An Analysis of 2012 and 2013 Smolt Trap Results

Lummi Indian Business Council
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Prepared by:

Lummi Natural Resources Department (LNR)
Water Resources Division
2665 Kwina Rd.
Bellingham, WA 98226

Contributors:

Craig Dolphin, Database Manager

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Executive Summary

The data obtained during 2012 and 2013 from the Lummi screwtrap estimated that approximately 378,495 and 193,903 wild-origin zero-age Chinook smolts outmigrated past the trap site in each year respectively. Compared to outmigration estimates since 2002, the wild-origin zero-age Chinook outmigration estimate for 2012 (BY2011) is 95% above the median production estimate and 55% above the long term mean, while the estimate for 2013 (BY2012) is equal to the median outmigration estimate but 21% below the long term mean.

The estimated production of yearling coho smolts outmigrating in 2012 (BY2010) was 310,385 smolts, which is 54% below the long-term median and 55% below the long term mean. To-date, this is the lowest production estimate for wild-origin yearling coho. For the 2013 season (BY 2011), the wild-origin yearling coho production estimate was 1,199,342 smolts. This value is 78% above the long term average and 71% above the long term mean production estimate.

The mark-recapture estimates for wild-origin steelhead smolts was 58,001 and 96,256 smolts outmigrating in 2012 and 2013 respectively. However, the Trap data relating to steelhead are probably not reliable and are presented for completeness only.

Absolute production estimates could not be determined for other species due to the lack of marked hatchery fish to use for mark-recapture analysis.

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. However, as previously predicted, the 2012 ‘high abundance year’ was low compared to the equivalent year class in earlier generations and now appears to be close to the same magnitude as the 3 ‘low-abundance’ year classes.

The 2012 outmigration of pink salmon was the largest outmigration to-date for the period of record.

Handling mortality rates from trap operations was low. 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 river debris or handling. The mortality rate of wild-origin zero-age Chinook smolts was 0.4% and 0.7% in the two seasons covered in the report respectively.

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1.0 Introduction

Lummi Natural Resources has operated a rotary-screw smolt trap (Trap) in the lower main-stem 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, cutthroat, and recently ESA listed stocks of steelhead 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 and the river's cross section 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.

This report considers data collected from December 2011 through to October 2013 and aims to report the results of the 2012 and 2013 sampling seasons, 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 2002 review has increased by 215% compared to the three years prior to the review, and Trap effort during the critical May/June months has increased by 257%. However, the amount of hours fished in the 2012 and 2013 seasons roughly doubled from the previous 10 year period.

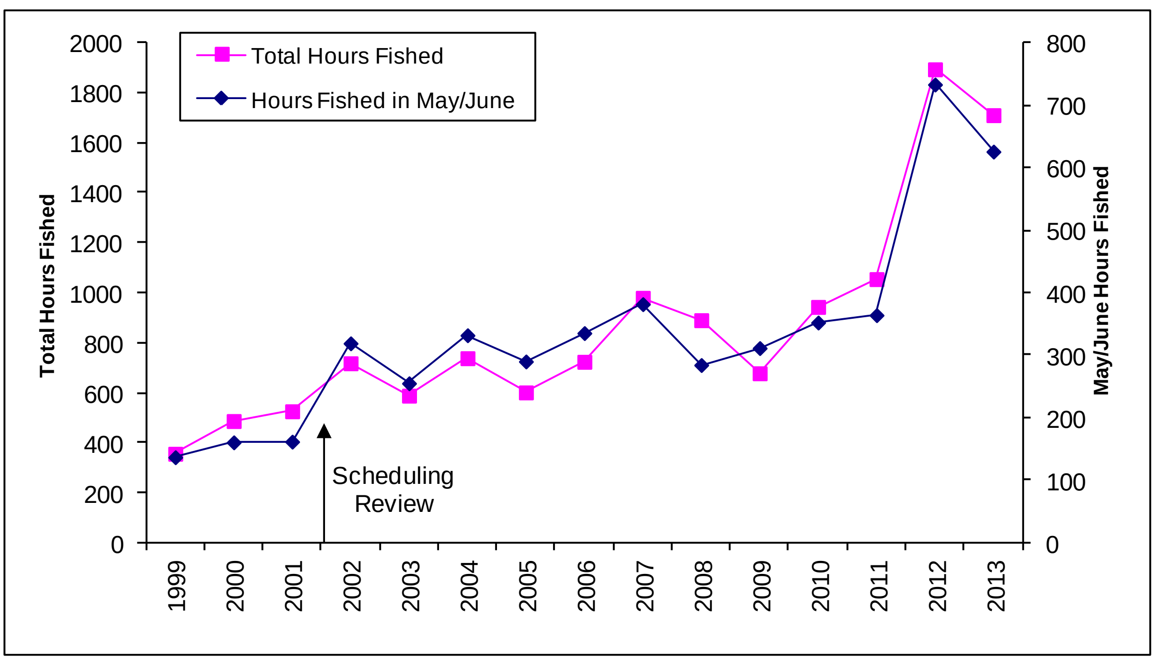
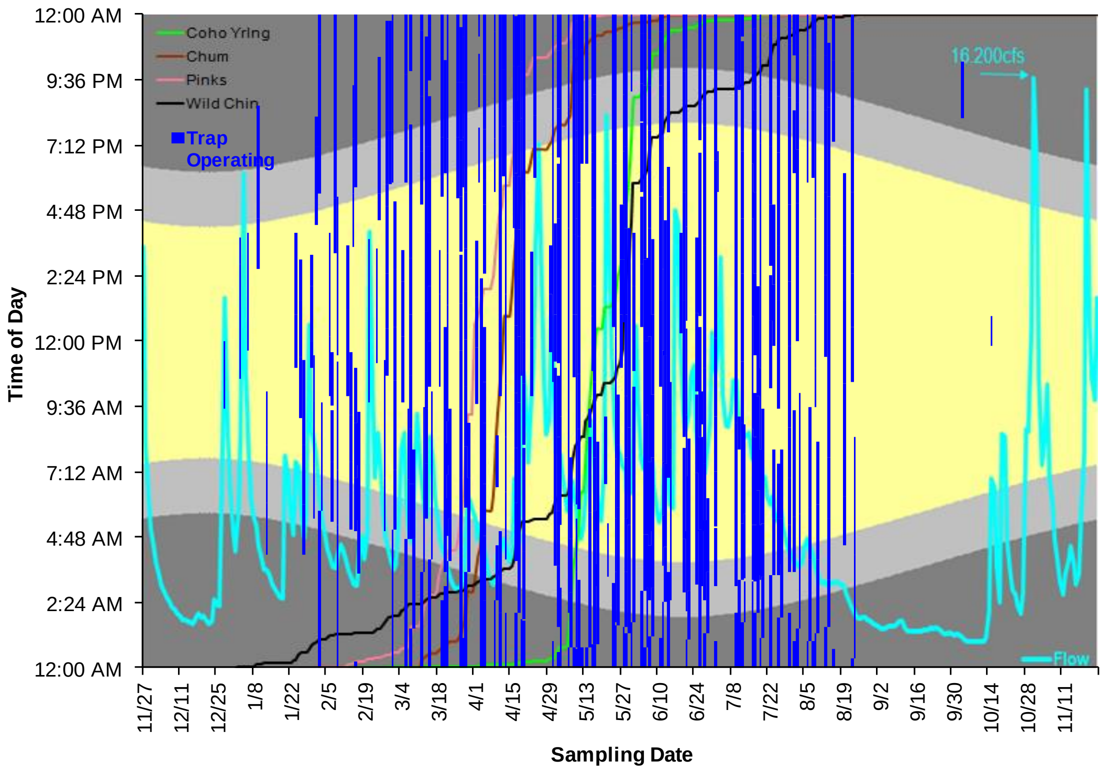


Figure 2.1. Comparison of Trap effort versus sampling season

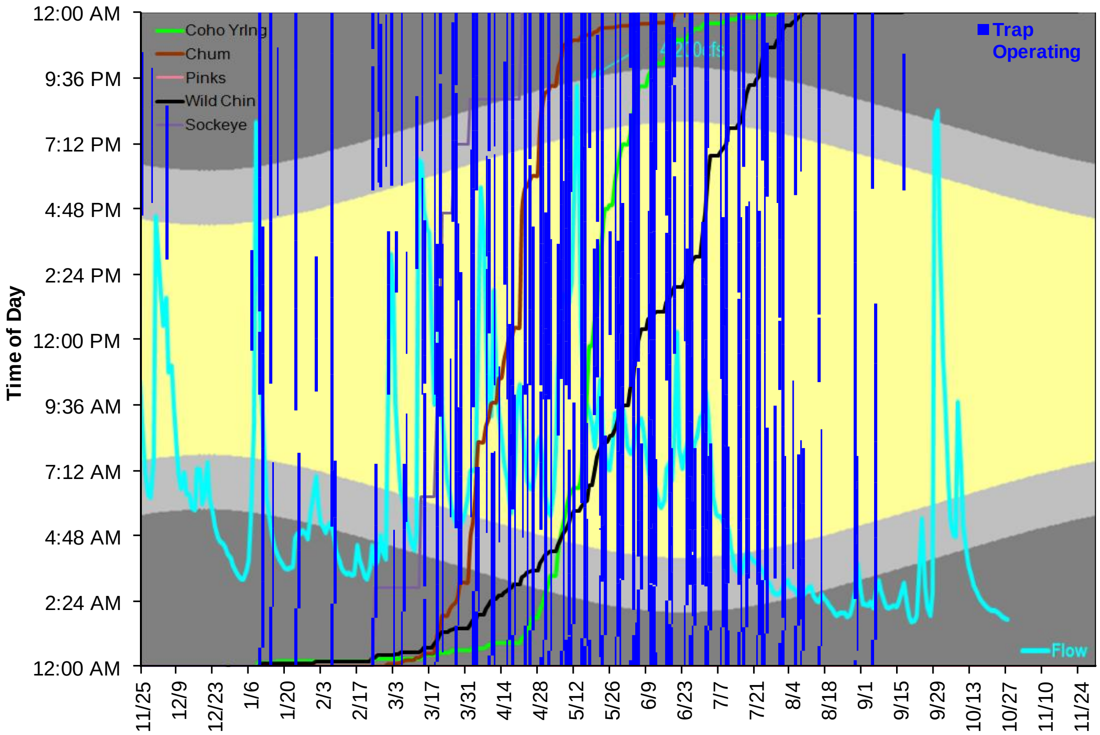
In the 2012 season the screwtrap was operated from December 28 2011 through to November 15 2012, although sampling intensity was highest from February through mid August (Figure 2.2). The average monthly relative efficiency of the 2012 sampling schedule is shown in Figure 2.4. In total, the Trap was operated on 149 days during the 2012 season.



Trap operating hours (dark blue) in 2012 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 2012 Season

In the 2013 season the screwtrap was operated from November 25 2012 through to September 17 2013, although sampling intensity was highest from March through July (Figure 2.3). The average monthly relative efficiency of the 2013 sampling schedule is shown in Figure 2.4. In total, the Trap was operated on 136 days during the 2013season.



Trap operating hours (dark blue) in 2013 superimposed on a background of daylight (yellow area), twilight (light gray area), and night (dark gray area), relative river flow at Ferndale (light blue line),and cumulative catch curves for unmarked Chinook zero-age smolts (black line), coho yearling smolts (green line), chum fry (brown line), and sockeye fry (violet line).

Figure 2.3. Trap operating hours during the 2013 season

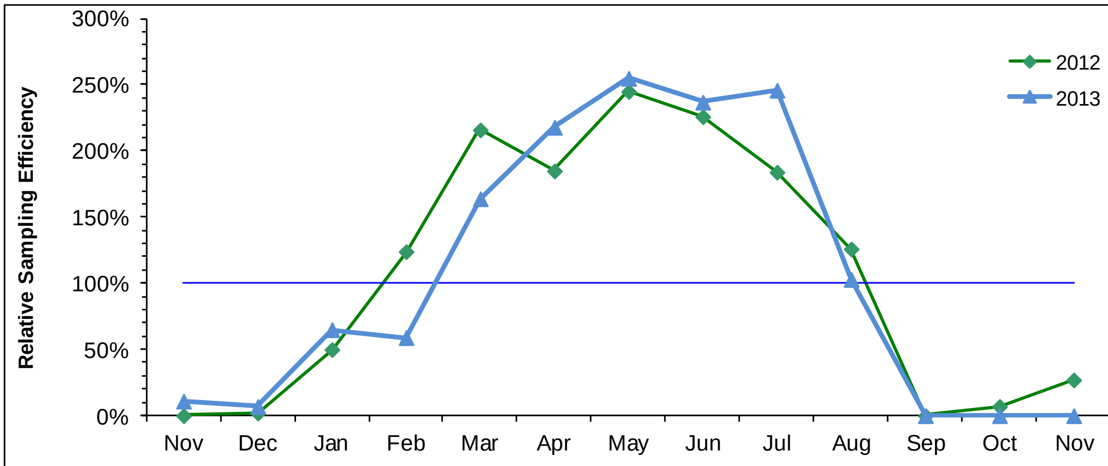


Figure 2.4. Relative efficiency of trap schedule during the 2012 and 2013 seasons

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 2.5).

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 2.5. 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 non-sampled portions of days (Figure 2.5 A).

The second stage is to estimate the catch rates for days when the Trap was not in operation at all (Figure 2.5 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 2.6). 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 2.6. Calculating average daily catch rate weighted by photoperiod for data shown in **Figure 2.5**

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 from 1995 to 1998 (Conrad & MacKay, 2000) and again from 1999 to 2003 (Michael McKay, Unpublished Data). These attempts to quantify Trap CE involved 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. 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%. Conrad and MacKay's early data suggested there may be a possible relationship between secchi-depth and catch efficiency (Conrad & MacKay, 2000). However, when combined with the data collected from 1999 to 2003 the published relationship between secchi depth and catch efficiency broke down ($r^2 < 0.2$; Figure 2.7), particularly in clear conditions. Similarly, the observed relationship with river flow (Figure 2.8) was found to be too variable to be used to predict catch efficiency using these factors.

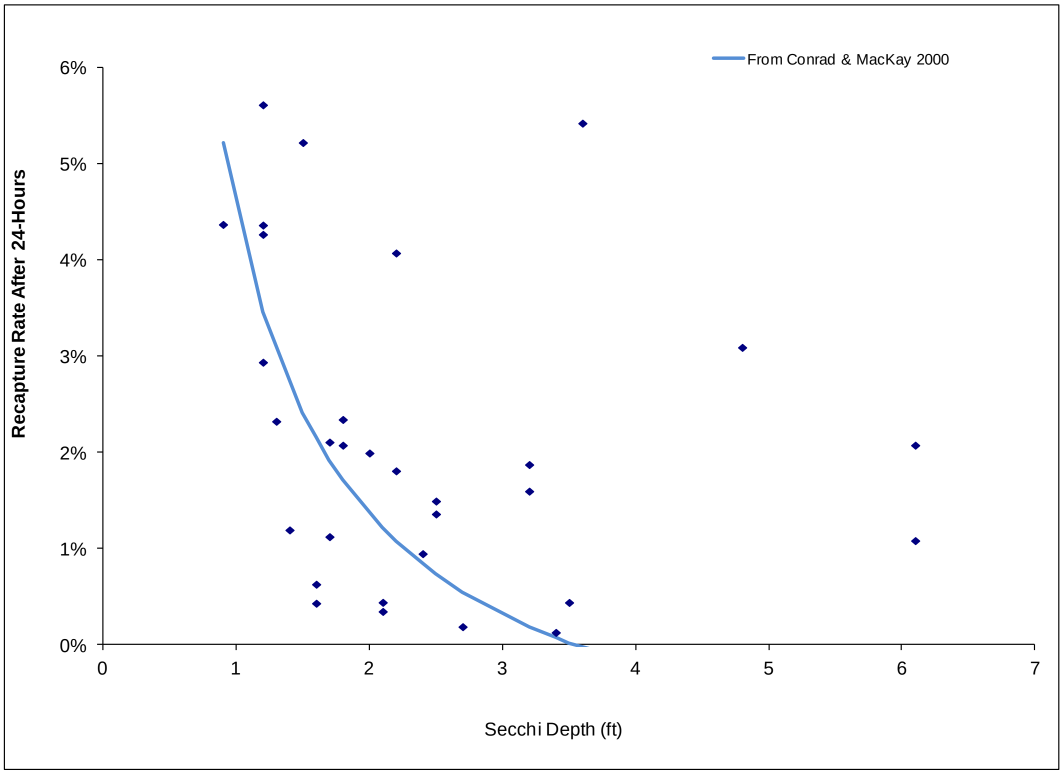


Figure 2.7. Recapture rates for groups of newly-released marked hatchery-origin zero-age Chinook versus water clarity (Secchi-Depth)

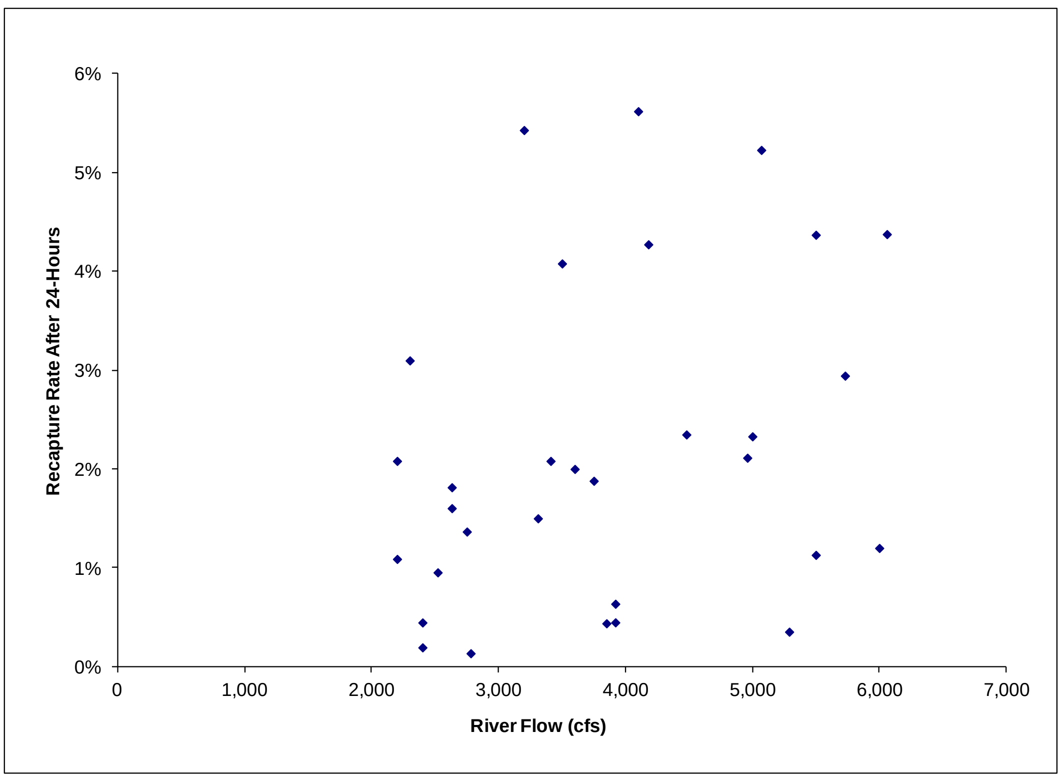


Figure 2.8. Recapture rates for groups of newly-released marked hatchery-origin zero-age Chinook versus river flow

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 did not provide reliable 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 2.9 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%

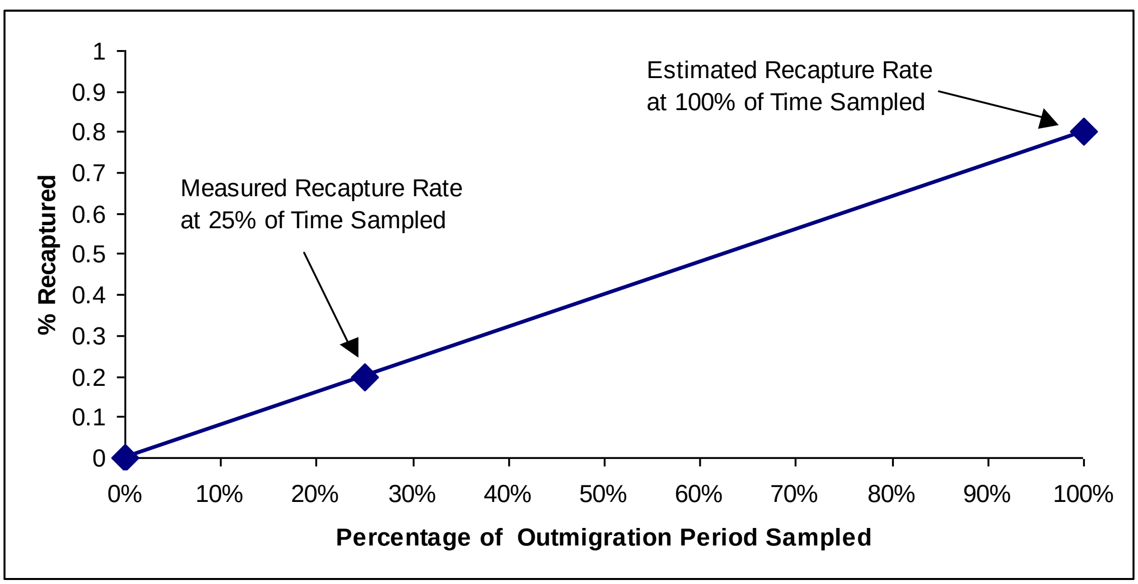


Figure 2.9. Hypothetical example of estimating seasonal trap catch efficiency

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 out-migrate 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:

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

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 out-migrate 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 main-stem 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 out-migrate during periods when the Trap sample effort is comparatively infrequent.

3.0 Chinook Salmon Results and Discussion

3.1 Hatchery Release Summary

Table 3.1 and Table 3.2, and Figure 3.1 and Figure 3.2 shows the total number of hatchery-origin zero-age Chinook released upstream from the Trap in 2012 and 2013 respectively.

In 2012, hatcheries released a total of 1,249,739 Chinook smolts upstream from the Trap site. Of this total, 99.5% (1,243,777 smolts) were externally marked, and 0.5% (5,962 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 16 2012 and the last release was on June 11 2012.

In 2013, hatcheries released a total of 1,298,007 Chinook smolts upstream from the Trap site. Of this total, 99.7% (1,294,155 smolts) were externally marked, and 0.3% (3,852 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 2013 and the last date of release was on June 7 2013.

Table 3.1. Upstream hatchery releases of zero-age Chinook in 2012

Start Release Date	End Release Date	Source Hatchery	Release Site	Externally Marked			Externally Unmarked*	Total Marked Chinook	Total Chinook Released
				AC Only	AC CWT	CWT Only			
4/16/2012	16-Apr-12	Kendall	Kendall Creek	56,340	0	0	0	56,340	56,340
5/2/2012	02-May-12	Kendall	Kendall Creek	55,888	0	0	112	55,888	56,000
5/3/2012	03-May-12	Kendall	McKinnon Pond	209,714	0	0	1,266	209,714	210,980
5/8/2012	08-May-12	Kendall	Boyd Creek	8,046	67,985	64,870	274	140,901	141,175
5/16/2012	16-May-12	Kendall	Boyd Creek	8,032	68,448	74,950	276	151,430	151,706
5/16/2012	16-May-12	Kendall	Kendall Creek	55,888	0	0	112	55,888	56,000
5/22/2012	22-May-12	Kendall	Boyd Creek	17,093	63,218	61,925	255	142,236	142,491
6/4/2012	05-Jun-12	Skookum	Skookum	0	0	32,350	327	32,350	32,677
6/11/2012	11-Jun-12	Lummi Bay	Bertrand Creek	399,030	0	0	3,340	399,030	402,370
			Total Released	810,031	199,651	234,095	5,962	1,243,777	**1,249,739**

*Based on reported fin clipping error and tag retention rates

Table 3.2. Upstream hatchery releases of zero-age Chinook in 2013

Start Release Date	End Release Date	Source Hatchery	Release Site	Externally Marked			Externally Unmarked*	Total Marked Chinook	Total Chinook Released
				AC Only	AC CWT	CWT Only			
4/15/2013	15-Apr-13	Kendall	Kendall Creek	0	42,126	0	169	42,126	42,295
5/1/2013	01-May-13	Kendall	Boyd Creek	67,814	0	0	136	67,814	67,950
5/1/2013	01-May-13	Kendall	Kendall Creek	0	39,825	0	240	39,825	40,065
5/2/2013	02-May-13	Kendall	Boyd Creek	67,814	0	0	136	67,814	67,950
5/14/2013	14-May-13	Kendall	McKinnon Pond	98,525	0	0	197	98,525	98,722
5/15/2013	15-May-13	Kendall	Kendall Creek	0	117,410	0	709	117,410	118,119
5/15/2013	15-May-13	Kendall	McKinnon Pond	98,525	0	0	198	98,525	98,723
5/16/2013	16-May-13	Kendall	Boyd Creek	71,881	0	0	144	71,881	72,025
5/17/2013	17-May-13	Kendall	Boyd Creek	71,881	0	0	144	71,881	72,025
5/21/2013	21-May-13	Kendall	Boyd Creek	84,889	0	0	512	84,889	85,401
6/3/2013	03-Jun-13	Lummi Bay	Bertrand Creek	378,621	0	0	379	378,621	379,000
6/3/2013	07-Jun-13	Skookum	Skookum	0	0	154,844	888	154,844	155,732
			Total Released	939,950	199,361	154,844	3,852	1,294,155	**1,298,007**

*Based on reported fin clipping error and tag retention rates

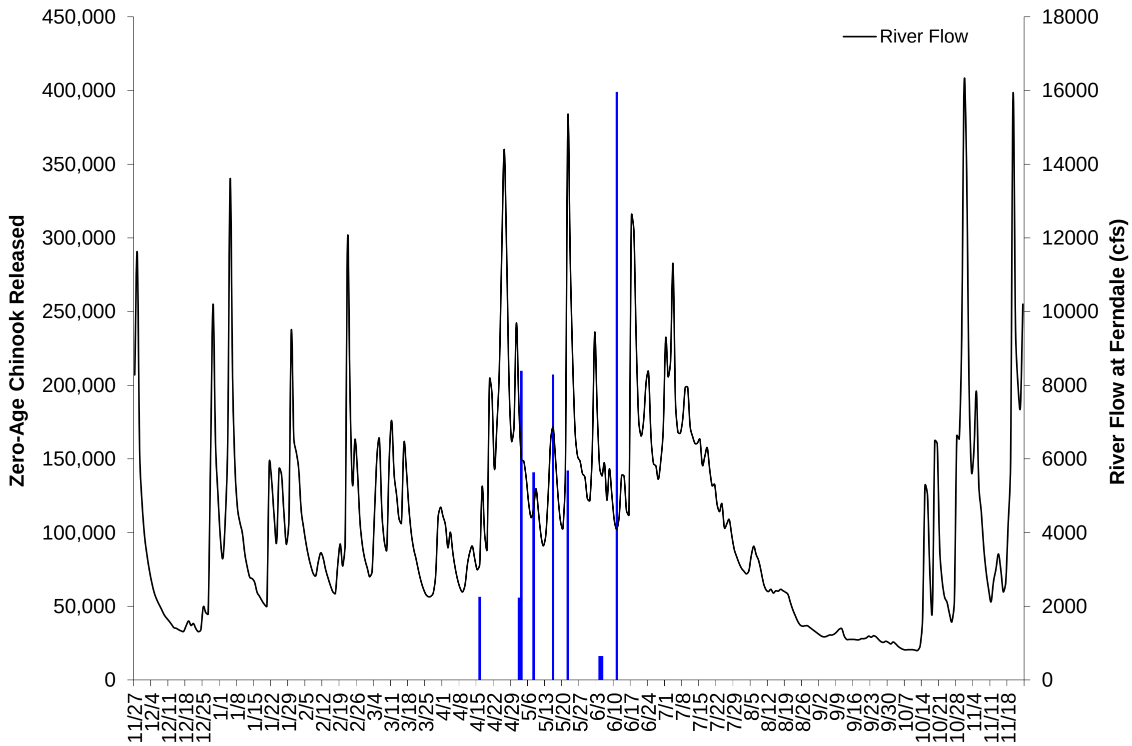


Figure 3.1. Hatchery releases of externally marked zero-age Chinook in 2012

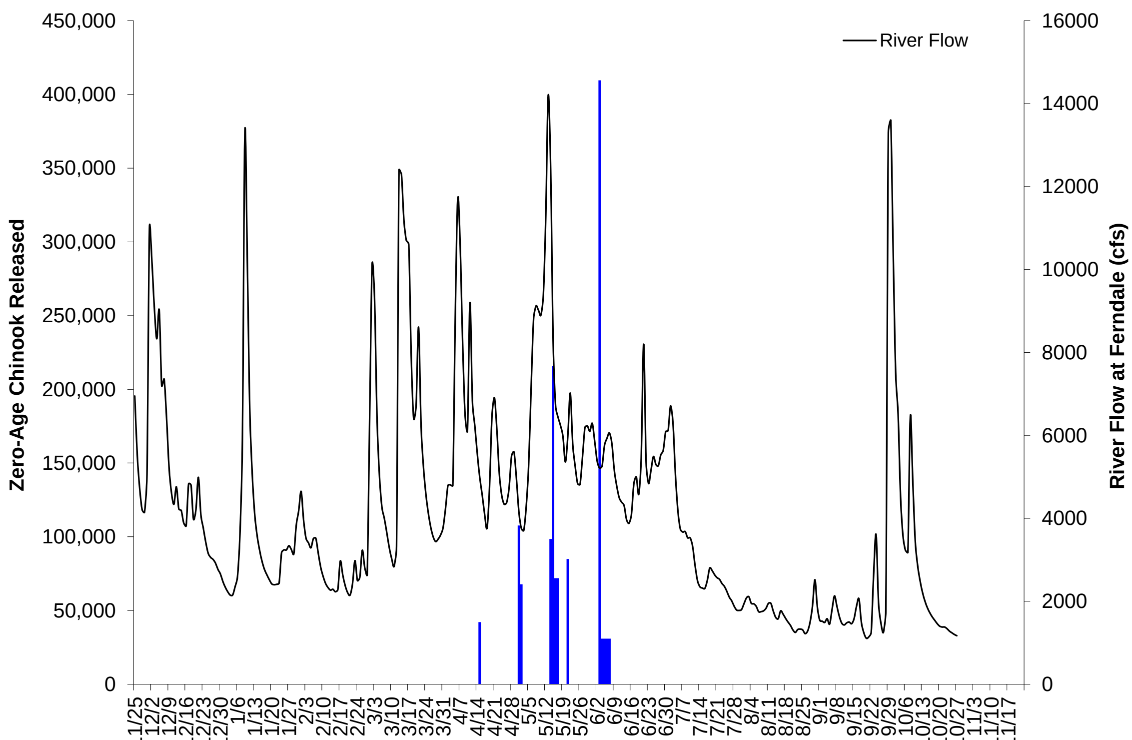


Figure 3.2. Hatchery releases of externally marked zero-age Chinook in 2013

3.2 Chinook Catch Totals

The 2012 and 2013 catches of Chinook outmigrants are shown in Table 3.3 along with the totals for previous sampling years, and showing the total number of hours that the Trap was fished, and the percentage of hatchery releases that were externally marked 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 3.3. 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		
2013	**15,716**	**2,428**	**0**	**114**	1710.9	**99.7%**
2012	**11,247**	**3,957**	**0**	**30**	1894.4	**99.5%**
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 3.4 and Table 3.5 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 2013.

