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Observations of Pink Salmon Hatchery Proportions in Selected Lower Cook Inlet Escapements, 2014–2017

by

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Symbols and Abbreviations

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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

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OBSERVATIONS OF PINK SALMON HATCHERY PROPORTIONS IN SELECTED LOWER COOK INLET ESCAPEMENTS, 2014–2017

by
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ABSTRACT

This project was initiated to collect baseline data associated with two recently reopened hatcheries in Lower Cook Inlet (LCI). Salmon hatcheries have long been used across the Pacific Northwest as a tool to enhance fisheries, but these benefits may come with some cost to wild stocks. Wild stocks may be adversely affected by hatchery-origin fish in spawning streams as, among other things, they can inflate escapement indices making it difficult for managers to assess escapement goals. In 2011, Cook Inlet Aquaculture Association (CIAA) reopened the Tutka Bay Lagoon Hatchery (TBLH) for pink salmon *Oncorhynchus gorbuscha* production and began releasing thermally marked fry in 2012. The CIAA also acquired the previously dormant Port Graham Hatchery (PGH) in 2014 and began releasing marked fry in 2015. Together, these hatcheries are permitted to take 250 million green eggs, potentially resulting in future releases of 200 million fry in LCI. From 2014 to 2017, otoliths were collected from carcasses of spawned-out pink salmon in 17 LCI streams to assess the presence of hatchery strays prior to TBLH and PGH reaching maximum production levels. The annual percent of sampled carcasses with marked otoliths in visited streams varied substantially across streams, as well as within streams across years, ranging from 0% to 95%. The proportion of hatchery marks originating from LCI hatcheries was highest in samples from streams closest to hatchery release sites (<6 mi). In addition, collections from some streams contained unexpectedly high percentages (0–87%) of pink salmon originating from hatcheries in Prince William Sound (PWS), 150–300 ocean miles away. This observation demonstrates that the scope of hatchery straying is broader than previously documented in Alaska. Further research is needed to quantify the hatchery-wild composition of pink salmon escapements in LCI and the scope of hatchery straying region-wide.

Key words: Lower Cook Inlet, Prince William Sound, Kachemak Bay, pink salmon, *Oncorhynchus gorbuscha*, stream surveys, otoliths, straying, thermal marks, hatchery salmon

INTRODUCTION

Salmon hatcheries have been part of the Alaskan landscape for over a century, but large-scale hatchery production of pink *Oncorhynchus gorbuscha* and chum *O. keta* salmon did not begin until the mid-1970s (Heard 2012). During the development of Alaska's hatchery program, the Alaska Department of Fish and Game (ADF&G) and Alaska Board of Fisheries (BOF) implemented several policies and regulations intended to guide salmon enhancement activity to avoid negative impacts on wild salmon stocks (McGee 2004). These included initiating policies addressing genetic (Davis et al. 1985, Davis and Burkett 1989) and pathology concerns (Meyers 2010). Much has been learned over the past few decades about wild hatchery salmon interactions and a good overview of contemporary research can be found in a recent issue of *Environmental Biology of Fishes* (Rand et al. 2012).

In 2011, Cook Inlet Aquaculture Association (CIAA) reopened the Tutka Bay Lagoon Hatchery (TBLH) for pink salmon production and began releasing fry in 2012. CIAA also acquired the inactive Port Graham Hatchery (PGH) in 2014 and began raising pink salmon at that location, with the first PGH release occurring in 2015. Together, these hatcheries are permitted to take 250 million green eggs, resulting in future anticipated releases of 200 million fry in Lower Cook Inlet (LCI) (Figure 1). The otoliths of 100% of the pink salmon raised at both facilities are now thermally marked, allowing managers to determine the origin (hatchery and release site) of marked fish.

The ADF&G is charged with balancing the mission of managing, protecting, and improving the fish resources of the state in the best interest of the economy and the well-being of the people of the state, consistent with the sustained yield principle (http://www.adfg.alaska.gov/index.cfm?adfg=about.statutes). Hatcheries were established with the goal of improving fish resources, but these benefits may come with some cost to wild stocks. One location where wild stocks may be adversely affected by hatchery-origin fish is in spawning streams. Here, hatchery fish can inflate escapement indices for wild stock streams making it difficult for managers to assess escapement goals (Brenner et al. 2012). Hatchery-origin fish can also compete for limited spawning and rearing resources with wild fish (Naish et al. 2008). Finally, successfully spawning hatchery-origin fish can potentially reduce genetic diversity among wild populations and potentially decrease the fitness and productivity of wild salmon populations (Waples 1999, reviewed in Naish et al. 2008, Grant 2012). In recognition of the need to better understand these issues, ADF&G and hatchery operators initiated the Alaska Hatchery Research Project (AHRP) in 2013 (ADF&G 2012), which includes focused studies on hatchery-wild interactions of pink salmon in PWS and chum salmon in southeast Alaska (SEAK). Lower Cook Inlet was not included in the AHRP study.

This project was initiated to collect baseline data associated with two recently restarted hatchery production programs in LCI. Otolith sampling of harvest and escapement allows for a complete assessment of hatchery programs and wild stock performance. This project also provides insight into the magnitude and distribution of hatchery-origin pink salmon occurring in wild stock streams in LCI. Since 2014 Homer staff has sampled otoliths from spawned-out pink salmon carcasses, primarily from index streams in the Southern and Outer districts of LCI that are within 30 miles of the Tutka Bay Lagoon and Port Graham hatcheries (Figure 1). Observations of hatchery proportions in pink salmon escapements from early, smaller releases as the Tutka and Port Graham hatchery programs restarted and release sizes increased, could provide insight into whether release size plays a significant role in hatchery straying. Results from this pilot study will be used to develop an operational plan for a more intensive sampling program to better quantify hatchery-wild interactions in LCI once directed funding is secured.

Based on previous studies that showed an inverse relationship between hatchery proportions in streams and distance from the release site (e.g., Brenner et al. 2012), spawned-out pink salmon carcasses were initially sampled for otoliths during 2014 at various distances from hatchery pink salmon release sites, primarily from index streams in the Southern District of LCI (Figure 1). When hatchery-origin pink salmon from outside Cook Inlet were detected in some of the 2014 samples, Homer staff expanded sampling efforts in 2015 to 2017 to include 2 additional index streams in the Outer District farther from the Cook Inlet release sites and closer to PWS releases. In addition to sampling from this core group of systems, otoliths were also sampled opportunistically from carcasses in other streams that either were of interest to department staff, or where unusually large escapements were reported. This report summarizes 4 years of observed pink salmon hatchery proportions as part of baseline data collection associated with two hatchery production programs that recently restarted in LCI.

