2011 Smolt Trap Results

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Lummi Indian Business Council
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Harvest Management Division

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2011 Smolt Trap Results

Prepared by:

Lummi Natural Resources Department (LNR)
Harvest Management Division
2616 Kwina Rd.
Bellingham, WA 98226

Contributors:

Craig Dolphin, Natural Resources Analyst

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Executive Summary

The data obtained during 2011 from the Lummi screwtrap indicated that 154,189 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 2011 (BY2010) is 25% below the median production estimate.

Similarly, the production estimate for yearling coho smolts outmigrating in 2011 (BY2009) was 514,353 smolts, which is also 25% below the long-term median estimate. To-date, this is the third-lowest production estimate for yearling coho.

No production estimates could be ascertained for steelhead because hatchery release data for these fish could not be acquired prior to writing this report.

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 year is followed by 3 low-abundance years. The 2011 season represented the third low abundance year in this cycle and it is anticipated that the 2012 season will be the next high-abundance year for chum outmigrants.

Handling mortality rates from trap operations were typically negligible for most species encountered. However, the highest mortality rates were 0.4% for zero-age chum smolts. The handling mortality rate for zero-age wild-origin Chinook smolts was 0.3%. 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. No wild-origin yearling Chinook smolts were killed during Trap operations in 2011.

Recapture rates of marked hatchery-origin smolts for Chinook, coho, and steelhead were all much higher than has been previously recorded for the screwtrap. River flows and water clarity during the peak of the outmigration were within ranges previously recorded and these are unlikely to explain the much higher catch efficiency noted in 2011. Changes in the river channel could explain the difference, but a new channel profile would be needed to determine whether significant changes in the river channel explain the change or not.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

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

A rotary-screw smolt trap is a barge-mounted sampling device that has a cone-shaped entrance that is lowered into the top of the water column 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 2010 (Dolphin 2011) to enumerate Chinook fry and coho yearling outmigrants passing downstream past the Trap site. The 2011 season was the seventh year since trap operations began in 1994 in which almost 100% of hatchery-released age-zero Chinook smolts were externally marked and could be reliably separated from wild-origin Chinook smolts.

This report considers data collected from December 2010 through to September 2011 and aims to report the results of the 2011 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 have also been 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 calculated 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 between-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

	N° 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%.

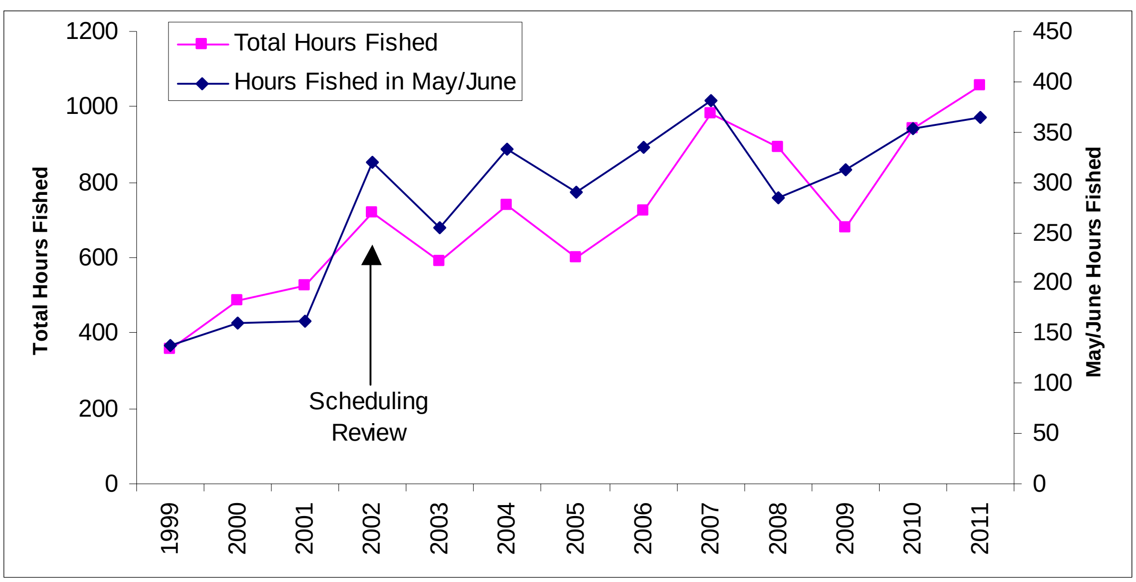
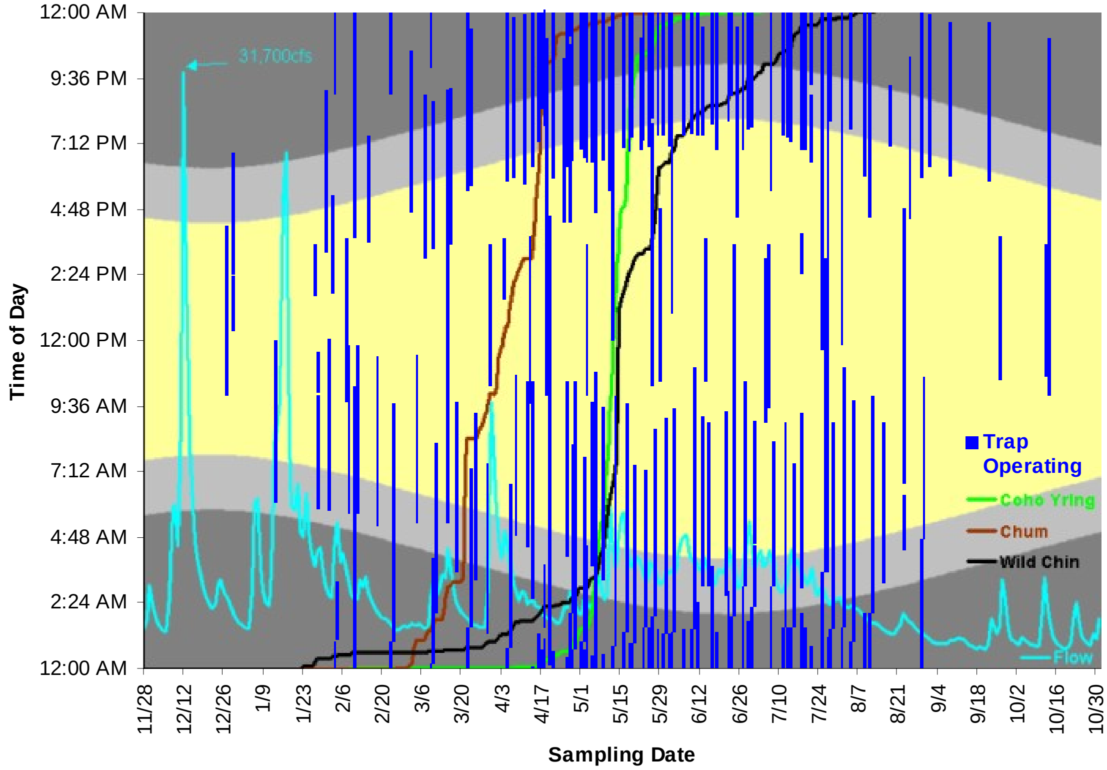


Figure 2.1. Comparison of Trap Effort Versus Sampling Season

In the 2011 season the screwtrap was operated from December 27 2010 through to October 31 2011, although sampling intensity was highest from April through July (Figure 2.2). The average monthly relative efficiency of the 2011 sampling schedule is shown in Figure 2.3. In total, the Trap was operated on 135 days during the 2011 season.



Trap operating hours (dark blue) in 2011 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), and chum fry (brown line).

Figure 2.2. Trap Operating Hours During the 2011 Season

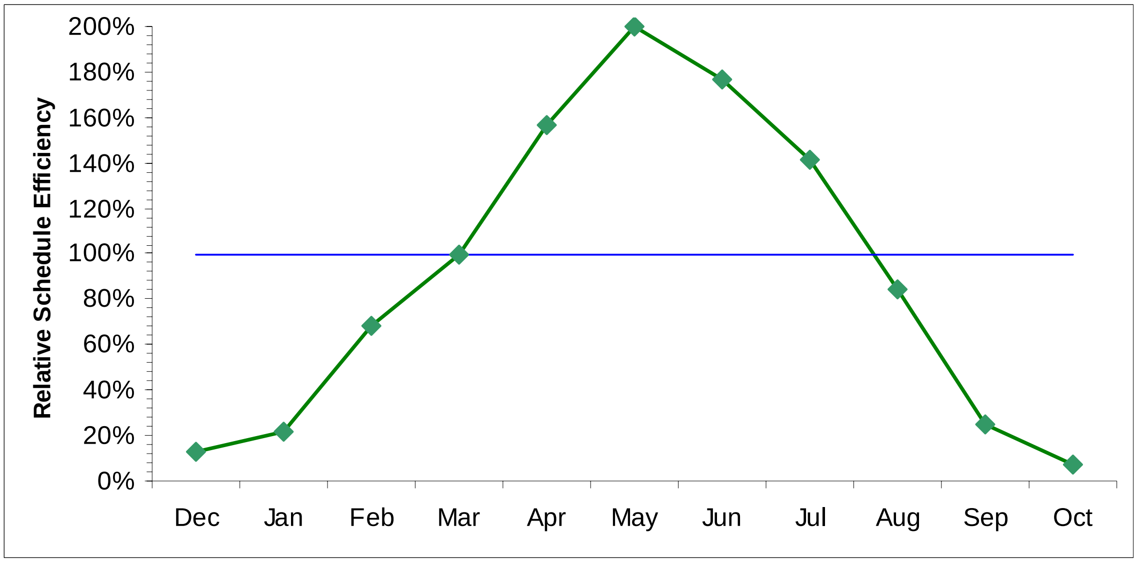


Figure 2.3. Relative Efficiency of Trap Schedule During the 2011 Season

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 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 Interpolation 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 differences between fishes such as size and behavior. Environmental conditions and the size and behavior of fishes can vary over time, which means that, ideally, the catch efficiency of the Trap could 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.

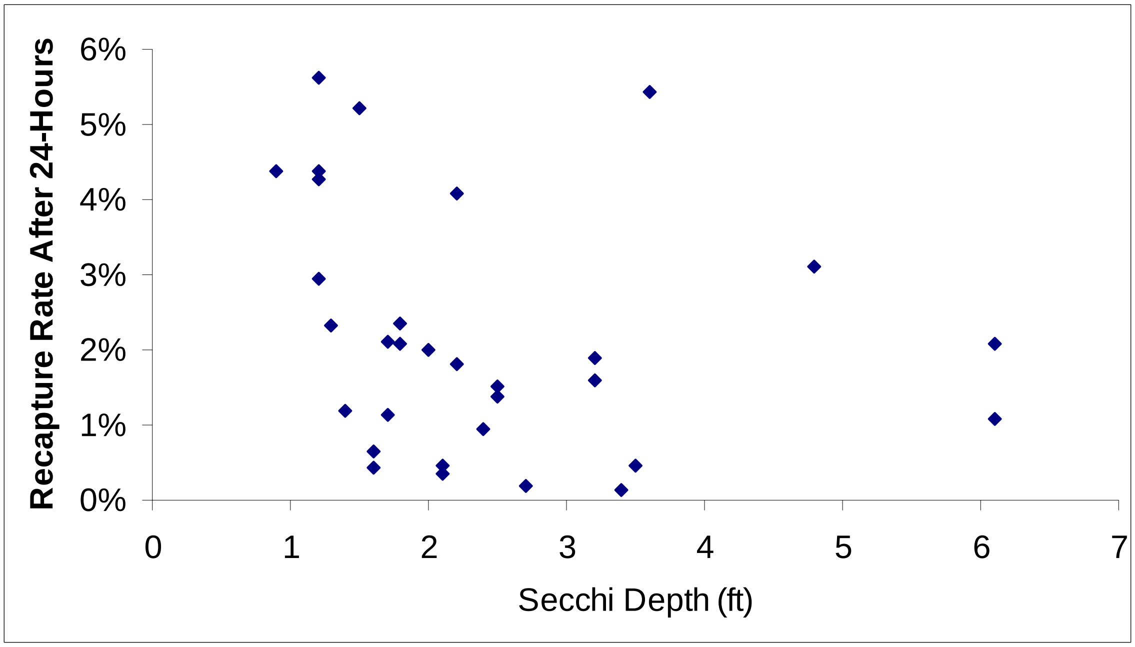


Figure 2.6. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus Water Clarity (Secchi-Depth)

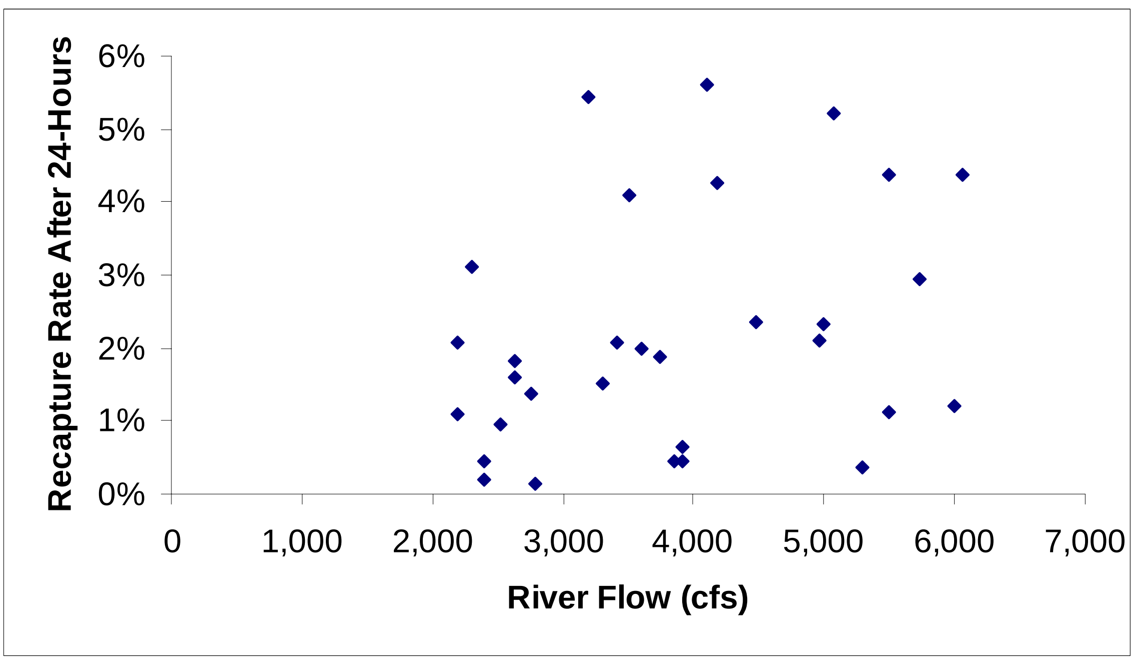


Figure 2.7. Recapture Rates for Groups of Newly-Released Marked Hatchery-Origin Zero-Age Chinook Versus River Flow

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 during which the Trap was actively sampling, it is possible to extrapolate from the number of marked fish that were caught 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%

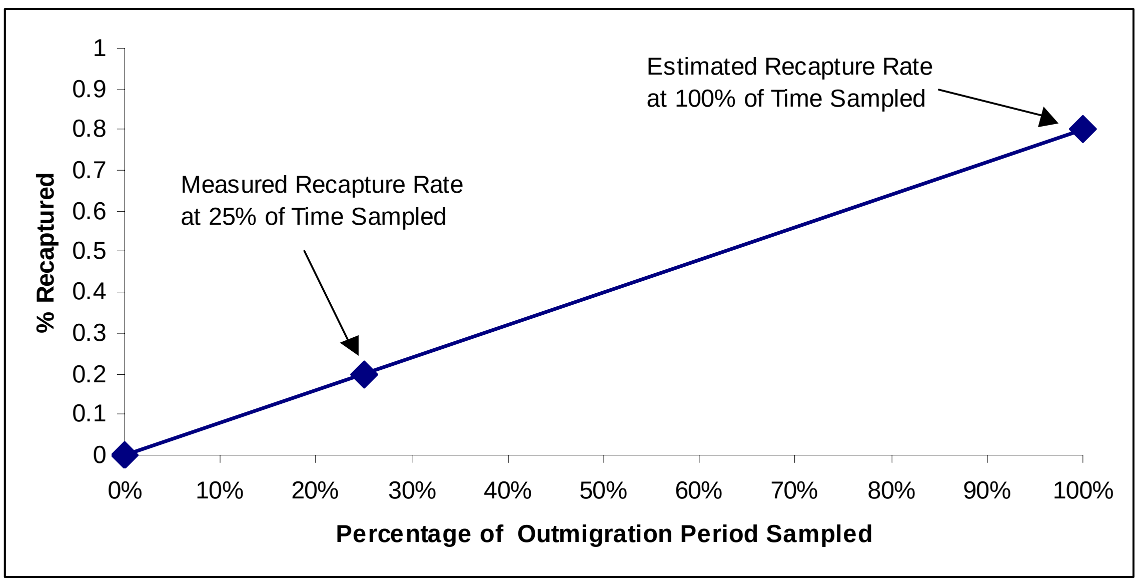


Figure 2.8. Hypothetical Example of Estimating Seasonal Trap Catch Efficiency

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 1,234,993 smolts. Of this total, 99.3% (1,226,233 smolts) were externally marked, and 0.7% (8,742 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 2011 and the last release was on May 25 2011. The 2011 season marks the first year that South Fork Spring Chinook smolts were released from the captive brood program.