Table 3.4. 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		0.62	0.39	0.44		0.81*	0.23*	0.72*
Night	0.81*		0.34	0.54	1.10		0.29*	0.79*
Dawn	0.23*	0.286*		0.55	0.30	0.40		0.79*
Day	0.72*	0.79*	0.79*		1.27	1.23	1.17	
	* Indicates a Statistically Significant Correlation (p<0.05)							

Table 3.5. 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		0.11	0.00	0.18		0.21*	-0.03	0.51*
Night	0.21*		0.12	0.08	0.52		0.25*	0.10
Dawn	-0.03	0.25*		0.22	0.00	0.65		0.37*
Day	0.51*	0.10	0.37*		1.56	0.28	0.68	
	* Indicates a Statistically Significant Correlation (p<0.05)							

3.3 Chinook Fork Lengths

The average daily fork lengths of Chinook smolts that were measured at the Trap are shown in Figure 3.3 for the 2012 season, and Figure 3.4 for the 2013 season (grouped by life stage and mark types). Overall, unmarked zero-age Chinook had an average fork length of 62.9 mm in the 2012 season, and 71.2 mm in the 2013 season. Externally marked zero-age Chinook had an average fork length of 81.5 mm during the 2012 season, and 82.9 in the 2013 season.

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. Consistent with a trend seen in previous years, the lengths of marked smolts remained relatively unchanged during the first few weeks following release, but the size of marked smolts increased with date thereafter. This may indicate 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 2012 had an average size of 103.2 mm, while yearlings caught in 2013 had an average length of 98.8 mm.

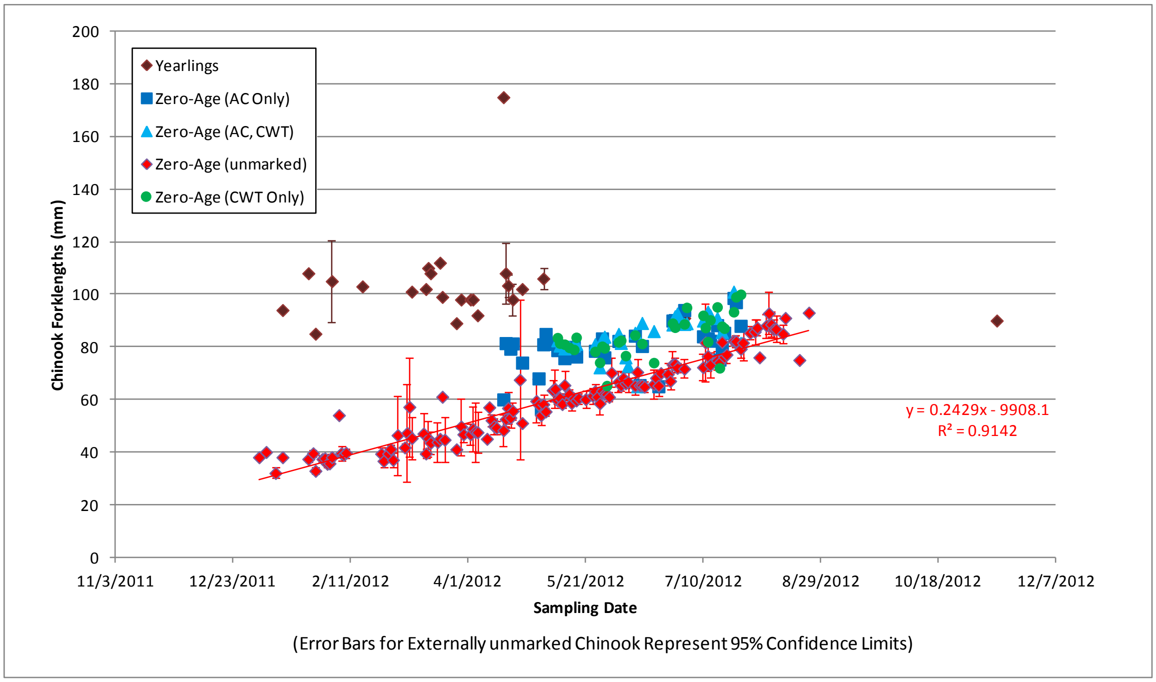


Figure 3.3. Average daily fork lengths for Chinook smolts caught during 2012

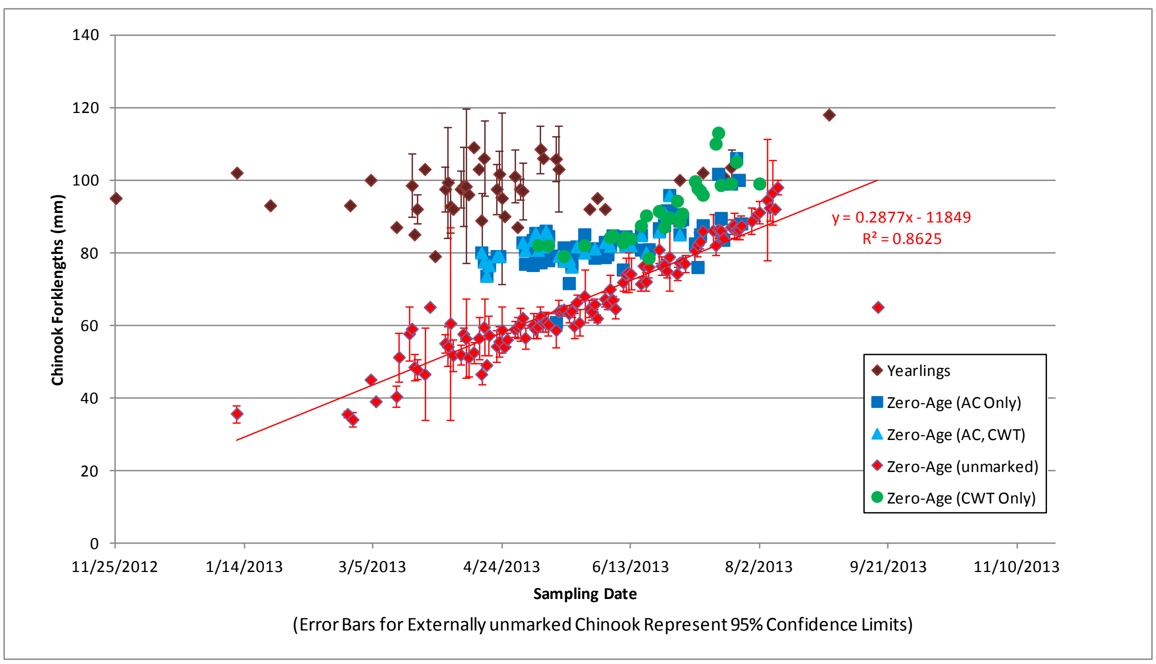


Figure 3.4. Average daily fork lengths for Chinook smolts caught during 2013

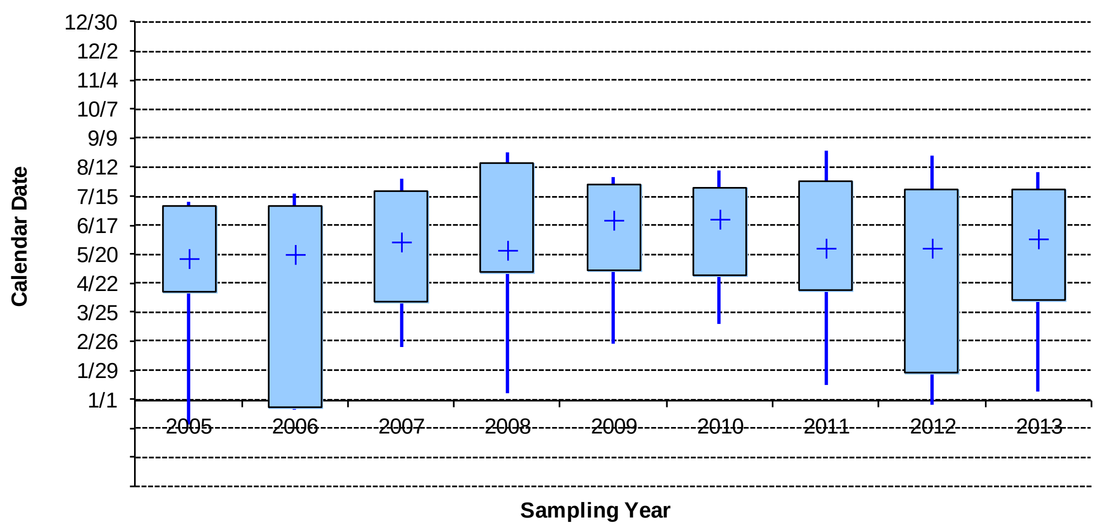
3.4 Chinook Seasonal Outmigration Timing

The timing of outmigration for unmarked wild smolts in 2012 and 2013 was within the broad range observed during previous years (Figure 3.5), however the 2012 season featured a prolonged and steady trickle of smolts earlier in the year than is usual, which was similar to that of the 2006 season. However, unlike the 2006 season this pattern was probably not an artifact of long interpolation intervals as the early season effort was somewhat higher than in 2006.

In the 2012 season the first unmarked zero-age Chinook smolt was caught in at the end of December and was followed by a small but relatively steady trickle of outmigrants thereafter. The last unmarked zero-age smolt was caught in mid-August.

In the 2013 season, the first unmarked smolt was not captured until March, and thereafter low catch rates were maintained through mid-August.

In the 2012 sampling season, 90% of the unmarked zero-age Chinook were caught between January 27 and July 21, and the median capture date occurred on May 26. In the 2013 season, 90% of the unmarked smolts were caught between April 5 and July 21, with the median capture date being June 4. Across all years, the median outmigration date is June 2.



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 2006 possibly skewed by interpolation caused by low Trap effort during winter coincident with a single abnormally high cpue set.

Figure 3.5. Outmigration timing for unmarked zero-age Chinook smolts from 2005-2013

The pattern and timing of outmigration of yearling Chinook smolts has been highly variable from year to year (Figure 3.6). Generally yearlings are not recognized as being present in the catch by the end of May in most years. However, a recent examination of the size and capture timing of unmarked Chinook (Figure 3.7) may indicate that this perception could be an artifact of the method used by field personnel to assign their presumptive life stage in the field. It is likely that some yearling Chinook are present in the catch (albeit at low abundance) but have not been recognized as yearlings by field personnel beyond the date ranges shown in Figure 3.6. The results of the size versus capture date analysis will be used to help inform the process of assigning presumptive life stages for unmarked Chinook in the future.

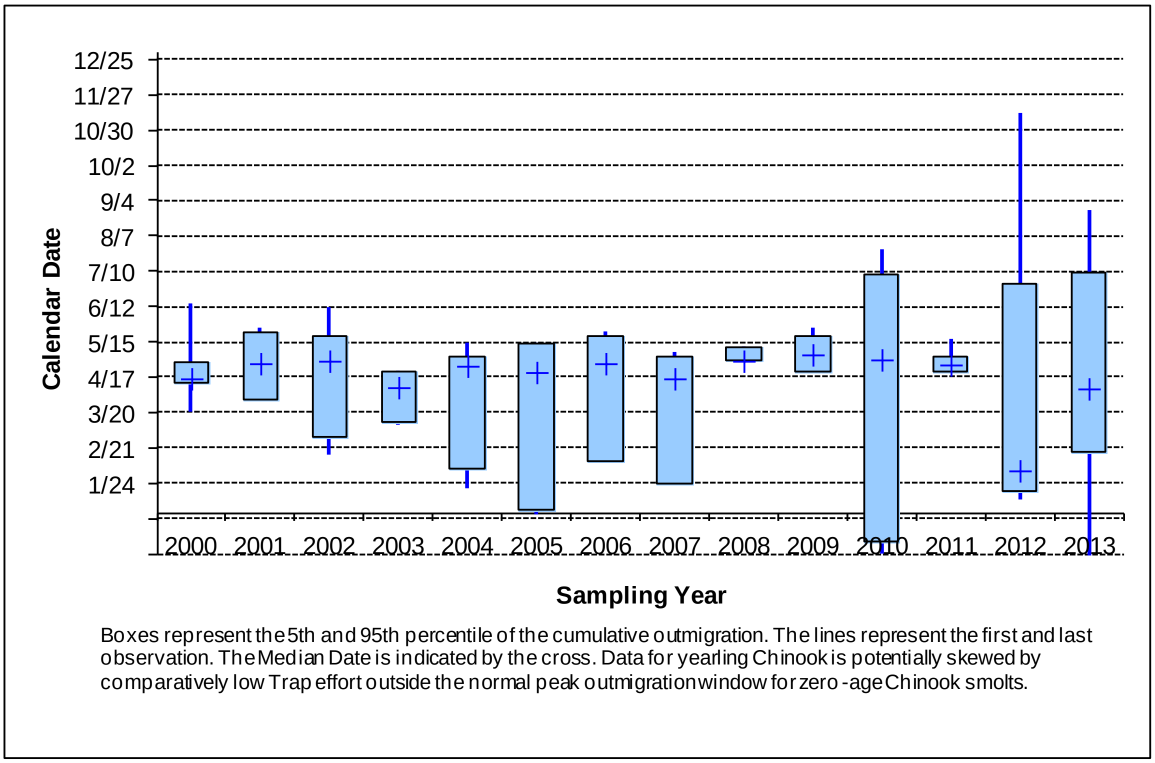


Figure 3.6. Outmigration timing for Unmarked Yearling Chinook smolts from 2000 to 2013

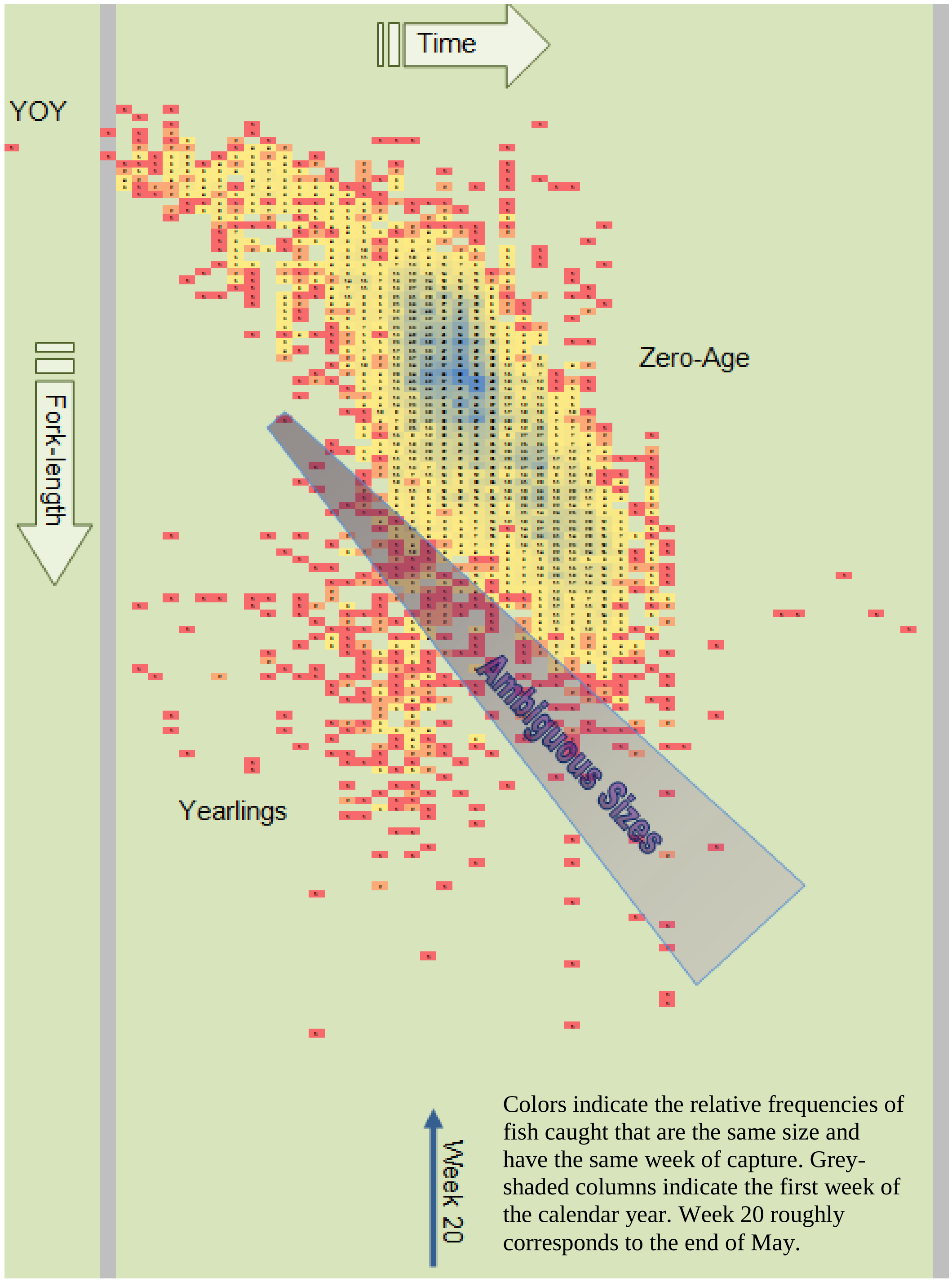


Figure 3.7. Frequency, size, and week-of-year for outmigrating unmarked Chinook caught at the screwtrap since 2006

3.5 Zero-Age Chinook Outmigrants

3.5.1 CPUE Time Series for Zero-Age Chinook

Figure 3.8 and Figure 3.9 shows the time series of interpolated hourly catch rates for zero-age Chinook throughout the 2012 and 2013 seasons respectively.

Unmarked zero-age Chinook were caught from late-December/early-January during the 2012 season, and from March during the 2013 season. Generally unmarked Chinook ceased to be caught during August of both seasons.

Externally marked Chinook smolts began to appear in the catch in mid April of both years, but the highest CPUE for hatchery origin smolts was generally observed from mid-May through to the end of July.

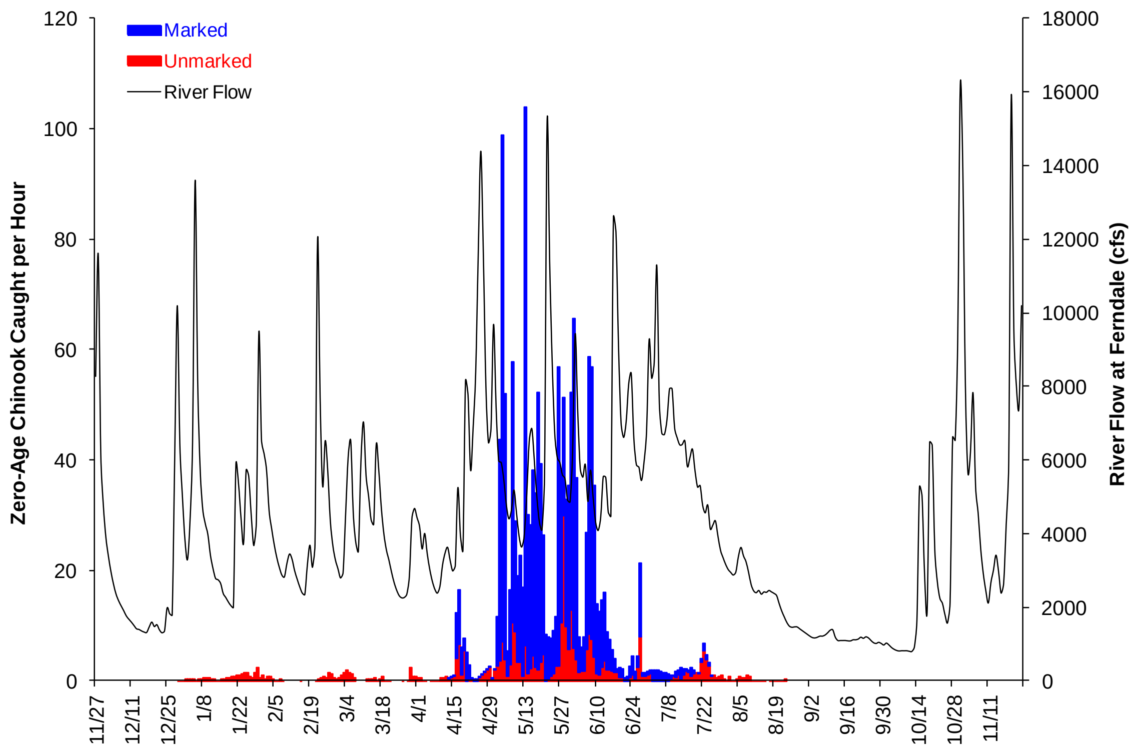


Figure 3.8. Interpolated CPUE of zero-age Chinook smolts during the 2012 season

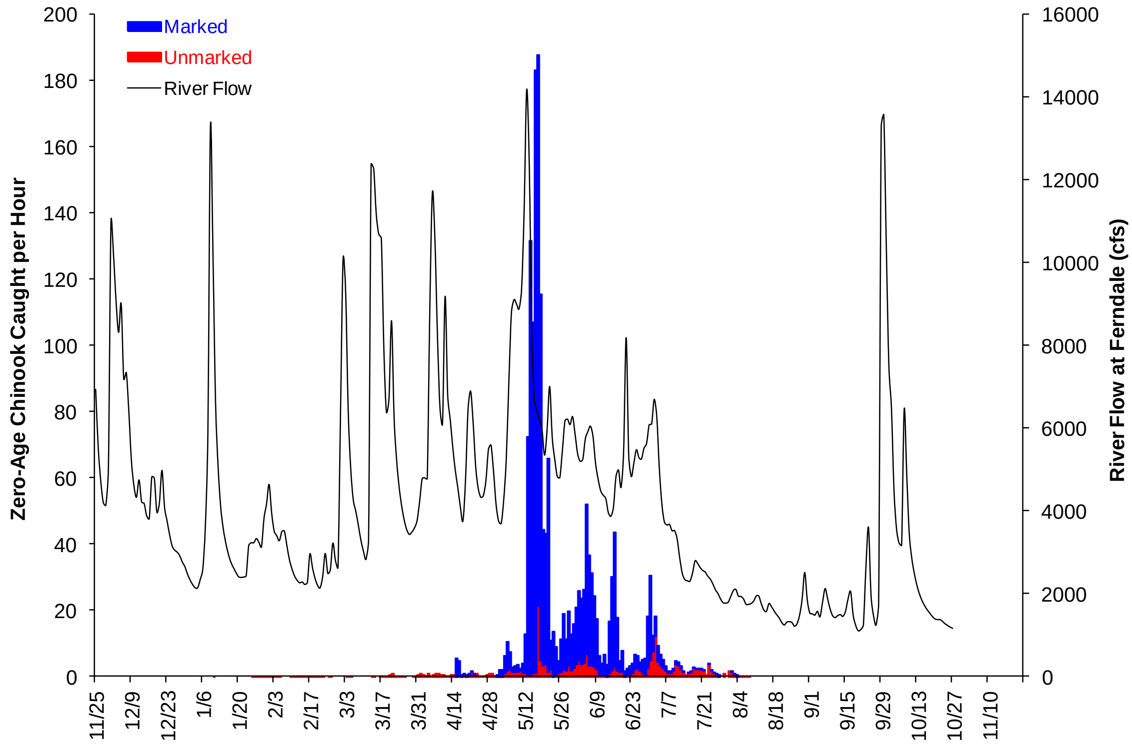


Figure 3.9. Interpolated CPUE of zero-age Chinook smolts during the 2013 season

3.5.2 Zero-Age Chinook Production Estimates in the 2010 Season

Peterson Estimate for Zero-Age Chinook

In the 2012 sampling year, 1,243,777 externally marked zero-age Chinook were released upstream from the Trap site. Of this total, 11,247 were recaptured at the Trap, and a further 3,957 unmarked zero-age Chinook smolts were also caught (total = 15,204 smolts). The Peterson mark-recapture estimate of total zero-age Chinook passing the Trap site in 2012 is 1,681,334 smolts. In 2012 hatcheries released a total of 1,249,739 Chinook smolts (includes some accidentally unmarked smolts). The difference between the known hatchery release and the Peterson estimate for all Chinook smolts is assumed to represent the wild-origin production estimate. For the 2012 sampling season, the Peterson-derived estimate of wild-origin zero-age Chinook is **431,595** smolts (Figure 3.10).

In the 2013 sampling year, 1,294,155 externally marked zero-age Chinook were released upstream from the Trap site. Of this total, 15,716 were recaptured at the Trap, and a further 2,428 unmarked zero-age Chinook smolts were also caught (total = 18,144 smolts). The Peterson mark-recapture estimate of all zero-age Chinook passing the Trap site in 2013 is 1,681,334 smolts. In 2013 hatcheries released a total of 1,298,007 Chinook smolts (includes some accidentally unmarked smolts). The difference between the known hatchery release and the Peterson estimate for all Chinook smolts is assumed to represent the wild-origin production estimate. For the 2013 sampling season, the Peterson-derived estimate of wild-origin zero-age Chinook is **196,073** smolts (Figure 3.10).

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.