PURPOSE

The initial purpose for this study was to gather baseline data as two recently reopened hatcheries in LCI began releasing thermally marked pink salmon fry as they restored production to their previously permitted capacities.

After discovery of non-LCI hatchery-origin fish in LCI streams during the first year (2014), the scope was expanded in subsequent years (2015–2017) to gain insights into the magnitude and distribution of non-LCI hatchery-origin pink salmon in wild stock streams in LCI.

STUDY SITES

There are 34 stocks of Pacific salmon with escapement goals in the LCI management area that are monitored primarily by aerial and/or ground survey (Otis et al. 2016, Otis and Hollowell 2016). For the original purpose of the study, in the first year (2014) 7 streams with escapement goals and 1 stream without an escapement goal in the Southern District were selected for sampling. These streams were distributed at distances up to about 19 mi east and west of the 2012 pink salmon release site (Tutka Lagoon; Table 1, Figure 1). For the revised goal in following years (2015 to 2017), visited locations included the original streams plus up to an additional 4 streams with escapement goals and 5 streams without escapement goals. The range of sampling locations expanded north to the north side of Kachemak Bay, and south into the Outer District (Table 1, Figure 1).

METHODS

Otoliths of all pink salmon raised in the TBLH and PGH beginning with brood years 2012 and 2014, respectively, have been thermally marked with unique banding patterns that represent the hatchery of origin and the program/release site. Department staff in Homer began sampling otoliths from spawned-out carcasses in 2014, the first year that marked adults returned to local hatcheries.

CARCASS SAMPLING

The core streams selected for annual carcass sampling were primarily wild stock index streams with escapement goals and a record of historical escapement levels. However, samples were also collected from English Bay River; a non-index stream that has historically had modest pink salmon runs but is in close proximity to a hatchery release site. Additional streams were sampled opportunistically based on their close proximity to a hatchery (Tutka Head End Creek), staff interest (Port Chatham, S. Nuka Island Creek), or when members of the public reported unusual abundances of pink salmon occurring in streams that normally did not have significant escapement (Beluga Slough, Fritz Creek, Lou's Creek, and Sadie Cove Creek; Figure 1, Table 1). None of the sampled streams were chosen randomly.

At each sampling event, otoliths were extracted from spawned-out carcasses in streams to assess hatchery proportions of pink salmon in selected LCI streams. Only spawned-out carcasses were targeted for sampling to minimize inclusion of fish that 1) might leave the stream before spawning (i.e., fish scouting streams on the way to spawn elsewhere), and 2) died in the stream, but failed to spawn. Carcasses were avoided if consumed by bears to the point that spawning condition could not be determined.

Where possible, otoliths from 96 fish were collected from each spawning system per sampling event and 1–3 sampling events were attempted each year from the core group of streams (Table 1). Sample sizes of 96 fish allowed estimation of marked vs. unmarked proportions within 8% of the true value 95% of the time (Thompson 1987). Samples were collected from throughout the stream wherever carcasses were located. Samplers were directed to collect fish for sampling as they were encountered with no regard to the sex or the condition of the carcass: whether rotten, maggot infested, or freshly dead. Samplers were instructed to only reject carcasses if they appeared to be unspawned (e.g., applying manual pressure to the body cavity yielded copious gametes). Typically, 1–2 dozen fish were collected in the lower reaches of an index system and the otoliths were extracted. The sampler would then move upstream several hundred yards and collect another 1–2 dozen fish for processing and extraction and then move upstream continuing the process. If the sampler reached the top of the stream and did not have a full 96-pair sample, they would head back downstream and complete the sample using fish that had been passed over.

Thermal Mark Processing

Pink salmon otoliths were sent to the ADF&G's otolith lab in Cordova for processing, where lab staff followed thermal mark recovery procedures established by the Mark, Tag and Age Lab (MTA Lab) in Juneau (Agler et al. 2016a). Thermal marks from fish sampled during this study were classified according to a "Region, Band, and ring" (RBr) code, written numerically as 'R:B.r' (Munk and Geiger 1998), and were also classified by hatch code. Relevant details associated with unique thermal marks that signify each hatchery, brood year, and release location in Alaska, including images of voucher specimens, can be found in the MTA Lab's voucher summary reports, which are available online at: https://mtalab.adfg.alaska.gov/OTO/reports/VoucherSummary.aspx.

Extracted otoliths (left otolith from each pair) were mounted sulcus side up, on a petrographic glass slide with thermoplastic glue, and the glass slide was marked with a bar-coded label. Otoliths were ground to the midsagittal plane manually using 1200-grit or 4000-grit silicon carbide paper and viewed under a compound microscope with transmitted light at 200X or 400X. After determining the origin of an otolith, a bar-code scanner recorded the slide identity to a database where additional relevant data about the otolith could be entered.

Data Analysis

Preliminary hatchery/wild proportion estimates were generated from the first reading of the otoliths collected. When second reads were available for a subset of otoliths (e.g., 2017), the final determination of the most experienced reader was used to resolve discrepancies. Only readable otoliths were included in the analyses; otoliths that were lost, damaged, deformed or destroyed during preparation were considered not readable (NR) and were excluded.

The proportion of hatchery-marked fish was estimated by dividing the number of marked otoliths in the sample by the total number of readable otoliths sampled for each sampling event. If more than one sampling event occurred on a given stream, the hatchery proportion during each event was reported separately. Hatchery proportion estimates from multiple sampling events (within a stream across sampling events, across streams within a year, or across streams and sampling events) were computed by summing the number of hatchery-marked fish divided by the number of readable otoliths sampled. Estimated proportions of hatchery fish identified in stream samples were further stratified by hatchery release area (LCI, PWS) and by individual hatchery (e.g., TBLH, PGH).

