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Hatchery Chum Salmon Straying Studies in Southeast Alaska, 2008–2010

by

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and

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY MANUSCRIPT SERIES NO. 12-01

HATCHERY CHUM SALMON STRAYING STUDIES IN SOUTHEAST ALASKA, 2008–2010

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ABSTRACT

From 2008 to 2010, we collected otoliths from chum salmon at wild stock index streams throughout Southeast Alaska to document the presence and distribution of stray hatchery fish. Summer chum salmon index streams in Southeast Alaska are grouped into aggregates of streams in three broad subregions—Southern Southeast (SSE), Northern Southeast Inside (NSEI), and Northern Southeast Outside (NSEO). Samples of greater than 50 fish were collected from 5 of 13 index streams in the SSE Subregion, 5 of 5 index streams in the NSEO Subregion, and 23 of 63 index streams in the NSEI Subregion. The proportion of hatchery fish was greater than 5% in 21 of 33 index streams: 2 of 5 in the SSE Subregion, 1 of 5 in NSEO Subregion, and 18 of 23 in the NSEI Subregion. The highest proportions of hatchery strays were found in streams located within 50 km of hatchery release sites. We observed significant year-to-year variation in the proportion of hatchery fish in four of nine streams that were sampled in multiple years. In the NSEI Subregion, we detected proportions of stray hatchery fish in excess of 5% at the majority of index streams. The overall estimated proportion of hatchery fish in the NSEI Subregion escapement index in 2010 was 13.5% (80% CI=12.5%–14.4%). In all three years the estimated overall proportion of hatchery strays in the NSEO Subregion was less than 2%.

Key words: chum salmon, escapement, enhancement, hatchery stray, *Oncorhynchus keta*, otolith, Southeast Alaska, straying, thermal mark.

INTRODUCTION

Chum salmon (*Oncorhynchus keta*) spawn in more than 1,200 streams in Southeast Alaska (Eggers and Heinl 2008). Annual commercial harvests of chum salmon in Southeast Alaska reached their highest levels in the 1920s after commercial fisheries developed in the early 1900s, then gradually declined to their lowest levels in the 1970s (Figure 1; Eggers and Heinl 2008). Chum salmon harvests increased again in the mid-1980s and reached historic high levels in the 1990s and 2000s, primarily due to increased production of hatchery chum salmon (Van Alen 2000). In 1980, hatchery operators in Southeast Alaska released 8.7 million chum salmon fry at eight locations. By 2007, this number had risen to 454 million fry released at 22 locations (Eggers and Heinl 2008). In Southeast Alaska, hatchery-produced chum salmon accounted for an average of 73% of the common property commercial harvest of this species—nearly 5 million fish per year—from 2001 to 2010.

While it is clear that the hatchery program in Southeast Alaska provides major economic benefits to the region's commercial fisheries (Clark et al. 2006), it is also widely recognized that there are risks to wild stocks associated with large-scale hatchery production (Chilcote et al. 2011, Araki and Schmid 2010, Naish et al. 2008, Myers et al. 2004, Waples 1999). The State of Alaska has numerous policies designed to minimize impacts of the salmon enhancement program on wild stocks, including a genetics policy (Davis et al. 1985), disease policies (McDaniel et al. 1994, Meyers 2000, Meyers 2010), a policy for the management of sustainable salmon fisheries (5 AAC 39.222), and a policy for management of mixed stock salmon fisheries, which gives the conservation of wild stocks, consistent with the sustained yield principle, the highest priority (5AAC 39.220). Of particular concern is the possibility that hatchery-produced salmon might stray in large numbers to wild stock streams, with potential genetic, ecological, and management implications (Naish et al. 2008).

High straying rates could make it difficult for fisheries managers to monitor chum salmon populations through standard survey techniques and reduce the Alaska Department of Fish and Game's (ADF&G) ability to formulate meaningful escapement goals and determine whether those goals are being met for wild chum salmon populations as required by the Sustainable Salmon Fisheries Policy. Chum salmon escapements are assessed primarily through aerial surveys at 81 summer-run and seven fall-run chum salmon index streams distributed across the

Southeast region (Eggers and Heinl 2008). These surveys do not provide a measure of total escapement but provide indices of relative abundance that are useful for assessing long-term trends in chum salmon escapement. Escapement goals for summer chum salmon are based on peak survey counts to aggregates of these streams in three broad subregions. Although ADF&G has assumed that hatchery-reared chum salmon successfully home to their release site, no organized, region-wide studies have been conducted to assess straying of hatchery salmon in Southeast Alaska.

Coded-wire tag data supported ADF&G's observation that chum salmon straying did not appear to be significant in Southeast Alaska during most of the growth of the hatchery program (Josephson 2010). Josephson (2010) examined coded-wire tag recoveries of hatchery chum salmon in Southeast Alaska since the late 1970s and found that only 10 of more than 8,000 tags recovered at hatchery brood stock collections were recovered more than five miles from the original release site. Marking fractions were extremely low (typically less than 0.003%), however, due to the large numbers of chum salmon fry released, and detection of coded-wire tagged hatchery fish in samples on the spawning grounds would have been difficult in most situations. Starting in the early 1990s, hatcheries in Southeast Alaska began mass-marking entire release groups of chum salmon fry with thermal-otolith marks. Since 2004, an average of 84% of all hatchery chum salmon released in Southeast Alaska have been otolith-marked (Figure 2), including 100% of Douglas Island Pink and Chum (DIPAC) and Southern Southeast Regional Aquaculture Association (SSRAA) releases. The advent of thermal-otolith marking (Mosegaard et al. 1987; Volk et al. 1990) has greatly improved the ability of fishery managers and hatchery operators to evaluate and monitor all aspects of hatchery programs, and to estimate contributions of hatchery fish to mixed-stock fisheries (Munk et al. 1993, Hagen et al. 1995, Joyce and Evans 2000, Jensen and Milligan 2001).

Limited otolith sampling conducted since 1995 indicated that hatchery fish may stray with greater frequency than was indicated by coded-wire tag data. From 1995 to 2006, ADF&G collected chum salmon otolith samples from 22 streams in southeast Alaska, primarily in the Juneau area (Josephson 2010). Although many of the samples were small and often collected on a single date, the results indicated that a large number of hatchery strays were present in many of the summer chum salmon systems that were examined. Approximately 50% of the fish sampled in three Juneau-area chum salmon index streams (Berners River, Sawmill Creek, and Fish Creek) were hatchery strays from local release sites. In 2006, otolith samples were collected from chum salmon carcasses at Traitors Creek, which is located in the next bay south of SSRAA's Neets Bay hatchery, in southern Southeast Alaska (Figure 3). Approximately 87% of the sampled fish were stray hatchery fish, primarily from Neets Bay. Traitors Creek was historically an important producer of wild chum salmon (e.g., chum salmon escapement of 32,000 in 1962; Mattson and Rowland 1963). Samples were also collected from fall chum salmon at Disappearance Creek, Prince of Wales Island, from 2008 to 2010 (Piston and Heinl 2010a-b; Piston and Brunette 2011), and the Chilkat River, near Haines, in 2009. No hatchery fish were detected in samples collected at the Chilkat River, which is not unexpected considering the lack of fall chum salmon releases in northern Southeast Alaska. The proportion of hatchery strays in the escapement at Disappearance Creek did not exceed 1.0%.

From 2008 to 2010, we sampled summer chum salmon index streams throughout Southeast Alaska to document the presence and distribution of stray otolith-marked hatchery fish in the region. Results from this study also provided information on how hatchery strays may affect

ADF&G's ability to monitor wild chum salmon abundance. In addition, improved understanding of the magnitude of hatchery chum salmon straying in Southeast Alaska was an important step in identifying potential impacts of large-scale chum salmon enhancement on wild stocks in the region.

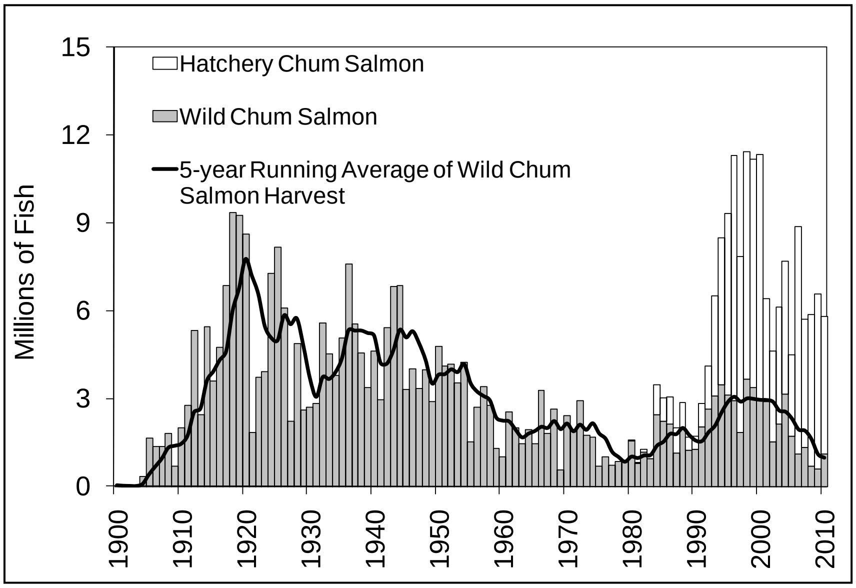

Figure 1.–Annual common property harvest of chum salmon in Southeast Alaska showing the estimated harvest of both hatchery-produced and wild chum salmon, 1890–2010. (Data prior to 1960 are from Byerly et al. 1999.)

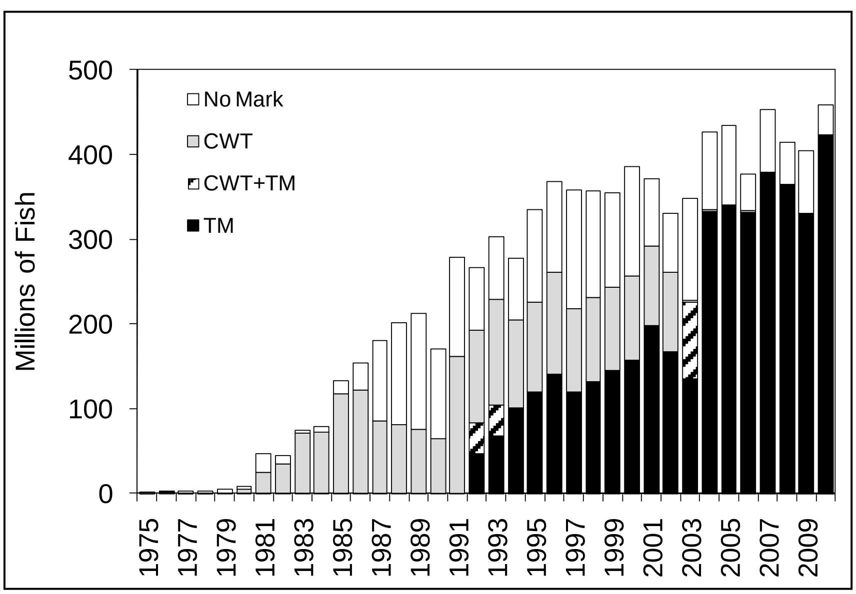

Figure 2.–Total releases of hatchery chum salmon in Southeast Alaska, 1975–2010. Releases are presented by type of mark: CWT=coded-wire tag; TM=thermal mark.