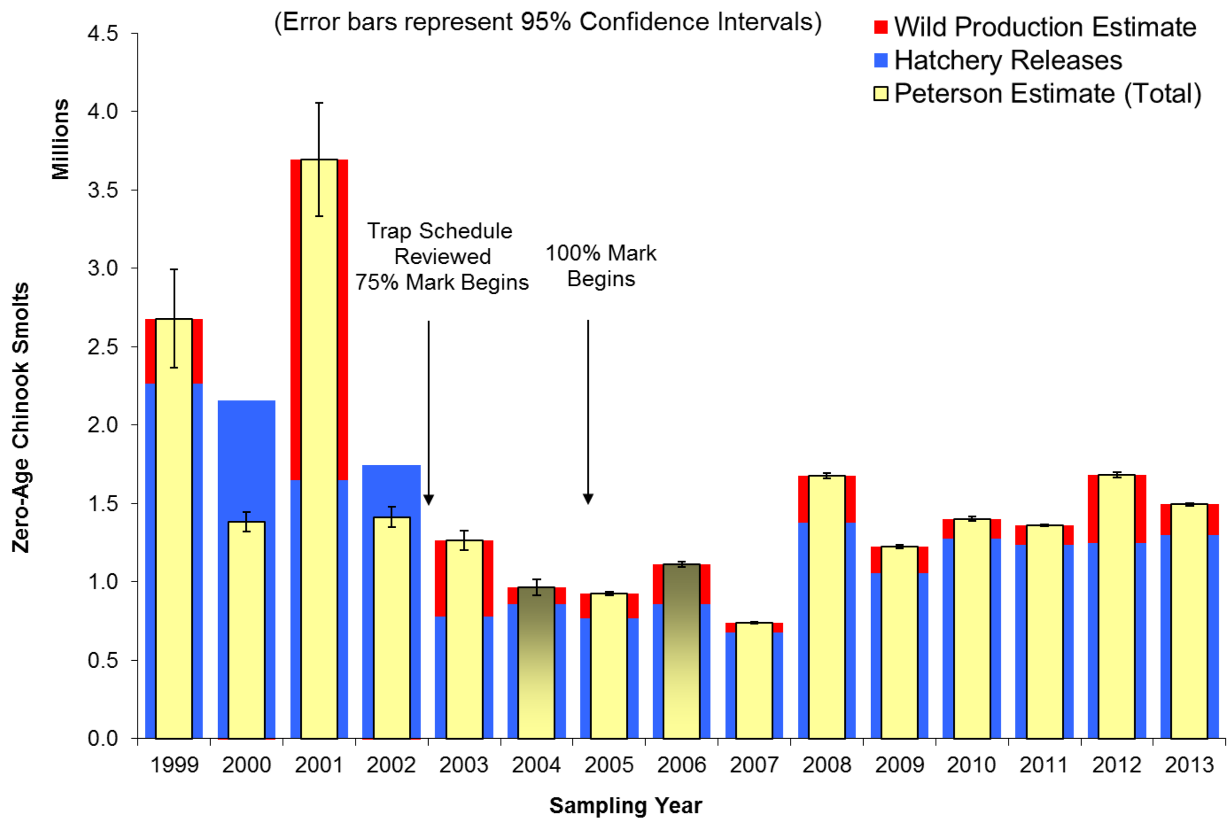


Figure 3.10. Peterson mark-recapture estimates for zero-age Chinook outmigrants by sampling year

CCE Estimate for Zero-Age Chinook

In the 2012 season, the Trap recaptured 0.9% of the marked Chinook smolts that were released upstream. The Trap was fishing 43.9% of the time that marked Chinook smolts were outmigrating past the Trap site. If the number of marked smolts recaptured by the Trap increases linearly with the amount of time fished during the outmigration period, then the 2012 season catch efficiency is estimated to have been 2.06% (Figure 3.11). Similarly, during the 2013 season the Trap recaptured 1.2% of the marked Chinook smolts that were released upstream. The Trap was operating 40.33% of the time when marked smolts were outmigrating. This indicates a seasonal catch efficiency of 3.01% for 2013 (Figure 3.11). Overall, the average catch efficiency of the Trap for zero-age Chinook is estimated to be 2.37% based on 13 years of mark-recapture data. (Note that this value excludes the estimates of catch efficiency for the 2000 and 2011 sampling seasons (10.56% and 5.6%) which are being treated as outliers).

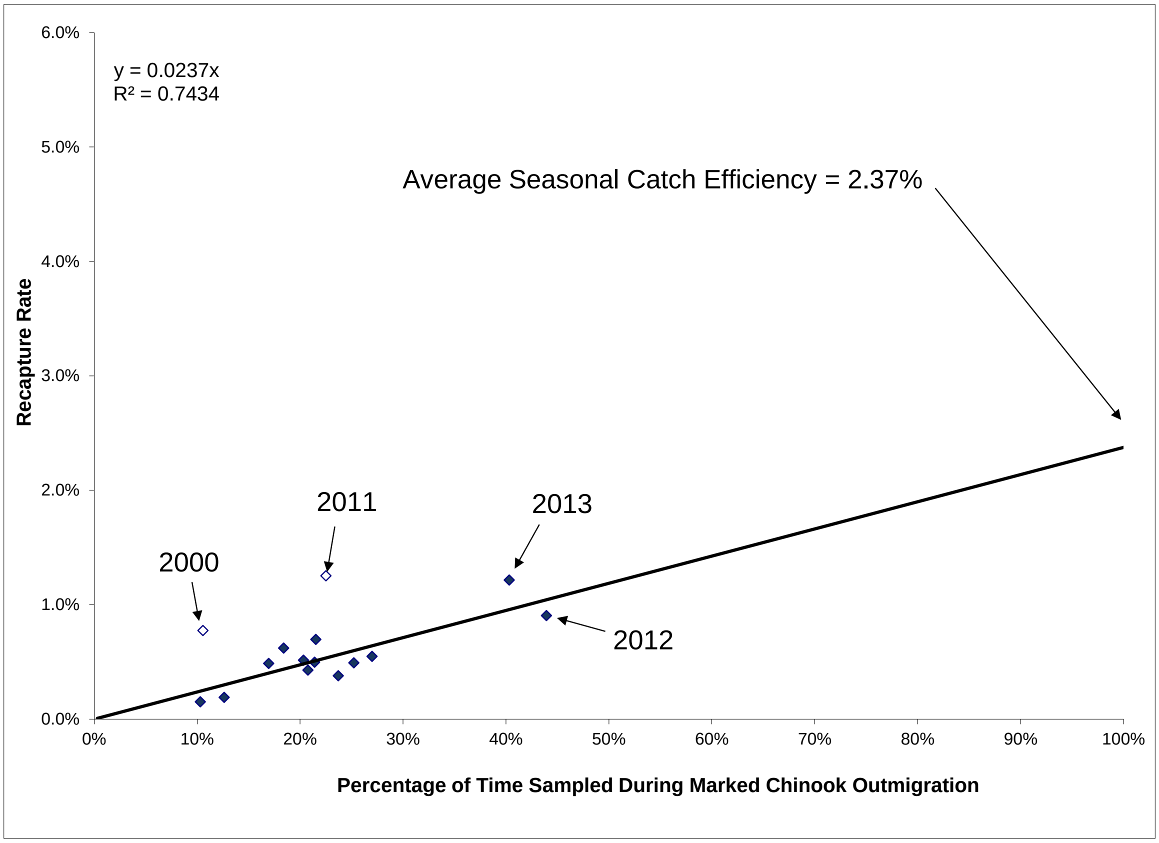


Figure 3.11. Seasonal trap catch efficiency estimates for marked zero-age Chinook

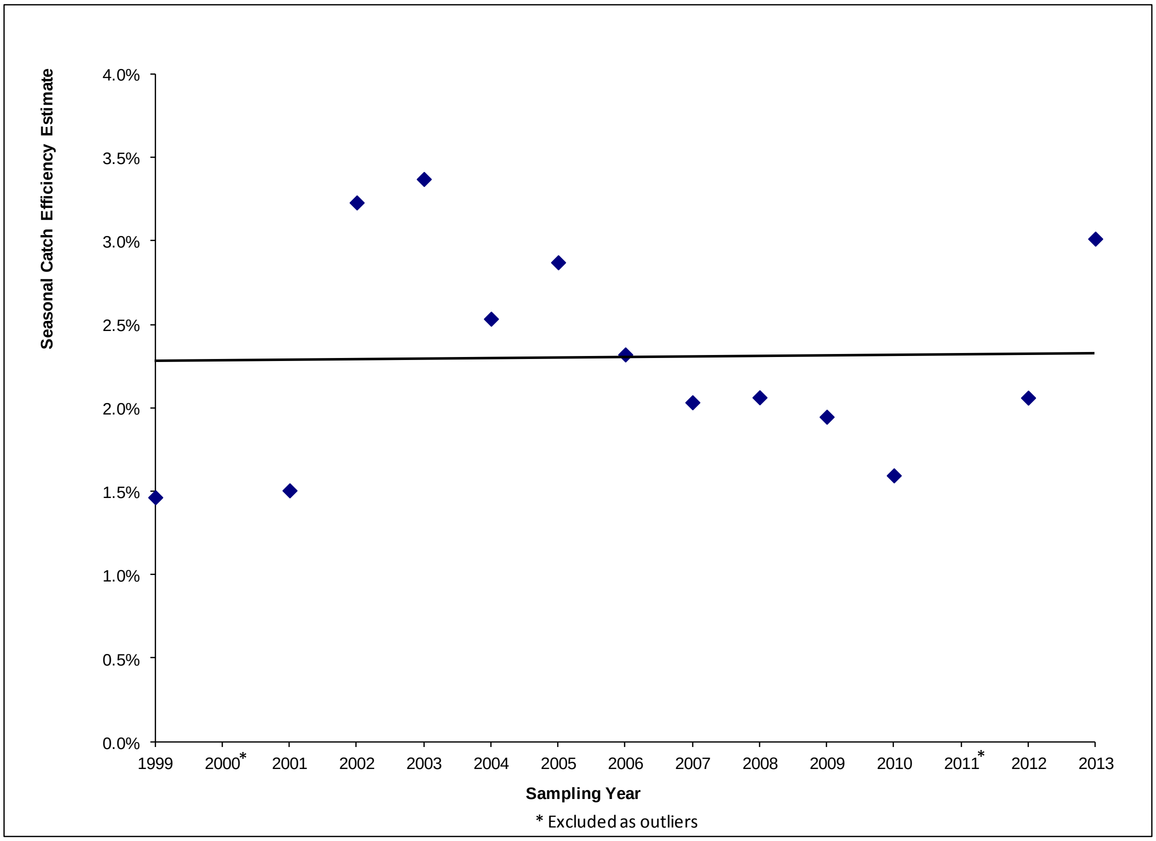


Figure 3.12. Comparison of estimates of seasonal catch efficiency for Chinook over time

The estimated numbers of marked and unmarked smolts passing the trap site per day for each season are shown in Figure 3.13 and Figure 3.14 respectively. These values were derived by using the average seasonal catch efficiency to convert the time series of hourly catch rates by multiplying by 24 hours per day.

The total number of smolts estimated to have outmigrated in 2012 was 1,575,135 zero-age Chinook. Since the hatcheries released 1,249,739 smolts in 2012, the CCE-derived wild production estimate for zero-age Chinook is **325,396** smolts.

The total number of smolts estimated to have outmigrated in 2013 was 1,489,739 zero-age Chinook. Since the hatcheries released 1,298,007 smolts in 2013, the CCE-derived wild production estimate for zero-age Chinook is **191,732** smolts.

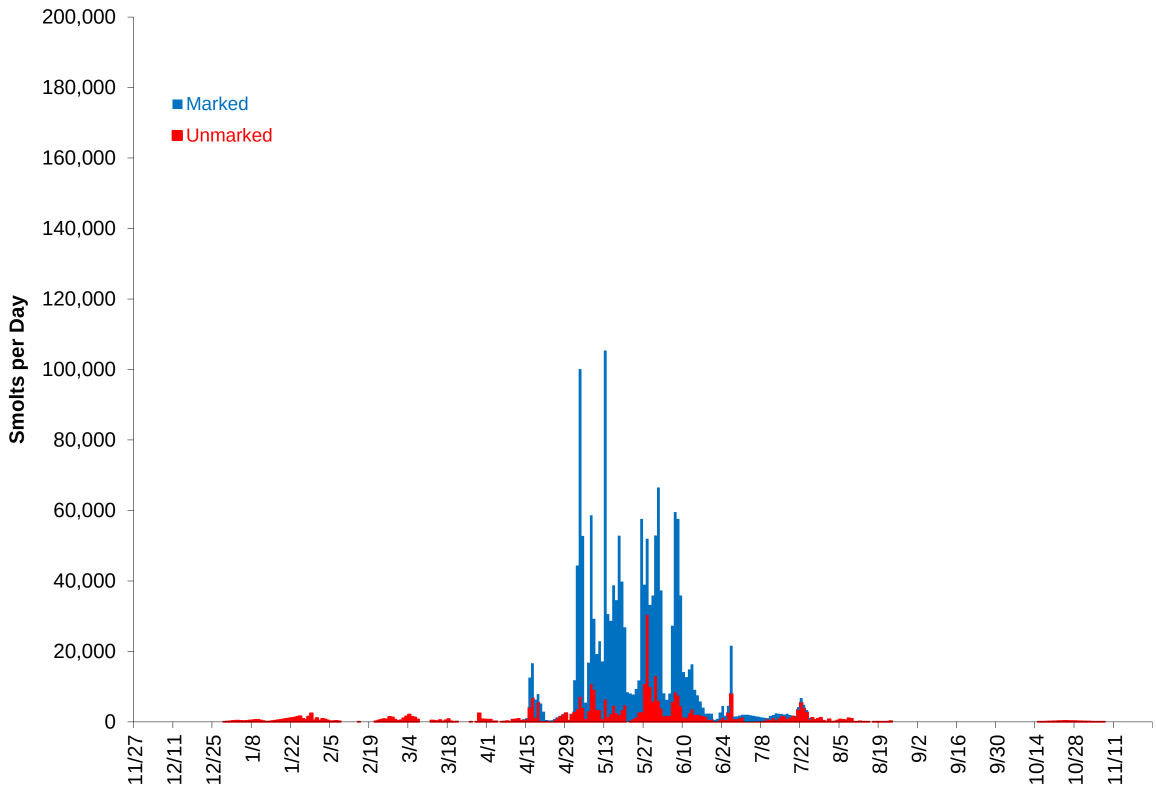


Figure 3.13. Daily production estimates for zero-age Chinook in 2012

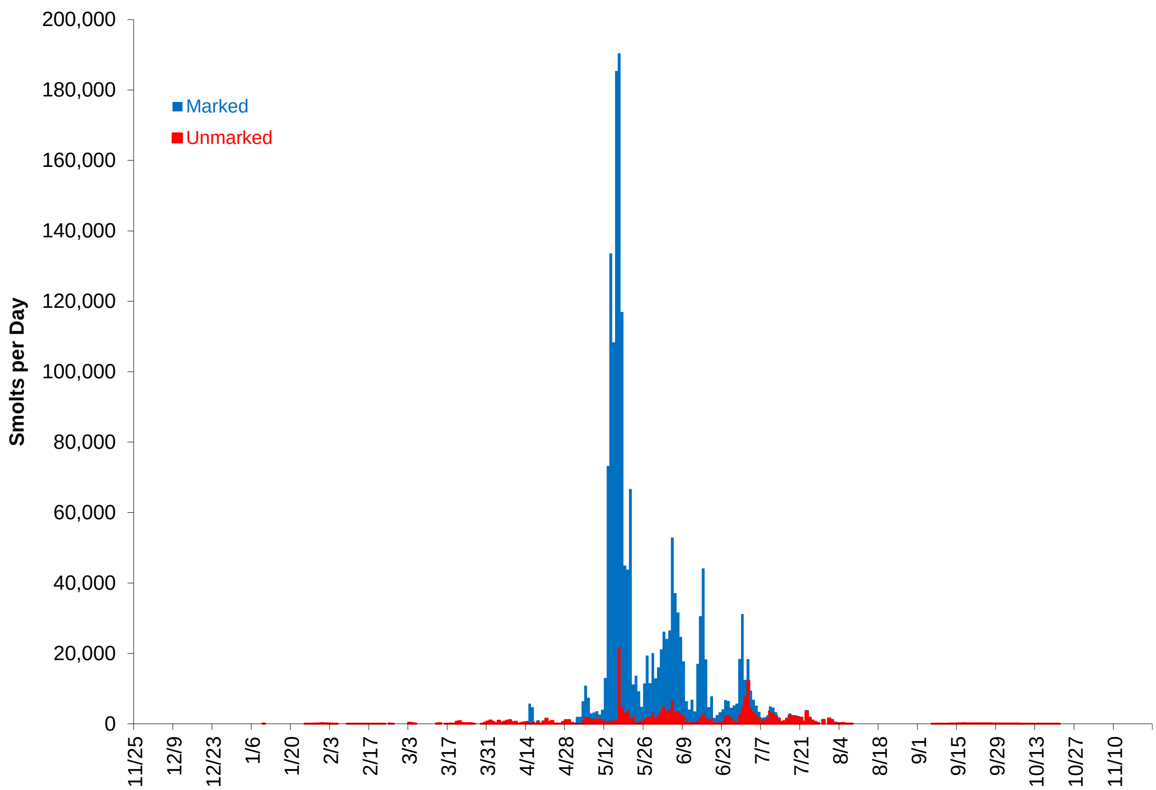


Figure 3.14. Daily production estimates for zero-age Chinook in 2013

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 **325,396** wild-origin Chinook smolts in 2012 is higher than the average outmigration of 267,755 smolts, while the 2013 estimate of 191,732 wild origin smolts is below the average outmigration.

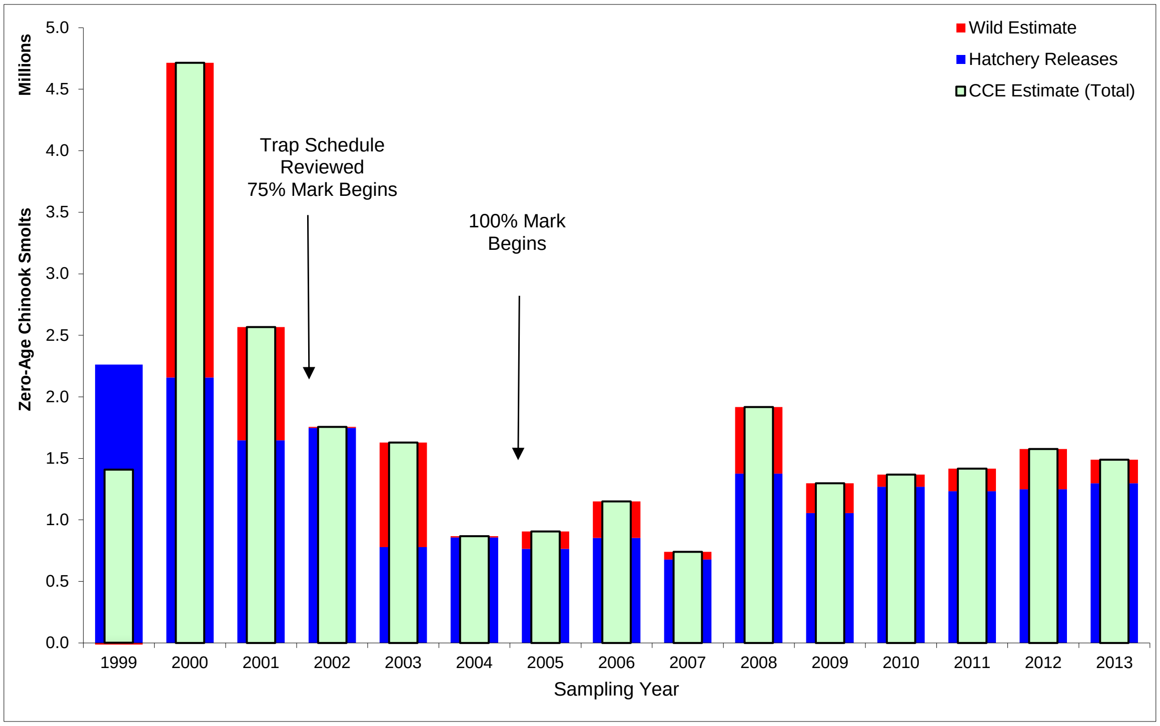


Figure 3.15. CCE estimates for zero-age Chinook outmigrants, by sampling year

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 2012 season is **378,495** wild-origin zero-age Chinook smolts. The average of the 2 production estimates for wild-origin zero-age Chinook in the 2013 season is **193,903** wild-origin zero-age Chinook smolts (Table 3.6).

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 3.16).

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.

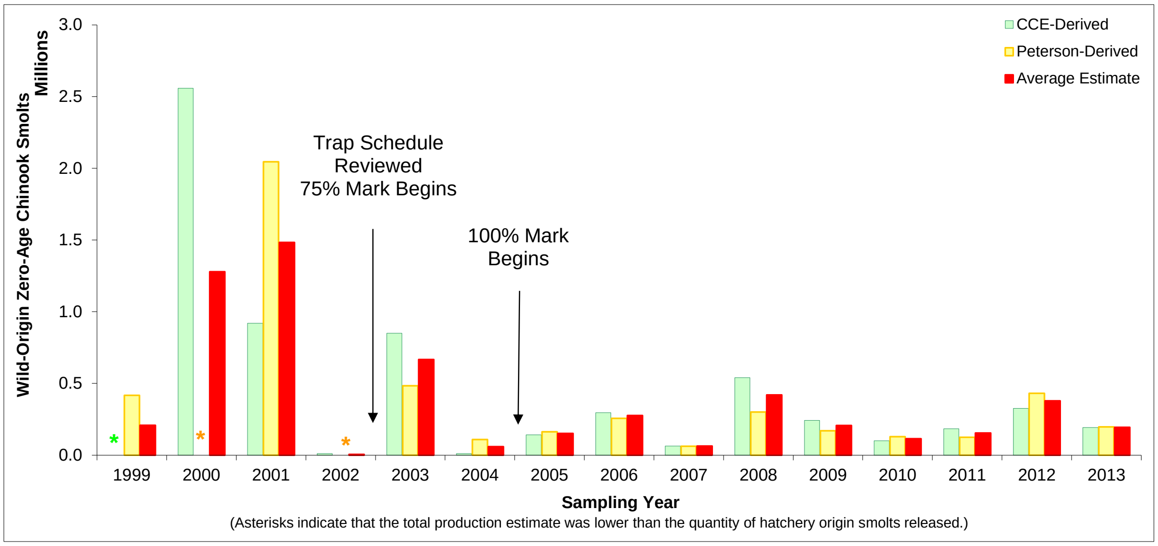


Figure 3.16. Comparison of wild-origin zero-age Chinook production estimates derived using the Peterson and CCE production estimate methods and hatchery release data

Table 3.6. 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
2011	2012	378,495
2012	2013	193,903

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

3.6 Yearling Chinook Outmigrants

3.6.1 CPUE Time Series for Yearling Chinook

In total, 30 yearling Chinook were caught during the 2012 sampling season and 114 were caught in the 2013 season. Figure 3.17 and Figure 3.18 shows the time series of interpolated hourly catch rates for yearling Chinook smolts throughout the 2012 and 2013 seasons respectively.

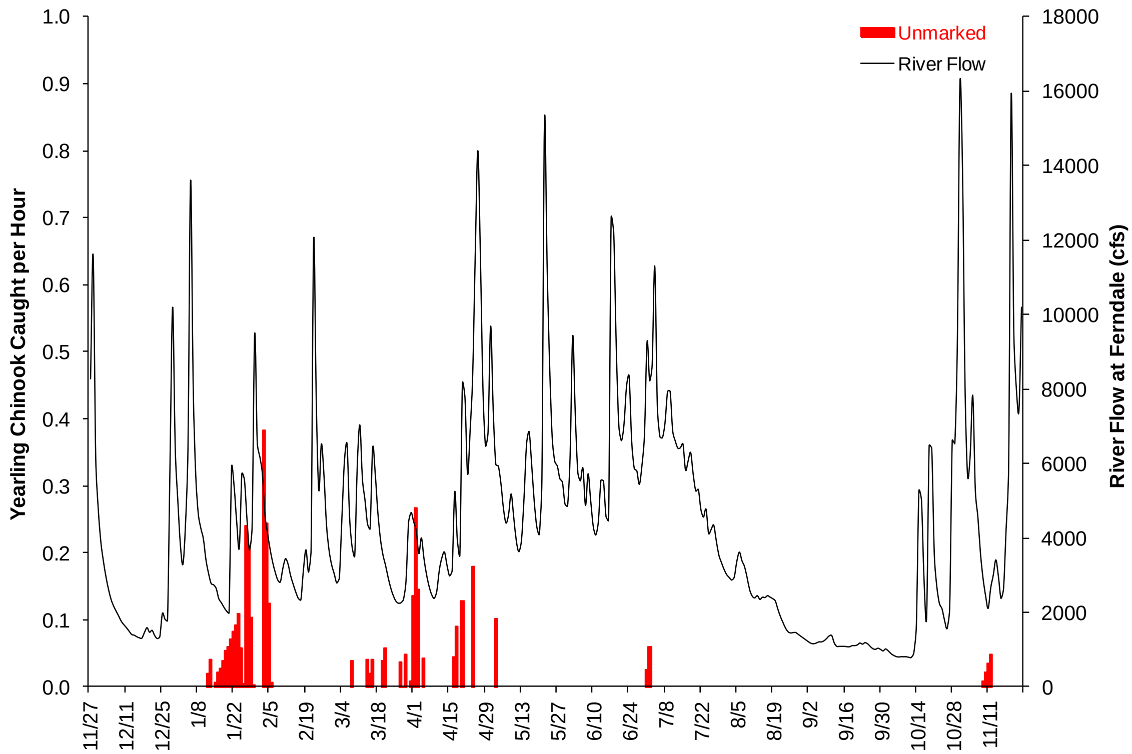


Figure 3.17. Interpolated catch per hour of yearling Chinook smolts in the 2012 season

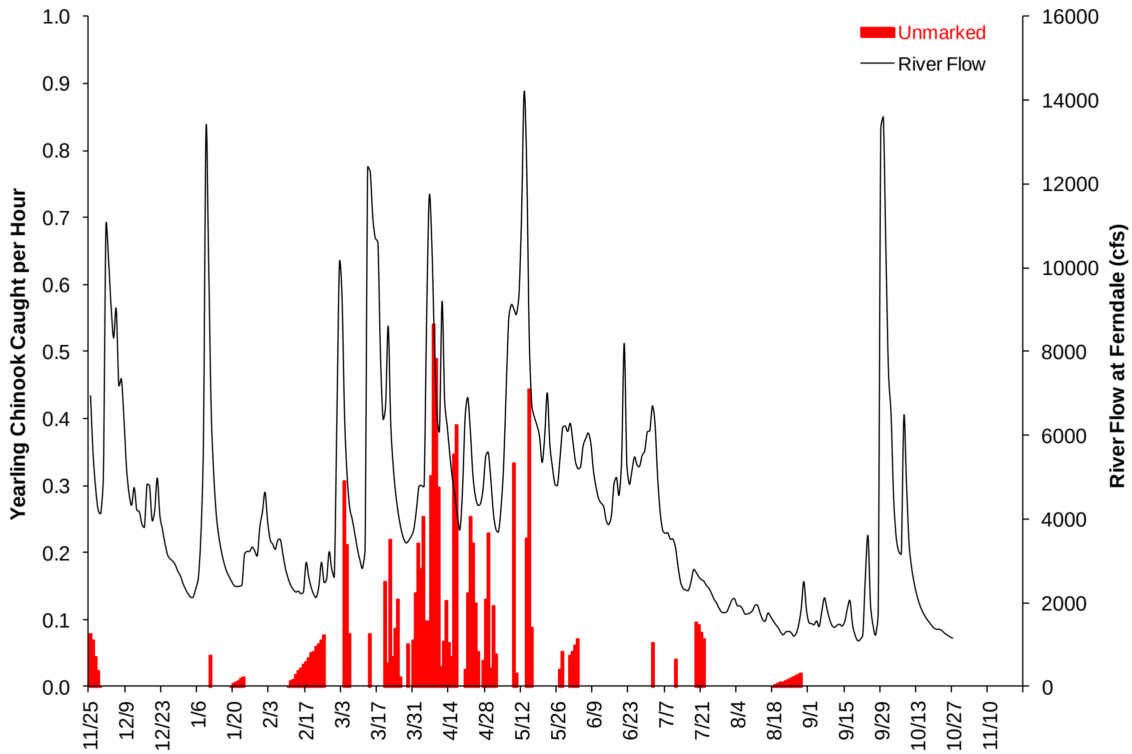


Figure 3.18. Interpolated catch per hour of yearling Chinook smolts in the 2013 season

3.6.2 Between-Year Comparisons for Yearling Chinook CPUE

Yearling Chinook smolts that outmigrated during the 2012 sampling season are the offspring of adult Chinook that spawned during the summer and fall of 2010 (Brood Year [BY] 2010). And Yearling Chinook smolts that outmigrated in the 2013 sampling season were spawned during the 2011 spawning season (BY 2011). The Index of Abundance (IOA) for yearling Chinook during the 2012 sampling season has a value of 3.6 while the IOA for 2013 is 9.5. The 2012 IOA is about half of the average Index of Abundance value (8) for the period of record, while the 2013 IOA score is about 20% higher than the average value. Figure 3.19 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 2012 will not out-migrate until the 2014 sampling season.