Quality Control

Reanalyzing a portion of the otoliths sampled is standard operating procedure defined by ADF&G's MTA Laboratory. In this process, the otolith laboratory evaluates reader agreement, assesses the quality of the hatchery marks, and verifies the accuracy and precision of preliminary results (Agler et al. 2016b). Funding was not available in 2014–2016 to reanalyze otoliths collected, and in 2017 funding was only available for the Cordova lab to re-read the otoliths from 5 sampling events as an initial investigation of the quality of the data.

RESULTS

Otoliths from 6,654 pink salmon were collected during 80 sampling events in 17 LCI streams from 2014–2017. Of these, 6,535 (98.2%) were analyzed for the presence of a hatchery mark. The remaining otoliths were unreadable (e.g., lost, broken, deformed, destroyed during preparation) and were not used in the analysis. The number of streams sampled per year ranged from 8 in 2014 to 16 streams in 2017 (Table 1). The locations of LCI pink salmon hatcheries and the 17 streams that were sampled at least once during 2014–2017 are shown in Figure 1.

Preliminary results documented in LCI Annual Management reports (Hollowell et al. 2015, Hollowell et al. 2016, Hollowell et al. 2017, Hollowell et al. *in press*) differ from the results presented here due to differences in summarizing the data. All readable otoliths were included in the analysis presented here, whereas "questionable" otoliths were excluded from earlier annual summaries.

2014

In 2014, 1,142 readable otoliths were collected from 1,176 pink salmon sampled in 8 streams during 14 individual sampling events (Tables 1 and 2). The percentage of hatchery fish identified in a sampling event ranged from 0.0% in Humpy Creek on 11 August to 93.7% in Barabara Creek on 8 September (Table 2). Except for Barabara Creek, streams inside or directly adjacent to pink salmon hatchery release sites or special harvest areas (SHAs) had the highest incidence of hatchery marks identified in our samples. The vast majority (89.1%) of hatchery-marked fish identified in the Tutka Lagoon Creek samples derived from the TBLH, which uses local broodstock from Tutka Lagoon Creek. Similarly, a high proportion (61.5%) of the pink salmon sampled from the Port Graham River had hatchery marks, most of which (74.6%) derived from TBLH remote-releases to Port Graham Bay (PGH was not yet operational). Broodstock for that remote release group came from the Port Graham River, which is <3 mi from the Port Graham Hatchery (Figure 1) and the remote release site. We also observed high percentages of hatchery-marked pink salmon in samples from other LCI streams that were relatively far away from the LCI hatcheries [e.g., Barabara Creek (87.5–93.7%), Dogfish Lagoon Creek (40.9%), English Bay River (31.2%), and Seldovia River (4.7–55.9%)]. The high incidence of hatchery fish observed in the Barabara Creek sampling events was particularly surprising, especially considering that 78.6–97.3% of the marked fish were from PWS hatcheries, 150–300 ocean miles away (Table 2). Of the 6 hatcheries (2 in LCI, 4 in PWS) producing thermal marks that were identified in our 2014 samples, TBLH (13.7%) and PGH (13.3%) contributed the highest proportions (Figure 2). This was primarily due to the high abundance of TBLH and PGH marks found in the Tutka Bay Lagoon Creek and Port Graham River samples, both of which were collected on streams adjacent to these hatcheries (Figure 1).

2015

In 2015, 2 index streams in Port Dick Bay (Port Dick and Island creeks) were added to the group of 8 core streams that were sampled in 2014. In addition, 2 other streams of interest were sampled opportunistically: 1 stream near TBLH (Tutka Head End Creek) and 1 stream in the Outer District (South Nuka Island Creek). These streams were added to further evaluate the presence of hatchery-origin pink salmon originating from the 2014 releases from LCI and PWS hatcheries (Table 1). Based on the 2014 sample results, the purpose for sampling was expanded in 2015 to include non-local hatchery marks.

In 2015, 1,878 readable otoliths were collected from 1,893 pink salmon sampled in 12 streams during 21 individual sampling events (Tables 1 and 3). The percentage of hatchery fish identified in the sampling events ranged from 0.0% in China Poot Creek on 9 September to 97.9% in Tutka Lagoon Creek on 13 August (Table 3). Streams sampled inside the Tutka SHA (Tutka Head End and Tutka Lagoon creeks) had the highest incidence of hatchery marks in 2015 (82.3–97.9%). All of the hatchery-marked fish identified in the 2015 Tutka Lagoon Creek samples derived from the TBLH as well as 93.7% of those in the Tutka Head End Creek samples. In contrast to the previous year, very few hatchery marks (1.1–2.1%) were found in the Port Graham River samples and 5.3–27.4% of the otoliths analyzed from 3 Barabara Creek samples were hatchery marked. Relatively high percentages (up to 37.5%) of hatchery-marked pink salmon were identified in samples collected from several other LCI streams in 2015 (e.g., Port Dick Creek, Island Creek, Seldovia River, and English Bay River; Table 3). The TBLH (14.7%) contributed the highest proportion of hatchery marks found in our 2015 samples, followed by the Solomon Gulch (SGH; 3.2%), Armin F. Koernig (AFKH; 2.3%), Cannery Creek (CCH; 1.5%) and Wally Noerenberg (WNH; 1.2%) hatcheries (Figure 3).

2016

In 2016, otolith sampling continued in the expanded 10 core streams that were sampled in 2015 (Table 1). A total of 1,172 readable otoliths were collected from 1,191 pink salmon sampled in 10 streams during 20 individual sampling events (Tables 1 and 4). The percentage of hatchery fish identified in the sampling events ranged from 0.0% in Humpy, China Poot, Seldovia, Port Dick, and Island creeks, up to 99.0% in Tutka Lagoon Creek on 12 August (Table 4). Virtually all (98.8–100.0%) of the hatchery-marked fish identified in the Tutka Lagoon Creek sampling events originated from TBLH. Similar to 2014, a relatively high percentage (19.6–28.7%) of the samples from Port Graham River were hatchery marked, 70.4–100% of which originated from the PGH. Samples collected from 3 additional streams—Barabara Creek (2.5–28.1%), Dogfish Lagoon Creek (17.2%), and English Bay River (22.0%)—also indicated relatively high proportions of hatchery fish, but the incidence of hatchery marks in samples from 4 other streams (China Poot, Humpy, Island, and Port Dick creeks) was relatively low in 2016 (0.0–1.7%; Table 4). The TBLH (16.4%) contributed the highest proportion of hatchery marks found in our 2016 samples, followed by PGH (5.5%), AFKH (1.7%), SGH (1.4%), CCH (1.1%), and WNH (0.3%; Figure 4).