Table 3.1. Upstream Hatchery Releases of Zero-Age Chinook in 2011

Release Date	Source Hatchery	Release Location	Externally Marked AC-CWT	AC Only	CWT Only	Externally Unmarked*	Total Marked Chinook	Total All Chinook Released
4/15/2011	Kendall	Kendall Creek	0	55,076	0	444	55,076	55,520
5/1/2011	Kendall	Kendall Creek	0	55,266	0	334	55,266	55,600
5/11/2011	Kendall	North Fork Nooksack	67,565	12,052	66,500	266	146,117	146,383
5/18/2011	Kendall	Middle Fork	0	205,650	0	0	205,650	205,650
5/19/2011	Kendall	North Fork Nooksack	66,500	23,571	66,001	264	156,072	156,336
5/20/2011	Skookum	Skookum Creek			1,946	18	1,946	1,964
5/23/2011	Kendall	North Fork Nooksack	66,000	8,369	61,914	248	136,283	136,531
5/24/2011	Kendall	Kendall Creek	0	55,800	0	0	55,800	55,800
5/25/2011	Lummi Bay	McClelland Creek	414,023			7,186	414,023	421,209
		Total Released	614,088	415,784	196,361	8,760	1,226,233	1,234,993

* Based on reported clipping and tagging error rates

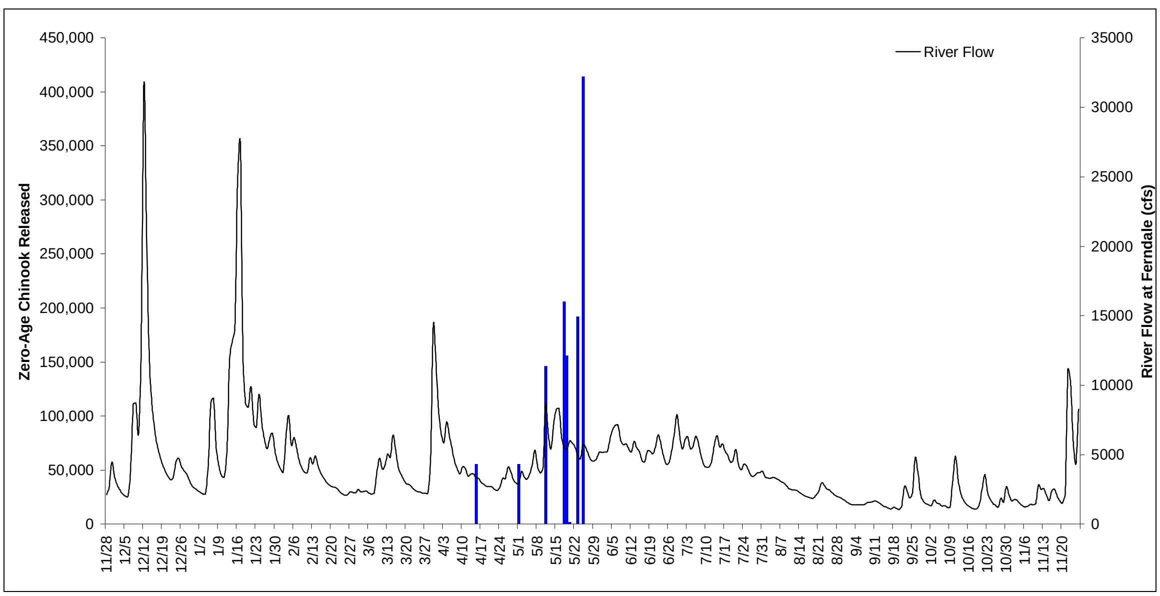


Figure 3.1. Timing and Magnitude of Hatchery Releases of Marked Zero-Age Chinook

3.2 Chinook Catch Totals

The 2011 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		
2011	**15,337**	**1,661**	**0**	**13**	1055	**99.3%**
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 the same 24-hour period, based on Trap data collected from 2005 to 2011. Dusk and nighttime catch rates for zero-age Chinook appear to be higher than daytime and dawn 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		0.66	0.27	0.46		0.901*	0.10	0.784*
Night	0.901*		0.43	0.50	1.26		0.27	0.794*
Dawn	0.10	0.27		0.71	0.16	0.27		0.88*
Day	0.784*	0.794*	0.88*		1.39	1.34	1.12	
	* 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		0.18	0.00	0.16		0.287*	-0.03	0.51*
Night	0.287*		0.00	0.04	0.54		-0.03	0.08
Dawn	-0.03	-0.03		0.21	0.00	0.00		0.437*
Day	0.51*	0.08	0.437*		1.69	0.40	1.00	
	* 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 2011 had an average fork length of 72.74 millimeters and marked zero-age Chinook had an average fork length of 85.78 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. As has been noted in past years, a pattern was evident for the length of marked smolts to remain relatively unchanged during the first few weeks following release, before increasing with date afterward. This suggests that hatchery-origin smolts have a period of acclimation during which they do not grow significantly until they learn to forage successfully. The lengths of marked and unmarked zero-age smolts appeared to exhibit similar rates of increase from the start of June 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 2011 had an average size of 107.7 millimeters.

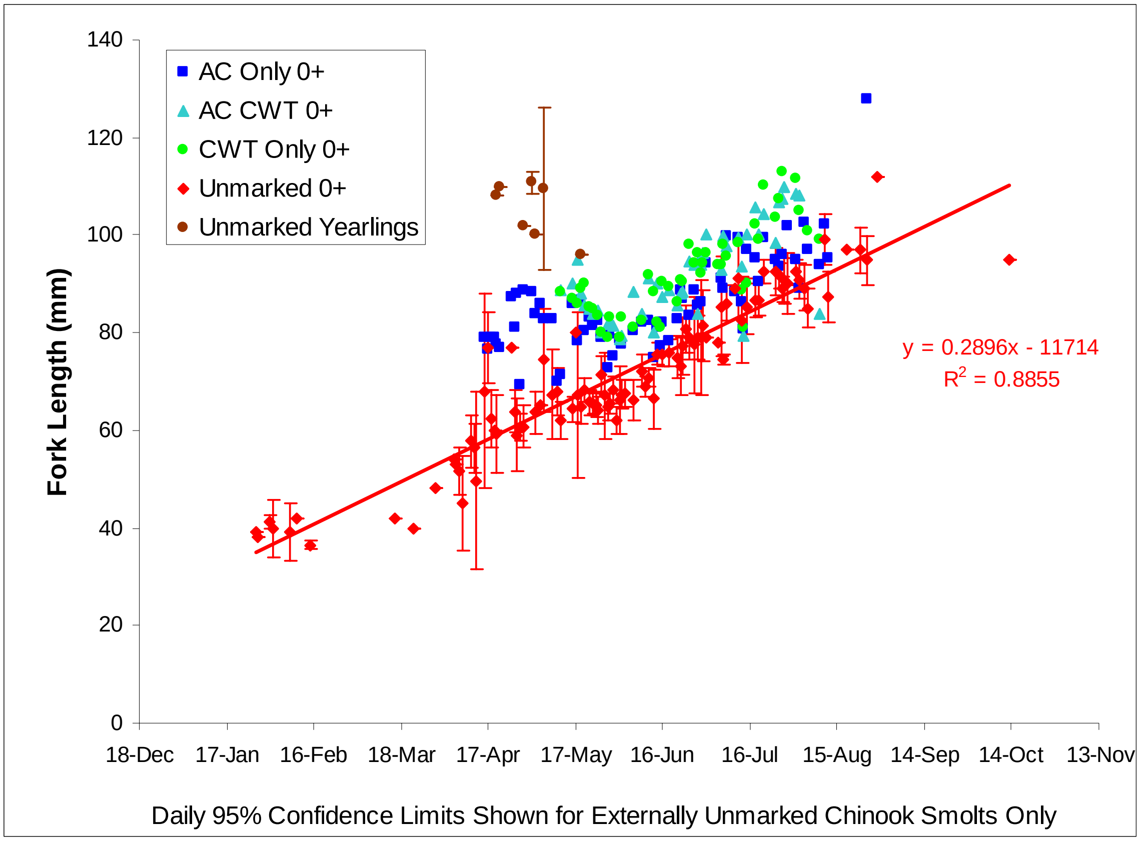


Figure 3.2. Average Daily Fork Lengths for Chinook Smolts Caught During 2011

3.4 Chinook Seasonal Outmigration Timing

The timing of outmigration for unmarked wild smolts in 2011 was within the range observed during previous years (Figure 3.3).

The first unmarked zero-age Chinook smolt was caught in mid-January and the last unmarked zero-age smolt was caught in late August. In the 2011 sampling season, 90% of unmarked zero-age Chinook outmigrated between April 21st and July 25th, and the 50th percentile occurred on June 3rd. The start of the main outmigration period, and the median date was early by approximately one week for zero-age smolts in 2011. The end of the main outmigration period for zero-age smolts was within a week of the long-term average date.

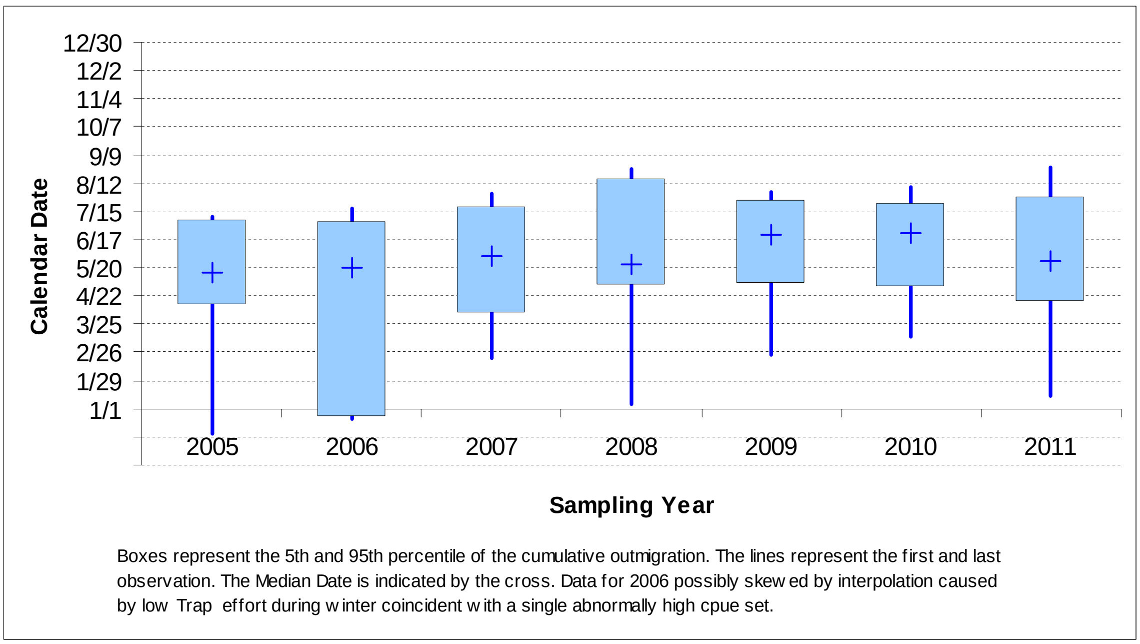
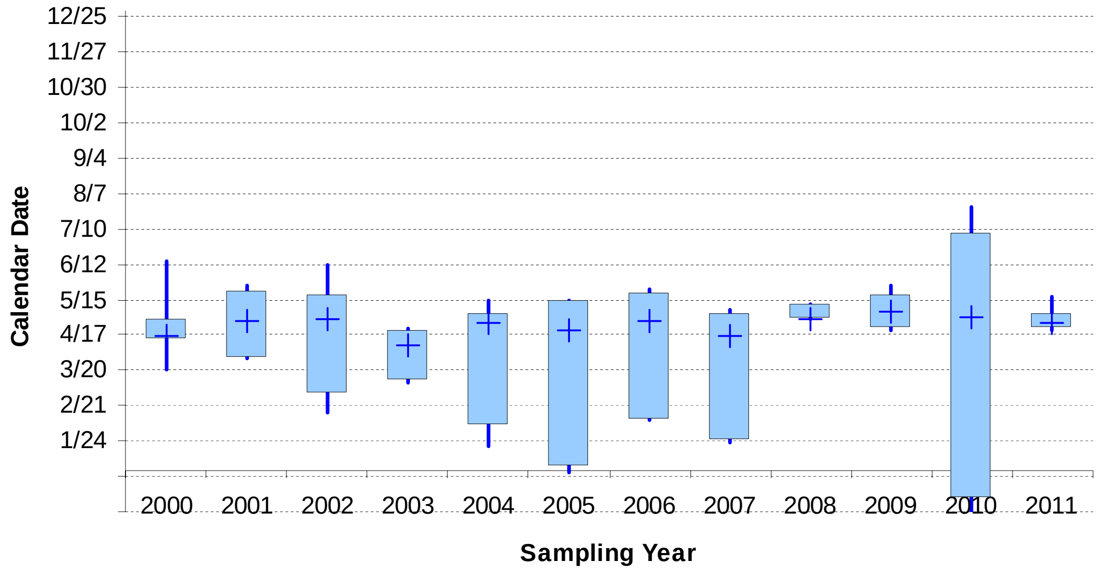


Figure 3.3. Outmigration timing for Unmarked Zero-Age Chinook smolts from 2005 to 2011

The outmigration of yearling Chinook smolts occurred during a relatively short period of time: starting in mid April and finishing by mid May, but at a relatively normal time of year (Figure 3.4). In the 2011 sampling season, 90% of yearlings outmigrated between April 22 and May 14, with the 50th percentile date occurring on April 27. This compares to the long-term average dates, which indicate that typically 90% of yearlings outmigrate between March 3 and May 14, with the median date usually occurring on April 24.



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

Figure 3.4. Outmigration timing for Unmarked Yearling Chinook smolts from 2000 to 2011

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.

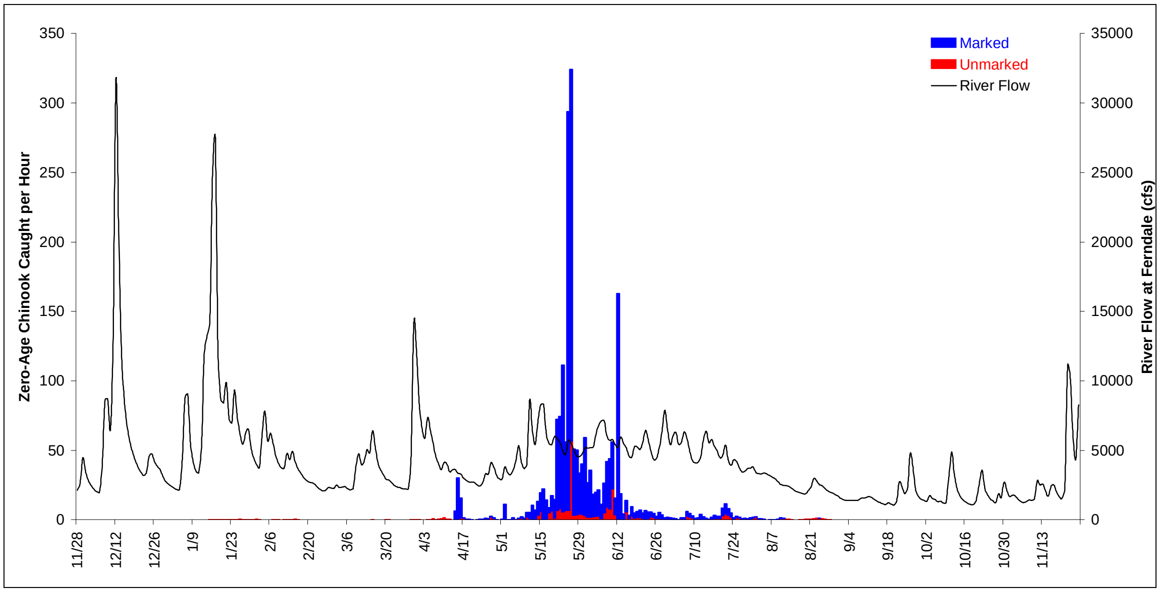


Figure 3.5. Interpolated Catch Per Hour of Zero-Age Chinook Smolts by Date and Mark Status

Unmarked zero-age Chinook began to be caught regularly from the middle of May through early June 2011. From mid-June onwards a steady trickle of a few unmarked Chinook were present in the catch until the outmigration finished in late August. The highest catch rate of unmarked zero-age Chinook occurred on May 26, 2011. This date coincides with the highest observed cpue for marked Chinook smolts and a number of the unmarked smolts caught at this time may actually be hatchery origin smolts released at McClelland Creek that were missed during the clipping process.

Marked hatchery-origin Chinook outmigrants were first noted in the catch on April 15 2011 and the last marked Chinook was caught on August 29, 2011. The majority of marked Chinook outmigrated between mid- May and the end of June. The highest catch rate of marked Chinook occurred on May 26, which was the day after a very large number of smolts were released upstream, relatively nearby to the trap site, in McClelland Creek.

3.5.2 Zero-Age Chinook Production Estimates in the 2010 Season

Peterson Estimate for Zero-Age Chinook

In the 2011 sampling year, 1,226,233 externally marked zero-age Chinook were released upstream from the Trap site. Of this total, 15,337 were recaptured at the Trap, and a further 1,161 unmarked zero-age Chinook smolts were also caught (total = 16,998 smolts). The Peterson estimate of total zero-age Chinook passing the Trap site in 2011 is 1,359,027 smolts.

The difference between the Peterson estimate for total smolts and the number of hatchery-origin smolts released in 2011 is assumed to represent the wild-origin production estimate. Total hatchery releases in 2011 were 1,234,993 smolts (includes 8,760 externally unmarked smolts). For the 2011 sampling season, the Peterson-derived estimate of wild-origin zero-age Chinook is **124,034** smolts. As shown in Figure 3.6, the production estimate for wild-origin zero-age Chinook in 2011 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.

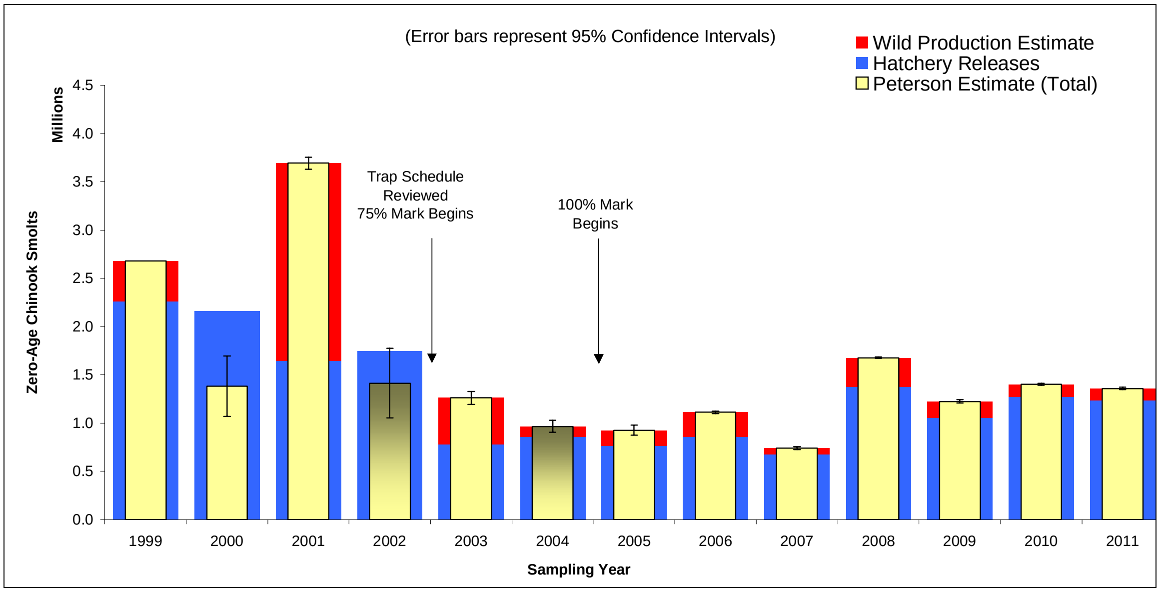


Figure 3.6. Peterson Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Zero-Age Chinook

In the 2011 season, the Trap recaptured 1.25% of the marked Chinook smolts that were released upstream. The Trap was fishing 22.52% of the time that marked Chinook smolts were outmigrating past the Trap site. Assuming that the number of marked smolts recaptured by the Trap increases linearly with the amount of time fished during the outmigration period for marked smolts, then the 2011 season catch efficiency is estimated to have been 5.55% (Figure 3.7). This value is considerably higher than the average seasonal catch efficiency of 2.61%, for the seasons from 1999 to 2011 (Figure 3.8). Note that the estimate for the 2000 sampling season (10.56%) is excluded as an outlier). The higher than usual recapture rate and the corresponding seasonal catch efficiency of the trap during 2011 is in marked contrast to lower than average efficiencies observed in the past four seasons (Figure 3.8), and is the highest seasonal catch efficiency recorded to date other than the discarded estimate for the trap year 2000. Personnel that were operating the trap during 2011 are unable to offer an explanation for the sudden change in the seasonal catch efficiency of the screwtrap. A discussion of possible environmental causes for changes in seasonal catch efficiency is presented in the discussion of coho results.