OBJECTIVES

1. Collect samples from 50% of the 81 summer chum salmon index streams in Southeast Alaska over a three-year period.
2. Sample at least one index stream from every major bay, inlet, and passage represented in the current escapement indices for Southeast Alaska.
3. Collect 192 otolith samples over two sampling events at each stream and distribute sampling effort throughout the length of each creek.
4. Estimate the proportion of hatchery fish in each stream such that the point estimate is within 5% of the true value 80% of the time.
5. Describe the relationship between the proportion of hatchery fish in a stream and the distance to hatchery release sites.
6. Estimate the proportion of hatchery fish in the summer chum salmon escapement indices using annual peak aerial survey counts as a weighting factor.

STUDY SITE

We sampled ADF&G summer chum salmon index streams throughout Southeast Alaska, from Portland Canal near the Canadian border in the south, to Berners Bay, near Juneau, in the north—a distance of approximately 600 km (Figure 3). These index streams provide the foundation for escapement indices and goals for summer chum salmon in Southeast Alaska, which are based on peak aerial surveys to aggregates of index streams in three broad subregions—Southern Southeast, Northern Southeast Inside, and Northern Southeast Outside (Figure 4, Appendix A). The Southern Southeast Subregion (SSE) includes 13 streams on the inner islands and mainland of southern Southeast Alaska, from Sumner Strait south to Dixon entrance (Districts 1–7). The Northern Southeast Inside Subregion (NSEI) includes 63 streams on the inside waters of northern Southeast Alaska north of Sumner Strait (Districts 8–12, 14, and District 13 subdistricts 51 to 59). The Northern Southeast Outside Subregion (NSEO) includes five streams on the outside waters of Chichagof and Baranof islands in northern Southeast Alaska (District 13, excluding Peril Straits and Hoonah Sound subdistricts 51 to 59).

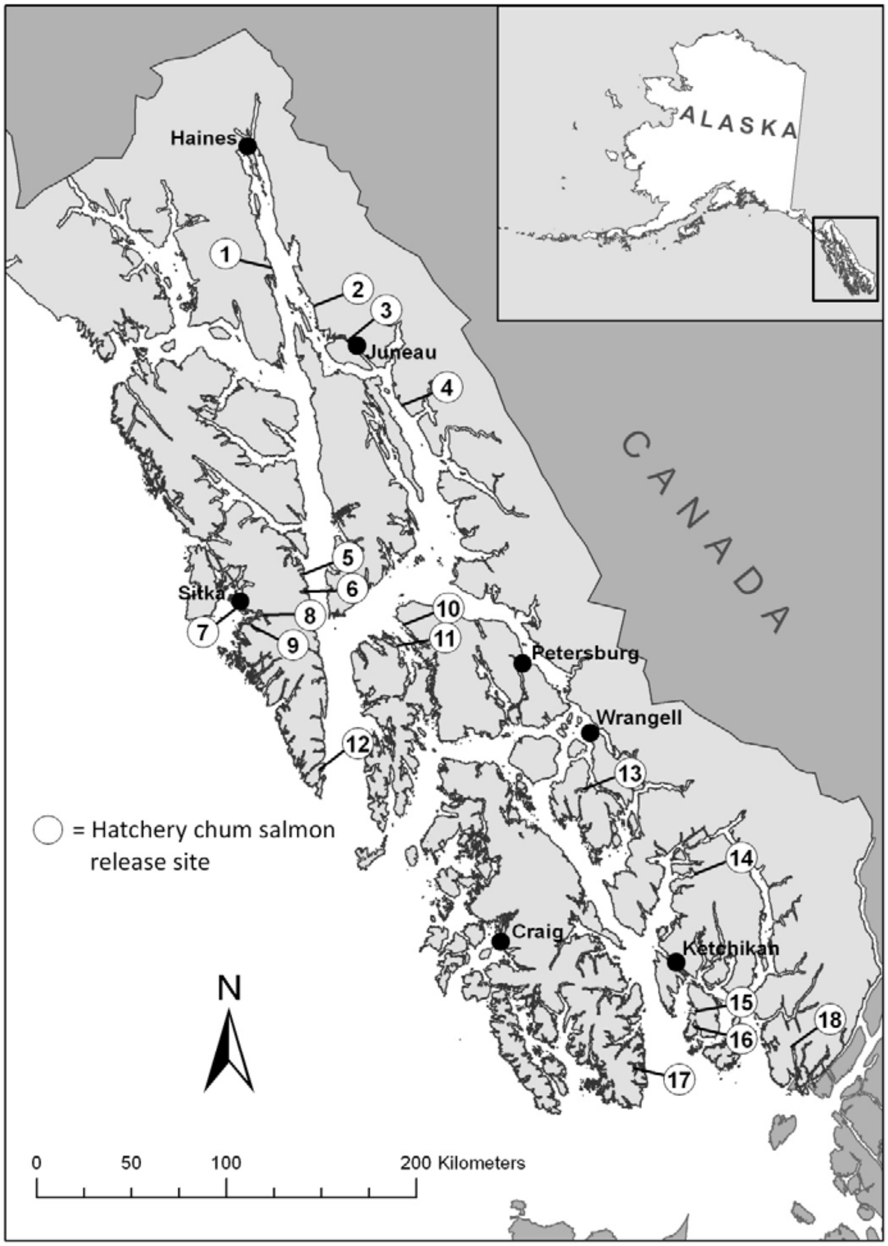

Figure 3.–Map of Southeast Alaska showing major towns and current hatchery chum salmon release sites. Hatchery release sites and operators are represented by numbered circles: 1) Boat Harbor (DIPAC), 2) Amalga Harbor (DIPAC), 3) Gastineau Channel (DIPAC), 4) Limestone Inlet (DIPAC), 5) Kasnyku Bay (NSRAA), 6) Takatz Bay (NSRAA), 7) Crescent Bay (SJC), 8) Bear Cove (NSRAA), 9) Deep Inlet (NSRAA), 10) Kake (KNFC), 11) Southeast Cove (KNFC), 12) Port Armstrong (AKI), 13) Anita Bay (SSRAA), 14) Neets Bay (SSRAA), 15) Chester Bay (MIC), 16) Tamgas Harbor (MIC), 17) Kendrick Bay (SSRAA), 18) Nakat Inlet (SSRAA).

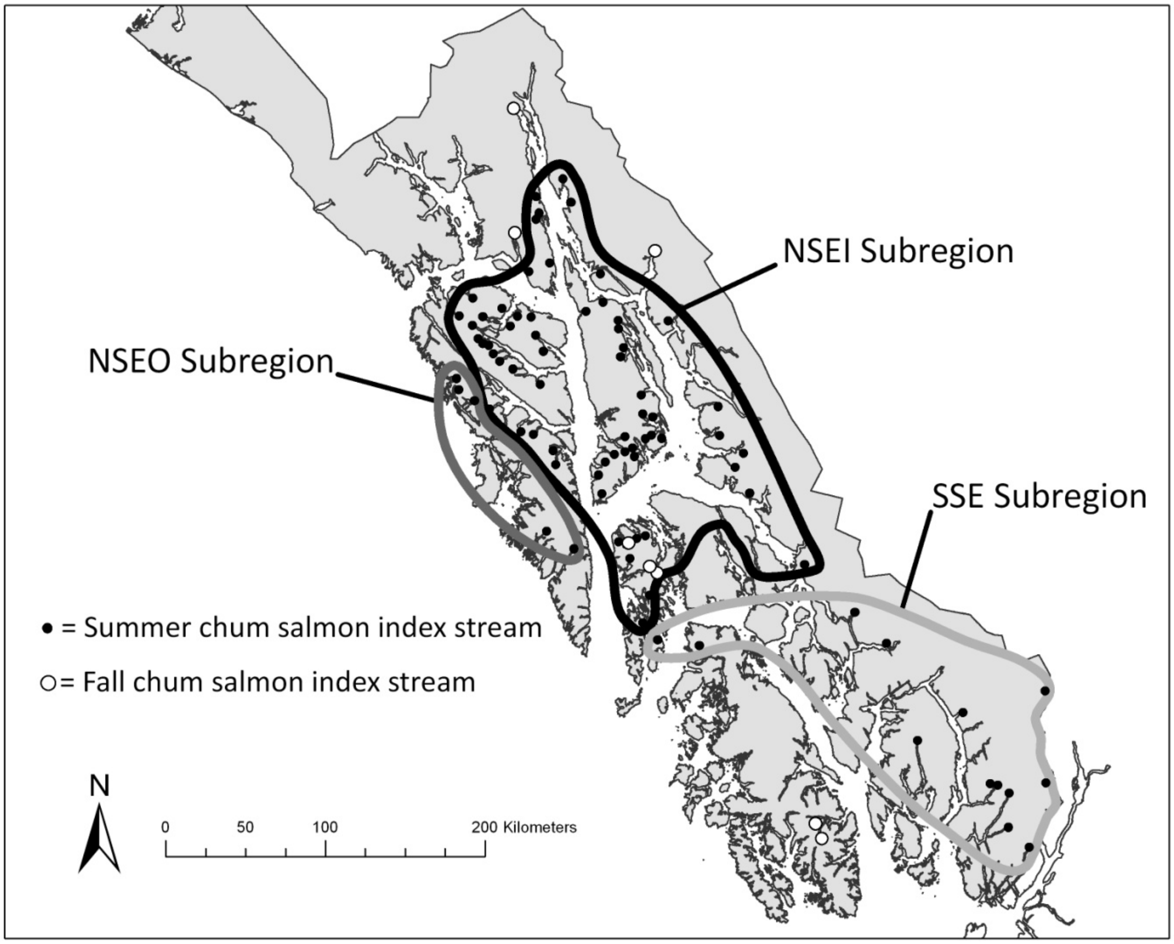

Figure 4.–The location of ADF&G chum salmon index streams and summer chum salmon stock groups in Southeast Alaska.

METHODS

STREAM SELECTION

The statistical population of interest was the collection of 81 summer chum salmon index streams that the department currently uses for monitoring wild chum salmon escapements in Southeast Alaska (Appendix A). Our objective was to sample 50% of these streams over the course of three seasons. To ensure complete geographic coverage of Southeast Alaska, we attempted to sample at least one index stream from every major bay, inlet, and passageway in the region. While the selection of streams was not random, the large sample size and thorough geographic representation allowed us to make broad statements about hatchery chum salmon strays in Southeast Alaska. The only index streams that were not well represented were the large mainland systems in east Behm Canal in southern Southeast Alaska, because sampling in this area was not logistically feasible.

Several non-index streams were also sampled. In 2009, samples were collected at Camp Coogan, near Sitka. This system was of interest to Sitka area managers who survey it on a regular basis. In 2010, we sampled two non-index summer chum salmon streams on Prince of Wales Island to obtain information from an area that is not well represented in the current summer chum salmon escapement index (Figure 4). Both systems, Staney Creek and Harris River, appear to have historically supported large runs of summer chum salmon (ADF&G unpublished data). In 2010, we also sampled Ketchikan Creek, a small, urban stream that probably never supported more than a very small run of chum salmon. This stream was sampled primarily to determine the source of what appeared to be unusually large numbers of chum salmon in 2010.