2017

In 2017, 2,343 readable otoliths were collected from 2,394 pink salmon sampled in 16 streams during 25 individual sampling events (Tables 1 and 5). These streams included the 10 core streams, an additional index stream with an escapement goal in the Outer District (Port Chatham Creek), and 5 streams sampled after members of the public reported unusual abundances of pink salmon occurring in streams that normally did not have significant escapement (Beluga Slough, Fritz Creek, Lou's Creek, Tutka Head End Creek, and Sadie Cove Creek). The percentage of hatchery fish identified in sampling events ranged from 0.0% in Humpy (12 September) and Seldovia (8 August) creeks to 96.8% in Tutka Lagoon Creek on 25 August (Table 5). Of the hatchery-marked fish identified in the Tutka Lagoon Creek samples, 93.9–100.0% derived from TBLH. Over 63% of the otoliths analyzed from Lou's Creek, a small stream in Little Tutka Bay and also within the Tutka Hatchery SHA, were thermally marked, but only 20.0% derived from the nearby TBLH. Less than 7% of the samples from the Port Graham River were hatchery marked in 2017. However, samples from 10 LCI streams outside hatchery SHAs had higher proportions (10.0–71.6%) of hatchery marks in samples collected in 2017. Four of these streams are not consistently monitored because they rarely produce many pink salmon and are not targeted in commercial fisheries [Beluga Slough (47.3–71.6%), Fritz Creek (70.5%), Sadie Cove Creeks (19.4%), and English Bay River (28.2–63.3%)], but 6 are pink salmon index streams with wild stock escapement goals [China Poot Creek (12.8%), Barabara Creek (6.3–35.4%), Seldovia River (0.0–20.2%), Dogfish Lagoon Creek (52.3%), Port Chatham Creek (47.9%), and Island Creek (8.9–22.7%)]. The TBLH (11.4%) contributed the highest proportion of hatchery marks found in our 2017 samples, followed by AFKH (10.7%), SGH (5.5%), CCH (5.4%), WNH (2.6%), and PGH (0.2%; Figure 5).

QUALITY CONTROL

Funding was not available to re-read otoliths collected during 2014–2016. In 2017, the Cordova otolith lab re-read 20.2% of the carcass sample otoliths. A total of 480 otolith samples from collections in 5 streams were given second reads (5 otolith trays, 96 samples per tray; Table 5). The first read of these samples showed 205 otoliths with TBLH marks, 145 with PWS marks, and 130 unmarked otoliths. The highest degree of read agreement occurred with PWS marks. Of the 145 initially examined with PWS marks, only three otolith pairs (2.1%) were reassigned to another category following a second read. The highest reassignment rate was associated with TBLH marks. Of the 205 otoliths initially identified as having TBLH marks, 10 were reassigned to unmarked status during the second read. In addition, 13 otoliths originally identified in the first read as unmarked were reassigned as having a TBLH mark following a second read. Of the 218 otolith pairs that were identified either in the first or second read as showing TBLH marks, 23 samples were reassigned (10.6%).

DISCUSSION

This pilot study was initiated as the first step in a process to gain an understanding of the presence and relative proportion of hatchery-origin pink salmon in LCI wild stock streams. Otoliths were collected from spawned-out pink salmon carcasses to estimate the hatchery proportions as a preliminary observation of the presence of hatchery fish spawning in wild streams. Although this project was not designed to investigate genetic introgression, sampling only spawned-out carcasses allowed us to evaluate whether hatchery strays had spawned in wild stock streams. While not chosen randomly, the original sampling plan included index streams with escapement goals located at various distances and on both sides of the release sites (TBLH releases returning 2014–2017, and PGH releases returning 2016–2017). Carcass sampling was conducted throughout the spawning habitat of the stream and it included sample sizes adequate to estimate hatchery proportions in carcasses available during the sampling event. Eleven of the streams were sampled in both odd and even years and the original 8 core streams were sampled during all 4 years. Core streams were generally sampled twice per year. Limited resources prevented more frequent sampling of the streams over the entire spawning season. Limited resources also prevented sampling more streams. These limitations in survey design narrow the scope to descriptive statistics of the samples only. Thus, results derived by combining multiple sampling events (e.g., across streams and sampling events [Figures 2–5], across streams within a year [Figure 6], or within a stream across sampling events [Figure 7]) should be interpreted within the confines of samples themselves. An analysis that yields estimates of the proportion of hatchery fish in the escapement for any given stream, or all LCI streams in general, is not yet possible. Sampling carcasses that had been dead for days or weeks and were highly rotten was expected to result in the inclusion of fish with earlier spawning timing, which would not be the case if only freshly dead fish were sampled. Often carcasses were encountered that had been sampled on previous visits. This may provide a degree of support that the intention of sampling fish throughout the run was achieved.

Lack of resources limited quality control analyses of otoliths. Additional funding was available in 2017 for a second read of a limited set of samples from 5 streams, so until funding allows for a second read on a random sample of the otoliths collected during 2014–2017, all results are considered preliminary.

After the first year of sampling in 2014, it was recognized that this project could provide insights into the presence of hatchery-origin pink salmon in LCI streams that originated from non-LCI hatcheries. In recognition of this, the original group of core streams to be consistently sampled was expanded in 2015 to include two more streams on the outer coast (Port Dick and Island creeks). In addition, opportunistic sampling of other streams of interest occurred in most years.

Based on our preliminary observations, it is possible that LCI hatchery fish do not substantially inflate observed escapements in LCI index streams with escapement goals, with the exception of Tutka Lagoon Creek and Port Graham River (Tutka Head End and Little Tutka Bay creeks are modest producers without escapement goals). The high percentages of TBLH pink salmon identified in the Tutka Lagoon Creek samples was not surprising given that the TBLH is located on Tutka Lagoon Creek, which provides both the water and the brood source for the hatchery (Stopha and Musslewhite 2012). The current escapement goal for Tutka Lagoon Creek was adopted by ADF&G to maintain historical levels of natural production and mitigate potential impacts from a total brood failure at the hatchery (Otis et al. 2016). More frequent sampling over the full spawning period over a number of years would be necessary in each index stream to estimate annual contribution of LCI-origin pink salmon to the observed escapements.