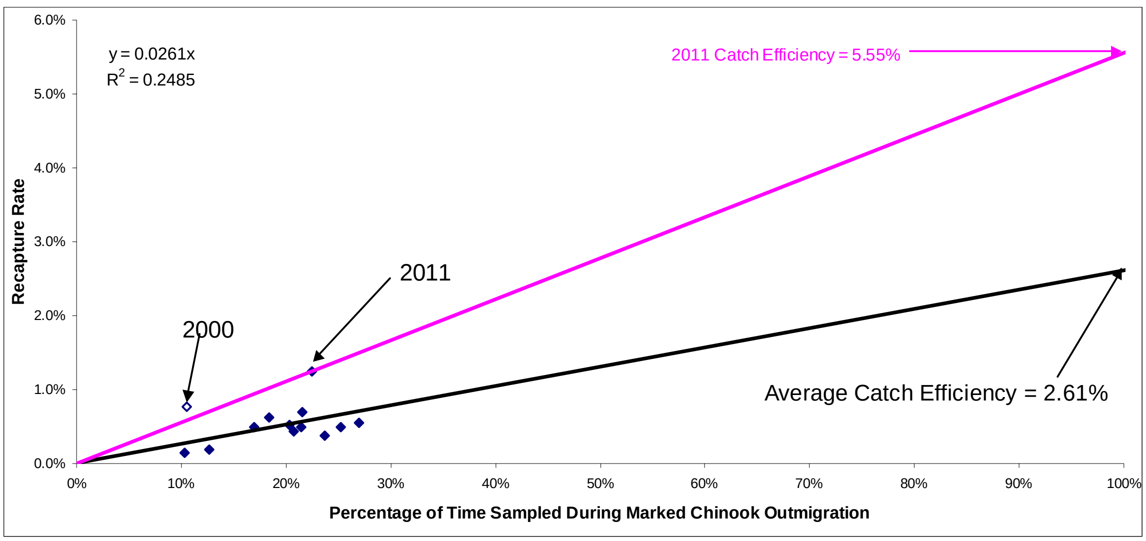


Figure 3.7. Seasonal Trap Catch Efficiency Estimates for Marked Zero-Age Chinook

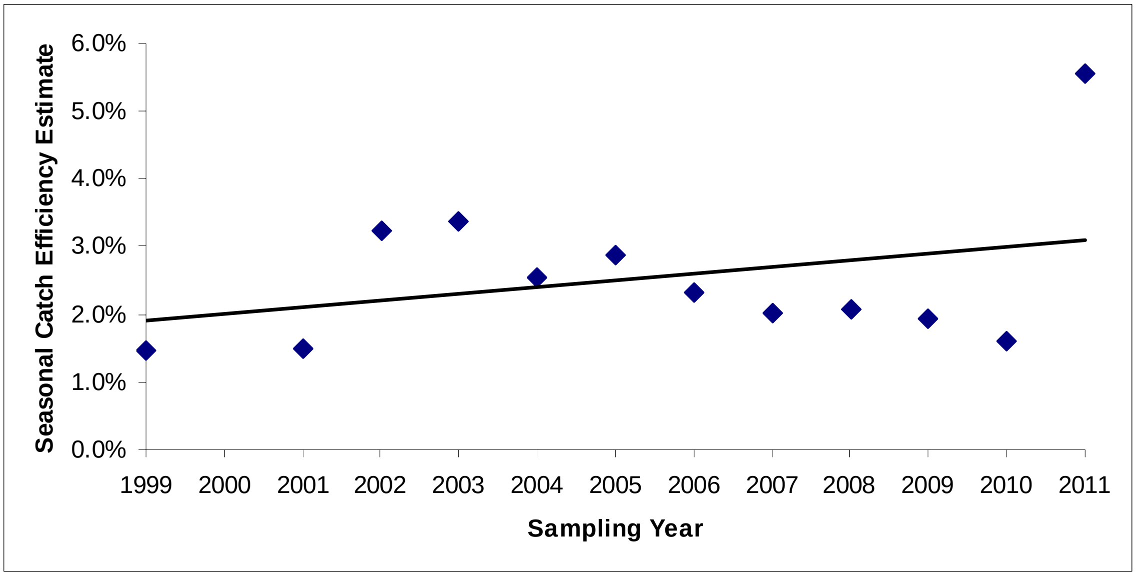


Figure 3.8. Comparison of Seasonal Catch Efficiency Estimates for Chinook over Time

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 3.7) and multiplying by 24 hours per day.

The total number of smolts estimated to have outmigrated in 2011 was 1,927,912 Zero-age Chinook. This total includes estimates of 1,665,622 marked smolts and 262,296 unmarked smolts. The estimate for marked smolts is 35.8% higher than the number of marked smolts that were released. Assuming that the same is also true for unmarked smolts, and removing 8,760 unmarked hatchery-origin smolts from the result, then the CCE-derived wild production estimate for zero-age Chinook is **184,343** smolts.

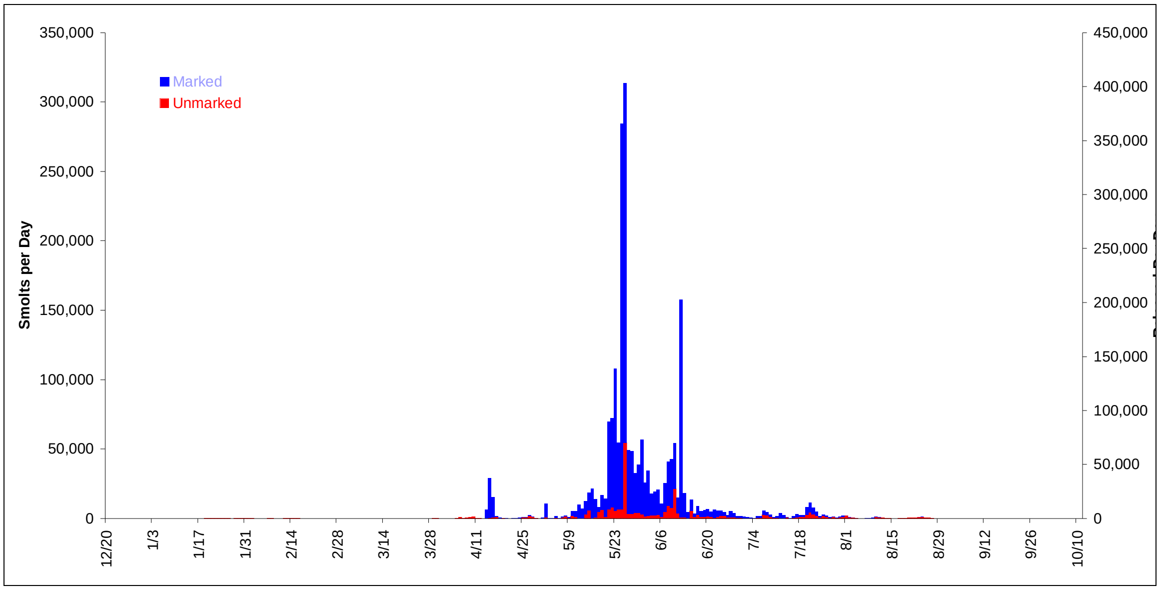


Figure 3.9. Daily Production Estimates for Zero-Age Chinook in 2011

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 184,343 wild-origin Chinook smolts in 2011 is lower than the average outmigration of 269,797 smolts.

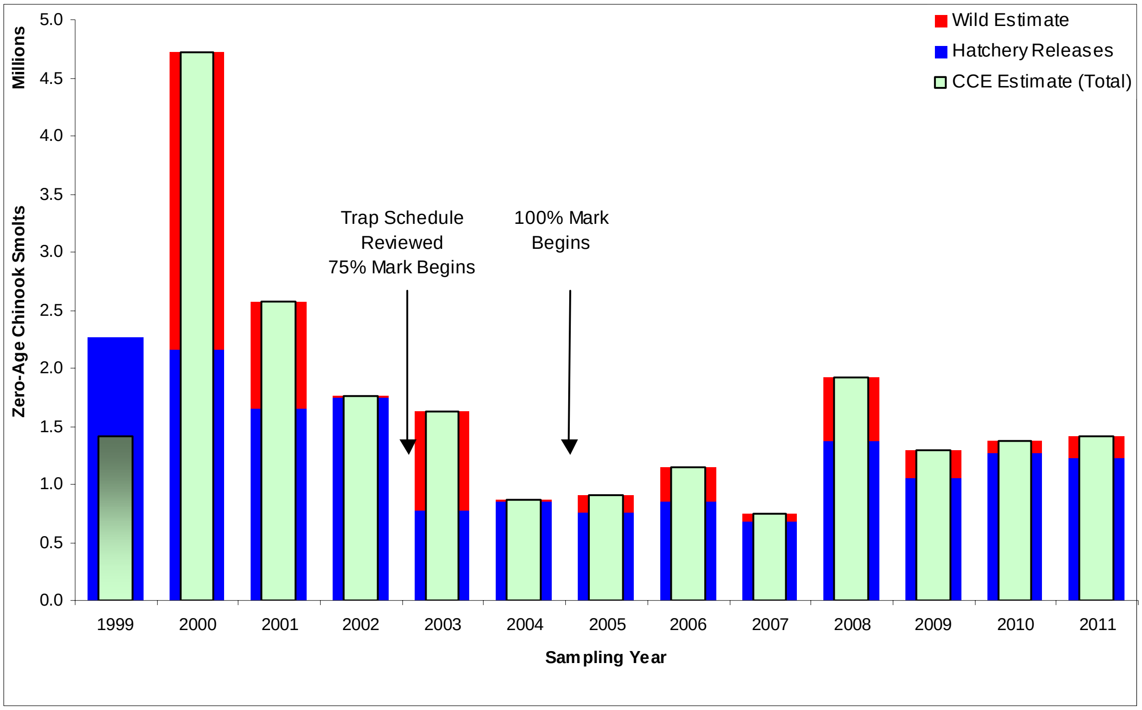


Figure 3.10. CCE Estimates for Zero-Age Chinook Smolts Outmigrating Past the Trap, by Sampling Year

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 2011 season is **154,189** 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.

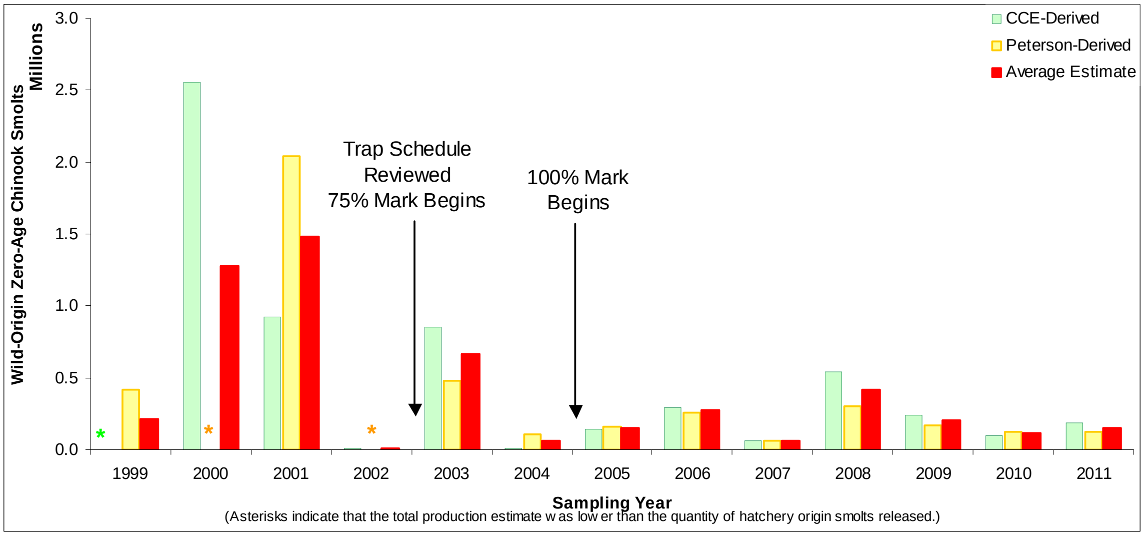


Figure 3.11. Comparison of Wild-Origin Zero-Age Chinook Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

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
2010	2011	154,189

**Earlier estimates are considered to be too unreliable.*

3.6 Yearling Chinook Outmigrants

3.6.1 CPUE Time Series for Yearling Chinook

In total, 13 yearling Chinook were caught between April 21 and May 20, 2011. Figure 3.12 shows the time series of interpolated hourly catch rates for yearling Chinook smolts throughout the 2011 season. The highest observed catch rate for yearling Chinook was 0.17 smolts per hour, which was recorded on May 2, 2011.

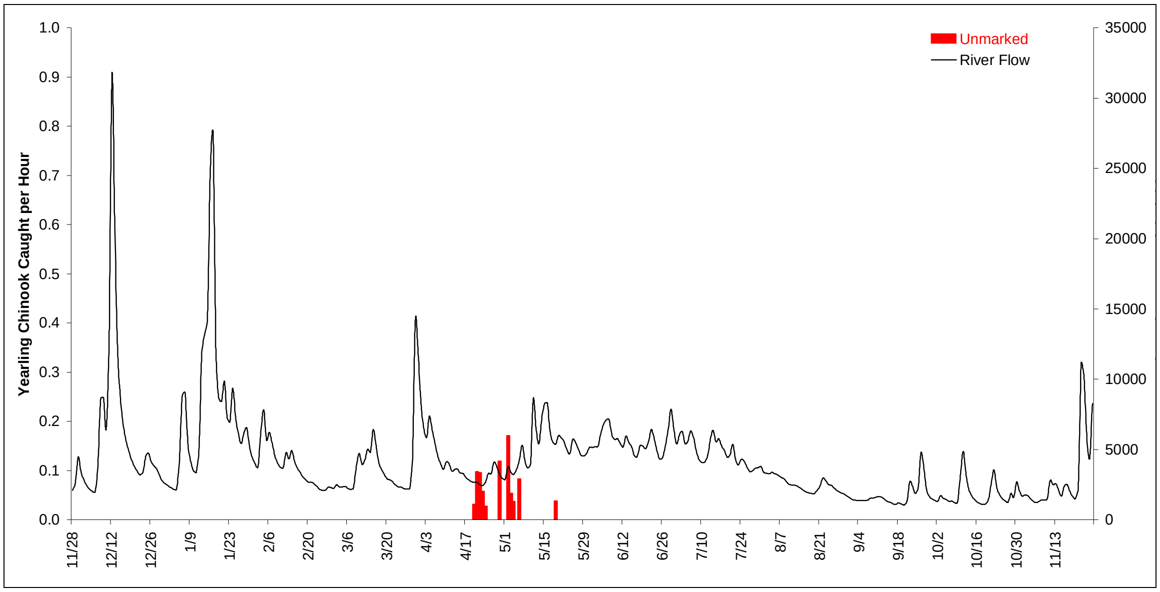


Figure 3.12. Interpolated Catch Per Hour of Yearling Chinook Smolts by Date

3.6.2 Between-Year Comparisons for Yearling Chinook CPUE

Yearling Chinook smolts that outmigrated during the 2011 sampling season are the offspring of adult Chinook that spawned during the summer and fall of 2009 (Brood Year [BY] 2009). The Index of Abundance for yearling Chinook during the 2011 sampling season has a value of 0.8. This is lower than the average Index of Abundance value for the period of record (8.2). 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. Note: yearling Chinook that were produced in BY 2010 will not outmigrate until the 2012 sampling season.

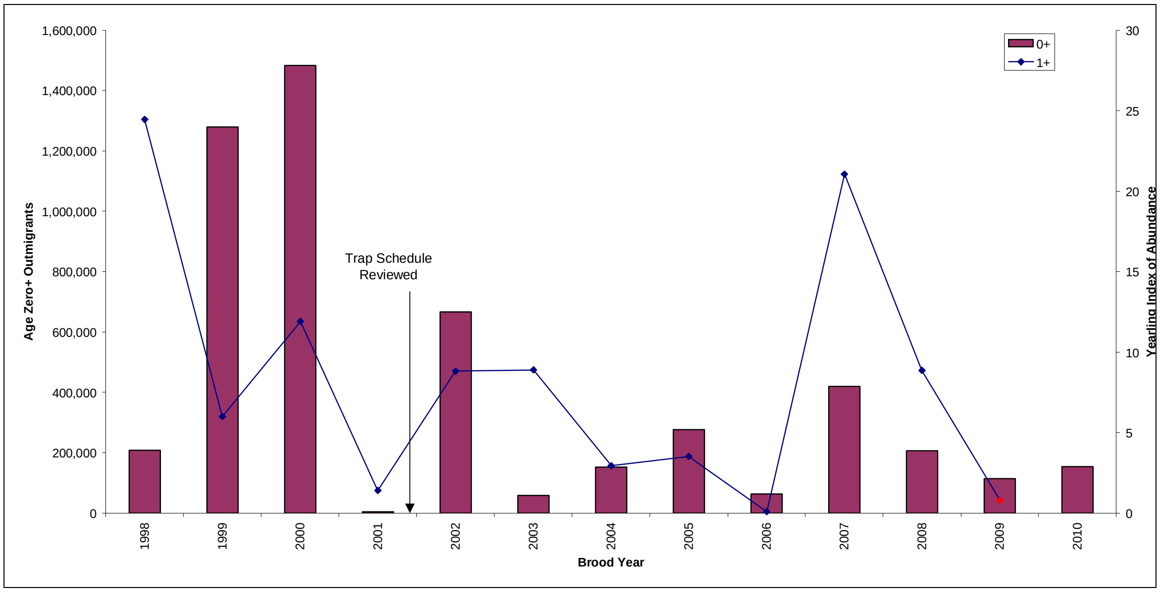


Figure 3.13. Comparison of Relative Zero-Age Production Estimates and Yearling Outmigrant Index of Abundance Based on Brood Year

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.

3.7 Chinook Discussion

The results for the Trap in the 2011 sampling season suggest that, relative to the previous 7 years, the production of wild-origin Chinook smolts was very low for yearling smolts produced in BY 2009, and below-average for zero-age smolts produced in BY 2010.

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 early egg incubation (October) for BY2009 were the most severe since 2003 and November flows were the worst since 2006, while the flows during BY2010 were relatively mild until December (Table 3.6).

The index of abundance scores for yearling outmigrants from BY2006 and BY2009 are the lowest and second lowest during the period of record for yearlings. The equivalent index score for BY2003 is much higher than would be expected based on the number of zero-age outmigrants from the same year class. However, the index of abundance score for that year class was potentially strongly impacted by interpolation bias. The number of zero-age outmigrants from BY2003, BY2006, and BY2009 are also the lowest on record subsequent to the trap scheduling review in 2002.

These results are generally consistent with the hypothesis that river flows during egg incubation may be partially responsible for determining year class strength for both zero-age and yearling outmigrants.

