Interactions of Wild and Hatchery Chum Salmon in Southeast Alaska

Report for 2022

For Alaska Department of Fish and Game
Contract CT 160001756

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ABSTRACT

The Sitka Sound Science Center, under contract by the Alaska Department of Fish & Game (ADF&G), conducted data collection for an investigation of the impact on fitness (productivity) of wild Chum Salmon due to straying of hatchery Chum Salmon. This is the sixth in a series of annual progress reports on data collection and analysis. During the 2022 field season, we sampled 2,002 individual Chum Salmon carcasses and tagged 390 live Chum Salmon for mark/recapture analysis during repeated visits to the spawning grounds of three Northern Southeast Alaskan streams; Fish Creek (AWC 111-50-10690), Sawmill Creek (AWC 115-20-10520), and Prospect Creek (AWC 111-33-10100). These streams have been previously sampled for this research since 2013. The relative reproductive success (RRS) for each fish will be analyzed through DNA extraction from collected tissue samples of carcasses and live Chum Salmon. Otoliths were collected from individual carcasses to assess the natal origins (hatchery versus wild) of Chum Salmon. Scales were collected to determine the age of both carcasses and tagged Chum Salmon during this study. Through mark/recapture analysis, we estimated the unstratified proportion sampled ranged from 25% in Sawmill Creek to 40% in Fish Creek and 42% in Prospect Creek. Unstratified estimated run size ranged from 3,090 in Fish Creek, 2,213 in Sawmill Creek, and 1,179 in Prospect Creek.

INTRODUCTION

The Alaska Department of Fish & Game (ADF&G), along with private-non-profit hatchery corporations, have engaged in research studies addressing concerns about straying and the genetic and ecological interactions between hatchery and wild salmon. These concerns relate to the value of hatchery-origin and wild stocks to Alaska salmon fisheries and the state mandate that hatchery production be compatible with sustainable productivity of wild stocks. The Hatchery-Wild Interactions Project began in 2011 to address these concerns. Initially, ADF&G convened a science panel that prioritized three major questions in Southeast Alaska:

1) What is the genetic stock structure of Chum Salmon in Southeast Alaska (SEAK)?
2) What is the extent and annual variability in straying of hatchery Chum Salmon in SEAK?
3) What is the impact on fitness (productivity) of wild Chum Salmon due to straying of hatchery Chum Salmon?

The first two objectives were addressed by tissue sampling from spawned out Pink and Chum Salmon in 64 streams across Prince William Sound and Southeast Alaska between 2013 and 2015. Estimates of the percent of hatchery-origin salmon for each stream, district, and regional spawning population over three years are now complete (Knudsen et al. 2016; Knudsen et al. 2021). The Sitka Sound Science Center (SSSC) was contracted by the ADF&G to collect genetic and life history samples from post-spawned summer Chum Salmon in three streams in the Northern Southeast region of Alaska beginning in 2017 to address the third objective. This report details the field summary and survey findings of those streams in the 2022 field season. Similar studies of Pink Salmon in Prince William Sound were managed by the Prince William Sound Science Center and results reported elsewhere. The raw data are available and were submitted via the Hatchery Wild Application.

METHODS

Daily surveys of study streams were intended to obtain samples for pedigree analysis and estimate the proportion sampled. Sample collected from each fish included otoliths, tissue samples for DNA analysis, scales, and meristic observations from post-spawned Chum Salmon. Crews also conducted mark-recapture studies to produce escapement estimates that could be used to estimate the proportion of the run that is sampled. Daily surveys were conducted in three study streams, Fish Creek (AWC 111-50-10690), Sawmill Creek (AWC 115-20-10520), and Prospect Creek (AWC 111-33-10100), in Southeast Alaska (Figure 1). Each day, crews also recorded the count of live fish, dead fish, and previously sampled fish in each stream. Crews also recorded weekly live counts of Pink Salmon in each stream and documented any other Pacific salmon species observed.

Logistical Strategy

SSSC was contracted to sample Chum Salmon throughout the entire run in each of three streams (Figure 1). Sampling focused on post-spawned summer Chum Salmon (*Oncorhynchus keta*) in Northern Southeast Alaska in 2022 between July 20 through August 26th, 2022. One four-person crew was tasked with conducting surveys on Fish Creek on Douglas Island and another four-person crew was tasked with conducting surveys on Sawmill Creek in Berner's Bay. Fish Creek is accessible by the road system on Douglas Island, Sawmill Creek is accessible by skiff from the Echo Cove boat launch North of Juneau. A remote field camp in Port Snettisham was established for a four-person crew to access Prospect Creek by skiff.

Figure 1. Location of streams sampled by SSSC field crews in 2022.

All SEAK field crews were directly employed by SSSC in 2022. Each field crew worked primarily independently, with guidance and support from two Project Coordinators. Crew leaders were given responsibility to maximize efficiency and achieve sampling goals when Project Coordinators were not present. Ten days prior to mobilization, crews were trained in Sitka, Alaska. Training included field sampling procedures, boating, bear, and firearm instruction, CPR and First Aid, tablet use, and data entry and quality control. Refer to Appendix A for further information on improved sampling efficiency through training procedures.

Pedigree Stream Sampling Methods and Execution

The study plan called for surveying streams from tidewater to the highest extent of salmon migration. For each study stream, the starting locations were determined by crew leaders, depending on tide stage, stream turbidity, and flow. Sampling would begin either in the lower intertidal zone or in the upper stream reaches. On days where high flow prevented a crew from completing a full survey stretch of the study stream, sampling would concentrate in accessible areas of high Chum Salmon carcass density. Crew members began targeting Chum Salmon collection after determining the start location of the survey, marked with GPS. After collecting a satisfactory amount of chum carcasses, the latitude and longitude of the processing area was marked on a tablet and sampling began. All efforts were made to sample the entire study stream length when conducting carcass surveys for pedigree analysis, accounting for factors such as carcass availability, the tide stage, and bears.

Carcasses were sampled as they were encountered. However, in locations where large numbers of carcasses were observed, carcasseswere randomly subsampled (goals of 80% sample coverage) to allow time for processing carcasses in other sections of the stream. The primary goal was to examine the entire length of the stream on each carcass survey. Starting on July 21st, complete carcass surveys were conducted every day for Sawmill Creek, which allowed for daily carcass surveys due to the short survey stretch. Starting on July 20th for Fish Creek, complete carcass surveys were conducted every day until August 5th. Afterwards, complete carcass surveys were conducted every other day, to allow for mark/recapture sampling. On the intervening days, carcasses were recovered and sampled opportunistically from locations near the mark-recapture areas. Like Fish Creek, Prospect Creek alternated between carcass sampling and mark-recapture sampling starting on July 25th.

