Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska

Progress Report for 2015

For Alaska Department of Fish and Game
Contract IHP-13-013

Volume 1

Authors:
Eric Knudsen, Peter Rand, Kristen Gorman, and Julia McMahon
Prince William Sound Science Center
P.O. Box 705
Cordova, AK 99574

Ben Adams and Victoria O'Connell
Sitka Sound Science Center
834 Lincoln St., Suite 200
Sitka, AK 99835

David R. Bernard
D.R. Bernard Consulting, LLC
2481 NW 87th Avenue
Ankeny, IA 50023-8829

November 18, 2016

Table of Contents

ABSTRACT

This is the fourth in a series of annual reports on data collection and analysis for studies of hatchery-wild interactions of Pink Salmon in Prince William Sound (PWS) and Chum Salmon in PWS and Southeast Alaska (SEAK). This work was performed by the Prince William Sound Science Center under contract to Alaska Department of Fish & Game. The SEAK portion was further subcontracted to Sitka Sound Science Center. Hatchery Pink Salmon and Chum Salmon in Alaska have thermal-marked otoliths that were used to determine hatchery or wild origin through samples collected at sea and in streams. As in 2013 and 2014, ocean sampling was conducted at nine stations near the entrances to PWS in 2015. Otoliths from 2,278 Pink Salmon and 1,296 Chum Salmon were analyzed for thermal marks indicating hatchery or wild origin. The overall 2015 proportion of hatchery fish across all ocean stations was 55% for Pink Salmon and 69% for Chum Salmon. The proportions of hatchery fish in the ocean sampling varied by station and time. Stream studies were conducted in 2015 for two major purposes: an analysis of straying of hatchery-origin spawners into natural populations in all study streams; and an investigation of the relative survival of hatchery-origin and wild-origin offspring following natural spawning (results of the latter will be forthcoming after DNA tissue analyses are completed). In 2015 field sampling on the spawning grounds, 88,749 individual fish of both species were sampled during repeated visits to 64 streams for both studies combined. Otoliths were collected from all specimens for identification of possible hatchery origin. Fractions of hatchery Pink Salmon were estimated for 28 PWS spawning populations and hatchery fractions of Chum Salmon were estimated for 17 PWS and 32 SEAK streams. Fractions in each case were estimated by stream, then by district (PWS) or Sub-region (SEAK), and then by region. PWS Pink Salmon hatchery fractions in 2015 ranged from 0.00 to 0.81 in individual streams. PWS Pink Salmon hatchery fractions tended to be high only in certain districts, such as the Eshamy District (0.81) and the Southwestern District (0.34). The estimated PWS-wide Pink Salmon hatchery fraction in spawning streams was 0.10. PWS Chum Salmon stream hatchery fractions were all equal to or less than 0.08, except in Siwash, Swamp, and Cabin Creeks where the hatchery fractions were 0.33, 0.79, and 0.90, respectively. The PWS-wide Chum Salmon stream hatchery fraction was estimated to be 0.03. Hatchery fractions in 32 SEAK Chum Salmon streams were similarly mostly low (≤0.20) except Sawmill, Glen, Prospect, and Fish Creeks where the hatchery fractions were 0.38, 0.40, 0.50, and 0.87, respectively. The SEAK-wide estimated Chum Salmon stream hatchery fraction was 0.09. Using information from both ocean sampling and field sampling programs, as well as data from the commercial fisheries, an estimated 140.9 million Pink Salmon entered PWS in 2015 of which an estimated 63.5 million were wild fish and 77.3 million were hatchery fish. An estimated 3.6 million Chum Salmon entered PWS in 2015 of which 1.1 million were wild fish and 2.5 million were hatchery fish.

INTRODUCTION

Prince William Sound Science Center (PWSSC) and its sub-contracting partner Sitka Sound Science Center (SSSC) are engaged in scientific data collection and analysis services requested under the State of Alaska contract IHP-13-013 entitled "Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska". This is the fourth annual report, focusing on the results of 2015 data collection and analysis, as well as summarizing some results from 2013 through 2015.

The plans and intentions of this contracted research are guided by two documents: 1) the ADF&G RFP 2013-1100-1020, dated May 7, 2012 entitled "Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska and 2) the PWSSC proposal for the project, dated June 29, 2012. The overarching purposes of this research are to:

- Estimate the proportion of the annual runs of Pink Salmon and Chum Salmon in Prince William Sound (PWS) comprised of first-generation offspring of hatchery salmon.
- Determine the extent and annual variability in straying into natural streams of hatchery Pink Salmon in PWS and Chum Salmon in PWS and Southeast Alaska (SEAK), and
- Assess the impact on fitness (productivity) of wild Pink Salmon and Chum Salmon stocks due to straying of hatchery fish into natural streams.

The 2015 field research was organized into three major activities:

- Ocean sampling near PWS entrances to estimate hatchery fractions of Pink Salmon and Chum Salmon runs;
- Adult sampling in streams to estimate the hatchery fractions of spawning salmon and to collect DNA samples for fitness studies; and
- Sampling of alevins from the gravel in two experimental streams for collecting DNA tissues for the fitness studies.

Adult salmon sampling in streams was further subdivided into PWS and SEAK activities implemented by PWSSC and SSSC, respectively. The 2015 adult sampling results are presented in this report.

The second spring sampling of alevins (2014 and 2015) in fitness study streams followed the second summer sampling of their parents (2013 and 2014) and the 2015 alevin sampling results are reported here.

The methods in this report reflect guidance in the RFP, some refinements made following the 2012 preliminary field season (Buckhorn et al. 2013), the 2013 full season (Knudsen et al. 2015a), and the 2014 field season (Knudsen et al. 2015b), as well as changes made as a result of consultation with the Science Panel in November 2012, December 2013, December 2014, and April 2015. A complete, revised 2015 field sampling protocol is presented in Appendices A-E.

This report includes summaries of sample collection during 2015 for estimating hatchery fractions and for the DNA-based fitness studies. DNA samples were delivered to the ADF&G Gene Conservation Lab and the subsequent fitness analysis will be reported later. This report includes analysis of hatchery proportions of Pink Salmon and Chum Salmon from the ocean sampling and analysis of hatchery fractions by stream, district or sub region, and region. It also includes estimates of the total run sizes of wild and hatchery-origin Pink Salmon and Chum Salmon in PWS. Last, sampling activities for alevins from Fish and Stockdale Creeks in spring of 2015, for part of the fitness study, are reported here.

REFERENCES

Buckhorn, M., T. Kline, and V. O'Connell. 2013. Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska. Annual Report 2012 for Contract IHP-13-013. Prince William Sound Science Center, Cordova.

Knudsen, E., M. Buckhorn, K. Gorman, D. Crowther, K. Froning, M. Roberts, L. Marcello, B. Adams, V. O'Connell, D. Bernard. 2015a. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2013, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

Knudsen, E., M. Buckhorn, K. Gorman, P. Rand, M. Roberts, B. Adams, V. O'Connell, D. Bernard. 2015b. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2014, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

PWS OCEAN SAMPLING 2015 SEASON

Authors - Pete Rand, Eric Knudsen, David Bernard

Introduction

The purpose of the ocean test fishery was to intercept salmon at the entrances of Prince William Sound to better estimate the proportion of hatchery to wild salmon throughout the Sound. Commercial fishery samples target hatchery fish and do not represent the true ratio of wild to hatchery fish in Prince William Sound. So sampling over 2013, 2014, and 2015 was intended to provide information on interannual variation on hatchery fractions while within-season sampling provided hatchery fractions plus near real-time run size indices on a bi-weekly basis. The results of the PWS ocean sampling also contributed in part to the estimation of the following (see PWS run-size section below):

- number of wild salmon spawning in the wild;
- number of hatchery salmon spawning in the wild (hatchery strays);
- total production of hatchery salmon (including hatchery strays); and
- total production of wild salmon (excluding hatchery strays).

Methods

Fish Collection Methods

The ocean sampling fishing portion of the work during the 2015 field season was conducted aboard a contracted 32' commercial fishing vessel named the F/V Rebound operated by Brad Reynolds, M.S., the same vessel and operator as in the previous two years. The sampling season for ocean-run Pink Salmon and Chum Salmon occurred from May 15 to August 30, 2015 with only slight modifications in the methods from 2013 (to improve catchability), and no changes from 2014. Fishing occurred at nine systematically selected stations, three of which were spaced approximately equidistant across Hinchinbrook Entrance (named Hinchinbrook stations H01, H02, and H03) and the remaining six (named Montague stations M01, M02, M03, M04, M05, and M06) across the entrances[1] to PWS just west of Montague Island (Figure 1).

The vessel made sets beginning in the area of each fixed station (Figure 1) using a 200-fathom drift gillnet consisting of four panels with different ($4^{3/8}$, $4^{3/4}$, $5^{1/8}$, and $5^{1/2}$ inch) stretch mesh. All nine stations were fished over a 2-day period (labeled by TRIP ID) and the catch was delivered to personnel at PWSSC. There were normally two sampling trips per week. This was repeated for the entire fishing season with the exception of a few days not fished due to rough weather. Sets were planned to be a maximum of one hour using the entire 200 fathoms of net with adjustments to decrease these maximums in the case of large catches, vessel traffic, weather, or the presence of marine mammals. If the full 200 fathoms were not used after fishing all stations, then the net was reversed on the reel for the next round of fishing. Date, time, latitude and longitude were recorded in the database at: 1) the start and end of any periods of net

---

[1] M01 and M02 in Montague Strait, M03 and MO4 in Latouche Passage, M05 off Point Erlington, and MO6 in Prince of Wales Passage.

setting; 2) the beginning and end of any drift; and 3) the start and end of any net retrieval. Other data recorded included weather and tide state.

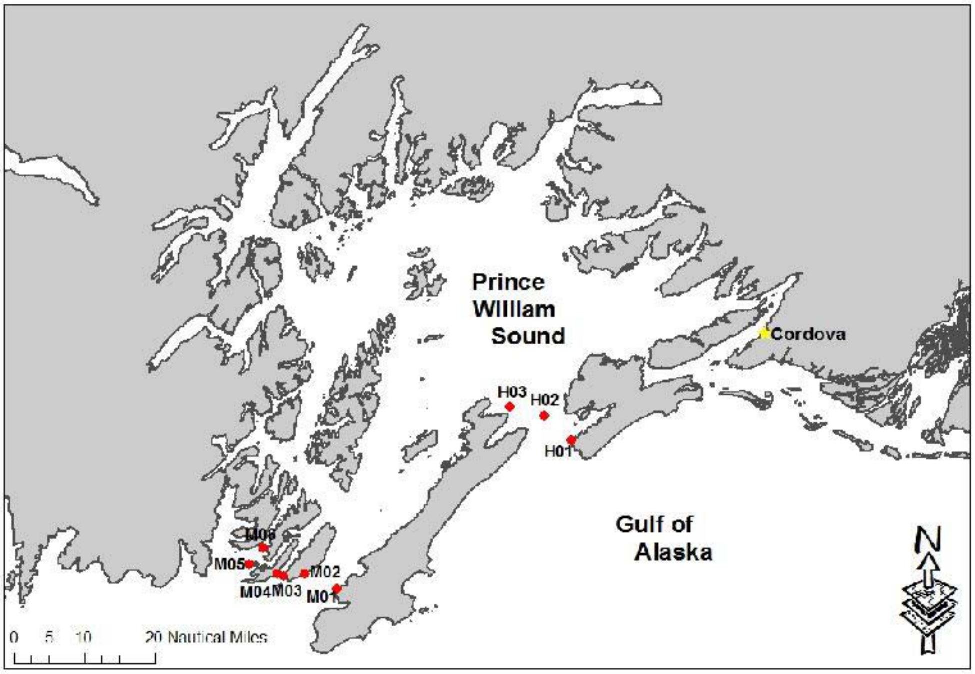


Figure 1. Ocean sampling stations in Montague Strait and Hinchinbrook Entrance.

Once the net was retrieved, fish were removed from the net and total number of each species in the catch was recorded. The target sample retained from each station (up to 20 per species from Hinchinbrook stations; 10 per species from Montague stations) was tagged with a color-coded Floy tag, bled in the field, and put on ice. Catches that exceeded the maximum target sample number per station were systematically subsampled to acquire the appropriate sample size. Chum Salmon and Pink Salmon samples beyond the maximum sample number were retained if it was determined they would not survive release. The same occurred for species of salmon that were not part of this study. All specimens retained were processed and the otoliths and data turned over to ADF&G (see Appendix A for complete fishing protocols).

Sample Processing Methods

Fish were delivered to PWSSC personnel and separated by station and species. The following fish morphometric data were collected to accompany the otolith extraction: total length (TL), standard length (SL), mid-eye socket to hypural bone length (MEH), total weight (TW), gonad weight (GW), and sex (S). Otoliths were extracted by making a horizontal cut from just above the eye straight back towards the posterior of the cranium. Otoliths were placed in individual cells in labeled trays and the tray and cell numbers were recorded for each fish in an electronic database following prescribed ADF&G methods (see Appendix A for complete sampling protocols).

Fish in good condition were gutted and returned to ice to be sold under the ADF&G commercial fishing permit. Fish that were not in sellable condition were disposed of at sea.

Otoliths were read by the ADF&G lab personnel in Cordova following their standard procedures. ADF&G personnel supplied the otolith reading results back to PWSSC and they were incorporated into the project database.

Data Analysis Methods

The objectives of the ocean sampling in 2013 - 2015 included estimating the fractions of hatchery fish in each run of Pink Salmon and Chum Salmon to PWS. The hatchery fractions and their variances were estimated at the trip within station, station, and entire Sound levels for each species. Because hatchery fraction estimates calculated from trip to trip were based on different total catches at each station, there was a need to first weight the fractions by the relative catch per unit of effort at each station on each trip.

Catch per Unit of Effort

All total catches were adjusted for comparability based on a standard unit of fishing effort: net fathoms times time fished. Fishing at each station on each day was characterized by setting the net, drifting it, sometimes adjusting the length of net, then retrieving it, and sometimes re-deploying and retrieving again. The expression below accounted for the simplest situation (one deployment, one drift, and one retrieval) or the more complex situation of multiple adjustments and drifts within one fishing event at a station (referred to later as one complete haul per station). A simplifying assumption is that, during deployment or retrieval, the net is fishing 50% of the deployment or retrieval time duration, even though the deployment or retrieval may not be exactly linear. Catch per unit of effort (CPUE) was calculated as:

$$CPUE = C_s /(((DS_1 - SB)/2)*L_1) + \sum_{d=1}^{n}(((DE_d - DS_d)*L_d)) +$$

$$\sum_{d=1}^{n}(((L_d*(DS_d - DE_{d-1})) + (((L_{d-1} - L_d)*((DS_d - DE_{d-1})/2))) + (((RE - DE_{d=n})/2)*L_{d=n})$$

Where C_s = number caught per date and station, L = fathoms of net, SB = set begin time, DS = drift start time, DE = drift end time, RE = retrieve end time, and *d* = drift number. The first term in the equation is the catch by species. The second term calculates the effort for the first deployment interval only (net length*time/2). The first summation calculates effort for one or more drifts in a given haul (i.e., station and date). The second summation calculates effort for any other intermediate deployments or retrievals. It accounts for the amount of net already out plus or minus 50% of the change in net length. The last term calculates effort during the final retrieval.

Estimates of Hatchery Fraction

There were 31 two-day fishing trips in 2015. Not all scheduled trips resulted in samples. There were four types of outcomes for the 31 scheduled trips for 9 stations (279 possible combinations) in 2015:

Outcome:	Comment:	Outcome frequency: Pink salmon	Chum salmon	Adjustment:
1. Target species caught, origin determined for all or some of the catch	Determination for only "some" due to subsampling large catches	227	207	None
2. Target species caught, origin determined for none of the catch	One target species caught, unable to determine origin from otolith	0	0	Exclude Trip – Most Calculations
3. No target species caught	CPUE = 0	51	71	Exclude Trip – Most Calculations
4. No fishing	Weather	2	2	Exclude Trip – All Calculations

Because there were catches of each species on almost every trip, the data were not truncated for extended gaps in catch as they were in 2013 (Knudsen et al. 2015a).

Trip Within Station

The fraction of hatchery fish in a catch from a specific trip at a specific station was estimated as

$$\hat{p}_{st} = \frac{z_{st}}{m_{st}} \tag{1}$$

where *s* is a specific station, t is a specific trip (date), m_{st} is the number sampled in the catch at station *s* during trip *t* of the target species for which origin was determined, and z_{st} is the number within m_{st} determined to be of hatchery origin.

By Station

Sample estimates of hatchery fractions for specific stations were weighted when combined to produce unbiased estimates of hatchery fractions for specific stations. Ideally weights would be based on numbers of Pink (or Chum) Salmon (*N*) passing near each station during a trip in relation to all the Pink (or Chum) Salmon passing during the season:

$$W_{st} = \frac{\text{a}_{st} N_{st}}{\sum_{t'=1}^{T_s} \text{a}_{st'} N_{st'}} \tag{2}$$

where t' represents trips to station *s* during the season including trip *t*, and $\text{a}_{st} = 1$ if the trip *t* to station *s* resulted in outcome 1 or $\text{a}_{st} = 0$ otherwise. Remember that, in 2015, $T_s = 31$ for both

Chum Salmon and Pink Salmon. Because values of the *N*s are unknown, catch per unit of effort (*CPUE*) was used as a surrogate. Note that catch *C* is a function of fishing effort (*E*), catchability (*q*), and abundance such that $C = qEN$, which makes $N = CPUE\ (1/q)$. Substitution into the equation above provides estimated weights in terms of catch per unit of effort:

$$\hat{W}_{st} = \frac{a_{st} CPUE_{st} (1/q_s)}{\sum_{t'=1}^{T_s} a_{st'} CPUE_{st'} (1/q_s)} = \frac{a_{st} CPUE_{st}}{\sum_{t'=1}^{T_s} a_{st'} CPUE_{st'}} \tag{3}$$

so long as the catchability is the same during all trips at station *s*. Fishing protocols at each station were standardized over the duration of ocean fishing to reduce variability in catchability, however, catch is a stochastic process even if catchability is a constant (see Appendix A). For these reasons surrogate weights add some uncertainty to estimated fractions, so weights were labeled $\hat{W}_{st}$ instead of W_{st}. The estimate for the fraction of hatchery fish at a specific station for the season was calculated as

$$\hat{p}_s = \sum_{t=1}^{T_s} \hat{W}_{st} \hat{p}_{st} \,. \tag{4}$$

Equation 4 is an unbiased estimator for a proportion estimated with random sampling without replacement through a two-stage design for each station. In our project, fish comprised the subsampling (second) stage and trips the first sampling stage.

For the Sound

The estimated mean fraction of hatchery-produced salmon of the target species in the overall PWS run for 2015 was calculated as the weighted average of the estimated fractions for stations:

$$\hat{\bar{p}} = \sum_{s=H01}^{H01 \cdots M06} \hat{W}_s \hat{p}_s \,. \tag{5}$$

Here the weights were based on the estimated mean CPUE for each station:

$$\hat{W}_s = \frac{\overline{CPUE}_s}{\sum_{s'=H01}^{H01 \ldots M06} \overline{CPUE}_{s'}} \tag{6}$$

$$\overline{CPUE}_s = \frac{\sum_{t=1}^{T_s} \mu_{st} CPUE_{st}}{\sum_{t=1}^{T_s} \mu_{st}} \tag{7}$$

where $\mu_{st} = 1$ if results during trip *t* to station *s* had outcomes 1, 2, or 3, and $\mu_{st} = 0$ if outcome 4.[2] Note that Equations 6 and 7 can be modified to estimate the hatchery fraction for any possible combination of stations (say Hinchinbrook stations vs. Montague Stations).

---

[2] Two different multipliers, λ and ω, are required because CPUE = 0 (outcome 3) provides no information on the fraction of hatchery fish in the catch, but does provide information on the appropriate weight to be used to estimate the fraction for the entire PWS.

Estimated Variance of Hatchery Fraction

By Station

The variance of a parameter estimated through a two-stage sampling design is the variance of the expected value of the parameter across first-stage units plus the expected value of variances of the parameter within first-stage units (Cochran 1977). By this rule estimated variance for the proportion $\hat{p}_s$ in our study became:

$$v(\hat{p}_s) = \hat{S}_{1s}^2 + \frac{\sum_{t=1}^{T_s} a_{st} \hat{S}_{2st}^2}{\sum_{t=1}^{T_s} a_{st}} \tag{8}$$

where $\hat{S}_{1s}^2$ represents the variance of the expected value of the parameter across first-stage units, and the right-most term in Equation 8 the expected value of variances within first-stage units. Equation 8 was adapted from the standard mathematic framework in Thompson (1992). The variance $\hat{S}_{2st}^2$ represents the variance of our parameter from the samples taken at station *s* during trip *t*. Because of the weighting involved in our study, the product $\hat{W}_{st}\hat{p}_{st}$ was treated as a single parameter for expressing variance, making $\hat{S}_{2st}^2$ the variance of the product of two variates. Following procedures in Goodman (1960), variance for such a product was approximated as:

$$\hat{S}_{2st}^2 = v(\hat{W}_{st})\hat{p}_{st}^2 + \hat{W}_{st}^2 v(\hat{p}_{st}) - v(\hat{W}_{st})v(\hat{p}_{st}) \tag{9}$$

where variance for $\hat{p}_{st}$ was estimated as the variance of a binomial proportion:

$$v(\hat{p}_{st}) = \begin{cases} \dfrac{\hat{p}_{st}(1-\hat{p}_{st})}{m_{st}-1} & \text{if } m_{st} \geq 2; \\ \hat{p}_{st}(1-\hat{p}_{st}) & \text{if } m_{st} = 1; \end{cases} \tag{10}$$

(the alternative formulations simplify calculations at the expense of negligible bias in results). Variance for $\hat{W}_{st}$ was approximated as:

$$v(\hat{W}_{st}) \cong v(CPUE_{st})\left(\frac{\sum_{t',t'\neq t} CPUE_{st'}}{\left(\sum_{t'} CPUE_{st'}\right)^2}\right)^2 + \left(-\frac{CPUE_{st}}{\left(\sum_{t'} CPUE_{st'}\right)^2}\right)^2 \sum_{t',t'\neq t} v(CPUE_{st'})\,. \tag{11}$$[3]

The derivation of Equation 11, the equation for $v(CPUE_{st})$ is described in Appendix B.

While the processes and procedures we used to select samples of individual fish (second-stage sampling units) arguably mimicked random selection, the scheduling of trips (first-stage sampling units) was decidedly not random, but systematic. Under such systematic selection no

[3] Note that in approximating the variance for a specific trip *t*, a summation over subscript t' indicates a sum over all trips in a station including trip *t*; the summation with configuration $t', t' \neq t$ indicates a sum over all trips excluding trip *t*.

exact estimate of variance for our first-stage units is possible—only an approximate variance could be calculated. Wolter (1985) concluded that under most conditions the sum of the squared differences between sequential statistics is the most robust estimator of variance for systematic sampling. With adaption of this estimator for our study,

$$\hat{S}_{1s}^2 \cong \frac{\sum_{t=2}^{T_s} \lambda_{st}\lambda_{s(t-1)}(\hat{W}_{st}\hat{p}_{st} - \hat{W}_{s(t-1)}\hat{p}_{s(t-1)})^2}{2\left(\sum_{t=1}^{T_s} \lambda_{st}\lambda_{s(t-1)}\right)\left(\sum_{t=2}^{T_s} \lambda_{st}\lambda_{s(t-1)} - 1\right)} \qquad (12)$$

was used to approximate variance of the expected value of the parameter across first-stage units. Here again the multipliers λ were used to adjust for missing data.

For the Sound

Estimated variance for the fraction of hatchery-produced salmon of the target species estimated for the Sound as a whole was approximated by again weighting with CPUE. The approximated variance for the Sound is the variance of the sum across stations of products:

$$v(\hat{p}) = v\left(\sum_{s=H01}^{H01\cdots M06} \hat{W}_s\hat{p}_s\right) \qquad (13)$$

Application of the delta method to Equation 13 provided an approximate variance for $\hat{p}$:

$$v(\hat{p}) \cong \sum_{s=H01}^{H01\ldots M06} [\hat{W}_s^2 v(\hat{p}_s) + \left(\frac{\hat{p}_s - \hat{p}}{\sum_{s'} \overline{CPUE}_{s'}}\right)^2 v(\overline{CPUE}_s)] \qquad (14)$$

Derivation of Equation 14 and of variance for $\overline{CPUE}_s$ is described in Appendix B. That formulation adapted for missing data is

$$v(\overline{CPUE}_s) = \frac{\sum_{t=1}^{T_s} \omega_{st} v(CPUE_{st})}{\left(\sum_{t=1}^{T_s} \omega_{st}\right)^2}. \qquad (15)$$

Statistics for any combination of stations can be calculated by restricting weights only to the stations in those combinations. Weights used in the combination must sum to 1 over the number of stations used in the combination. Regardless, the general assumption is that catchability of the target species is the same for all stations included in the combination.

Results

Ocean Salmon Sampling

Extraneous factors that had an impact on fishing included fog, whales (humpback, orca, grey), Dahl's porpoises, sea lions, seals, otters, sport fisher vessels, tankers and/or tugs, rip tides, wind, and flotsam. The vessel captain actively watched for and avoided all such factors which at times either completely prevented a set or limited the set time and/or net fathoms set. The vessel captain also attached whale pingers which he reported may have prevented many close encounters with whales in 2015 as they did during 2014.