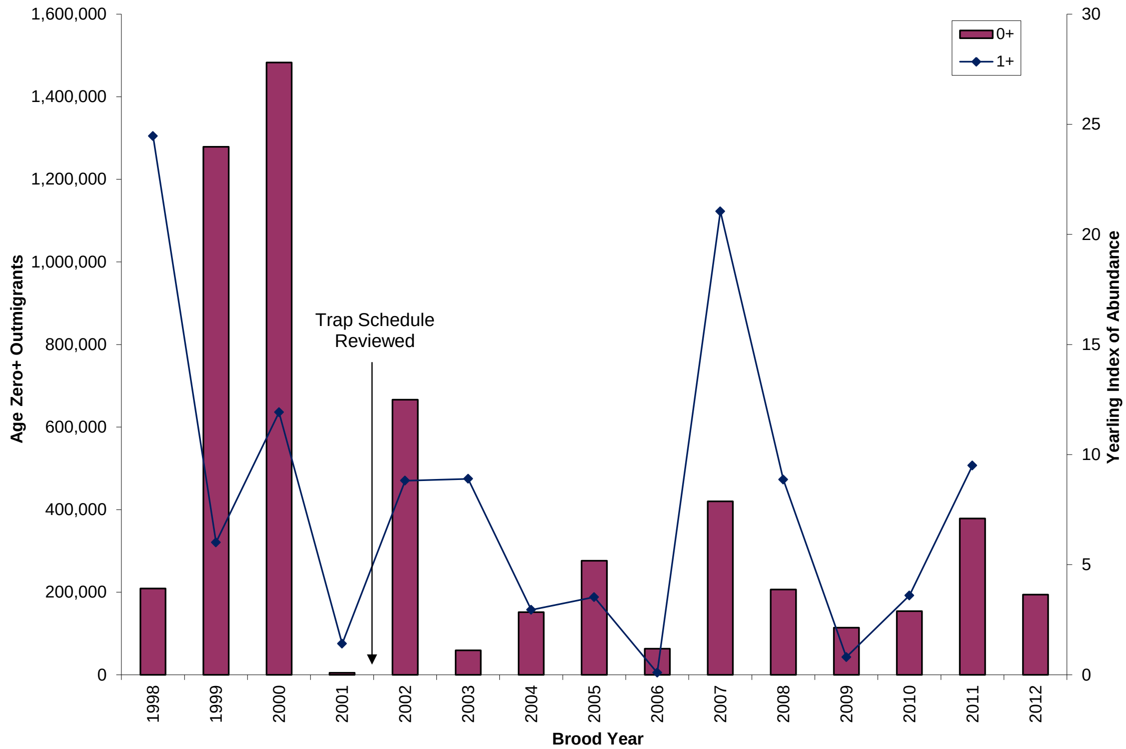


Figure 3.19. Comparison of zero-age production estimates and yearling outmigrant Index of Abundance scores based on brood year

Because no yearling Chinook smolts 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 for yearling Chinook.

3.7 Chinook Discussion

The results for the Trap in the 2012 and 2013 sampling seasons suggest that, relative to the previous 9 seasons, BY2010 is a very weak year class, BY2011 is an above-average year class (3rd highest), and BY2012 is shaping up to be a lower than average year class.

Analyses of data from previous years have suggested the possibility of a link between high river flows during October/November/December and the number of zero-age smolts outmigrating the following year. Scouring/smothering of Chinook redds during these flow events may be causal mechanisms underlying the apparent relationship. Flow conditions during egg incubation for BY2010 were relatively mild until a severe flow occurred in December, BY2011 had extremely favorable flows through the egg incubation period, and BY2012 experienced moderate to large flows during both October and November (Table 3.7).

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.

Table 3.7 Comparison of maximum daily river-flow at Ferndale by month and year to production estimates for wild-origin zero-age Chinook and annual Index of Abundance scores for yearling Chinook

	1997	1998	1999	2000	2001	2002*	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
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	13,300
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	6,390
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	12,400
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	14,400	11,700
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	**15,200**	14,200
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	12,600	8,200
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	11,300	6,710
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	3,630	2,520
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	1,390	13,600
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	**16,200**	7,530
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	**15,900**	
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	11,000	
Wild Production Estimate (0+ Chinook Numbers)		Brood Year	*208,723* Zero-Age Migrants	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	378,495	193,903
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	3.6	9.5

* Trap sample schedule reviewed at end of 2002

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 out-migrate 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 9 years. Prior to the Trap schedule review trends between zero-age and yearling smolts do not appear to correlate well. 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 almost certainly over-estimated the true catch rate if the Trap had been operating. 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 Results and Discussion

4.1 Hatchery Release Summary

Yearling coho smolts were released from May 25 through May 31, 2012, and from May 9 to May 12, 2013, from the Skookum Creek hatchery. As shown in Table 4.1 and Table 4.2, and in Figure 4.1, the total number of hatchery-origin yearling coho smolts released upstream from the Trap was 895,628 in 2012 and 1,085,244 in 2013. Of these, 97.1% were externally marked using adipose fin clips in 2012, and 100% were externally marked with adipose fin clips in 2013.

Because hatchery-released coho smolts usually exhibit a short 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 sometimes 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 2012

Start Release Date	End Release Date	Source Hatchery	Release Site	Externally Marked		Externally Unmarked*		Total Marked Coho	Total Coho Released
				AC Only	AC CWT	CWT Only	No CWT No AC		
5/25/2012	31-May-12	Skookum	Skookum	87	869,926	25,612	3	870,013	895,628
			Total Releas	87	869,926	25,612	3	870,013	**895,628**

*Based on reported fin clipping error and tag retention rates and lack of reliable detection for coho CWT's in catch

Table 4.2 Upstream hatchery releases of yearling coho in 2013

Start Release Date	End Release Date	Source Hatchery	Release Site	Externally Marked		Externally Unmarked*		Total Marked Coho	Total Coho Released
				AC Only	AC CWT	CWT Only	No CWT No AC		
5/9/2013	13-May-13	Skookum	Skookum	16,604	1,068,640	0	0	1,085,244	1,085,244
			Total Releas	16,604	1,068,640	0	0	1,085,244	**1,085,244**

*Based on reported fin clipping error and tag retention rates and lack of reliable detection for coho CWT's in catch

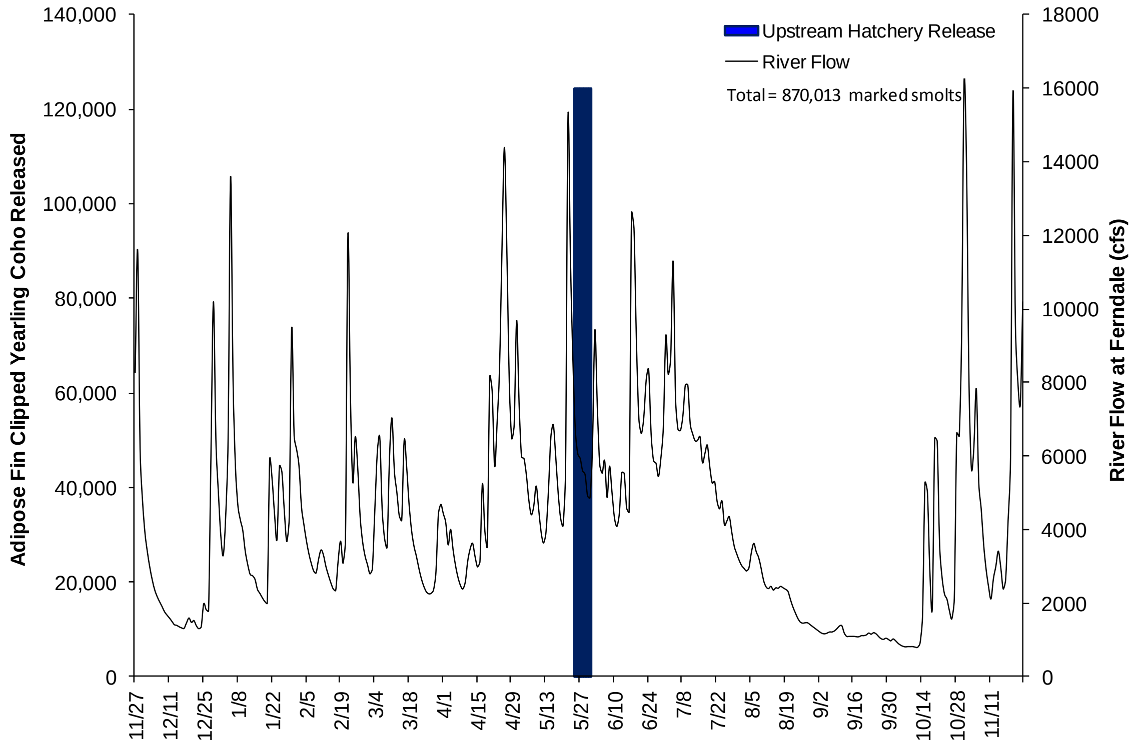


Figure 4.1. Hatchery releases of marked yearling coho in 2012

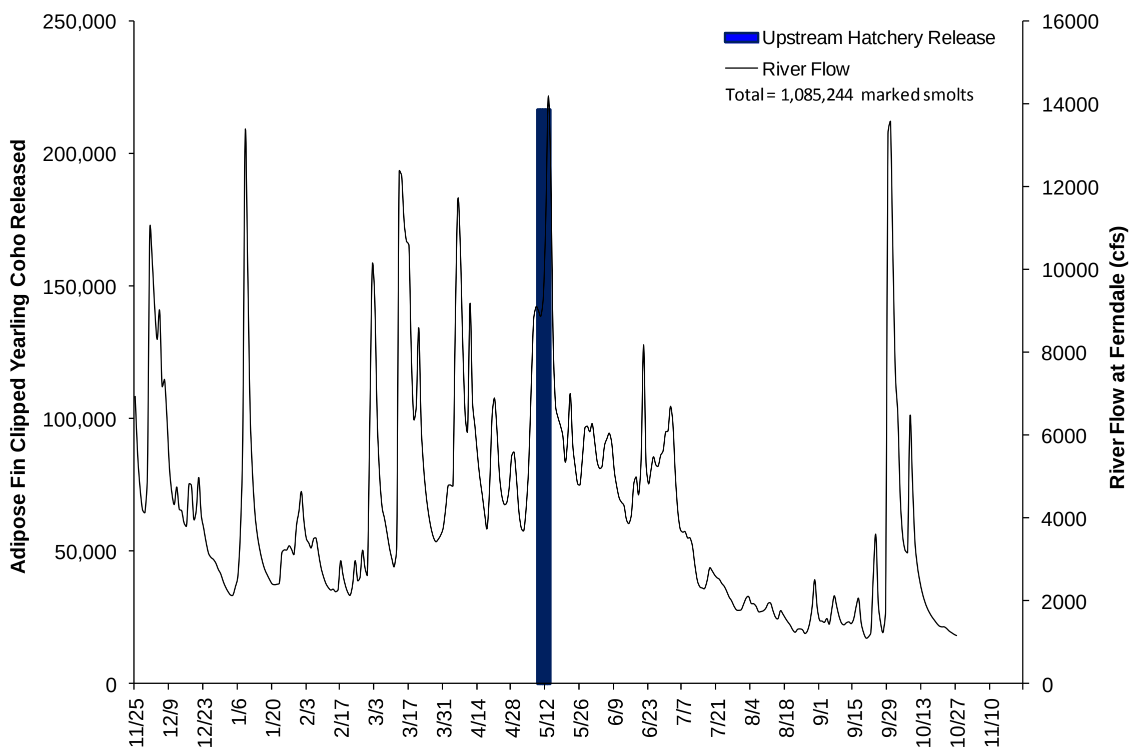


Figure 4.2. Hatchery releases of marked yearling coho in 2013

4.2 Coho Catch Totals

The catch totals for coho outmigrants in 2012 and 2013 are shown in Table 4.3 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 both marked and unmarked yearling coho caught in the Trap during the 2012 season was the highest on record and due, at least in part, to the very high fishing effort during the 2012 season. However, the similarly high level of effort in 2013 caught only an 'average' number of unmarked coho yearlings and one of the lowest totals for marked yearling coho during the past 13 years. When adjusted for the total effort, it is hard to explain why the recorded catch rates for coho in 2013 were so low. If there is a problem with trap catch efficiency in 2013, then it should manifest similarly across species but there is no corroborating evidence of massively reduced catches of zero-age Chinook, chum, or hatchery-origin steelhead in 2013.

Table 4.3. Catch totals for coho outmigrants by year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	% Marked in Released Hatchery Coho
	Marked	Unmarked	Marked	Unmarked		
2013	**0**	**28**	**1,409**	**1,447**	1710.9	**97.1%**
2012	**0**	**92**	**15,473**	**5,122**	1894.4	**100.0%**
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 4.4 and Table 4.5 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 2013.

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 4.4. 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	0.42		0.17	-0.02	0.54*
Night	0.17		0.19	0.01	0.09		0.66*	0.03
Dawn	-0.02	0.66*		0.43	0.00	2.28		0.55*
Day	0.54*	0.03	0.55*		0.71	0.21	0.73	
	* Indicates a Statistically Significant Correlation (p<0.05)							

Table 4.5. 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		1.63	0.81	0.39		0.69*	0.78*	0.65*
Night	0.69*		0.34	0.15	0.31		0.80*	0.53*
Dawn	0.78*	0.80*		0.17	0.80	1.94		0.72*
Day	0.65*	0.53*	0.72*		1.15	2.04	3.17	
	* Indicates a Statistically Significant Correlation (p<0.05)							

4.3 Coho Fork Lengths

The average daily fork lengths of coho smolts that were measured at the Trap are shown in Figure 4.3 and Figure 4.4 (grouped by life stage and mark status). Unmarked coho yearlings had an average fork length of 102.1 mm in 2012 and 104.6 mm in 2013. Marked hatchery-origin coho yearlings had an average fork length of 134.5 mm in 2012 and 121.3 mm in 2013. Unmarked zero-age coho had an average fork length of 35.5 mm in 2012 and 35.2 mm in 2013.

In general, unmarked yearling smolts tended to be smaller overall than marked coho yearlings caught on the same date. There was no clear relationship between the fork lengths of yearling coho smolts versus date although some small 'yearlings' were caught during the winter months of both seasons.

The lengths of unmarked zero-age smolts did not appear to increase during the year in either season.

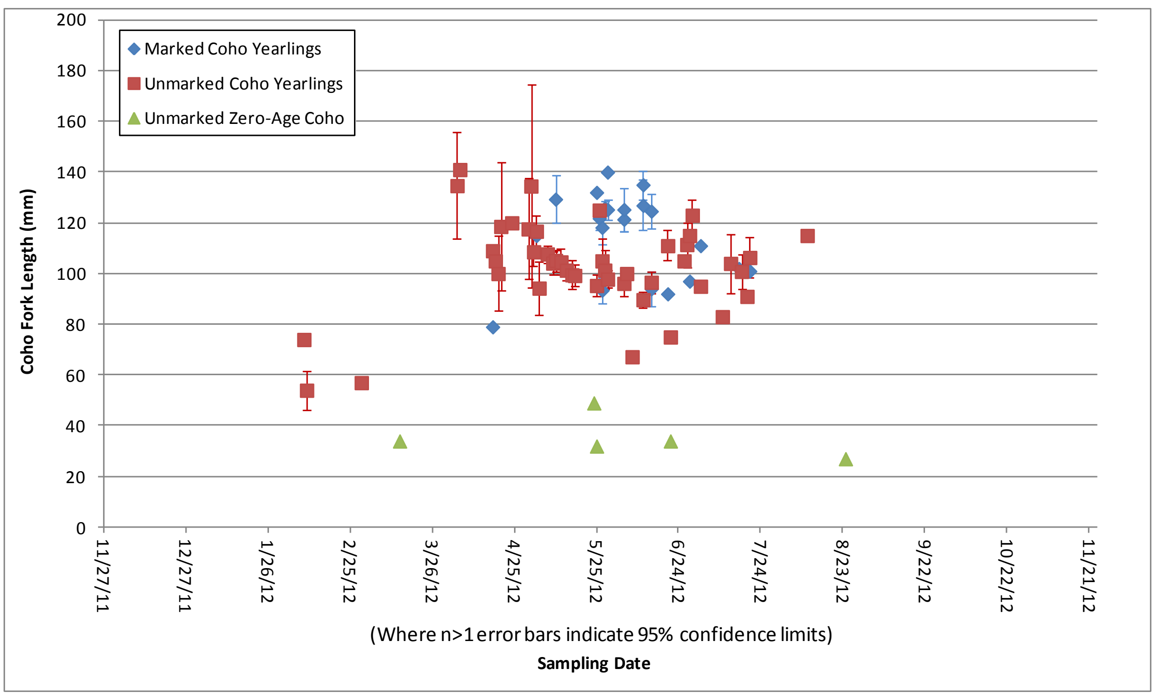


Figure 4.3. Average daily fork lengths for coho smolts caught during 2012

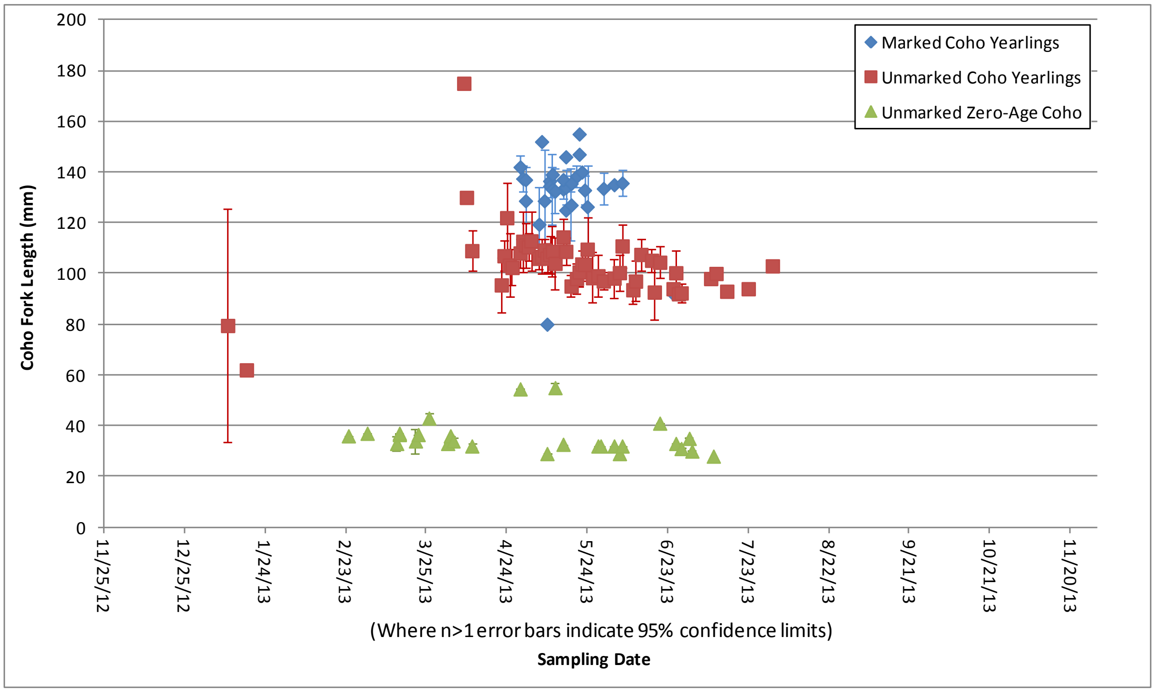


Figure 4.4. Average daily fork lengths for coho smolts caught during 2013

4.4 Coho Seasonal Outmigration Timing

The timing of outmigration for zero-age coho smolts is highly variable from year to year (Figure 4.5). 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 13 seasons, and which has an average duration of 34 days during which 90% of yearling coho out-migrate (Figure 4.6).

For the 2012 season, the first unmarked yearling coho smolt was caught on Feb 8 and for the 2013 season the first unmarked yearling coho was caught on Jan 8. The last unmarked yearling coho was caught on August 10 and August 1 in 2012 and 2013 respectively. The median outmigration date for unmarked yearling coho was May 19 or May 18, which was just 1 or 2 days earlier than the long-term median date. Ninety percent of yearling coho outmigrated between May 4 and June 9 (2012) or April 29 and June 9 (2013), which compares to the long term 90% dates of May 3 and June 7.

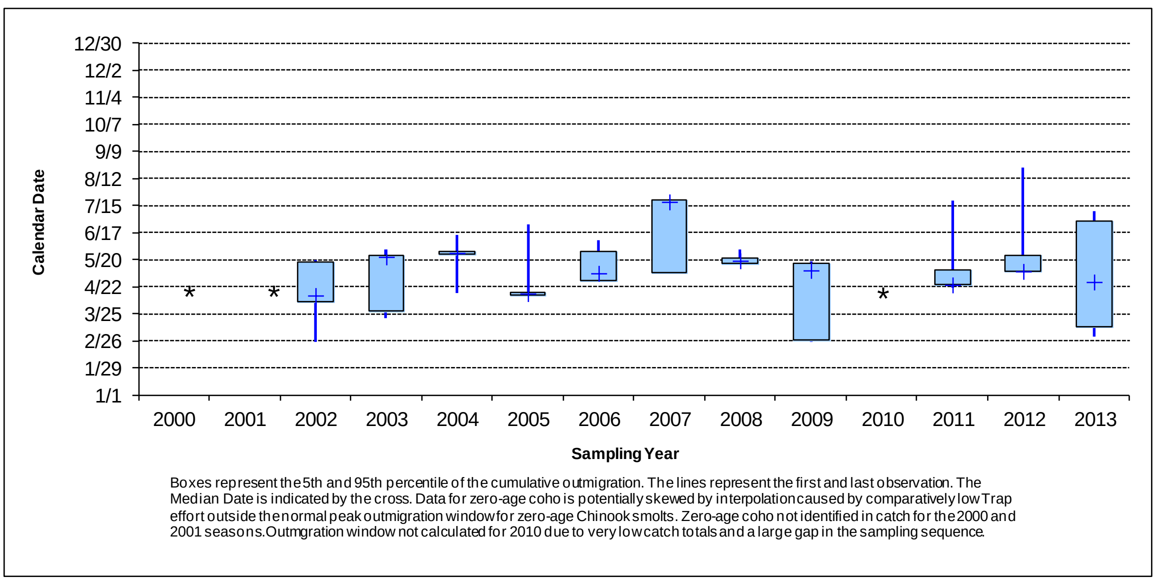
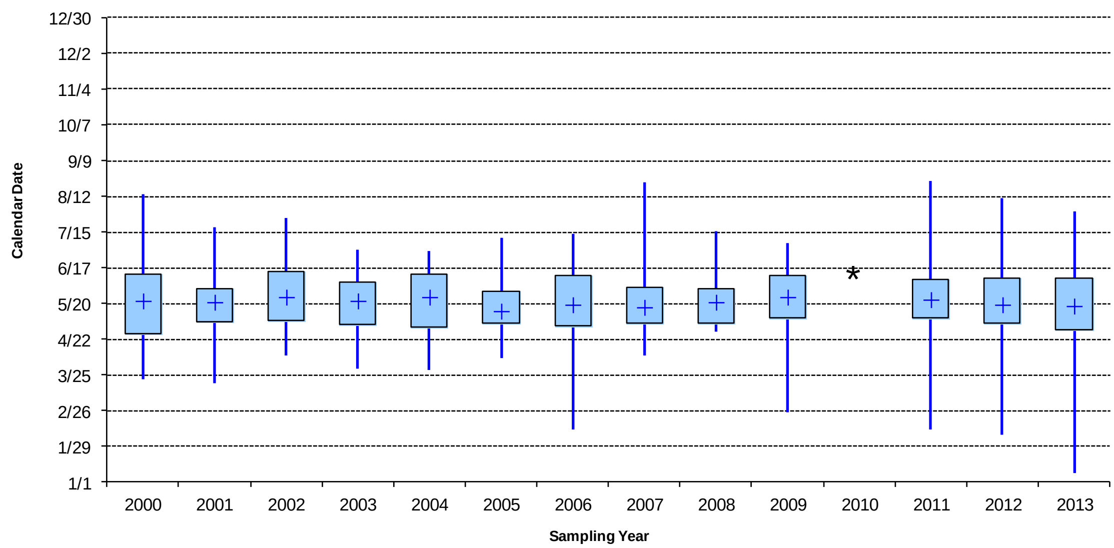


Figure 4.5. Outmigration timing for Unmarked Zero-Age Coho smolts from 2002 to 2013



Boxes represent the 5th and 95th percentile of the cumulative outmigration. The lines represent the first and last observation. The Median Date is indicated by the cross. Data for yearling Coho is potentially skewed by interpolation caused by comparatively low Trap effort outside the normal peak outmigration window for zero-age Chinook smolts. No outmigration window was calculated for 2010 due to a prolonged gap in sampling during the peak of the outmigration.

Figure 4.6. Outmigration timing for Unmarked Yearling Coho smolts from 2000 to 2013

4.5 Zero-Age Coho Outmigrants

Very few zero-age coho smolts are caught in the Trap in most years (Table 4.3).

4.5.1 CPUE Time Series for Zero-Age Coho

In the 2012 season 92 zero-age coho smolts were caught, while 28 zero-age coho were caught in the 2013 season. In 2012 these individuals were primarily caught on one day in May (Figure 4.7), while in 2013 they were encountered at very low rates from February through June (Figure 4.8).

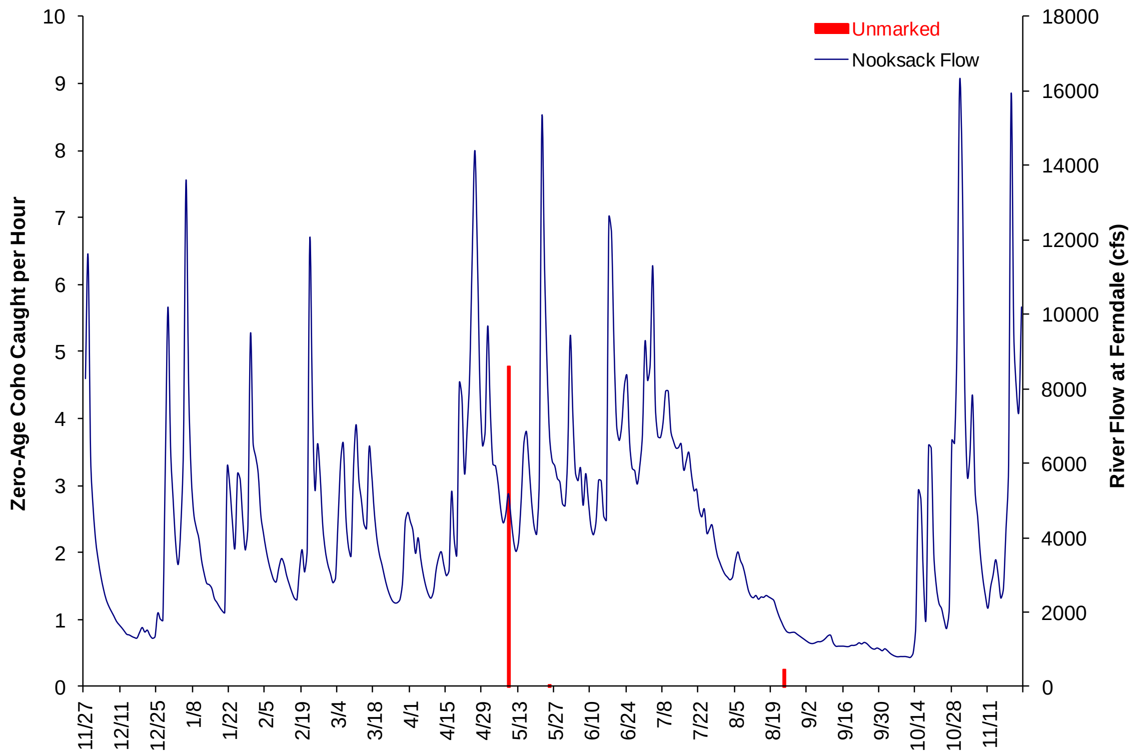


Figure 4.7. Interpolated cpue of zero-age coho smolts versus flow in the 2012 season

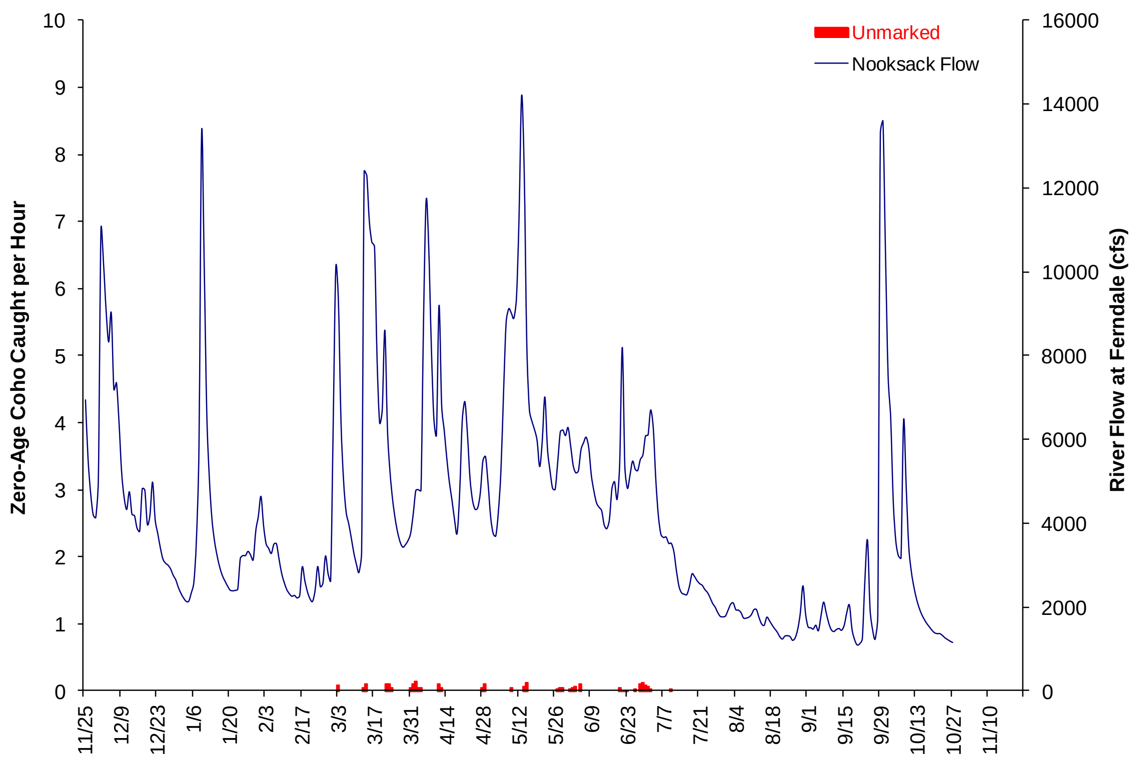


Figure 4.8. Interpolated cpue of zero-age coho smolts versus flow in the 2013 season

4.5.2 Between-Year Comparisons for Zero-Age Coho CPUE

Because the number of zero-age coho smolts caught in the Trap are usually very low, and also because it is thought that these few 'outmigrants' are not part of a deliberate migration strategy, no attempt has 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 4.3).