The proportion of LCI hatchery fish identified in stream samples decreased with distance from release sites. Of the 17 streams sampled during 2014–2017, only Tutka Lagoon Creek (86.1–94.8%%), Tutka Head End Creek (35.0–77.1%), Port Graham River (1.1–45.8%) and Lou's Creek in Little Tutka Bay (13.7%) averaged double-digit percentages of LCI hatchery pink salmon in their respective samples (Figure 7). These were also the 4 streams closest in proximity to the Tutka Bay Lagoon and Port Graham hatcheries (approximately 0–6 miles from release sites; Figure 1). In the 13 streams occurring outside of SHAs, the average percentage of LCI-hatchery marked pink salmon in our samples ranged from 0.0% (Fritz Creek, Port Chatham) to 7.1% (Seldovia River) and the overall average was 2.6% during 2014–2017 (Table 6). This pattern of decreasing proportion of hatchery fish with increasing distance from release sites is similar to observations in PWS where Brenner et al. (2012) found higher proportions of hatchery fish on streams closest to the hatcheries.

During 2014–2017, the presence of pink salmon from LCI hatcheries was generally low in samples from streams not associated with release areas. However, these proportions are likely to increase as TBLH and PGH increase production to their full permitted capacities. Currently, interpretation of our mark recovery results is limited to just the samples available, but our data provide insights into how permitted stocking levels might affect hatchery proportions in LCI streams. Extrapolations from these data to entire escapements in streams or to area-wide escapement will require more spatially and temporally intensive sampling to account for sources of uncertainty associated with estimating hatchery proportions from periodic carcass sampling. For example, studies in PWS showed large changes in hatchery proportions occurred in many streams throughout the season (Brenner et al. 2012, Gorman et al. 2017). The results from the current set of samples may provide biased estimates if sampling did not represent the full spawning period or account for changes in the abundance of spawning fish.

While results from our samples indicate relatively low levels of pink salmon from LCI hatcheries in wild stock streams outside of SHAs, our observations also documented the presence of pink salmon from PWS hatcheries in LCI streams. High proportions of PWS hatchery fish in some stream/year combinations were observed in all 4 years (Tables 2–6). While PWS hatchery proportions in samples from some systems were highly variable across years (e.g., Dogfish Lagoon Creek; Table 6), the average proportion of PWS hatchery marks during sampling events in streams with 3 or more years of data exceeded 5% on 6 streams and exceeded 20% on 3 streams (Table 6, Figure 7).

Annual variability in the proportion of PWS hatchery fish observed in LCI index streams may, in part, be a function of annual variability in natural production and differences between the odd and even-year runs in this species. For example, record high wild returns to LCI occurred in 2015, coincident with relatively low PWS hatchery fish proportions in samples (average = 10.9%), whereas the lowest average PWS hatchery proportion observed in LCI streams (4.0%) occurred in 2016, the year PWS and LCI were included in a disaster declaration due to exceptionally low wild and hatchery pink salmon returns. Our current samples do not allow testing for trends, however, our results support continued monitoring of hatchery-origin fish in LCI. Further, more intensive monitoring is needed to quantify annual straying levels and develop appropriate management actions to mitigate the presence of hatchery-origin pink salmon in wild stock index streams.

Prince William Sound hatchery-marked pink salmon consistently outnumbered LCI hatchery-marked pink salmon in samples collected in LCI streams. This pattern was consistent in all years except 2016 (Table 6, Figure 6) and at three streams closest to the Tutka Bay Lagoon and Port Graham hatcheries (Tutka Lagoon Creek, Tutka Head End Creek, Port Graham River; Tables 2–5). The proportion of PWS hatchery fish in our samples approached or exceeded 50% in 3 streams: Beluga Slough (57.0%), Fritz Creek (70.5%), and Port Chatham (47.9%), the first 2 of which do not usually have significant pink salmon escapement. Proportions approached or exceeded 25% in an additional three streams: Barabara Creek (33.8%), Dogfish Lagoon Creek (23.0%), and English Bay River (25.3%; Table 6). Three of these 6 streams (Dogfish Lagoon, Barabara Creek, and Port Chatham) are pink salmon index streams with wild stock escapement goals.

The high proportion of PWS hatchery fish observed in some LCI samples was unanticipated given the 4 hatcheries in PWS that produce pink salmon are 150–300 ocean miles away from LCI (Figure 8). However, there is evidence to suggest that pink salmon may stray even greater distances from their natal streams. Witkowski and Glowacki (2010) reported finding spawning condition male and female pink salmon in the Revelva River, Spitsbergen, an island in the Barents Sea mid-way between Greenland and the coasts of Russia, Finland, Sweden, and Norway. The source for these strays is unknown, but the nearest location that pink salmon had been previously introduced and are known to naturally reproduce is >500 miles away across open ocean.

Not all unmarked fish in our samples necessarily represent naturally produced fish from the stream sampled or even from LCI. Our quality control analysis revealed that some LCI hatchery pink salmon had poorly-executed marks. The higher reassignment rate (10.6%) for TBLH marks during the second read in 2017 was likely due to a thermal marking issue that TBLH staff is aware of and is actively seeking to resolve. Additional potential sources for unmarked otoliths in our samples might include stray naturally-produced pink salmon from other wild streams or fish released from the Kitoi Bay Hatchery (KBH) on Afognak Island (<150 miles from LCI, Figure 8), none of which were thermally marked during the period of this pilot study.

This study identified relatively high levels of hatchery pink salmon in several streams in LCI. Pacific salmon naturally stray at varying levels (Groot and Margolis 1991, Quinn 1993, Westley et al. 2012, Keefer and Caudill 2014) and this trait is considered an evolutionary advantage that enables colonization of new habitats opened up by deglaciation and other natural and anthropogenic means (Milner and Bailey 1989, Quinn 2005). For instance, stray chum *O. keta* and coho *O. kisutch* salmon have recently begun colonizing the Paint River in Kamishak Bay, which was recently made accessible by opening a fish ladder that allows migration past a 30-foot tidewater falls (personal communication with A. Wizik, Cook Inlet Aquaculture Association). Very few studies have estimated stray rates for natural populations of pink salmon, but Heard (1991) suggested 10% as a reasonable estimate based on a review of the literature. Sharp et al. (1994) examined pink salmon stray rates in PWS following the Exxon Valdez Oil Spill and reported a range from 9–54%. A more recent study in Alaska reported that overall, natural stray rates for pink salmon were relatively low (5.1%), but that intertidal spawners strayed at higher rates (9.2%) than upstream spawning stocks (3.7%; Thedinga et al. 2000). Both Sharp et al. (1994) and Thedinga et al. (2000) used coded wire tags (CWT) to assess stray rates and some research suggests coded-wire tagged fish may stray at higher rates (Thedinga et al. 2000), especially if the CWTs are implanted in a way that damages olfactory organs and nerves (Habicht et al. 1998).