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. Similarly, very large flow events (>30,000 cfs) that occur in December of January appear to have less of an impact on year class strength than less-large (15,000 – 20,000 cfs) events that occur during October and November. This would suggest that high flows during the early part of the incubation period have a more profound impact on survival than high flows later in incubation or pre-emergence. If so, then this could be due to the eggs being more fragile during early incubation, or redds becoming more resilient to scour over time as fines infiltrate the cleaned gravels and bind the larger particles together, or the ability of hatched fry to migrate through the gravels to avoid being exposed.

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	2012
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**	13,600
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	12,000
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	14,200	7,040
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	8,270	
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	8,630	
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	7,880	
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	6,370	
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	3,400	
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	4,790	
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	4,870	
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	11,600	
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**	9,880	
		Brood Year														
Wild Production Estimate (0+ Chinook Numbers)			*208,723*	1,278,838	1,482,803	4,987	666,424	59,216	151,832	275,975	63,088	420,194	206,231	114,236	154,189	?
			Zero-Age Migrants													
Yearling Chinook Ind. of Abund.				24.5 Yearling Migrants	6.0	11.9	1.4	8.8	8.9	2.9	3.5	0.1	21.0	8.9	0.8	?

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 7 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 BY 2003 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

Yearling coho smolts were released from May 25 through June 3, 2011 from the Skookum Creek hatchery. 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 985,420 smolts. Of these, 99.9% were externally marked using adipose fin clips.

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 always scanning each coho for coded wire tags in order to reduce the amount of time required to process the catch. Unfortunately, this means that coho that are not adipose clipped but that do have a coded wire tag cannot be reliably distinguished from wild-origin smolts and for the purposes of this report are considered to be externally unmarked. (This issue does not apply to Chinook as all Chinook caught at the trap are always scanned for coded wire tags.)

Table 4.1 Upstream Hatchery Releases of Yearling Coho in 2011

Release Date	Source Hatchery	Location	Marked Coho Released		Unmarked Coho Released		Total Coho Released
			AC Only	AC & CWT	CWT Only	No AC No CWT	
05/25/11	Skookum	Skookum Creek	67,447	3,415	0	135	70,997
05/26/11	Skookum	Skookum Creek	137,184	6,945	0	275	144,404
05/27/11	Skookum	Skookum Creek	118,646	6,007	0	238	124,891
05/28/11	Skookum	Skookum Creek	133,477	6,758	0	267	140,502
05/29/11	Skookum	Skookum Creek	125,925	6,375	0	252	132,553
05/30/11	Skookum	Skookum Creek	110,086	5,573	0	221	115,880
05/31/11	Skookum	Skookum Creek	81,352	4,119	0	163	85,634
06/01/11	Skookum	Skookum Creek	69,442	3,516	0	139	73,097
06/02/11	Skookum	Skookum Creek	69,441	3,516	0	139	73,096
06/03/11	Skookum	Skookum Creek	23,149	1,171	0	47	24,366
			936,149	47,395	0	1,876	985,420

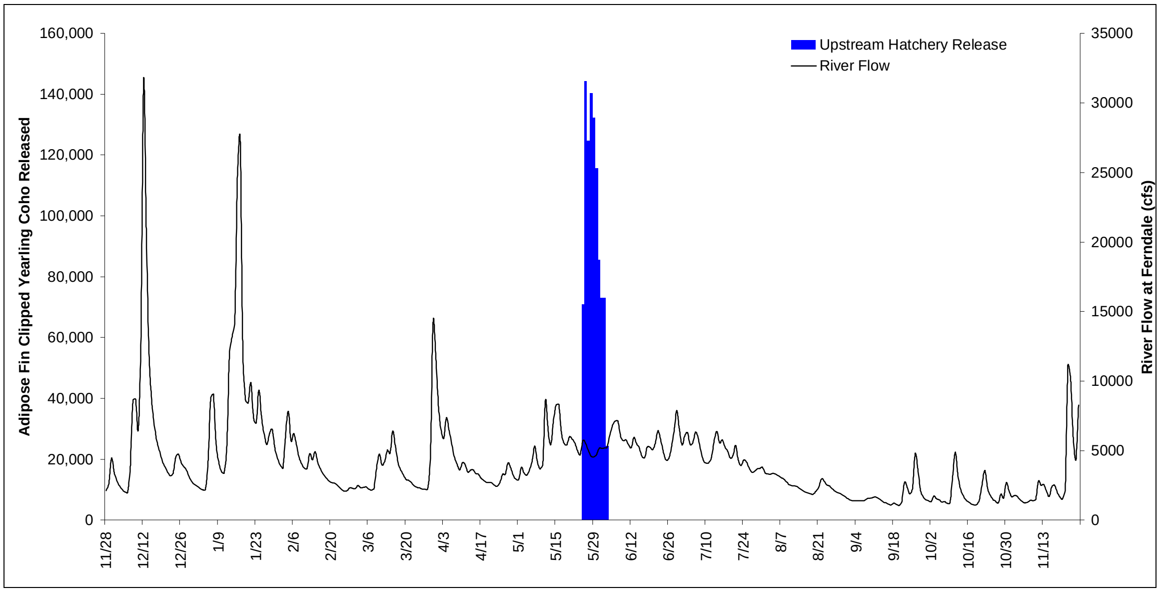


Figure 4.1. Timing and Magnitude of Hatchery Releases of Marked Yearling Coho

4.2 Coho Catch Totals

The 2011 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 2011 season was the highest on record. The overall catch of unmarked yearling coho was also the highest on record since the advent of mass marking of hatchery-origin smolts. Since the number of marked yearling coho released in 2011 was similar to recent seasons, these data support the hypothesis that the seasonal catch efficiency of the trap in 2011 was markedly higher than in previous seasons.

Table 4.2. Catch Totals for Coho Outmigrants by Year

Sampling Year	Zero-Age Outmigrants Marked	Zero-Age Outmigrants Unmarked	Yearling Outmigrants Marked	Yearling Outmigrants Unmarked	Hours Fished	% Marked in Released Hatchery Coho
2011	**0**	**20**	**6,648**	**3,554**	1055	**99.80%**
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%

Table 4.3 and Table 4.4 show the correlation coefficients and the slopes for the relationships between observed catch rates of zero-age and yearling coho from sets conducted during different daylight conditions within 24 hours, based on Trap data collected from 2005 to 2011. Nighttime catch rates of yearling coho tend to be approximately twice as high as daytime catch rates, which is consistent with published descriptions of a strongly nocturnal migratory behavior for coho (e.g., Mehan and Siniff, 1962).

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

Independent Variable	Dependent Variables							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		0.36	0.00	0.43		0.17	0.05	0.55*
Night	0.17		0.20	0.07	0.09		0.724*	0.11
Dawn	0.05	0.724*		0.45	0.00	2.74		0.583*
Day	0.55*	0.11	0.583*		0.72	0.22	0.78	
	* Indicates a Statistically Significant Correlation ($p<0.05$)							

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

Independent Variable	Dependent Variables							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		0.97	0.30	0.19		0.8*	0.681*	0.525*
Night	0.8*		0.18	0.19	0.71		0.401*	0.546*
Dawn	0.681*	0.401*		0.77	1.82	1.35		0.738*
Day	0.525*	0.546*	0.738*		1.75	1.89	0.74	
	* Indicates a Statistically Significant Correlation ($p<0.05$)							

4.3 Coho Smolt Sizes

The average daily fork lengths of coho smolts that were measured at the Trap are shown in Figure 4.2 (grouped by life stage and mark status). Unmarked coho yearlings caught in 2011 had an average fork length of 110.6 millimeters. Marked hatchery-origin coho yearlings had an average fork length of 118.4 millimeters. Unmarked zero-age coho had an average fork length of 53.1 millimeters.

In general, unmarked yearling smolts were in the same approximate size range as marked yearling smolts caught on the same date, although they tended to be smaller overall. 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.

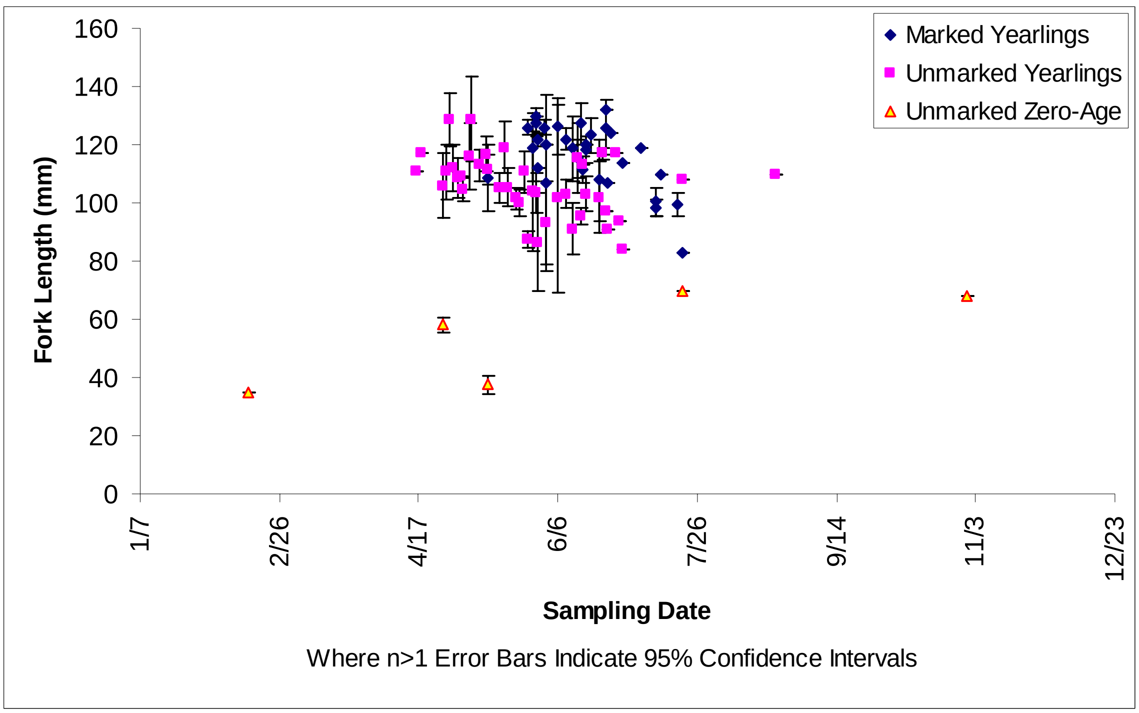


Figure 4.2. Average Daily Fork Lengths for Coho Smolts Caught During 2011

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 reasonably consistent outmigration window, which has a median outmigration date that has varied by less than one week over the past 11 seasons, and which has an average duration of 34 days during which 90% of yearling coho outmigrate (Figure 4.4).

For the 2011 season, the first unmarked yearling coho smolt was caught on Feb 11. The last unmarked yearling coho was caught on August 23. The median outmigration date for unmarked yearling coho was May 23, which was just 2 days later than the long-term median date. Ninety percent of yearling coho outmigrated between May 9 and June 8, which compares to the long term 90% dates of May 3 and June 6.

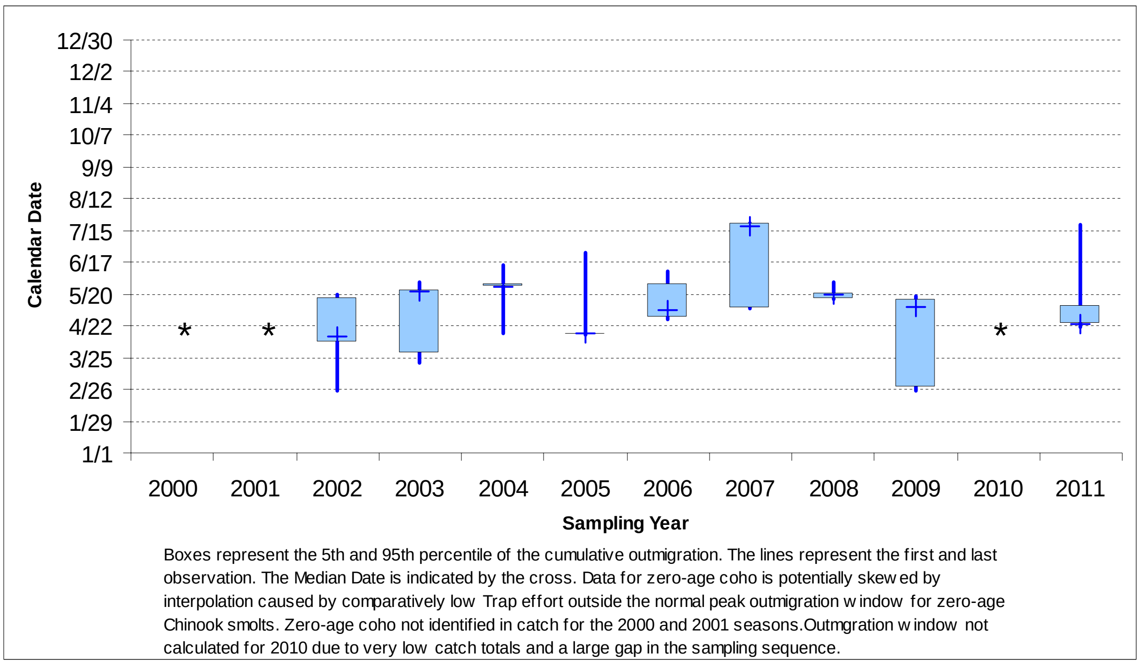


Figure 4.3. Outmigration timing for Unmarked Zero-Age Coho smolts from 2002 to 2011

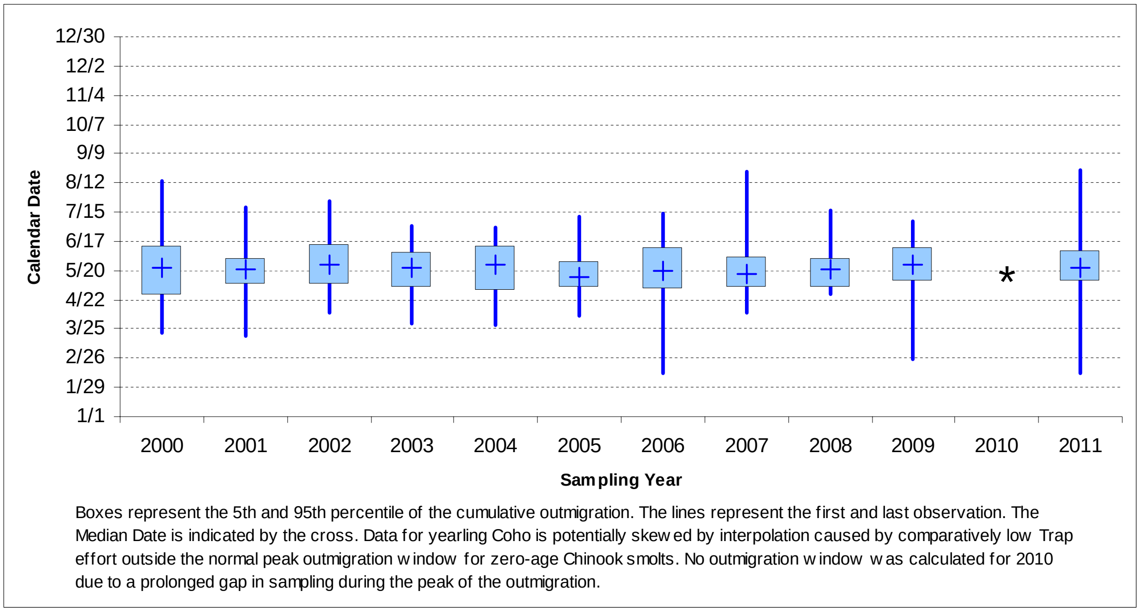


Figure 4.4. Outmigration timing for Unmarked Yearling Coho smolts from 2000 to 2011

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 2011 season, only 20 zero-age coho smolts were caught and these individuals were primarily caught in May (Figure 4.5), with one other being caught in late July.

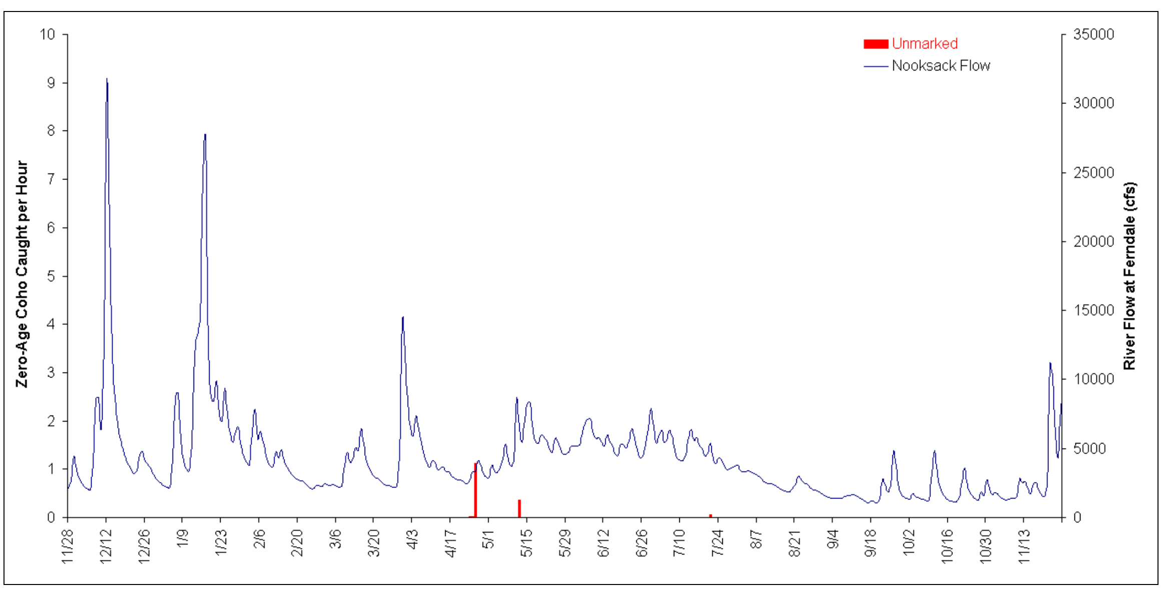


Figure 4.5. Interpolated Catch Per Hour of Zero-Age Coho Smolts by Date Versus Flow

4.5.2 Between-Year Comparisons for Zero-Age Coho CPUE

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

4.6 Yearling Coho Outmigrants

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

4.6.1 CPUE Time Series for Yearling Coho

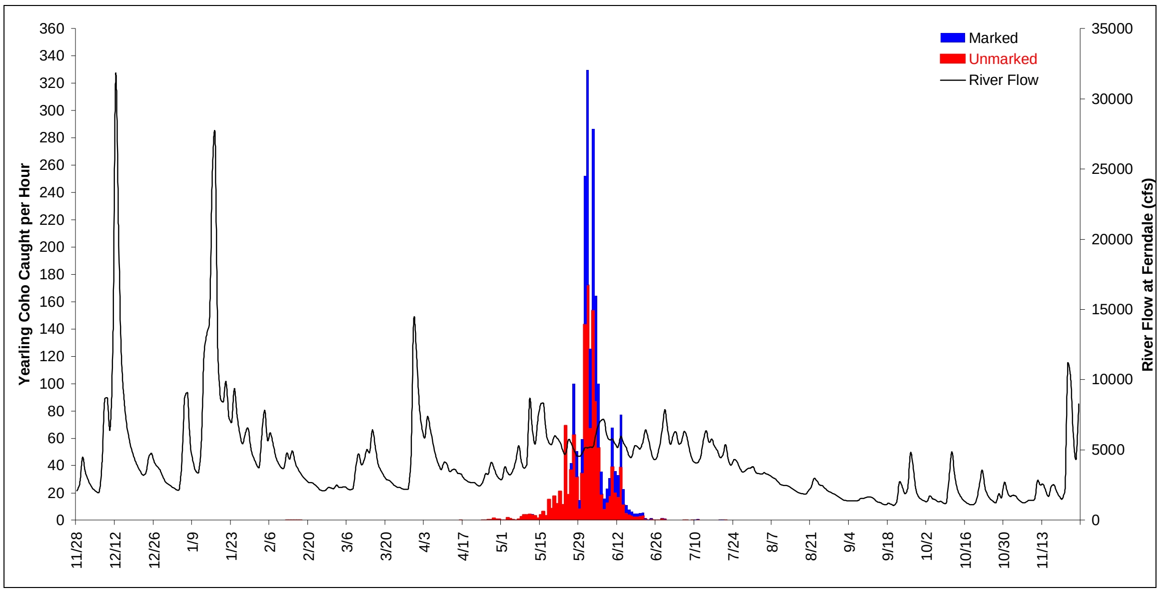


Figure 4.6 Interpolated Catch Per Hour of Yearling Coho Smolts by Date

In 2011 unmarked yearling coho began to be caught regularly from the end of the first week of May through to late-June. The first unmarked yearling coho was caught on February 2 and the last was caught on August 25. The highest catch rate of unmarked yearling coho (172 smolts per hour) occurred on June 1 2011.