A total of 15,761 salmon were caught in the ocean test fishery during 2015. Fishing was conducted at all nine stations over a two (sometimes three) day period throughout the season. For analysis and graphic purposes, each fishing period is defined as a "Trip" with Trip 1 beginning on May 25, 2015 and Trip 31 ending on August 31, 2015. Pink Salmon were the most numerous salmon caught (12,060), followed by Chum Salmon (2,022), Sockeye Salmon (1,411), and then Coho Salmon (259). Nine Chinook Salmon were caught and released. From here on we focus on results for Pink Salmon and Chum Salmon only. Pink Salmon started showing up in the catch on May 18 (TRIP 2). Pink Salmon trended upward until the first peak on July 8 (TRIP 16). The highest peak occurred on July 23 (TRIP 20) and then trended downward until fishing ceased (Figure 2). Chum was the first species caught at the beginning of the season and were caught fairly consistently for the entirety of the season, but started to decline by July 5 (TRIP 16) (Figure 2).

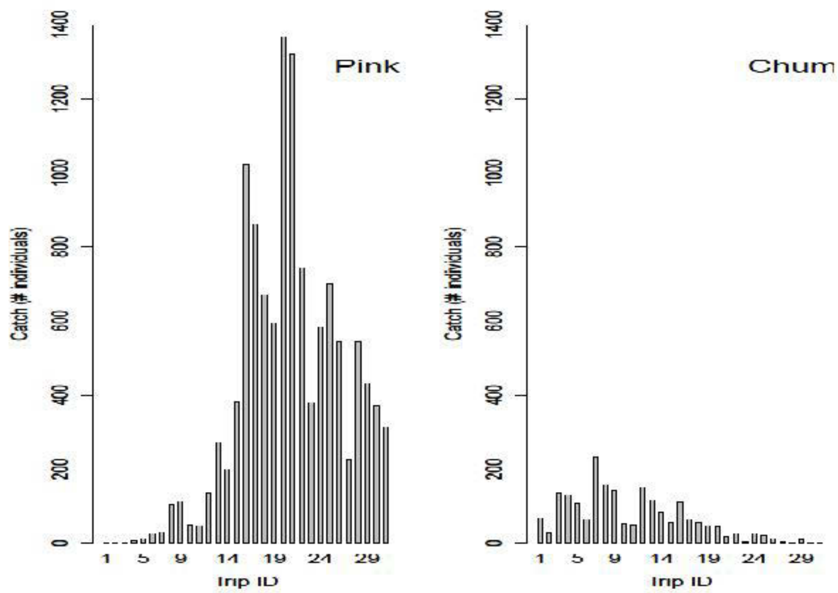


Figure 2. Total Pink Salmon (left) and Chum Salmon (right) caught at all stations during 2015 by TRIP ID.

Trends in CPUE (fish caught per hour per fathom of net length) were qualitatively similar across years, but the CPUE of Pink Salmon during 2015 appeared to be more protracted compared to the previous years, with relatively high catches through to the end of the test fishing period in late August (Figure 3).

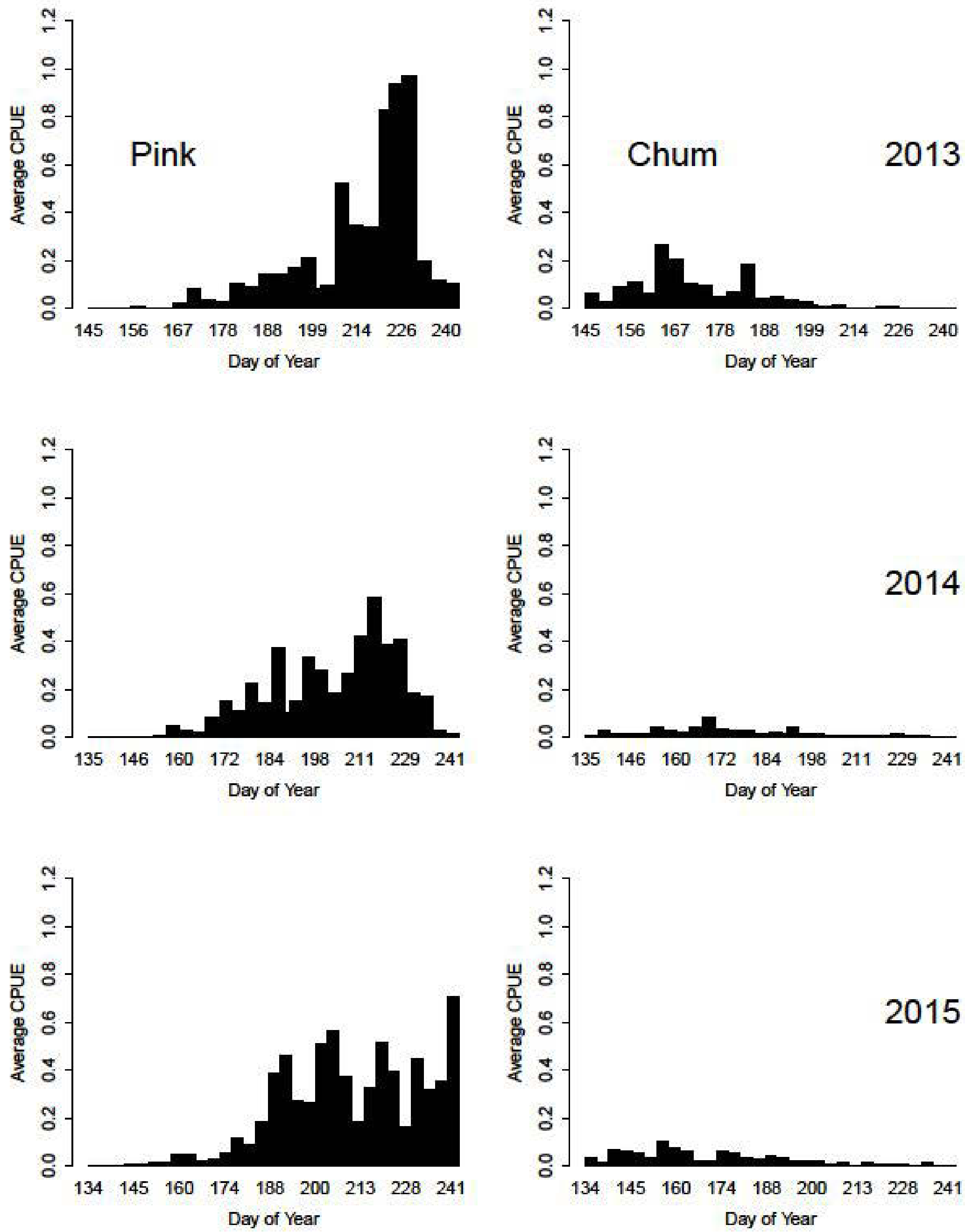


Figure 3. Mean CPUE for Pink Salmon (left) and Chum Salmon (right) by day of year during each year of the study.

Catches of salmon by station were variable in 2015. Station M02 had the greatest seasonal catch of Pink Salmon (2,197) while the fewest Pink Salmon (555) were caught at H02 (Figure 4). The station with the greatest Chum Salmon catch was M06 (330) and the lowest catch (93) was at

H02 (Figure 4), a station positioned near the center of the large Hinchinbrook Entrance (Figure 1).

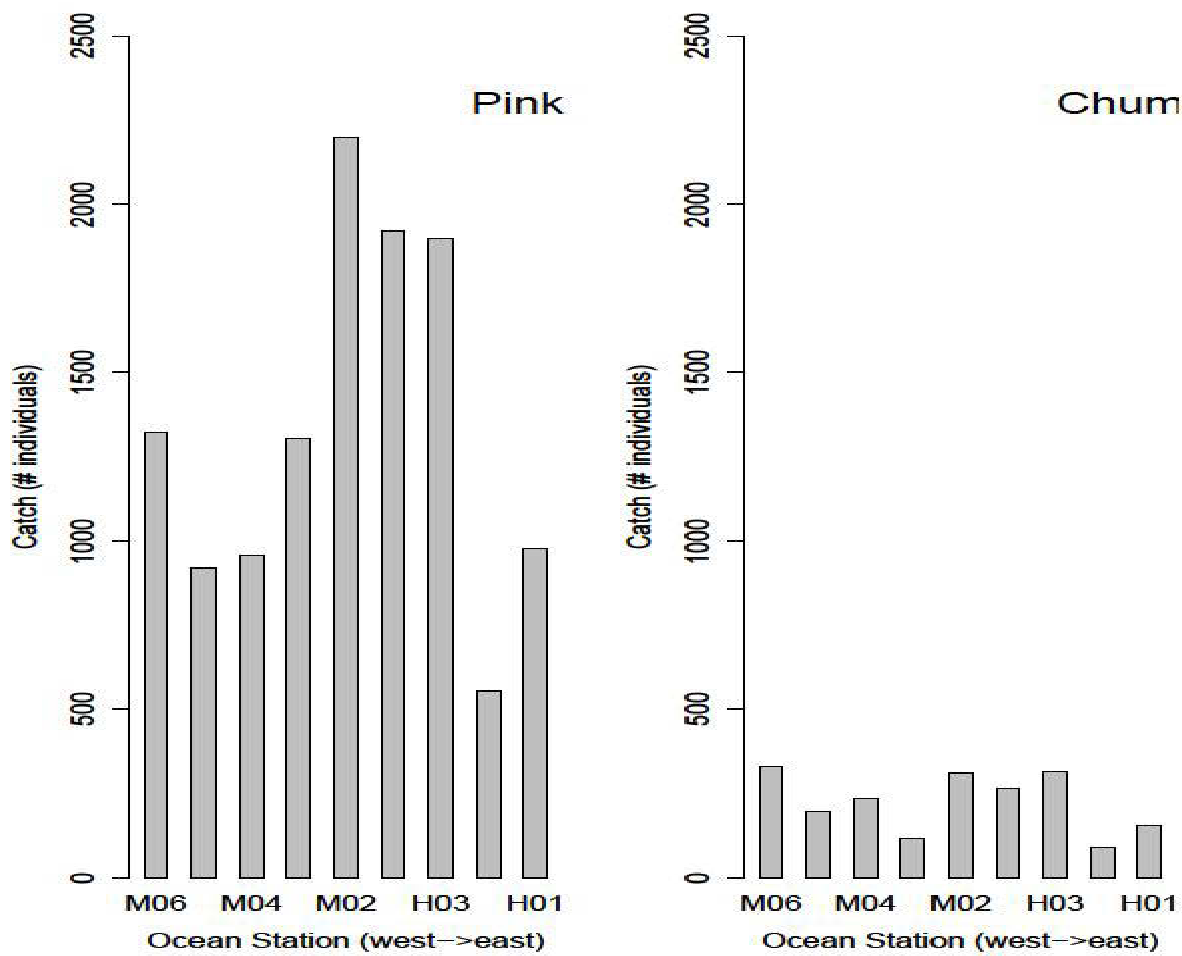


Figure 4. Total Pink Salmon and Chum Salmon caught by station from May 25 to August 31, 2015 (H=Hinchinbrook, M=Montague).

During 2015, mean CPUE by station for Pink Salmon ranged from 0.07 (H02) to 0.42 (M02) and for Chum Salmon ranged from 0.01 (H02) to 0.04 (H03) (Figure 5). Station M05 yielded the highest Pink Salmon CPUE for all three years, while the highest Chum Salmon CPUE by station was at M05 in 2013 and at H03 in 2014 and 2015 (Figure 5). Chum Salmon CPUE appeared to be more consistent across stations compared to Pink Salmon (Figure 5).

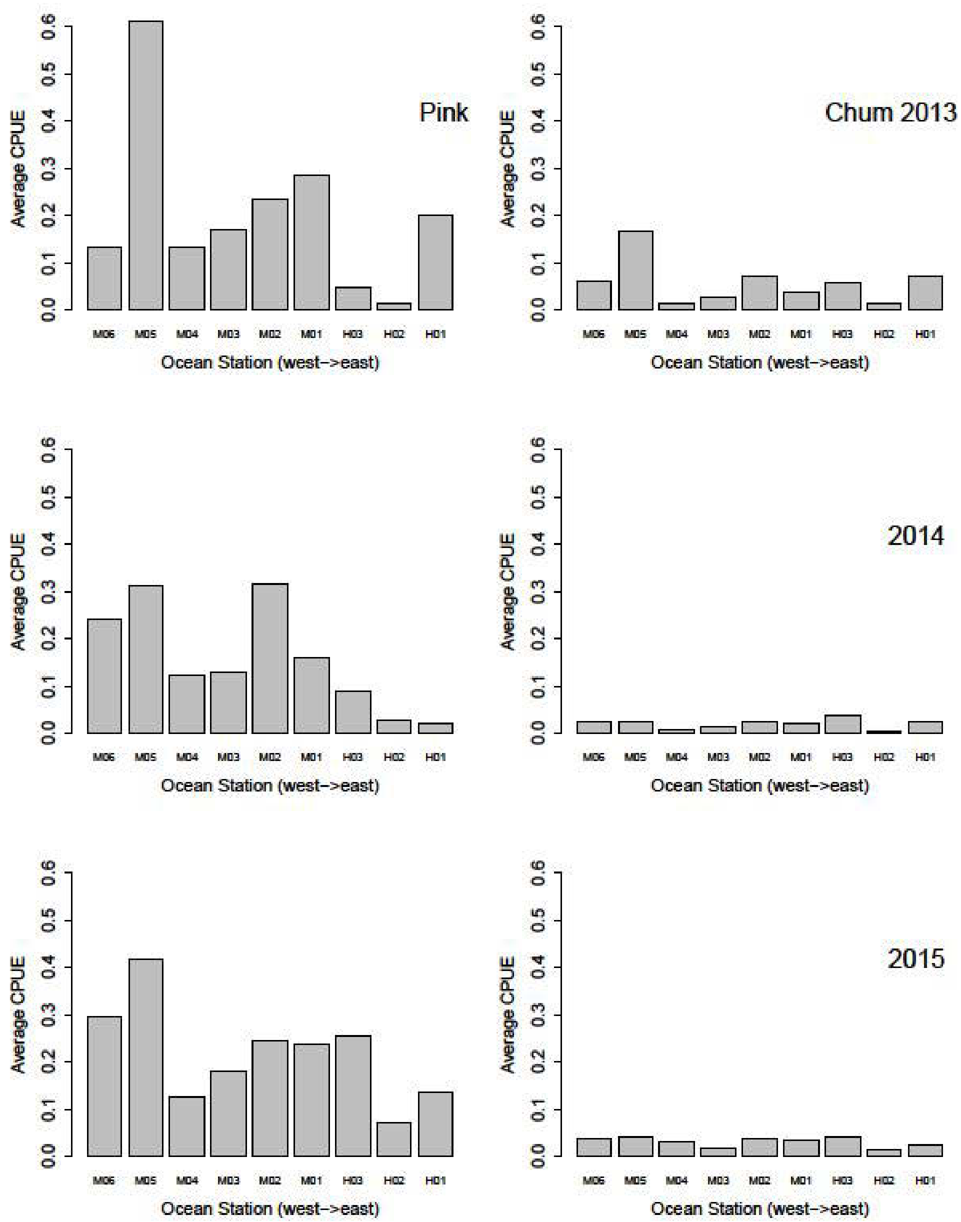


Figure 5. Mean CPUE for Pink Salmon (left) and Chum Salmon (right) by station during each year of the study.

Ocean Salmon Processing

A total of 3,716 salmon were processed for weight-length measurements and otoliths, including 2,278 Pink Salmon and 1,296 Chum Salmon. Mean standard lengths for Pink Salmon and Chum Salmon were 462 mm and 557 mm, respectively.

As in previous years, there was a marked male bias in the sex ratio of returning Pink Salmon. The processed Pink Salmon were 67.1% male while the sex ratio of Chum Salmon was more even (56.2% male, Table 1). The sex ratio of both wild and hatchery Pink Salmon at all stations was skewed toward males in 2015, as was observed in the previous years of the study (Figure 6). The disparity in sex ratios between wild and hatchery Chum Salmon was less marked than in previous years (Figure 6), and was generally closer to a 50:50 ratio (Figure 6). As in previous years, wild Chum Salmon sex ratios showed more variability across ocean stations (Figure 6) than did Pink Salmon.

Table 1. Sex ratios by total number and percentage for 2015.

Species Common Name	Metric	Female	Male	Unknown	Grand Total
Chum Salmon	count	566	728	2	1296
	percent	43.7%	56.2%	0.1%	
Pink Salmon	count	742	1529	7	2278
	percent	32.6%	67.1%	0.3%	

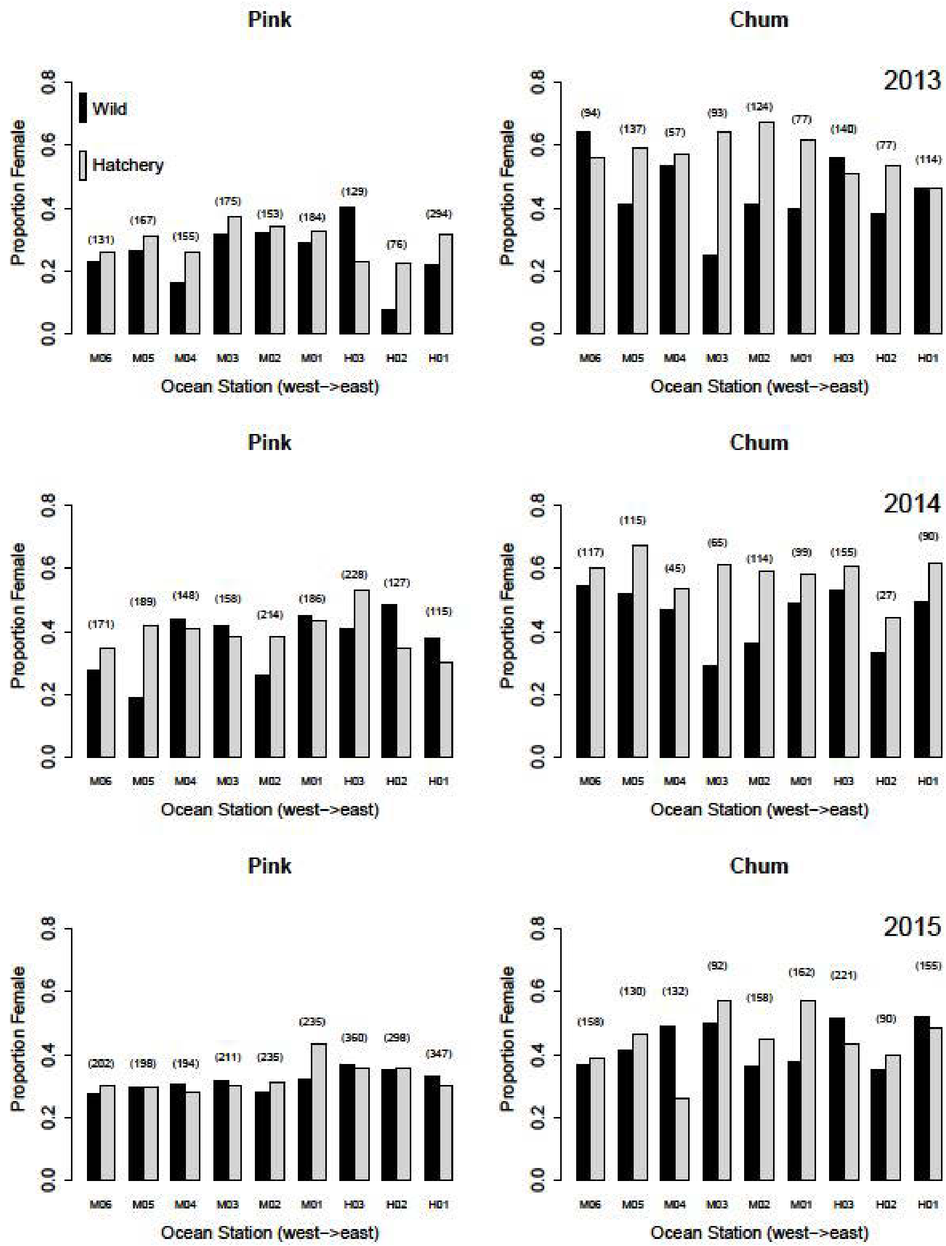
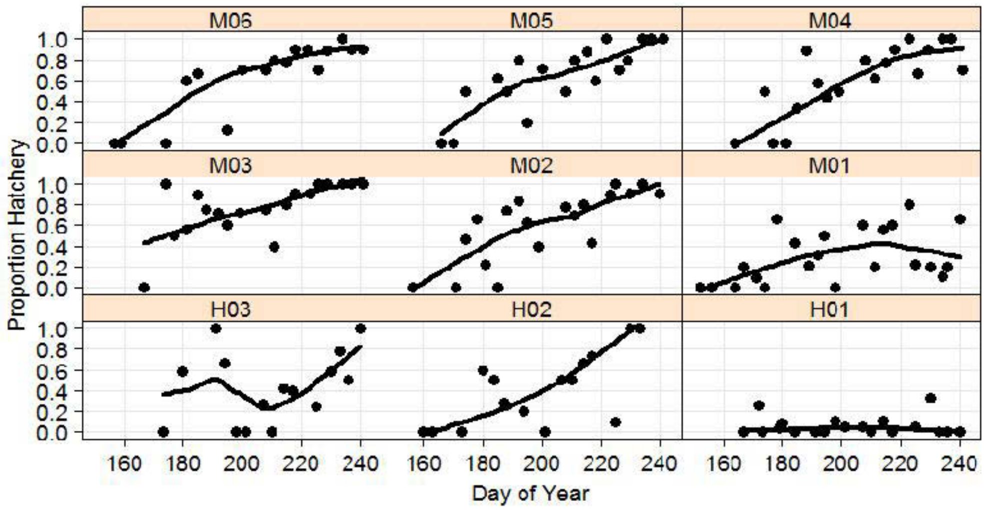


Figure 6. Proportion of female Pink Salmon (left) and Chum Salmon (right) by origin (wild and hatchery) and by ocean station for each year of the study. Numbers in parentheses are the sample size over the entire season at each station.

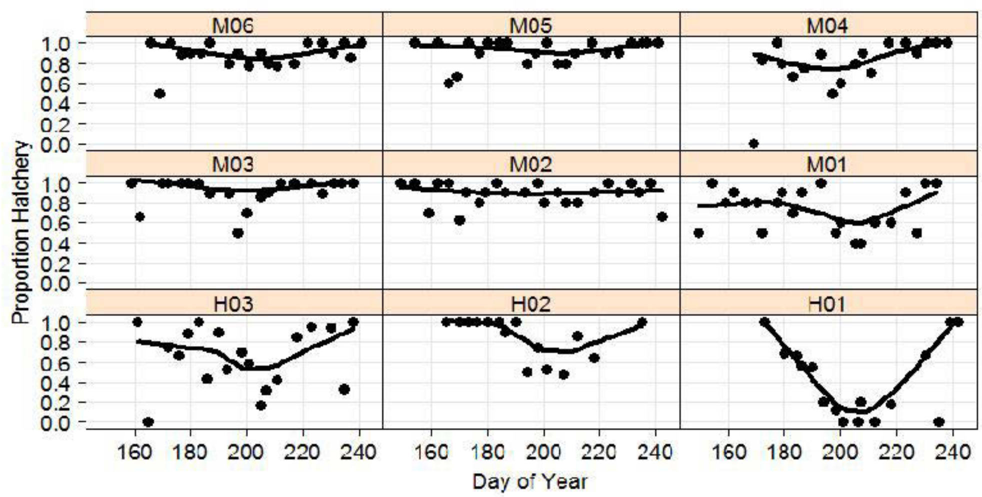
Ocean hatchery fractions

Unweighted hatchery proportions of processed fish varied by date and by station for both Pink Salmon and Chum Salmon (Figures 7 and 8). The same patterns generally held in 2015 compared to previous years. Odd years usually have greater run sizes of wild Pink Salmon in PWS than even years, and the effect of this phenomenon can be discerned in the plots, particularly at the Hinchinbrook stations (Figure 7). In both 2013 and 2015, the unweighted hatchery proportions of Pink Salmon were generally lower at all stations (particularly early in the season and at Hinchinbook stations) compared to 2014. Also, as in previous years, the H01 station in Hinchinbrook was a very important migratory corridor for wild Pink Salmon in 2015 (Figure 7). The wild proportion of the Pink Salmon run appeared to be greatest during the early part of the season in 2013 and 2015 (Figure 7).

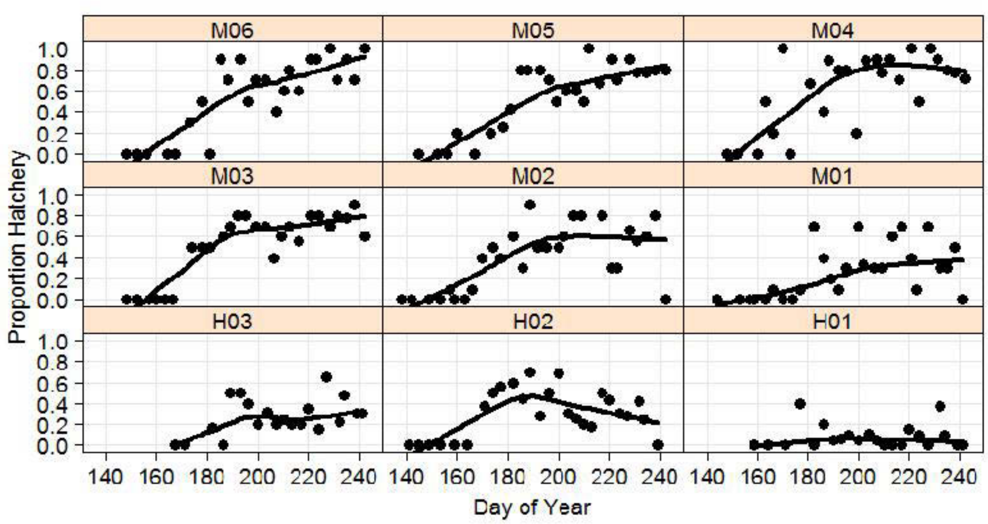
The temporal trends in the unweighted hatchery fractions for Chum Salmon were remarkably consistent across years and stations (Figure 8). Most of the early run of Chum Salmon in 2015 was composed of hatchery fish, as was observed in previous years. Wild Chum Salmon were predominately observed at the H01 station in Hinchinbrook Entrance (Figure 9), as documented above for Pink Salmon.