To compare the proportions of hatchery fish in sampled streams to the distance from the nearest release of otolith-marked hatchery fish, we measured the approximate water distance in km (i.e., the distance a fish would have to swim) using the measuring tool in Google Earth[1]. Straight line measurements between two points would be misleading for comparing salmon straying distances due to the numerous islands and passages in Southeast Alaska; e.g., the straight line distance between Neets Bay Hatchery and the Carroll River is 17 km, but the distance for a swimming fish is more than 100 km.

OTOLITH COLLECTION

Distribution of Samples

We attempted to collect otolith samples on two sampling events at each stream selected for sampling. The number of days between sampling trips and the number of sampling events varied for each stream, depending on chum salmon abundance, run timing, and weather. We communicated regularly with ADF&G management biologists responsible for conducting aerial surveys regarding inseason chum salmon abundance and the availability of carcasses at target streams. Samples were collected throughout the accessible length of the stream on each sampling event; however, we were only able to sample the lower few miles of available spawning habitat at a few of the larger streams. In some cases, spawning chum salmon and carcasses were only available for a very short time and all samples for a particular stream in a given year were collected on one sampling event. In most cases, these samples still provided a representative sample of the chum salmon present at the peak of the run.

Condition of Sampled Fish

Otolith samples were primarily collected from chum salmon carcasses on the spawning grounds to ensure that we sampled fish that were spawning and to avoid fish that may have been probing into a stream. We sampled carcasses in all stages of decay to ensure that our samples represented the entire run. The few samples that were collected from live, unspawned fish still provided useful information on how stray hatchery chum salmon affect ADF&G's chum salmon monitoring program, because peak aerial surveys used to evaluate chum salmon escapements in Southeast Alaska include live fish in the intertidal area and fish holding in saltwater at the mouth of the creek (Heinl et al. 2004).

In 2008, most samples were collected from carcasses or spawned out fish, with the exception of samples from two streams in the Sitka Management Area: Ralph's Creek and West Crawfish NE Arm Head. Samples from these streams were collected from live fish, primarily near the mouth of the creek, and may have included probing fish. Similarly, in 2009, nearly all samples were collected from carcasses or spawned out fish with the exception of Ralph's Creek and West Crawfish NE Arm Head, near Sitka, and Fish Creek, near Juneau. Samples from the two Sitka streams were again collected from live fish holding near the mouth of the creek. Fish Creek

[1] Reference to trade names does not imply endorsement by the Alaska Department of Fish and Game.

samples were obtained from fish holding in the stream, some of which were snagged out of pools and may not have been committed to spawning in the system. In 2010, in an effort to increase our sample sizes, we used snagging gear to capture live fish from most targeted streams in addition to the recovery of otoliths from carcasses. When live fish were sampled, we targeted fish that were spawned out. This helped ensure that the vast majority of the fish sampled had spawned in the stream where they were captured.

Sample Size

We wanted to estimate the proportion of hatchery fish in the escapement at each creek so that we were 80% confident that the point estimate was in error by less than 5%. We chose an 80% confidence level in an effort to balance the precision of our estimates with the need to keep sample sizes to a level that allowed for sampling a large number of streams while staying within budget constraints. The sample size (*n*) for each stream was calculated using methods described in Thompson (1992) for determining the sample size for estimating a proportion:

$$n = \frac{z^2 p(1-p)}{d^2}.$$

The value of *z* is equal to 1.28, which is the upper 0.10 limit of the normal distribution, and *d* is our maximum error tolerance of 5%. Since the proportion of hatchery fish in the escapement was unknown, we used a value of 0.5 for *p* to estimate the sample size that would meet our objective for any proportion of hatchery fish. Using this formula, we obtained a sampling goal of 164 fish per stream. We increased the sample size to 192 otoliths per stream to ensure that we met our sampling goal if a number of samples were damaged or unreadable.

If we assume that the presence of hatchery fish in stream *i* has a binomial distribution, with *p* representing the true proportion of hatchery fish in the stream, we can calculate the probability of at least one hatchery fish in a sample size of 192 for different sizes of *p*. Using the binomial distribution, $p^0(1 - p)^{192}$ is the probability of exactly zero hatchery fish in a sample size of 192. Therefore, $1 - p^0(1 - p)^{192}$ is the probability of at least one hatchery fish in the sample. If, on average, 5% of the fish in a particular stream are hatchery fish, the probability of detecting at least one marked otolith in a sample of 192 is nearly 100%. Even in cases where only 50 samples were obtained, the probability of detecting at least one hatchery fish was still greater than 90% when the true proportion of hatchery fish was only 5%. A sample size of 192 provided reasonable precision in our estimates of the proportion of hatchery fish and ensured that we would detect the presence of hatchery fish in streams with low proportions of hatchery strays. We did not calculate standard errors and confidence intervals for samples of less than 50 fish, and only consider those samples to be potentially useful for identifying the presence or absence of hatchery strays.

Otolith Extraction and Preparation

The left and right sagittal otoliths were removed from each fish and each pair was placed into a single cell of a 96-cell assay tray. Otoliths were cleaned using a treatment described by Hagen et al. (1995): otoliths were soaked in a 0.5% chlorine solution for up to 8 minutes, followed by a rinse in dechlorinating solution (0.7% sodium thiosulfate), and a rinse in tap water. Otolith samples were subsequently analyzed for thermal marks at the ADF&G Commercial Fisheries Mark, Tag, and Age Laboratory in Juneau, Alaska.

DATA ANALYSIS

The estimated proportion, $\hat{p}$, of otolith-marked fish in the escapement was calculated as,

$$\hat{p} = m/n,$$

where *m* denotes the number of fish sampled that had otolith marks, and *n* denotes the number of fish sampled for otolith marks. In several cases we were able to calculate an overall proportion of hatchery strays in an entire subregion. In this case, streams were the basic sampling unit, and fish within streams were a second-stage sampling unit. Each of the 81 index streams (*i*) had a true proportion, p_i, of hatchery strays, i = 1, …81, as a basic attribute of the sampling unit. Then if each stream has an escapement h_i in the year of interest, the true proportion of hatchery fish in the escapement index for a given subregion is given by,

$$p = \frac{\sum_i p_i h_i}{\sum_i h_i}.$$

After all otoliths were examined for thermal marks, the sample proportion of hatchery otoliths in the *i*th stream was denoted as $\hat{p}_i$. The estimated proportion of hatchery fish in a subregion's chum salmon escapement index in that year was constructed from a weighted average of the sample proportions, with weights constructed from a consistent chum salmon escapement surrogate for the year. We let h^* denote the peak escapement count, which served as that surrogate, so that the estimated proportion of hatchery strays in the entire escapement index for the region examined was given by,

$$\hat{p} = \frac{\sum_{sample} \hat{p}_i h_i^*}{\sum_{sample} h_i^*}.$$

The variance of the estimated proportion of otolith-marked fish in each stream and each subregion was calculated as (Cochran 1977, page 52),

$$\hat{\text{var}}(\hat{p}) = \left[\frac{\hat{p}(1-\hat{p})}{n-1}\right].$$

If a sample proportion is close to 0 or 1, calculation of confidence intervals using methods based on the normal distribution may be inappropriate (Morisette and Khorram 1998). Therefore, the 80% confidence interval of the proportion of hatchery strays was calculated using methods based on the relationship between the *F* distribution and the binomial distribution (Zar 2010), where *X* equals the number of marked fish in a random sample of *n* fish, and $F_{\alpha(2),v_1,v_2}$ is the upper $100 \cdot (1\text{-alpha})^{th}$ percentile from the *F* distribution, with v_1 and v_2 degrees of freedom. The lower 80% confidence limit (L_1) was calculated as,

$$L_1 = \frac{X}{X + (n - X + 1)F_{\alpha(2),v_2,v_1}},$$

where

$$v_1 = 2(n - X + 1),$$

and

$$v_2 = 2X.$$

The upper 80% confidence limit (L_2) was calculated as,

$$L_2 = \frac{(X+1)F_{\alpha(2),v_1' v_2'}}{n - X + (X+1)F_{\alpha(2),v_1' v_2'}},$$

where

$$v_1' = 2(X+1) = v_2 + 2,$$

and

$$v_2' = 2(n - X) = v_1 - 2.$$

For cases in which no hatchery fish were detected in a sample, we calculated exact confidence limits following Zar (2010):

$$L_1 = 0,$$

and,

$$L_2 = 1 - \sqrt[n]{\alpha/2}\,.$$

To compare the year-to-year variability in the proportion of hatchery fish present in the index streams, a test for differences between proportions was conducted for streams where a sample size of >50 fish was reached in two years. We used a level of significance of 0.05 for each test, which were calculated following Zar (2010):

$$Z_c = \frac{|\hat{p}_1 - \hat{p}_2| - \frac{1}{2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}{\sqrt{\frac{\bar{p}\bar{q}}{n_1} + \frac{\bar{p}\bar{q}}{n_2}}},$$

where

$$\bar{p} = \frac{(X_1 + X_2)}{(n_1 + n_2)},$$

and

$$\bar{q} = 1 - \bar{p}.$$

The 95% confidence interval for the difference between the two population proportions was calculated as,

$$95\%\ \text{C.I. for } p_1 - p_2 = (\hat{p}_1 - \hat{p}_2) \pm \left[Z_{0.05(2)} \sqrt{\frac{\bar{p}\bar{q}}{n_1} + \frac{\bar{p}\bar{q}}{n_2}} + \frac{1}{2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right) \right].$$

For cases in which we obtained three or more years of data from a single stream, we used the Chi-square contingency-table analysis outlined by Zar (2010) to test for differences between proportions among years:

$$\chi^2 = \sum\sum \frac{(f_{ij} - \hat{f}_{ij})^2}{\hat{f}_{ij}}$$

where f_{ij} is the observed frequency of unmarked fish in a sample and $\hat{f}_{ij}$ is the expected frequency of unmarked fish in the sample, assuming the null hypothesis that there is no difference between proportions among samples is true. The degrees of freedom (*DF*) were calculated as,

$$DF = (r - 1)(c - 1),$$

which, in the case of our two column (*c*) by three row (*r*) contingency tables, is equal to two.

Not all releases of hatchery chum salmon have been otolith marked and we could not account for hatchery releases that were 100% unmarked (e.g., releases at Chester Bay, Tamgas Harbor, Southeast Cove, Kake, Bear Cove, Crescent Bay). Hatchery chum salmon released at Deep Inlet (Medvejie stock) were partially marked in brood years 2003 (33.7%), 2004 (23.7%), and 2006 (18.5%). We expanded recoveries of these fish in West Crawfish NE Arm Head (2008), Lake Stream Ford Arm (2009 and 2010), and Camp Coogan (2009) using the proportion of marked to unmarked for each brood year. The 2005 brood year release for this stock and location was 100% unmarked.