Marked hatchery-origin coho outmigrants were first caught on April 29 and the last was caught on July 21. However, the majority of marked coho outmigrated between the May 26 and June 21. The highest catch rate of marked coho (157 smolts per hour) occurred on June 1, which was approximately one week after the first day of release from the Skookum hatchery.

4.6.2 Production Estimates for Yearling Coho in the 2010 Season

Peterson Estimate for Yearling Coho

In the 2011 sampling year, 983,544 externally marked (adipose fin clipped) yearling coho were released upstream from the Trap site. Of this total, 6,648 were recaptured at the Trap, and a further 3,554 unmarked yearling coho smolts were also caught (total = 10,202 smolts). Based on these values, the Peterson estimate for all yearling coho outmigrating during the 2011 season is 1,509,344 smolts. The difference between the Peterson estimate and the known number of hatchery-origin smolts is assumed to represent the number of wild-origin coho yearlings. The total number of hatchery-origin smolts released in 2011 was 985,420 smolts (including 1,876 accidentally unmarked individuals). According, the wild-origin production estimate for smolts outmigrating in 2011 is 523,924 smolts.

This value is compared to results from previous years in (Figure 4.7).

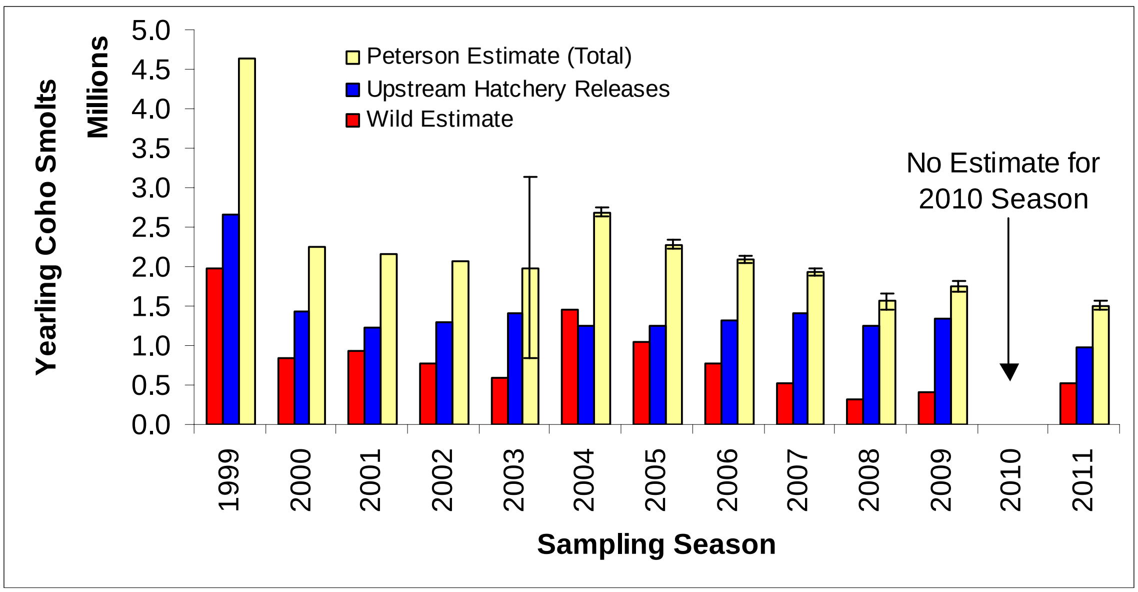


Figure 4.7. Peterson Estimates for Yearling Coho Smolts Outmigrating Past the Trap, by Sampling Year

CCE Estimate for Yearling Coho

During the 2011 season the Trap recaptured 0.68% of the clipped coho smolts that were released upstream. During the time period when clipped coho smolts were outmigrating, the Trap was fishing 23.44% 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 2011 season catch efficiency is estimated to have been 2.88% (Figure 4.8). This value is considerably higher than the average seasonal catch efficiency of 1.18% and is the highest seasonal catch efficiency recorded to-date.

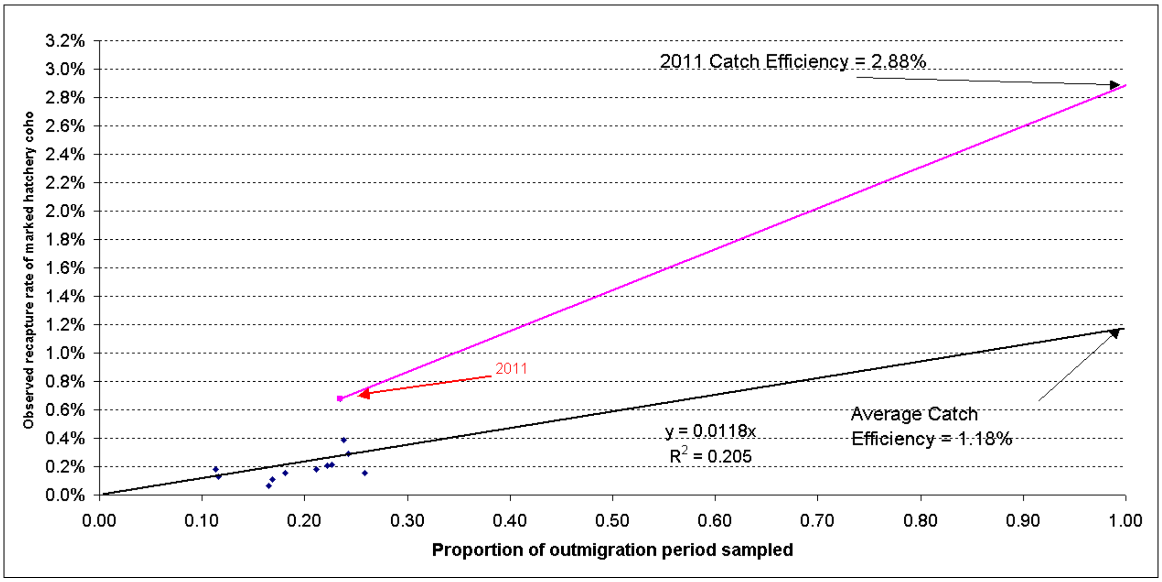


Figure 4.8. Seasonal Trap Catch Efficiency Estimates for Marked Yearling Coho

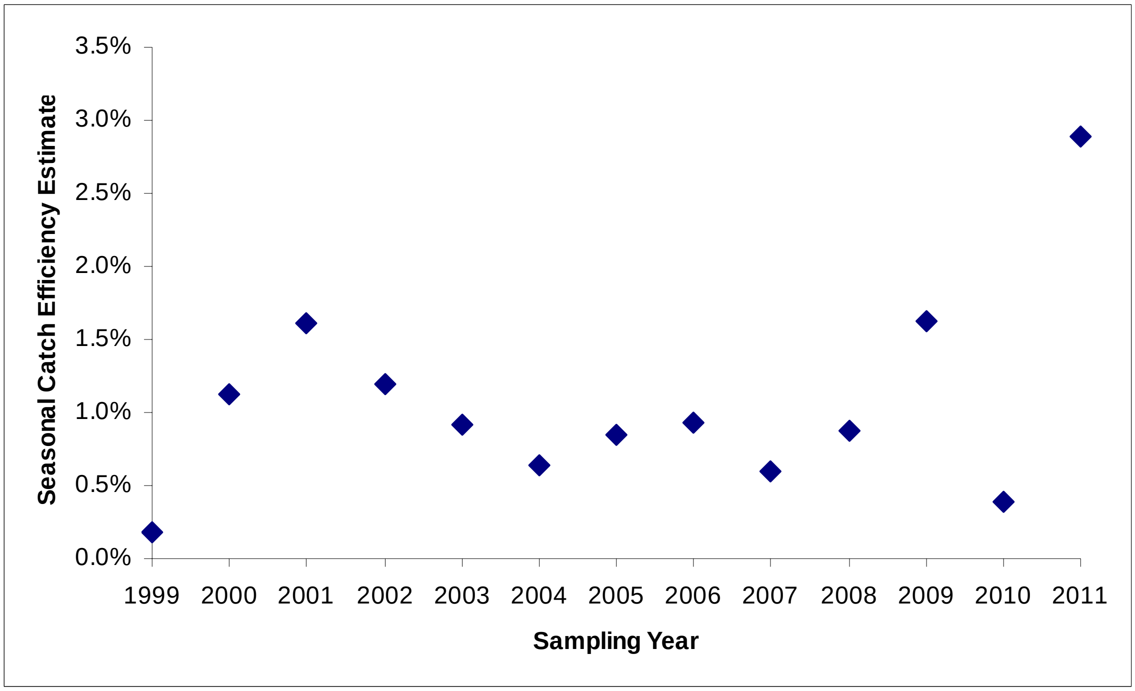


Figure 4.9. Comparison of Seasonal Catch Efficiency Estimates for Coho over Time

Using the average seasonal catch efficiency estimate of 1.18% to convert the time series of hourly catch rates shown in Figure 4.6, the total number of marked smolts estimated was 1,732,143, which was approximately 76% higher than the known number of marked smolts released. This large over-estimate is primarily a consequence of a large disparity between the seasonal catch efficiency for the 2011 season and the average catch efficiency for all seasons. If the 2011 season catch efficiency were used instead, the estimate would have underestimated the known release by 28%. The daily production estimates for marked and unmarked smolts, after the known bias has been removed, are shown in Figure 4.10. After deducting unclipped hatchery-origin smolts, the final estimate of wild-origin yearling coho outmigrating in 2011 was estimated to be 504,783 smolts.

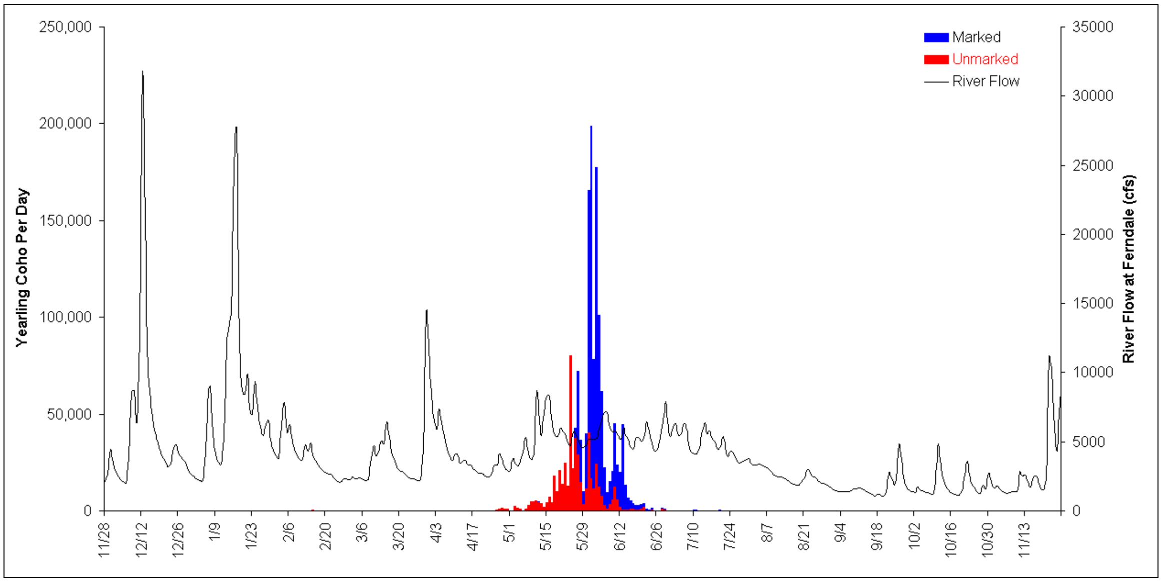


Figure 4.10 Daily Production Estimates for Yearling Coho in 2011

4.6.3 Between-Year Comparisons for Yearling Coho Production Estimates

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

The average of the two different production estimates for wild-origin yearling coho in the 2011 season is **514,353** smolts. This is the third-lowest estimate of wild origin yearling coho to date. Only the 2008 and 2009 seasons had lower estimates for the total wild production of yearling coho.

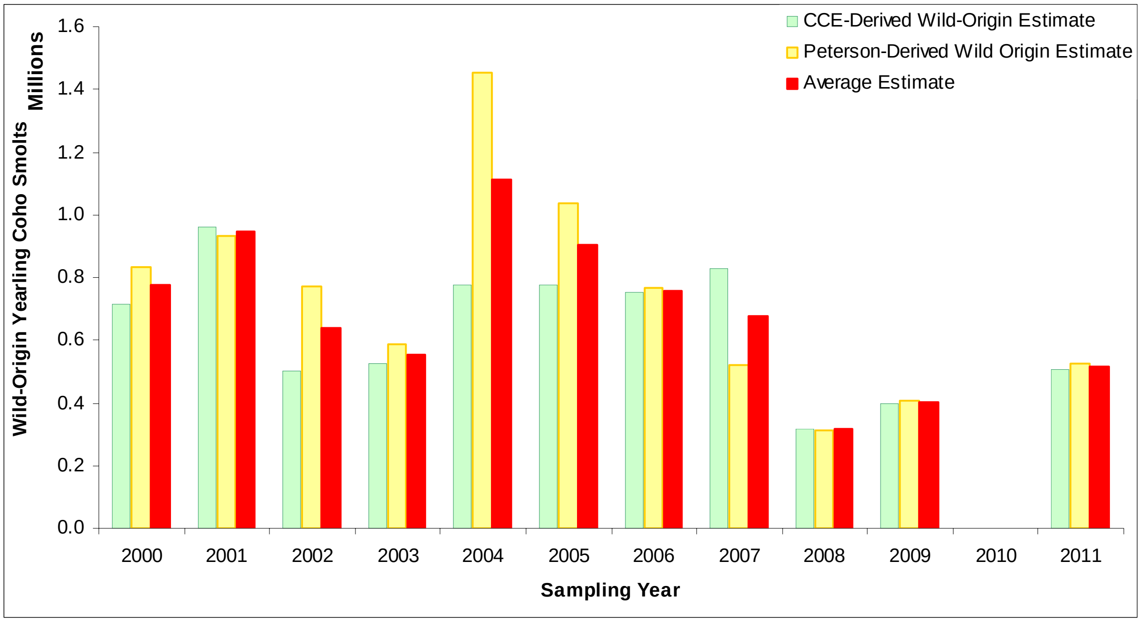


Figure 4.11. Comparison of Wild-Origin Yearling Coho Smolt Production Estimates Derived Using the Peterson and CCE Production Estimate Models and Hatchery Release Data

4.7 Coho Discussion

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

Yearling coho appear to outmigrate in a very well defined time period that, on average, typically varies by less than a week between years and this was also true again in 2011.

The estimates of the production of wild yearling coho in 2008, 2009, and 2011 (BY2006, BY2007, and BY2009) are the lowest to-date, although the 2011 estimate was the highest of these three and was comparable to the 2003 outmigration (BY2001). There does not appear to be any clear explanation for this.

Although incubation flows during the fall of 2009 were quite high, flows during the fall of 2006 and 2007 were not unusually severe compared to flows during the previous few years indicating that mechanisms such as scour or flushing of fry are possibly not a causal factor. And the higher production of coho in 2011 despite worse incubation conditions also suggests that flows may not be the dominant factor in year class strength for coho. It would be interesting to compare these results to spawner escapement estimates for coho salmon to see whether there is a relationship between smolt production and the number of spawning adults.

The unusually high catch efficiency for coho yearlings in 2011 is something of a mystery but this phenomenon was not restricted to coho as unusually high seasonal recapture rates were observed for hatchery-origin Chinook smolts also. In addition, the number of marked steelhead smolts captured at the trap was also a record high. Taken together, this does suggest that the catch efficiency of the Trap was genuinely much higher in 2011 than in most recent years.

River flows during May and June were well within the range of flows previously seen in other seasons so it would appear to be unlikely to be related to unusual flow conditions (Figure 4.12).

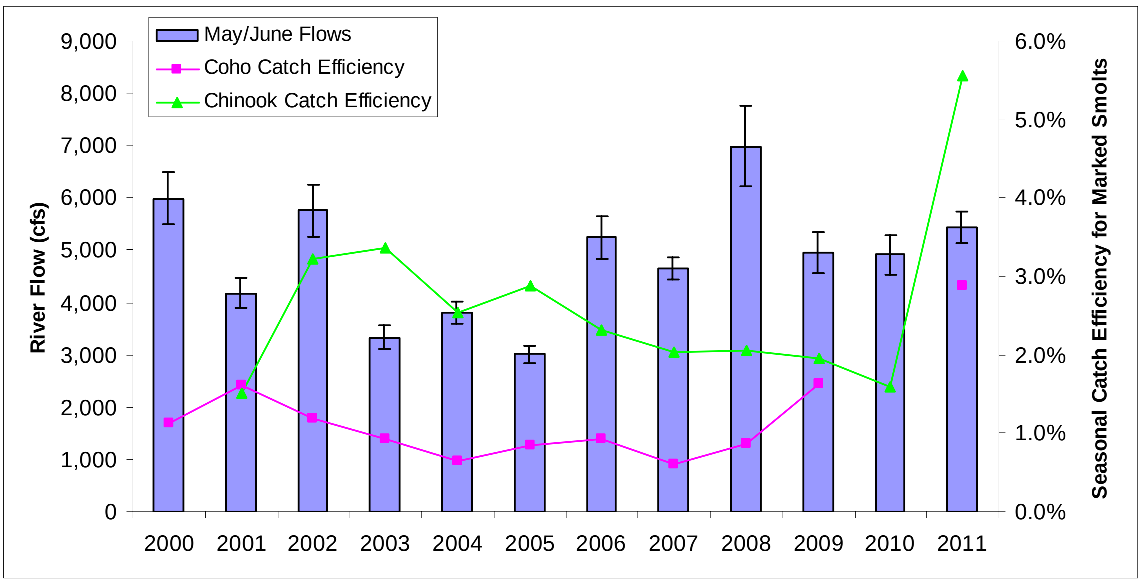


Figure 4.12. Comparison of Average May/June River Flows versus Seasonal Catch Efficiency Estimates for Marked Hatchery Origin Smolts

Another factor that could explain the high catch efficiency was the low water clarity during May and June 2011, which was one of the lowest years on record (Figure 4.13). However, even though there does appear to be an inverse trend between seasonal catch efficiency and secchi depths, the trend explains virtually none of the variation in the seasonal catch efficiencies for zero-age Chinook smolts, and only a tiny amount of the variation in catch efficiency for yearling Coho smolts (Figure 4.14). It is unlikely that the very large changes in seasonal catch efficiency are driven solely by changes in water clarity from year to year.