Carcass sampling was intended to determine the sex, size, age, origin, and pedigree. For each carcass we recorded the sex, length (mid-eye to hypural plate length mm), and body depth (mm). We collected four scales for age analysis, both sagittal otoliths to determine origin, and sampled cardiac tissue (bulbus arteriosus) for pedigree analysis. In addition we recorded the recovery date and carcass condition. In addition we examined the carcasses for the presence of tags (opercular fin punches and Floy tags) associated with the mark-recapture analysis (described below). Carcasses were aligned in rows of eight by six, mimicking the 48 deep well plates (DWP) samples were stored in. Once collected, otoliths, tissue samples, and recovered Floy tags if present, were stored in high concentration ethanol. When the survey was complete, a crew member marked the GPS end location of the survey, checked the count numbers, and made any additional comments. A quality control review of the collected data was conducted after every survey, comparing collected tablet data to otolith and DNA samples in the DWP, then electronically delivered to ADF&G once reviewed (Appendix A).

<u>Proportion of Run Sampled Methods and Execution</u>

A mark-recapture study was incorporated into the sampling to provide precise estimates of Chum Salmon run size and estimate the proportion of the run sampled for pedigree analysis. The mark-recapture study consisted of periodic sampling of live Chum Salmon entering Fish Creek, Sawmill Creek, and Prospect Creek, double marking them, and releasing them. The recapture phase coincided with carcass sampling. For mark-recapture surveys, efforts were made to maximize the number of live Chum Salmon tagged, with efforts dependent on the density of untagged pre-spawn summer Chum Salmon, stream flow and turbidity, and the ability to complete a full carcass survey on that same day.

The tagging of pre-spawn Chum Salmon was conducted over a period of approximately four weeks in each stream. Tagging began on July 21st, conducted every other day until August 18th for Fish and Sawmill Creek. Prospect Creek tagging began on July 27th and ended on August 18th, occurring every other day. All marking ceased the third week of August due to the incoming fall chum run and to allow all tagged salmon sufficient time to spawn. Live fish for tagging and release were captured at fixed locations in each stream using beach seines and/or dip nets. Release locations were far enough upstream to minimize the number of probing fish that might emigrate the stream after tagging. Once captured, fish were given uniquely numbered Floy tags and unique opercular punches that corresponded to the week of release. The date of tagging, tissue samples (axillary process) for genetic analysis, two scales, sex, spawning state, and length were taken for each fish, and released back into the stream. Lengths of tagged fish were recorded at tip-of-snout to fork-of- tail (SFL) to minimize handling. The lengths of subsequent recaptures were recorded as MEHL. The lengths of all tagged and released fish were converted to MEHL using a linear regression of the MEHL on SFL for the recaptures. Release data were recorded in the field using the computer application. A "Survey Type" field allowed us to distinguish release samples from recapture samples. A quality control review of the collected data was conducted after every survey, comparing collected tablet data to Floy tag numbers and DNA samples in the DWP, then electronically delivered to ADF&G once reviewed (Appendix A).

1.1 Estimation of the Proportion Sampled

The proportion of the run sampled for each of the streams was calculated using the ratio of the number of unique samples collected to the estimated run size. The number of unique samples (N_u) is the sum of the number of tagged fish released and the observed number of unmarked carcasses. Run size ($\hat{N}$) was estimated using Chapman's modification of the Peterson estimate:

$$\hat{N} = \left(\frac{(M+1)(C+1)}{R+1}\right) + 1 \qquad \text{equation 1}$$

Where *M* = is the total number of marks released, *C* is the number of carcasses inspected, and *R* is the number of recaptured fish. The variance estimator is given by:

$$V_{\hat{N}} = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \qquad \text{equation 2}$$

The proportion of the population sampled (p) is estimated as:

$$P = \frac{N_u}{\hat{N}} \qquad \text{equation 3}$$

Where N_u is the number of unique samples collected from the stream. The 95% confidence interval for the run size was estimated as

$$C.I. = 1.96 * \sqrt{V_{\hat{N}}} \qquad \text{equation 4}$$

There are a number of important assumptions underlying the Peterson estimator that must be examined to understand the potential for bias in the estimates. Specifically, these include:

1) Marking does not affect the catchability of a fish. This includes no mortality associated with handling.
2) Fish do not lose marks between sampling events.
3) Recruitment and death of fish cannot occur between sampling events.

These assumptions were met in our study by holding marked fish briefly to ensure they recovered from the marking event. Fish were double marked to determine if the fish lost marks, and finally, marking and recovery occurred throughout the run which minimizes the possibility for recruitment into the stream during the study. There is some potential for emigration from the study, but we located our marking area above the high tide line to minimize any marking of fish probing the system. Removal by predators is another source of emigration, but our carcass surveys also examined areas along stream banks.

In addition, it is important that at least one of these three criteria are also met to minimize bias:

1. Every fish has an equal probability of being marked and released alive during the first sampling event.
2. Every fish has an equal probability of being captured during the second sampling event.

3. Marked fish mix completely with unmarked fish between sampling events.

We examined these criteria by examining the proportion of males and females and the size distributions of fish collected in the marking and recovery events. Comparisons of the proportion of males and females employed Chi-square analysis of the proportion of Marked and Recaptured fractions of the data set. Rejection of the null hypothesis led to the conclusion samples were biased with result to sex in the recovery data (Failure of criterion 2). Comparisons of the sex ratios in the Captured and Recaptured fractions that rejected the null hypothesis led to the conclusion that sampling was biased in the marking event (Failure of criterion 1). Comparisons of the ratios in the Marked and Captured fractions were used to examine criterion 3. A similar process was used to compare lengths relative to criteria 1 through 3 with Chi-square analysis, comparing the proportion of small versus large fish. Critical values for hypothesis testing relied on $\alpha = 0.05$.

Stratified estimates of the proportion sampled were calculated as:

$$C.I. = 1.96 * \frac{\Sigma N_u}{\Sigma \hat{N}} \qquad \text{equation 5}$$

RESULTS

Survey timing and coverage:

All three study streams were surveyed throughout the 38-day field season in 2022, yielding an above average number of samples for pedigree analysis. Sampling lasted from July 20th to August 26th for Fish Creek, July 21st to August 25th for Sawmill Creek, and July 25th to August 26th for Prospect Creek. Fish Creek had 33 unique stream visits, Sawmill Creek had 30 unique stream visits, and Prospect Creek had 27 unique stream visits. Crew members recorded lengths, identified sex, and collected DNA tissue samples, scales, and otoliths from over 2,300 samples representing 2,002 chum carcasses and 390 live Chum Salmon (Table 1). The 2022 field season yielded an above average number of carcass samples compared with the median number of samples collected between 2013 and 2021 (Table 1). The previous medians were 893, 248, and 288 samples in Fish Creek, Sawmill Creek, and Prospect Creek, respectively.