2013

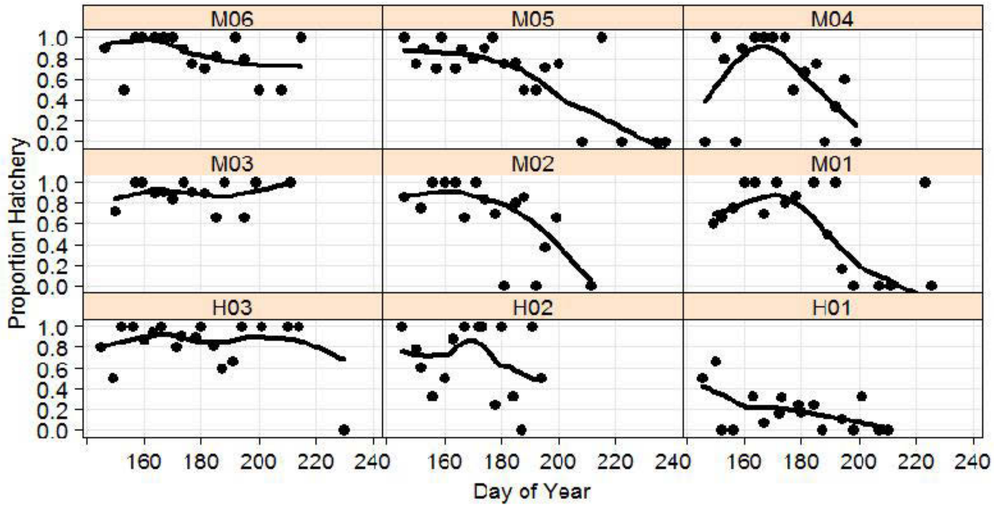


2014

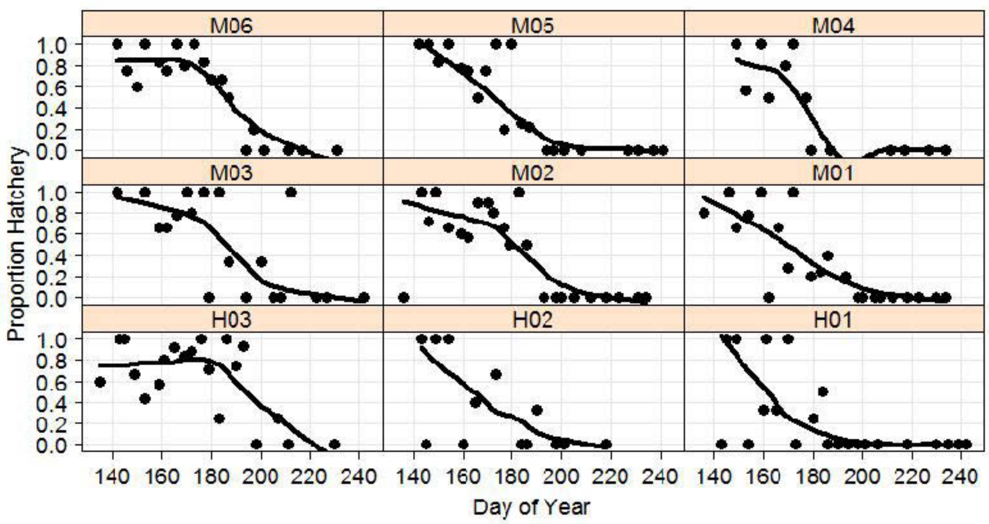


2015

Figure 7. Pink Salmon unweighted hatchery proportion by day of year and Station ID by year. A loess smoothing function was used to illustrate the general temporal trend observed at each ocean station.



2013



2014

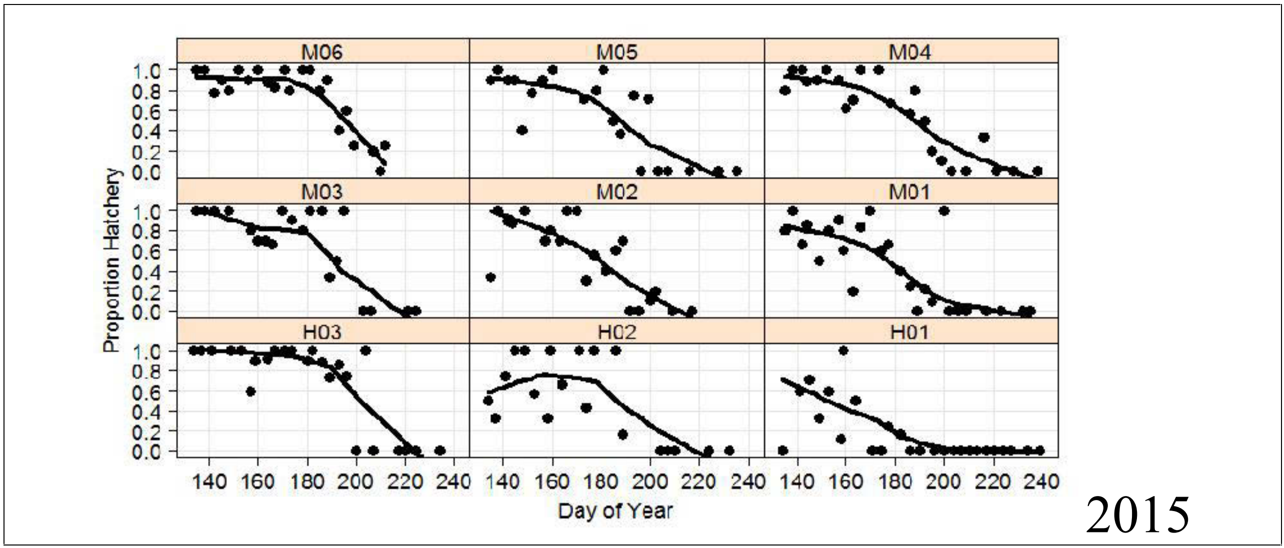


Figure 8. Chum Salmon unweighted hatchery proportions by day of year and Station ID by year. A loess smoothing function is included to illustrate the general temporal trend observed at each ocean station.

The 2015 weighted hatchery proportions calculated for Pink Salmon and Chum Salmon for all Prince William Sound entrances combined were 0.55 (SE = 0.004) and 0.69 (SE = 0.015), respectively. In 2015, Pink Salmon weighted hatchery proportions ranged from 0.08 (SE = 0.004) at station H01 to 0.79 (SE = 0.01) at M06 (Figure 9). Chum Salmon hatchery proportions ranged in 2015 from 0.20 (SE = 0.011) at H01 to 0.85 (SE = 0.046) at H03 (Figure 9). Weighted ocean-entry hatchery fractions can be compared across the three years for each species.

Species Common Name	Year	Hatchery Proportion	SE
Pink Salmon	2013	0.679	.016
	2014	0.864	.03
	2015	0.549	.004
Chum Salmon	2013	0.725	.019
	2014	0.511	.029
	2015	0.688	.015

The estimated relative proportion of hatchery Pink Salmon entering PWS was greatest in 2014 compared to the years of high wild returns (2013, 2015) while the reverse was the case for Chum Salmon (see also Figure 9). These differences, however, were not statistically tested.

Pink Salmon hatchery proportions indicate more hatchery fish were entering PWS at the Montague Strait stations than at the Hinchinbrook Entrance stations (Figure 9) and the hatchery-specific origin was variable across ocean stations (Figure 10). The A.F. Koernig and Solomon Gulch hatcheries appeared to be the largest contributors to Pink Salmon hatchery returns across most stations in 2015 (Figure 10).

Chum Salmon hatchery proportions were variable by ocean sampling stations for 2015 (Figure 9). In 2015 we once again observed lower hatchery proportions in the chum returns through the Hinchinbrook H01 station, as was documented in previous years (Figures 9 and 11). Also, as in previous years, most of the hatchery Chum Salmon originated from Wally Noerenberg Hatchery (Figure 11).

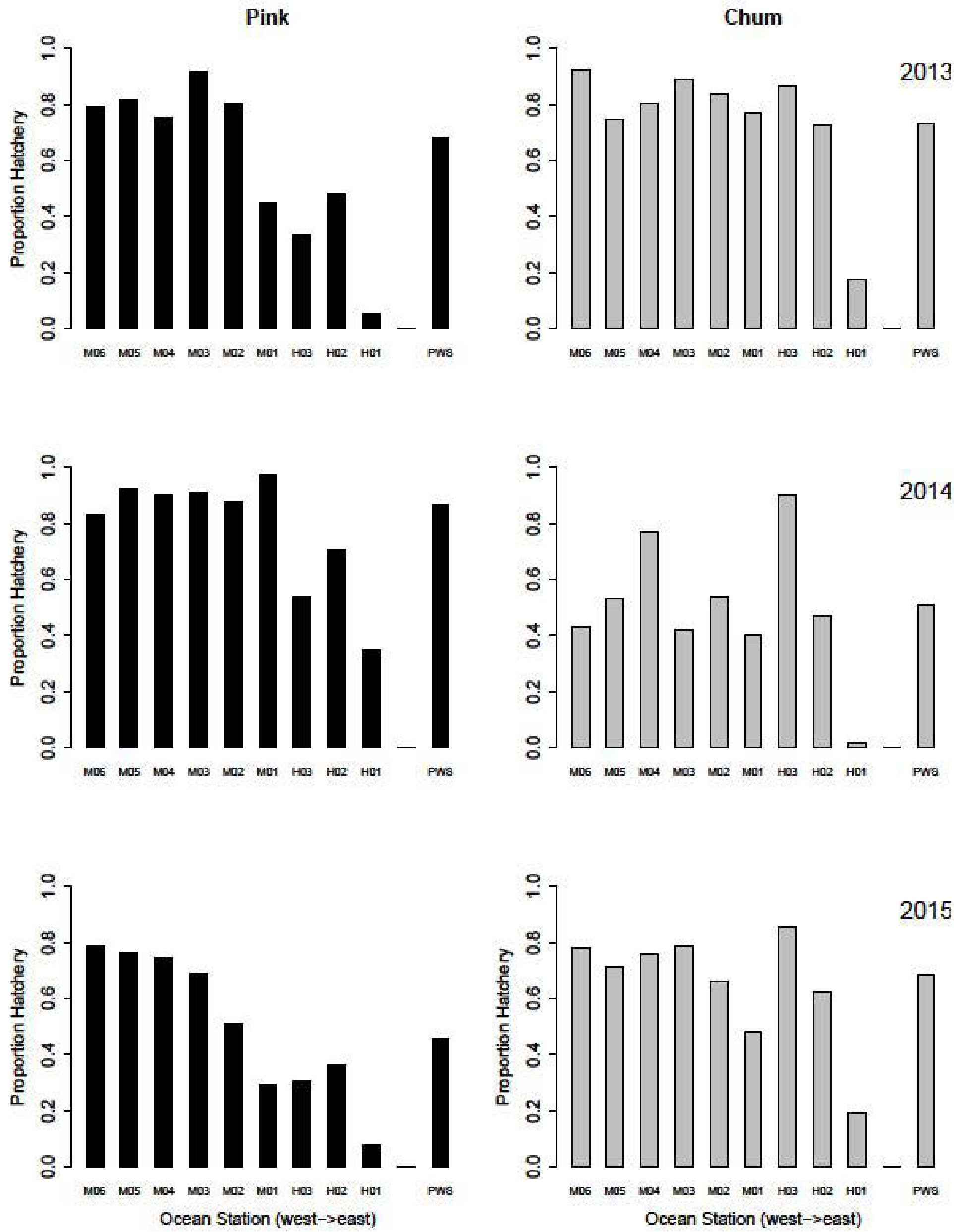


Figure 9. Weighted hatchery proportions of Pink Salmon (left) and Chum Salmon (right) by individual station in 2013-2015. Stations are oriented west to east, left to right. The right-most bar represents the hatchery proportion for the aggregate Prince William Sound run.

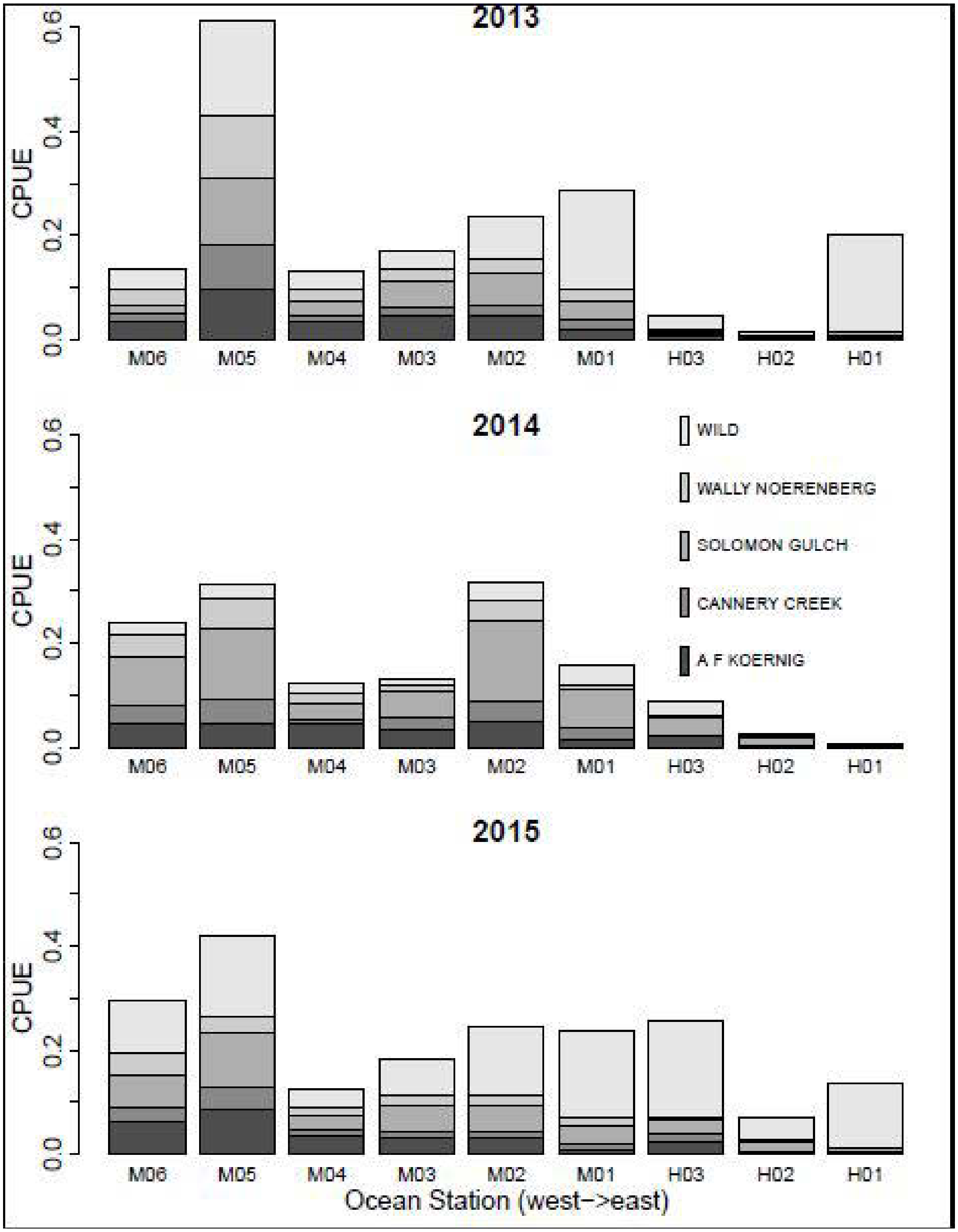


Figure 10. The CPUE of Pink Salmon captured by station during 2013-2015, apportioned by origin. The stations are oriented west to east, with the three Hinchinbrook stations on the right.

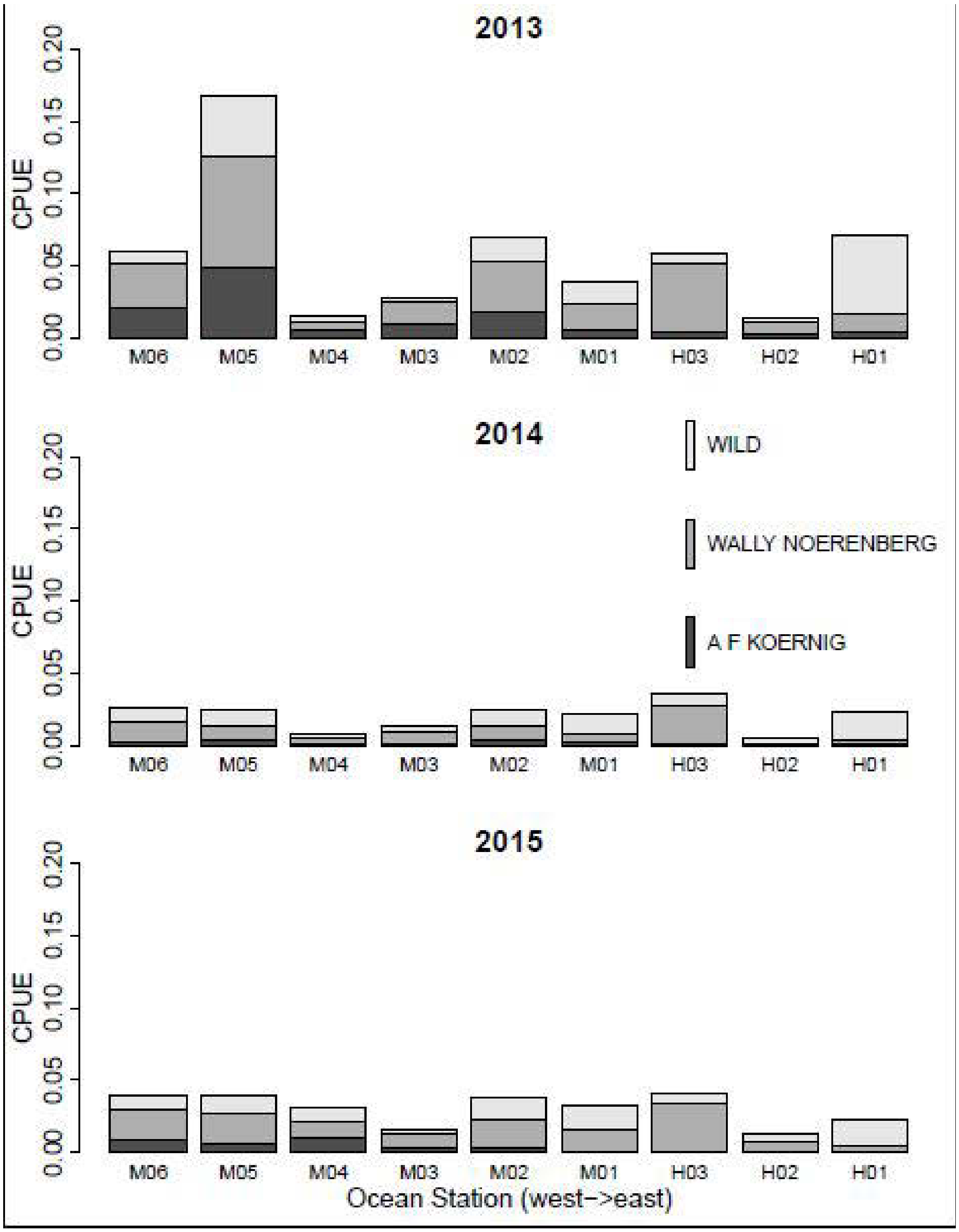


Figure 11. The CPUE of Chum Salmon captured by station during 2013-2015, apportioned by origin. The stations are oriented west to east, with the three Hinchinbrook stations on the right.

.

References

Botz, J., T. Sheridan, A. Wiese, S. Moffitt, R. Brenner. 2014. 2013 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No, 14-43, Anchorage.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons, New York.

Knudsen, E., M. Buckhorn, K. Gorman, D. Crowther, K. Froning, M. Roberts, L. Marcello, B. Adams, V. O'Connell, D. Bernard. 2015. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2013, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

Goodman, L. A. 1960. On the exact variance of a products. Journal of the American Statistical Association 55:708-713.

Thompson, S. K. 1992. Sampling. John Wiley & Sons, New York.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

ADULT SAMPLING IN STREAMS

Authors –Kristen Gorman, Ben Adams, Julia McMahon, Eric Knudsen, and Victoria O'Connell

Background

Based on the original RFP from ADF&G, there were two primary purposes for sampling adult Pink Salmon and/or Chum Salmon in streams: 1) to further assess the degree and the range of interannual variability in hatchery straying rates; and 2) determine the effects of hatchery fish spawning with wild populations on the fitness of wild populations. The former was determined by collecting otoliths from spawned out adults. The otoliths were examined in ADF&G laboratories to determine whether the individuals are of hatchery or wild origin. The results are estimates of the percent of hatchery fish that comprise each stream's spawning population. The latter was accomplished by collecting tissues for DNA analysis from adults in a subset of the same streams, referred to here as "fitness" streams. The DNA "markers" of these parents can be used to identify either their pre-emergent offspring collected the following spring, or progeny returning to the streams as adults, so that relative reproductive success (fitness) of hatchery- and natural-origin fish can be estimated for both males and females.

Methods

Data collection for this study required repeated sampling of 32 streams throughout PWS and 32 streams throughout SEAK (Figures 12 and 13) with only slight variations for improvement of the methods used in 2013 and 2014 (Knudsen et al. 2015a, b). The field effort was divided into two major activities: the PWS stream sampling was accomplished by field crews from PWSSC, while the stream sampling in SEAK was subcontracted to the SSSC. Final 2013 stream selection was made based on information provided in the RFP combined with some preliminary evaluations of some streams and discussions with ADF&G staff and the Science Panel, and those same streams were sampled in 2014 and 2015.

In PWS, otoliths were collected for the straying analysis from Pink Salmon adults in 28 of the 32 streams and Chum Salmon otoliths were collected from 18 of the streams (Figure 12). Each PWS stream was sampled during a minimum of three visits per stream. In SEAK, otoliths were collected from Chum Salmon (only) in all 32 streams during at least two, and often more, stream visits (Figure 13). For the fitness studies, DNA tissues were collected along with the otoliths from adult Pink Salmon in six of the PWS streams (Figure 12). DNA tissue samples were not collected from the four SEAK Chum Salmon fitness study streams in 2015 because the first adults from the baseline sampling in 2013 and 2014 will not return as three-year-olds until 2016.

The experimental design elucidated in the RFP for the straying analysis called for collecting a target of 384 otolith samples for each species in each straying study stream, with the sampling spread roughly evenly across the run timing and throughout the salmon-accessible stream length. Because it is extremely difficult to predict the timing and abundance of salmon that will eventually enter the stream, and because it is logistically impossible to arrive at each stream exactly at the best times to sample, we implemented a strategy for "oversampling" whenever possible during the early visits to each stream. This was to create a higher likelihood of achieving the target of 384 in cases where the early visits coincided with the peak availability of adults to sample and subsequent visits yielded fewer than the required samples. The outcomes of this process are described below.

The RFP originally specified that fitness study streams have sampling targets of 500 individuals in high-stray-rate streams and 1,000 individuals in streams with lower stray rates. Subsequent discussions with ADF&G Gene Conservation Laboratory staff and the Science Panel in late 2013, and again in December 2014 and April 2015, indicated the importance of exceeding the sampling targets from these streams. Therefore, a strategy of maximizing the number of samples from fitness streams was increased in 2015 to make every effort to sample the low-fraction fitness streams every day and the high-fraction streams every other day.

Overall Field Sampling Strategy – Prince William Sound

From July 10 through September 23, 2015, six crews sampled 32 streams for adult Pink and Chum Salmon otoliths and Pink Salmon DNA (Figure 12). These crews were directly employed or contracted by the PWSSC. For the straying study, 28 of the 32 streams were sampled for Pink Salmon otoliths and 18 streams were sampled for Chum otoliths. Six fitness streams sampled in 2013 and 2014 were also sampled in 2015 for adult Pink Salmon tissues for genetic tissue samples. The combined efforts of six PWS crews resulted in 311 stream visits and 78,098 otoliths were collected during 2015.

There were three live-aboard vessel based crews, two camping crews, and a Cordova-based crew. These crews required two training sessions and deployed on three different dates in 2015. The contracted vessels were the *M/V Cathy G*, *M/V Auklet* and *S/V Adelie*, the camping crews were Texas A&M University (TAMU) and Paddy Camp, and the local crew was based in Cordova. The *Cathy G*, TAMU, and Cordova crews received training July 13-17, 2015. The *Auklet* and Paddy Camp crews trained July 27-31, 2015. Training included boating, bear and firearms safety, CPR and First Aid, protocol review, tablet use, data entry, and field training. All field crews were deployed the Saturday after training except for the *Adelie* crew, which deployed August 19, 2015 to sample at Hogan Bay during the peak of the run.

All three vessels were contracted, live-aboards, housing between two and six people. First to deploy on July 18, 2015, the *Cathy G* completed three transits around PWS. They made 80 stream visits to 26 straying streams and sampled two fitness streams, Spring Creek and Hogan Bay Creek, late in the season. The *Cathy G* traveled between sampling locations early in the morning and these streams, scattered throughout PWS, were efficiently accessed with the *Cathy G's* landing craft the M/V *Bayhawk.* The *Cathy G* made three Cordova port calls on July 31, August 26 and September 17, 2015 to refuel and resupply. Another vessel-based crew aboard the *Auklet* deployed August 1, 2015 and made one port-call on August 21, 2015. In the beginning of the season, the *Auklet* crew sampled two straying streams and three fitness streams on Montague and Knight Islands. Later in the season, to maximize the number of samples collected during the peak-season, fitness sampling was conducted every day on Stockdale and Gilmore creeks. Last to deploy was the *Adelie* crew of two that took over Hogan Bay Creek fitness sampling from August 21 through August 30, 2015. In 2015, the *Auklet* made 67 stream visits and the *Adelie* made 10 stream visits.