RESULTS

SUMMER CHUM SALMON

Achieving our sampling objective of 192 otoliths per stream was difficult or impossible for some streams because chum salmon runs were below average from 2008 to 2010 (Piston and Heinl 2011). We obtained samples of greater than 50 fish from 33 summer chum salmon index streams in Southeast Alaska: from 5 of 13 index streams in the SSE Subregion, 5 of 5 index streams in the NSEO Subregion, and 23 of 63 index streams in the NSEI Subregion (Tables 1–3). We collected samples of fewer than 50 fish from six index streams in the NSEI Subregion. Of the 33 summer chum salmon index streams from which samples of greater than 50 fish were obtained, the proportion of hatchery fish was greater than 5.0% in 21 streams—2 of 5 in the SSE Subregion, 1 of 5 in NSEO Subregion, and 18 of 23 in the NSEI Subregion (Tables 1–3). Detailed results of all samples collected during our study, including distances from nearest release sites and samples by date, are presented in Appendix B.

The proportion of hatchery strays decreased as distance from release sites increased (Figure 5). The mean proportion of hatchery strays in the 12 sampled streams located within 50 km of the nearest release site was 28.3% (range: 3.4%–87.5%), and all samples that were composed of more than 40% hatchery fish were from these streams. The mean proportion of hatchery strays from streams located 50–100 km from the nearest release site was 8.0% (range: 0.0%–17.8%). For streams greater than 100 km from the nearest release site, the mean proportion of hatchery strays declined to 3.3% (range: 0.0%–16.6%).

Table 1.–Streams sampled for hatchery chum salmon strays in the Southern Southeast Subregion of Southeast Alaska, 2008–2010.

Year	Stream	Anadromous Stream Number	Index Stream	Sample Size	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper
2009	Hidden Inlet	101-11-01010	Yes	74	6.8%	2.9%	3.3%	12.2%
2009	Fish Creek-Portland Canal	101-15-10500-2028	Yes	120	0.8%	0.8%	0.1%	3.2%
2009	Marten River	101-30-10600	Yes	87	1.1%	1.1%	0.1%	4.4%
2010	Marten River	101-30-10600	Yes	64	1.6%	1.6%	0.2%	5.9%
2008	Carroll River	101-45-10780	Yes	190	0.0%	0.0%	0.00%	1.2%
2009	Carroll River	101-45-10780	Yes	202	3.0%	1.2%	1.6%	5.2%
2010	Ketchikan Creek	101-47-10250	No	188	66.0%	3.5%	61.2%	70.5%
2010	Harris River	102-60-10820	No	84	1.2%	1.2%	0.1%	4.6%
2010	Staney Creek	103-90-10310	No	60	3.3%	2.3%	0.9%	8.6%
2010	Harding River	107-40-10490	Yes	188	5.3%	1.6%	3.3%	8.1%

Table 2.–Streams sampled for hatchery chum salmon strays in the Northern Southeast Outside Subregion of Southeast Alaska, 2008–2010.

Year	Stream	Anadromous Stream Number	Index Stream	Sample Size	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper
2010	Whale Bay Great Arm Head	113-22-10150	Yes	95	2.1%	1.5%	0.6%	5.5%
2008	West Crawfish NE Arm Head	113-32-10050	Yes	192	4.2%	1.4%	2.4%	6.7%
2009	West Crawfish NE Arm Head	113-32-10050	Yes	96	0.0%	0.0%	0.0%	2.4%
2009	Camp Coogan	113-41-10340	No	94	5.9%	2.4%	3.0%	10.3%
2008	Sisters Lake SE Arm Head	113-72-10040-2025	Yes	192	0.5%	0.5%	0.1%	2.0%
2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	184	1.1%	0.8%	0.3%	2.9%
2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	269	3.0%	1.0%	1.7%	4.8%
2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	291	16.6%	2.2%	13.8%	19.7%
2010	Black River	113-81-10110	Yes	92	0.0%	0.0%	0.0%	2.5%

Table 3.–Streams sampled for hatchery chum salmon strays in the Northern Southeast Inside Subregion of Southeast Alaska, 2008–2010.

Year	Stream	Anadromous Stream Number	Index Stream	Sample Size	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper
2010	Saginaw Creek	109-44-10390	Yes	57	17.5%	5.1%	11.2%	25.7%
2010	Sample Creek	109-62-10140	Yes	224	6.3%	1.6%	4.3%	8.9%
2010	Dry Bay Creek	110-13-10040	Yes	146	13.0%	2.8%	9.5%	17.3%
2010	Cannery Cove-Pybus Bay	110-22-10140	Yes	214	17.8%	2.6%	14.4%	21.6%
2010	Snug Cove-Gambier Bay	110-23-10190	Yes	138	10.1%	2.6%	7.0%	14.3%
2010	Glen Creek	110-34-10060	Yes	50	8.0%	3.9%	3.5%	15.4%
2010	Swan Cove Creek	111-16-10450	Yes	189	9.0%	2.1%	6.4%	12.3%
2010	Prospect Creek	111-33-10100	Yes	152	18.4%	3.2%	14.4%	23.1%
2009	Admiralty Creek	111-41-10050	Yes	117	41.0%	4.6%	34.9%	47.4%
2010	Admiralty Creek	111-41-10050	Yes	113	12.4%	3.1%	8.5%	17.3%
2009	Fish Creek-Douglas Island	111-50-10690	Yes	192	87.5%	2.4%	83.9%	90.5%
2010	Fish Creek-Douglas Island	111-50-10690	Yes	94	70.2%	4.7%	63.3%	76.4%
2009	Robinson Creek	112-15-10620	Yes	82	17.1%	4.2%	11.8%	23.6%
2010	Wilson River	112-19-10100	Yes	122	47.1%	4.5%	39.8%	52.1%
2008	Ralphs Creek	112-21-10060	Yes	189	3.2%	1.3%	1.7%	5.5%
2009	Ralphs Creek	112-21-10060	Yes	93	10.1%	3.1%	5.9%	14.8%
2010	Ralphs Creek	112-21-10060	Yes	95	5.3%	2.3%	2.6%	9.5%
2008	Seal Bay Creek	112-46-10070	Yes	188	0.0%	0.0%	0.0%	1.2%
2009	Seal Bay Creek	112-46-10070	Yes	182	2.7%	1.2%	1.3%	5.0%
2010	Seal Bay Creek	112-46-10070	Yes	188	2.7%	1.2%	1.3%	4.9%
2008	Long Bay Head	112-47-10100	Yes	140	0.7%	0.7%	0.1%	2.7%
2008	Big Goose Creek	112-48-10150	Yes	172	0.0%	0.0%	0.0%	1.3%
2008	Tenakee Inlet Head	112-48-10350	Yes	146	0.7%	0.7%	0.1%	2.6%
2010	Freshwater Creek	112-50-10300-2001	Yes	95	11.6%	3.3%	7.5%	17.0%
2010	Chaik Creek	112-80-10280	Yes	165	5.5%	1.8%	3.3%	8.5%
2010	Saook Bay West head	113-53-10030	Yes	93	9.7%	3.1%	5.9%	14.8%
2009	Game Creek	114-31-10130	Yes	117	4.3%	1.9%	2.1%	7.8%
2009	St. James Bay NW Side	115-10-10420	Yes	94	16.0%	3.8%	11.2%	21.9%
2009	Sawmill Creek	115-20-10520	Yes	149	77.9%	3.4%	72.9%	82.2%
2010	Sawmill Creek	115-20-10520	Yes	83	47.0%	5.5%	39.5%	54.6%

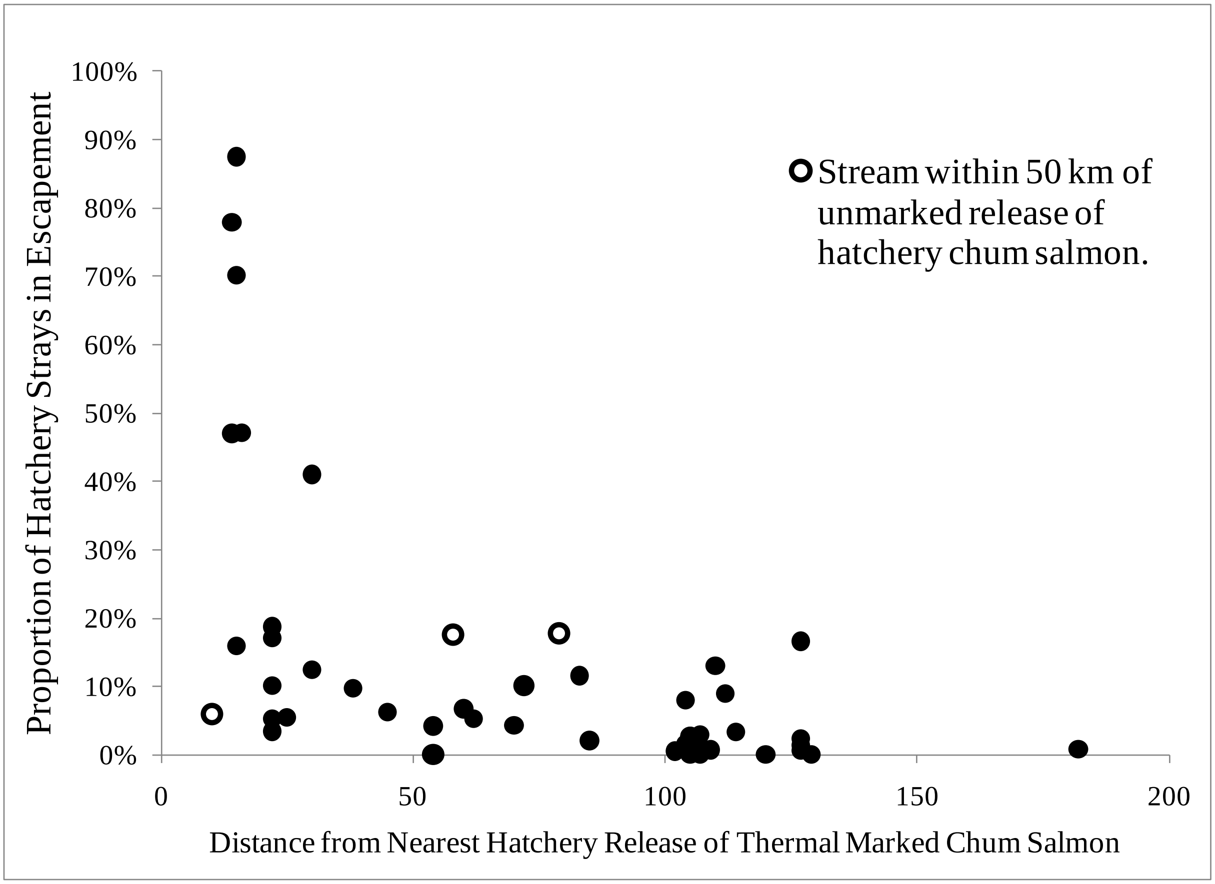

Figure 5.–The relationship between distance from the nearest release site of otolith-marked chum salmon and the proportion of hatchery strays in Southeast Alaska chum salmon streams sampled from 2008 to 2010 (sample size >50 fish per stream). Only index streams and streams that are historic producers of summer chum salmon (peak survey estimate >1,000 fish) are shown.