Table 1. Starting and ending dates from Chum Salmon streams surveys and gross counts of live chum, dead chum sampled, live chum sampled, the number of otolith samples collected, and the number of scale samples collected in 2022.

	Start Date	End Date	Cumulative Live Observed	Number carcasses sampled	Number live fish sampled	Number otolith samples	Number scale samples
Fish Creek	7/20/2022	8/26/2021	5,613	1,053	270	1,026	1,323
Sawmill Creek	7/21/2021	8/25/2021	5,727	479	85	463	565
Prospect Creek	7/25/2021	8/26/2021	3,235	470	35	440	505

Live chum counts differed for Sawmill and Prospect Creek compared to Fish Creek in respect to scale and peak timing (Figures 2-4). Peak live counts were the highest and occurred the earliest in Fish Creek, during the first week of August with 669 Chum Salmon observed on 8/5/2022. Carcass samples peaked two weeks later for Fish Creek, with 150 salmon sampled on 8/19/2022 (Figure 2). Sawmill Creek had a peak live count of 498 salmon on 8/11/2022 with peak sampling happening three days later, with 62 fish sampled on 8/13/2022 (Figure 3). Peak live counts were the smallest for Prospect Creek, with 343 salmon on 8/9/2022 (Figure 4). Like Fish Creek, carcass sampling peaked two weeks later, with 66 samples on 8/23/2022.

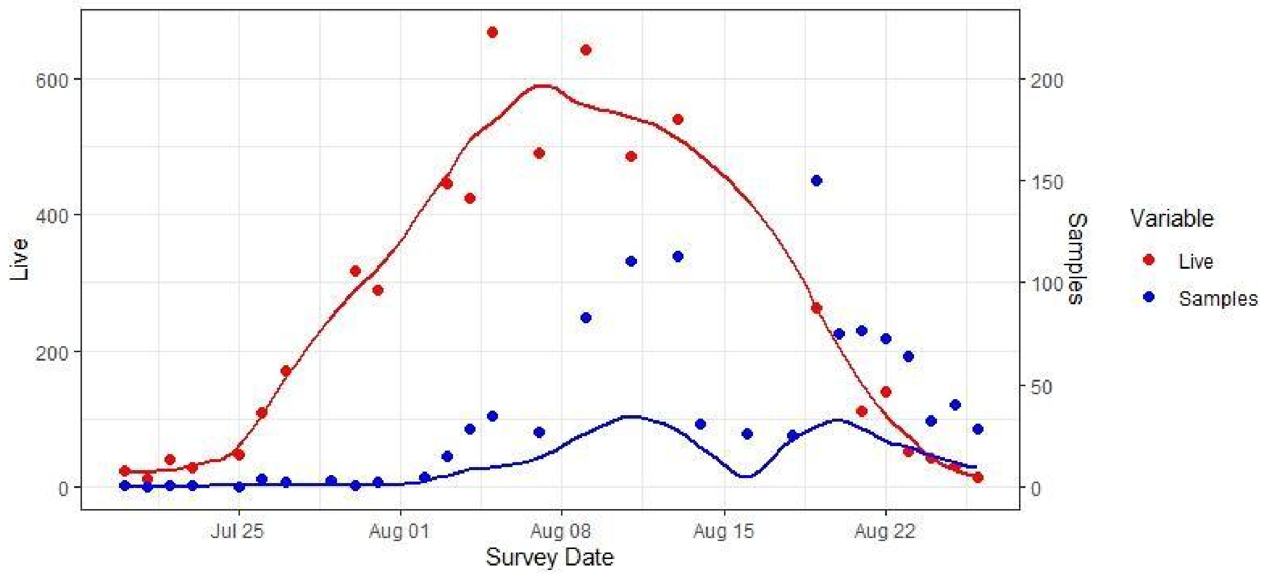

Figure 2. Daily live counts and sample numbers for Fish Creek Chum Salmon as a function of survey date. Lines show Loess smoother drawn through data points. Sample numbers track the daily dead counts. Note sample numbers track the daily dead counts.

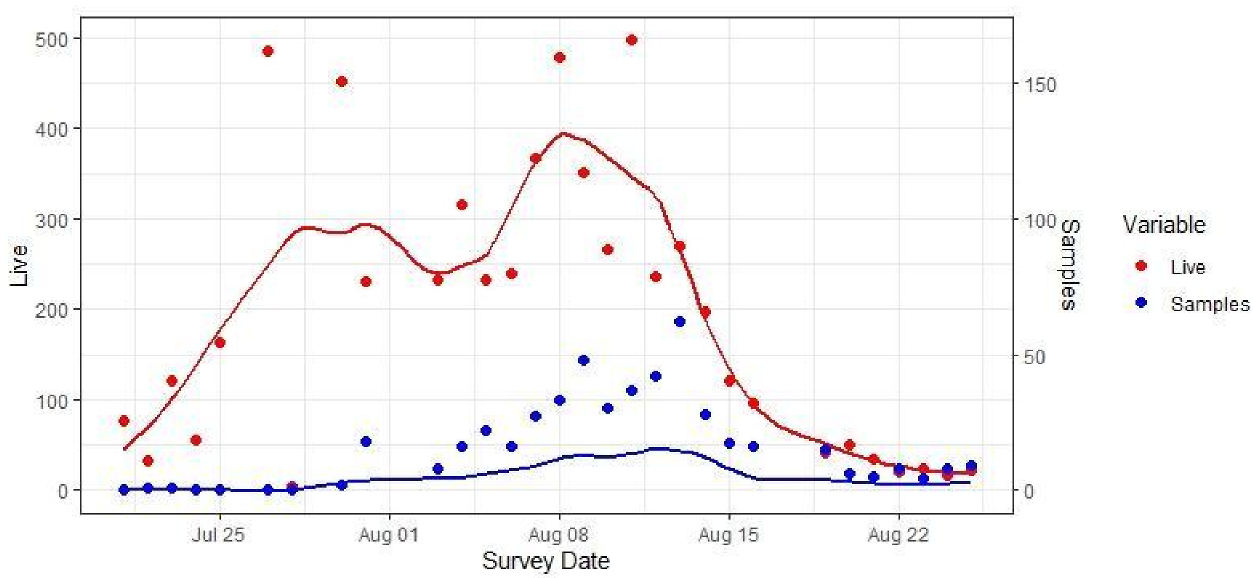

Figure 2. Daily live counts and sample numbers for Sawmill Creek Chum Salmon as a function of survey date. Lines show Loess smoother drawn through data points. Sample numbers track the daily dead counts. Note differences in scale relative to Figure 2.