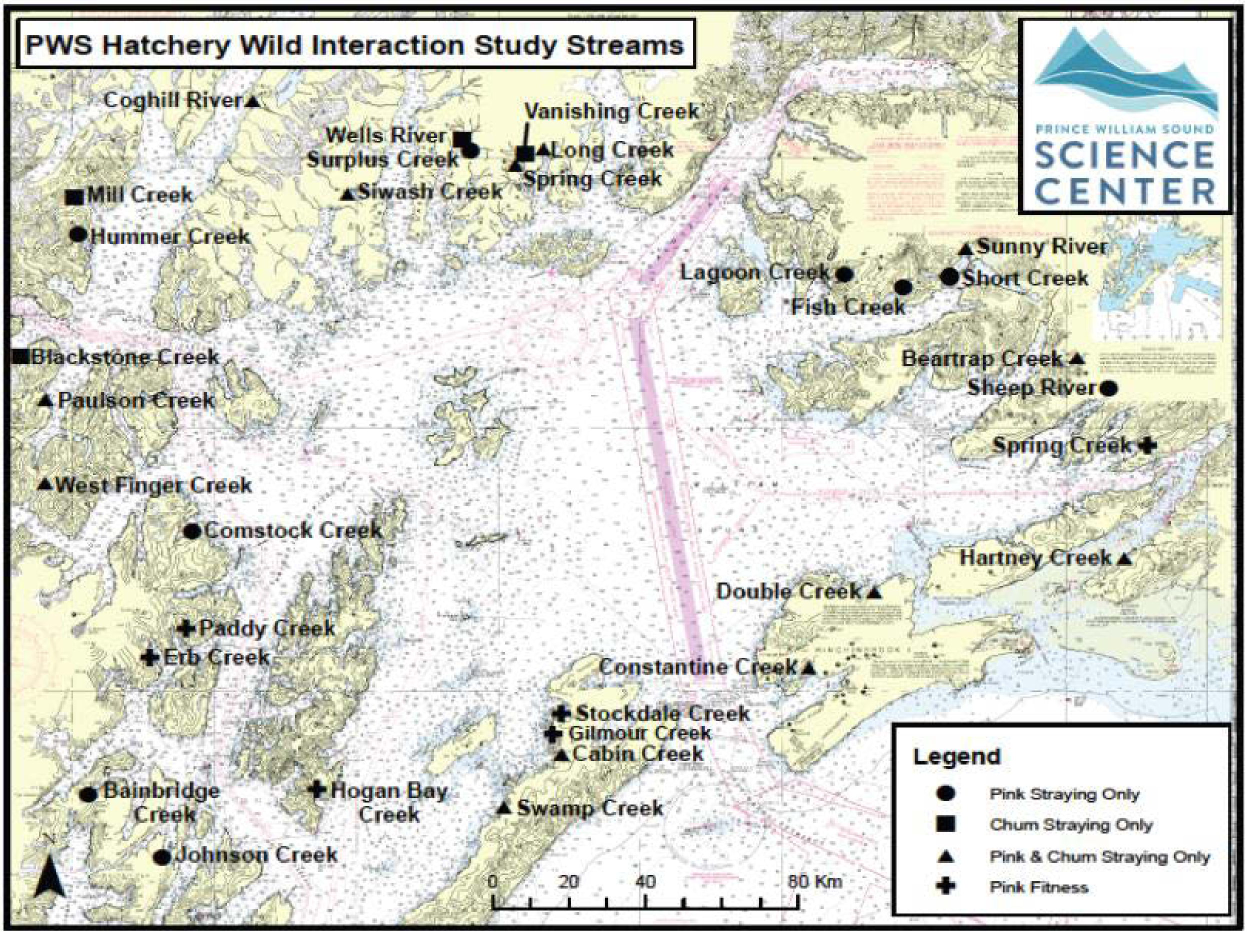


Figure 12. PWS streams sampled for Pink Salmon and Chum Salmon otoliths and DNA tissues.

There were two camping crews in 2015 - one four-person crew subcontracted to TAMU and based in Alice Cove, which sampled Spring Creek, and another four-person PWSSC crew based in Paddy Bay, which sampled Paddy and Erb Creeks. Both crews sampled their fitness streams daily and made a total of 144 stream surveys. The TAMU crew collected samples for six weeks from July 10 to August 21, 2015 making 36 visits to Spring Creek. TAMU returned from the field on August 22, 2015. Then the Cordova and *Cathy G* crews sampled Spring Creek 11 times following the TAMU crew departure with the last survey occurring on September 20, 2015. The Paddy crew was deployed for eight weeks, from August 1 to September 26, 2015 completing 97 fitness stream surveys at Erb and Paddy Creeks. The Paddy crew used a rigid hull inflatable skiff to navigate between camp in Paddy Bay and Erb Creek. The *Cathy G* assisted Paddy camp set-up and take-down by deploying camp on August 3 and taking the camp out on September 24, 2015.

The Cordova crew operated from July 10 through September 13, 2015 with two to seven people. They primarily sampled streams within vehicle and skiff distance of Cordova, but when necessary, they fulfilled time-sensitive sampling goals on more distant streams out of logistical reach by other crews. Many of these trips were made possible by chartering a gillnet vessel or float plane. The Cordova crew made 19 visits to two nearby streams and three distant streams. The nearby streams included Hartney and Spring Creeks (once TAMU left) and the distant streams accessed were Double Creek, Sheep River, and Coghill River.

Stream sampling is a dynamic process influenced by historic run timing, current ADF&G aerial surveys, weather, crew location, and distance between streams. The 2015 crew leaders were astute in making decisions to maximize efficiency and achieve sampling goals. Armed with historic data and current aerial surveys, the field crews strategized sample timing with suggestions from PWSSC, ADF&G, and their own observations to guide their sampling tactics.

Stream Sampling Methods and Execution

Upon arriving at a study stream, the crew leader would indicate where to begin and how to focus on post spawner and carcass collection depending on stream size and tide stage. Sampling began in either the upper stream reaches or lower intertidal zone, and crews worked together for speed or leapfrogged in separate teams for efficiency. Crews were equipped with shotguns and VHF radios for safety. All efforts were made to sample and survey as much of the stream length as possible, accounting for factors such as carcass availability, incoming tide, deep water, strong current, impassable barriers, and bears.

After determining and marking the start location of a survey, all crew members began targeted species collection. Sample collection success at any given processing area depended on carcass abundance and sampling goals. After collecting a sufficient number of carcasses at a processing area, the latitude and longitude of the processing area was marked on the tablet and the crew began processing carcasses.

On fitness study streams, carcasses were aligned in rows of eight by six, mimicking the 48 well deep well plates (DWP). On straying-only streams, carcasses were aligned in rows of 12 by eight; this mimicked the rows and columns of the 96-well otolith trays. The popular cutting technique for accessing both heart DNA tissue and otoliths was to make two cuts. First, a horizontal cut dorsal to the eye was made to expose the brain cavity and otoliths. Second, a ventral cut was made perpendicular to, and slightly posterior of, the isthmus below the gill juncture. This cut exposed tissue of the bulbous arteriosus, a piece of which was removed for genetic analysis. The otoliths and tissue were placed in DWP plates for fitness or stock structure streams. For straying only streams, the second cut was unnecessary and otoliths only were placed in 96-well, otolith trays (See Appendices C and D for specific stream sampling protocols).

The last phase of stream sampling was to perform a fish survey to establish a rough index of fish abundance at the time of the sampling visit. When fish sampling was close to completion, two or more crew members conducted both a live and dead estimate of all Pink Salmon and Chum Salmon throughout the system. If multiple people were counting the same species, estimates were discussed at the end of the survey and averaged to produce a final count. When the survey was complete, a responsible crew member marked the end location of the survey, checked the count numbers, and made any additional comments.

Communication and Data Transmission

All crews had float plans and checked in daily with the PWSSC stream PI on Delorme inReach devices, satellite phone, or personal cell phones. Crews checking in also told the PI the daily count and sample numbers. Satellite and cell phones were used when longer conversations were necessary. Each night all crews backed up data on their laptop computer and to a secondary external drive. Data was transmitted daily, or as soon as internet service was available. Between the tablets, laptop computers, external drive backup, and regular data upload to the host database, the likelihood of data being lost was very low and no data was lost in 2015.

After completion of a final quality control review in Cordova at the end of the season, the straying-only otoliths were delivered to the Cordova ADF&G office for processing on September 24, 2015. Similarly, fitness stream otoliths and tissues were shipped to ADF&G's Gene Conservation Laboratory in Anchorage on September 18 and October 7, 2015 where otoliths were extracted and shipped back to the Cordova ADF&G office for processing. Electronic data delivery to ADF&G followed the quality control review so that otolith and DNA results could be matched to the field observation data.

Overall Field Sampling Strategy – Southeast Alaska

The Sitka Sound Science Center (SSSC) coordinated sampling of 32 Chum Salmon streams across Southeast Alaska in 2015. In contrast to previous years, all 32 of these steams were sampled for otoliths, length, and sex only, to be used just for straying analyses (Figure 13).

The SSSC employed 13 field personnel on a total of four field crews in 2015. Field crews were comprised of three vessel-based crews and a land-based crew in Tenakee Springs. The Tenakee Springs crew was subcontracted; the other three crews were composed of seasonal employees of the SSSC.

Of the 32 otolith-only streams that were sampled, 29 streams were sampled by the vessel-based crews stationed aboard the *M/V Nepenthe, M/V Bear,* and *M/V Surveyor.* These crews sampled the Northernmost, North central, and Southernmost portions of Southeast Alaska, respectively. The crew based in Tenakee Springs sampled two streams in their vicinity and supported the vessel-based crew in sampling a third stream. SSSC employees based in Sitka also sampled from a creek 20 miles south of Sitka.

Field training was held between July 17-21, 2015 for the SSSC seasonal employees. Training included project orientation and goals, field safety, salmon identification, biological sampling techniques, and tablet use for data entry. The Tenakee subcontractors with prior experience did not attend training in Sitka, but received the project protocol in advance of sampling and were instructed on data entry and field methods by the SSSC project coordinator. On July 22, 2015 the three SSSC vessel-based crews departed Sitka to begin sampling. The *M/V Bear* stopped in Tenakee Inlet on July 24, 2015 where they delivered supplies to the Tenakee Springs crew.

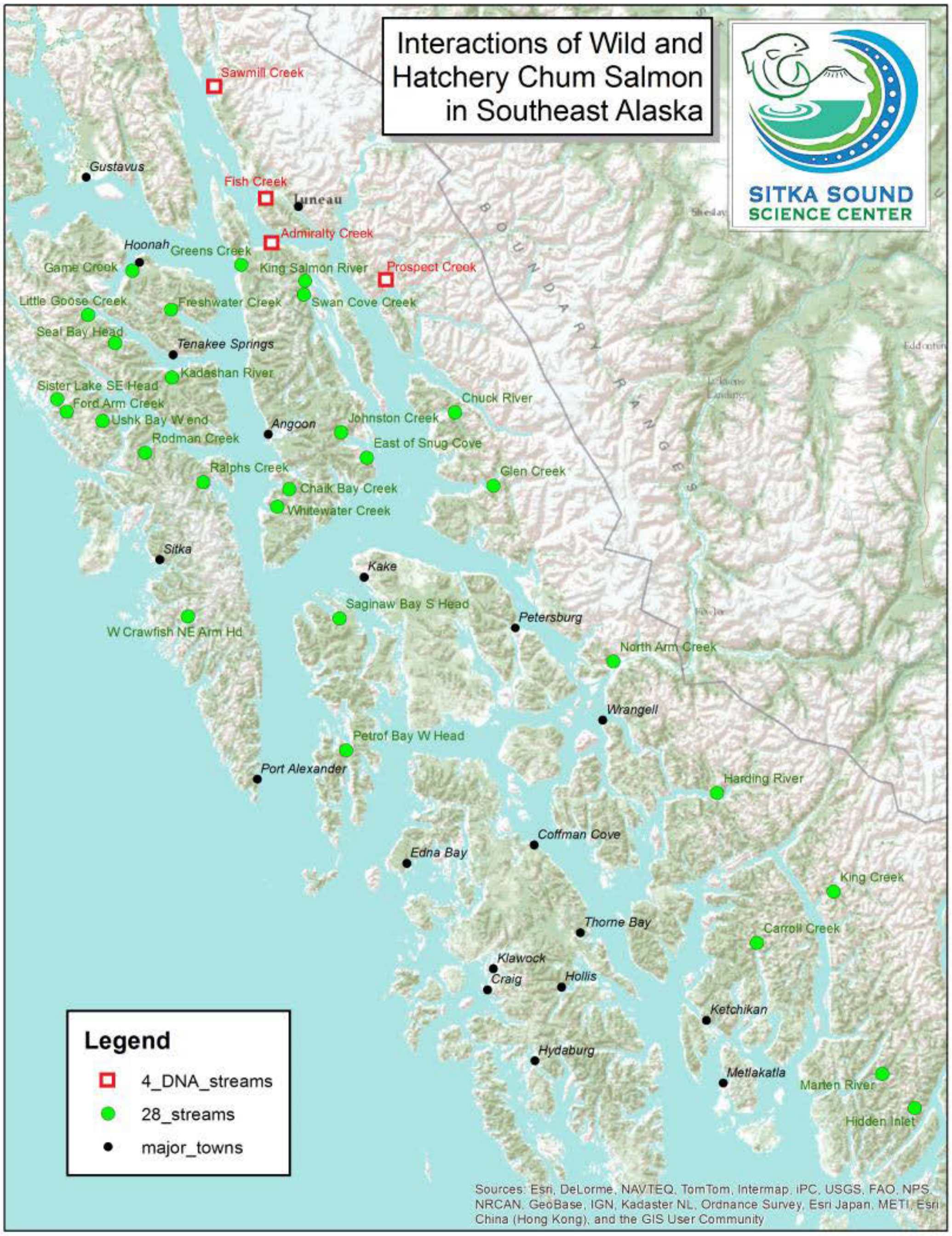


Figure 13. SEAK streams that were sampled for otoliths in 2015 (green dots and red squares). The 4 DNA fitness streams (red dots) were only sampled for otoliths in 2015, but will be sampled for otoliths and DNA tissues starting again in 2017.

Stream Sampling Methods and Execution

Field crews made 2-4 visits to each of the 32 streams in 2015. The *M/V Nepenthe* crew surveyed much of the northern portion of the study area, including streams on Admiralty and Chichagof Islands as well as Douglas Island and the mainland. The *M/V Bear* crew sampled from streams on Baranof, Chichagof, Admiralty, and Kuiu islands as well as the mainland. The *M/V Surveyor* crew focused on the southern portion of the study area, including streams on the mainland as well as Admiralty and Revillagigedo Islands. All vessels had skiffs for beach access and the *M/V Surveyor* crew was also equipped with a jet boat for travelling up the larger Southern area rivers and traversing long tide flats. The *M/V Bear* and *M/V Surveyor* carried three SSSC field crew members, as well as their own three-person crew. One or two of these vessel crewmembers accompanied SSSC personnel into the field to serve as bear protection for each otolith-only stream visit. The *M/V Nepenthe* carried four SSSC crewmembers, as well as their own two-person crew. The SSSC employees on this crew were trained in firearm and bear safety.

The two primary goals of routing vessels to visit the 32 streams were:

- To visit each stream a minimum of two times allowing sampling along the entire length of the anadromous reach.
- To structure visits so that they coincide with both the early and late stages of the run.

Pre-season stream visit itineraries were created for all vessel-based crews to best meet these goals. They took into account historical run timing, data from previous field seasons, distance between streams, and potential weather issues. The SSSC field crew leaders knew that it would be very likely that their schedules would change due to actual run timing and weather. Thus, after each stream visit, crew leaders reported to the SSSC project coordinator the numbers of live/dead fish seen, samples collected, water conditions, and other observations. This information, as well as information from ADF&G aerial and foot surveys, high water events, and other weather-related issues, comprised the basis for in-season schedule changes. Most transits between streams occurred in the evenings. Travel days were scheduled when stream-to-stream distances required over ten hours in transit. Each vessel had occasional resupply days in various ports.

The Northernmost crew sampled a total of seven streams, with support from a graduate student sampling one stream. The North central crew sampled a total of 11 streams, with support from the Tenakee crew sampling one stream, the Northernmost crew sampling three streams, and the Southernmost crew sampling one stream. Many of the streams in the Northernmost and North central portions of Southeast are within close enough proximity that mid-season changes and collaboration between crews could occur without difficulty.

The southern crew sampled a total of 10 streams with support from both Northern crews co-sampling one stream. The SSSC project coordinator and ADF&G foot survey crews also took supplementary samples on one stream. Many of the streams in the southern portion are larger and much farther apart than those in the northern portion (Figure 13). This, when coupled with bad weather, made for slightly fewer visits on the southern portion of Southeast.

The Tenakee Springs crew primarily sampled two otolith-only study streams: Little Goose Creek and Seal Bay Head. They also played a large role in sampling from Kadashan River. They furnished a skiff that was used for day-trips to each location.

Communication and Data Transfer

The SSSC project coordinator communicated daily with the vessel crews using Delorme inReach, satellite-based texting devices. Satellite or cell phone check-ins occurred when longer conversations were needed. The Tenakee area contractors communicated via email and phone and transmitted their stream survey data regularly. The vessel-based crews were able to transmit surveys when within cell phone service.

The three SSSC field crews returned to Sitka between August 31, 2015 and September 2, 2015 for gear storage and debriefing. The Tenakee Springs returned all gear via USPS shipping.

Specific Biological Sampling Methods

Every effort was made to use consistent field methodologies throughout the data collection in both regions. Detailed methodological protocols were developed to guide 2015 field data collection (Appendices C-D). The protocols were developed primarily from previous practices established within ADF&G, modified as necessary to facilitate the current study and from experience in 2013 and 2014. The protocols included specific methods for biological sampling including techniques for collecting post-spawned adult salmon, extracting otoliths, measuring lengths, determining sex, and collecting tissues for Pink Salmon DNA analysis in PWS fitness streams. Consistent methods and collection trays were used throughout the study. All otoliths were sent to the respective ADF&G labs for processing (Cordova and Juneau), while DNA tissue samples were sent to ADF&G's Gene Conservation Lab in Anchorage for processing.

All field data were collected on-site using electronic tablets running an Android application developed specifically for collecting this project's data (developed under a subcontract to Finsight LLC of Juneau). Guidance for the use of the field tablet application for data collection was integrated into the protocols. A more rigorous process of field and post-field quality control was implemented in 2014 and improved in 2015. All otolith and DNA samples were checked for completeness and accuracy at the end of each sample tray row, before leaving a processing area, and at the end of the day. Data errors were immediately corrected in the tablet or on the laptop.

A project SQL database was also established in 2013 and modified for the 2014 and 2015 seasons by Finsight LLC. Field data was backed up nightly on laptop computers and then uploaded to the host database from the laptops whenever the crews had access to the internet. The survey data were imported nightly from the tablets to laptop computers where they were run through a series of quality assurance checks on a custom laptop application.

Hatchery Fraction Data Analysis

As in 2013 and 2014, the objectives of the field sampling in 2015 on the spawning grounds of PWS and Southeast included estimates for the fractions of hatchery fish in each spawning population of Pink and Chum Salmon that year. Sampling followed a stratified, two-stage design in which districts are strata, streams are first-stage sampling units, and fish the second-stage units. Streams included in the study were chosen randomly with probability proportional to their size, based on the 25-year average of spawning abundance indices generated from aerial surveys by ADF&G over years 1986 through 2010 (see Botz et al. 2014). The number of streams to sample for the hatchery fraction study was allocated across PWS districts proportional to run size (summed abundance indices) according to procedures in Cochran (1972). Streams to be sampled within a district were selected with probability according to run size (again abundance indices) with replacement. Each sampled stream was visited at least three to five times from late July through late September in PWS and two to five times from late July to end of August in Southeast. The number of dead and live salmon of each species was usually counted in the stream during each visit, and otolith samples were taken from dead or moribund salmon during each visit. An otolith was excised from each sampled salmon, and its origin (hatchery or wild) was determined later after sampling had finished.

Estimated Fractions and Estimated Variances

By the District (PWS) or Sub-region (Southeast)

From Thompson (1992, p. 132), an unbiased estimate of the population total ² from any multi-stage sampling design in which the first-stage units (here streams) were chosen proportional to their size with replacement is:

$$\tau = \frac{1}{n}\sum_{i=1}^{n}\frac{\tau_i}{\pi_i}, \qquad \pi_i = \frac{M_i}{M}, \quad \text{and} \quad \tau_i = M_i\bar{y}_i, \qquad \text{(1a, 1b, 1c)}$$

where in this study τ is an unbiased estimate of the number of hatchery fish on the spawning grounds in a district (PWS) or sub-region (Southeast), *n* is the number of first-stage units visited in that district, π_i is the relative size of the *i*th stream among all streams in the district[4], M_i is the number of second-stage units (hatchery and wild spawning fish) in *i*th stream in that district, *M* is the number of spawning fish in the district, τ_i is the estimated number of hatchery salmon on the spawning grounds in the *i*th stream, and $\bar{y}_i$ is the estimated fraction of hatchery spawning fish on the spawning ground of the *i*th stream. However, the objective of our field study is not to estimate the total number of hatchery-produced Chum Salmon or Pink Salmon on the spawning ground, but to estimate the mean hatchery fraction of the spawning population across all streams. The estimated mean fraction over all streams $\bar{q}$ is found by dividing the estimated number of salmon of hatchery origin in the spawning population (here τ) by the spawning abundance *M* of the target species in the district:

$$\bar{q} = \tau/M = \frac{1}{M}\frac{1}{n}\sum_{i=1}^{n}\frac{M_i\bar{y}_i}{M_i/M} = \frac{1}{n}\sum_{i=1}^{n}\bar{y}_i \qquad (2)$$

Thompson (1992) provides the following equation for estimating the variance for the population total under these circumstances:

[4] Identifiers τ, *y*, and *q* are estimates, while identifiers π, *M*, and *n* are actual values.

$$v(\tau) = \frac{1}{n(n-1)} \sum_{i=1}^{n} \left(\frac{\tau_i}{\pi_i} - \tau \right)^2 . \qquad (3)$$

Dividing the above equation by the square of the number on the spawning grounds within the district (*M*) provides the estimated variance for the estimated fraction of hatchery fish in the population:

$$v(\overline{q}) = v(\tau) / M^2 = \frac{1}{M^2} \frac{1}{n(n-1)} \sum_{i=1}^{n} \left(\frac{\tau_i}{\pi_i} - \tau \right)^2 = \frac{1}{n(n-1)} \left(\sum_{i=1}^{n} \overline{y}_i^2 - \frac{\left(\sum_{i=1}^{n} \overline{y}_i \right)^2}{n} \right) . \qquad (4)$$

By the Stream

Part of the sampling design described above is that a single sample of m_i salmon is drawn randomly from each of the *n* streams in a district[5]. Each fish in the sample is scored with a "1" if it's a hatchery fish, or a "0" if otherwise. The sum of these m_i recordings is divided by m_i to produce $\overline{y}_i$ for that stream. However, streams in our study were visited several times each to account for changes in the hatchery fraction in the stream over the season. A quasi-random sample from the spawning population was drawn during each visit to estimate the hatchery fraction during that visit. The term quasi-random is used because we assumed that natural forces were sufficient to have distributed hatchery fish evenly among the spawning population such that the sample was representative of the spawning population at the time of the visit. Under these circumstances, the weighted average for the *i*th stream across visits is:

$$\overline{y}_i \equiv \overline{q}_i = \sum_{v=1}^{V_i} w_{iv} q_{iv} \text{, where } w_{iv} = \frac{C_{iv}}{\sum_{v'=1}^{V_i} C_{iv'}} \text{ and } q_{iv} = \frac{\sum_{j=1}^{m_{iv}} y_{ijv}}{m_{iv}} \text{, and} \qquad (5a, 5b, 5c)$$

where *v* denotes a visit, V_i is the number of visits to the *i*th stream, C_{iv} the number of dead/live salmon counted during a visit, m_{iv} the number of fish of the target species sampled in a visit, and y_{ijv} is the result of sampling a fish (y_{ijv} = 1 if the fish is of hatchery origin, 0 otherwise). The estimated mean fraction across visits is an unbiased estimate for the mean hatchery fraction for the stream.

From Thompson (1992) the variance of the $\overline{y}_i$ is implied in Equation 4 when first-stage units are selected with a probability according to their size and second-stage units are selected randomly. While first-stage units were so selected in our study, second-stage units were not strictly selected randomly. Nevertheless, several factors ameliorate the need to explicitly consider the variance for $\overline{y}_i$:

1. the frequent visits to streams;
2. the large number of fish sampled during the season;

---

[5] Identifier *w* , *v*, *V*, *C*, and *m* are actual values.

3. weights were based on actual counts;
4. the effect of random (quasi) sampling in the design; and
5. fractions were often unchanging across visits (often near zero).

For these reasons Equation 4 as written was used to express uncertainty in estimated hatchery fractions for the spawning populations in the districts.