We observed considerable year-to-year variation in the proportion of hatchery fish in some streams that were sampled in multiple years. The proportions of strays in three streams located in the NSEI Subregion near Juneau were significantly higher in 2009 than in 2010 (Table 4). At Admiralty Creek, the proportion of hatchery strays was 41.0% in 2009, but only 12.4% in 2010. At Fish Creek-Douglas Island, the proportion of hatchery strays was 87.5% in 2009 and 70.2% in 2010. The proportion of hatchery fish at Sawmill Creek dropped from 77.9% in 2009 to 47.0% in 2010. The only other sampled stream in which the proportions of hatchery strays were significantly different between years was Lake Stream Ford Arm in the NSEO Subregion, where proportions ranged from 1.1% in 2008 to 16.6% in 2010 (Table 5).

Table 4.–Year-to-year variability in the proportions of hatchery fish in individual chum salmon index streams, 2008–2010.

Year	Stream	Index	Sample Size	% Hatchery Fish	SE of Proportion	Z Value	Critical Value	95% CI Lower	95% CI Upper
2009	Marten River	SSE	87	1.1%	1.1%				
2010	Marten River	SSE	64	1.6%	1.6%				
	Test for diff. in proportions					-0.92	±1.96	-0.05	0.05
2008	Carroll River	SSE	190	0.0%	0.0%				
2009	Carroll River	SSE	202	3.0%	1.2%				
	Test for diff. in proportions					1.79	±1.96	-0.06	0.00
2009	Admiralty Creek	NSEI	117	41.0%	4.6%				
2010	Admiralty Creek	NSEI	113	12.4%	3.1%				
	Test for diff. in proportions					4.67	±1.96	0.16	0.41
2009	Fish Creek-Douglas Island	NSEI	192	87.5%	2.4%				
2010	Fish Creek-Douglas Island	NSEI	94	70.2%	4.7%				
	Test for diff. in proportions					3.29	±1.96	0.07	0.28
2008	West Crawfish NE Arm Head	NSEO	192	4.2%	1.4%				
2009	West Crawfish NE Arm Head	NSEO	96	0.0%	0.0%				
	Test for diff. in proportions					1.39	±1.96	-0.02	0.05
2009	Sawmill Creek	NSEI	149	77.9%	3.4%				
2010	Sawmill Creek	NSEI	83	47.0%	5.9%				
	Test for diff. in proportions					4.55	±1.96	0.17	0.44

Table 5.–Chi-square contingency-table analysis tests for differences in the proportions of hatchery fish in individual chum salmon index streams sampled in all years, 2008–2010.

Year	Stream	Index	Sample Size	% Hatchery Fish	SE of Proportion	χ^2 Value	Critical Value	*p*-Value
2008	Ralphs Creek	NSEI	189	3.2%	1.3%			
2009	Ralphs Creek	NSEI	93	10.1%	3.1%			
2010	Ralphs Creek	NSEI	95	5.3%	2.3%			
	Test for diff. in proportions					5.25	5.99	0.073
2008	Seal Bay Creek	NSEI	188	0.0%	0.0%			
2009	Seal Bay Creek	NSEI	182	2.7%	1.2%			
2010	Seal Bay Creek	NSEI	188	2.7%	1.2%			
	Test for diff. in proportions					5.18	5.99	0.075
2008	Lake Stream Ford Arm	NSEO	184	1.1%	0.8%			
2009	Lake Stream Ford Arm	NSEO	269	3.0%	1.0%			
2010	Lake Stream Ford Arm	NSEO	291	16.6%	2.2%			
	Test for diff. in proportions					49.87	5.99	<0.001

Southern Southeast Subregion

We sampled 5 of the 13 summer chum salmon index streams in the SSE Subregion (Table 1, Appendix B). The mean proportion of hatchery strays in these streams was 2.7% (range: 0.0–6.8%; Table 1). Similar proportions of hatchery fish were found in samples from two non-index streams on Prince of Wales Island (Harris River and Staney Creek; Table 1). The highest proportions of hatchery strays were found at the two index streams closest to release sites: Hidden Inlet (6.8%; 60 km from the Nakat Inlet release site) and Harding River (5.3%; 62 km from the Anita Bay release site). We did not obtain a representative sample of index streams in the SSE Subregion in any one year with which to estimate the overall proportion of hatchery strays in the escapement index.

In 2010, we also collected otolith samples from Ketchikan Creek, which is not considered a chum salmon system. More than 65% of the fish sampled were hatchery strays, primarily from the Kendrick Bay release site on Prince of Wales Island, approximately 65 km distant.

Northern Southeast Outside Subregion

We sampled all five summer chum salmon index streams in the NSEO Subregion (Table 2, Appendix B). The mean proportion of hatchery strays in these streams was 3.4% (range: 0.0–16.6%; Table 2). The only index stream that had a proportion of hatchery fish greater than 5% in any given year was Lake Stream Ford Arm in 2010 (16.6%). One non-index summer chum salmon stream in Sitka Sound (Camp Coogan) was sampled in 2009 and 5.9% of the fish were identified as hatchery strays; however, this stream is located within 10 km of two release sites where none of the chum salmon were marked and the true proportion of hatchery strays in the stream is likely much higher than indicated by our sample. The estimated proportion of hatchery strays in the NSEO escapement index, weighted by peak survey counts, was less than 2.0% in all three years (Table 6).

Table 6.–Estimated overall proportion of hatchery chum salmon strays, weighted by peak survey estimates, for the five index streams in the Northern Southeast Outside Subregion of Southeast Alaska, 2008–2010.

Year	Stream	Sample Size	% Hatchery Fish	Peak Survey	Hatchery Fish	Overall % Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper
2008	West Crawfish NE Arm Head	192	4.2%	4,300	181				
2008	Sisters Lake SE Arm Head	192	0.5%	14,900	78				
2008	Lake Stream Ford Arm	184	1.1%	8,475	93				
2008	NSEO Index Total	568		27,675	352	1.3%	0.5%	0.7%	2.1%
2009	West Crawfish NE Arm Head	96	0.0%	3,500	0				
2009	Lake Stream Ford Arm	269	3.0%	820	25				
2009	NSEO Index Total	365		4,320	25	0.6%	0.4%	0.2%	1.5%
2010	Whale Bay Great Arm Head	95	2.1%	2,420	51				
2010	Lake Stream Ford Arm	291	16.6%	595	99				
2010	Black River	92	0.0%	7,500	0				
2010	NSEO Index Total	478		10,515	150	1.4%	0.5%	0.8%	2.4%

Northern Southeast Inside Subregion

We sampled 29 of the 63 summer chum salmon index streams in the NSEI Subregion and obtained samples of more than 50 fish from 23 of those streams (Table 3, Appendix B). The mean proportion of hatchery strays in these streams was 19.1% (range: 0.0–87.5%; Table 3). Nearly all of the streams with stray proportions less than 5.0% were located in Tenakee Inlet, Chichagof Island. The mean proportion of hatchery strays in the four index streams sampled within Tenakee Inlet was 1.1%. Outside of Tenakee Inlet, 18 of 19 index streams sampled (>50 fish) in the subregion had more than 5.0% hatchery fish in their escapements, and the remaining stream (Game Creek) contained an estimated 4.3% hatchery fish. The mean proportion of hatchery strays in the 19 NSEI index streams outside of Tenakee Inlet was 23.6% (Table 3). In 2010, we collected samples from 18 of the 63 index streams in the subregion and the sampled streams were well distributed, with the inclusion of at least one stream from nearly every major bay or passage in the subregion (Figure 6). The estimated proportion of hatchery fish in the NSEI escapement index in 2010, weighted by peak survey counts, was 13.5% (80% CI=12.5%–14.4%; Table 7).

Table 7.–Estimated overall proportion of hatchery chum salmon strays, weighted by peak survey estimates, for the 63 index streams in the Northern Southeast Inside Subregion of Southeast Alaska, 2010.

Year	Stream	Sample Size	% Hatchery Fish	Peak Survey	Hatchery Fish
2010	Saginaw Creek	57	17.5%	600	105
2010	Sample Creek	224	6.3%	4,300	269
2010	Dry Bay Creek	146	13.0%	1,776	231
2010	Cannery Cove-Pybus Bay	214	17.8%	780	139
2010	Snug Cove-Gambier Bay	138	10.1%	700	71
2010	Glen Creek	50	8.0%	850	68
2010	Mole River	44	15.9%	2,500	398
2010	Swan Cove Creek	189	9.0%	238	21
2010	Prospect Creek	152	18.4%	2,900	534
2010	Admiralty Creek	113	12.4%	300	37
2010	Fish Creek-Douglas Island	94	70.2%	764	536
2010	Wilson River	122	47.1%	1,014	465
2010	Ralphs Creek	95	5.3%	2,600	137
2010	Seal Bay Creek	188	2.7%	2,800	74
2010	Freshwater Creek	95	11.6%	700	81
2010	Chaik Creek	165	5.5%	900	49
2010	Saook Bay West Head	93	9.7%	2,400	232
2010	Sawmill Creek	83	47.0%	200	94
	Total	2,262		26,322	3,541
Overall NSEI Hatchery Fish Proportion		13.5%			
SE of Proportion		0.7%			
80% CI Lower		12.5%			
80% CI Upper		14.4%			

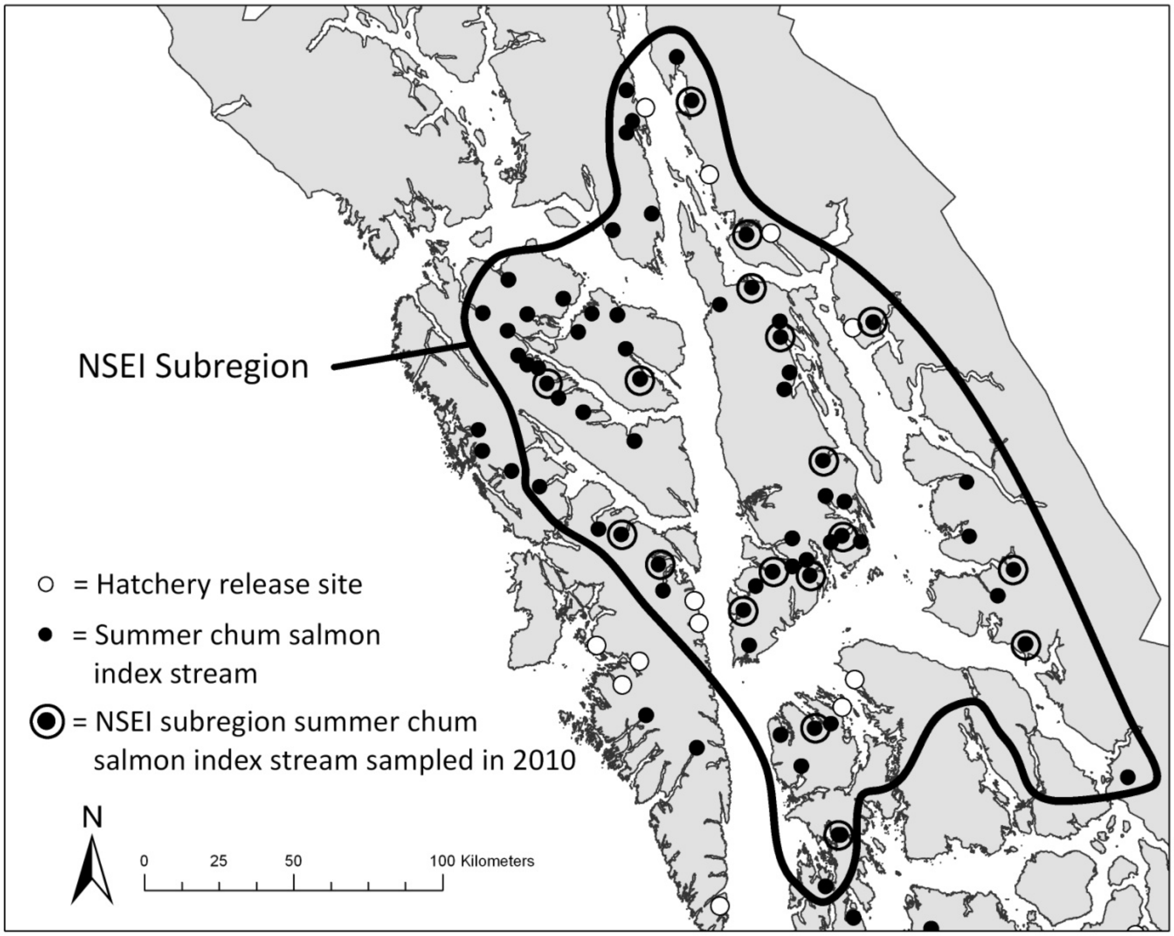

Figure 6.–Index streams sampled in 2010 in the Northern Southeast Inside Subregion of Southeast Alaska. Index streams are represented by black dots and streams sampled in 2010 are circled.

