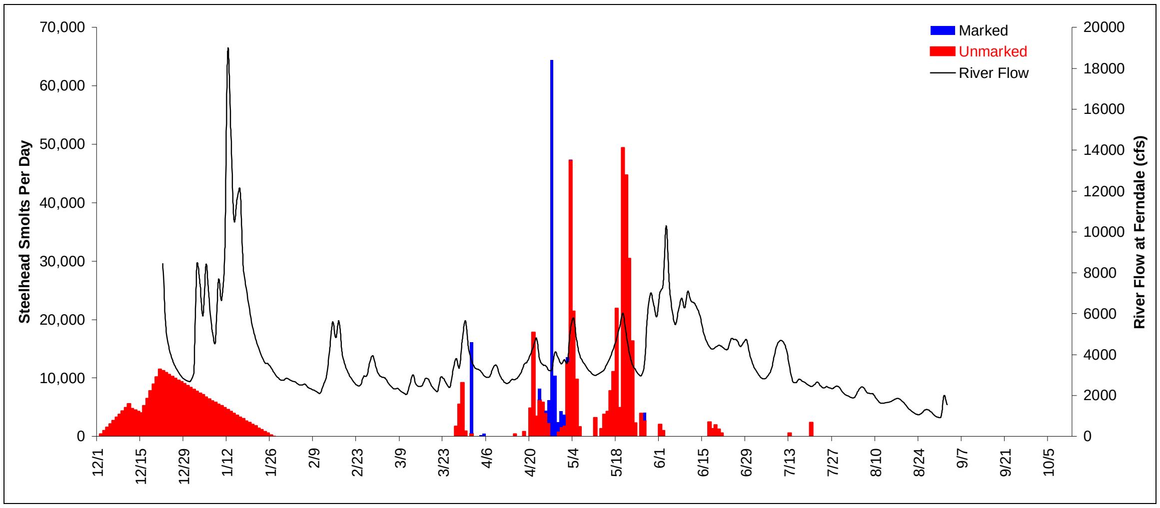


Figure 8.4. Daily Production Estimates for Steelhead Smolts in 2010

8.7 Between-Year Comparisons for Steelhead Production Estimates

Marked steelhead smolts were not reliably distinguished from unmarked smolts by the screwtrap crewmembers during previous seasons, so no valid between-year comparisons can be made for wild-origin steelhead at this time. Although there is some confidence that that adipose fin clips were reliably detected in the 2009 season, the much lower recapture rate in 2010 suggests that the detection rate for steelhead clips may have become suspect for some other reason. However, if the detection rate for 2010 were accurate, then the index of abundance score for unclipped steelhead smolts is approximately twice as high in 2010 as it was in 2009.

8.8 Steelhead Discussion

The only known release of hatchery steelhead in 2010 occurred on May 12. However, some clipped steelhead were detected from April 22 – 26. 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.

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.

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 2010 is provided in Table 9.1.

Table 9.1. Organisms Present in Trap Catch Between 2006 and 2010

Salmonids	Total Count	Non Salmonid Fish	Total Count	Invertebrates	Total Count	Amphibians	Total Count
Bulltrout/Char	12	Bass	573	Crayfish	1	Tadpoles	5
Chinook	73,343	Dace	115			Frog	1
Chum	143,217	Lamprey (eyes)	1,200				
Coho	42,022	Lamprey (no eyes)	199				
Cutthroat	178	Mountain Whitefish	11				
Pink	48,548	Pumpkin Seed	14				
Rainbow Trout	1	Sculpin	75				
Sockeye	120	Starry Flounder	2				
Steelhead	4,160	Stickleback	10,164				
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. (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	
2010	**1**	**0.1**	**0**	**0**	**359**	**51.1**	**2,777**	**456.8**	**8**	**0.8**	943.7
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 Sampling Mortality Rates

The Trap field protocol requires that any dead fishes that are removed from the Trap's live box be recorded as mortalities (Table 10.1). 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 10.1. Summary of Mortalities and Number of Fishes Handled at the Trap in the 2010 Season

Species_Name	Lifestage	Presumptive Origin	Accidental Death	Dead on Arrival	Sacrificed Intentionally	Total Handled	Mortality Rate
Chinook	Yearling	Wild	0	0	0	51	0%
Chinook	Zero-Age	Hatchery	36	3	0	4,794	0.8%
Chinook	Zero-Age	Wild	0	1	0	502	0.2%
Chum	Zero-Age	Wild	0	0	1	9,200	0%
Coho	Yearling	Hatchery	15	0	0	663	2.3%
Coho	Yearling	Wild	5	0	0	847	0.6%
Coho	Zero-Age	Hatchery	0	0	0	46	0%
Coho	Zero-Age	Wild	0	0	0	4	0%
Cutthroat	Not Recorded	Wild	0	0	0	1	0%
Dace	Not Recorded	Wild	0	0	0	1	0%
Lamprey (eyes)	Mature Adult	Wild	0	0	0	2	0%
Lamprey (eyes)	Not Recorded	Wild	0	0	0	357	0%
Lamprey (no eyes)	Larval	Wild	0	0	0	3	0%
Lamprey (no eyes)	Not Recorded	Wild	0	0	0	54	0%
Mountain Whitefish	Not Recorded	Wild	0	0	0	2	0%
Pink	Zero-Age	Wild	1	0	0	5,966	0%
Sculpin	Not Recorded	Wild	0	0	0	8	0%
Sockeye	Zero-Age	Wild	0	0	0	2	0%
Steelhead	Not Recorded	Hatchery	0	0	0	92	0%
Steelhead	Not Recorded	Wild	1	0	0	184	0.5%
Steelhead	Zero-Age	Wild	0	0	0	1	0%
Stickleback	Juvenile	Wild	0	0	0	148	0%
Stickleback	Mature Adult	Wild	0	0	0	10	0%
Stickleback	Not Recorded	Wild	0	0	0	2,619	0%