For the Entire PWS or Southeast

Equations above are germane to any population sampled according to a two-stage design, a population that in our situation is the spawning population in a district of PWS or sub-region of Southeast. Given that there are nine such districts in the Sound[6], there are potentially nine populations per species. Similarly, there are three sub-regions in Southeast. An unbiased estimate of the hatchery fraction for a species across all districts is:

$$\hat{q} = \sum_{h=221}^{221,\ldots,229} W_h \overline{q}_h \text{ , where } W_h = \frac{A_{h(2013)}}{\sum_{h'=221}^{221,\ldots,229} A_{h'(2013)}} \text{ , and} \qquad \text{(6a, 6b)}$$

where h denotes stratum (district), $A_{h(2013)}$ the aerial abundance index by ADFG for stratum (district) h in 2013, and $\overline{q}_h \equiv \overline{q}$ in Equation 2 (the specific district or sub-region is now explicitly identified), and $\hat{q}$ is the estimated fraction of hatchery fish across the entire Sound or Southeast. The estimated variance for the estimated sound-wide fraction $\hat{q}$ is:

$$v(\hat{q}) = \sum_{h=221}^{221,\ldots,229} W_h^2 v(\overline{q}_h) \, . \qquad (7)$$

The calculations described above were first explicitly framed in Excel and then coded into R statistical software for repetitious analytical runs. Equations for calculating stray rates of hatchery Pink and Chum Salmon at the level of study stream, district or sub-region, and then region, for both PWS and SEAK, were implemented in R (R Core Team 2014) following the equations defined above.

Results

Overall, the stream sampling was successful relative to the goals of the project, as described further below. A total of 88,749 individual fish were sampled from all PWS and SEAK streams and species combined in 2015. Many streams were sampled beyond their targets and others were below the targets. A combination of increased effort on PWS fitness streams and better fish availability and weather generally contributed to increased success in 2015 compared to 2013 or 2014 when about 33,500 and 30,600 individuals were sampled.

---

[6] There are only 8 districts in regards to PWS Chum Salmon in that District 229 (the Unakwik District) has virtually no Chum Salmon spawning in the district.

PWS Stream Sampling Results

Pink Salmon and Chum Salmon were observed in all streams sampled across PWS, where the general pattern of Pink Salmon running in streams was earlier in the season in northeast PWS and later for the southwest portions of PWS. In 2015, record numbers of Pink Salmon returned to PWS. This significantly increased the sampling on fitness streams in order to sample the greatest proportion of returning fish.

Pink Salmon Hatchery Fraction Sampling

Across all 28 streams sampled for Pink Salmon otoliths (Figure 12), 70,815 pairs of otoliths were taken, reaching or exceeding the sampling goal in all streams (Table 2). Oversampling, as described in the general methods, occurred during the peak of the Pink Salmon run at most streams. Further, 2015 was a record year for Pink Salmon returns in PWS in general, especially as compared with 2013, which was also a record season at the time (Botz et al. 2014). The number of samples varied per stream visit (Appendix F). Foot survey-based live and dead counts were made on all stream surveys (Appendix F) and then later used to weight the hatchery fraction estimates per visit based on dead counts.

Table 2. Summary of sampling and hatchery fractions by stream for PWS Pink Salmon in 2015. Target sample size per stream was 384 for estimating the hatchery fraction. Counts of live and dead salmon were taken during each visit with dead counts used to weight the hatchery fraction of salmon sampled each visit to produce weighted average seasonal hatchery fractions for each stream.

Stream name	AWC code	Samples collected 2015	Number of stream visits 2015	Average hatchery fraction weighted by counts per visit (2013)	Average hatchery fraction weighted by counts per visit (2014)	Average hatchery fraction weighted by counts per visit (2015)
Hartney C	221-10-10020	557	9	0.024	0.072	0.011
Spring (fitness)	221-20-10200	12469	47	0.031	0.040	0.009
Sheep R	221-20-10360	576	3	0.000	0.013	0.002
Beartrap R	221-30-10480	480	3	0.025	0.001	0.013
Sunny R	221-40-10875	447	4	0.000	0.022	0.016
Short C	221-40-10880	580	3	0.006	0.081	0.039
Fish C	221-40-10890	606	3	0.000	0.054	0.026
Lagoon C	221-40-10990	628	3	0.016	0.077	0.055
Long C	222-10-12140	454	4	0.070	0.415	0.161
Spring C	222-10-12170	611	3	0.002	0.017	0.037
Delta C	222-20-12335	536	3	0.010	0.294	0.172
Siwash R	222-20-12640	599	3	0.098	0.367	0.324
Coghill R	223-30-13220	485	5	0.018	0.099	0.000
Hummer C	224-10-14240	553	3	0.020	0.197	0.206
Paulson C	224-10-14550	614	3	0.058	0.005	0.212
W. Finger C	224-40-14850	436	3	0.025	0.000	0.053
Comstock C	225-20-15040	445	4	0.868	0.899	0.807
Paddy C	226-20-16010	8710	47	0.154	0.595	0.328
Erb C	226-20-16040	13039	50	0.113	0.228	0.214
Bainbridge C	226-20-16300	620	3	0.174	0.000	0.169
Hogan Bay	226-30-16810	9441	29	0.640	0.915	0.583
Johnson C	226-40-16269	624	3	0.370	0.712	0.387
Swamp C	227-20-17390	628	5	0.063	0.125	0.130
Cabin C	227-20-17464	557	5	0.103	0.321	0.107
Gilmour C [b]	227-20-17480	6548	20	NA	0.557	0.225
Stockdale C	227-20-17520	8602	22	0.163	0.735	0.240
Double C	228-40-18310	400	3	0.002	0.048	0.013
Constantine C	228-60-18150	570	3	0.000	0.023	0.006

[a] Formerly erroneously designated as Surplus Creek in 2013 and 2014 reports but Delta Creek was actually sampled consistently in all three study years.
[b] Data collected and hatchery fraction calculated at the stream level but Gilmour Creek was not included in the district or PWS-wide hatchery fraction estimations because it was not part of the original hatchery fraction experimental design.

Chum Salmon Hatchery Fraction Sampling

A total of 6,492 Chum Salmon samples were taken with sampling goals reached or exceeded in 12 out of 17 streams in the analysis (Figure 12, Table 3). The least productive streams for Chum Salmon samples were Blackstone Creek (13.3% of the sampling goal), Siwash (32.8%), Paulson (37.2%), Spring (44.3%), and Swamp (52.1%) Creeks, and the Coghill River (60.9%). Because Blackstone Creek had such low numbers of Chum Salmon, we also surveyed nearby Tebenkof Creek, which added 45 samples (see Appendix H for more details). Tebenkof Chum Salmon samples were combined with those from Blackstone for the hatchery fraction analysis.

Oversampling was possible in many Chum Salmon systems such as Beartrap Creek, Vanishing Creek, and Mill Creek. The number of Chum samples varied per stream visit (Appendix G). Foot survey-based live and dead counts were made on most stream surveys (Appendix G) with dead counts later used to weight the hatchery fraction estimates per visit. See Appendix H for more details on the sampling of each PWS stream.

Table 3. Summary of sampling and hatchery fractions by stream for PWS Chum Salmon in 2015. Target sample size per stream was 384 for estimating the hatchery fraction. Counts of live and dead salmon were taken during each visit with dead counts used to weight the hatchery fraction of salmon sampled each visit to produce weighted average hatchery fractions for each stream.

Stream name	AWC code	Samples collected 2015	Number of stream visits 2015	Average fraction weighted by counts per visit 2013	Average fraction weighted by counts per visit 2014	Average fraction weighted by counts per visit 2015
Hartney C	221-10-10020	535	9	0.005	0.034	0.022
Beartrap R	221-30-10480	554	3	0.005	0.051	0.014
Sunny R	221-40-10875	384	4	0.001	0.038	0.003
Long C	222-10-12140	428	4	0.261	0.058	0.075
Vanishing C	222-10-12157	548	3	0.045	0.025	0.027
Spring C	222-10-12170	170	3	0.023	0.000	0.009
Wells R	222-20-12340	469	3	0.021	0.065	0.045
Siwash R	222-20-12640	126	3	0.049	0.120	0.326
Coghill R	223-30-13220	234	5	0.049	0.000	0.008
Mill C	224-10-14210	628	3	0.042	0.003	0.011
Tebenkoff [a]	224-10-14500	45	3	NA	NA	NA
Blackstone C	224-10-14510	6	3	0.093	0.000	0.065
Paulson C	224-10-14550	143	3	0.056	0.043	0.040
W. Finger C	224-40-14850	474	3	0.017	0.015	0.038
Swamp	227-20-17390	200	5	0.601	NA	0.794
Cabin C	227-20-17464	519	5	0.965	0.803	0.897
Double C	228-40-18310	422	3	0.039	0.001	0.026
Constantine C	228-60-18150	612	3	0.005	0.000	0.035

[a] Samples from Tebenkof Creek were combined under neighboring Blackstone Creek for the analyses described below.

PWS Pink Salmon Fitness Sampling

Overall, sampling was successful at all of the six selected Pink Salmon PWS fitness study streams in 2015 (Table 4). Unlike in 2014, Spring Creek was highly productive with large number of Pink Salmon running from early to late in the season. Because 2015 was a record year for Pink Salmon returns in PWS, sampling on fitness streams was intense in order to sample the greatest proportion of spawning fish on each stream (see Appendix H for more details on the sampling of each PWS stream).

Table 4. Total Pink Salmon DNA and otolith samples collected in Prince William Sound during July through September 2015.

Stream name	AWC code	Total collected	Visits
Erb Creek	226-20-16040	13,039	50
Gilmour Creek	227-20-17480	6,548	20
Hogan Creek	226-30-16810	9,441	29
Paddy Creek	226-20-16010	8,710	47
Spring Creek	221-20-10200	12,469	47
Stockdale Creek	227-20-17520	8,602	22
	Total	58,809	215

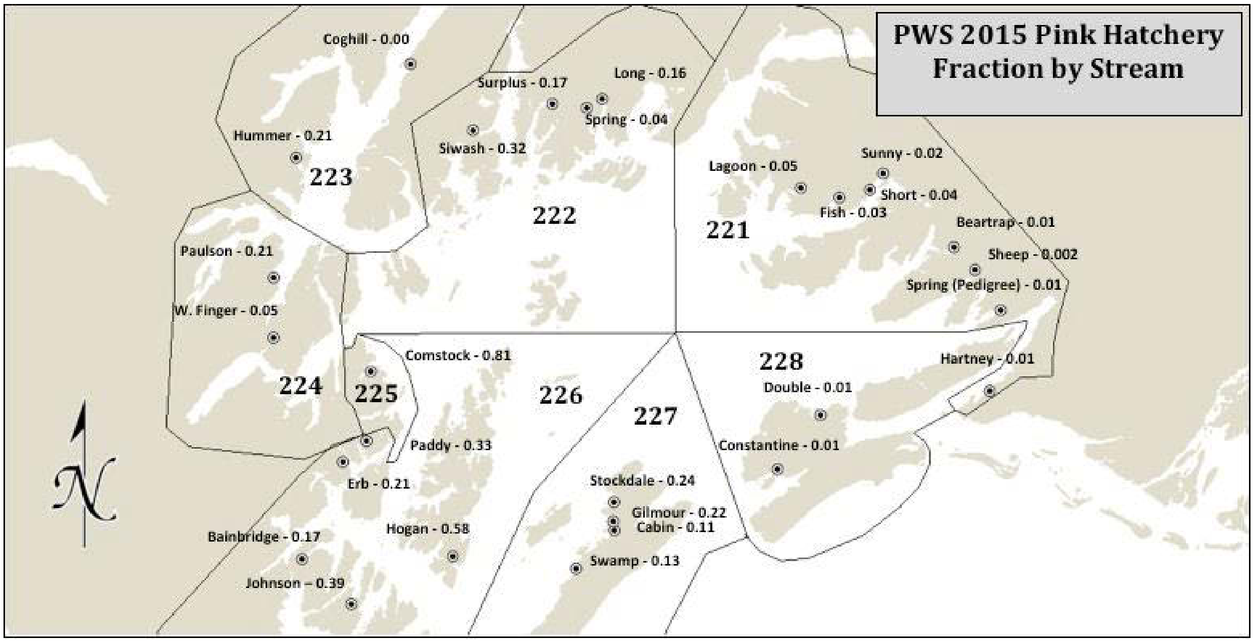
PWS Stream Hatchery Fraction Results

Pink Salmon and Chum Salmon hatchery fractions in the natural spawning streams were analyzed at the level of study stream, district, and then PWS-wide.

PWS Pink Salmon Hatchery Fractions

At the stream level (n = 28), fractions of straying hatchery Pink Salmon ranged from 0 at the Coghill River to 0.81 in Comstock Creek in 2015 (Table 2, Figure 14). Other study streams with notable straying fractions of hatchery Pink Salmon were Hogan Bay, Johnson, Paddy and Siwash Creeks (0.58, 0.39, 0.33, 0.32, respectively). All other study streams had hatchery fractions less than 0.25. Some 2015 straying fractions of hatchery Pink Salmon by study stream varied from those observed in 2013 and 2014 (Table 2).

Figure 14. PWS Pink Salmon hatchery stray rates by stream in 2015. Black lines represent district borders.



Hatchery Pink Salmon straying fractions in 2015, and their associated variances, across management districts in PWS are reported in Table 5 (n=27 as Gilmour Creek was excluded from district and sound-wide analyses, since it was not part of the original experimental design).

Table 5. Estimated PWS Pink Salmon district-wide stream hatchery fractions and their standard errors 2013 - 2015. The aerial survey fraction for each district was used to weight the contribution of each district to the overall fraction estimate.

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)	Estimated hatchery SE (2015)	Number of streams sampled	Aerial survey fraction for district (2015)
Eastern (221)	0.013	0.045	0.021	<0.001	8	0.223
Northern (222)	0.045	0.273	0.173	0.003	4	0.109
Coghill (223)	0.018	0.099	0.000	NA	1	0.112
Northwestern (224)	0.034	0.067	0.157	0.003	3	0.063
Eshamy (225)	0.868	0.899	0.807	NA	1	0.010
Southwestern (226)	0.290	0.490	0.336	0.005	5	0.110
Montague (227)	0.110	0.394	0.159	0.002	3	0.090
Southeastern (228)	0.001	0.036	0.010	<0.001	2	0.283
Overall	0.044	0.148	0.095	0.035	27	1.000

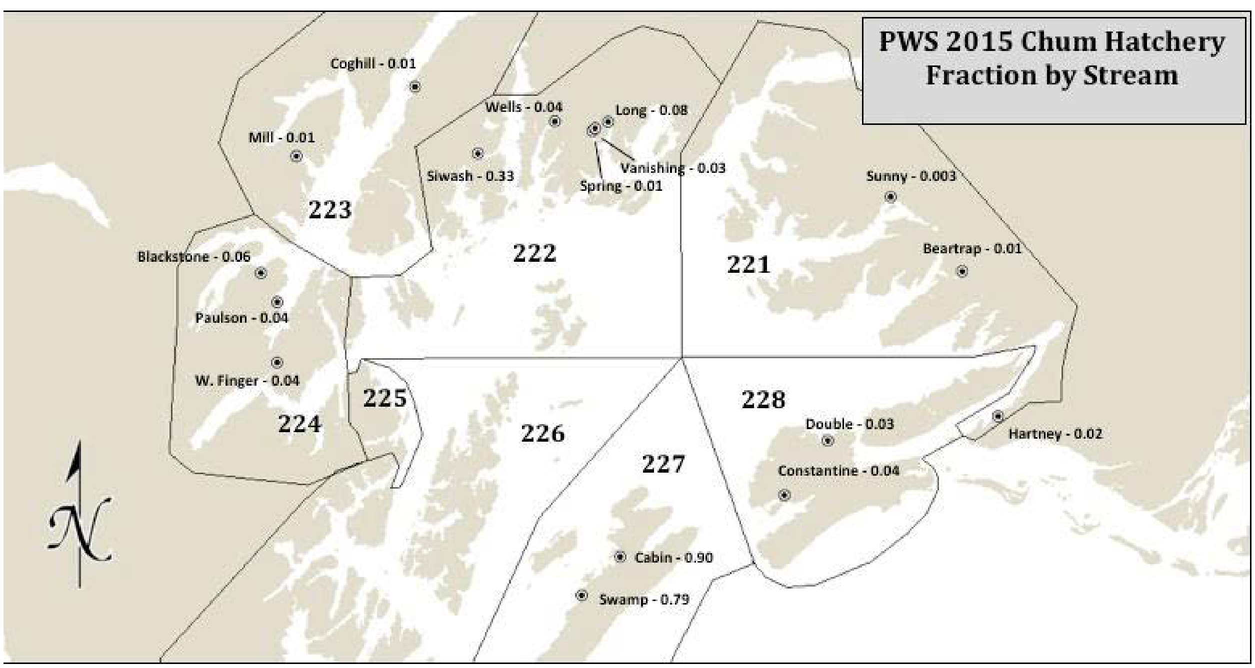
Based on these results, the Eshamy management district in PWS had the highest fraction of hatchery Pink Salmon due to the fact that Comstock Creek is the only study stream in this district and it had the highest straying fraction of hatchery Pink Salmon of all study streams. The

Southwestern district had the second highest district-wide straying fraction of hatchery Pink Salmon (0.34). The Northern, Northwestern, and Montague districts all had hatchery fractions close to 0.16. The remaining three districts had hatchery fractions ≤ 0.02. All districts except Eshamy (represented by one stream) exhibited apparently lower hatchery fractions in 2015 than 2014, but six out of eight districts had higher fractions in 2015 in comparison with 2013 (Table 5). For the entire PWS region in 2015, the straying fraction of hatchery Pink Salmon in all spawning streams was calculated to be 0.096 ± 0.035. This hatchery fraction estimate was apparently greater than it was in 2013, but lower than 2014 (Table 5).

PWS Chum Salmon Hatchery Fractions

At the stream level (n = 17), hatchery fractions of PWS Chum Salmon ranged from 0.003 to 0.90 in 2015 (Table 3, Figure 15). Straying of hatchery Chum Salmon was detected at all study streams in PWS. Like 2014, Cabin Creek had the highest Chum Salmon hatchery fraction among all study streams in 2015 (0.90). Swamp Creek had the next highest return of hatchery fish in 2015 (0.79). (Interestingly, no Chum Salmon returned to Swamp Creek in 2014.) Siwash Creek had a moderate fraction of hatchery fish observed in 2015 (0.33). All other study streams had lower hatchery fractions (< 0.09). Hatchery fractions of Chum Salmon by study stream in 2015 varied from those observed in 2013 and 2014, however, Swamp and Cabin Creeks consistently had large fractions of hatchery fish over all three years of the study (Table 3).

Figure 15. PWS Chum Salmon hatchery stray rates by stream in 2015. Black lines represent district borders.



Based on estimated hatchery fractions across management districts in PWS, the Montague management district had the highest fraction of hatchery Chum Salmon in 2015 (Table 6). Both Cabin and Swamp Creeks are in the Montague management district and these streams had the highest fractions of hatchery Chum Salmon among all study streams in 2015. The Coghill management district had the lowest fraction of hatchery Chum Salmon in PWS during 2015 (0.008). All but one district (Eastern) apparently had higher Chum Salmon hatchery fractions in 2015 than in 2014 (Table 6). For the entire PWS region in 2014, the straying fraction of hatchery Chum Salmon on spawning streams was estimated to be 0.031, very similar to the 2013 and 2014 estimates (0.028, 0.032, Table 6).

Table 6. Estimated PWS Chum Salmon district-wide stream hatchery fractions and their standard errors 2013-2015. The aerial survey fraction for each district was used to weight the contribution of each district to the overall fraction estimate.

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)	Estimated hatchery fraction SE (2015)	Number of streams sampled	Aerial survey fraction for district (2015)
Eastern (221)	0.004	0.041	0.013	<0.001	3	0.457
Northern (222)	0.080	0.054	0.097	0.003	5	0.180
Coghill (223)	0.049	0.000	0.008	NA	1	0.064
Northwestern (224)	0.052	0.015	0.038	<0.001	4	0.030
Montague (227)	0.783	0.803	0.846	0.003	2	0.072
Southeastern (228)	0.022	0.000	0.031	<0.001	2	0.189
Overall	0.028	0.032	0.031	0.025	17	1.000

Southeast Alaska Stream Sampling Results

SSSC field crews were highly efficient in the 2015 season, conducting 116 stream visits in 45 days. There were fewer total stream visits in 2015 vs 2014 because we were not maintaining the nearly daily presence on fitness streams. The added benefit of having three vessel-based crews, each of which was covering a large geographic area, allowed for schedules to be easily manipulated and was the key to our success on many of the creeks in 2015. Roughly once a week a crew would either stay on a stream for two days in a row, or return to a stream at a different time than originally scheduled, both without consequence to later stream visits. This flexibility across the region was not possible in previous seasons.

The increase in visit frequency allowed us to keep track of run timing based on our own observations. Project coordinators still maintained good communication with ADF&G Area Management Biologists, but relied more heavily on their own findings in the field to decide future visit timing. In-season communication between field crews and project coordinators regarding sample numbers, field logistics, and other pertinent topics were discussed at length throughout the project, leading to multiple schedule revisions while maintaining proper visit timing as a priority. Altogether, the run coverage and average sample load on each creek was much better in 2015 than any other season to date.

Unlike the 2014 field season, where we saw historically high rainfall and low Chum Salmon returns, both of which greatly affected our success in accessing creeks and collecting samples, the 2015 season was met with good conditions and plentiful Chum Salmon across the region.

For most Southeast streams sampled in 2015, Chum Salmon numbers were much higher than in 2014. On others, we saw the most Chum Salmon of any season to date and on a select few, we saw fewer than any season to date. Lower counts were especially noticeable on Kadashan River, the King Salmon River, Little Goose Creek, and Seal Bay Head. On some streams we have now seen very low numbers of Chum Salmon three years in a row. This is especially true on Glen Creek and Saginaw Creek where we have yet to see over 200 Chum Salmon, live or dead, in the river during any visit in any year. On many occasions there never appeared to be a strong concentration of spawning fish, but rather a collection of small groups lingering in pools throughout the stream.

Higher counts were also seen, especially on Ford Arm, Game Creek, Hidden Inlet, King Creek, and the Marten River. While some of these higher counts may be attributed to more spatial coverage and time spent on the stream, there is no doubt that we saw more chums here than in any other year.

Several high water events occurred during the season, which created dangerous conditions where we were unable to safely wade in the upper reaches of streams. Despite these circumstances, our crews always got ashore and made the most of the day by sampling the lower reaches or tide flats during high water. However, our progress was never truly stopped because of flooding in 2015.

Strong winds were another factor that occasionally prevented us from travelling or adequately sampling. Occasionally, when we would know that a storm was brewing, we would rearrange the schedule in order to reach the more exposed creeks while travel was still possible. There were only a few occasions where crews had to stand down altogether and wait for conditions to improve. Once conditions did improve, we had to prioritize creeks and do our best to make up for lost time. This is especially true for the *M/V Bear* crew. See Appendix J for details of surveys on each Southeast stream.

Chum Salmon Hatchery Fraction Sampling

Chum Salmon were sampled for otoliths in 32 streams across Southeast Alaska (Figure 13). SSSC field crews visited the 32 otolith-only streams 2-4 times each from July 12 to September 2, 2015. Field crews collected a total of 10,651 pairs of otoliths across all Southeast Alaska streams (see Appendix I for a listing of each Southeast stream survey). We exceeded ADF&G's otolith sampling goal of 384 at 16 of the 32 streams (Table 7).

Table 7. Summary of sampling and hatchery fractions by stream for SEAK Chum Salmon in 2015. Target sample size per stream was 384 for estimating the hatchery fraction. Counts of live and dead salmon were taken during each visit with dead counts used to weight the hatchery fraction of salmon sampled each visit to produce weighted average hatchery fractions for each stream.

Stream name	AWC code	Samples collected 2015	Stream visits 2015	Average hatchery fraction weighted by counts per visit (2013)	Average hatchery fraction weighted by counts per visit (2014)	Average hatchery fraction weighted by counts per visit (2015)
Hidden Inlet	101-11-11010	409	2	0.063	0.062	0.052
Marten River	101-30-10600	593	3	0.047	0.091	0.030
Carroll Creek	101-45-10780	480	2	0.044	0.027	0.021
King Creek	101-71-10040-2006	423	4	0.084	0.023	0.021
Harding River	107-40-10490	92	2	0.167	0.050	0.127
North Arm Creek	108-40-10150-2007	363	3	0.043	0.031	0.036
Saginaw Bay S Head	109-44-10370	35	3	0.007	0.149	0.160
Petrof Bay W Head	109-62-10240	402	2	0.000	0.004	0.015
Johnston Creek	110-23-10100	503	3	0.026	0.000	0.006
East of Snug Cove	110-23-10210	549	3	0.000	0.000	0.042
Chuck River	110-32-10090	153	2	0.013	0.070	0.095
Glen Creek	110-34-10060	5	2	0.014	0.000	0.400
Swan Cove Creek	111-16-10450	334	4	0.029	0.000	0.010
King Salmon River	111-17-10100	311	3	0.028	0.002	0.010
Prospect Creek	111-33-10100	111	3	0.241	0.040	0.496
Admiralty Creek	111-41-10050	201	3	0.047	0.036	0.100
Fish Creek - Douglas	111-50-10690	629	3	0.728	0.719	0.873
Ralphs Creek	112-21-10060	442	3	0.007	0.000	0.002
Kadashan River	112-42-10250	5	3	0.000	0.028	0.200
Seal Bay Head[a]	112-46-10070	328	4	0.004	0.034	0.003
Little Goose Creek	112-48-10190	14	3	0.000	0.000	0.000
Freshwater Creek	112-50-10300	134	4	0.018	0.020	0.033
Greens Creek	112-65-10240	262	3	0.000	0.000	0.046
Chaik Bay Creek	112-80-10280	403	4	0.004	0.000	0.019
Whitewater Creek	112-90-10140	393	3	0.041	0.144	0.087
W Crawfish NE Arm	113-32-10050	576	2	0.019	0.009	0.010
Rodman Creek	113-54-10070	385	4	0.011	0.007	0.008
Ushk Bay W End[b]	113-56-10030	32	2	0.008	0.079	0.004
Sister Lake SE Head	113-72-10040-2025	513	2	0.015	0.022	0.027
Ford Arm Creek	113-73-10030	487	2	0.023	0.012	0.025
Game Creek	114-31-10130	500	4	0.036	0.000	0.011
Sawmill Creek	115-20-10520	564	22	0.465	0.193	0.381

[a] Both 112-46-10070 and nearby 112-46-10080 were sampled to increase the number of samples.