A large body of literature discusses hatchery straying as a potential cause for a wide variety of negative impacts to wild salmon (e.g., National Resource Council 1996, Naish et al. 2008, Grant 2012). Many factors likely play a role in determining the effect hatchery-origin salmon may have on wild populations (Waples 1999, Pearsons 2008), but the effect can be expected to scale with the magnitude of hatchery-origin spawners relative to affected wild populations (Grant 2012). Unfortunately, it is not clear what level of straying is benign and what levels should be prevented to avoid potentially negative impacts. Several published studies offer useful insight into the risks (Hutchings 1991, Waples 1999, Grant 2012, Brenner et al. 2012), but very few have attempted to measure actual effects of strays on wild pink salmon populations. In response to this information gap, the ongoing AHRP study is the first comprehensive study to measure hatchery straying and the effect it may have on the fitness of wild pink salmon (Gorman et al. 2017). If "threshold" straying levels to avoid exist, they likely differ by species, population, and perhaps even population segment (e.g., intertidal vs. river spawners), which further complicates the interpretation of straying results (Waples 1999). Until more of this uncertainty is resolved, it may be prudent to manage hatchery production using a pre-cautionary approach, while prioritizing research into poorly understood aspects of the genetic and ecological impacts that large-scale hatchery salmon production may have on species they interact with in freshwater and marine environments (Waples 1999, Pearsons 2008). Waples (1999) and Pearsons (2008) also recommend that objective risk assessments and comprehensive cost:benefit analyses be periodically conducted to help inform appropriate hatchery management strategies as new information becomes available.

FUTURE RESEARCH

This pilot study documented the presence of hatchery-origin individuals in pink salmon escapements in LCI. The information collected can be used to refine management questions and identify the research needed to improve our understanding of hatchery-wild salmon interactions in LCI. As soon as funding is available, an intensive catch and escapement sampling program will be formalized as part of the annual monitoring/assessment of hatchery programs in LCI. Using these 4 years of observations, an operational plan will be developed that will 1) define the question(s) to answer, 2) establish project goal(s) and objective(s) to achieve, and 3) refine sample design and data analysis. The operational plan will include changes to the sampling design to facilitate estimating hatchery proportions over the entire run and throughout LCI. These changes will allow for better extrapolations required to fully assess the magnitude and distribution of hatchery fish originating both within and outside LCI.

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TABLES AND FIGURES

Table 1.–Relevant details associated with 17 LCI streams that were sampled during 2014–2017 to assess stock composition (numbers preceding stream name correspond to those in Figure 1).

		Sample Year							
		2014		2015		2016		2017	
	Number streams sampled	8		12		10		16	
	Number readable otoliths collected	1,142		1,878		1,172		2,343	
Stream name	Escapement goal range	# sample events	Sample dates	# sample events	Sample dates	# sample events	Sample dates	# sample events	Sample dates
1. Beluga Slough	No Esc. Goal	--	--	--	--	--	--	3	9/5, 9/11, 9/18
2. Fritz Creek	No Esc. Goal	--	--	--	--	--	--	1	9/14
3. Humpy Creek[1]	17,500–51,400	2	8/11, 9/4	2	8/19, 9/3	3	8/17, 8/24, 9/7	2	8/25, 9/12
4. China Poot[1]	2,500–6,300	2	8/28, 9/5	2	8/27, 9/9	1	8/30	1	9/1
5. Sadie Cove Creek	No Esc. Goal	--	--	--	--	--	--	1	8/28
6. Tutka Head End Creek[2]	No Esc. Goal	--	--	1	8/26	--	--	1	8/25
7. Tutka Lagoon Creek[1,2]	6,500–17,000	2	8/18, 9/8	2	8/13, 9/4	2	8/12, 9/12	2	8/25, 9/15
8. Little Tutka Bay (Lou's Ck.)[2]	No Esc. Goal	--	--	--	--	--	--	1	9/18
9. Barabara Creek[1]	2,000–5,600	2	8/26, 9/8	3	8/14, 8/28, 9/10	3	8/16, 8/26, 9/9	2	8/18, 8/29
10. Seldovia River[1]	21,800–37,400	2	8/14, 8/27	2	8/4, 9/8	3	8/8, 8/29, 9/14	3	8/8, 8/17, 8/30
11. Port Graham River[1,3]	7,700–19,700	2	8/25, 9/11	2	8/6, 8/24	2	8/11, 9/2	1	8/21
12. English Bay River[1]	No Esc. Goal	1	8/26	1	8/11	1	9/8	2	8/15, 9/20
13. Dogfish Lagoon Creek[1]	800–7,100	1	9/9	1	8/20	1	9/6	1	8/24
14. Port Chatham	7,800–18,100	--	--	--	--	--	--	1	9/11
15. Port Dick Creek[4]	17,900–49,800	--	--	2	8/5, 9/15	3	8/9, 8/31, 9/13	1	9/7
16. Island Creek[4]	9,600–32,500	--	--	2	9/2, 9/15	1	9/1	2	8/23, 9/8
17. South Nuka Island Creek	2,800–11,200	--	--	1	9/2	--	--	--	--

[1] Stream is one of the 8 core streams sampled annually since 2014.

[2] Stream is inside the Tutka Hatchery Special Harvest Area.

[3] Stream is adjacent to the Port Graham Hatchery Special Harvest Area.

[4] Stream was added in 2015 to the core group of streams to be sampled annually.

Table 2.–Results showing the number of fish collected, the number of thermal marked otoliths in samples identified to hatchery, and percentage of thermal marked otoliths in samples collected from spawned-out pink salmon in 8 streams in Lower Cook Inlet, 2014.