DISCUSSION

We found hatchery fish in nearly every stream that was sampled, which indicates that most chum salmon streams in Southeast Alaska, even those far removed from hatchery release sites, have at least some hatchery fish present. The proportions of stray hatchery fish were generally highest in streams closest to hatchery release sites. The mean proportion of hatchery strays in the 12 sampled streams located within 50 km of the nearest release site was 28.3%, and all samples of greater than 40% hatchery fish were from these streams. Although proportions of strays were generally lower with greater distance from release sites, stray proportions greater than 10% were still detected in six of 24 streams at distances more than 50 km from the nearest release site. Our estimated proportions of hatchery fish in some streams may have been biased low due to nearby releases of unmarked hatchery fish. Only two index streams in Southeast Alaska, however, were within 50 km of a release of 100% unmarked chum salmon.

Achieving our sample size objective of 192 otoliths per stream was difficult in most cases due to low wild chum salmon abundance during this study. Escapement indices were below the lower-bound sustainable escapement goals in the SSE and NSEI subregions from 2008 to 2010, and below goal in the NSEO Subregion in 2009 (Piston and Heinl 2011). Many streams had very poor escapements, which resulted in few carcasses to sample. The 2008 summer chum salmon escapement was particularly poor in the SSE Subregion, where the escapement index was the lowest of the past three decades (Piston and Heinl 2011). Despite the poor escapements, we obtained samples of greater than 50 fish from 33 summer chum salmon index streams—the probability of detecting at least one hatchery stray in a sample of 50 fish from a population with a true proportion of 5% hatchery strays was still greater than 90%. Therefore, we deemed this sample size sufficient for documenting the presence and distribution of stray otolith-marked hatchery fish in the region, with the understanding that smaller sample sizes could reduce the precision of our estimated stray proportions for individual streams.

The proportions of stray hatchery fish were lower in index streams in the NSEO and SSE subregions and highest in the index streams of the NSEI Subregion. In the NSEO escapement index, the overall proportion of strays was estimated to be less than 2% in each year (Table 6). Although streams were not randomly chosen, the fact that all five index streams in this subregion were sampled over three years, combined with the generally low proportions of strays in samples from all five index streams, makes it unlikely that stream selection bias would have significantly affected the results. The brood year 2005 release of Medvejie chum salmon at Deep Inlet was 100% unmarked, and may have contributed undetected strays to some streams in the NSEO Subregion index.

Although we were not able to obtain a representative sample of the entire SSE escapement index, our results suggest the overall proportion of hatchery strays was likely less than 5%. Despite poor escapements of wild chum salmon during the years of this study, the average proportion of hatchery strays in the five sampled index streams in this subregion was only 3%. The eight index streams in this subregion that were not sampled are all greater than 60 km from the nearest hatchery release site, and the three rivers with the largest average escapements in the subregion are located on the mainland in excess of 100 km from the nearest release sites (Appendix A). Unmarked hatchery releases at Annette Island (Chester Bay and Tamgas Harbor; Figure 3) may contribute undetectable hatchery strays to index streams in the SSE Subregion. These unmarked releases, however, accounted for only 6% of the hatchery chum salmon released in the SSE Subregion from 2005 to 2008.

In the NSEI Subregion, proportions of stray hatchery fish in the majority of index streams exceeded 5%, and we estimated that approximately 13.5% of the overall NSEI escapement index in 2010 was composed of hatchery chum salmon. The proportion of hatchery strays in three streams in or adjacent to lower Lynn Canal, near Juneau, was significantly higher in 2009 than in 2010 (Table 4), which suggests that the annual proportions of hatchery strays in streams in the same area may fluctuate synchronously. This also suggests that the overall proportion of stray hatchery fish in the NSEI Subregion could vary significantly from year-to-year due to variation in survival rates and the magnitude of wild and hatchery chum salmon runs.

Low proportions of hatchery strays in index streams in NSEO and SSE subregions suggest that straying likely had a minor impact on ADF&G's ability to monitor wild summer chum salmon abundance in those areas. Changes in abundance of less than 5% are unlikely to be detected during aerial survey counts (Bevan 1961, Jones et al. 1998). Higher proportions of strays in the NSEI Subregion, however, suggest straying could affect index counts of chum salmon, particularly in streams closest to release sites. Modifying escapement indices in the NSEI Subregion to account for stray hatchery fish would be difficult without more information on the annual variation in straying. In addition, adjustments that account for small proportions of strays would be meaningless given the high degree of variation in observer counting rates and the error that is inherent in aerial survey estimates (Jones et al. 1998). Removing index streams closest to hatchery release sites (e.g., <50 km) would leave the index much less representative of the region as a whole (Figure 7). This approach would also set the stage for eliminating additional index streams if new hatchery release sites are approved in the future, reducing ADF&G's ability to monitor wild chum salmon runs.

While our focus has been on documenting hatchery strays in chum salmon index streams, these streams represent a small proportion of all the chum salmon systems in Southeast Alaska. Index streams were chosen primarily because of the availability of consistent long-term survey data (Eggers and Heinl 2008). ADF&G management biologists obtained survey estimates of more than 1,000 chum salmon from approximately 400 streams in Southeast Alaska between 1960 and 1980, prior to large-scale chum salmon enhancement. There are also hundreds of additional streams with smaller runs of chum salmon. At current release levels, it appears that the proportions of hatchery chum salmon in the majority of *index* streams in the NSEO and SSE subregions are less than 5%, but this should not be construed as meaning that hatchery chum salmon do not stray in significant numbers into *non-index* streams in these subregions.

A small non-index stream, Ketchikan Creek, was of interest because of the number of stray hatchery fish that likely entered the creek in 2010. More than 65% of the fish sampled were hatchery strays, primarily from the Kendrick Bay release site on Prince of Wales Island, approximately 65 km distant. We assume, based on the high proportions of strays we found at streams within 30 km of hatchery release sites, that many of the unmarked chum salmon in this sample originated from 100% unmarked releases of hatchery chum salmon only 25 km away at Annette Island. While the proportion of hatchery strays is not surprising, due to the lack of a large wild chum salmon run there, it was the *number* of hatchery strays that was surprising given the distance to the source of most of the otolith-marked fish. On 3 August 2010 we estimated there was a total of approximately 900 chum salmon in Ketchikan Creek. Given the short stream life of chum salmon in Southeast Alaska (Heinl et al. 2000, Piston and Heinl 2010a, Piston and Heinl 2010b) and the presence of live and dead chum salmon in the creek from late July to the end of August, it is likely that well over 1,000 stray hatchery chum salmon entered Ketchikan Creek over the course of the season.

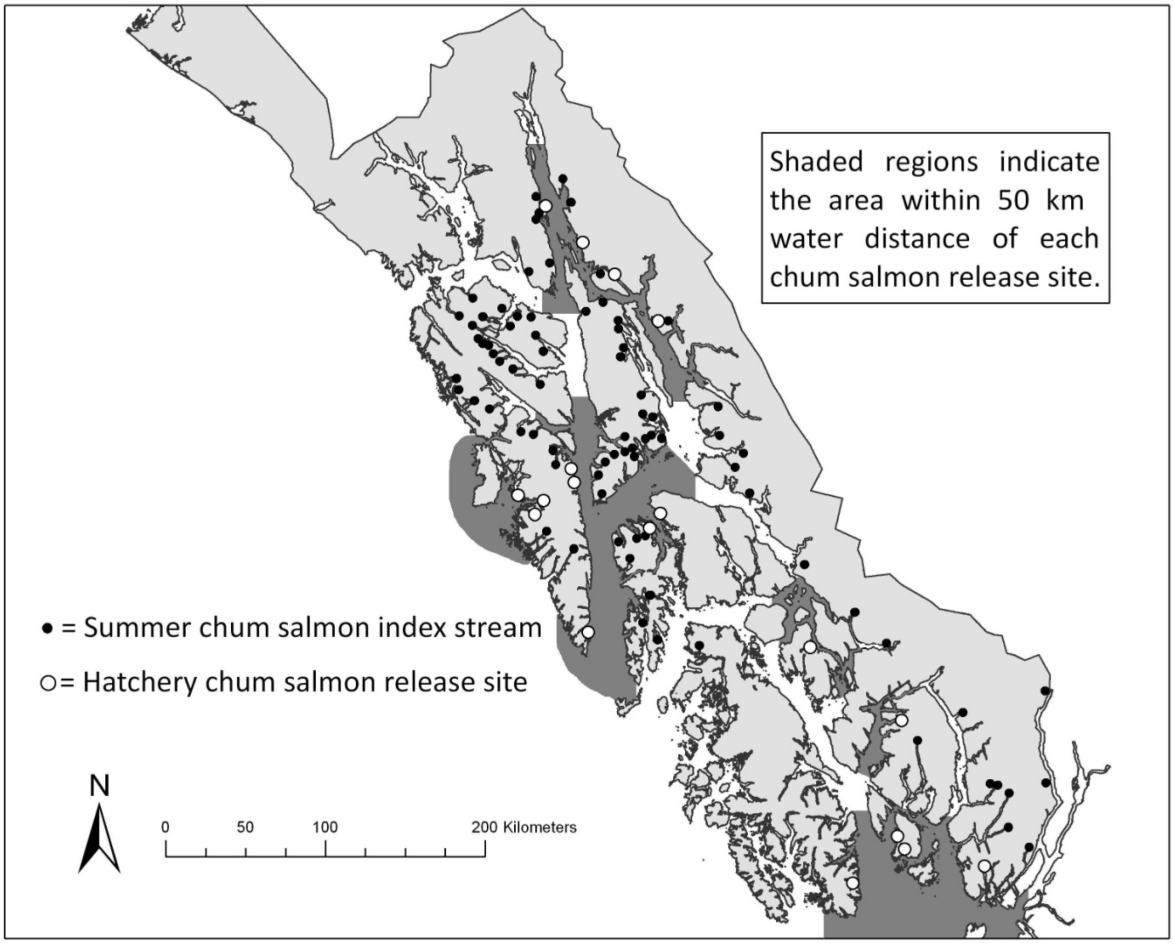

Figure 7.–Southeast Alaska summer chum salmon index streams and hatchery release sites. Shaded areas indicate the approximate area within 50 km water-distance of a release site.