[b] Both 113-56-10030 and nearby 113-56-10020 were sampled to increase the number of samples.

Southeast Stream Hatchery Fraction Results

At the stream level (n = 32), hatchery fractions of Chum Salmon in SE Alaska ranged from 0 to 0.87 in 2015 (Table 7, Figure 16). No hatchery Chum Salmon were detected at Little Goose Creek. The highest fraction of hatchery Chum Salmon in 2015 was detected at Fish Creek (0.87), similar to 2014. All other study streams had lower hatchery fractions (< 0.18) in 2015 with the exception of Kadashan (0.20), Sawmill (0.38), Glen (0.40), and Prospect (0.50) Creeks (Table 7).

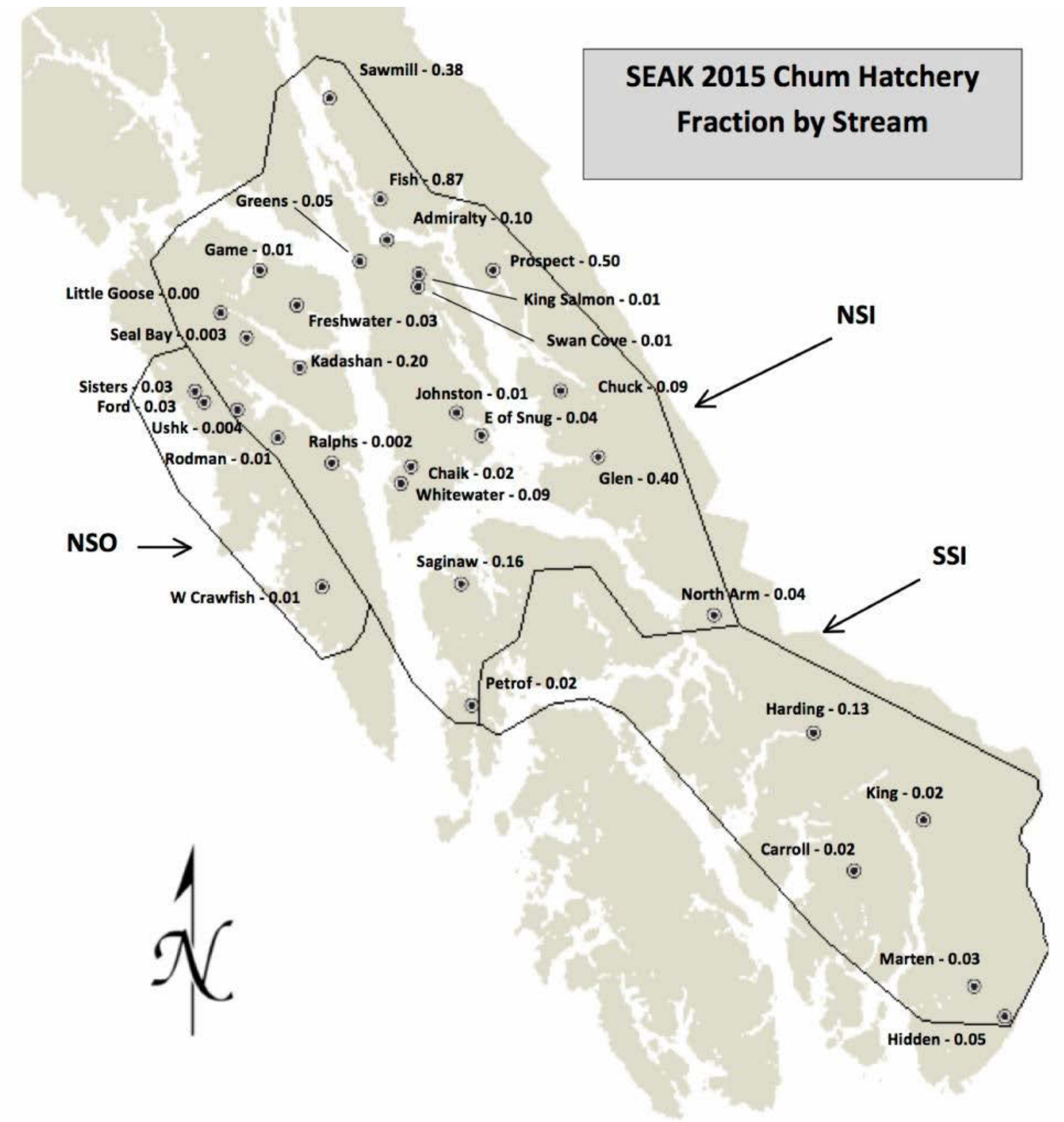


Figure 16. SEAK Chum Salmon hatchery proportions by stream in 2015. Black lines represent district borders.

Hatchery Chum Salmon straying fractions in 2015 across SEAK management sub-regions indicated that the Northern Southeast Inside had the highest fraction of hatchery Chum Salmon (0.127), which was about 2 times higher in 2015 than in 2014 and 2013 (Table 8). Fish Creek, which had the highest hatchery fraction of all study streams for Chum Salmon, is located within the Northern Southeast Inside sub-region along with other higher hatchery fractions streams such as Kadashan, Sawmill, Glen, and Prospect Creeks. The overall 2015 fraction of hatchery Chum Salmon in SEAK study streams was estimated to be 0.092, which was almost 2 times higher than the 2014 estimate (Table 8).

Table 8. Estimated SEAK Chum Salmon district-wide stream hatchery fractions and their standard errors 2013 - 2015. The aerial survey fraction for each district was used to weight the contribution of each district to the overall fraction estimate.

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)	Estimated hatchery fraction SE (2015)	Number of streams sampled	Aerial survey fraction for district (2015)
Northern Southeast Outside	0.019	0.015	0.021	<0.001	3	0.075
Northern Southeast Inside	0.074	0.065	0.127	0.002	24	0.572
Southern Southeast	0.081	0.051	0.050	<0.001	5	0.353
Overall	0.073	0.054	0.092	0.035	32	1.000

DISCUSSION

The overall hatchery fractions in the study streams by species and region over the three-year hatchery fraction study were:

	2013	2014	2015
PWS Pink Salmon	0.044	0.148	0.095
PWS Chum Salmon	0.028	0.032	0.031
SEAK Chum Salmon	0.073	0.054	0.092

PWS Pink Salmon hatchery fractions appeared to vary from year, probably related to the huge differences in even-odd year wild run sizes influencing the fraction, while the other two Chum Salmon groups were somewhat more consistent between years. When considering stray rates by management unit, they varied by species and region (Tables 5, 6, and 10), but were generally low. Considering stray rates in individual streams, a few exhibited high strays, some exhibited medium stray rates, but a majority of streams had low or no straying (Tables 2, 3 and 7). As in 2013 and 2014, the hatchery fractions for 2015 generally reflect the same patterns of higher stray rates in streams closer to hatcheries than in more distant streams, as reported in Brenner et al

(2012) for PWS Pink Salmon and Chum Salmon and Piston and Heinl (2012) for Chum Salmon in SEAK.

REFERENCES

Botz, J., T. Sheridan, A. Wiese, S. Moffitt, R. Brenner. 2014. 2013 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No, 14-43, Anchorage.

Brenner, R. E., S. D. Moffitt, and W. S. Grant. 2012. Straying of hatchery salmon in Prince William Sound, Alaska. Environmental Biology of Fish 94:179-195.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons, New York.

Knudsen, E., M. Buckhorn, K. Gorman, D. Crowther, K. Froning, M. Roberts, L. Marcello, B. Adams, V. O'Connell, D. Bernard. 2015a. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2013, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

Knudsen, E., M. Buckhorn, K. Gorman, P. Rand, M. Roberts, B. Adams, V. O'Connell, D. Bernard. 2015b. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2014, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

Piston, A. W., and S. C. Heinl. 2012. Hatchery Chum Salmon Straying Studies in Southeast Alaska, 2008–2010. Alaska Department of Fish and Game, Fishery Manuscript Series No. 12-01, Anchorage.

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Thompson, S. K. 1992. Sampling. John Wiley & Sons, New York.

RUN SIZE AND SPAWNING ABUNDANCE

David R. Bernard, Eric Knudsen, Pete Rand, and Kristen Gorman

Abundances of spawning Pink and Chum Salmon in both Prince William Sound (PWS) and Chum Salmon in Southeast Alaska (SEAK) are not estimated, but indexed with aerial surveys designed to provide information for in-season management of common property fisheries. Those fish counted from the air are either the progeny of fish that spawned a generation ago in the same streams, or were spawned in hatcheries and have strayed onto the spawning grounds. Because every hatchery-produced Chum Salmon and Pink Salmon in PWS and Chum Salmon in SEAK have thermally marked otoliths, the processes described above from the ocean and stream sampling in 2015 allowed estimates of the hatchery fraction of spawning populations, as described in the foregoing sections. While knowledge of the hatchery fraction of the spawning populations is of great interest in its own right, that statistic, along with others, can be used to estimate run size and spawning abundance as well.

Spawning abundance over a large geographic area can be estimated independent of aerial surveys with knowledge of:

- catches;
- the fraction of the total run comprised of hatchery salmon; and
- the fraction of escapement comprised of hatchery fish.

Current ADF&G catch sampling programs provide the needed knowledge on catches for both wild and hatchery-produced fish. These catch sampling programs for a common property fishery can also provide estimates on the fraction of the run comprised of hatchery fish if both wild and hatchery salmon have the same harvest rate in that fishery. However, when the stated policy of management is to concentrate on catching hatchery salmon in the common property fishery, separate ocean sampling is needed to get the statistic for the run before it is accessed by the fishery. Ocean sampling was impractical in Southeast Alaska due to the many ocean entrances but ocean sampling is theoretically not needed in SEAK because catches of Chum Salmon in common property fisheries there are incidental to catches of Pink Salmon, the targeted species. However, on closer examination of SEAK Chum Salmon catch sampling, it was decided that there were too many imprecisions in assigning the catches to summer Chum Salmon only, so a decision was made to not try to generate estimates for SEAK Chum Salmon. The stream sampling in this study has also provided the last bulleted statistic: the fraction of natural escapement comprised of hatchery fish.

METHODS

This section describes calculations of estimators for run size and spawning abundance for Pink and Chum Salmon in PWS. Methods for calculating approximate variances for estimates are also given. These methods were predicated on independent stream, ocean, and catch sampling programs to deliver statistics for input. The estimators could also work for Chum Salmon in SEAK in which catch sampling does double duty by replacing the ocean sampling to estimate the hatchery fraction of run size. However, the variance equations in this working paper are not correct for SEAK. (Approximate variance using catch sampling as a surrogate for ocean sampling will be described in a later working paper if so desired.)

Estimators

Notation and definition of variables:

R_H is the size of the run of hatchery fish;

R_W is the size of the run of wild fish;

S_H is the number of hatchery strays that survive the fishery (end up spawning);

S_W is the number of wild fish that end up spawning;

C_W is the "catch" of wild fish (in the common property, in cost recovery, and rack return);

C_H is the "catch" of hatchery fish (in the common property, in cost recovery, and rack return);

p is the fraction of the run comprised of hatchery fish; and

q is the fraction of the spawning population comprised of hatchery strays.

Note that by definition:

$$q = \frac{S_H}{S_W + S_H} \quad \text{or} \quad \frac{S_W}{S_H} = \frac{R_W - C_W}{R_H - C_H} = \frac{1-q}{q} = b\,, \tag{1}$$

where q can be estimated from stream sampling, and b is a redefined variable solely a function of stream sampling. Also note that by definition

$$p = \frac{R_H}{R_W + R_H} \quad \text{or} \quad \frac{R_W}{R_H} = \frac{1-p}{p} = a\,, \tag{2}$$

where p can be estimated from ocean sampling, and a is a redefined variable solely a function of ocean sampling. Equation 2 can be rearranged such that $R_W = aR_H$. When this relationship is plugged into Equation 1 and solved for R_H, the result is

$$R_H = \frac{C_W - bC_H}{a-b}\,. \tag{3}$$

Using the relationship $R_W = aR_H$ in the context of Equation 3,

$$R_W = aR_H = \frac{a(C_W - bC_H)}{a-b}\,. \tag{4}$$

Further relationships involving catch and spawning abundance are

$$S_W = R_W - C_W = \frac{a(C_W - bC_H)}{a-b} - C_W \tag{5}$$

$$S_H = R_H - C_H = \frac{C_W - bC_H}{a-b} - C_H \tag{6}$$

$$R = R_W + R_H = \frac{(1+a)(C_W - bC_H)}{a-b} \tag{7}$$

$$S = R - C = \frac{(1+a)(C_W - bC_H)}{a-b} - C \tag{8}$$

Substitution of estimates including statistics from ocean sampling ($\hat{p} \to p$), field sampling ($\hat{q} \to q$), and catch sampling ($\hat{C}_W \to C_W$ and $\hat{C}_H \to C_H$) changes Equations 3 – 5 into estimators of run size and spawning abundance.

Variances

By the delta method an approximate variance of a non-linear function of variables g[**X**] where **X** is the vector [x_1, x_2, … x_n] can be approximated with the non-quadratic terms in a Taylor series expansion of g[**X**] as follows:

$$v(g[\mathbf{X}]) \cong \sum_i v(x_i)\left(\frac{\partial g}{\partial x_i}\right)^2 + 2\sum_{i<j}\sum Cov(x_i, x_j)\left(\frac{\partial g}{\partial x_i}\right)\left(\frac{\partial g}{\partial x_j}\right).$$

In our study there are several non-linear functions (Equations 3–8) with variables $\hat{p}$, $\hat{q}$, $\hat{C}_W$, and $\hat{C}_H$. These variables serve as the x_i for the delta method. In that the stream, ocean, and catch sampling were conducted independently, covariances among statistics from those programs are zero with one possible exception. Some covariances do exist between $\hat{C}_W$, and $\hat{C}_H$ depending on how the catch sampling was conducted. At this time we have no information on a possible covariance so we have chosen to ignore the possibility. The consequence will be to slightly inflate our approximations of variance.

The first step in approximating variances for the right-hand sides of Equations 3 − 8 is to approximate variances for $\hat{a}$ and $\hat{b}$. First derivatives are

$$\frac{\partial \hat{a}}{\partial \hat{p}} = -\hat{p}^{-2} \quad \text{and} \quad \frac{\partial \hat{b}}{\partial \hat{q}} = -\hat{q}^{-2}.$$

The approximate variances are therefore

$$v(\hat{a}) \cong \frac{v(\hat{p})}{\hat{p}^4} \quad \text{and} \quad v(\hat{b}) \cong \frac{v(\hat{q})}{\hat{q}^4}.$$

The next steps were to apply the delta method to Equations 3 – 8 to get approximate variances for run size and spawning abundance. The next series of equations is just such an application.

Approximate variance for Equation 3:

$$v(\hat{R}_H) \cong v(\hat{a})\left(\frac{\partial \hat{R}_H}{\partial \hat{a}}\right)^2 + v(\hat{b})\left(\frac{\partial \hat{R}_H}{\partial \hat{b}}\right)^2 + v(\hat{C}_W)\left(\frac{\partial \hat{R}_H}{\partial \hat{C}_W}\right)^2 + v(\hat{C}_H)\left(\frac{\partial \hat{R}_H}{\partial \hat{C}_H}\right)^2$$

Derivatives: $\frac{\partial \hat{R}_H}{\partial \hat{a}} = -\frac{\hat{R}_H}{\hat{a}-\hat{b}}$ $\quad \frac{\partial \hat{R}_H}{\partial \hat{b}} = \frac{\hat{C}_W - \hat{a}\hat{C}_H}{(\hat{a}-\hat{b})^2}$ $\quad \frac{\partial \hat{R}_H}{\partial \hat{C}_W} = \frac{1}{\hat{a}-\hat{b}}$ $\quad \frac{\partial \hat{R}_H}{\partial \hat{C}_H} = -\frac{\hat{b}}{\hat{a}-\hat{b}}$

Approximate variance for Equation 4:

$$v(\hat{R}_W) \cong v(\hat{a})\left(\frac{\partial \hat{R}_W}{\partial \hat{a}}\right)^2 + v(\hat{b})\left(\frac{\partial \hat{R}_W}{\partial \hat{b}}\right)^2 + v(\hat{C}_W)\left(\frac{\partial \hat{R}_W}{\partial \hat{C}_W}\right)^2 + v(\hat{C}_H)\left(\frac{\partial \hat{R}_W}{\partial \hat{C}_H}\right)^2$$

Derivatives: $\frac{\partial \hat{R}_W}{\partial \hat{a}} = -\hat{b}\frac{\partial \hat{R}_H}{\partial \hat{a}}$ $\quad \frac{\partial \hat{R}_W}{\partial \hat{b}} = \hat{a}\frac{\partial \hat{R}_H}{\partial \hat{b}}$ $\quad \frac{\partial \hat{R}_W}{\partial \hat{C}_W} = \hat{a}\frac{\partial \hat{R}_H}{\partial \hat{C}_W}$ $\quad \frac{\partial \hat{R}_w}{\partial \hat{C}_H} = \hat{a}\frac{\partial \hat{R}_H}{\partial \hat{C}_H}$

Approximate variance for Equation 5:

$$v(\hat{S}_W) \cong v(\hat{a})\left(\frac{\partial \hat{S}_W}{\partial \hat{a}}\right)^2 + v(\hat{b})\left(\frac{\partial \hat{S}_W}{\partial \hat{b}}\right)^2 + v(\hat{C}_W)\left(\frac{\partial \hat{S}_W}{\partial \hat{C}_W}\right)^2 + v(\hat{C}_H)\left(\frac{\partial \hat{S}_W}{\partial \hat{C}_H}\right)^2$$

Derivatives: $\frac{\partial \hat{S}_W}{\partial \hat{a}} = \frac{\partial \hat{R}_W}{\partial \hat{a}}$ $\quad \frac{\partial \hat{S}_W}{\partial \hat{b}} = \frac{\partial \hat{R}_W}{\partial \hat{b}}$ $\quad \frac{\partial \hat{S}_W}{\partial \hat{C}_W} = \frac{\partial \hat{R}_W}{\partial \hat{C}_W} - 1$ $\quad \frac{\partial \hat{S}_W}{\partial \hat{C}_H} = \frac{\partial \hat{R}_W}{\partial \hat{C}_H}$

Approximate variance for Equation 6:

$$v(\hat{S}_H) \cong v(\hat{a})\left(\frac{\partial \hat{S}_H}{\partial \hat{a}}\right)^2 + v(\hat{b})\left(\frac{\partial \hat{S}_H}{\partial \hat{b}}\right)^2 + v(\hat{C}_W)\left(\frac{\partial \hat{S}_H}{\partial \hat{C}_W}\right)^2 + v(\hat{C}_H)\left(\frac{\partial \hat{S}_H}{\partial \hat{C}_H}\right)^2$$

Derivatives: $\frac{\partial \hat{S}_H}{\partial \hat{a}} = \frac{\partial \hat{R}_H}{\partial \hat{a}}$ $\quad \frac{\partial \hat{S}_H}{\partial \hat{b}} = \frac{\partial \hat{R}_H}{\partial \hat{b}}$ $\quad \frac{\partial \hat{S}_H}{\partial \hat{C}_W} = \frac{\partial \hat{R}_H}{\partial \hat{C}_W}$ $\quad \frac{\partial \hat{S}_H}{\partial \hat{C}_H} = \frac{\partial \hat{R}_H}{\partial \hat{C}_H} - 1$

Approximate variance for Equation 7:

$$v(\hat{R}) \cong v(\hat{a})\left(\frac{\partial \hat{R}}{\partial \hat{a}}\right)^2 + v(\hat{b})\left(\frac{\partial \hat{R}}{\partial \hat{b}}\right)^2 + v(\hat{C}_W)\left(\frac{\partial \hat{R}}{\partial \hat{C}_W}\right)^2 + v(\hat{C}_H)\left(\frac{\partial \hat{R}}{\partial \hat{C}_h}\right)^2$$

Derivatives: $\frac{\partial \hat{R}}{\partial \hat{a}} = \frac{\partial \hat{R}_H}{\partial \hat{a}} + \frac{\partial \hat{R}_W}{\partial \hat{a}}$ $\frac{\partial \hat{R}}{\partial \hat{b}} = \frac{\partial \hat{R}_H}{\partial \hat{b}} + \frac{\partial \hat{R}_W}{\partial \hat{b}}$ $\frac{\partial \hat{R}}{\partial \hat{C}_W} = \frac{1+\hat{a}}{\hat{a}-\hat{b}}$

$$\frac{\partial \hat{R}}{\partial \hat{C}_H} = -\frac{(1+\hat{a})\hat{b}}{\hat{a}-\hat{b}}$$

Approximate variance for Equation 8: $\hat{S} = \frac{(1+\hat{a})(\hat{C}_W - \hat{b}\hat{C}_H)}{\hat{a}-\hat{b}} - C$

Being that the total catch C here is a constant (known supposedly without error), $v(\hat{S}) = v(\hat{R})$.

Equations 3 – 8, their approximate variances, and the accompanying derivatives at first glance appear daunting. However, the calculations were adapted to a spreadsheet. Only eight numbers are needed as input to estimate spawning abundance and run size.

RESULTS

The eight numbers mentioned in the previous section for PWS Pink Salmon in 2015 are:

	p	q	C_W	C_H
Estimate→	0.549	0.09548429	25,558,145	73,326,971
Variance→	0.0000143	0.0012001	940000000	940000000

and for PWS Chum Salmon in 2015 are:

	p	q	C_W	C_H
Estimate→	0.688	0.03089557	237,430	2,455,950
Variance→	0.0002346	0.00063121	940000000	940000000

where p, q, C_W, and C_H are estimates from ocean, stream, and catch sampling programs[7]. Variances for $\hat{C}_W$ and $\hat{C}_H$ are not available at this writing, so their variances were roughly estimated to be 940,000,000 which one would expect from a catch of 4,000,000 with 1,000 fish sampled randomly from it to determine the hatchery fraction[8].

The total 2015 run size ($\hat{R}$) of Pink Salmon in PWS was estimated to be over 140 million (Table 9) which was record-setting. It was about 37% larger than the previous record in 2013 (Table 10). The 2015 run was more than 2.5 times larger than in 2014. Much of the interannual variation in run size is attributable to the wild component of the run whereas the hatchery production is somewhat more consistent from year to year (Table 10).

---

[7] Note the "^" are missing from the identifiers.

[8] HINT: Hardly affects precision of estimates at all.

PWS Chum Salmon total run size was about 3.6 million (Table 9) which was about 50% greater than in 2014 and was about 12% less than 2013 (Table 10). In Chum Salmon, the majority of the difference was apparently in hatchery returns because the wild run was quite consistent among the three years (Table 10).

Table 9. Run size estimates, approximated standard errors, and coefficients of variation for 2015.

	PWS Pink Salmon			PWS Chum Salmon		
Factor	**Estimate**	**Approx SE**	**Approx CV (%)**	**Estimate**	**Approx SE**	**Approx CV (%)**
$\hat{R}_H$	77,335,497	117,104	0.15	2,484,332	31,234	1.26
$\hat{R}_W$	63,530,617	1,062,591	1.67	1,127,706	82,832	7.35
$\hat{S}_W$	37,972,472	1,063,118	2.80	890,276	88,481	9.94
$\hat{S}_H$	4,008,526	112,227	2.80	28,382	2,821	9.94
$\hat{R}$	140,866,114	952,084	0.68	3,612,039	91,058	2.52
$\hat{S}$	41,980,998	952,084	2.27	918,659	91,058	9.91

Table 10. Comparative 2013 - 2015 population estimates in millions of fish (the 2013 and 2014 estimates are derived in Knudsen et al. 2015a,b).

	Wild spawners	**Hatchery spawners**	**Total spawners**	**Wild run**	**Hatchery run**	**Total run**
Pink Salmon						
2013	15.7	0.7	16.4	33.1	69.9	103.0
2014	5.1	0.7	5.9	7.0	42.8	49.7
2015	38.0	4.0	42.0	63.5	77.3	140.9
Chum Salmon						
2013	0.9	0.05	0.9	1.1	3.0	4.1
2014	0.9	0.05	1.0	1.2	1.2	2.4
2015	0.9	0.03	0.9	1.1	2.5	3.6

DISCUSSION

Our 2015 estimate above for PWS Pink Salmon spawning abundance (about 42 million, from $\hat{S}_W + \hat{S}_H$) is approximately 2 times larger than ADF&G's estimate of 20.6 million fish (S. Moffitt and T. Sheridan, pers. comm.). ADF&G's estimate was based on an aerial survey index expanded through area-under-the-curve methodology, which takes several assumptions into consideration, including stream life, observer efficiency, and a proportion of PWS streams flown as estimated in Bue et al. (1998). Possible reasons for this difference can include inaccurate assumptions being used for ADF&G's expansion and/or imprecise aerial survey indices due to reduced survey effort (T. Sheridan, pers. comm.). Budget limitations and poor weather have negatively impacted the PWS Pink Salmon and Chum Salmon aerial survey program in recent years, leading to fewer surveys being flown, and increasing duration between surveys (T. Sheridan, pers. comm.). Budget limitations in particular led ADF&G to systematically reduce the numbers of PWS streams flown in 2015 to 129 from the 214 historical index streams that had been flown during previous two field seasons (T. Sheridan, pers. comm.).