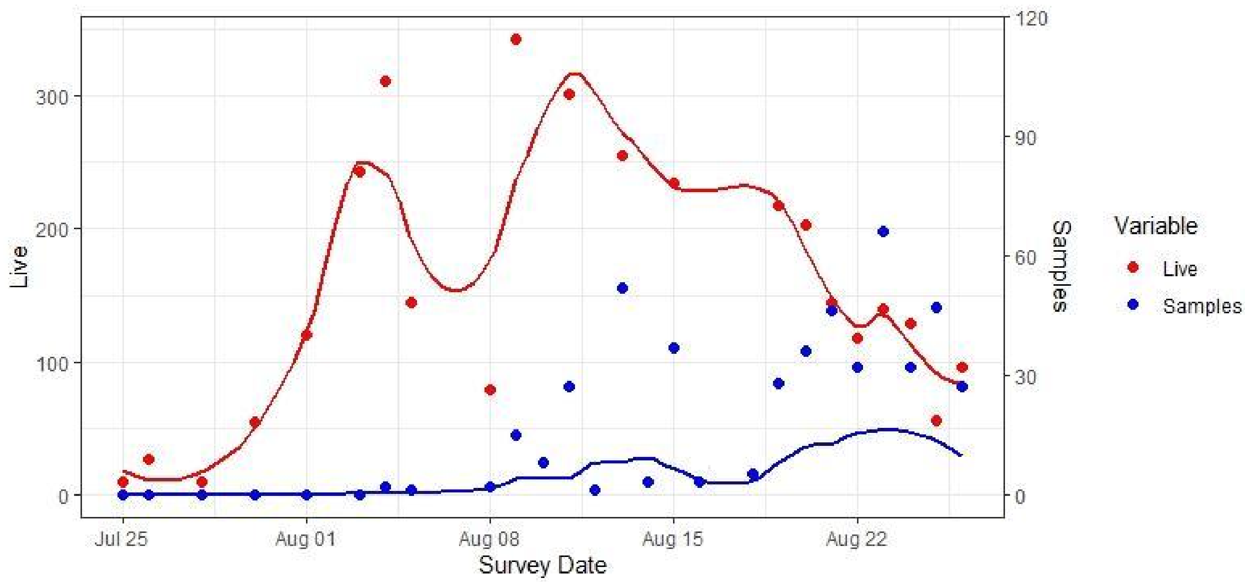

Figure 3. Daily live counts and sample numbers for Prospect Creek Chum Salmon as a function of survey date. Lines show Loess smoother drawn through data points. Sample numbers track the daily dead counts. Note differences in scale relative to Figure 2.

Weather was challenging during the beginning of the 2022 field season, with numerous surveys being canceled or curtailed. In Fish Creek, one carcass survey was cut short (8/2), and three surveys were canceled (7/24, 7/28, and 8/15) due to high water. The terrain and nature of Fish Creek, with it being the main drainage for a large portion of North Douglas Island, led to major flooding events that made surveying impossible. In Sawmill Creek, one survey was curtailed (7/28) and four carcass surveys were canceled (7/26, 7/29, 8/2, and 8/18) due to high water and/or unsafe skiff conditions. In Prospect Creek, surveys were the most affected by high water events due to remote terrain and the nature of the stream. Eleven carcass surveys were curtailed (7/25, 7/26, 7/28, 7/30, 8/1, 8/3, 8/5, 8/8, 8/24, 8/25, and 8/26), and five surveys were canceled altogether (7/29, 7/31, 8/2, 8/6, and 8/7) due to weather and high flow.

Sex Ratio:

The sex ratio of sampled Chum Salmon differed between carcass surveys and mark/recapture surveys for the 2022 field season. Sex ratios were slightly skewed towards female for carcass sampling. In Fish Creek, 56.7% of chum carcasses were female, with similar results seen in Sawmill Creek with 53.9% being female. In Prospect Creek 60.0% were female. Prospect Creek's higher female percentage could be attributed to early survey cancellations. It was observed that a higher percentage of male salmon were present at the beginning of the survey season, possibly moving in before females to secure adequate spawning territory. These ratios differed slightly from our nine-year average for these streams (Figure 5). For the mark/recapture analysis, sex ratios were skewed towards male in 2022. In Fish Creek, 40.0% of the tagged Chum Salmon were females, while only 32.9% of the tagged Chum Salmon were female in Sawmill Creek. Prospect Creek had a more even sex ratio, with 45.7% of the tagged Chum Salmon being female.