4.6.1 CPUE Time Series for Yearling Coho

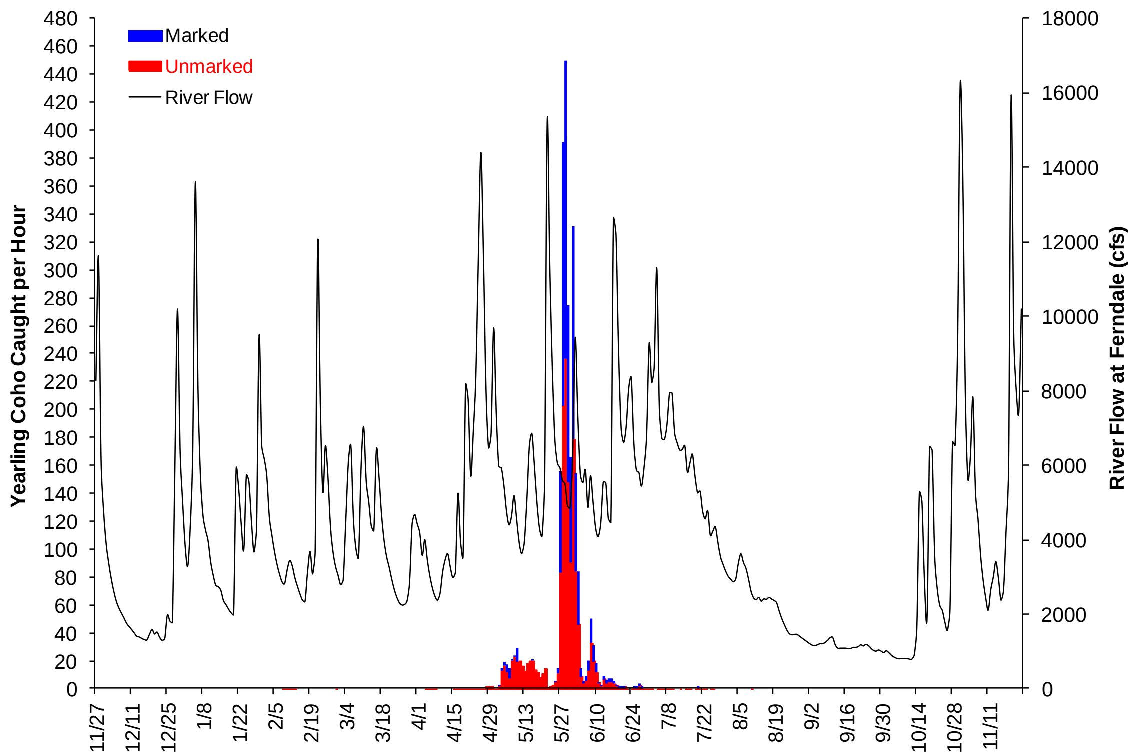
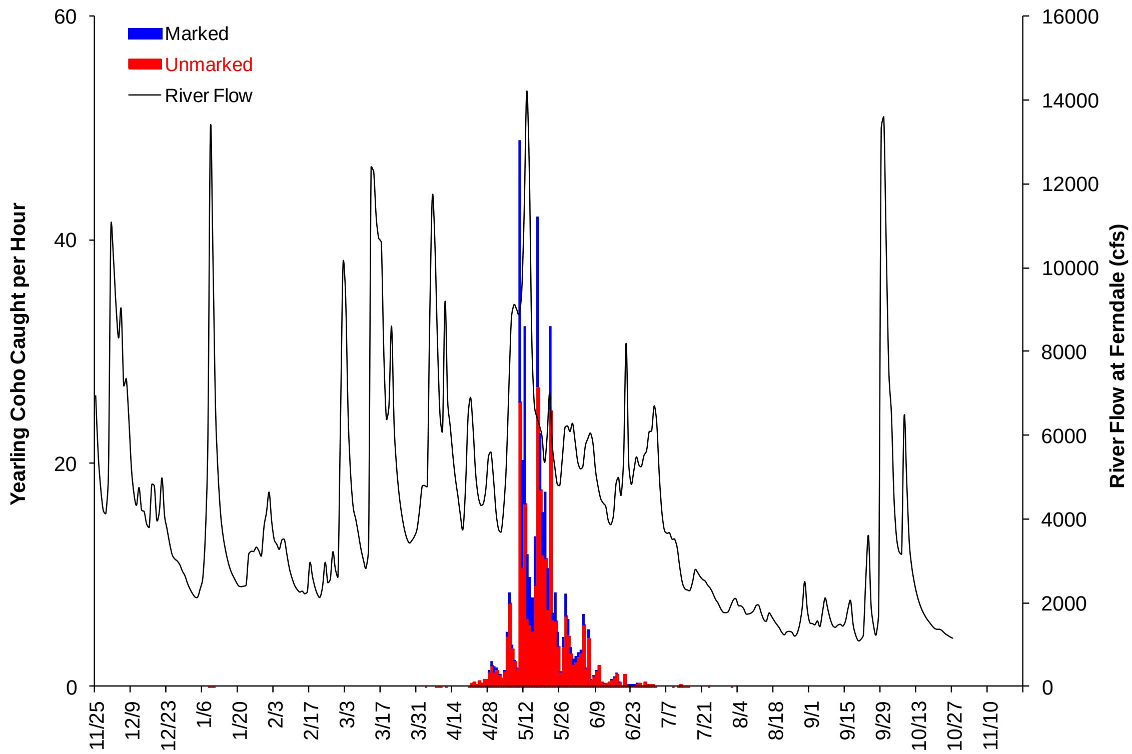


Figure 4.9 Interpolated catch per hour of yearling coho smolts during the 2012 season



4.10. Interpolated catch per hour of yearling coho smolts during the 2013 season

In 2012 unmarked yearling coho began to be caught regularly from the end of the first week of May through to mid-June. In 2013, unmarked yearling coho began to be caught regularly from the last week in April until the end of June. During the 2012 season the highest catch rate of unmarked yearling coho (25.9 smolts per hour) occurred on June 1, while in 2013 the highest catch rate of unmarked yearling coho (17.2 smolts per hour) occurred on May 22.

Marked hatchery-origin coho outmigrants were first caught on April 15 and April 28 in 2012 and 2013 respectively. The last marked yearling coho was caught on July 25 (2012) and July 26 (2013). However, the majority of marked coho outmigrated between the May 26 and June 21. The highest catch rate of marked coho occurred on May 29 (2012; 213 smolts per hour) and May 10 (2013; 23.5 smolts per hour). Overall, the maximum catch rate for marked yearling coho in 2013 was only 13% of the average maximum catch rates for marked yearling coho from all previous seasons.

4.6.2 Production Estimates for Yearling Coho

Peterson Estimate for Yearling Coho

In the 2012 sampling year, 870,013 externally marked (adipose fin clipped) yearling coho were released upstream from the Trap site. Of this total, 15,473 were recaptured at the Trap, and a further 5,122 unmarked yearling coho smolts were also caught (total = 20,595 smolts). Based on these values, the Peterson estimate for all yearling coho outmigrating during the 2012 season is 1,158,012 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 2012 was 895,628 smolts (including 25,615 accidentally unclipped individuals). Accordingly, the wild-origin production estimate for smolts outmigrating in 2012 is **262,384** smolts.

Similarly, in the 2013 sampling year 1,085,244 externally marked yearling coho were released upstream from the Trap site. Of these marked smolts, 1,409 were recaptured during Trap operations and a further 1,447 unmarked coho yearling were also caught (total = 2,856 coho yearlings caught). The Peterson estimate for the 2013 season was therefore 2,199,756 coho yearlings. Deducting the total known hatchery release (1,085,244) from the Peterson estimate provides a wild-origin production estimate of **1,114,512** smolts for the 2013 season.

These values are compared to results from previous years in Figure 4.11.

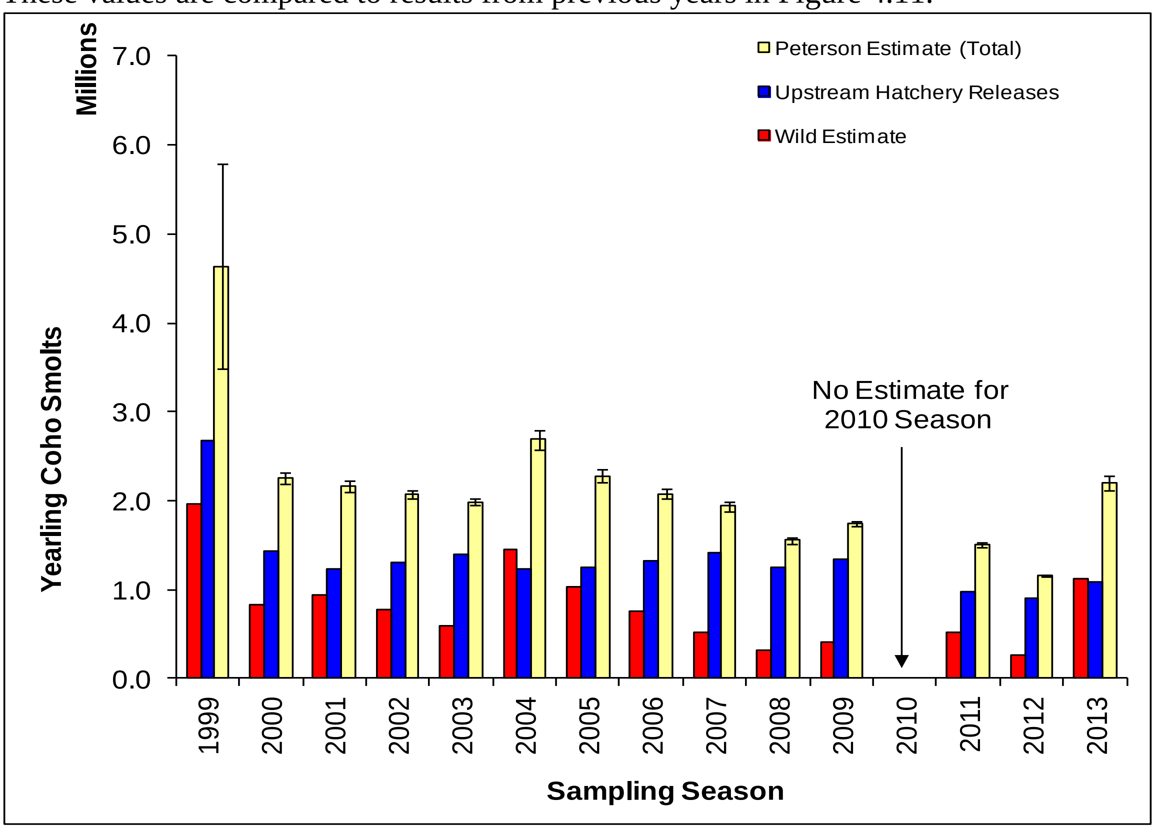


Figure 4.11. Peterson mark-recapture estimates for yearling coho by sampling year

CCE Estimate for Yearling Coho

During the 2012 season the Trap recaptured 1.78% of the clipped coho smolts that were released upstream. During the time period when clipped coho smolts were outmigrating, the Trap was fishing 43.5% of the time. If the number of marked smolts recaptured by the Trap increases linearly with the amount of time fished during this period, then the 2012 season catch efficiency is estimated to have been 4.09% (Figure 4.12). This value is considerably higher than the average seasonal catch efficiency of 1.61% and is the highest seasonal catch efficiency recorded to-date. By contrast, during the 2013 season only 0.13% of the marked hatchery smolts were recaptured. The Trap was operating 43.6% of the time during the outmigration period for marked coho, so this gives an estimated seasonal catch efficiency of just 0.3% for the 2013 season. This is the lowest seasonal catch efficiency since the Trap schedule was reviewed in 2002.

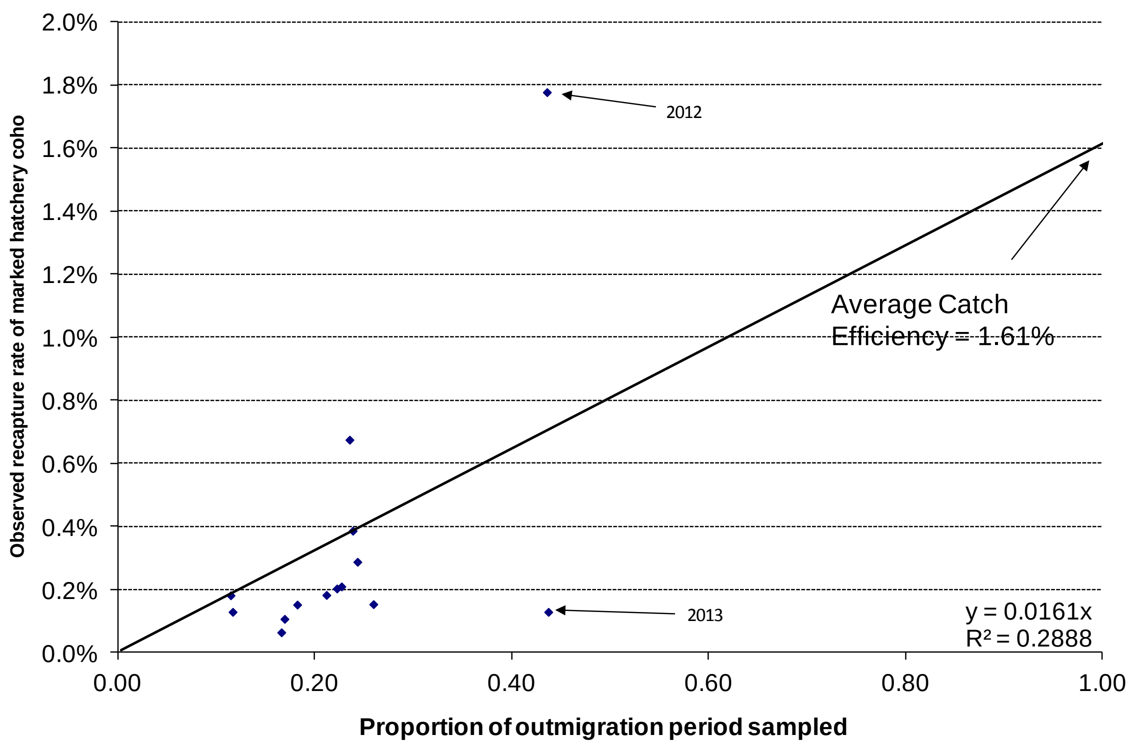


Figure 4.12. Seasonal trap catch efficiency estimates for marked yearling coho

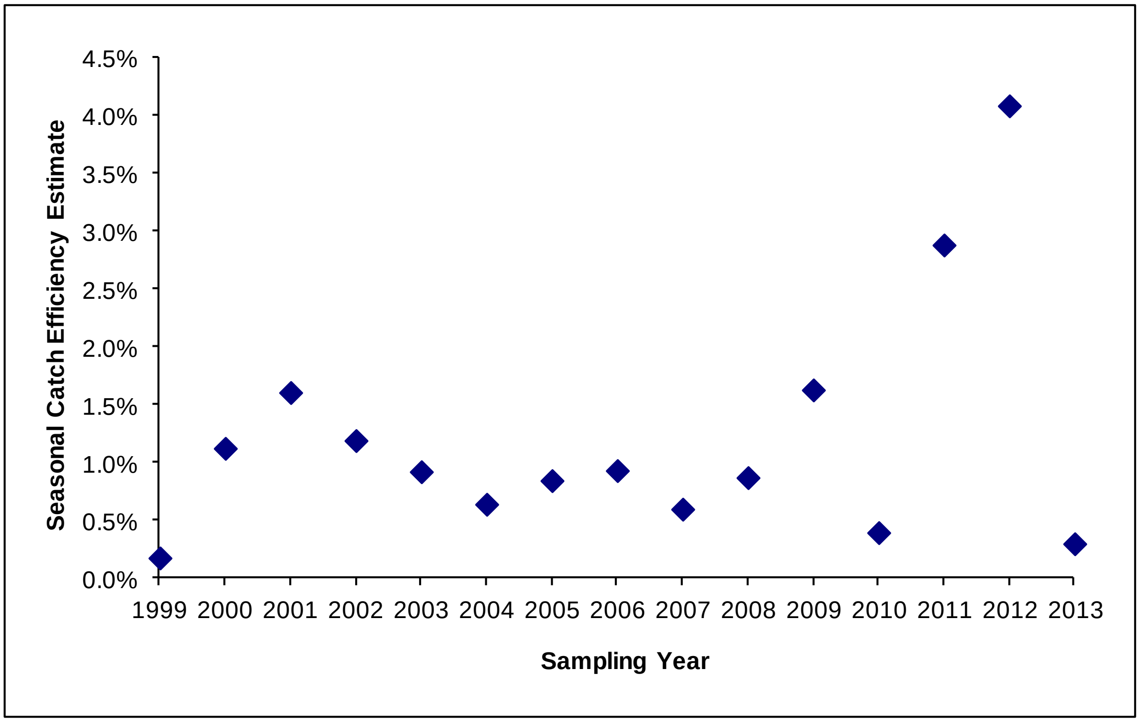


Figure 4.13. Comparison of Seasonal Catch Efficiency Estimates for Coho over Time

Using the average seasonal catch efficiency estimate of 1.61% to convert the time series of hourly catch rates shown in Figure 4.7, the total number of marked smolts estimated for 2012 was 1,558,367, which was approximately 79% 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 2012 season and the average catch efficiency for all seasons. If the 2012 season catch efficiency were used instead, the estimate would have underestimated the known release by 30%. After deducting unclipped hatchery-origin smolts, the final estimate of wild-origin yearling coho outmigrating in 2012 was estimated to be **358,386** smolts.

Similarly, using the average seasonal catch efficiency to convert the 2013 catch per hour results (Figure 4.8) resulted in a total estimate of 188,134 marked coho smolts, which was just 17% of the known release of marked hatchery smolts. Using the 2013 seasonal catch efficiency instead of the average resulted in an estimate of 1,009,645 marked coho smolts, which was 7% below the known number of marked smolts released. Again, this divergence in estimates is largely the result of the seasonal catch efficiency for 2013 diverging markedly from the average seasonal efficiency across years. After adjusting for bias and deducting unmarked hatchery coho, the final production estimate for wild-origin coho smolts in 2013 was 1,286,483.

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 2012 and 2013 seasons are **310,385** and **1,199,342** smolts respectively. The 2012 estimate is the lowest estimate of wild origin yearling coho to date. In contrast, the 2013 estimate is the highest estimate for the period of record.

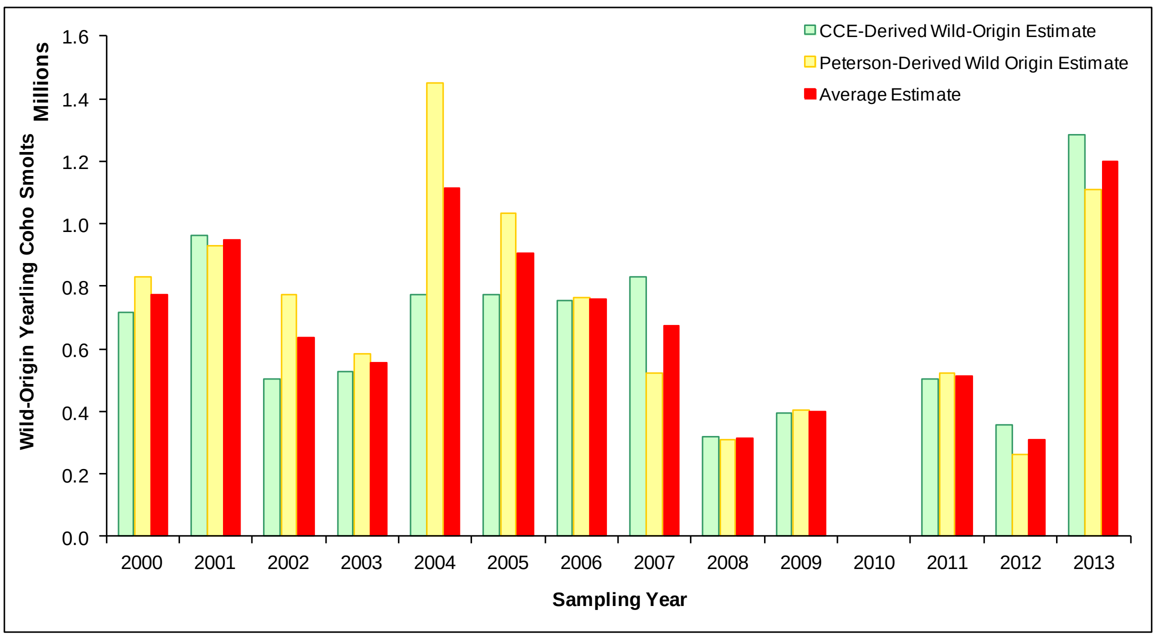


Figure 4.14. Comparison of wild-origin yearling coho smolt production estimates derived using the Peterson and CCE production estimate models and hatchery release data

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 2012 and 2013.

The estimates of the production of wild yearling coho in 2008, 2009, 2011, and 2012 (BY2006, BY2007, BY2009, BY2010) are the lowest to-date. There does not appear to be any clear explanation for this recent trend. On the other hand, the production estimate of wild coho outmigrating in the 2013 season (BY2011) was the highest to date, and is very similar to the previous largest year class that outmigrated in 2004 (BY2002)

No clear reason presents itself as to why the year class strength in most recent years is reduced. It is tempting to assign credit for the strong BY2002 and BY2011 to the favorable incubation flows that were present during incubation for these two year classes However, favorable incubation flows were also present for BY2000 and the resulting outmigration in 2002 was fairly mediocre. Also, unfavorable flow conditions were present during incubation for other years that had above average outmigrations two years later (e.g., BY2003 and BY2004). Unlike Chinook, there doesn’t seem to be as clear of a relationship between flow and subsequent year class strength for coho.

The unusually high catch efficiency for coho yearlings in 2012 is something of a mystery although it immediately followed another high-efficiency year (2011), which might suggest a recent change in conditions has occurred. However, whereas the high efficiency observed for coho in 2011 was also observed for other species, the high catch efficiency for coho in 2012 is not echoed in the results for other species where catch efficiencies were close to average. Moreover, the catch efficiency for coho in the 2013 season was a record low, but catch efficiencies observed for other species were close to average. Whatever is happening with the catch efficiency of the Trap for coho, it does not appear to be impacting other species where catch efficiency can be quantified.

One possible explanation boils down to the fact that marked coho outmigrate during a relatively short period of time and the observed catch efficiencies during that short period of time may be quite different each year.

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 4.15).

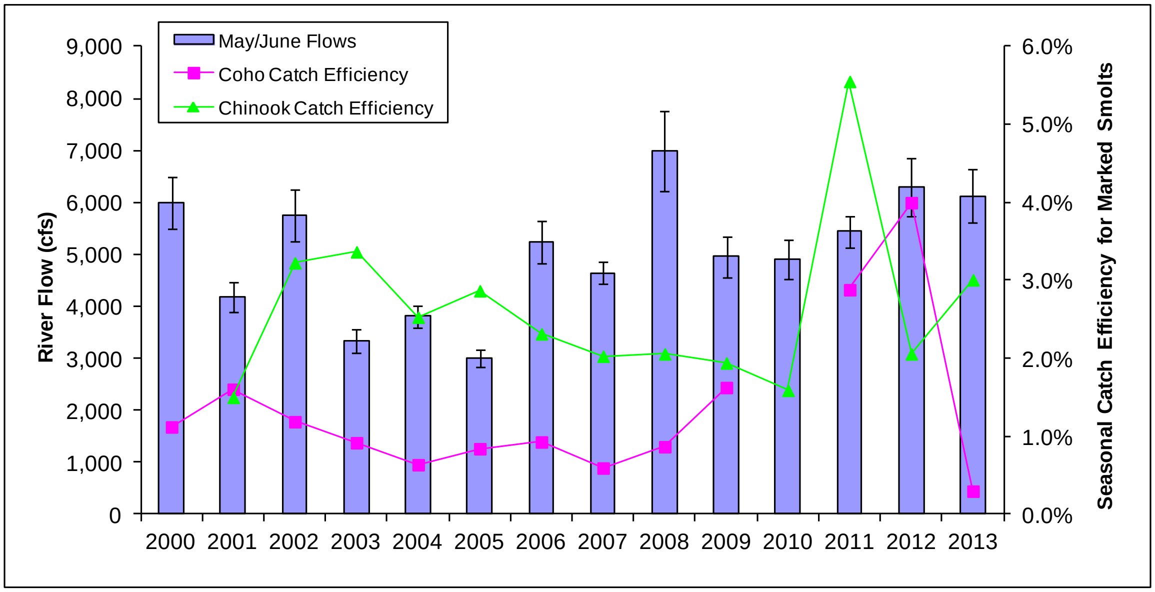


Figure 4.15. Comparison of average May/June river flows versus seasonal catch efficiency estimates for marked hatchery origin coho smolts

Another factor that could explain the high catch efficiency was the very clear water clarity during May and June for both 2012 and 2013 (Figure 4.16). However, even though there does appear to be a weak inverse trend between seasonal catch efficiency and secchi depths, this does not explain why the 2012 catch efficiency was so high for coho (Figure 4.17). It is unlikely that the very large changes in seasonal catch efficiency are driven solely by changes in water clarity from year to year.