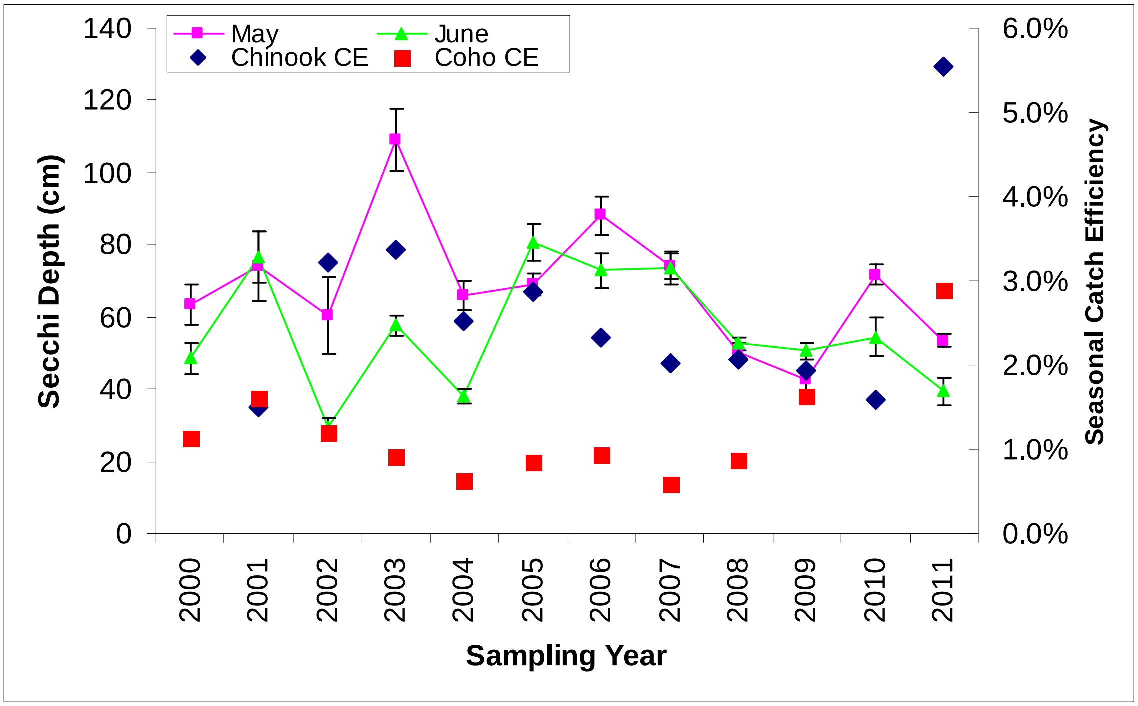


Figure 4.13. Comparison of Average Secchi Depth Readings in May and June by Sampling Season

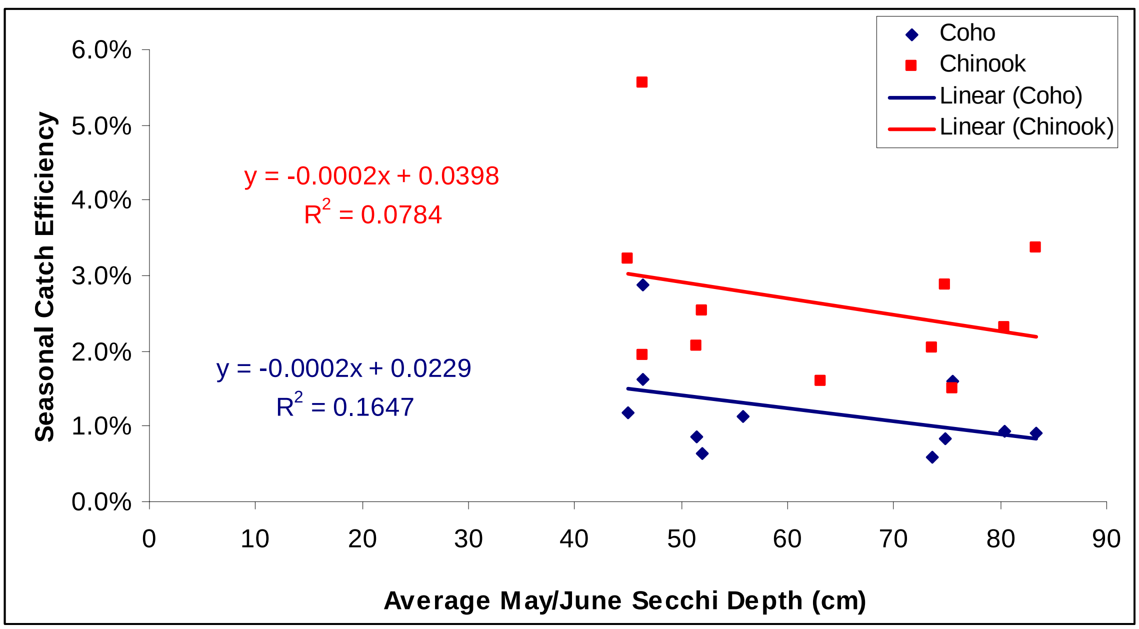


Figure 4.14. Scatterplot showing Seasonal Catch efficiency versus Average May/June Secchi Depth

The last explanations that might explain large changes in the catch efficiency of the Trap would be if the configuration of the river channel itself has changed significantly between years, or if the fishing position of the Trap was changed between years.

According to field personnel, the fishing position of the Trap has not been changed significantly for many years so this is an unlikely explanation.

The shape and configuration of the river channel itself has undergone some incremental changes over time. However, the position of the thalweg has been relatively stable and the Trap is fished in this portion of the river. Nonetheless, a large mid-stream bar has accumulated upstream from the Trap site over the past few years and this may impact the position of smolts within the channel and vertically within the water column as well. Unfortunately, no cross-sections of the river channel at the Trap site have been done recently to evaluate whether the situation at the Trap site has undergone a major change since the 2008 season.

5.0 Chum Salmon

5.1 Hatchery Release Summary

There are no known releases of chum salmon from hatcheries.

5.2 Chum Catch Totals

The 2011 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 2011 season was lower than the mean score but higher than the median score for the period of record.

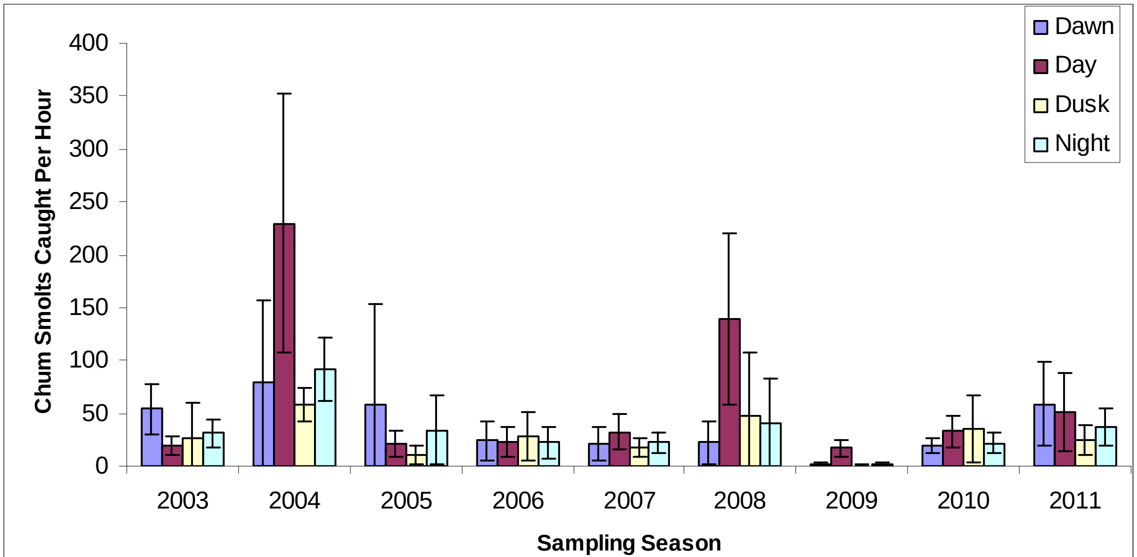
Table 5.1. Catch Totals for Chum Outmigrants by Year

Sampling Year	Zero-Age Outmigrants Marked	Zero-Age Outmigrants Unmarked	Yearling Outmigrants Marked	Yearling Outmigrants Unmarked	Hours Fished	Index of Abundance (Unmarked)
2011	**0**	**11,839**	**0**	**0**	1055	**2,219**
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

Error! Reference source not found. 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 2011. 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		1.26	2.86	1.10		0.793*	0.523*	0.579*
Night	0.793*		1.04	0.54	0.53		0.261	0.224*
Dawn	0.523*	0.261		0.69	0.13	0.14		0.706*
Day	0.579*	0.224*	0.706*		0.35	0.17	0.77	
	* 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 38.85 millimeters in 2011. 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 67 mm and was caught on Jun 24, 2011.

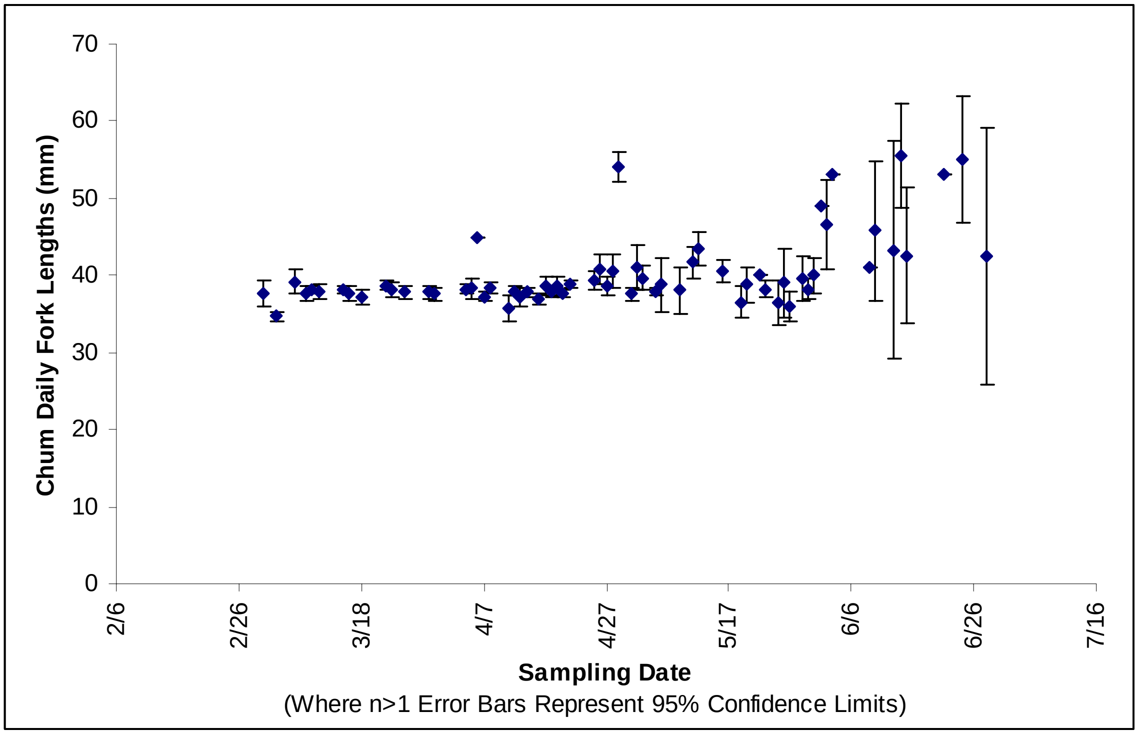
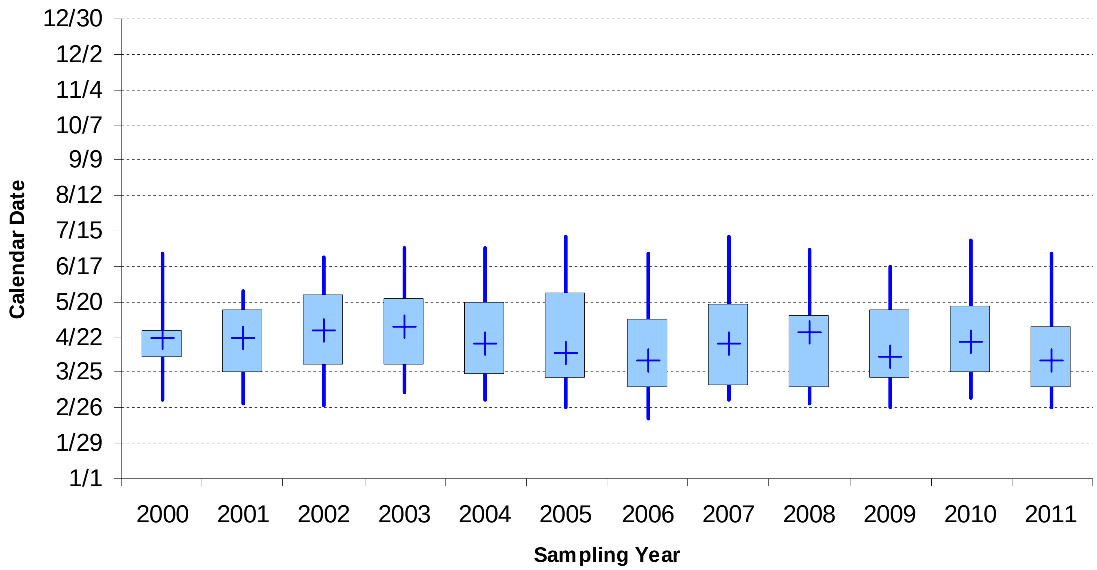


Figure 5.2. Average Daily Fork Lengths for Chum Smolts Caught During 2011

5.4 Chum Seasonal Outmigration Timing

In 2011, the median outmigration date was April 4, which is one-day later than the earliest median date from previous years. The first chum was caught on February 26 2011 and the last was caught on June 28 2011. The 5th and 95th percentile dates were March 13 2011, and May 1 2011, respectively. Overall, the 2011 outmigration period for chum was generally earlier than usual.

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 12 seasons; ranging from April 3rd in 2006 to May 1st in 2003. Overall, the average median date for the chum outmigration is April 16. 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).



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

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

5.5 Zero-Age Chum Outmigrants

5.5.1 CPUE Time Series for Zero-Age Chum

The highest catch rate for chum smolts during the 2011 season was 225 smolts per hour, which occurred on March 30 (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 during the chum outmigration window. Consequently, the time-series of CPUE is probably a good representation of trends during the outmigration window for chum smolts.

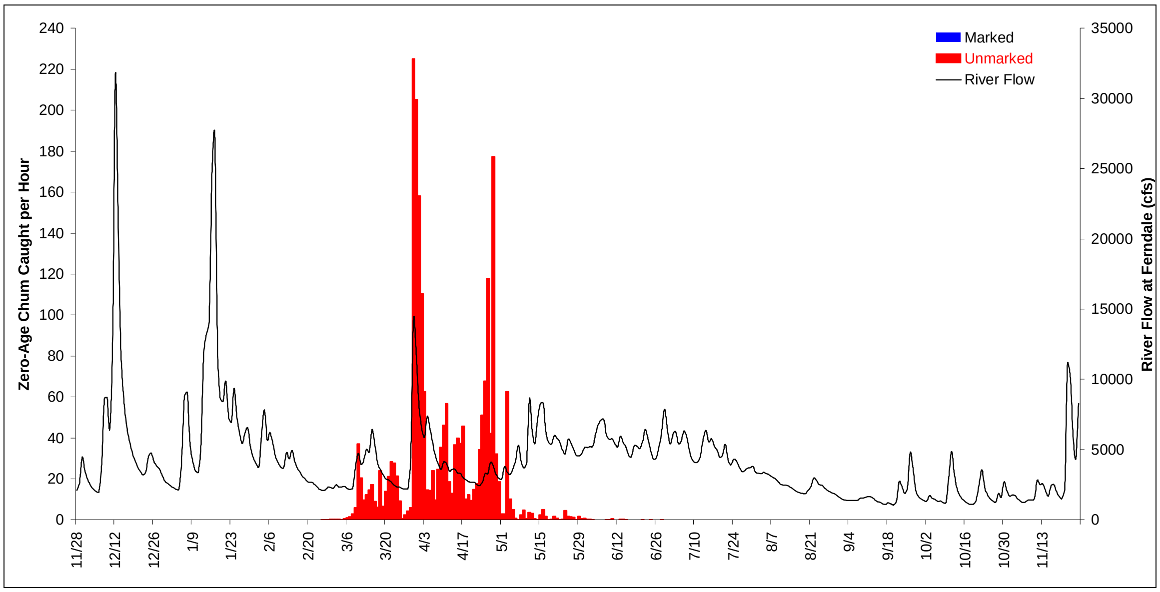


Figure 5.4. Interpolated Catch Per Hour of Zero-Age Chum Smolts by Date Versus Flow

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 intervening 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. The 2011 outmigration is similar in magnitude to that seen in 2003.