In the 2010 sampling season, the mortality rate for most groups of fishes was relatively low. The highest mortality rate was for hatchery-origin yearling coho smolts where 2.3% of 663 fish were killed. The mortality rate during the 2010 season was generally intermediate compared to previous years (Figure 10.1)

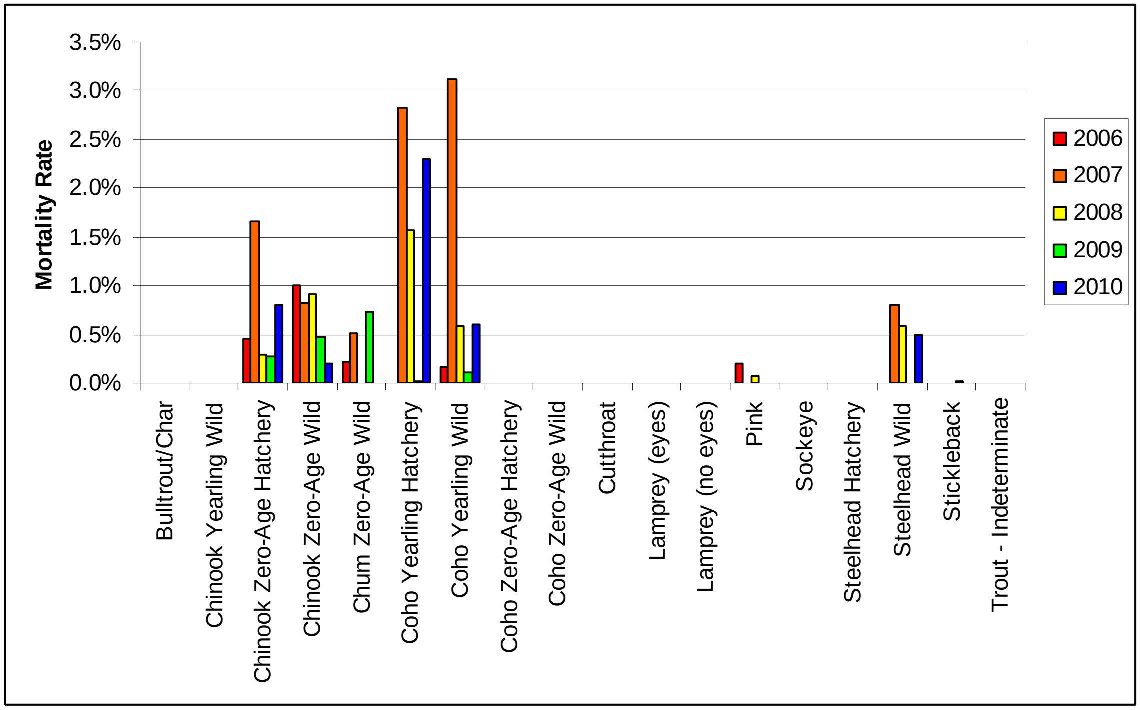


Figure 10.1. Comparison of Total Mortality Rates at the Trap by Sampling Year

11.0 References

Conrad R.H. & MacKay, M.T. 2000 *Use of a rotary Screwtrap to monitor the outmigration of Chinook salmon smolts from the Nooksack River: 1994-1998*. Northwest Fishery Resource Bulletin, Project Report Series No. 10. Northwest Indian Fisheries Commission, Olympia, WA. 120p

Dolphin, 2002. *A review of data analysis from the 2002 smolt trap program on the Nooksack River at Ferndale*. Lummi Natural Resources. Technical Report.

Dolphin, C.H. 2009. *An analysis of 2009 data from the Lummi smolt trap on the Nooksack Mainstem.* Lummi Natural Resources Technical Report.

Meehan, W.R. and Siniff, D.B. 1962. *A Study of the Downstream Migrations of Anadromous Fishes in the Taku River, Alaska*. Transactions of the American Fisheries Society 1962; 91: 399-407

Ricker, W.E. 1975. *Computation and interpretation of biological statistics of fish populations*. Bull. Fish. Res. Board Can. No. 191, 382 p.