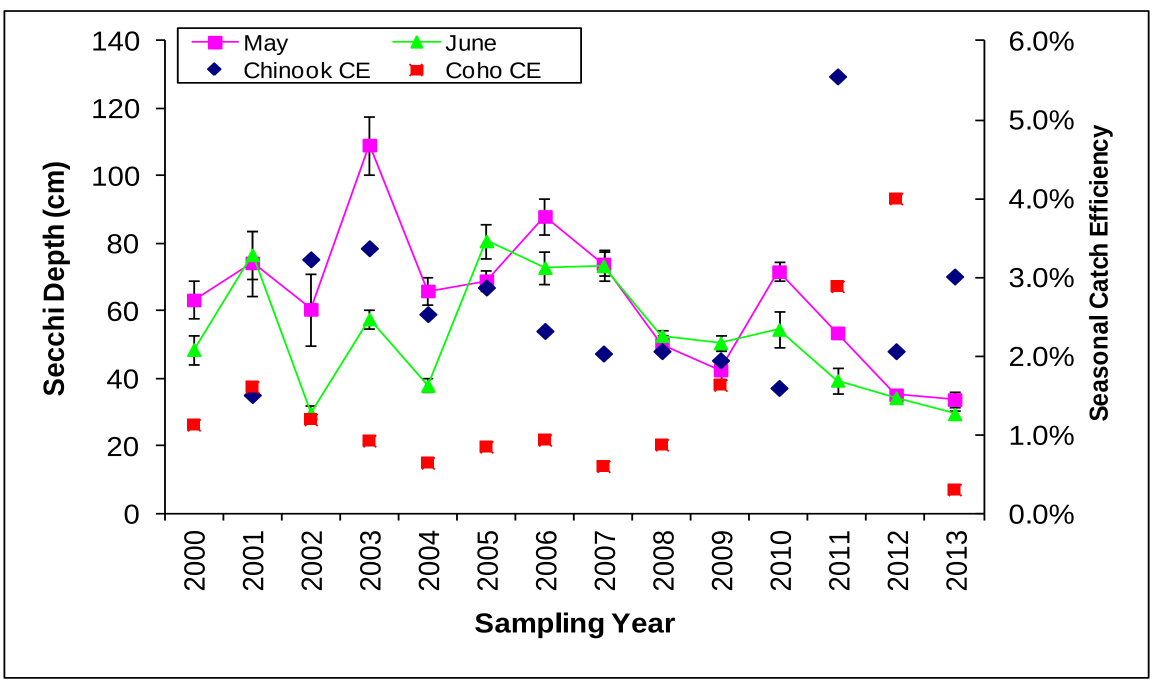


Figure 4.16. Comparison of average secchi depth readings in May and June by sampling season

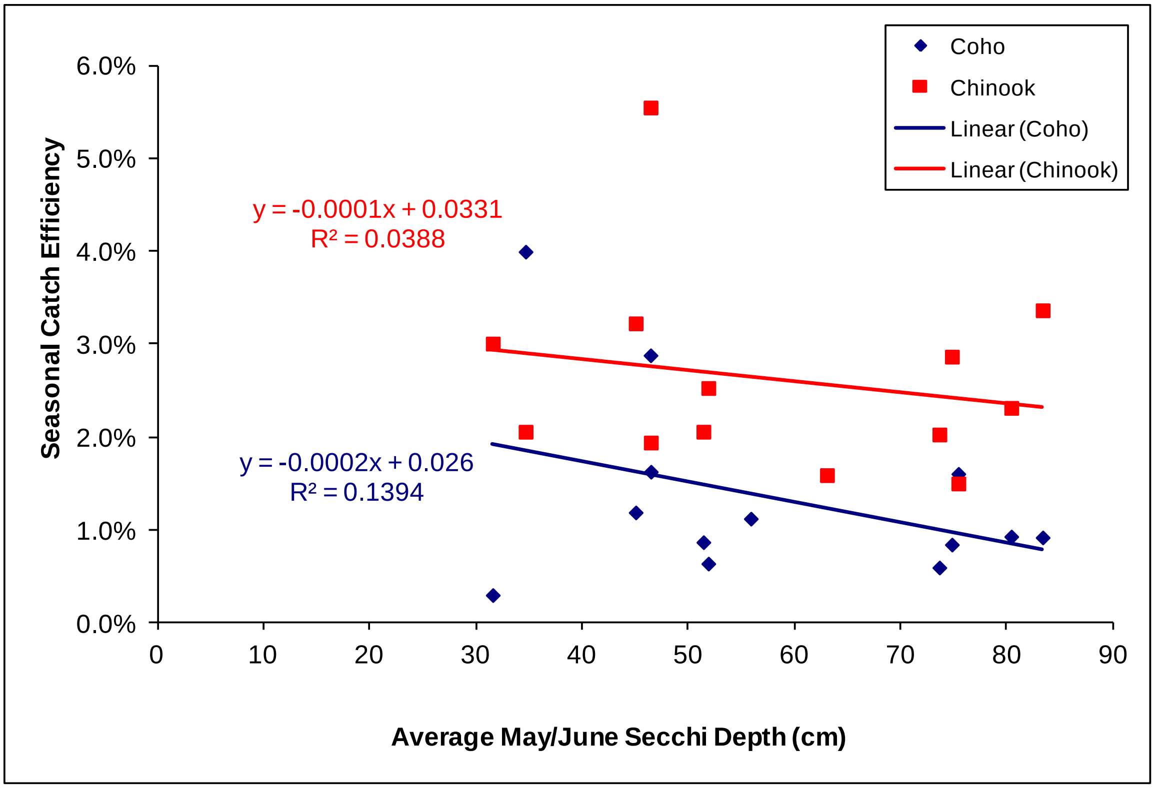


Figure 4.17. Scatterplot showing seasonal catch efficiency versus average May/June secchi depth

Another explanation 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. Moreover, if the river channel were contributing to a change in Trap catch efficiencies, you would expect this to affect all species in a similar way. Since the changes in catch efficiency for coho differ from those for Chinook, this seems to be an unlikely explanation.

Finally, the estimates of seasonal catch efficiency could be distorted if the hatchery release data is inaccurate or incomplete, or if large-scale mortalities occur after the release but before the smolts arrive at the trap. Unfortunately, there is no way to test for this. However, there is no indication that dead-on-arrival corpses of hatchery coho were present in 2013 which you might expect to see if large-scale mortalities occurred immediately after release.

5.0 Chum Salmon Results and Discussion

5.1 Hatchery Release Summary

There are no known releases of chum salmon from hatcheries.

5.2 Chum Catch Totals

The 2012 and 2013 catches of chum outmigrants are 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 scores for both seasons were higher than the median score (1,543) but lower than the mean score (3,322) for the period of record.

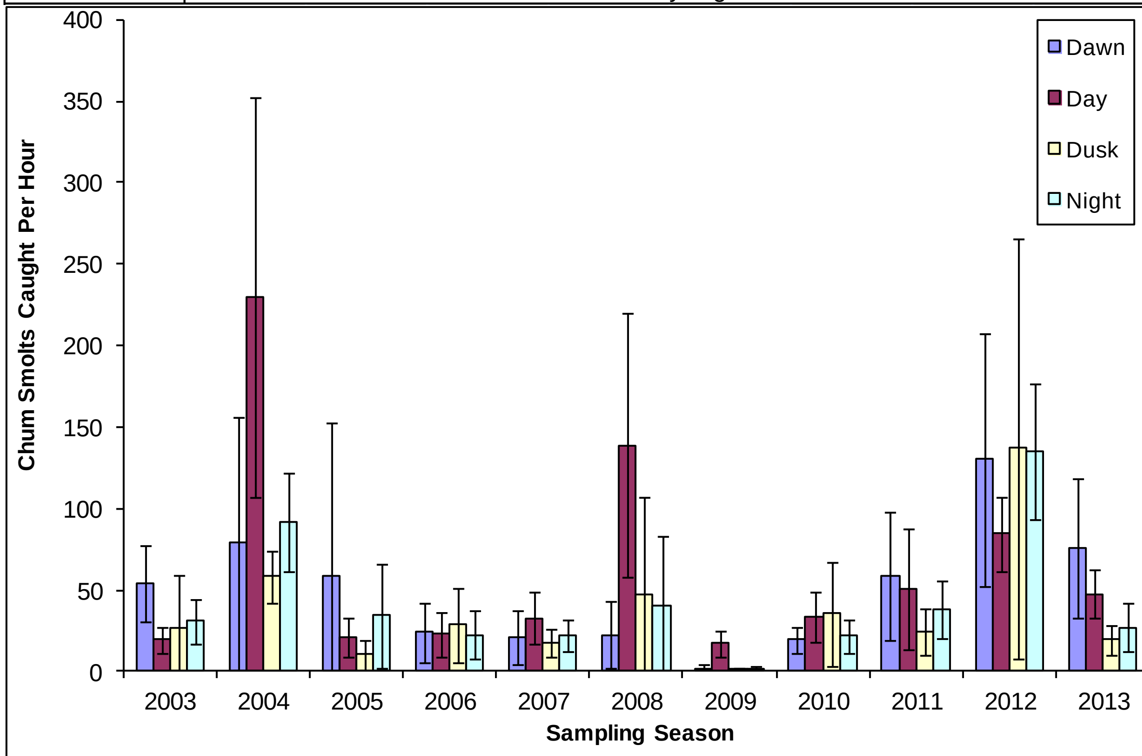
Table 5.1. Catch Totals for Chum Outmigrants by Year

Sampling Year	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance (Unmarked)
	Marked	Unmarked	Marked	Unmarked		
2013	**0**	**15,845**	**0**	**0**	**1710.9**	**1,732**
2012	**0**	**31,603**	**0**	**0**	**1894.4**	**3,100**
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

Table 5.2 shows the correlation coefficients and the slopes for the relationships between observed catch rates of zero-age chum from sets conducted during different daylight conditions within 24 hours, based on Trap data collected from 2005 to 2013. 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 and 2012 the nighttime and dawn sets tended to produce the highest catch rates of chum (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 during different daylight conditions

Independent Variable	Dependent Variables							
	Dusk	**Night**	**Dawn**	**Day**	**Dusk**	**Night**	**Dawn**	**Day**
Dusk		0.99	1.42	0.75		0.797*	0.6*	0.589*
Night	0.797*		0.65	0.55	0.66		0.494*	0.435*
Dawn	0.6*	0.494*		0.71	0.29	0.46		0.769*
Day	0.589*	0.435*	0.769*		0.52	0.44	0.88	
	* 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 Fork Lengths

The average daily fork lengths of chum smolts that were measured at the Trap are shown in Figure 5.2 and Figure 5.3. In general, chum smolts outmigrated at an average size of 40 mm in 2012, and 38.7 in 2013. However, later in the season there was more variability in sizes compared with earlier in the season, and some smolts larger than 50 mm were encountered in both years. The largest reported individual chum caught in the screwtrap was 75 mm and was caught on April 11, 2013.

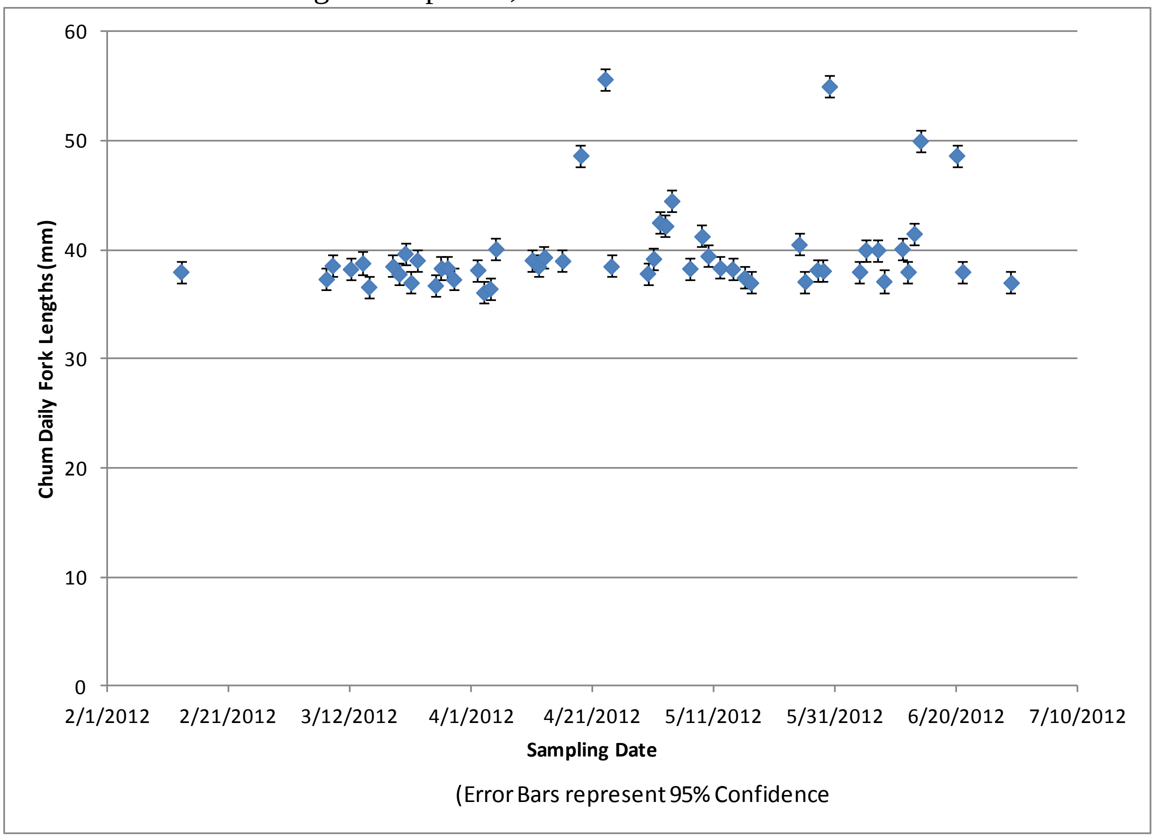


Figure 5.2. Average daily fork lengths for chum smolts caught during 2012

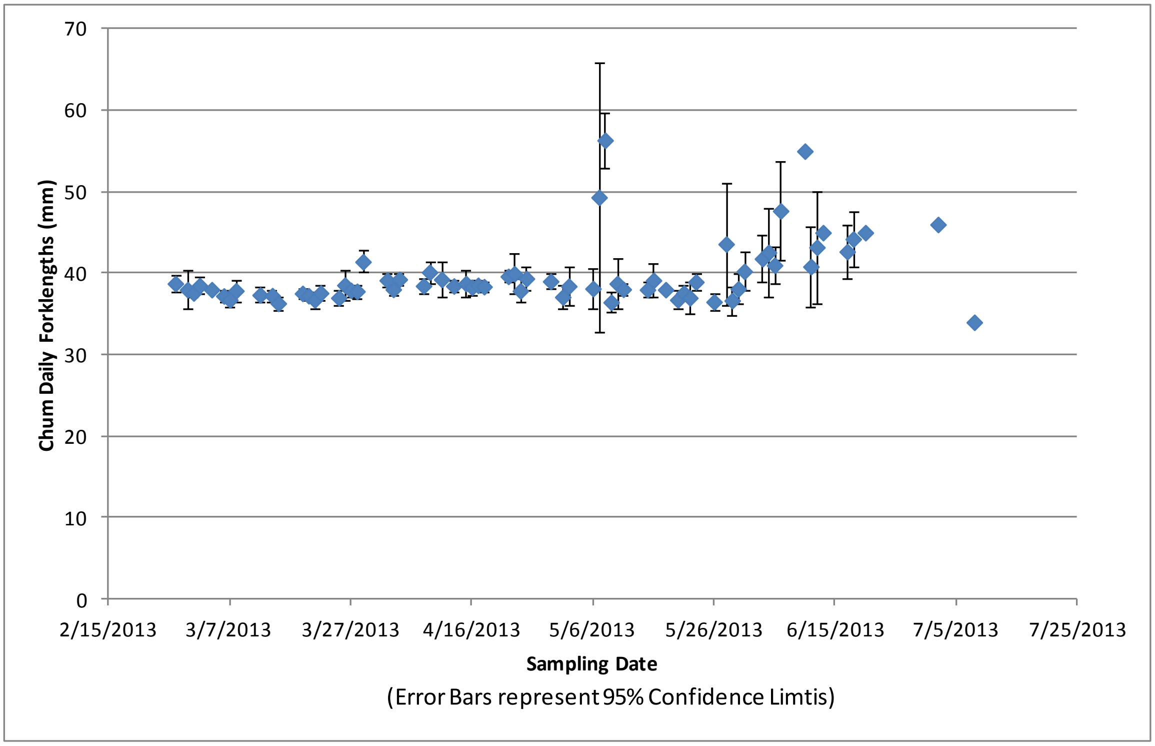
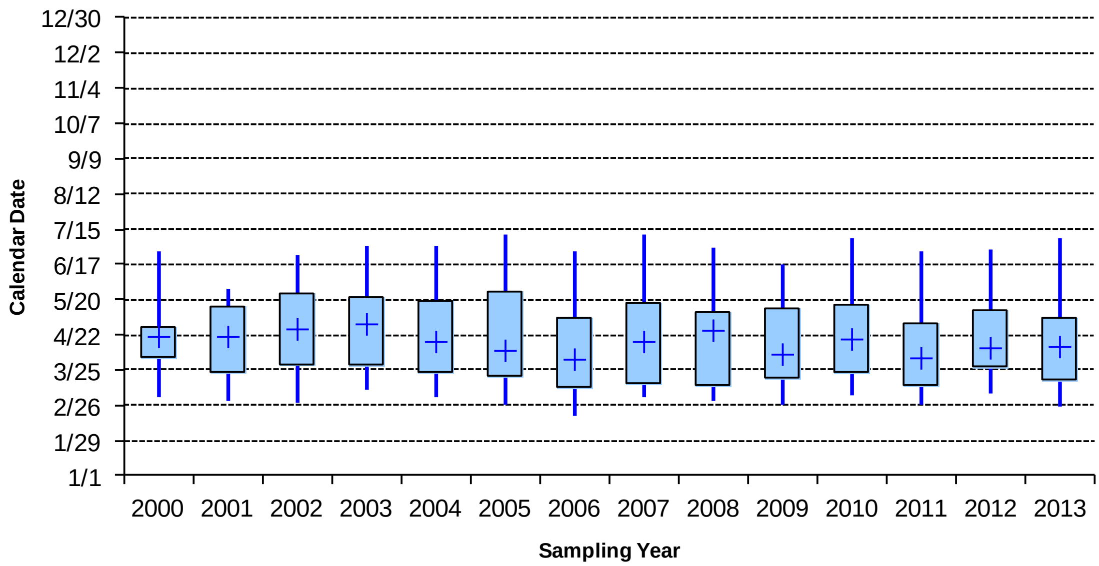


Figure 5.3. Average daily fork lengths for chum smolts caught during 2013

5.4 Chum Seasonal Outmigration Timing

Chum smolts have a somewhat fairly consistent outmigration window (Figure 5.4) but the median outmigration date has varied by up to 28 days over the past 14 seasons; ranging from April 3rd in 2006 to May 1st in 2003. Overall, the average median date for the chum outmigration is April 16, and the median dates for the 2012 and 2013 seasons were April 12th and April 13th respectively. The main outmigration window has an average duration of 53 days during which 90% of chum smolts outmigrate. 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 5.4. 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 2012 season was 197 smolts per hour, which occurred on April 13 (Figure 5.5). The highest catch rate in 2013 was 229 smolts per hour which occurred on April 22 (Figure 5.6). Overall Trap sampling effort from March through May in both years was relatively high compared to some previous years. This means that interpolation intervals used in the analysis are short during the chum outmigration window and, consequently, the time-series of CPUE is probably a good representation of trends during the outmigration window for chum smolts.

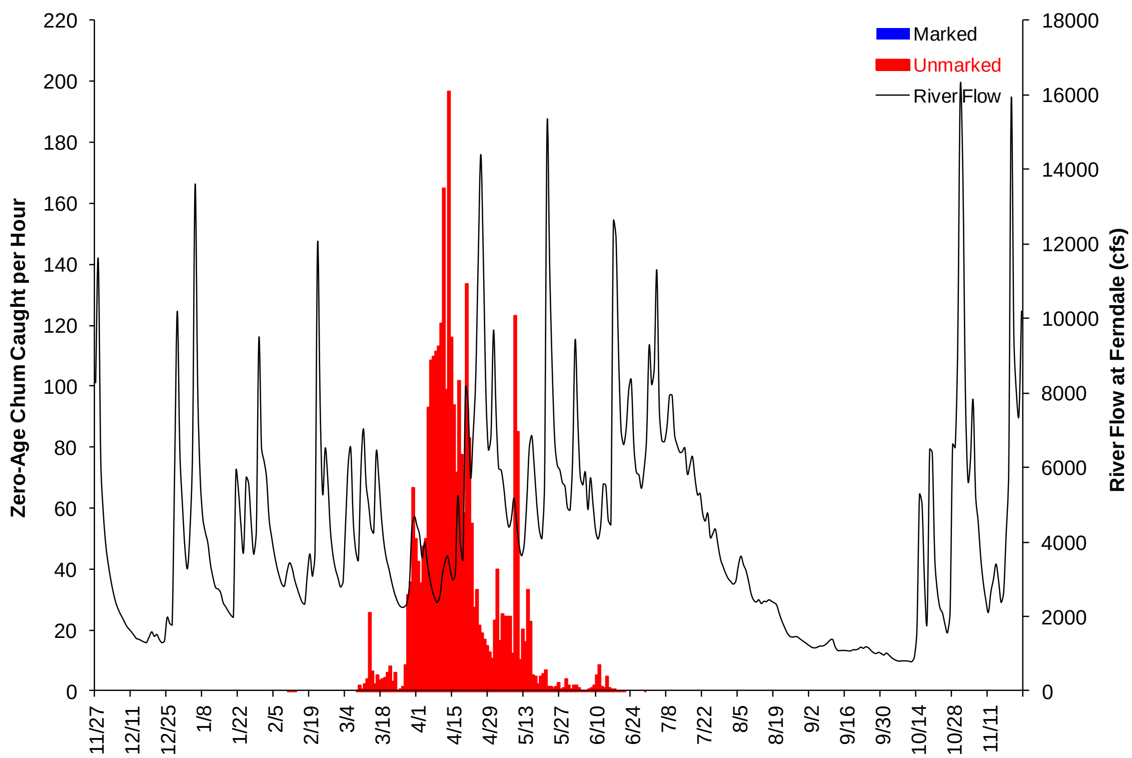


Figure 5.5. Interpolated catch per hour of zero-age chum by date vs. flow for 2012

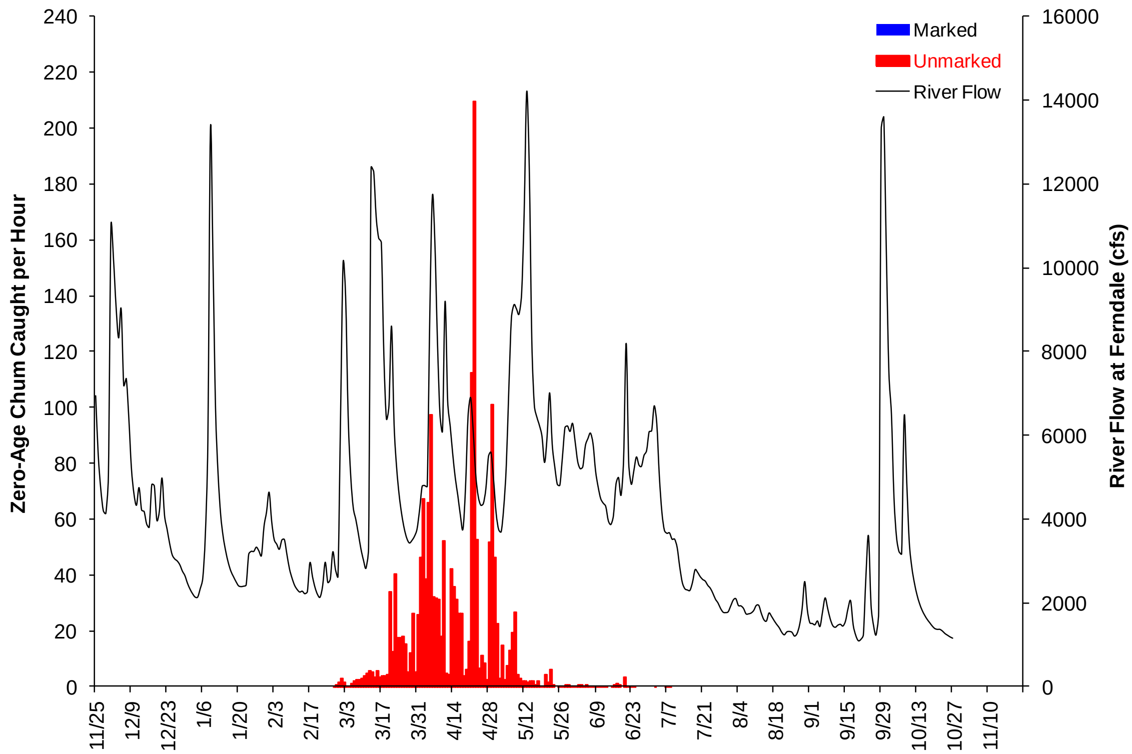


Figure 5.6. Interpolated catch per hour of zero-age chum by date vs. flow for 2013

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 5.7. The most notable feature is the recurring pattern of a strong year class every four years . This may be evidence that a particularly strong year class returned to spawn in 1999, 2003, 2007, and 2011 because the high index of abundance values do not appear to be related to river flows during egg incubation (Table 3.7). However, the index of abundance for this strong year class appears to be trending downwards with each generation and in 2012 was not much larger than the preceding year class. 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 may slightly bolster the year class strength of the preceding cohort.

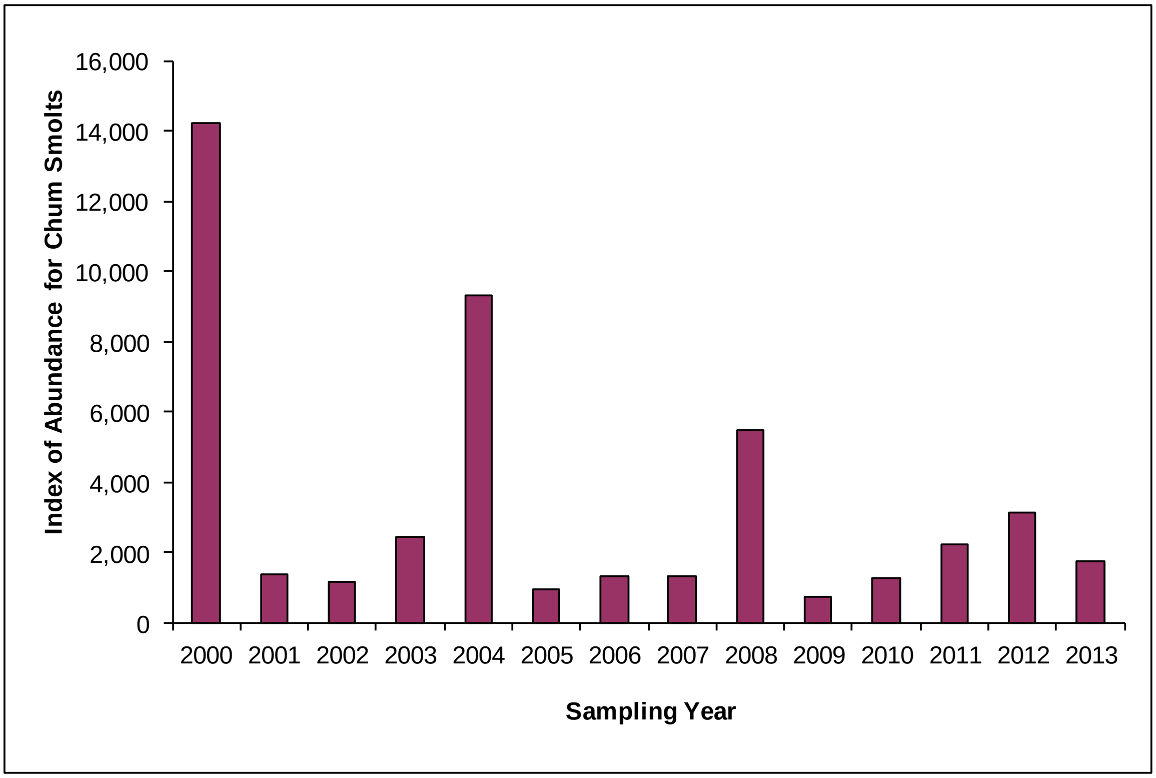


Figure 5.7. Comparison of the Index of Abundance for chum smolts by sampling year

5.6 Chum Discussion

Chum salmon out-migrate earlier than Chinook or coho smolts and generally 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 out-migrate at the end of the outmigration season at larger-than-average sizes. However, it might be helpful to obtain DNA samples to confirm the identification of larger individuals that have been identified as chum by trap personnel.

Overall, there appears to be a repeating pattern of 3 consecutive ‘weak’ year classes, followed by one ‘strong’ year class, and the strength of the ‘strong’ year class appears to be waning with each generation.

The number of chum smolts produced each year seems to be relatively unrelated to the severity of flow events during the preceding fall and winter. This may be the result of pink salmon spawning preferences for tributaries and off-channel habitats rather than in the main channels of the Nooksack River, which may afford them some protection from scour resulting from large flow events. The incubation flows for the ‘strong’ year class smolts that outmigrated in 2012 (brood year 2011) were extremely favorable so the fact that the trend of weakening year class strength continued in that circumstance is very disappointing and perhaps suggests that interference from a large pink salmon return may have contributed to suppressing chum spawning success in 2011. However, the highest index score for chum salmon outmigrants coincided with the previous highest index score for pink salmon outmigrants (brood year 1999) so the evidence for redd interference from pink salmon adversely impacting chum salmon is very ambiguous.

The presence of a ‘strong’ year class of returning adults seems to be the best explanation for the much higher index of abundance values and total catches of chum smolts in the 2000, 2004, 2008 and 2012 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 other than a prolonged period of generally unfavorable ocean conditions.

6.0 Pink Salmon Results and Discussion

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

A total of 42,264 pink salmon smolts were caught during Trap operations in the 2012 sampling season (Table 6.1) and none were caught during the 2013 season.

Table 6.1. Catch totals for pink salmon outmigrants by year

Sampling	Zero-Age Outmigrants		Yearling Outmigrants		Hours Fished	Index of Abundance
Year	Marked	Unmarked	Marked	Unmarked		
2013	**0**	**0**	**0**	**0**	1710.9	**0.0**
2012	**0**	**42,264**	**0**	**0**	1894.4	**5,042.8**
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 dusk and night sets (Table 6.2 and Figure 6.1).