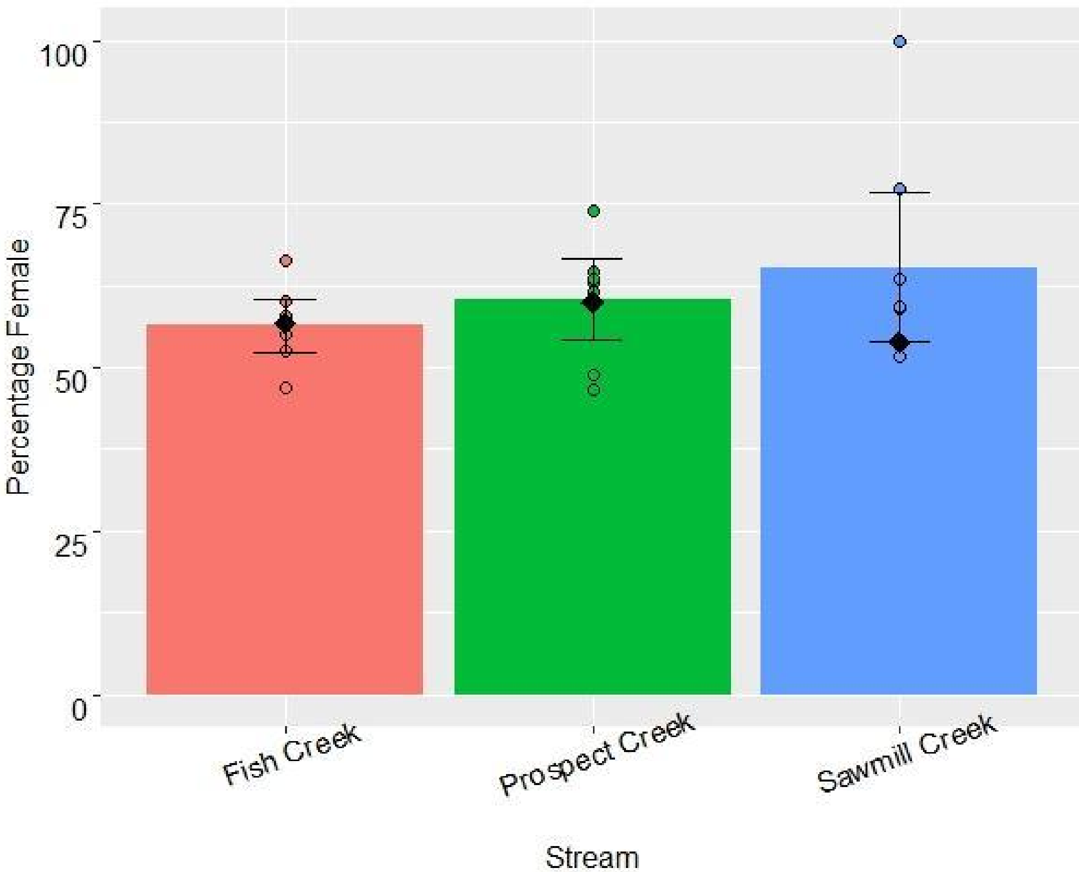

Figure 4. Mean percentage of females in Chum Salmon streams sampled between 2013 and 2022. Error bars depict the 95% confidence interval of the mean. Points show observed values for each stream. Black diamonds depict female percentage means for 2022.

Size:

Two types of length measurements were taken for the 2022 season. The length from mid-eye to hypural plate (MEHL) was used to measure chum carcasses, while the length from the snout to the caudal fork (SFL) was used to measure live Chum Salmon. SFL measurements for all fish were corrected to MEHL by regressing the MEHL observed for the recaptured fish on their SFL ($r^2 = 0.317$, $p < 0.05$) recorded at tagging. The resulting model was applied to all tagged fish (Table 2). Comparing the average corrected MEHL of tagged live chum to the average MEHL of carcasses, live females and males were smaller than carcass females and males for all three creeks. Sawmill Creek had the largest female and male carcass lengths while Fish Creek had the smallest carcass lengths for both sexes. However, Fish Creek had the largest female tagged live chum, with Prospect Creek having the largest male tagged live chum. Sawmill Creek saw the smallest male and female tagged live Chum Salmon (Table 2).

Table 2. Live Chum Salmon lengths by sex compared to carcass survey Chum Salmon lengths by sex for each survey stream. Standard errors for each value are in parentheses.

Stream	Average Female Carcass Survey MEHL (SE)	Average Male Carcass Survey MEHL (SE)	Average Female Tagging Survey Corrected MEHL (SE)	Average Male Tagging Survey Corrected MEHL (SE)
Fish Creek	499.4 (±1.08)	513.6 (±1.75)	497.41 (±1.76)	508.3 (±1.43)
Sawmill Creek	520.3 (±2.55)	538.7 (±4.65)	494.8 (±2.69)	512.3 (±2.66)
Prospect Creek	509.1 (±2.68)	526.3 (±3.71)	473.5 (±6.6)	518.6 (±3.56)

Age:

Scales were collected from both chum carcasses and live chum, providing information on the age structure of the runs. We recently received the age data from the DIPAC fish aging lab. Our initial review indicates a carcass and tagged live Chum Salmon scale loss rate of 0.86% and 4.4% for Fish Creek, 0.21% and 4.7% for Sawmill Creek, and 0.21% and 2.9% for Prospect Creek. The higher level of scale loss seen for tagged live Chum Salmon could be attributed to the lower number of scales taken for each sample, two, compared to the four scales taken for Chum Salmon carcasses. The lower number of scales collected for live chum was a result of minimizing the amount of time Chum Salmon were out of the water, along with the increased difficulty of collecting scales from live fish.

The age distribution of Chum Salmon carcasses in relation to stream and for sex was analyzed. For Fish Creek males and females averaged 4.1 years. Tagged Chum Salmon from Fish Creek also averaged 4.1 years for both males and females. For Sawmill Creek, carcass males averaged 4.1 years and females averaged 4.2 years, while tagged Chum Salmon females and males averaged 4.0 years. For Prospect Creek, carcass males averaged 4.1 years and females averaged 4.2 years, while tagged Chum Salmon females averaged 4.1 years and males averaged 4.4 years (Figure 5). When comparing age classes, less than 1% of all Chum Salmon sampled were 2 years old, 4.8% were 3 years old, 75.5% were 4 years old, 19.5% were 5 years old, and less than 1% of fish were 6 years and 7 years old.

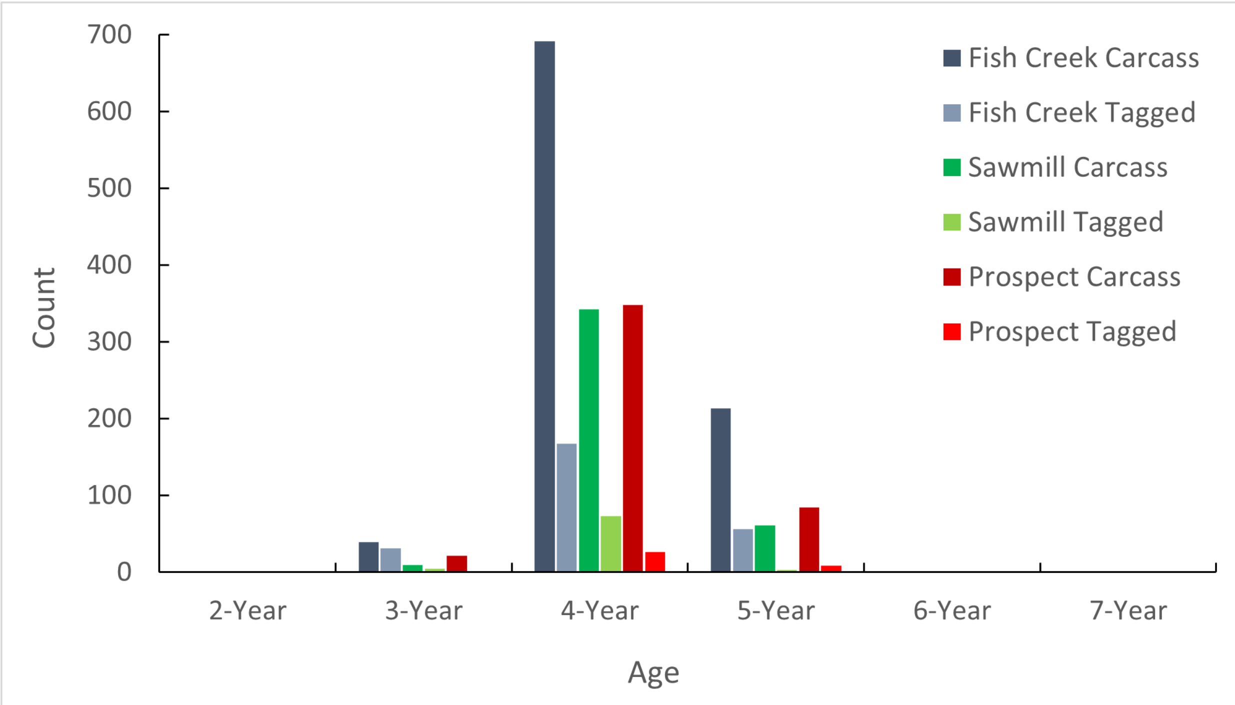

Figure 5. Age distribution and counts of carcasses and tagged Chum Salmon for each survey stream sampled in 2022.