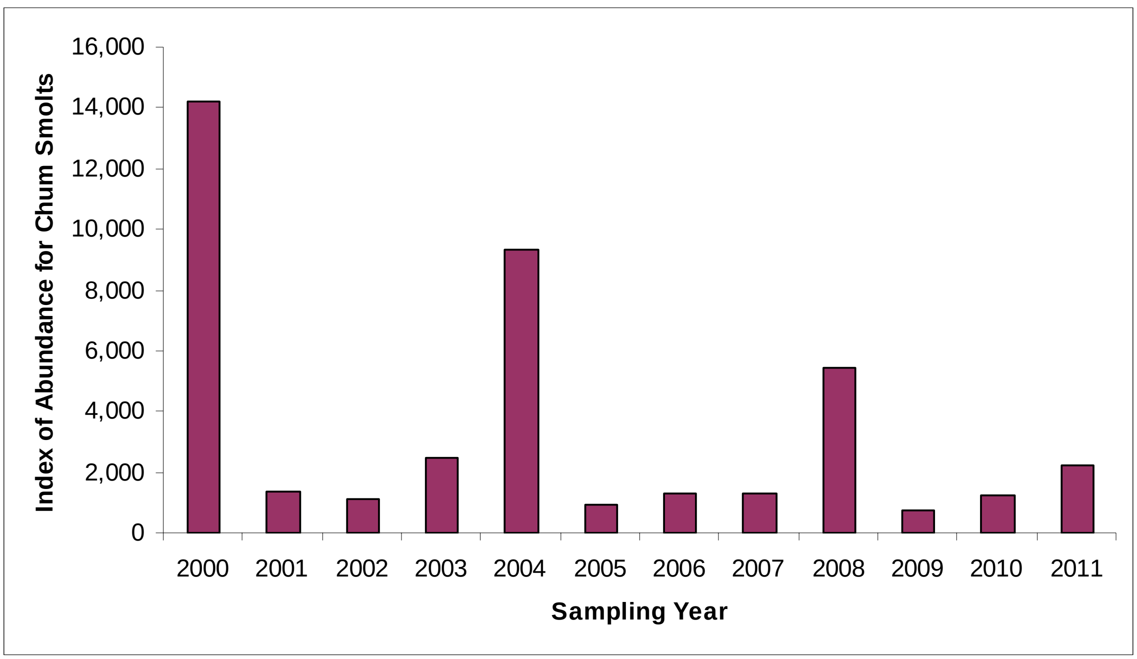


Figure 5.5. Comparison of the Index of Abundance for Chum Smolts by Sampling Year

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. Overall, there appears to be a repeating pattern of 3 consecutive 'weak' year classes, followed by one 'strong' year class.

The number of chum smolts produced each year seems to be more unrelated to the severity of flow events during the fall and winter than appears to be the case for Chinook. 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 some protection from large flow events. However, the largest flow event that has been observed during the time period considered in this report occurred in early January of 2009, and the index of abundance for chum smolts in the 2009 outmigration season was the lowest to-date. So it is possible that 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 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. 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.

The magnitude of the 2011 chum outmigration was within the range of results for previous seasons, and generally is in the middle of the spectrum. However, the result was the highest for a 'weak' year class since the 2003 outmigration. The next strong outmigration event is likely to occur in 2012.

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

Only 15 pink salmon smolts were caught during Trap operations in the 2011 sampling season (Table 6.1).

Table 6.1. Catch Totals for Pink Salmon Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance
	Marked	Unmarked	Marked	Unmarked		
2011	**0**	**15**	**0**	**0**	**1055**	**1.4**
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		1.26	2.86	1.10		0.793*	0.523*	0.579*
Night	0.793*		1.04	0.54	0.53		0.261*	0.224*
Dawn	0.523*	0.261*		0.69	0.13	0.14		0.706*
Day	0.579*	0.224*	0.706*		0.35	0.17	0.77	

* Indicates a Statistically Significant Correlation

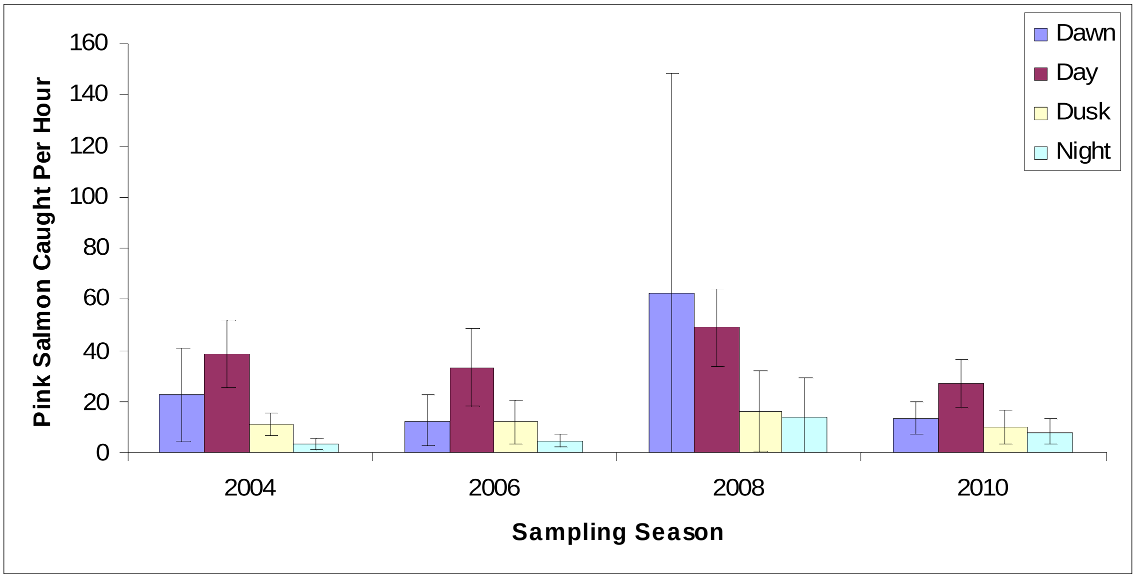


Figure 6.1. Comparison of Average Pink Salmon Catch Rates in March and April, by Daylight Stratum and Sampling Season.

6.3 Pink Salmon Smolt Sizes

Only two pink salmon smolts were measured during the 2011 season. The average daily fork lengths of pink smolts that were measured at the Trap are shown in Figure 6.2. The largest individual chum caught in the screwtrap was 39 mm on April 26 2011, and the smallest was 31mm, which was caught on March 23 2011.

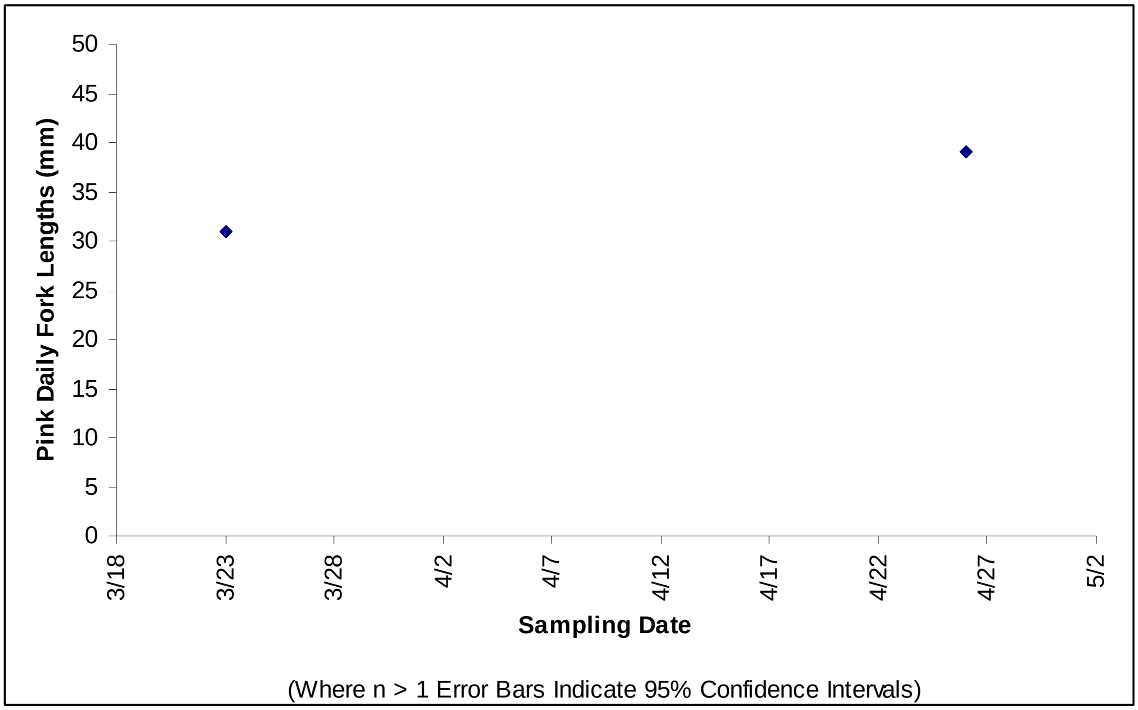


Figure 6.2. Average Daily Fork Lengths for Pink Smolts Caught During 2011

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.

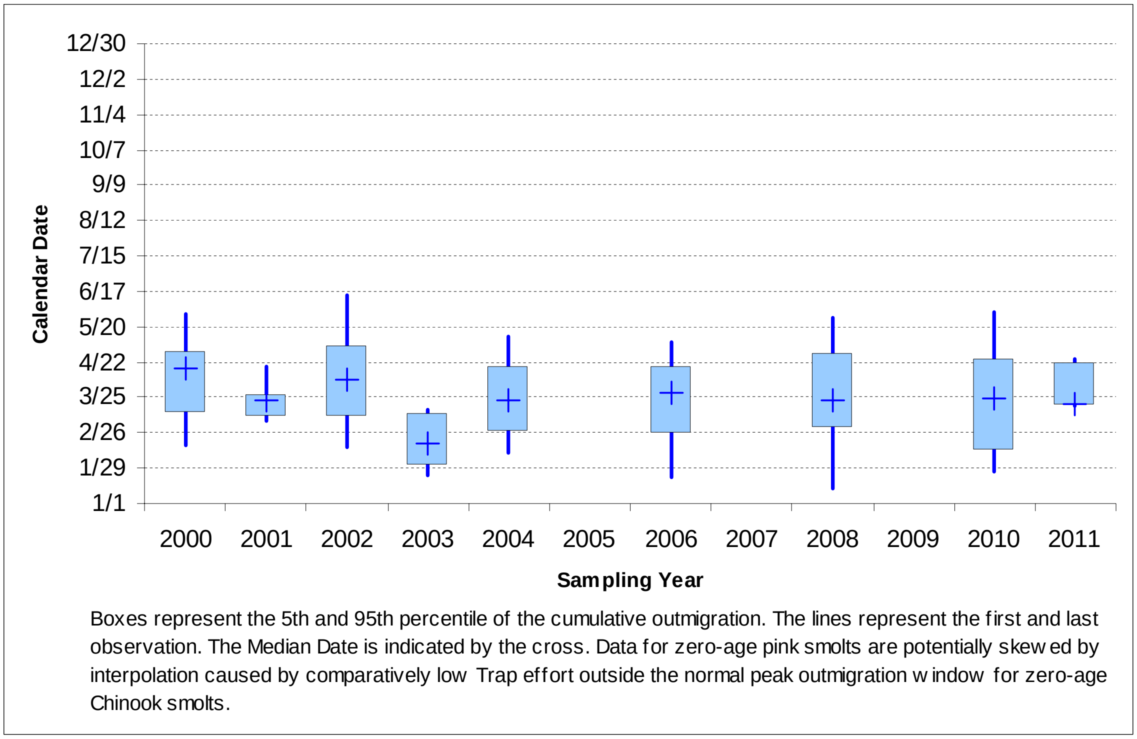


Figure 6.3. Comparison of Outmigration Window for Pink Salmon Smolts by Season

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 2011 season was 0.56 smolts per hour, which occurred on March 23 (Figure 6.4).

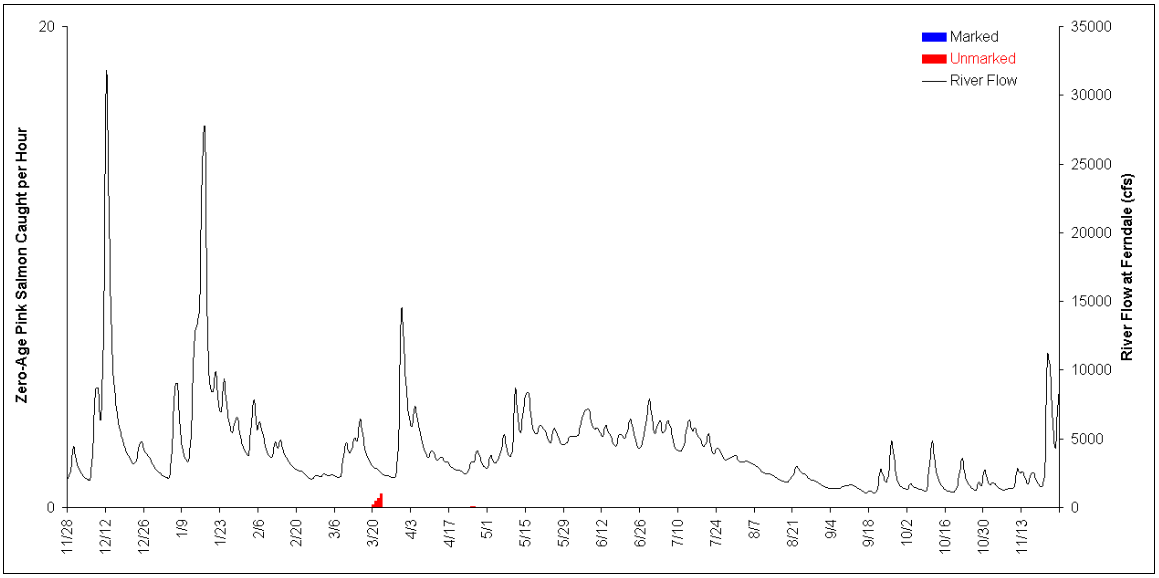


Figure 6.4. Interpolated Catch per Hour of Zero-Age Pink Smolts by Date Versus Flow

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).

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).

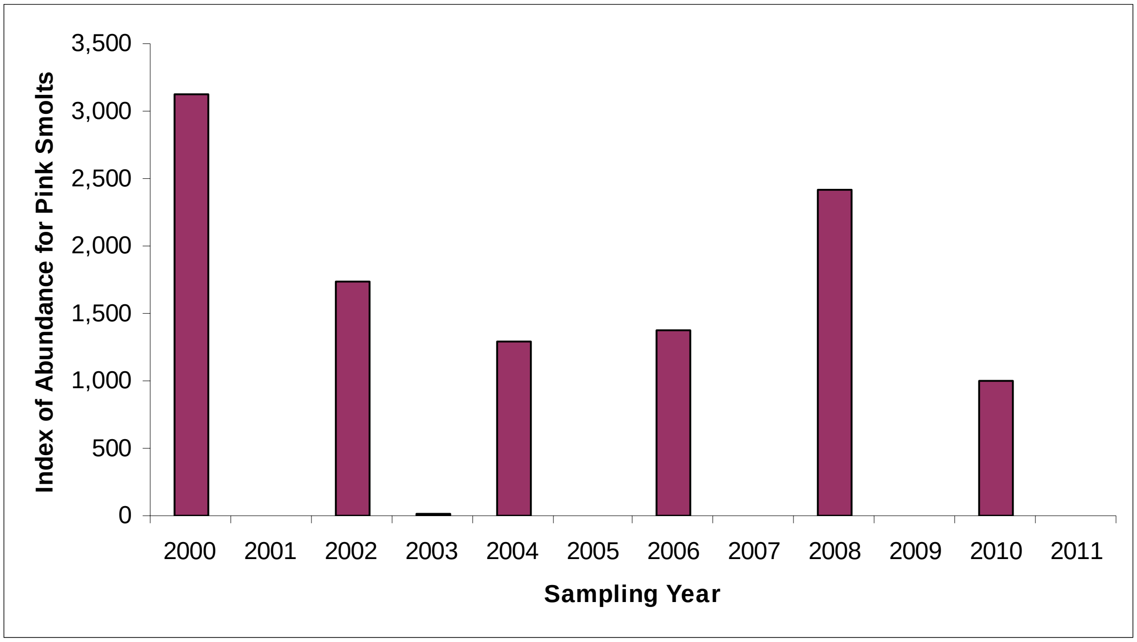


Figure 6.5. Comparison of the Index of Abundance for Pink Salmon by Sampling Year

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 outmigrant salmonids when they move downstream.

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 outmigration of Chinook smolts, which occurs later in the year, 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 zero-age 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 no sockeye salmon smolts caught during the 2011 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		
2011	**0**	**0**	**0**	**0**	1,055.0	**0**
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
2004	0	0	0	0	738.6	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

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							

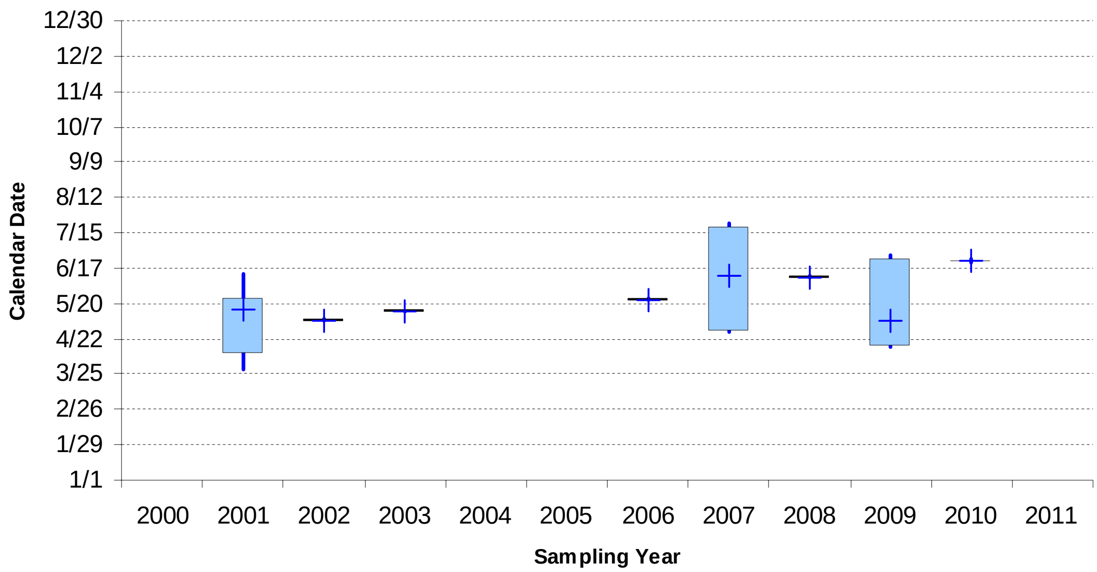
7.3 Sockeye Salmon Smolt Sizes

No sockeye salmon smolts were caught in 2011.

7.4 Sockeye Salmon Seasonal Outmigration Timing

No sockeye salmon were caught during the 2011 season.

The timing of the sockeye outmigration period has been relatively variable over time (Figure 7.1). 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 7.1 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 7.1. 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

No sockeye salmon smolts were caught in 2011.

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 7.2). The second and third highest sockeye index scores were for the 2009 and 2007 outmigration seasons. Index scores for the remaining seasons, including 2011, 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.