Table 6.2. Within-day correlation coefficients (Green Cells) and slopes of relationships (Gray Cells) for catch rates of zero-age pink salmon during different daylight conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		0.88	1.29	2.31		0.742*	0.721*	0.867*
Night	0.742*		0.85	1.36	0.64		0.632*	0.782*
Dawn	0.721*	0.632*		1.13	0.42	0.51		0.648*
Day	0.867*	0.782*	0.648*		0.33	0.46	0.40	
	* Indicates a Statistically Significant Correlation							

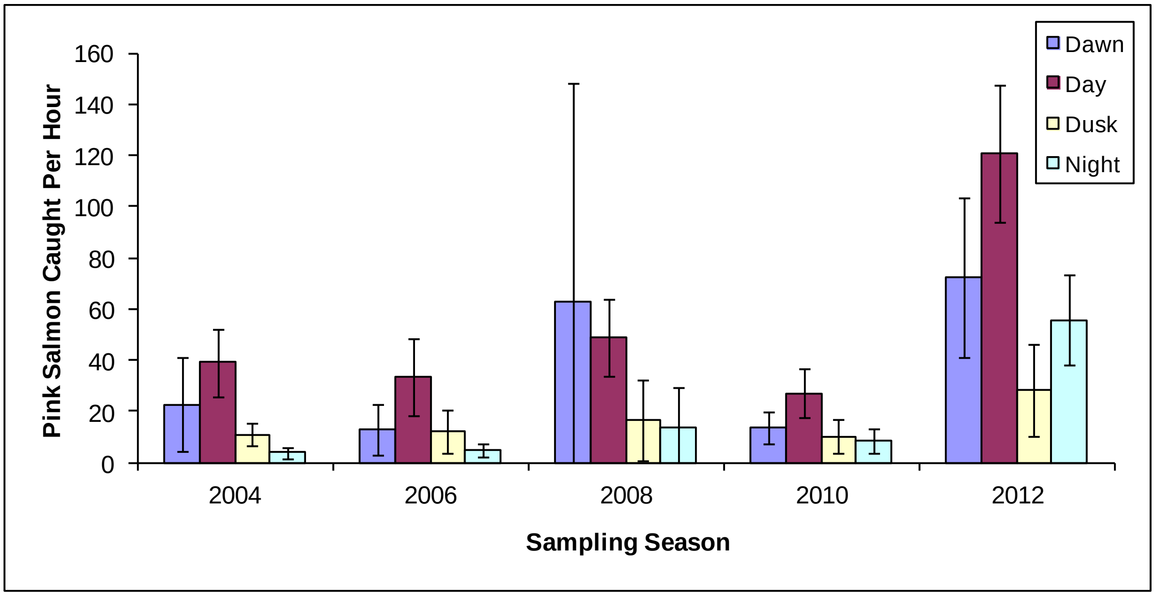


Figure 6.1. Comparison of average pink salmon catch rates in March and April, by daylight stratum and sampling season.

6.3 Pink Salmon Fork Lengths

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 49 mm which was caught on April 23 2012, and the smallest was 29 mm, which was caught on January 31 2012. The average size pink smolt was 34.8 mm.

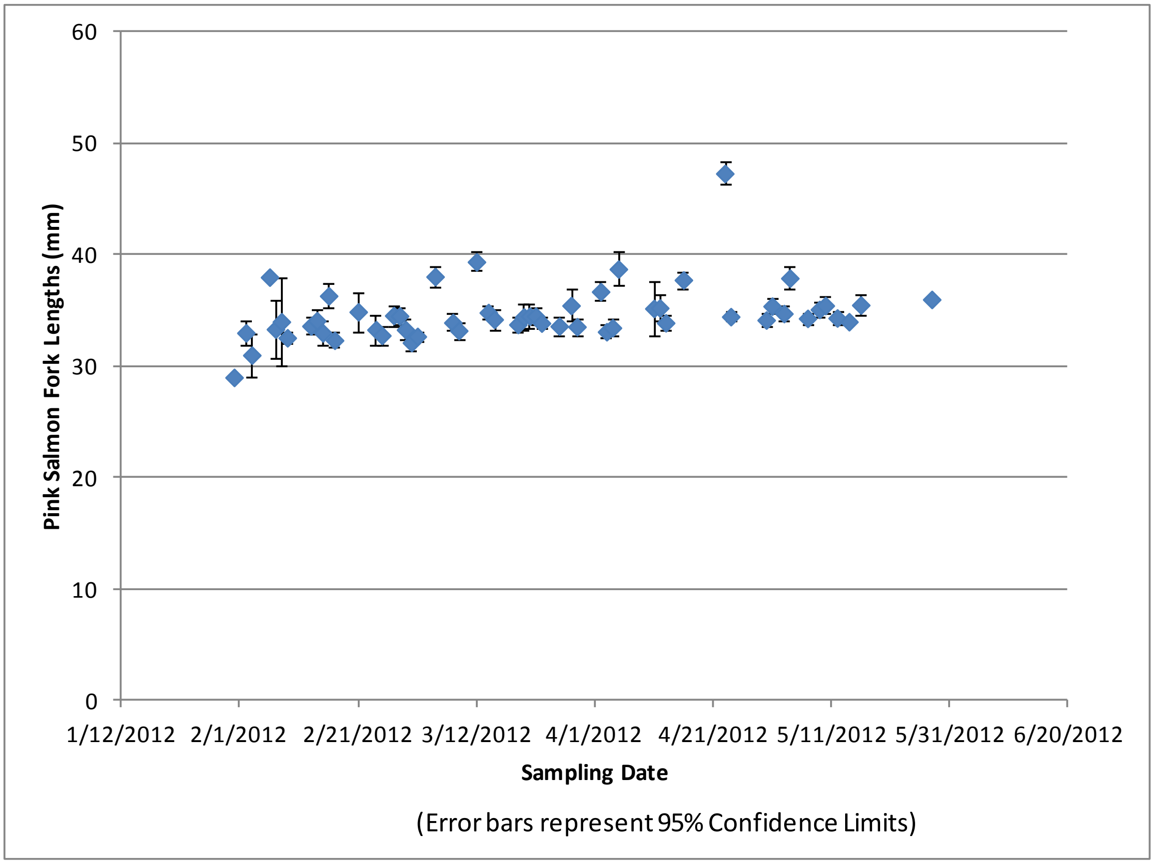


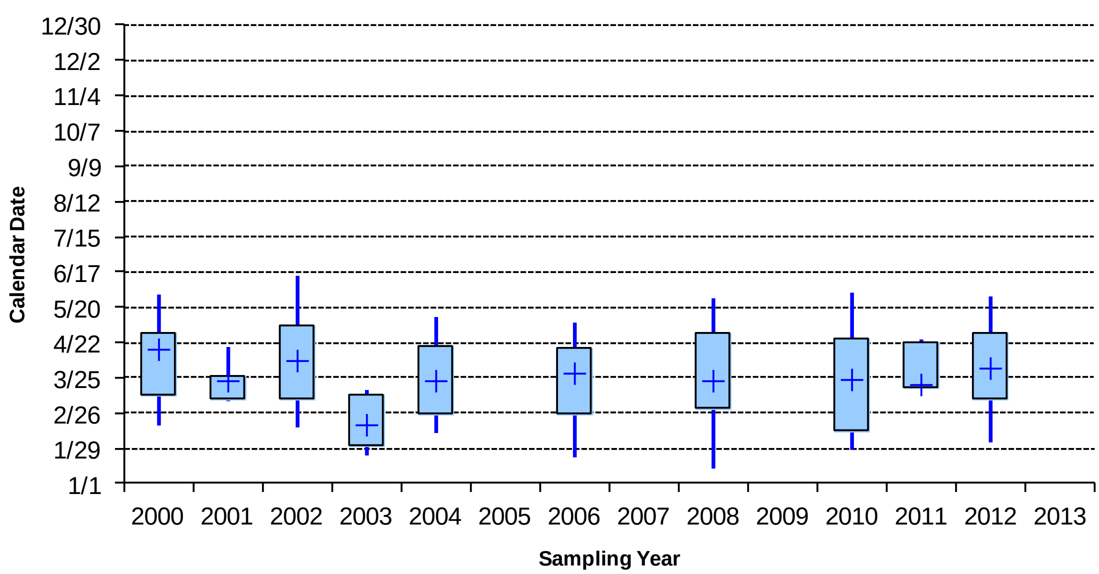
Figure 6.2. Average daily fork lengths for pink smolts caught during 2012

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 54 days during which 90% of pink salmon out-migrate. The median outmigration date for the 2012 season was April 2.

It is possible that the low sampling effort during the pink salmon outmigration window in previous seasons 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. In the 2012 season there was a much increased sampling effort during the February/March time period which likely means that the information for that season is less prone to bias caused by large interpolation intervals.

The very low number of pink salmon caught outmigrating during the 2001, 2003, and 2011 seasons makes determining the outmigration window for these seasons very problematic. Accordingly, the outmigration periods for these seasons are not included with the results from even-numbered years.



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

Figure 6.3. Comparison of outmigration window for pink salmon smolts by season

6.5 Zero-Age Pink Salmon Outmigrants

6.5.1 CPUE Time Series for Zero-Age Pink

In 2012 the pink salmon outmigration began on early February and ended by late May. However, most smolts outmigrated from the end of March through the end of April. The highest catch rate for pink smolts during the 2012 season was 328.8 smolts per hour, which occurred on March 31 (Figure 6.4).

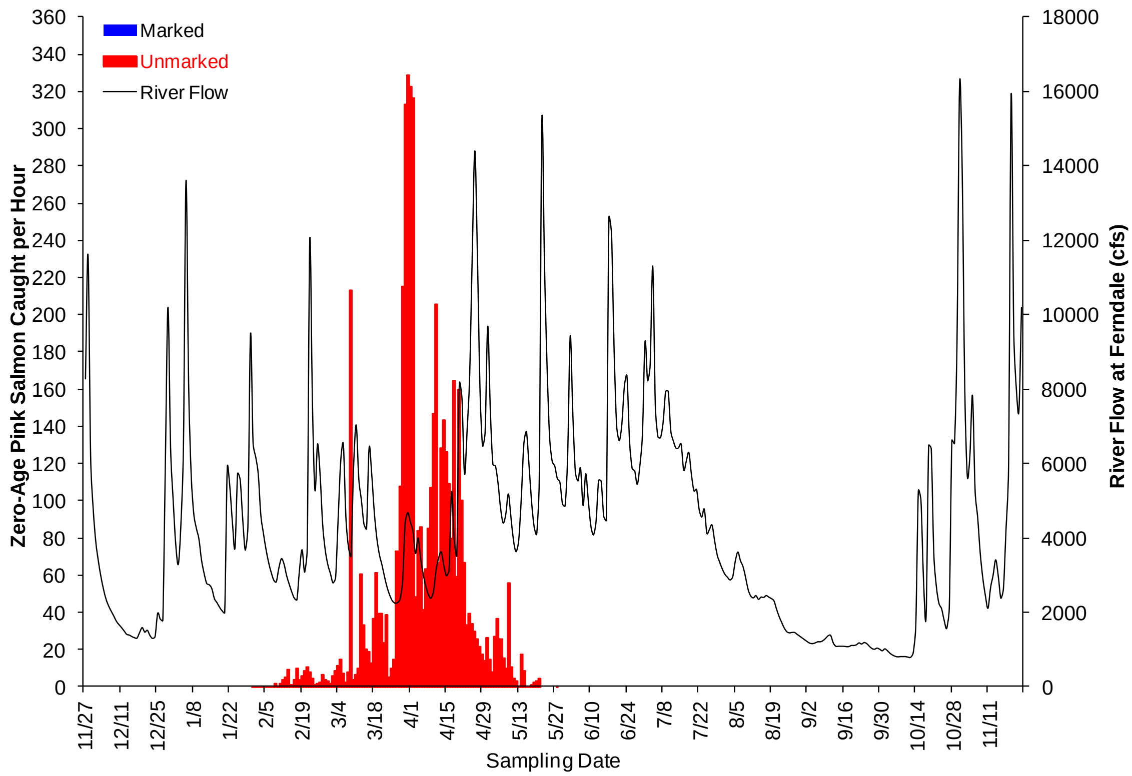


Figure 6.4. Interpolated catch per hour of zero-age pink smolts by date vs. flow in 2012

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 previous high of 3,119 in 2000 (Table 6.1). The index score for the 2012 season set a new high value of just over 5,000 indicating that brood year 2011 cohort is the strongest year class of pink salmon to be produced from the Nooksack River since at least 1999.

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 previous 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 (the lowest index of abundance score) (Table 3.7). On the other hand, the favorable incubation conditions for brood year 2011 may have helped contribute to the strength of the year class.

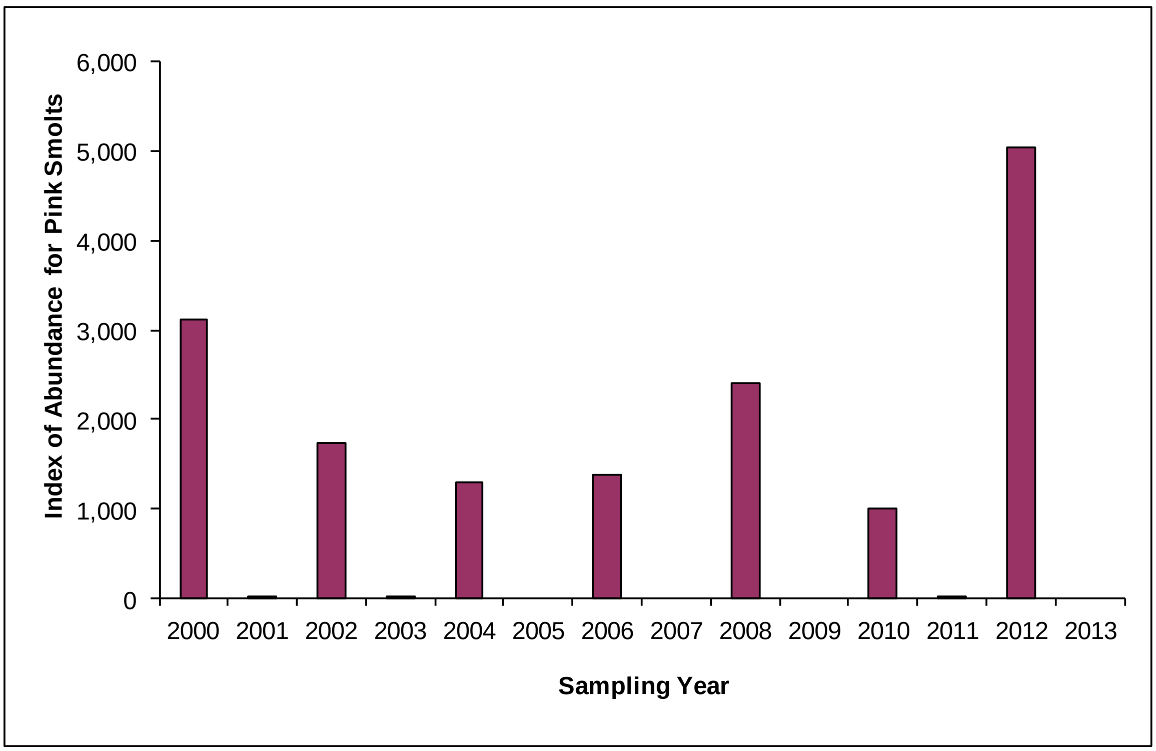


Figure 6.5. Comparison of the Index of Abundance for pink salmon by sampling year

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 out-migrate, and they are the smallest of the outmigrating salmonids when they move downstream.

The number of pink salmon outmigrants does not appear to be closely linked to incubation flows, nor to chum salmon outmigrant index scores. It may be that ocean survival may be an important factor in year class strength for pink salmon. If that is the case, and the high index of abundance for pink salmon outmigrants in 2012 indicates that a large number of adults returned to spawn in 2011, then this may indicate that generally favorable ocean conditions were present when those adults (BY 2009) outmigrated as smolts in 2010. If this hypothesis holds true, then we might expect to see improved returns of other brood year 2009 salmon when they return as adults.

7.0 Sockeye Salmon Results and Discussion

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 just 4 sockeye salmon smolts caught during the 2012 sampling season, and 9 caught during the 2013 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		
2013	**0**	**9**	**0**	**0**	1,710.9	**0.94**
2012	**0**	**4**	**0**	**0**	1,894.4	**0.15**
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 that were 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 during different daylight conditions

Independent Variable	Dependent Variables							
	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day
Dusk		0.08	0.00	0.04		0.461*	-0.01	0.063
Night	0.461*		1.00	0.15	2.82		N/A	0.041
Dawn	-0.01	N/A		0.00	0.00	0.00		-0.011
Day	0.063	0.041	-0.011		0.13	0.02	0.00	
	* Indicates a Statistically Significant Correlation							

7.3 Sockeye Salmon Fork Lengths

The average size of sockeye salmon caught in 2012 was 37.7 mm, with the smallest being 33 mm and the largest being 45mm. The average size of sockeye smolts caught in 2013 was 26.9 mm with the smallest being 24 mm and the largest being 31 mm. The difference in size may be a function of misidentification or timing. The sockeye caught in 2013 were caught in March whereas the sockeye caught in 2012 were caught in August (Figure 7.1).

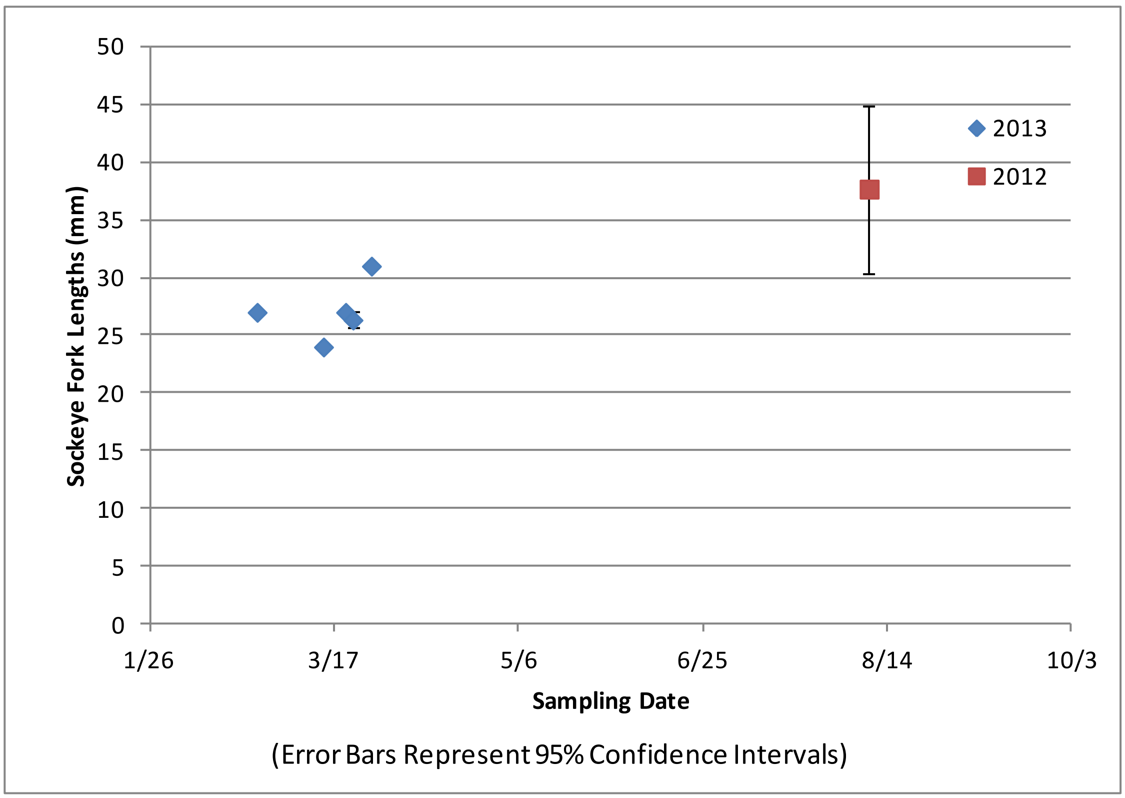
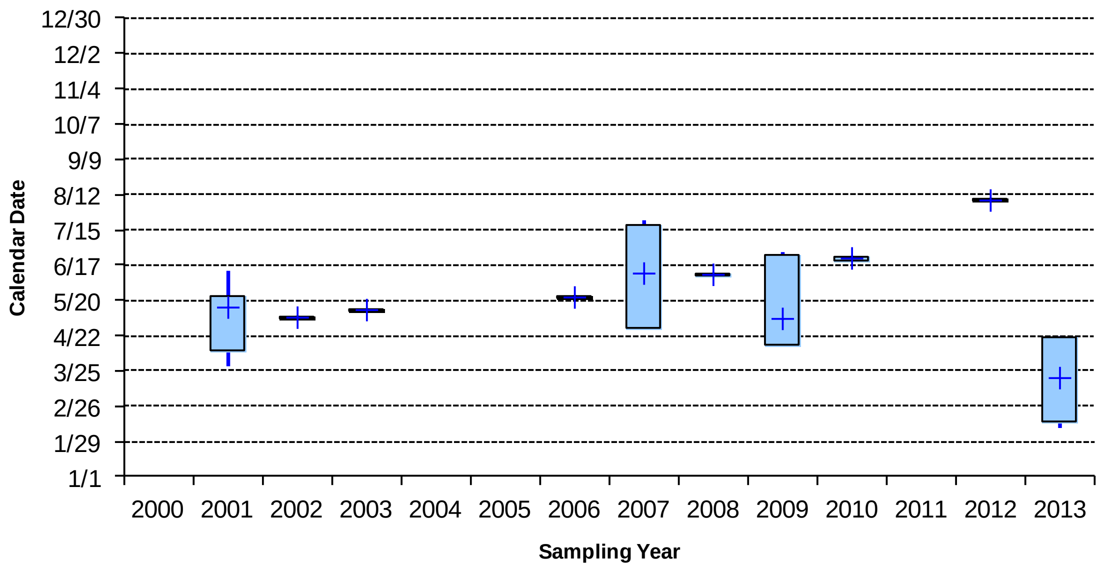


Figure 7.1. Average daily fork lengths for sockeye smolts caught during 2012 and 2013

7.4 Sockeye Salmon Seasonal Outmigration Timing

The timing of the sockeye outmigration period has been extremely variable over time (Figure 7.2). Across all seasons, the median outmigration date for sockeye salmon is May 26, with the main window of outmigration typically occurring between May 12 and June 7, lasting approximately 26 days on average. However, the outmigration period calculated for most years is exceptionally short. This is because the total catch of sockeye salmon smolts during those years was just 1 - 4 smolts. In years with only one smolt, the ranges indicated on Figure 7.2 are the result of interpolation during gaps in the trap schedule. The outmigrating timing in 2012 was the latest outmigration time for the period of record, while the timing of outmigration in 2012 was the earliest in the period of record. The very low numbers of sockeye caught probably make the observed timing of outmigration extremely fickle.



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

Figure 7.2. Comparison of outmigration for sockeye salmon smolts by season

7.5 Zero-Age Sockeye Outmigrants

7.5.1 CPUE Time Series for Zero-Age Sockeye

In 2012 sockeye salmon were only caught in the trap on August 9 (Figure 7.3). In 2013 the sockeye salmon outmigration began in early February and ended by mid-April (Figure 7.4).

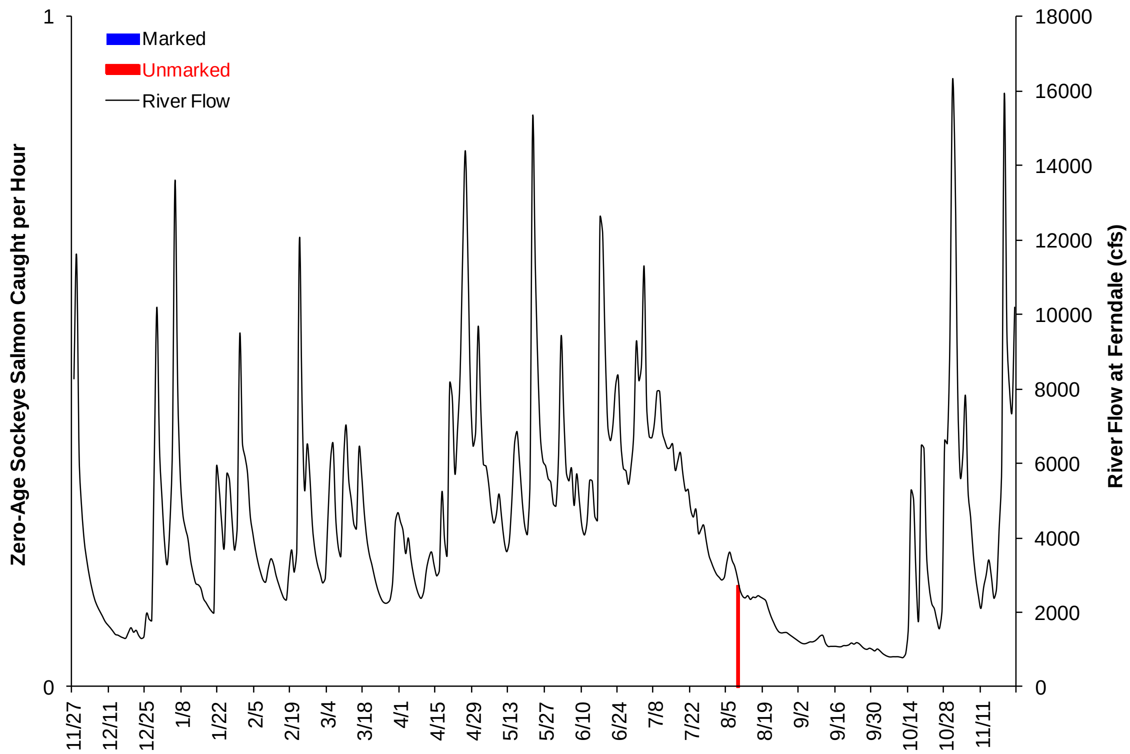


Figure 7.3. Interpolated catch per hour of sockeye smolts by date vs. flow in 2012

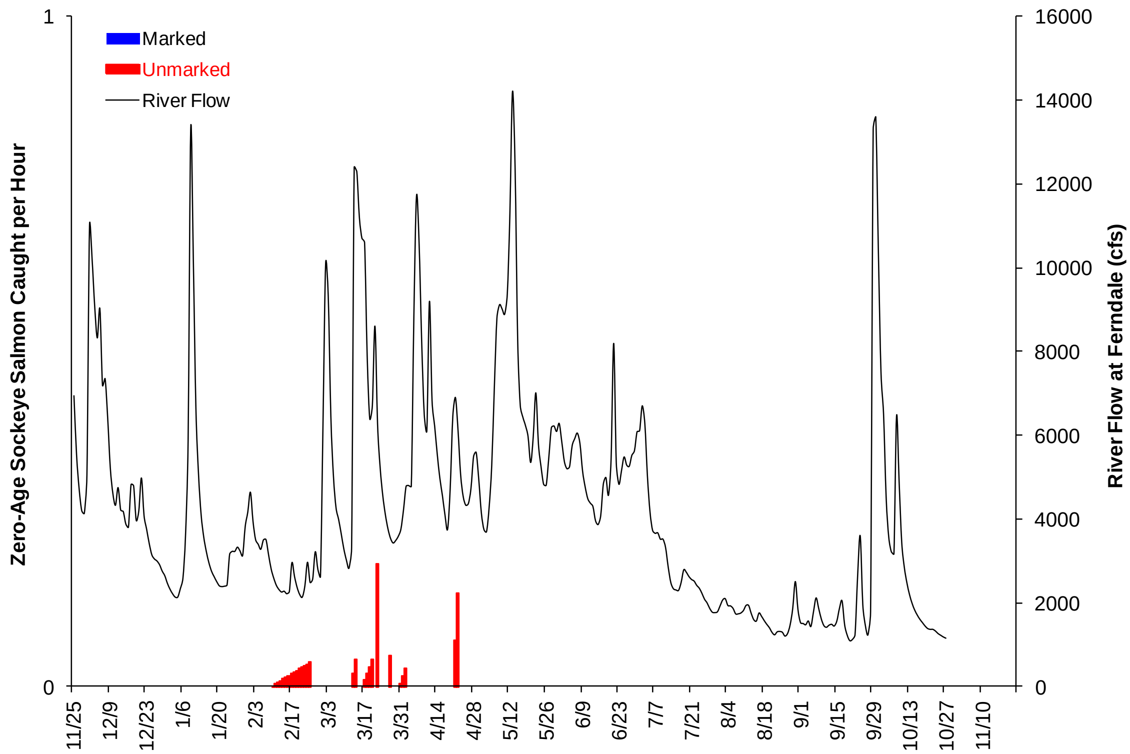


Figure 7.4. Interpolated catch per hour of sockeye smolts by date vs. flow in 2013

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 7.5). The second and third highest sockeye index scores were for the 2009 and 2007 outmigration seasons. Index scores for the remaining seasons, including 2012 and 2013, 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.