		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Barabara	Combined	4	1	5	31	25	3	24	83	88	7	95	92.6%	2
	8/26	2	1	3	6		2	3	11	14	2	16	87.5%	2
	9/8	2		2	25	25	1	21	72	74	5	79	93.7%	0
China Poot	Combined			0				3	3	3	90	93	3.2%	8
	8/28			0				2	2	2	49	51	3.9%	5
	9/5			0				1	1	1	41	42	2.4%	3
Dogfish Lagoon	9/9	8	1	9	14	5		10	29	38	55	93	40.9%	5
English Bay	8/26	1		1	14	5	1	8	28	29	64	93	31.2%	3
Humpy	Combined			0				1	1	1	188	189	0.5%	3
	8/11			0					0	0	94	94	0.0%	2
	9/4			0				1	1	1	94	95	1.1%	1
Port Graham	Combined	88		88	11	9	1	9	30	118	74	192	61.5%	1
	8/25	50		50	1	1	1	1	4	54	41	95	56.8%	1
	9/11	38		38	10	8		8	26	64	33	97	66.0%	
Seldovia	Combined	45		45	5	3		4	12	57	143	200	28.5%	6
	8/14	5		5					0	5	102	107	4.7%	3
	8/27	40		40	5	3		4	12	52	41	93	55.9%	3
Tutka Lagoon	Combined	6	155	161	2	5	1	5	13	174	13	187	93.0%	6
	8/18	2	85	87			1		1	88	7	95	92.6%	1
	9/8	4	70	74	2	5		5	12	86	6	92	93.5%	5
Total		152	157	309	77	52	6	64	199	508	634	1,142	44.5%	34

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery, NR = Not Readable (e.g., missing, broken, destroyed during preparation, etc.).

Table 3.–Results showing the number of fish collected, the number of thermal marked otoliths in samples identified to hatchery, and percentage of thermal marked otoliths in samples collected from spawned-out pink salmon in 12 streams in Lower Cook Inlet, 2015.

		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Barabara	Combined		10	10	4	9	11	12	36	46	240	286	16.1%	2
	8/14			0			5		5	5	90	95	5.3%	1
	8/28		3	3	1		6	5	12	15	81	96	15.6%	0
	9/10		7	7	3	9		7	19	26	69	95	27.4%	1
China Poot	Combined	1	1	2			5		5	7	130	137	5.1%	1
	8/27	1	1	2			5		5	7	34	41	17.1%	1
	9/9			0					0	0	96	96	0.0%	0
Dogfish Lagoon	8/20		1	1	3	1			4	5	90	95	5.3%	1
English Bay	8/11		4	4			31	1	32	36	60	96	37.5%	0
Humpy	Combined		3	3	1		2		3	6	183	189	3.2%	3
	8/19		3	3			1		1	4	91	95	4.2%	1
	9/3			0	1		1		2	2	92	94	2.1%	2
Island	Combined			0	22	8	2	6	38	38	153	191	19.9%	1
	9/2			0	12	3	2	5	22	22	74	96	22.9%	0
	9/15			0	10	5		1	16	16	79	95	16.8%	1
Port Dick Creek	Combined	1		1	4	8		2	14	15	107	122	12.3%	1
	8/5	1		1					0	1	31	32	3.1%	1
	9/15			0	4	8		2	14	14	76	90	15.6%	0
Port Graham	Combined	2	1	3					0	3	185	188	1.6%	4
	8/6	1	1	2					0	2	92	94	2.1%	2
	8/24	1		1					0	1	93	94	1.1%	2

-continued-

Table 3.–Page 2 of 2.

Stream name	Sample Dates	Lower Cook Inlet PGH	TBLH	LCI marks	Prince William Sound AFKH	CCH	SGH	WNH	PWS marks	Sample Marked	Not marked	Total read	Hatchery percent	NR
Seldovia	Combined	3		3	3	3	1	2	9	12	179	191	6.3%	1
	8/4	3		3					0	3	92	95	3.2%	1
	9/8			0	3	3	1	2	9	9	87	96	9.4%	0
South Nuka	9/2	1	1	2	6				6	8	87	95	8.4%	1
Tutka Head End	8/26		74	74			5		5	79	17	96	82.3%	0
Tutka Lagoon	Combined		182	182					0	182	10	192	94.8%	0
	8/13		94	94					0	94	2	96	97.9%	0
	9/4		88	88					0	88	8	96	91.7%	0
Total		8	277	285	43	29	57	23	152	437	1,441	1,878	23.3%	15

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery, NR = Not Readable (e.g., missing, broken, destroyed during preparation, etc.).

Table 4.–Results showing the number of fish collected, the number of thermal marked otoliths in samples identified to hatchery, and percentage of thermal marked otoliths in samples collected from spawned-out pink salmon in 10 streams in Lower Cook Inlet, 2016.

		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Barabara	Combined	5	4	9	12	4	13	2	31	40	144	184	21.7%	1
	8/16	1		1					0	1	39	40	2.5%	0
	8/26		2	2	3	1	6		10	12	36	48	25.0%	1
	9/9	4	2	6	9	3	7	2	21	27	69	96	28.1%	0
China Poot	8/30			0					0	0	8	8	0.0%	0
Dogfish Lagoon	9/6	12		12	2	1		1	4	16	77	93	17.2%	3
English Bay	9/8	13		13	3	4			7	20	71	91	22.0%	5
Humpy	Combined			0			1		1	1	189	190	0.5%	3
	8/17			0					0	0	37	37	0.0%	0
	8/24			0			1		1	1	58	59	1.7%	1
	9/7			0					0	0	94	94	0.0%	2
Island Creek	9/1			0					0	0	10	10	0.0%	0
Port Dick	Combined			0					0	0	40	40	0.0%	1
	8/9			0					0	0	3	3	0.0%	0
	8/31			0					0	0	28	28	0.0%	1
	9/13			0					0	0	9	9	0.0%	0
Port Graham	Combined	29	5	34	1	1	1		3	37	108	145	25.5%	2
	8/11	10		10					0	10	41	51	19.6%	0
	9/2	19	5	24	1	1	1		3	27	67	94	28.7%	2
Seldovia	Combined	5	4	9	2	2	1	1	6	15	202	217	6.9%	4
	8/8			0					0	0	25	25	0.0%	1
	8/29	4	4	8	2	2	1		5	13	82	95	13.7%	1
	9/14	1		1				1	1	2	95	97	2.1%	2

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		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Tutka Lagoon	Combined		179	179		1			1	180	14	194	92.8%	0
	8/12		95	95					0	95	1	96	99.0%	0
	9/12		84	84		1			1	85	13	98	86.7%	0
Total		64	192	256	20	13	16	4	53	309	863	1,172	26.4%	19

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery, NR = Not Readable (e.g., missing, broken, destroyed during preparation, etc.).