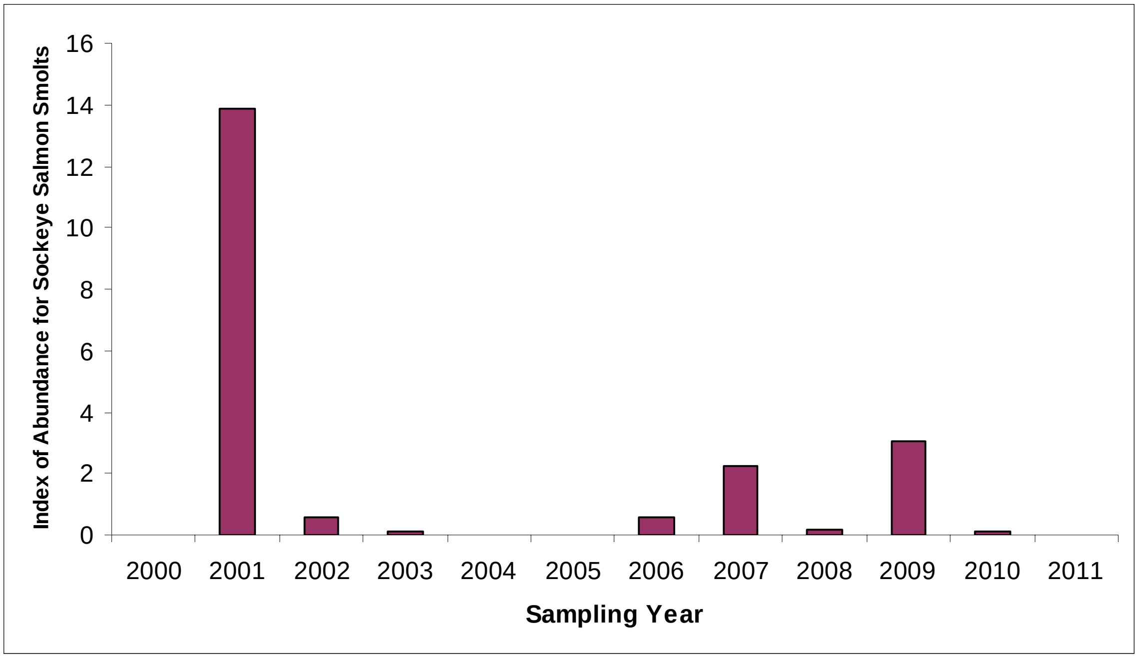


Figure 7.2. Comparison of the Index of Abundance for Sockeye Salmon by Sampling Year

7.6 Sockeye Discussion

Sockeye salmon smolts typically outmigrate during May until early June, a period that 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.

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 available data detailing the releases of hatchery-origin steelhead is shown in Table 8.1. Unfortunately data for Steelhead releases in 2011 could not be obtained prior to writing this report. Trap results clearly indicate the presence of marked hatchery-origin steelhead smolts in the catch during 2011. The first of these smolts was detected on May 6 indicating that a hatchery release occurred on, or before, that date.

Table 8.1. Upstream Hatchery Releases of Steelhead since 2001

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			
2011	**Kendall**	Kendall Creek	**?**	**?**	**?**	**?**	**?**	**?**
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

8.2 Steelhead Catch Totals

In total, 661 steelhead smolts were caught in the 2011 season. Of these, 141 were recorded as having their adipose fin clipped, and 520 were recorded as unclipped. 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			
2011	**141**	**520**	1055	**115.6**	**?**
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 (187.3 mm) that was 26 millimeters bigger than unclipped steelhead trout (161.6 mm), although the sizes of steelhead were highly variable and considerable overlap existed between the two groups. Steelhead fork lengths ranged from 121 to 256 millimeters for clipped fish, and from 31 to 255 millimeters for unclipped fish.

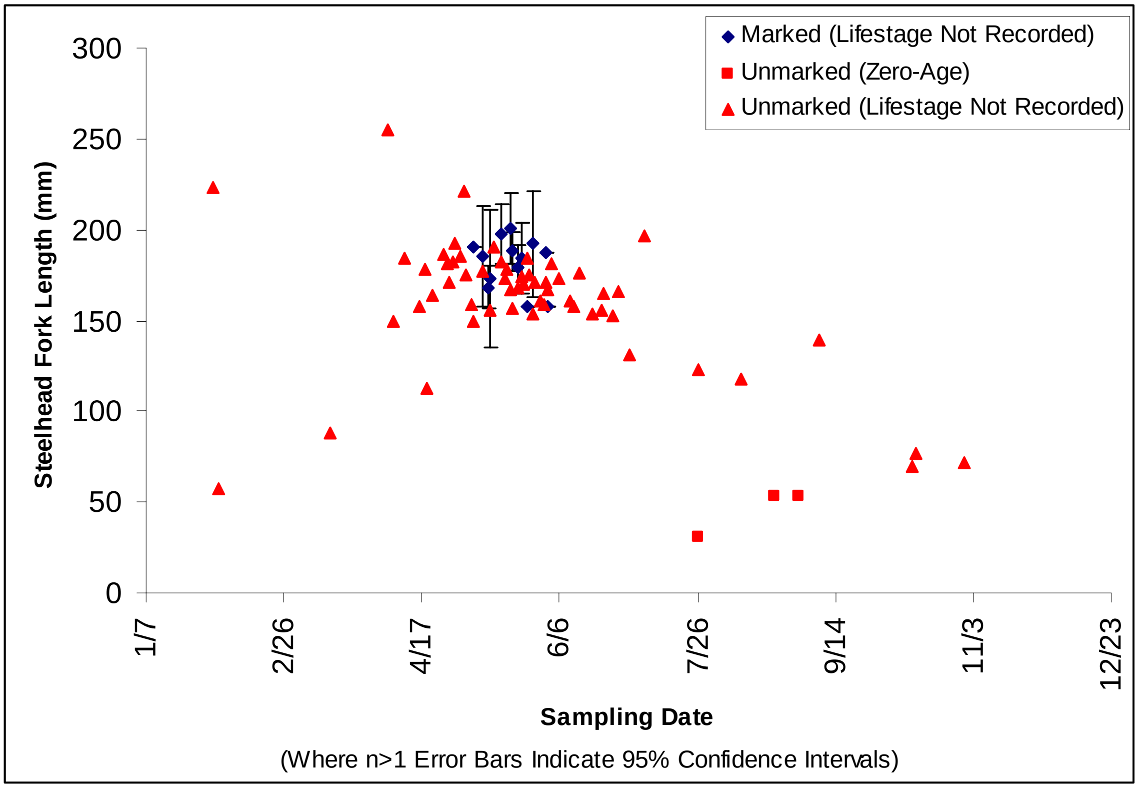


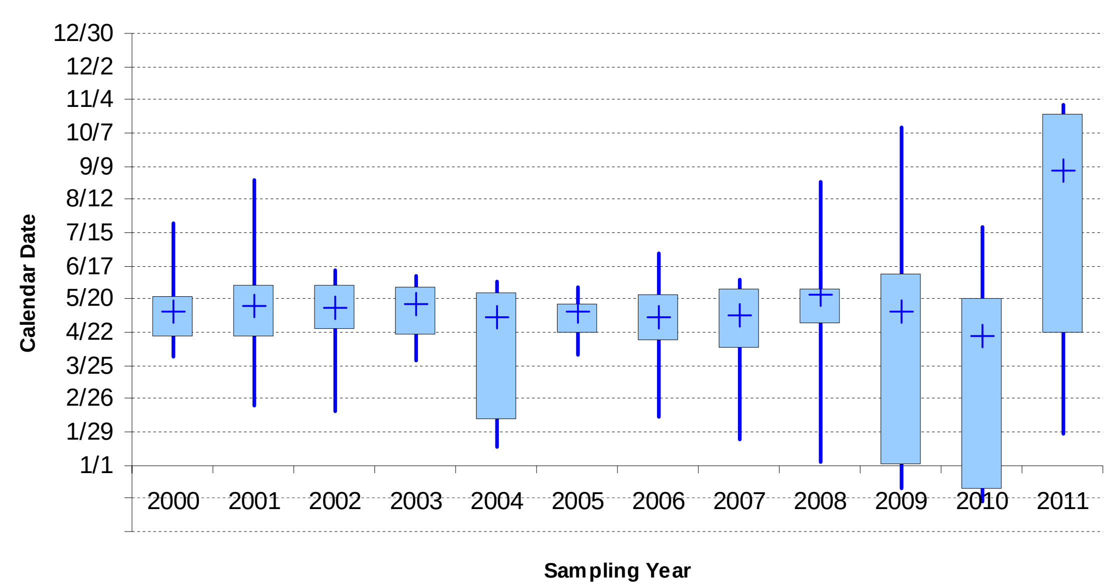
Figure 8.1. Average Daily Fork Lengths for Steelhead Outmigrants Caught During 2011

8.4 Steelhead Seasonal Outmigration Timing

The timing of steelhead outmigration in 2011 was strongly skewed by the existence of long interpolation intervals in October 2011. These long intervals, combined with an abnormally high cpue on October 13, resulted in a much higher-than-usual interpolated cpue during this period of the year. The net result of this is that the outmigration period for 2011 appears t obe significantly later than in previous seasons. It is very likely that the 2011-outmigration statistics are highly misleading due to this interpolation issue.

Steelhead smolts were caught from January 28 2010 to October 31 2011. The median outmigration date was September 6, and 90% of the outmigration was estimated to have occurred between April 21 and October 23. Although this appears to be considerably later than usual, this is likely to be largely an artifact of the interpolation process and one or two dates where steelhead were caught at unusually high rates very late in the year.

If the October data were excluded, the median outmigration date would be May 17, and the 90% outmigration window would begin on April 9 and end on June 16, 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. This issue probably explains the anomalous results for 2011.

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 3.7 fish per hour, which occurred on October 12. Usually the peak catch rate for unclipped steelhead occurs during May. The highest catch rate for 'clipped' steelhead trout was 5.6 fish per hour, which occurred on May 17.

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 October meant that the abundance of steelhead was strongly exaggerated from late September to the start of November. It is unlikely that the early period of sustained late 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 and 2010 seasons, although in those seasons the interpolation problems arose in the early part of the season.

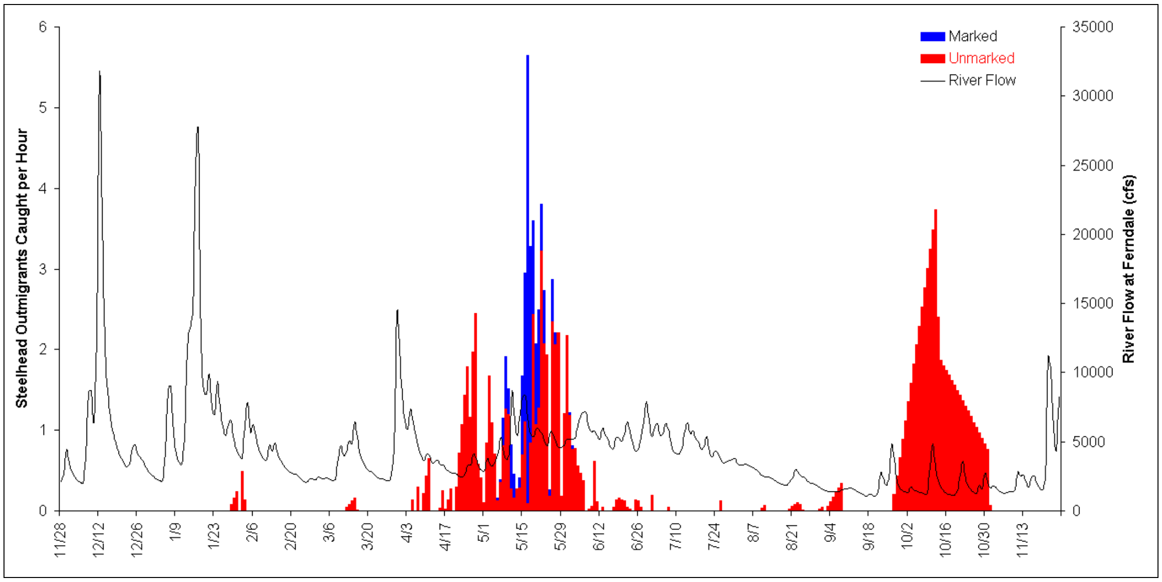


Figure 8.3. Interpolated Catch Per Hour of Steelhead Outmigrants by Date and Flow

8.6 Steelhead Production Estimates in the 2010 Season

8.6.1 Peterson Estimate for Steelhead

No Peterson estimate could be made for wild-origin steelhead due to the unavailability of hatchery release data in 2011.

8.6.2 CCE Estimate for Steelhead

No CCE estimate could be made for wild-origin steelhead due to the unavailability of hatchery release data in 2011.

8.7 Between-Year Comparisons for Steelhead Production Estimates

No production estimates could be made for the 2011 season, therefore no comparisons can be made with earlier years. The raw number of unmarked steelhead caught in 2011 was the highest seasonal total to-date.

8.8 Steelhead Discussion

The record number of unclipped steelhead caught at the Trap in 2011 hints that perhaps the 2011 natural-origin steelhead outmigration is the best in recent history. However, the much higher-than-usual catch efficiency of the Trap for Chinook in 2011 casts suspicion that the very high relative catch of steelhead could be due to a much-improved seasonal catch efficiency rather than a higher absolute abundance of natural origin steelhead. Lacking any hatchery release data for steelhead it is difficult to gain insight into whether the marked-steelhead recapture rate was also higher than usual, which could corroborate that hypothesis. Additionally, if the clipping rate for hatchery origin steelhead were significantly lower than in past years, this could explain the higher number of unmarked steelhead being encountered during 2011.

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, and the difficulty in obtaining useful hatchery release data. 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 2011 is provided in Table 9.1.

Table 9.1. Organisms Present in Trap Catch Between 2006 and 2011

Salmonids	Total Count	Non Salmonid Fish	Total Count	Invertebrates	Total Count	Amphibians	Total Count
Bulltrout/Char	17	Bass	573	Crayfish	2	Tadpoles	12
Chinook	90,354	Dace	118			Frog	1
Chum	155,056	Lamprey (eyes)	1,408				
Coho	52,244	Lamprey (no eyes)	293				
Cutthroat	208	Mountain Whitefish	11				
Pink	48,565	Pumpkin Seed	16				
Rainbow Trout	1	Sculpin	82				
Sockeye	120	Starry Flounder	4				
Steelhead	4,822	Stickleback	10,655				
Trout - Indeterminate	35	Sucker	3				

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).

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	
2011	**30**	**2.98**	**5**	**0.51**	**208**	**32.7**	**491**	**110.8**	**7**	**0.52**	1055
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

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

10.0 Sampling Mortality Rates

The field protocol used during sampling 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 2011 Season

Species_Name	Lifestage	Presumptive Origin	Accidental Death	Dead on Arrival	Sacrificed Intentionally	Total Handled	Mortality Rate
Bulltrout/Char	Not Recorded	Wild	0	0	0	5	0%
Chinook	Yearling	Wild	0	0	0	15	0%
Chinook	Zero-Age	Hatchery	3	0	0	15,337	0%
Chinook	Zero-Age	Wild	2	3	0	1,659	0.30%
Chum	Zero-Age	Wild	41	2	0	11,839	0.40%
Coho	Yearling	Hatchery	2	0	0	6,647	0%
Coho	Yearling	Wild	0	0	0	3,554	0%
Coho	Zero-Age	Hatchery	0	0	0	1	0%
Coho	Zero-Age	Wild	0	0	0	20	0%
Cutthroat	Mature Adult	Wild	0	0	0	5	0%
Cutthroat	Not Recorded	Wild	0	0	0	25	0%
Dace	Not Recorded	Wild	0	0	0	3	0%
Lamprey (eyes)	Not Recorded	Wild	0	0	0	208	0%
Lamprey (no eyes)	Not Recorded	Wild	0	0	0	94	0%
Pink	Mature Adult	Wild	0	0	0	2	0%
Pink	Zero-Age	Wild	0	0	0	15	0%
Pumpkin Seed	Not Recorded	Wild	0	0	0	2	0%
Sculpin	Not Recorded	Wild	0	0	0	7	0%
Starry Flounder	Not Recorded	Wild	0	0	0	2	0%
Steelhead	Not Recorded	Hatchery	0	0	0	141	0%
Steelhead	Not Recorded	Wild	0	0	0	517	0%
Steelhead	Zero-Age	Wild	0	0	0	3	0%
Stickleback	Not Recorded	Wild	0	1	0	491	0.20%
Sucker	Not Recorded	Wild	0	0	0	2	0%
Trout - Indeterminate	Zero-Age	Wild	0	0	0	3	0%

In the 2011 sampling season, the mortality rate for most groups of fishes was low relative to previous seasons (Figure 10.1). The highest mortality rate was for zero-age chum smolts where 43 (0.4%) out of 11,839 fish were killed.

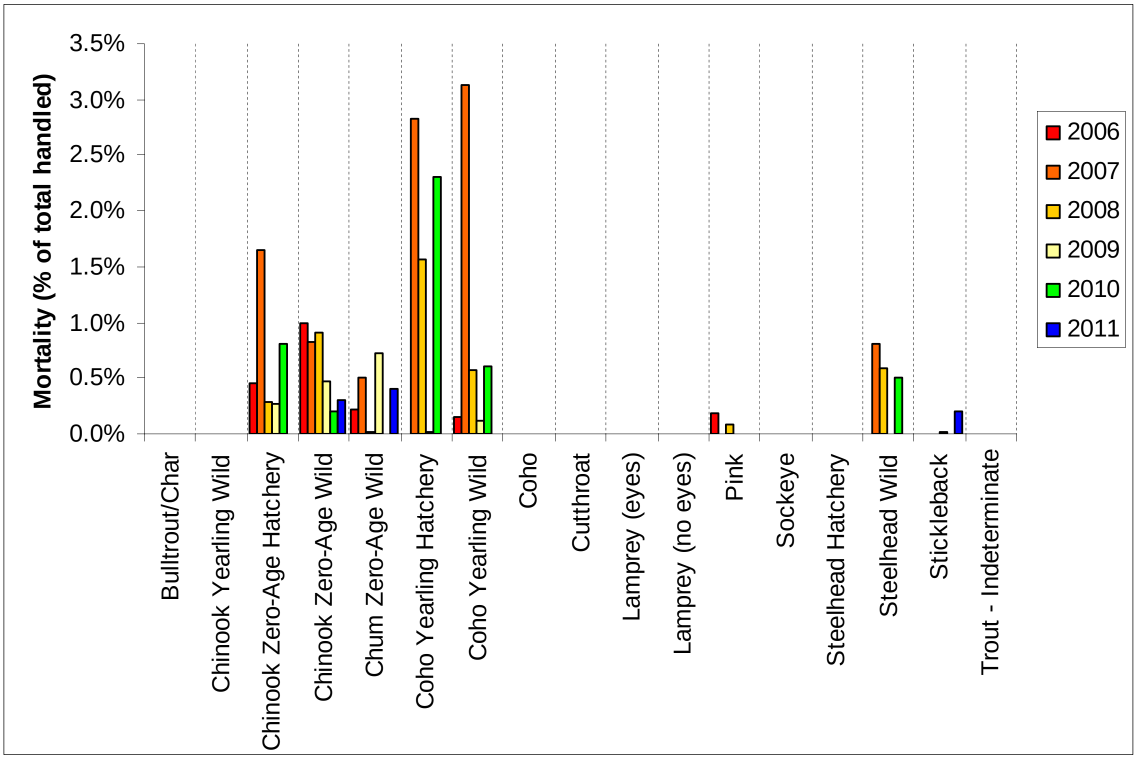


Figure 10.1. Comparison of Total Mortality Rates at the Trap by Sampling Year

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