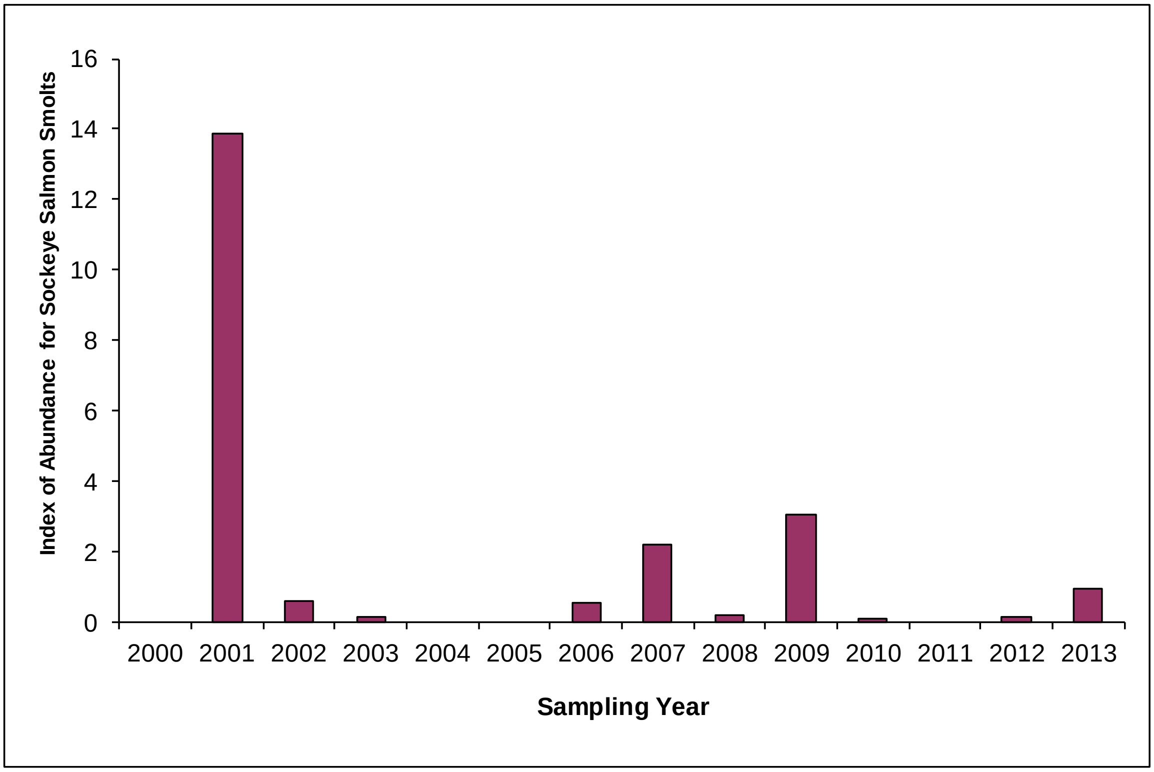


Figure 7.5. Comparison of the Index of Abundance for sockeye salmon by sampling year

7.6 Sockeye Discussion

Sockeye salmon smolts typically out-migrate 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 true 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 Results and Discussion

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			
5/8 - 5/10/2013	**Kendall**	**Kendall Creek**	118,806	**0**	**0**	**0**	118,806	118,806
5/7/2012	**Kendall**	**Kendall Creek**	115,895	**0**	**0**	**465**	115,895	116,360
May-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, 1,347 steelhead smolts were caught in the 2012 season. Of these, 895 were recorded as having their adipose fin clipped, and 452 were recorded as unclipped. During the 2013 season, 924 steelhead outmigrants were caught. Of these, 510 were adipose fin clipped and 414 were not adipose fin clipped.

Unfortunately, because the emphasis of the screwtrap program is on Chinook and coho, many of the field crewmembers have historically 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 sometimes been compromised and the yearly totals for each mark status are fairly meaningless. As a consequence, even though the index of abundance for unclipped steelhead outmigrants is calculated and displayed in Table 8.2, no further analysis of the relative abundance of steelhead will be attempted.

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			
2013	**510**	**414**	1710.9	**48.9**	**100%**
2012	**895**	**452**	1894.4	**158.6**	**99.60%**
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 Fork Lengths

Overall, clipped steelheads that are caught in the Trap tend to be larger than unclipped steelhead, although the sizes of steelhead are highly variable and considerable overlap exists between the two groups. Clipped steelhead fork lengths averaged 178.6 mm in 2012, and 186.7 in 2013. Unclipped steelhead fork lengths averaged 129.1 mm in 2012, and 149.9 mm in 2013. Interestingly, a clipped adult steelhead that was 580mm was caught in the screwtrap during March 2012.

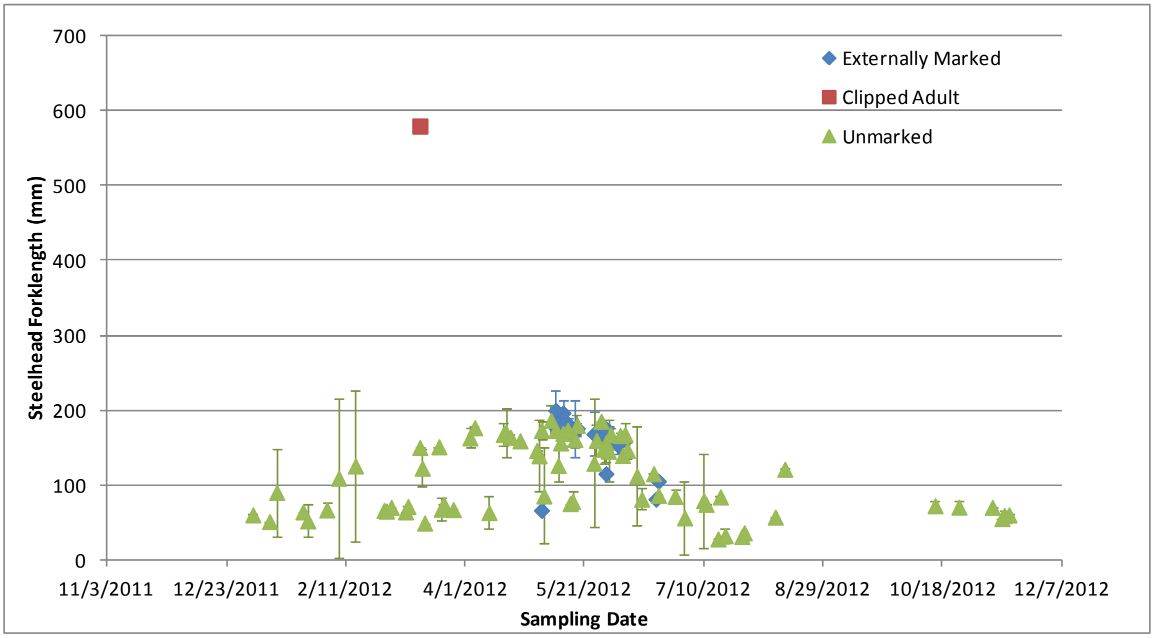
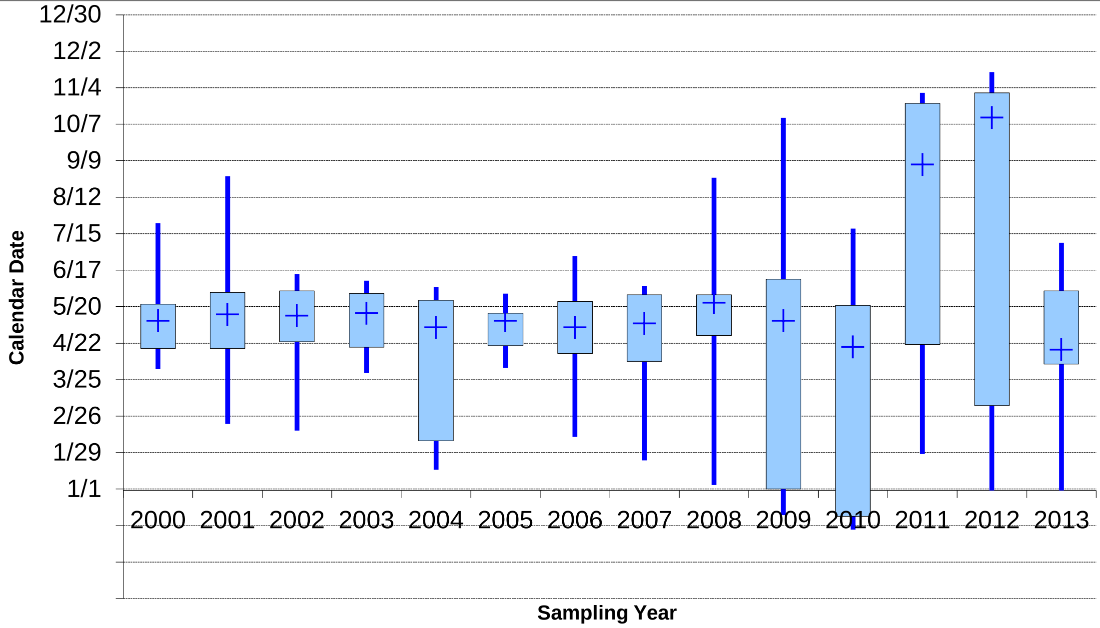


Figure 8.1. Average Daily Fork Lengths for Steelhead Outmigrants Caught During 2012

8.4 Steelhead Seasonal Outmigration Timing

The timing of steelhead outmigration in 2012 was strongly skewed by the existence of long interpolation intervals in October 2012 that began/finished with a single relatively high catch rate set. As was also true in 2011, this resulted in a much higher-than-usual interpolated catch per hour during this period of the year (Figure 8.3). The net result of this was that the outmigration period for 2012 appears to be significantly later than in most previous seasons. However, the prolonged period of high catch rates in October 2012 is most like to be an artifact of interpolation.

The outmigration window for the 2013 season was much more typical of most years with the bulk of outmigrants being caught from early April to late May.



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 after the normal peak outmigration window for zero-age Chinook smolts. This issue probably explains the anomalous results for 2011 and 2012.

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 2012 season was 6.8 fish per hour, which occurred on May 8. The highest catch rate for 'clipped' steelhead trout was 11.5 fish per hour, which occurred on May 9. The highest catch rate for 'unclipped' steelhead trout in the 2013 season was 25.8 fish per hour, which occurred on April 19. The highest catch rate for 'clipped' steelhead trout was 8.5 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 an atypical catch of steelhead in October of the 2012 season meant that the abundance of steelhead was strongly exaggerated during that month. It is unlikely that the late 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, 2010, and 2011 seasons, although in two of those seasons the interpolation problems arose in the early part of the season instead of at the end.

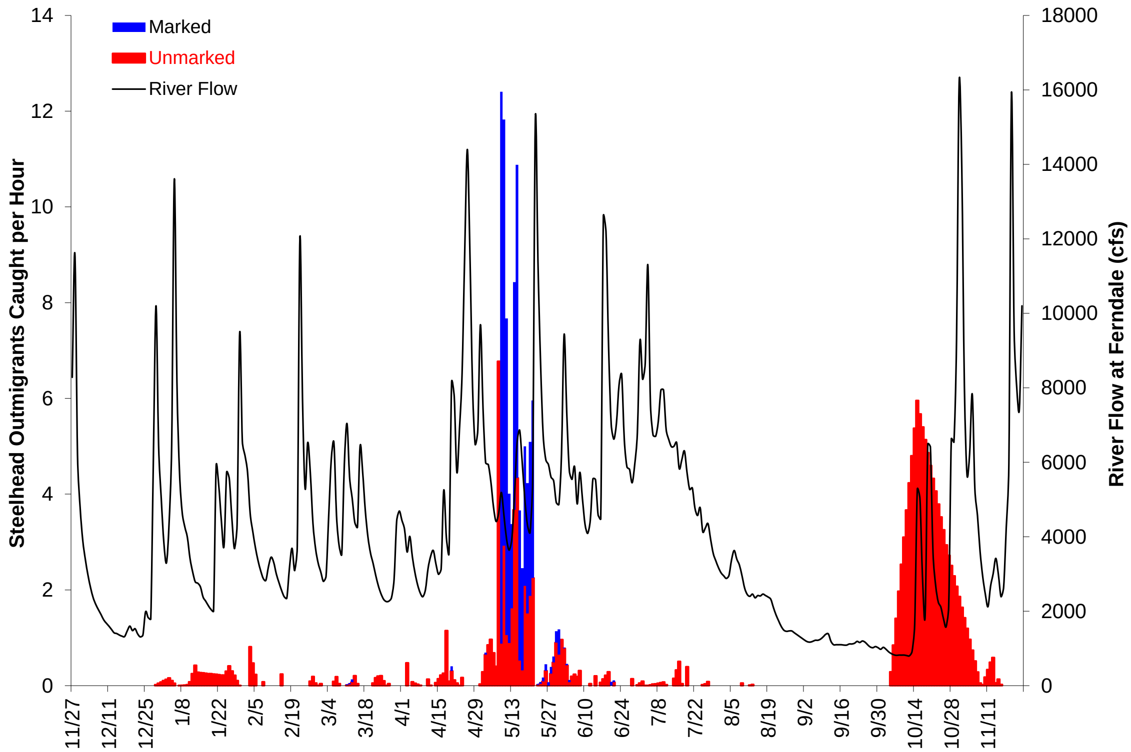


Figure 8.3. Interpolated catch per hour of steelhead outmigrants during 2012

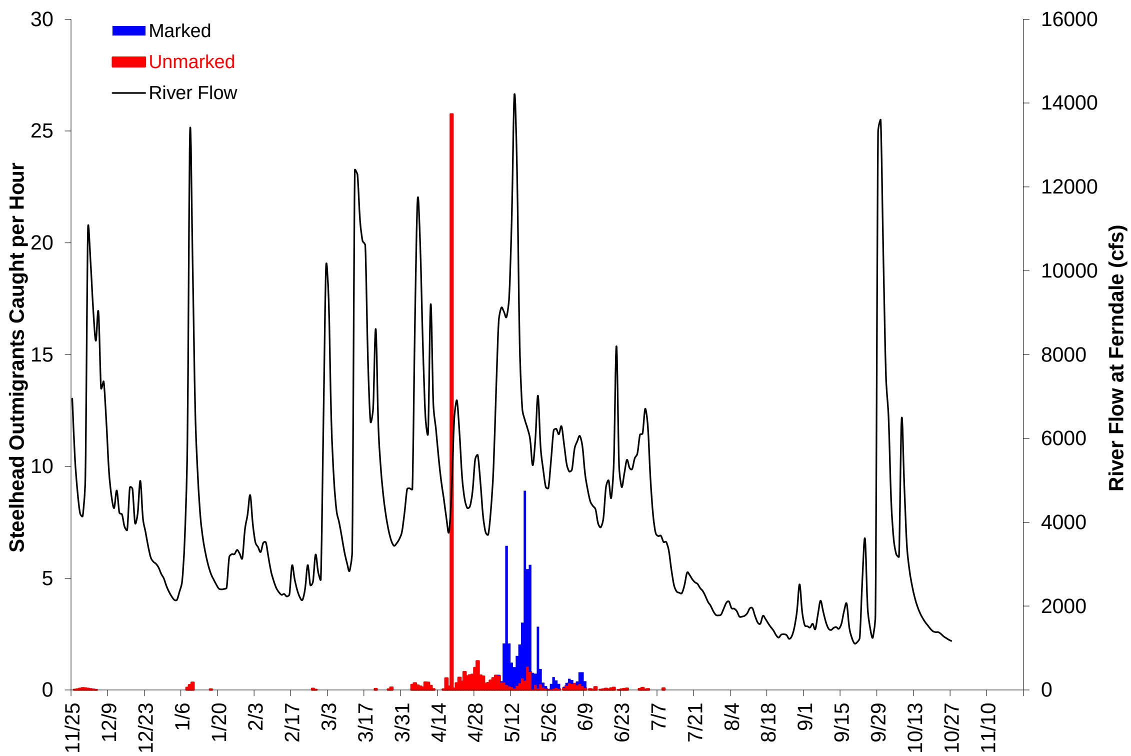


Figure 8.4. Interpolated catch per hour of steelhead outmigrants during 2013

8.6 Steelhead Production Estimates in the 2010 Season

8.6.1 Peterson Estimate for Steelhead

In 2012, 115,895 marked smolts were released from Kendall hatchery. Of these, 895 were recaptured during Trap operations. A further 452 unmarked smolts were also caught. The Peterson estimate for steelhead smolts in 2012 is 174,361 smolts. Deducting known marked and unmarked hatchery-origin smolts leaves an estimate of **58,001** wild-origin steelhead smolts outmigrating in 2012.

In 2013, 118,806 marked smolts were released from Kendall hatchery. Of these, 510 were recaptured during Trap operations. A further 414 unmarked smolts were also caught. The Peterson estimate for steelhead smolts in 2013 is 227,497 smolts. Deducting known marked and unmarked hatchery-origin smolts leaves an estimate of **96,256** wild-origin steelhead smolts outmigrating in 2013.

8.7 Between-Year Comparisons for Steelhead Production Estimates

The raw numbers of unmarked steelhead caught from 2011 to 2013 are the three highest seasonal totals to-date. However, this trend is largely due to the increased total effort sampling in the past three seasons.

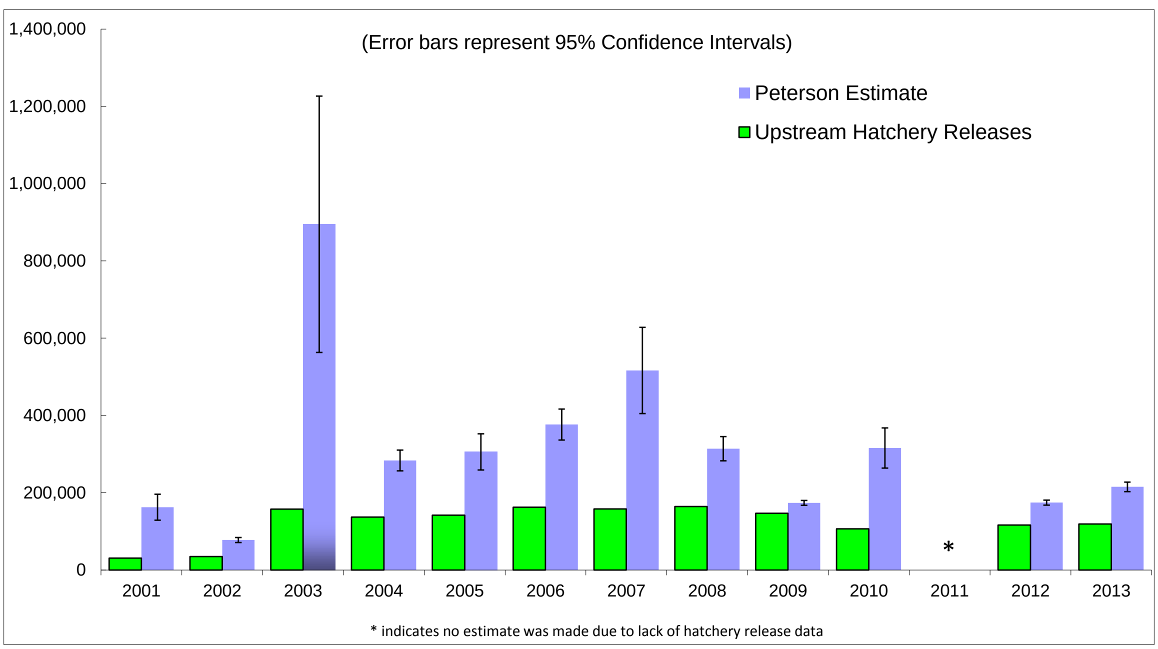


Figure 8.5. Comparison of Peterson estimates for steelhead by season

8.8 Steelhead Discussion

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 due to the effect of long interpolation intervals when high counts of steelhead catches occur either early or late in the year. Additionally, the large year-to-year variability in catch rates for marked steelhead when hatchery releases are relatively consistent indicate that there are large unexplained differences in Trap catch efficiency for these fishes. This may be due to the much larger size of steelhead smolts compared to other species that are quantified in this report. These issues preclude 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. The results for steelhead are reported more for the sake of transparency than because they are useful.

9.0 Other Species Results

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 2013 is provided in Table 9.1.

Table 9.1. Organisms present in trap catch between 2006 and 2013

Salmonids	Total Count	Non Salmonid Fish	Total Count	Invertebrates	Total Count	Amphibians	Total Count
Bulltrout/Char	34	Bass	607	Crayfish	3	Tadpoles	15
Chinook	123,863	Dace	123			Frog	9
Chum	203,025	Lamprey (eyes)	2,368				
Coho	75,827	Lamprey (no eyes)	707				
Cutthroat	241	River Lamprey	1				
Pink	91,099	Longfin Smelt	1				
Rainbow Trout	2	Mountain Whitefish	11				
Sockeye	133	Perch, Yellow	8				
Steelhead	7,095	Pumpkin Seed	20				
Trout - Indeterminate	36	Sculpin	112				
		Starry Flounder	5				
		Stickleback	12,242				
		Sucker	4				

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: prior to the 2006 field season, non-salmonid bycatch was not entered into the juvenile salmon database.

Table 9.2. Catch totals and Index of Abundance by year for selected species

Sampling	Cutthroat Trout		Bull Trout		Lamprey (eyes)		Sticklebacks		Sculpins		
Year	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	Counts	Index of Abundance	Hours Fished
2013	**20**	**1.4**	**4**	**0.26**	**696**	**67.2**	**1197**	**138**	**20**	**3.5**	1710.9
2012	**13**	**0.8**	**13**	**1.4**	**264**	**22.5**	**390**	**38.5**	**10**	**0.7**	1894.4
2011	30	3.0	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

10.0 Mortality Rates Results

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; Table 10.2). In some instances the cause of death can be ascribed to mechanical damage due to an excess of debris in the cone of the Trap, 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, and otolith).

Table 10.1 Summary of mortalities and count of fishes handled at the trap in the 2012 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	13	0%
Chinook	Yearling	Hatchery	0	0	0	1	0%
Chinook	Yearling	Wild	0	0	0	31	0%
Chinook	Zero-Age	Hatchery	5	1	0	11,247	0.10%
Chinook	Zero-Age	Wild	7	9	0	3,957	0.40%
Chum	Yearling	Wild	0	0	0	2	0%
Chum	Zero-Age	Wild	0	0	0	31,603	0%
Coho	Yearling	Hatchery	1	0	0	15,473	0%
Coho	Yearling	Wild	0	0	0	5,121	0%
Coho	Zero-Age	Wild	0	0	0	95	0%
Cutthroat	Not Recorded	Wild	0	0	0	12	0%
Cutthroat	Yearling	Wild	0	0	0	1	0%
Dace	Not Recorded	Wild	0	0	0	1	0%
Lamprey (eyes)	Not Recorded	Wild	0	0	0	264	0%
Lamprey (no eyes)	Not Recorded	Wild	0	0	0	221	0%
Pink	Zero-Age	Wild	3	2	0	42,264	0%
Pumpkin Seed	Not Recorded	Wild	0	0	0	1	0%
Rainbow Trout	Not Recorded	Wild	0	0	0	1	0%
Sculpin	Not Recorded	Wild	0	0	0	10	0%
Sockeye	Zero-Age	Wild	0	0	0	4	0%
Steelhead	Mature Adult	Hatchery	0	0	0	1	0%
Steelhead	Not Recorded	Hatchery	0	0	0	892	0%
Steelhead	Not Recorded	Wild	0	0	0	437	0%
Steelhead	Yearling	Hatchery	0	0	0	2	0%
Steelhead	Yearling	Wild	0	0	0	15	0%
Stickleback	Not Recorded	Wild	0	0	0	390	0%

Table 10.2. Summary of mortalities and count of fishes handled at the trap in the 2013 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	4	0%
Chinook	Yearling	Wild	0	0	0	114	0%
Chinook	Zero-Age	Hatchery	84	1	0	15,716	0.50%
Chinook	Zero-Age	Wild	15	1	0	2,428	0.70%
Chum	Not Recorded	Wild	0	0	0	335	0%
Chum	Zero-Age	Wild	103	8	0	15,814	0.70%
Coho	Yearling	Hatchery	0	0	1	1,409	0.10%
Coho	Yearling	Wild	12	0	0	1,444	0.80%
Coho	Zero-Age	Wild	0	0	0	40	0%
Cutthroat	Mature Adult	Wild	0	0	0	5	0%
Cutthroat	Not Recorded	Wild	1	0	0	15	6.70%
Dace	Not Recorded	Wild	0	0	0	4	0%
Lamprey (eyes)	Not Recorded	Wild	0	0	0	696	0%
Lamprey (no eyes)	Not Recorded	Wild	0	0	0	193	0%
Longfin Smelt	Not Recorded	Wild	0	0	0	1	0%
Pink	Mature Adult	Wild	0	0	0	7	0%
Pumpkin Seed	Not Recorded	Wild	0	0	0	3	0%
Sculpin	Not Recorded	Wild	0	0	0	20	0%
Sockeye	Zero-Age	Wild	0	0	0	9	0%
Starry Flounder	Not Recorded	Wild	0	0	0	1	0%
Steelhead	Not Recorded	Hatchery	15	0	0	510	2.90%
Steelhead	Not Recorded	Wild	2	1	0	414	0.70%
Stickleback	Not Recorded	Wild	0	0	0	1,197	0%
Sucker	Not Recorded	Wild	0	0	0	1	0%
Trout - Indeterminate	Zero-Age	Wild	0	0	0	1	0%

In the 2012 and 2013 sampling seasons, the mortality rate for most groups of fishes was low relative to previous seasons (Figure 10.1). The highest mortality rate was for cutthroat trout in 2013 where 1 fish out of a total of 15 cutthroat trout caught was accidentally killed. However, mortality rates for Chinook, coho, chum, and pink salmon outmigrants were generally well below 1%.

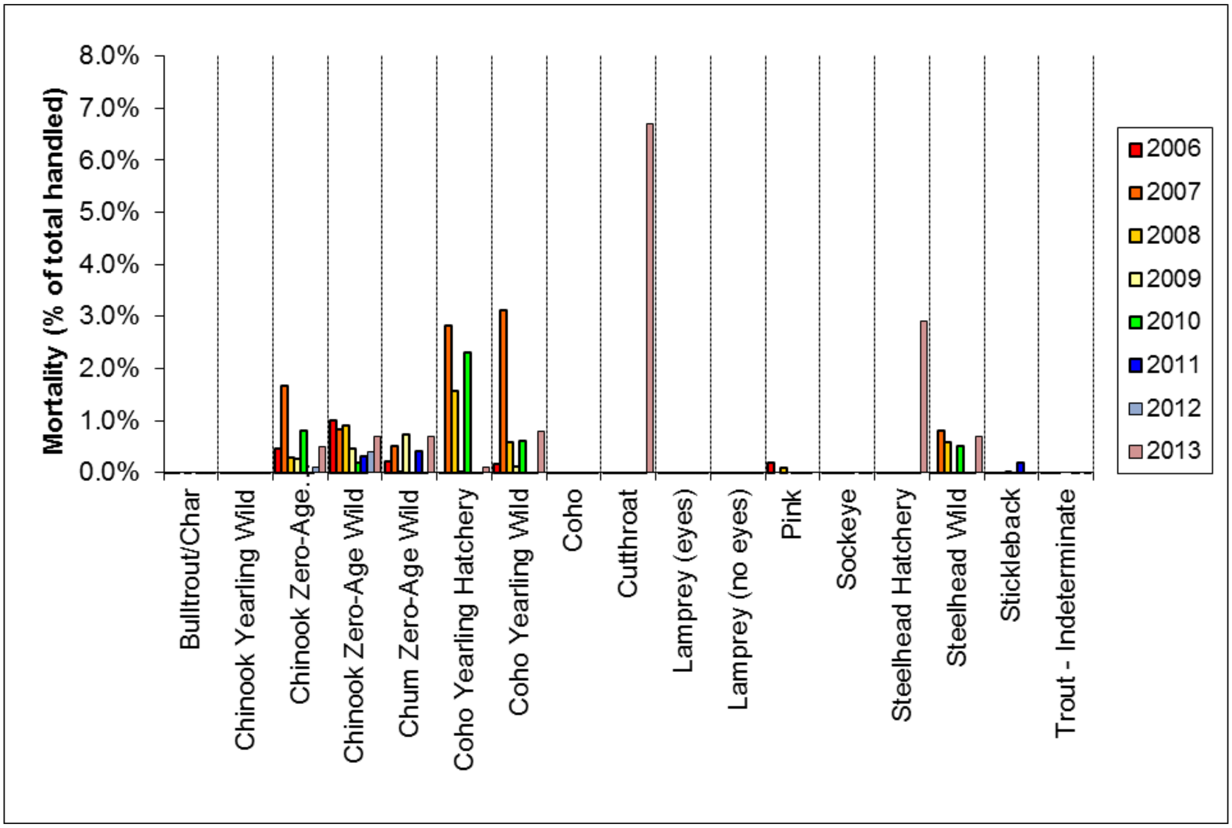


Figure 10.1. Comparison of mortality rates at the trap by sampling year

11.0 References

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