Origin:

Otolith samples were submitted to the ADF&G Mark Tag and Aging Lab at the end of the field season. We have not yet received results back from the lab.

Proportion of Run Sampled:

Marking began on the first day of sampling in each creek and ended approximately one week before the end of sampling (Figure 6). Initially the plan called for marking to be conducted every other day until the beginning of the last week of August. Fish were to be captured at fixed locations ("staging areas") in each stream using beach seines or dip nets. These locations were located near or just beyond the tidal influence in these streams. This was problematic for all three survey streams because flows were sufficiently fast and/or water level deep enough to impede use of the seine nets and limited visibility for dip net capture. Prospect Creek modified their use of the seine net by cordoning off a branch of Prospect Creek, corralling fish upstream of the adjacent branch back downstream into the waiting seine net. Dip netting was effective, but it appears that catchability was highest for fish intending to spawn in the lower spawning area reach. Table 3 summarizes the number of tagged fish released (M in equation 1), the number of recaptures (R in equation 1) and the number of carcasses examined for tags (C in equation 1).

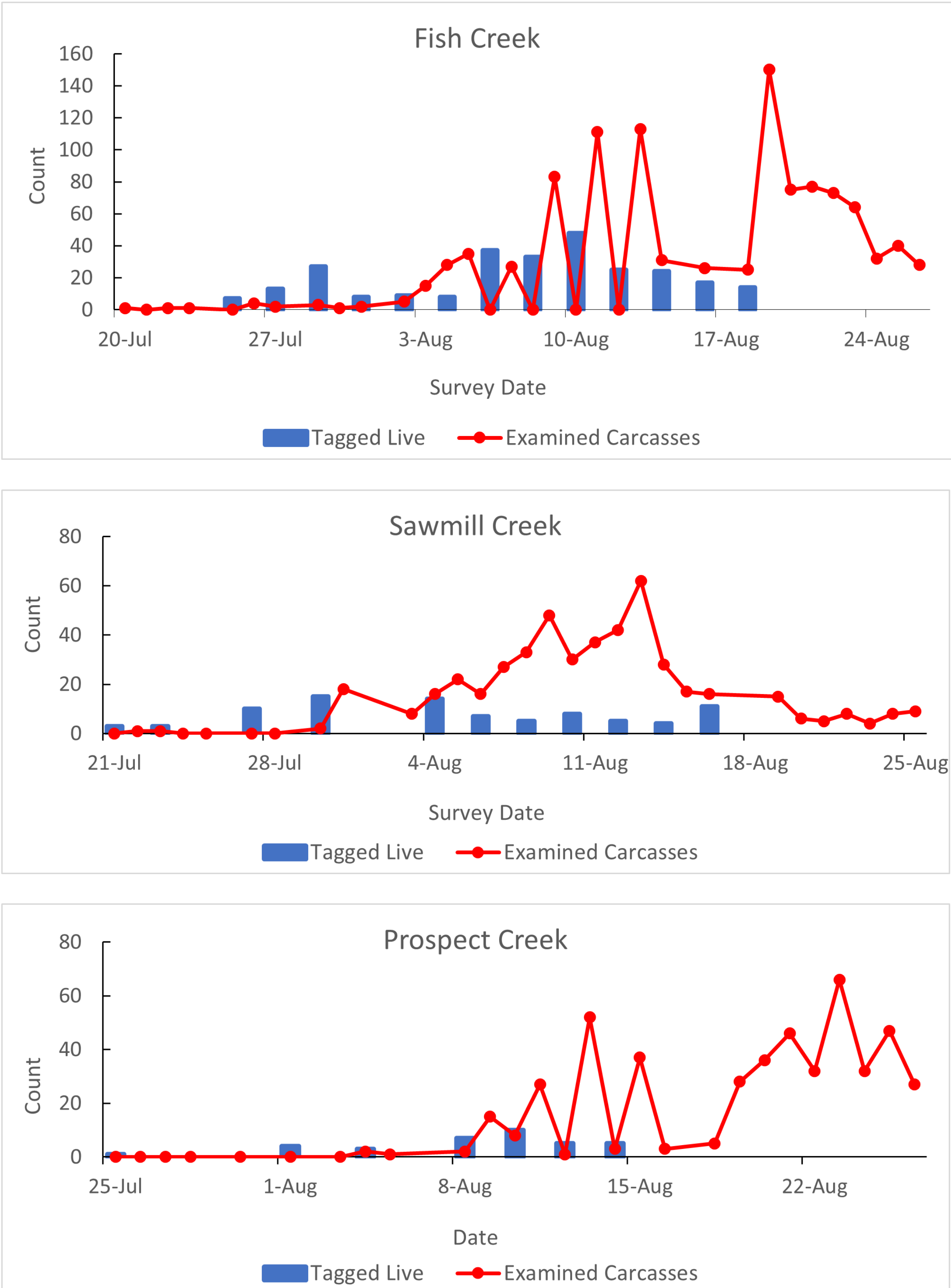

Figure 6. Daily numbers of fish marked and released, and the number of carcasses surveyed for each of the three study streams. Note difference in ordinate scale for Fish Creek.

Table 3. Marks released (M), recaptures (R) and the number of unmarked carcasses inspected (C) in each of the three study streams. Recaptures include all fish with mutilated opercula. Percent lost tags is the percentage of R for which no Floy tag was observed. Numbers in parentheses are females and males. Fish with unknown sex are included in totals.

	M	R	% Lost Tags	C
Fish Creek	270 (108, 162)	84 (40, 42)	15 (7, 5)	969 (556, 389)
Sawmill Creek	85 (28, 57)	17 (5, 11)	53 (3, 6)	462 (253, 204)
Prospect Creek	35 (16, 19)	13 (9, 4)	46 (3, 3)	457 (273, 178)

Examination of the sex ratios observed in the different fractions (Table 4) indicated the presence of bias with respect to sex in the Fish Creek sample as indicated by the rejection of the null hypothesis for the comparison of the sex ratios in M vs. R (second sampling event) and M vs. C. There was also evidence of a sex bias for Prospect Creek indicated by the significant difference between M vs. R. Sawmill Creek indicated some evidence of sex bias due to the significant difference between M vs. C.