Another statistic of interest, from values in the table above, is the estimated 2015 Sound-wide harvest rate of wild fish $(\hat{C}_w/\hat{R}_w)$ which is 40.2% for PWS Pink Salmon and 21.1% for PWS Chum Salmon. These results compare to 2013 observations, when the estimated Sound-wide harvest rate of wild fish $(\hat{C}_w/\hat{R}_w)$ was 52.6% for PWS Pink Salmon and 21.6% for PWS Chum Salmon (Knudsen et al 2015a). Low Chum Salmon values for both years likely speak to the fact that most PWS fisheries do not target, and are not managed for, harvesting wild Chum Salmon (Fair et al. 2008). Lower wild Pink Salmon harvest rates in 2015 are likely due in part to a relatively conservative management approach in western PWS during early August to allow for hatchery escapement (T. Sheridan, pers. comm.). It should also be noted that, when compared to 2013, a relatively conservative management approach in western PWS in 2015 was also accompanied by higher hatchery stray rates as measured by the number of hatchery strays that ended up spawning in streams: 4.3% in 2013 and 10.0% in 2015.

REFERENCES

Botz, J., T. Sheridan, A. Wiese, S. Moffitt, R. Brenner. In Press. 2014 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. 14-43, Anchorage.

Knudsen, E., M. Buckhorn, K. Gorman, D. Crowther, K. Froning, M. Roberts, L. Marcello, B. Adams, V. O'Connell, D. Bernard. 2015a. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2013, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

Knudsen, E., M. Buckhorn, K. Gorman, P. Rand, M. Roberts, B. Adams, V. O'Connell, D. Bernard. 2015b. Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2014, For Alaska Department of Fish and Game Contract IHP-13-013, Cordova, Prince William Sound Science Center, Alaska.

HATCHERY-WILD ALEVIN SAMPLING 2015

Authors: Ben Adams, Julia McMahon, Megan Roberts, and Eric Knudsen

INTRODUCTION

The overarching purpose of sampling salmon alevins in March and April, 2015 was to assess the relative feasibility and costs of collecting offspring from the previous year's spawners for survival comparisons between hatchery- and natural-origin progeny for both males and females. Although the ultimate comparison of the relative survival between the two groups will be made when the offspring return to the streams as adults, assessing the relative survival at the alevin stage will help to reveal whether any differences in survival occur before or after the alevin stage. Samples were systematically collected from a designated proportion of the total spawning area from where adult DNA tissues were collected the previous summer. The origins of the two alevin groups from each stream will be determined by their DNA "fingerprints" corresponding to their parents DNA.

Objectives

The 2015 sampling for Chum Salmon in Fish Creek on Douglas Island, and Pink Salmon in Stockdale Creek on Montague Island was conducted similarly to 2014 to evaluate: a) the field sampling techniques, b) the relative success of capturing alevins, and c) the number of individual alevins required to successfully determine relative survival rates.

METHODS

Our goal in sampling alevins was to collect 1-25 fry in at least 250 redd samples in each stream by hydraulic sampling ("fry-pumping") in March and early April (Figure 17). The reason for collecting a large number of alevins is because only some of the parents were sampled for genetic tissue, and there may be many other alevins of unknown parentage mixed with those whose parentage can be identified. Specific, pre-season alevin sampling protocols are described in Appendix E. The methods below describe how the 2015 sampling was conducted.

<u>Selecting Sample Locations</u>

Sites were sampled with a standard redd pump sampler to collect alevins (Figure 18). Sampling was distributed approximately in proportion to spawning distribution in the previous summer. Because some sample sites produced no target alevins, we knew we would need to "oversample" so the target of 250 positive samples could be attained. However, we did not know in advance what proportion of samples would be positive. Therefore, we initially sampled throughout the entire spawning reach of each stream to assess the relative distribution and success rate. After passing through the stream reach once, we determined how many more positive samples would be required and approximately how they should be distributed throughout the stream to make another representative pass through the stream.

At each sampling location, the sampling net hoop was placed over the substrate wherever it was possible to get a reasonable "seal" of the bottom ring of the net to prevent escape of alevins under the bottom of the ring. If the net did not lay flat on the substrate, it was moved slightly until it sat as flat as possible.

The location of each sample was recorded with GPS coordinates, using the position averaging feature to get a better position. Some samples that were in close proximity were recorded with the same GPS fix. Sample sites were numbered sequentially in chronological order.

Pumping to Collect Alevins

At each sample site, one or two team members worked the 0.5-m net frame down into the substrate as far as practical so that alevins could not escape underneath the frame during pumping (Figure 17). The codend of the net was on the downstream flow side of the net frame.

With the 1½-in gas-powered water pump running, the injector probe was submerged into multiple locations within the net frame, to 12-24 inches deep whenever possible, repeating this action until all alevin had been released or it was thought that the 25 targeted alevin were in the codend. The amount of time the substrate was probed with pumped water from start to end was recorded.

Figure 17. Redd pumping on Stockdale Creek, April, 2014.

If alevins were observed on the surface within the net frame, they were scooped with a dip-net and retained in a water-filled container. After pumping, the net frame was removed and all materials were washed into the codend. The contents of the codend were emptied into a round container or on hard surface to reveal the alevins. All alevins from one pump sample were kept separate from any other sample.

Alevin Samples

All alevins from each sample site were sorted and counted by species and recorded. All non-target species, and excess target species, were released alive into the stream whenever possible. Up to 25 of the target species (if available in the sample) were retained for genetic analysis in sample-specific, pre-labeled, ethanol-filled vials (Isopropanol/Methanol/Ethanol - EtOH). The vials contained 4:1 EtOH to fish tissue. The date, stream, and sample number were written on a small, write-in-the-rain sample label and placed inside the bottle. The sample number corresponded to the last four digits from the vial's bar code. The number of fish was written on the outside of the bottle. The sample vial number was recorded on the data sheet, being certain that the vial number is associated with the GPS data for the same pump sample.

Field Approach – Fish Creek (Douglas Island)

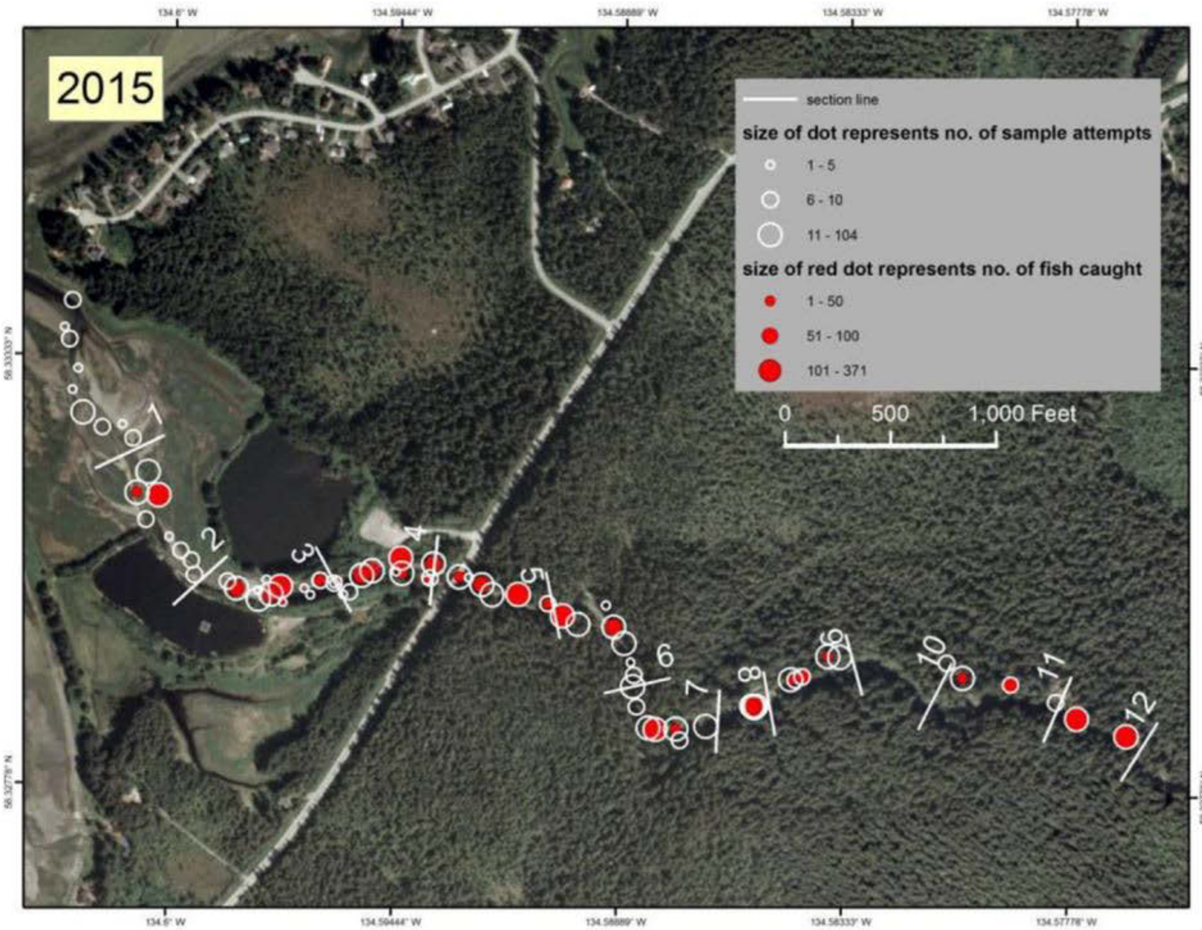
Chum salmon alevin were sampled in Fish Creek on Douglas Island near Juneau February 24-28, 2015. The weather was dry with temperatures ranging between about 18 and 36 degrees F daily. The stream was low and clear with no ice.

To help distribute the sampling throughout the known spawning areas, sampling was apportioned among 12 stream reaches, two of which extended past the existing 10 sections from 2014 (Figure 18). These uppermost two sections where not sampled in 2014 due to ice and lack of time and personnel. Sampling began in section 4 which corresponds to the area near the footbridge, the site of the most intensive spawning the previous summer. Sampling then progressed downstream into the intertidal zone to the downstream-most Chum salmon spawning observed in summer 2014. Sampling was then conducted from section 4 upwards, ending in the uppermost section where spawning was observed the previous summer and where chum abundance sharply tapers off.

Throughout the stream, success rates were much higher than in 2014, likely due to better access and earlier sampling when alevins were still present in the stream. We sampled very thoroughly throughout the stream except in sections 1 and 10, which corresponded to the lower intertidal reach and an area of large substrate that is not conducive to spawning whatsoever. In several areas, the large rock substrate prevented us from digging very deep, however we continued to sample everywhere until we had thoroughly sampled the entire stream.

Figure 18. Map of 12 stream reaches and sampling locations in Fish Creek in 2015. Size of open circles indicates number of redd digs attempted. Size of solid red circles indicates number of alevins captured at a sample

location.



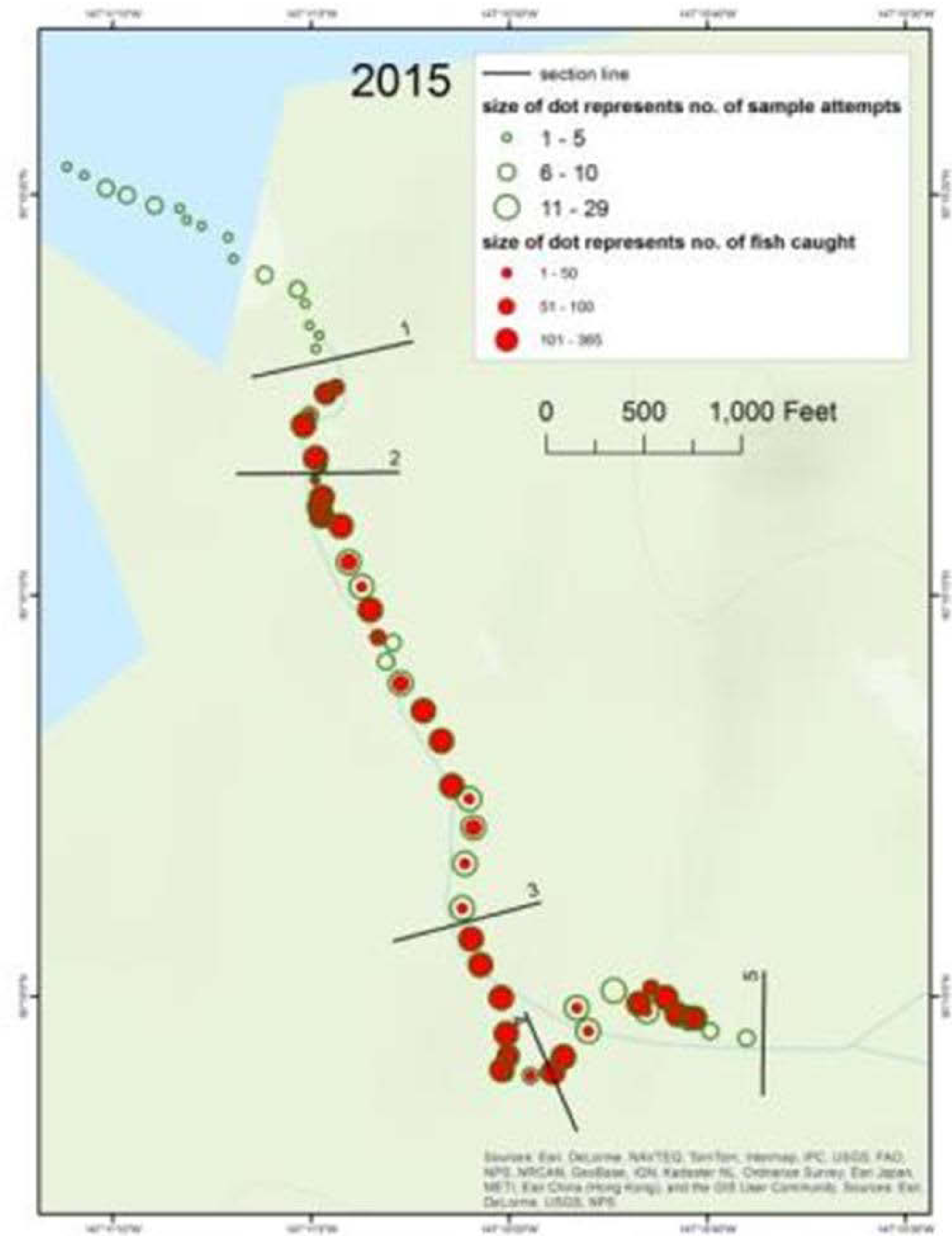
Field Approach – Stockdale Creek

Pink Salmon alevin were sampled in Stockdale Creek on Montague Island in Prince William Sound March 11-16, 2015. The sampling crew traveled to the study site aboard the *Auklet*, which anchored in Stockdale Harbor as a live-aboard vessel for the week. The five-person crew and sampling gear were transported daily by zodiac to the mouth of the study stream. Weather was variable; starting clear and cold, with ice thickening for three days. Then it snowed for a day, and then the wind blew 30-40 knots with sleet and flooding on the last day. Temperatures ranged from 10 to 40 degrees Fahrenheit daily.

The stream was divided into five sections, starting from the mouth: 1) the lower intertidal flat, 2) the high tide gravel bar, 3) the lower straight, 4) the upper straight and first bend and 5) the last sampled creek bends (Figure 19). The first sample site in the intertidal area was within 20 m of the first processing area from the summer 2014 adult sampling. The alevin dig furthest upstream was 650 m downstream of the uppermost summer 2014 adult sampling area and 400 m upstream of the highest alevin dig in 2014. The first five days were used to sample all sections of the stream, except where the ice was too thick. There was 125 m of unbreakable ice-covered sections which were scattered over the 1,000 total meters of stream sampled. The crew used rocks, axes and pry bars to break ice up to 15 cm thick. The sixth day was used to sample downstream from the uppermost point to attain the sampling goal of 250 positive samples.

Two teams sampled about 30 m apart, leapfrogging their way upstream. Each waypoint represents a new pump placement with multiple digs. In areas with a high density of alevins, the digs were about 1 m apart and in low density areas, digs were about 3 m apart. Each dig site was pumped for 50-60 seconds. Digs were terminated early if a large number of alevins were seen in the net in order to avoid unnecessary destruction of the redd.

Figure 19. Stockdale redd sampling stream reaches and sample locations in 2015. Size of open circles indicates number of redd digs attempted. Size of solid red circles indicates number of alevins captured at a sample location.



RESULTS

Results – Fish Creek (Douglas Island)

We conducted 975 sample attempts throughout the anadromous reach in Fish Creek from February 24 to 28. In total, we collected 160 positive samples (Table 11). The total number of Chum Salmon alevins captured ranged between 1 and 147 for all positive samples. Pink Salmon alevin were caught as well and were present in 29 sample attempts. The total number of chum alevin caught in all positive samples was 3,243 and the total number of pinks caught was 591.

In general, positive samples were obtained in large clusters spread out across the stream and in areas of medium to fine substrate. We had the highest sampling success midway along the reach and at the uppermost areas (sections 2-9, 11, and 12) where the most spawning was seen the previous summer (Table 12). When on the creek, we noted that our most successful areas from 2014 continued to yield good results. In 2015, we also obtained positive samples in many places where we had no success in 2014. Occasionally dead alevin and decomposing eggs were flushed out of the gravel throughout the stream, but less frequently than in 2014. Live eggs were also found and assumed to be Coho Salmon.

Table 11. Sampling success of alevins on Fish Creek in March 2015. Sample attempts represent one sampling event in a specific location and positive samples represents the occasions when we captured live Chum Salmon alevin. Percentages of successful sampling attempts are noted as well as total Chum Salmon and Pink Salmon alevins for all positive samples within that section. Average pump time (duration of sampling event) is noted in seconds.

Section #	Sample Attempts	Positive Samples	% Positive Samples	Avg Pump Time	Total Chum Caught	Total Pink Caught
1	35	0	0.00%	32.7	0	0
2	92	2	2.17%	39.8	122	318
3	104	16	15.38%	54.4	296	15
4	85	20	23.53%	65.5	559	170
5	95	17	17.89%	69.8	304	0
6	123	30	24.39%	60.2	481	26
7	93	15	16.13%	60.9	224	0
8	88	25	28.41%	61.3	511	5
9	109	11	10.09%	52.3	236	0
10	7	0	0.00%	47.6	0	0
11	29	2	6.90%	45.1	53	1
12	114	22	19.30%	55.1	457	56
Totals	**974**	**160**	**16.43%**	**53.7**	**3243**	**591**

The Fish Creek Chum Salmon alevin sampling results exhibited a higher success rate in 2015 than in similar sampling in 2014. This may have been because sampling was later in 2014 so that alevin were missed because they had emerged from the gravel.

Year	Sampling dates	Number of attempts	Positive Chum samples	Percent sampling success	Total Chum captured	Chum samples sent to laboratory
2014	March 25-31	774	69	8.9	757	569
2015	February 24-28	975	160	16.4	3,243	1,985

The number sent to the laboratory was less than the number captured because only a maximum of 25 alevins were submitted from samples that exceeded 25 in one pump sample attempt.

Table 12. Total chum and Pink Salmon alevins captured by section over the five days of sampling Fish Creek in 2015. Pumping time for each positive sample is recorded in seconds. This table shows the 160 positive samples obtained out of 974 sampling attempts. Sculpin presence and intertidal influence was also noted as was the coordinates for each positive sample collected.

Section #	Date	Chum Alevin	Pink Alevin	Sculpin Presence	Pump time (sec)	Intertidal	Latitude	Longitude
2	2/24/2015		1	Y	30	YES	58.33183	-134.6006
2	2/24/2015		1	Y	34	YES	58.33153	-134.60033
2	2/24/2015		2		50	YES	58.33156	-134.60087
2	2/24/2015	110	16		36	YES	58.33153	-134.60033
2	2/24/2015		23	Y	32	YES	58.33153	-134.60033
2	2/24/2015		25		50	YES	58.3324	-134.60174
2	2/24/2015		26	Y	18	YES	58.33153	-134.60033
2	2/24/2015		47		27	YES	58.33183	-134.6006
2	2/24/2015		62	Y	42	YES	58.33153	-134.60033
2	2/24/2015		115	Y	35	YES	58.33183	-134.6006
2	2/24/2015	12			45	YES	58.33156	-134.60087
3	2/25/2015	5	1		61	NO	58.33026	-134.59753
3	2/25/2015	59	1	Y	44	NO	58.33026	-134.59753
3	2/25/2015		1		53	NO	58.33026	-134.59753
3	2/25/2015		1	Y	60	NO	58.33026	-134.59753
3	2/25/2015		11		60	NO	58.33036	-134.5973
3	2/24/2015	1			48	NO	58.33045	-134.59632
3	2/24/2015	1			27	NO	58.33033	-134.59838
3	2/24/2015	4			70	YES	58.33016	-134.59724
3	2/24/2015	7		Y	70	NO	58.33044	-134.59588

3	2/24/2015	9			30	NO	58.33033	-134.59838
3	2/24/2015	16		Y	50	YES	58.33016	-134.59724
3	2/24/2015	47			30	NO	58.33033	-134.59838
3	2/25/2015	1		Y	40	NO	58.33026	-134.59753
3	2/25/2015	1			50	NO	58.33036	-134.5973
3	2/25/2015	4			77	NO	58.33026	-134.59753
3	2/25/2015	8			75	NO	58.33036	-134.5973
3	2/25/2015	30			100	NO	58.33036	-134.5973
3	2/25/2015	49			75	NO	58.33036	-134.5973
3	2/25/2015	54			60	NO	58.33036	-134.5973
4	2/25/2015		0		45	NO	58.33052	-134.5953
4	2/25/2015		1		43	NO	58.33052	-134.5953
4	2/25/2015		1		105	NO	58.33075	-134.59433
4	2/25/2015		3	Y	100	NO	58.33075	-134.59433
4	2/25/2015	59	15		120	NO	58.33075	-134.59433
4	2/25/2015	12	50		80	NO	58.33058	-134.59504
4	2/25/2015		100	Y	85	NO	58.33058	-134.59504
4	2/25/2015	1			65	NO	58.33058	-134.59504
4	2/25/2015	1			70	NO	58.33075	-134.59433
4	2/25/2015	3			45	NO	58.33052	-134.5953
4	2/25/2015	5			65	NO	58.33058	-134.59504
4	2/25/2015	6			125	NO	58.33075	-134.59433
4	2/25/2015	8			75	NO	58.33075	-134.59433
4	2/25/2015	13		Y	49	NO	58.33047	-134.59369
4	2/25/2015	18			47	NO	58.33055	-134.5943
4	2/25/2015	19			125	NO	58.33075	-134.59433
4	2/25/2015	22			140	NO	58.33075	-134.59433
4	2/25/2015	26			90	NO	58.33075	-134.59433
4	2/25/2015	30			95	NO	58.33075	-134.59433
4	2/25/2015	35			135	NO	58.33075	-134.59433
4	2/25/2015	37			80	NO	58.33058	-134.59504
4	2/25/2015	38			65	NO	58.33058	-134.59504
4	2/25/2015	46			60	NO	58.33075	-134.59433
4	2/25/2015	89			35	NO	58.33052	-134.5953
4	2/25/2015	91			120	NO	58.33075	-134.59433
5	2/25/2015	2			55	NO	58.33068	-134.59352
5	2/25/2015	6			50	NO	58.33068	-134.59352
5	2/25/2015	9			60	NO	58.33052	-134.59289
5	2/25/2015	25			80	NO	58.33052	-134.59289
5	2/25/2015	62			50	NO	58.33068	-134.59352
5	2/26/2015	1			90	NO	58.33042	-134.59233
5	2/26/2015	1			80	NO	58.33042	-134.59233
5	2/26/2015	2			60	NO	58.33042	-134.59233

5	2/26/2015	3			56	NO	58.3303	-134.59143
5	2/26/2015	7			130	NO	58.33042	-134.59233
5	2/26/2015	7			125	NO	58.33042	-134.59233
5	2/26/2015	7			190	NO	58.33042	-134.59233
5	2/26/2015	16			80	NO	58.33042	-134.59233
5	2/26/2015	21			105	NO	58.33042	-134.59233
5	2/26/2015	37			140	NO	58.33042	-134.59233
5	2/26/2015	39			60	NO	58.3303	-134.59143
5	2/26/2015	59			58	NO	58.3303	-134.59143
6	2/26/2015		1		35	NO	58.32968	-134.5888
6	2/26/2015	5	25		60	NO	58.33003	-134.59033
6	2/26/2015	1			120	NO	58.33003	-134.59033
6	2/26/2015	1			110	NO	58.33003	-134.59033
6	2/26/2015	1			40	NO	58.32989	-134.58906
6	2/26/2015	2			100	NO	58.33003	-134.59033
6	2/26/2015	3			120	NO	58.33003	-134.59033
6	2/26/2015	3			60	NO	58.33003	-134.59033
6	2/26/2015	4			50	NO	58.3303	-134.59143
6	2/26/2015	4			50	NO	58.33003	-134.59033
6	2/26/2015	5			70	NO	58.33003	-134.59033
6	2/26/2015	7			35	NO	58.33003	-134.59033
6	2/26/2015	7			55	NO	58.33003	-134.59033
6	2/26/2015	7			110	NO	58.32989	-134.58906
6	2/26/2015	8			55	NO	58.3303	-134.59143
6	2/26/2015	9		Y	45	NO	58.3303	-134.59143
6	2/26/2015	11			75	NO	58.33003	-134.59033
6	2/26/2015	12			40	NO	58.33003	-134.59033
6	2/26/2015	14			100	NO	58.33003	-134.59033
6	2/26/2015	17			53	NO	58.3303	-134.59143
6	2/26/2015	17			54	NO	58.33018	-134.59069
6	2/26/2015	17			50	NO	58.32989	-134.58906
6	2/26/2015	26			40	NO	58.33003	-134.59033
6	2/26/2015	27			45	NO	58.33003	-134.59033
6	2/26/2015	27			45	NO	58.33003	-134.59033
6	2/26/2015	29			90	NO	58.33003	-134.59033
6	2/26/2015	30			30	NO	58.32989	-134.58906
6	2/26/2015	34			140	NO	58.33003	-134.59033
6	2/26/2015	39			40	NO	58.33003	-134.59033
6	2/26/2015	50			50	NO	58.33003	-134.59033
6	2/26/2015	64			45	NO	58.33003	-134.59033
7	2/27/2015	1			60	NO	58.32857	-134.58801
7	2/27/2015	1			75	NO	58.32857	-134.58801
7	2/27/2015	1			80	NO	58.32857	-134.58801