This study represents the first region-wide attempt to document the distribution of stray hatchery fish in Southeast Alaska streams that ADF&G monitors for wild stock chum salmon abundance. Additional sampling would clarify the range of variation in the proportions of stray hatchery fish in wild stock index streams, and would be important for documenting the effects on straying of increased hatchery production in Southeast Alaska. Incremental increases in permitted capacity, maximization of current permitted capacity, and the development of new release sites may result in additional hatchery chum salmon strays and changes to the distribution of hatchery strays in the region. Additional studies are also needed to clarify the genetic stock structure of chum salmon in Southeast Alaska, determine if hatchery strays are effectively spawning with wild fish and, if so, whether this is affecting the genetic structure or productivity of wild stocks in the region. ADF&G is currently working with the University of Alaska, private non-profit aquaculture corporations, and the National Marine Fisheries Service to develop research projects to assess impacts of large-scale chum salmon enhancement on wild stocks.

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APPENDIX A
SOUTHEAST ALASKA SUMMER CHUM SALMON INDEX STREAMS

Appendix A1.–Southern Southeast Subregion Index Streams.

Stream Name	Anadromous Stream Number	Survey Type	Sampled for Stray Hatchery Fish, 2008–2010
Hidden Inlet	101-11-01010	Aerial	Yes
Tombstone River	101-15-10190	Aerial	No
Fish Creek	101-15-10500-2028	Foot	Yes
Keta River	101-30-10300	Aerial	No
Marten River	101-30-10600	Aerial	Yes
Carroll Creek	101-45-10780	Aerial	Yes
Wilson River	101-55-10200	Aerial	No
Blossom River	101-55-10400	Aerial	No
King Creek	101-71-10040-2006	Aerial	No
P Beauclerc S Arm E	105-20-10120	Aerial	No
Calder Creek	105-42-10050	Aerial	No
Oerns Creek	107-40-10250	Aerial	No
Harding River	107-40-10490	Aerial	Yes

Appendix A2.–Northern Southeast Inside Subregion Index Streams.

Stream Name	Anadromous Stream Number	Survey Type	Sampled for Stray Hatchery Fish, 2008–2010
North Arm Creek	108-40-10150-2007	Foot	No
Tyee Head East	109-30-10160	Aerial	No
Saginaw Bay S Head	109-44-10370	Aerial	No
Saginaw Creek	109-44-10390	Aerial	Yes
Lookout Point Cr Sec B	109-45-10170	Aerial	No
Rowan Creek	109-52-10060	Aerial	No
Sample Creek	109-62-10140	Aerial	Yes
Petrof Bay W Head	109-62-10240	Aerial	No
Dry Bay Creek	110-13-10040	Foot	Yes
Amber Creek - N Arm Pybus	110-22-10040	Aerial	No
Donkey Creek	110-22-10100	Aerial	No
Cannery Cove - Pybus Bay	110-22-10140	Aerial	Yes
Johnston Creek	110-23-10100	Aerial	No
Bowman Creek	110-23-10150	Aerial	No
Snug Cove - Gambier Bay	110-23-10190	Aerial	Yes
East of Snug Cove	110-23-10400	Aerial	No
Chuck River - Windham Bay	110-32-10090	Aerial	No
Lauras Creek	110-33-10130	Aerial	No
Glen Creek	110-34-10060	Aerial	Yes
Sanborn Creek	110-34-10080	Aerial	No
Mole River	111-13-10100	Aerial	No
Windfall Harbor W Side	111-15-10240	Aerial	No
Pack Creek	111-15-10300	Aerial	No
Swan Cove Creek	111-16-10450	Aerial	Yes
King Salmon River	111-17-10100	Aerial	No
Prospect Creek - Speel	111-33-10100	Aerial	Yes
Admiralty Creek	111-41-10050	Aerial	Yes
Fish Creek-Douglas I	111-50-10690	Foot	Yes
Robinson Creek	112-15-10620	Aerial	Yes
Wilson River	112-19-10100	Aerial	Yes
Clear River - Kelp Bay	112-21-10050	Aerial	No
Ralphs Creek	112-21-10060	Aerial	Yes
Kadashan Creek	112-42-10250	Aerial	No
Saltery Bay Head	112-44-10100	Aerial	No
Seal Bay Head	112-46-10070	Aerial	Yes
Long Bay Head	112-47-10100	Aerial	Yes
Big Goose Creek	112-48-10150	Aerial	Yes
Little Goose Creek	112-48-10190	Aerial	No
West Bay Head Creek	112-48-10230	Aerial	No
Tenakee Inlet Head	112-48-10350	Aerial	Yes
Kennel Creek	112-50-10250	Aerial	No
Freshwater Creek	112-50-10300-2001	Aerial	Yes
Greens Creek	112-65-10240	Aerial	No
Weir Creek N Arm Hood Bay	112-72-10110	Aerial	No
Weir Creek S Arm Hood Bay	112-73-10240	Aerial	No
Chaik Bay Creek	112-80-10280	Aerial	Yes
Whitewater Creek	112-90-10140	Aerial	No
Saook Bay West Head	113-53-10030	Aerial	Yes
Rodman Creek	113-54-10070	Aerial	No
Ushk Bay W End	113-56-10030	Aerial	No
Mud Bay River	114-23-10700	Aerial	No
Homeshore Creek	114-25-10100	Aerial	No
Spasski Creek	114-27-10300	Aerial	No

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Stream Name	Anadromous Stream Number	Survey Type	Sampled for Stray Hatchery Fish, 2008–2010
Game Creek	114-31-10130	Aerial	Yes
Seagull Creek	114-32-10040	Aerial	No
Neka River	114-33-10230	Aerial	No
Humpback Creek	114-34-10100	Aerial	No
Trail River	114-40-10350	Aerial	No
St James Bay NW Side	115-10-10420	Aerial	Yes
St. James River	115-10-10460	Aerial	No
Endicott River	115-10-10800	Aerial	No
Berners River	115-20-10100	Aerial	No
Sawmill Creek - Berners River	115-20-10520	Aerial	Yes

Appendix A3.–Northern Southeast Outside Subregion Index Streams.

Stream Name	Anadromous Stream Number	Survey Type	Sampled for Stray Hatchery Fish, 2008–2010
Whale Bay Great Arm Head	113-22-10150	Aerial	Yes
W Crawfish NE Arm Hd	113-32-10050	Aerial	Yes
Sister Lake SE Head	113-72-10040-2025	Aerial	Yes
Lake Stream Ford Arm	113-73-10030-0010	Foot	Yes
Black River	113-81-10110	Aerial	Yes

APPENDIX B
HATCHERY CHUM SALMON STRAYING STUDY RESULTS, 2008–2010

Appendix B1.–Straying study results for the Southern Southeast Subregion, 2008–2010.

Date Collected	Stream	Anadromous Stream Number	Index Stream	Sample Size	Unmarked	Marked	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper	Distance from Nearest Release Site (km)	Within 50 km of Unmarked Hatchery Releases
8/13/2009	Hidden Inlet	101-11-01010	Yes	74	69	5	6.8%	2.9%	3.3%	12.2%	60	No
7/27/2009	Fish Creek-Portland Canal	101-15-10500-2028	Yes	2	2	0	0.0%					
8/26/2009	Fish Creek-Portland Canal	101-15-10500-2028	Yes	118	117	1	0.8%					
	Total			120	119	1	0.8%	0.8%	0.1%	3.2%	182	No
8/6/2009	Marten River	101-30-10600	Yes	23	22	1	4.3%					
8/10/2009	Marten River	101-30-10600	Yes	27	27	0	0.0%					
8/18/2009	Marten River	101-30-10600	Yes	29	29	0	0.0%					
8/26/2009	Marten River	101-30-10600	Yes	8	8	0	0.0%					
	Total			87	86	1	1.1%	1.1%	0.1%	4.4%	104	No
8/9/2010	Marten River	101-30-10600	Yes	41	40	1	2.4%					
8/22/2010	Marten River	101-30-10600	Yes	23	23	0	0.0%					
	Total			64	63	1	1.6%	1.6%	0.2%	5.9%	104	No
9/4/2008	Carroll River	101-45-10780	Yes	190	190	0	0.0%	0.0%	0.00%	1.2%	107	No
8/11/2009	Carroll River	101-45-10780	Yes	109	103	6	5.5%					
9/2/2009	Carroll River	101-45-10780	Yes	93	93	0	0.0%					
	Total			202	196	6	3.0%	1.2%	1.6%	5.2%	107	No
8/4/2010	Ketchikan Creek	101-47-10250	No	95	26	69	72.6%					
8/13/2010	Ketchikan Creek	101-47-10250	No	93	38	55	59.1%					
	Total			188	64	124	66.0%	3.5%	61.2%	70.5%	38	Yes
8/21/2010	Harris River	102-60-10820	No	37	37	0	0.0%					
8/26/2010	Harris River	102-60-10820	No	47	46	1	2.1%					
	Total			84	83	1	1.2%	1.2%	0.1%	4.6%	107	No
8/22/2010	Staney Creek	103-90-10310	No	29	27	2	6.9%					
9/2/2010	Staney Creek	103-90-10310	No	31	31	0	0.0%					
	Total			60	58	2	3.3%	2.3%	0.9%	8.6%	114	No
8/9/2010	Harding River	107-40-10490	Yes	96	91	5	5.2%					
9/3/2010	Harding River	107-40-10490	Yes	92	87	5	5.4%					
	Total			188	178	10	5.3%	1.6%	3.3%	8.1%	62	No

Appendix B2.–Straying study results for the Northern Southeast Inside Subregion, 2008–2010.