Table 4. Results of $\chi 2$ testing of sex ratios in different fraction of the mark-recapture data set. M is the Marked and released fraction, R is the recaptured fraction, and C is the fraction representing the second sampling event.

Comparison	Fish Creek	Sawmill Creek	Prospect Creek
M vs. R	**Reject H_0**	Accept H_0	**Reject H_0**
C vs. R	**Reject H_0**	**Reject H_0**	**Reject H_0**
M vs. C	**Reject H_0**	**Reject H_0**	Accept H_0
Conclusion	Bias in the first event, bias in second event	No bias in first event, evidence of bias in second event	Bias in first event, unknown bias in second event

Similarly, analysis of the lengths (Table 5) indicated evidence of size bias in Sawmill Creek. Consequently, population estimates were made for all the fish combined in each stream and broken down by size. Size was partitioned into “small” and “large” fish using the recaptured fish median lengths 504 mm for Fish Creek, 519 mm for Sawmill Creek, and 514 mm for Prospect Creek as the break point.

Table 5. Results of $\chi 2$ testing on length frequency distributions in different fractions of the mark-recapture data sets for each stream. M is the marked and released fraction, R is the recaptured fraction and C is the fraction representing the second sampling event.

Comparison	Fish Creek	Sawmill Creek	Prospect Creek
M & R	Accept H_0	**Reject H_0**	Accept H_0
C & R	Accept H_0	**Reject H_0**	**Reject H_0**
M & C	Accept H_0	**Reject H_0**	Accept H_0
Conclusion	No bias in the first event, no bias in second event	Bias in the first event, bias in second event	No bias in first event, unknown bias in second event

The estimated proportion sampled in each stream ranged moderately. Estimated run sizes, the number of unique samples, and the 95% confidence intervals for the proportion sampled are given in Table 6. Unstratified estimates for the proportion sampled ranged from 25% in Sawmill Creek to 40% in Fish

Creek and 42% in Prospect Creek. Unstratified estimated run size ranged from 3,090 in Fish Creek, 2,213 in Sawmill Creek, and 1,179 in Prospect Creek. Stratified estimates for run size and the percentage of the run sampled regarding sex in all three creeks was nearly equal to the estimates made without stratification. Stratified estimates of the percentage of the run sampled regarding size (using the proportion of “small” fish to “large”) for Fish Creek and Sawmill Creek varied minimally compared to estimates made without stratification (less than 10%). Unstratified estimates of run size for Fish Creek and Sawmill Creek was higher compared to stratified estimates. Prospect Creek was not stratified dependent on the size of the fish due to insufficient sample numbers. Comparing estimated proportion sampled stratified by sex versus by size varied moderately. Comparing sex versus size bias of stratified samples were nearly equal in Fish Creek. Both Sawmill and Prospect Creek saw a reduced estimated proportion sampled when stratified by size compared to stratification by sex.

Table 6. Run size estimates, the number of unique samples, and the estimated percentage of the run sampled in each of the study streams. Stratified estimates do not include unknown sex specimens.

Stream	$\hat{N}$	$V_{\hat{N}}$	N_u	Percent sampled	95% CI of percent sampled
Fish Creek	3,090	69,640	1,239	40	34 - 48
Fish C. – female	1,588	32,340	664	41	34 - 54
Fish C. – male	1,479	32,537	551	37	30 - 49
Fish C. – stratified	3,089	71,878	1,215	39	34 - 47
Fish Creek	2,850	66,211	1,089	38	32 - 46
Fish C. – small	1,379	30,221	537	34	31 - 52
Fish C. – large	1,450	33,044	552	38	31 - 50
Sawmill Creek	2,213	195,727	547	25	17 - 40
Sawmill C. – female	1,229	166,729	281	23	14 - 66
Sawmill C. – male	992	56,389	261	26	18 - 50
Sawmill C. – stratified	2,318	230,399	542	23	16 - 39
Sawmill Creek	1,893	392,354	238	13	8 - 36
Sawmill C. – small	931	151,032	120	13	7 - 70
Sawmill C. – large	595	56,733	118	20	11 - 92
Prospect Creek	1,179	54,781	492	42	30 - 68
Prospect C. – female	467	7,825	289	62	45 - 98
Prospect C. – male	717	62,292	197	27	16 - 86
Prospect C. – stratified	1,163	53,332	486	42	30 - 68
Prospect Creek- small + large	1,055	62,071	356	34	23 - 63

DISCUSSION

The start of the 2022 field season was marked by two weeks of heavy rainfall and fog, resulting in impeded sampling efforts for all three streams, but particularly worse at Prospect Creek. For Prospect Creek, field crews experienced a series of atmospheric river events that led to major flooding, poor stream visibility, and unsafe surveying conditions from July 25th to August 4th. During this period, over 19 cm (7 inches) of rain fell. The rainfall created impassable conditions for Prospect Creek that already possesses challenging terrain and a long survey stretch. By August 5th the rain relented, allowing crews to finally reach the topmost portion of the survey stretch and begin taking accurate daily fish counts and samples.

Weather conditions also influenced the sampling effort at Sawmill Creek. During a major atmospheric river event in the summer of 2021, a significant portion of the lower reach of Sawmill Creek began diverting, shortening the survey stretch by an estimated 400 meters. This diversion caused the creek to bypass a saltwater marsh and a large woody debris pile. In addition, there is now the formation of a stagnant tannin-heavy eddy where the diversion occurred. It should be noted that the area cut off from the diversion was observed to be productive spawning grounds where in the past years of surveying we collected a significant number of carcasses. Salmon were observed congregating and spawning in the eddy and in the newly diverted section of Sawmill Creek. The eddy created a new location where Chum and Pink Salmon would congregate in small numbers, increasing our ability to use dip nets to capture Chum Salmon for mark/recapture analysis. The steep nature of the terrain prevented the use of beach seine nets in this new location.

From our first year of mark/recapture sampling, we learned that Chum Salmon do not gather in large numbers in staging areas before moving upstream, making capturing and subsequent tagging in large numbers difficult. Using beach seine nets turned out to be moderately effective in capturing salmon. Prospect Creek had the most success utilizing the seine nets, where fish could be easily corralled into the net using the local topography and lots of trial and error. However, the beach seines overall were too lightweight to work in fast currents and shallow waters. Dip nets were more effective and crews in all three streams heavily relied on dip netting to sample fish for marking and release.