7	2/27/2015	1		90	NO	58.32857	-134.58801
7	2/27/2015	2		57	NO	58.32858	-134.5875
7	2/27/2015	6		45	NO	58.32857	-134.58801
7	2/27/2015	6		140	NO	58.32857	-134.58801
7	2/27/2015	8		60	NO	58.32857	-134.58801
7	2/27/2015	8		59	NO	58.32858	-134.5875
7	2/27/2015	12		110	NO	58.32857	-134.58801
7	2/27/2015	13		60	NO	58.32857	-134.58801
7	2/27/2015	15		60	NO	58.32858	-134.5875
7	2/27/2015	20		52	NO	58.32858	-134.5875
7	2/27/2015	45		30	NO	58.32857	-134.58801
7	2/27/2015	85		105	NO	58.32857	-134.58801
8	2/27/2015	1	5	90	NO	58.32887	-134.58558
8	2/27/2015	1		60	NO	58.32887	-134.58558
8	2/27/2015	1		105	NO	58.32887	-134.58558
8	2/27/2015	1		53	NO	58.32889	-134.58553
8	2/27/2015	1		48	NO	58.32889	-134.58553
8	2/27/2015	1		60	NO	58.32889	-134.58553
8	2/27/2015	1		56	NO	58.32889	-134.58553
8	2/27/2015	1		80	NO	58.32889	-134.58553
8	2/27/2015	1		45	NO	58.32889	-134.58553
8	2/27/2015	2		90	NO	58.32887	-134.58558
8	2/27/2015	2		61	NO	58.32889	-134.58553
8	2/27/2015	2		52	NO	58.32889	-134.58553
8	2/27/2015	2		45	NO	58.32889	-134.58553
8	2/27/2015	6		42	NO	58.32889	-134.58553
8	2/27/2015	7		47	NO	58.32889	-134.58553
8	2/27/2015	7		65	NO	58.32889	-134.58553
8	2/27/2015	12		40	NO	58.32889	-134.58553
8	2/27/2015	14		95	NO	58.32887	-134.58558
8	2/27/2015	16		50	NO	58.32887	-134.58558
8	2/27/2015	37		46	NO	58.32889	-134.58553
8	2/27/2015	45		50	NO	58.32887	-134.58558
8	2/27/2015	53		40	NO	58.32889	-134.58553
8	2/27/2015	70		55	NO	58.32887	-134.58558
8	2/27/2015	80		40	NO	58.32887	-134.58558
8	2/27/2015	147		36	NO	58.32889	-134.58553
9	2/27/2015	5		120	NO	58.32889	-134.58562
9	2/27/2015	50		40	NO	58.32889	-134.58562
9	2/28/2015	1		50	NO	58.32924	-134.58468
9	2/28/2015	1		70	NO	58.32924	-134.58468
9	2/28/2015	1		50	NO	58.32924	-134.58468
9	2/28/2015	1		52	NO	58.32928	-134.5844

9	2/28/2015	8		100	NO	58.32924	-134.58468
9	2/28/2015	20		45	NO	58.32924	-134.58457
9	2/28/2015	27		49	NO	58.32955	-134.58377
9	2/28/2015	36		95	NO	58.32924	-134.58468
9	2/28/2015	86		35	NO	58.32928	-134.5844
11	2/28/2015	2	1	44	NO	58.32929	-134.58044
11	2/28/2015	51		47	NO	58.32921	-134.57925
12	2/28/2015	3	1	40	NO	58.32878	-134.57761
12	2/28/2015		5	30	NO	58.32878	-134.57761
12	2/28/2015		50	45	NO	58.32878	-134.57761
12	2/28/2015	1		45	NO	58.32878	-134.57761
12	2/28/2015	2		30	NO	58.32878	-134.57761
12	2/28/2015	4		55	NO	58.32878	-134.57761
12	2/28/2015	4		65	NO	58.32878	-134.57761
12	2/28/2015	5		50	NO	58.32878	-134.57761
12	2/28/2015	7		120	NO	58.32878	-134.57761
12	2/28/2015	7		60	NO	58.32878	-134.57761
12	2/28/2015	14		60	NO	58.32856	-134.57639
12	2/28/2015	14		45	NO	58.32856	-134.57639
12	2/28/2015	15		30	NO	58.32878	-134.57761
12	2/28/2015	17		45	NO	58.32878	-134.57761
12	2/28/2015	18		40	NO	58.32878	-134.57761
12	2/28/2015	20		50	NO	58.32878	-134.57761
12	2/28/2015	22		60	NO	58.32878	-134.57761
12	2/28/2015	23		60	NO	58.32878	-134.57761
12	2/28/2015	24		75	NO	58.32878	-134.57761
12	2/28/2015	35		60	NO	58.32878	-134.57761
12	2/28/2015	40		50	NO	58.32878	-134.57761
12	2/28/2015	45		100	NO	58.32878	-134.57761
12	2/28/2015	62		120	NO	58.32878	-134.57761
12	2/28/2015	75		60	NO	58.32856	-134.57639

<u>Results – Stockdale Creek</u>

Sampling for Pink Salmon alevins at Stockdale Creek from March 11-16 was successful, yielding the goal of 250 positive samples out of 720 sample attempts (Tables 13, 14), 200 more digs than in 2014. A total of 5,737 alevin were counted and 3,091 alevin were retained for the study. Positive pumps had an average of 23 alevin. Samples were spread throughout the spawning area with distinct regions of low and high alevin densities. No positive samples were collected in the lower intertidal flat (Section 1) where substrate was very fine grained and silty. Positive digs were relatively evenly distributed between the remaining 4 sections. Section 2, with 44% positive digs was centered around the highest tide line with a mix of gravel and cobble. The largest portion of positive digs came from man-made holes within the 200 m reach of stream covered in thick ice (Section 3). A moderate number of positive samples were found in section 4, substrate was a mix of cobble, small gravel and some larger rocks. Section 5 was sampled over two days and had the highest number of digs and alevin caught. Overall, the success rate of positive digs was 35% throughout the 1,000 m study area. Stream flow was low in comparison to summer sampling.

Table 13. Sampling success of alevins at Stockdale Creek in April 2015.

Section #	Sample Attempts	Positive Samples	% Positive Samples	Average Pump Time (sec)	Total Chum Caught	Total Pink Caught
1	73	0	0.00%	47.9	0	0
2	47	22	46.81%	58	0	388
3	265	111	41.89%	57.5	0	2,425
4	130	47	36.15%	51.3	0	893
5	205	70	34.15%	49.7	0	1,332
Total	720	250	34.72%	52.88	0	5038

The Stockdale Pink Salmon alevin sampling results exhibited a greater success rate per pump sample in 2014 than in similar sampling in 2015 even though the sampling was later in 2014 and possibly subject to emergence from the gravel. The success rate for sampling Pink Salmon alevins in Stockdale Creek was notably greater than it was in Fish Creek for Chum Salmon in both years (see above).

Year	Sampling dates	Number of attempts	Positive Pink Salmon samples	Percent sampling success	Total Pink Salmon captured	Pink Salmon samples sent to laboratory
2014	April 3-6	520	250	48.0	4,229	2,098
2015	March 11-16	720	250	34.7	5,038	3,091

The number sent to the laboratory was less than the number captured because only a maximum of 25 alevins were submitted from samples that exceeded 25 in one pump sample attempt.

Table 14. Total Pink alevins caught over six days of sampling at Stockdale Creek in April 2015. Table represents the 250 positive Pink alevin samples by stream section and location.

Section #	Date	# Chum Caught	# Pink Caught	Sculpin	Pump Time (sec)	Intertidal	Latitude	Longitude
1	3/11/2015	0	3	1	35	YES	60.30418	147.18315
1	3/11/2015	0	28	0	59	YES	60.30422	147.18301
1	3/11/2015	0	121	0	20	YES	60.30418	147.18315
1	3/11/2015	0	24	0	15	YES	60.30418	147.18315
1	3/11/2015	0	18	0	45	YES	60.30418	147.18315
1	3/11/2015	0	2	0	35	YES	60.30422	147.18301
1	3/11/2015	0	6	0	57	YES	60.30422	147.18301
1	3/11/2015	0	1	0	45	YES	60.30418	147.18315
1	3/11/2015	0	1	0	50	YES	60.30418	147.18315
1	3/11/2015	0	3	2	50	YES	60.30418	147.18315
2	3/11/2015	0	114	0	40	YES	60.30396	147.18346
2	3/11/2015	0	1	0	40	YES	60.30396	147.18346
2	3/11/2015	0	2	0	30	YES	60.30396	147.18346
2	3/11/2015	0	36	0	80	YES	60.30403	147.18338
2	3/11/2015	0	2	0	60	YES	60.30396	147.18346
2	3/11/2015	0	2	0	50	YES	60.30396	147.18346
2	3/11/2015	0	8	0	60	YES	60.30396	147.18346
2	3/11/2015	0	1	0	57	YES	60.30367	147.18320
2	3/11/2015	0	9	0	45	YES	60.30396	147.18346
2	3/11/2015	0	1	0	113	YES	60.30367	147.18320
2	3/12/2015	0	1	0	50	NO	60.30373	147.18329
2	3/12/2015	0	2	0	48	NO	60.30358	147.18330
2	3/12/2015	0	4	0	40	NO	60.30373	147.18329
2	3/12/2015	0	5	0	38	NO	60.30358	147.18330
2	3/12/2015	0	9	0	60	NO	60.30373	147.18329
2	3/12/2015	0	117	0	25	NO	60.30373	147.18329
2	3/12/2015	0	2	0	60	NO	60.30373	147.18329
2	3/12/2015	0	48	0	48	NO	60.30373	147.18329
2	3/12/2015	0	4	0	67	NO	60.30373	147.18329
3	3/12/2015	0	2	0	120	NO	60.30339	147.18324
3	3/12/2015	0	3	0	66	NO	60.30339	147.18324
3	3/12/2015	0	66	0	44	NO	60.30339	147.18324
3	3/12/2015	0	5	1	60	NO	60.30339	147.18324
3	3/12/2015	0	7	0	45	NO	60.30346	147.18320
3	3/12/2015	0	3	0	62	NO	60.30339	147.18324
3	3/12/2015	0	21	0	63	NO	60.30339	147.18324
3	3/12/2015	0	49	0	30	NO	60.30346	147.18320
3	3/12/2015	0	1	0	67	NO	60.30339	147.18324
3	3/12/2015	0	1	0	77	NO	60.30339	147.18324
3	3/12/2015	0	41	0	40	NO	60.30346	147.18320

3	3/12/2015	0	159	0	63	NO	60.30339	147.18324
3	3/12/2015	0	1	0	57	NO	60.30333	147.18321
3	3/12/2015	0	9	0	50	NO	60.30328	147.18324
3	3/12/2015	0	8	0	47	NO	60.30333	147.18321
3	3/12/2015	0	1	0	50	NO	60.30328	147.18324
3	3/12/2015	0	26	0	53	NO	60.30333	147.18321
3	3/12/2015	0	54	0	62	NO	60.30333	147.18321
3	3/12/2015	0	43	0	43	NO	60.30333	147.18321
3	3/12/2015	0	2	0	53	NO	60.30333	147.18321
3	3/12/2015	0	81	0	62	NO	60.30326	147.18294
3	3/12/2015	0	6	0	77	NO	60.30326	147.18294
3	3/12/2015	0	55	0	56	NO	60.30333	147.18321
3	3/12/2015	0	65	0	46	NO	60.30326	147.18294
3	3/12/2015	0	25	0	55	NO	60.30326	147.18294
3	3/12/2015	0	14	0	62	NO	60.30326	147.18294
3	3/12/2015	0	2	1	61	NO	60.30301	147.18283
3	3/12/2015	0	1	0	45	NO	60.30326	147.18294
3	3/12/2015	0	22	0	48	NO	60.30301	147.18283
3	3/12/2015	0	6	0	57	NO	60.30326	147.18294
3	3/12/2015	0	1	0	57	NO	60.30301	147.18283
3	3/12/2015	0	21	0	75	NO	60.30326	147.18294
3	3/12/2015	0	1	0	76	NO	60.30301	147.18283
3	3/12/2015	0	1	0	60	NO	60.30301	147.18283
3	3/12/2015	0	4	0	56	NO	60.30326	147.18294
3	3/12/2015	0	13	0	52	NO	60.30301	147.18283
3	3/12/2015	0	46	0	20	NO	60.30326	147.18294
3	3/12/2015	0	23	0	53	NO	60.30301	147.18283
3	3/12/2015	0	18	0	30	NO	60.30326	147.18294
3	3/12/2015	0	21	0	35	NO	60.30326	147.18294
3	3/12/2015	0	1	0	43	NO	60.30301	147.18283
3	3/12/2015	0	2	0	60	NO	60.30268	147.18253
3	3/12/2015	0	2	0	70	NO	60.30284	147.18265
3	3/12/2015	0	11	0	55	NO	60.30268	147.18253
3	3/12/2015	0	1	0	50	NO	60.30268	147.18253
3	3/12/2015	0	16	0	40	NO	60.30268	147.18253
3	3/12/2015	0	1	0	55	NO	60.30268	147.18253
3	3/12/2015	0	8	0	42	NO	60.30268	147.18253
3	3/12/2015	0	42	0	35	NO	60.30268	147.18253
3	3/12/2015	0	25	0	15	NO	60.30268	147.18253
3	3/12/2015	0	1	0	51	NO	60.30284	147.18265
3	3/12/2015	0	22	0	30	NO	60.30268	147.18253
3	3/12/2015	0	4	0	60	NO	60.30268	147.18253
3	3/12/2015	0	37	0	55	NO	60.30284	147.18265
3	3/12/2015	0	1	0	60	NO	60.30284	147.18265
3	3/12/2015	0	84	0	40	NO	60.30249	147.18242

4	3/13/2015	0	5	0	50	NO	60.30217	147.18210
4	3/13/2015	0	4	0	35	NO	60.30217	147.18210
4	3/13/2015	0	1	0	69	NO	60.30217	147.18210
4	3/13/2015	0	8	0	65	NO	60.30217	147.18210
4	3/13/2015	0	26	0	81	NO	60.30217	147.18210
4	3/13/2015	0	158	0	51	NO	60.30198	147.18178
4	3/13/2015	0	17	0	15	NO	60.30217	147.18210
4	3/13/2015	0	115	0	63	NO	60.30198	147.18178
4	3/13/2015	0	25	0	18	NO	60.30177	147.18153
4	3/13/2015	0	1	0	55	NO	60.30198	147.18178
4	3/13/2015	0	2	0	43	NO	60.30177	147.18153
4	3/13/2015	0	91	0	27	NO	60.30198	147.18178
4	3/13/2015	0	1	1	79	NO	60.30177	147.18153
4	3/13/2015	0	42	0	50	NO	60.30177	147.18153
4	3/13/2015	0	181	0	25	NO	60.30146	147.18138
4	3/13/2015	0	6	0	55	NO	60.30177	147.18153
4	3/13/2015	0	12	0	60	NO	60.30177	147.18153
4	3/13/2015	0	2	0	72	NO	60.30177	147.18153
4	3/13/2015	0	79	0	18	NO	60.30177	147.18153
4	3/13/2015	0	11	0	33	NO	60.30177	147.18153
4	3/13/2015	0	1	0	58	NO	60.30146	147.18138
4	3/13/2015	0	23	0	62	NO	60.30177	147.18153
4	3/13/2015	0	1	0	53	NO	60.30146	147.18138
4	3/13/2015	0	1	0	65	NO	60.30177	147.18153
4	3/13/2015	0	4	0	54	NO	60.30146	147.18138
4	3/13/2015	0	58	2	25	NO	60.30177	147.18153
4	3/13/2015	0	23	0	60	NO	60.30177	147.18153
4	3/13/2015	0	7	0	25	NO	60.30177	147.18153
4	3/13/2015	0	1	0	57	NO	60.30177	147.18153
4	3/13/2015	0	6	0	53	NO	60.30146	147.18138
4	3/13/2015	0	9	1	63	NO	60.30137	147.18114
4	3/13/2015	0	1	0	68	NO	60.30137	147.18114
4	3/13/2015	0	22	0	60	NO	60.30117	147.18108
4	3/13/2015	0	43	0	45	NO	60.30117	147.18108
4	3/13/2015	0	1	0	48	NO	60.30137	147.18114
4	3/13/2015	0	19	0	50	NO	60.30137	147.18114
4	3/13/2015	0	1	0	66	NO	60.30137	147.18114
4	3/13/2015	0	5	0	50	NO	60.30117	147.18108
4	3/13/2015	0	1	0	45	NO	60.30117	147.18108
4	3/13/2015	0	7	0	55	NO	60.30117	147.18108
4	3/13/2015	0	1	0	75	NO	60.30092	147.18120
4	3/13/2015	0	3	0	45	NO	60.30117	147.18108
4	3/13/2015	0	3	0	57	NO	60.30117	147.18108
4	3/13/2015	0	1	0	55	NO	60.30117	147.18108
4	3/13/2015	0	5	0	81	NO	60.30092	147.18120

4	3/13/2015	0	16	0	65	NO	60.30092	147.18120
4	3/13/2015	0	1	0	75	NO	60.30092	147.18120
4	3/13/2015	0	1	0	85	NO	60.30092	147.18120
4	3/14/2015	0	17	0	65	NO	60.30040	147.18111
4	3/14/2015	0	12	0	78	NO	60.30040	147.18111
4	3/14/2015	0	4	0	47	NO	60.30040	147.18111
4	3/14/2015	0	15	0	52	NO	60.30061	147.18124
4	3/14/2015	0	26	0	67	NO	60.30040	147.18111
4	3/14/2015	0	2	0	64	NO	60.30040	147.18111
4	3/14/2015	0	5	0	45	NO	60.30061	147.18124
4	3/14/2015	0	8	0	60	NO	60.30040	147.18111
4	3/14/2015	0	25	0	55	NO	60.30040	147.18111
4	3/14/2015	0	6	0	63	NO	60.30040	147.18111
4	3/14/2015	0	9	0	54	NO	60.30040	147.18111
4	3/14/2015	0	11	0	65	NO	60.30040	147.18111
4	3/14/2015	0	1	0	40	NO	60.30040	147.18111
5	3/14/2015	0	61	0	30	NO	60.30022	147.18098
5	3/14/2015	0	11	0	48	NO	60.30022	147.18098
5	3/14/2015	0	28	0	48	NO	60.30022	147.18098
5	3/14/2015	0	12	1	45	NO	60.29999	147.18069
5	3/14/2015	0	21	0	50	NO	60.30022	147.18098
5	3/14/2015	0	1	0	48	NO	60.30022	147.18098
5	3/14/2015	0	45	0	50	NO	60.29999	147.18069
5	3/14/2015	0	1	0	50	NO	60.30022	147.18098
5	3/14/2015	0	22	0	30	NO	60.29999	147.18069
5	3/14/2015	0	31	0	33	NO	60.30022	147.18098
5	3/14/2015	0	16	0	30	NO	60.29999	147.18069
5	3/14/2015	0	1	0	55	NO	60.30022	147.18098
5	3/14/2015	0	78	0	50	NO	60.29999	147.18069
5	3/14/2015	0	11	0	48	NO	60.29999	147.18069
5	3/14/2015	0	51	0	36	NO	60.29999	147.18069
5	3/14/2015	0	37	0	45	NO	60.29999	147.18069
5	3/14/2015	0	1	0	50	NO	60.29949	147.18068
5	3/14/2015	0	42	0	20	NO	60.29949	147.18068
5	3/14/2015	0	1	0	48	NO	60.29974	147.18062
5	3/14/2015	0	9	0	40	NO	60.29949	147.18068
5	3/14/2015	0	21	0	30	NO	60.29974	147.18062
5	3/14/2015	0	15	0	45	NO	60.29949	147.18068
5	3/14/2015	0	23	0	10	NO	60.29974	147.18062
5	3/14/2015	0	3	0	35	NO	60.29949	147.18068
5	3/14/2015	0	36	0	20	NO	60.29974	147.18062
5	3/14/2015	0	25	1	58	NO	60.29949	147.18068
5	3/14/2015	0	2	0	55	NO	60.29974	147.18062
5	3/14/2015	0	22	0	45	NO	60.29949	147.18068
5	3/14/2015	0	7	0	58	NO	60.29974	147.18062

5	3/14/2015	0	1	0	45	NO	60.29974	147.18062
5	3/14/2015	0	74	0	20	NO	60.29949	147.18068
5	3/14/2015	0	1	0	50	NO	60.29974	147.18062
5	3/14/2015	0	38	0	48	NO	60.29974	147.18062
5	3/14/2015	0	4	0	50	NO	60.29945	147.18028
5	3/15/2015	0	2	0	64	NO	60.29958	147.17982
5	3/15/2015	0	1	0	42	NO	60.29480	147.18010
5	3/15/2015	0	1	0	64	NO	60.29480	147.18010
5	3/15/2015	0	57	0	30	NO	60.29480	147.18010
5	3/15/2015	0	9	0	56	NO	60.29958	147.17982
5	3/15/2015	0	51	0	54	NO	60.29480	147.18010
5	3/15/2015	0	14	0	50	NO	60.29480	147.18010
5	3/15/2015	0	18	0	50	NO	60.29958	147.17982
5	3/15/2015	0	6	0	65	NO	60.29958	147.17982
5	3/15/2015	0	25	0	50	NO	60.29480	147.18010
5	3/15/2015	0	22	0	49	NO	60.29958	147.17982
5	3/15/2015	0	27	0	45	NO	60.29480	147.18010
5	3/15/2015	0	45	0	56	NO	60.29958	147.17982
5	3/15/2015	0	51	0	51	NO	60.29958	147.17982
5	3/15/2015	0	2	0	47	NO	60.29958	147.17982
5	3/15/2015	0	4	0	45	NO	60.29976	147.17947
5	3/15/2015	0	7	0	50	NO	60.29958	147.17982
5	3/15/2015	0	4	0	45	NO	60.29958	147.17982
5	3/15/2015	0	1	0	45	NO	60.29992	147.17963
5	3/15/2015	0	3	0	43	NO	60.29992	147.17963
5	3/15/2015	0	23	0	38	NO	60.29992	147.17963
5	3/15/2015	0	5	0	53	NO	60.29976	147.17947
5	3/15/2015	0	1		63	NO	60.29976	147.17947
5	3/15/2015	0	8	0	59	NO	60.29976	147.17947
5	3/15/2015	0	1	0	50	NO	60.29995	147.17876
5	3/15/2015	0	21	1	46	NO	60.29995	147.17876
5	3/15/2015	0	2	0	45	NO	60.29995	147.17876
5	3/15/2015	0	31	0	51	NO	60.29995	147.17876
5	3/15/2015	0	33	0	50	NO	60.29995	147.17876
5	3/15/2015	0	13	0	75	NO	60.29981	147.47787
5	3/15/2015	0	1	0	45	NO	60.29995	147.17876
5	3/15/2015	0	24	0	45	NO	60.29981	147.47787
5	3/15/2015	0	68	0	27	NO	60.29995	147.17876
5	3/15/2015	0	79	0	60	NO	60.29981	147.47787
5	3/15/2015	0	1	0	60	NO	60.29981	147.47787
5	3/15/2015	0	1	0	55	NO	60.29981	147.47787
5	3/15/2015	0	9	0	45	NO	60.29981	147.47787
5	3/15/2015	0	75	0	53	NO	60.29985	147.17798
5	3/15/2015	0	1	0	45	NO	60.29985	147.17798
5	3/15/2015	0	1	0	50	NO	60.29985	147.17798

5	3/15/2015	0	1	0	48	NO	60.29985	147.17798
5	3/15/2015	0	28	0	42	NO	60.29985	147.17798
5	3/16/2015	0	5	0	45	NO	60.29999	147.17838
5	3/16/2015	0	31	0	50	NO	60.29999	147.17838
5	3/16/2015	0	81	0	50	NO	60.29999	147.17838
5	3/16/2015	0	1	0	60	NO	60.29985	147.17805
5	3/16/2015	0	2	0	45	NO	60.29985	147.17805
5	3/16/2015	0	4	0	45	NO	60.29999	147.17838
5	3/16/2015	0	5	0	55	NO	60.29985	147.17805
5	3/16/2015	0	4	0	40	NO	60.29999	147.17838
5	3/16/2015	0	17	0	35	NO	60.29999	147.17838
5	3/16/2015	0	2	0	45	NO	60.29999	147.17838
5	3/16/2015	0	4	0	30	NO	60.29985	147.17805
5	3/16/2015	0	11	0	40	NO	60.29990	147.17865
5	3/16/2015	0	2	0	37	NO	60.29990	147.17865
5	3/16/2015	0	5	0	45	NO	60.29990	147.17865
5	3/16/2015	0	4	0	45	NO	60.29990	147.17865
5	3/16/2015	0	5	0	45	NO	60.29990	147.17865
5	3/16/2015	0	11	0	42	NO	60.29990	147.17865
5	3/16/2015	0	1	0	70	NO	60.30006	147.17859
5	3/16/2015	0	4	0	63	NO	60.30006	147.17859
5	3/16/2015	0	6	0	4	NO	60.30006	147.17859
5	3/16/2015	0	15	0	45	NO	60.30006	147.17859
5	3/16/2015	0	2	0	46	NO	60.30006	147.17859
5	3/16/2015	0	113	0	50	NO	60.29959	147.18059
5	3/16/2015	0	1	0	32	NO	60.29959	147.18059
5	3/16/2015	0	3	0	40	NO	60.29945	147.18060
5	3/16/2015	0	137	0	20	NO	60.29959	147.18059
5	3/16/2015	0	12	0	43	NO	60.29945	147.18060
5	3/16/2015	0	67	0	7	NO	60.29959	147.18059