Date Collected	Stream	Anadromous Stream Number	Index Stream	Sample Size	Unmarked	Marked	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper	Distance from Nearest Release Site (km)	Within 50 km of Unmarked Hatchery Releases
8/12/2010	Saginaw Creek	109-44-10390	Yes	25	18	7	28.0%					
8/26/2010	Saginaw Creek	109-44-10390	Yes	32	29	3	9.4%					
	Total			57	47	10	17.5%	5.1%	11.2%	25.7%	58	Yes
8/27/2010	Rowan Creek	109-52-10060	Yes	26	25	1	3.8%				52	No
8/13/2010	Sample Creek	109-62-10140	Yes	130	119	11	8.5%					
8/25/2010	Sample Creek	109-62-10140	Yes	94	91	3	3.2%					
	Total			224	210	14	6.3%	1.6%	4.3%	8.9%	45	No
8/28/2010	Dry Bay Creek	110-13-10040	Yes	146	127	19	13.0%	2.8%	9.5%	17.3%	110	No
8/13/2010	Cannery Cove-Pybus Bay	110-22-10140	Yes	47	37	10	21.3%					
8/27/2010	Cannery Cove-Pybus Bay	110-22-10140	Yes	167	139	28	16.8%					
	Total			214	176	38	17.8%	2.6%	14.4%	21.6%	79	Yes
8/12/2010	Snug Cove-Gambier Bay	110-23-10190	Yes	77	69	8	10.4%					
8/25/2010	Snug Cove-Gambier Bay	110-23-10190	Yes	61	55	6	9.8%					
	Total			138	124	14	10.1%	2.6%	7.0%	14.3%	72	No
8/14/2010	Glen Creek	110-34-10060	Yes	50	46	4	8.0%	3.9%	3.5%	15.4%	104	No
8/16/2009	Mole River	111-13-10100	Yes	12	9	3	25.0%				74	No
8/11/2010	Mole River	111-13-10100	Yes	44	37	7	15.9%				74	No
8/12/2009	Swan Cove Creek	111-16-10450	Yes	10	8	2	20.0%				112	No
7/29/2010	Swan Cove Creek	111-16-10450	Yes	94	89	5	5.3%					
8/5/2010	Swan Cove Creek	111-16-10450	Yes	95	83	12	12.6%					
	Total			189	172	17	9.0%	2.1%	6.4%	12.3%	112	No
8/13/2010	Prospect Creek	111-33-10100	Yes	125	105	20	16.0%					
7/30/2010	Prospect Creek	111-33-10100	Yes	27	19	8	29.6%					
	Total			152	124	28	18.4%	3.2%	14.4%	23.1%	22	No
8/12/2009	Admiralty Creek	111-41-10050	Yes	96	57	39	40.6%					
8/17/2009	Admiralty Creek	111-41-10050	Yes	21	12	9	42.9%					
	Total			117	69	48	41.0%	4.6%	34.9%	47.4%	30	No
8/6/2010	Admiralty Creek	111-41-10050	Yes	66	54	12	18.2%					
8/20/2010	Admiralty Creek	111-41-10050	Yes	47	45	2	4.3%					
	Total			113	99	14	12.4%	3.1%	8.5%	17.3%	30	No
7/23/2009	Fish Creek-Douglas Island	111-50-10690	Yes	96	14	82	85.4%					
8/6/2009	Fish Creek-Douglas Island	111-50-10690	Yes	96	10	86	89.6%					
	Total			192	24	168	87.5%	2.4%	83.9%	90.5%	15	No
7/28/2010	Fish Creek-Douglas Island	111-50-10690	Yes	94	28	66	70.2%	4.7%	63.3%	76.4%	15	No
8/11/2009	Robinson Creek	112-15-10620	Yes	82	68	14	17.1%	4.2%	11.8%	23.6%	22	No
8/16/2010	Wilson River	112-19-10100	Yes	122	66	56	45.9%	4.5%	39.8%	52.1%	16	No

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Date Collected	Stream	Anadromous Stream Number	Index Stream	Sample Size	Unmarked	Marked	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper	Distance from Nearest Release Site (km)	Within 50 km of Unmarked Hatchery Releases
7/21/2008	Ralphs Creek	112-21-10060	Yes	94	89	5	5.3%					
7/30/2008	Ralphs Creek	112-21-10060	Yes	95	94	1	1.1%					
	Total			189	183	6	3.2%	1.3%	1.7%	5.5%	22	No
7/24/2009	Ralphs Creek	112-21-10060	Yes	93	84	9	10.1%	3.1%	5.9%	14.8%	22	No
7/26/2010	Ralphs Creek	112-21-10060	Yes	95	90	5	5.3%	2.3%	2.6%	9.5%	22	No
8/15/2009	Kadashan Creek	112-42-10250	Yes	12	12	0	0.0%					
8/28/2009	Kadashan Creek	112-42-10250	Yes	1	1	0	0.0%					
	Total			13	13	0	0.0%				85	No
9/1/2010	Kadashan Creek	112-42-10250	Yes	12	10	2	16.7%				85	No
8/21/2008	Saltery Bay Creek	112-44-10100	Yes	26	25	1	3.8%				95	No
8/6/2008	Seal Bay Creek	112-46-10070	Yes	95	95	0	0.0%					
8/11/2008	Seal Bay Creek	112-46-10070	Yes	93	93	0	0.0%					
	Total			188	188	0	0.0%	0.0%	0.00%	1.2%	105	No
8/8/2009	Seal Bay Creek	112-46-10070	Yes	90	86	4	4.4%					
8/20/2009	Seal Bay Creek	112-46-10070	Yes	92	91	1	1.1%					
	Total			182	177	5	2.7%	1.2%	1.3%	5.0%	105	No
8/9/2010	Seal Bay Creek	112-46-10070	Yes	95	94	1	1.1%					
8/26/2010	Seal Bay Creek	112-46-10070	Yes	93	89	4	4.3%					
	Total			188	183	5	2.7%	1.2%	1.3%	4.9%	105	No
7/29/2008	Long Bay Head	112-47-10100	Yes	44	44	0	0.0%					
8/3/2008	Long Bay Head	112-47-10100	Yes	96	95	1	1.0%					
	Total			140	139	1	0.7%	0.7%	0.1%	2.7%	109	No
7/28/2008	Big Goose Creek	112-48-10150	Yes	37	37	0	0.0%					
8/4/2008	Big Goose Creek	112-48-10150	Yes	40	40	0	0.0%					
8/15/2008	Big Goose Creek	112-48-10150	Yes	95	95	0	0.0%					
	Total			172	172	0	0.0%	0.0%	0.0%	1.3%	120	No
8/3/2008	Tenakee Inlet Head	112-48-10350	Yes	2	2	0	0.0%					
8/20/2008	Tenakee Inlet Head	112-48-10350	Yes	96	95	1	1.0%					
8/20/2008	Tenakee Inlet Head	112-48-10350	Yes	48	48	0	0.0%					
	Total			146	145	1	0.7%	0.7%	0.1%	2.6%	127	No
8/19/2008	Kennel Creek	112-50-10250	Yes	2	2	0	0.0%				85	No
8/5/2009	Kennel Creek	112-50-10250	Yes	11	11	0	0.0%				85	No
8/19/2008	Freshwater Creek	112-50-10300-2001	Yes	5	5	0	0.0%				83	No
8/23/2010	Freshwater Creek	112-50-10300-2001	Yes	95	84	11	11.6%	3.3%	7.5%	17.0%	83	No

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Appendix B2.–Page 3 of 3.

Date Collected	Stream	Anadromous Stream Number	Index Stream	Sample Size	Unmarked	Marked	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper	Distance from Nearest Release Site (km)	Within 50 km of Unmarked Hatchery Releases
8/17/2010	Weir Creek N. Arm Hood Bay	112-72-10110	Yes	1	1	0	0.0%					
8/31/2010	Weir Creek N. Arm Hood Bay	112-72-10110	Yes	20	19	1	5.0%					
	Total			21	20	1	4.8%				44	No
8/9/2009	Chaik Creek	112-80-10280	Yes	1	1	0	0.0%					
8/19/2009	Chaik Creek	112-80-10280	Yes	10	7	3	30.0%					
	Total			11	8	3	27.3%				25	No
8/18/2010	Chaik Creek	112-80-10280	Yes	11	11	0	0.0%					
8/30/2010	Chaik Creek	112-80-10280	Yes	154	145	9	5.8%					
	Total			165	156	9	5.5%	1.8%	3.3%	8.5%	25	No
7/3/2010	Saook Bay West Head	113-53-10030	Yes	93	84	9	9.7%	3.1%	5.9%	14.8%	38	No
8/6/2009	Game Creek	114-31-10130	Yes	8	7	1	12.5%					
8/24/2009	Game Creek	114-31-10130	Yes	109	105	4	3.7%					
	Total			117	112	5	4.3%	1.9%	2.1%	7.8%	70	No
8/13/2009	St. James Bay NW Side	115-10-10420	Yes	94	79	15	16.0%	3.8%	11.2%	21.9%	15	No
7/31/2009	Sawmill Creek	115-20-10520	Yes	149	33	116	77.9%	3.4%	72.9%	82.2%	14	No
8/2/2010	Sawmill Creek	115-20-10520	Yes	38	20	18	47.4%					
8/11/2010	Sawmill Creek	115-20-10520	Yes	25	10	15	60.0%					
8/16/2010	Sawmill Creek	115-20-10520	Yes	20	14	6	30.0%					
	Total			83	44	39	47.0%	5.5%	39.5%	54.6%	14	No

Appendix B3.–Straying study results for the Northern Southeast Outside Subregion, 2008–2010.

Date Collected	Stream	Anadromous Stream Number	Index Stream	Sample Size	Unmarked	Marked	Expanded Marked	% Hatchery Fish	SE of Proportion	80% CI Lower	80% CI Upper	Distance from Nearest Release Site (km)	Within 50 km of Unmarked Hatchery Releases
8/9/2010	Whale Bay Great Arm Head	113-22-10150	Yes	95	93	2		2.1%	1.5%	0.6%	5.5%	85	No
8/12/2008	West Crawfish NE Arm Head	113-32-10050	Yes	96	95	1	1	1.0%					
8/18/2008	West Crawfish NE Arm Head	113-32-10050	Yes	96	94	2	7	7.3%					
	Total			192	189	3	8	4.2%	1.4%	2.4%	6.7%	54	No
8/9/2009	West Crawfish NE Arm Head	113-32-10050	Yes	96	96	0		0.0%	0.0%	0.0%	2.4%	54	No
9/4/2009	Camp Coogan	113-41-10340	No	94	90	4	5.5	5.9%	2.4%	3.0%	10.3%	10	Yes
8/20/2008	Sisters Lake SE Arm Head	113-72-10040-2025	Yes	96	96	0		0.0%					
8/24/2008	Sisters Lake SE Arm Head	113-72-10040-2025	Yes	96	95	1		1.0%					
	Total			192	191	1		0.5%	0.5%	0.1%	2.0%	102	No
8/17/2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	47	45	2		4.3%					
8/26/2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	46	46	0		0.0%					
9/9/2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	43	43	0		0.0%					
9/16/2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	12	12	0		0.0%					
9/22/2008	Lake Stream Ford Arm	113-73-10030-0010	Yes	36	36	0		0.0%					
	Total			184	182	2		1.1%	0.8%	0.3%	2.9%	127	No
8/19/2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	28	24	4	6	21.4%					
8/25/2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	41	41	0	0	0.0%					
9/1/2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	89	89	0	0	0.0%					
9/7/2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	90	90	0	0	0.0%					
9/21/2009	Lake Stream Ford Arm	113-73-10030-0010	Yes	21	19	2	2	9.5%					
	Total			269	263	6	8	3.0%	1.0%	1.7%	4.8%	127	No
8/16/2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	51	49	2	3	5.9%					
8/23/2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	90	85	5	27	30.0%					
9/6/2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	52	50	2	2	3.8%					
9/13/2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	93	90	3	16.2	17.4%					
9/20/2010	Lake Stream Ford Arm	113-73-10030-0010	Yes	5	5	0	0	0.0%					
	Total			291	279	12	48.2	16.6%	2.2%	13.8%	19.7%	127	No
7/1/2010	Black River	113-81-10110	Yes	92	92	0		0.0%	0.0%	0.00%	2.5%	129	No