Last year it was observed that once tagged, few salmon were observed spawning further upstream of the tagging area. This pattern was also observed in the 2022 field season in all three creeks. Most of the recaptured Chum Salmon were caught in the same vicinity of the location of where they were tagged. However, by tracking the GPS locations of recaptured tagged Chum Salmon, we observed that Fish Creek had recaptured tagged Chum Salmon at the end of their survey stretch, approximately 1.5 km upstream of the tagging location. This is the farthest by 1 km we have ever observed Chum Salmon straying beyond their tagging site.

This marks our second attempt to estimate the proportion of the run sampled for pedigree analysis. Unstratified run size estimates were 40%, 25% and 42% for Fish Creek, Sawmill Creek, and Prospect Creek, respectively. Our goal for the proportion of the run size estimated to have been sampled was 40%, which was met for Fish Creek and Prospect Creek. However, by targeting individual chum using dip nets, crews potentially introduced bias into sampling by being more likely to sample larger slower moving fish. Chi-square analyses relating to sex and size stratification confirmed the presence of bias in our capture efforts. Comparisons between the stratified estimates and unstratified estimates of both size and sex indicate minimal to moderate impact of this bias on the overall estimates of the proportion sampled.

When evaluating biases on the basis of sex and size for mark/recapture analysis, low sample size numbers impacted the confidence in our estimates. The few fish recaptured in Sawmill and Prospect Creek (n<10) made evaluation of bias based on sex and size difficult because testing often had too few expected values. Consequently, estimates of the run size and proportion sampled in Sawmill Creek and Prospect Creek should be viewed with caution.

Observations by technicians this year helped strengthen possible explanations for biases. With evidence of bias in terms of sex when tagging fish, observations over the duration of this project have noted that when the sampling season begins, many fish observed are males. These males tend to move into freshwater first, competing for spawning territory. Technicians have also observed a distinct change in the proportion of males versus females during the midway point of the field season, with females eventually being the majority sampled. This may contribute to sex and size ratio bias, with males dominating tagging earlier in the season. Further analysis is needed to better understand the differences in sex and size distribution and timing, especially in terms of sampling bias.

Like last year, low capture rates for marking led to concern that on scheduled tagging days we would get insufficient genetic samples to maximize collection. Moreover, we believed that allowing carcasses to sit for 24 hours between surveys would further reduce the number of genetic samples. To maximize the number of genetic samples collected for the pedigree analysis, carcasses were sampled opportunistically even on scheduled tagging days. For Sawmill Creek it was possible to conduct tagging and complete carcass surveys each day. For Fish Creek, smaller carcass numbers allowed crews to conduct both survey types for the first two weeks of the season. After this period, the crew switched to tagging days every other day. However, for Prospect Creek, carcass surveys on tagging days were limited to carcasses observed in the immediate tagging area for the entire field season. No effort was extended beyond those areas and live counts were not recorded. Consequently, for Fish Creek and Prospect Creek, the number of live, dead, and previously sampled counts were not entered on most tagging days.

For the 2022 season, Chum Salmon returns throughout Southeast Alaska were average. Preliminary estimates from ADF&G suggest the 2022 harvest was ~9.4 million fish, ~94% of the ten-year average for SE Alaska (~10 million fish) (Information Services Section, Division of Commercial Fisheries 2022). This was over 2 million more Chum Salmon estimated compared to 2021 (~7.2 million fish). Coincidently, the numbers of live chum observed in our surveys were above our nine-year averages for each of the streams. However, we can expect that the estimated run sizes are relatively large for each of these streams. For example, McConnel et al. 2018 reported 854 spawners in Sawmill Creek in 2015 compared with our estimate of 2,294 spawners. For context, the estimated harvest of Chum Salmon in Southeast Alaska during 2015 was near 8.5 million fish.

An above average number of carcass and tagging samples were collected compared to the median number of samples collected between 2013 and 2021. A reason for the increased number of carcass samples collected could be from a new strategy of targeting bear caches of fish in a 2-meter zone on either side of the creeks when sampling. This change in protocols resulted from frequent atmospheric river events in the first two weeks of sampling that pushed carcasses up into the surrounding vegetation when creek beds would overflow. When surveying in the woods for displaced carcasses, technicians began specifically targeting bear caches. Bear caches allowed technicians to gather high concentrations of carcasses with little effort. Special care was taken in terms of bear safety when sampling the riparian zone. Increased tagging efficiency could be a result of modified protocols that emphasized the use of dip nets once the seine nets were deemed insufficient for the stream conditions.

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Appendix A: Sampling Equipment & Data Quality Improvements

Most sampling equipment worked well in 2022. We had issues using the seine nets for the mark-recapture study due to a lack of adequate staging areas where Chum Salmon were gathering in sufficient numbers, as well as the nets themselves being too lightweight to hold up against strong currents. In addition, the space between the netting was too small, allowing for high amounts of drag. We also had issues with clickers freezing. Despite these equipment setbacks, crew members felt well prepared and satisfied with the equipment used in the field.

Communication between field crews and project coordinators was effective and frequent. The use of both cell phones and Garmin InReach SE Satellite texting devices allowed crews to remain in contact with the SSSC project coordinators and field support staff throughout the season. Sample numbers, field logistics, schedule revisions, field crew requests, and other challenges were discussed throughout the season. The project coordinators also maintained communication with ADF&G Area Management Biologists in Juneau and Haines with updates on fish numbers, as well as stream and sampling conditions. Updates were also communicated to ADF&G project supervisors and the HWI science panel.

The quality and integrity of the data was further enhanced in 2022 through updates to the field technician training. Crews primarily focused on sampling Chum Salmon carcasses for pedigree analysis. To obtain more samples while conducting carcass surveys, crews included sampling of live post-spawned Chum Salmon in the absence of more readily available carcasses. This method was especially relevant for the crew assigned at Prospect Creek, which encountered poor weather that hindered sampling efforts in the first two weeks of the season. Crews used snagging equipment and dip nets to target post-spawned live individuals. However, special care had to be taken to not unnecessarily capture pre-spawned individuals.

The laptop application allowed for easy review of all field data and data were submitted after returning to base camp. Prior to data transmission, the laptop application prompted a complete review of the samples collected and required the identification of milestone cells (missing otolith, last specimen, etc.). Once these checks were complete, the surveys were transmitted to the Hatchery-Wild Database via the internet. Data was backed up on multiple storage devices daily by all field crews. The Prospect Creek-based crew had limited internet access and transmitted surveys as service was available, typically occurring every two weeks during crew transfers. The Hatchery-Wild Database was critical to acquisition of error-free data and was used by project personnel throughout the season to produce reports, conduct data checks, and confirm survey transmission. The database was also used during the season to conduct final quality assurance checks prior to delivering otolith and DNA tissue samples to the ADF&G Mark, Tag, and Age Lab and scales to the Douglas Island Pink & Chum lab in Juneau.