Table 5.–Results showing the number of fish collected, the number of thermal marked otoliths in samples identified to hatchery, and percentage of thermal marked otoliths in samples collected from spawned-out pink salmon in 16 streams in Lower Cook Inlet, 2017. Otoliths from streams denoted by an asterisk (*) were read a second time.

		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Barabara	Combined		5	5	8		27		35	40	151	191	20.9%	1
	8/18		1	1			5		5	6	89	95	6.3%	1
	8/29		4	4	8		22		30	34	62	96	35.4%	0
Beluga Slough*	Combined		4	4	87	42	3	30	162	166	118	284	58.5%	4
*	9/5			0	51	8	3	6	68	68	27	95	71.6%	1
	9/11		1	1	21	20		12	53	54	42	96	56.3%	0
	9/18		3	3	15	14		12	41	44	49	93	47.3%	3
China Poot	9/1		2	2	4	2	2	2	10	12	82	94	12.8%	2
Dogfish Lagoon	8/24			0	12	2	31	1	46	46	42	88	52.3%	8
English Bay	Combined	2	5	7	16	21	12	3	52	59	113	172	34.3%	4
	8/15	1	2	3	4		12		16	19	11	30	63.3%	2
	9/20	1	3	4	12	21		3	36	40	102	142	28.2%	2
Fritz*	9/14			0	39	20	3	5	67	67	28	95	70.5%	1
Humpy	Combined		1	1			3		3	4	186	190	2.1%	2
	8/25		1	1			3		3	4	91	95	4.2%	1
	9/12			0					0	0	95	95	0.0%	1
Island	Combined		2	2	18	7	7	4	36	38	157	195	19.5%	4
	8/23			0			4		4	4	41	45	8.9%	3
	9/8		2	2	18	7	3	4	32	34	116	150	22.7%	1
Lou's Creek*	9/18	1	12	13	24	14		9	47	60	35	95	63.2%	1
Port Chatham	9/11			0	28	13	1	4	46	46	50	96	47.9%	0
Port Dick	9/7		2	2	3	1			4	6	85	91	6.6%	5

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		Lower Cook Inlet			Prince William Sound					Sample				
Stream name	Sample Dates	PGH	TBLH	LCI marks	AFKH	CCH	SGH	WNH	PWS marks	Marked	Not marked	Total read	Hatchery percent	NR
Port Graham	8/21	1		1	2		3		5	6	89	95	6.3%	1
Sadie Cove	8/28		4	4	2		12		14	18	75	93	19.4%	3
Seldovia	Combined			0	7	2	14	1	24	24	168	192	12.5%	3
	8/8			0					0	0	48	48	0.0%	0
	8/17			0			5		5	5	45	50	10.0%	1
	8/30			0	7	2	9	1	19	19	75	94	20.2%	2
Tutka Head End*	8/25		64	64			11		11	75	108	183	41.0%	9
Tutka Lagoon*	Combined		167	167	1	3		1	5	172	17	189	91.0%	3
*	8/25		90	90					0	90	3	93	96.8%	3
	9/15		77	77	1	3		1	5	82	14	96	85.4%	0
Total		4	268	272	251	127	129	60	567	839	1,504	2,343	35.8%	51

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery, NR = Not Readable (e.g., missing, broken, destroyed during preparation, etc.).

Table 6.–Percent occurrence of Lower Cook Inlet (LCI) and Prince William Sound (PWS) hatchery-marked otoliths in samples from pink salmon carcasses in LCI streams, excluding streams in or directly adjacent to pink salmon hatchery special harvest areas, 2014–2017.

	2014		2015		2016		2017		Avg : 2014–17	
Stream name	LCI	PWS	LCI	PWS	LCI	PWS	LCI	PWS	LCI	PWS
Barabara Creek	5.3%	87.4%	3.5%	12.6%	4.9%	16.8%	2.6%	18.3%	4.1%	33.8%
Beluga Slough							1.4%	57.0%	1.4%	57.0%
China Poot Creek	0.0%	3.2%	1.5%	3.6%	0.0%	0.0%	2.1%	10.6%	0.9%	4.4%
Dogfish Lagoon Creek	9.7%	31.2%	1.1%	4.2%	12.9%	4.3%	0.0%	52.3%	5.9%	23.0%
English Bay River	1.1%	30.1%	4.2%	33.3%	14.3%	7.7%	4.1%	30.2%	5.9%	25.3%
Fritz Creek							0.0%	70.5%	0.0%	70.5%
Humpy Creek	0.0%	0.5%	1.6%	1.6%	0.0%	0.5%	0.5%	1.6%	0.5%	1.1%
Island Creek			0.0%	19.9%	0.0%	0.0%	1.0%	18.5%	0.3%	12.8%
Port Chatham							0.0%	47.9%	0.0%	47.9%
Port Dick Creek			0.8%	11.5%	0.0%	0.0%	2.2%	4.4%	1.0%	5.3%
Sadie Cove							4.3%	15.1%	4.3%	15.1%
Seldovia River	22.5%	6.0%	1.6%	4.7%	4.1%	2.8%	0.0%	12.5%	7.1%	6.5%
South Nuka Bay			2.1%	6.3%					2.1%	6.3%
Average	6.4%	26.4%	1.8%	10.9%	4.5%	4.0%	1.5%	28.2%	2.6%	23.8%
Lower 25%	0.3%	3.9%	1.1%	4.2%	0.0%	0.0%	0.0%	12.0%	0.5%	6.3%
Median (50%)	3.2%	18.1%	1.6%	6.3%	2.1%	1.6%	1.2%	18.4%	1.4%	15.1%
Upper (75%)	8.6%	30.9%	2.1%	12.6%	6.9%	5.1%	2.3%	49.0%	4.3%	33.8%

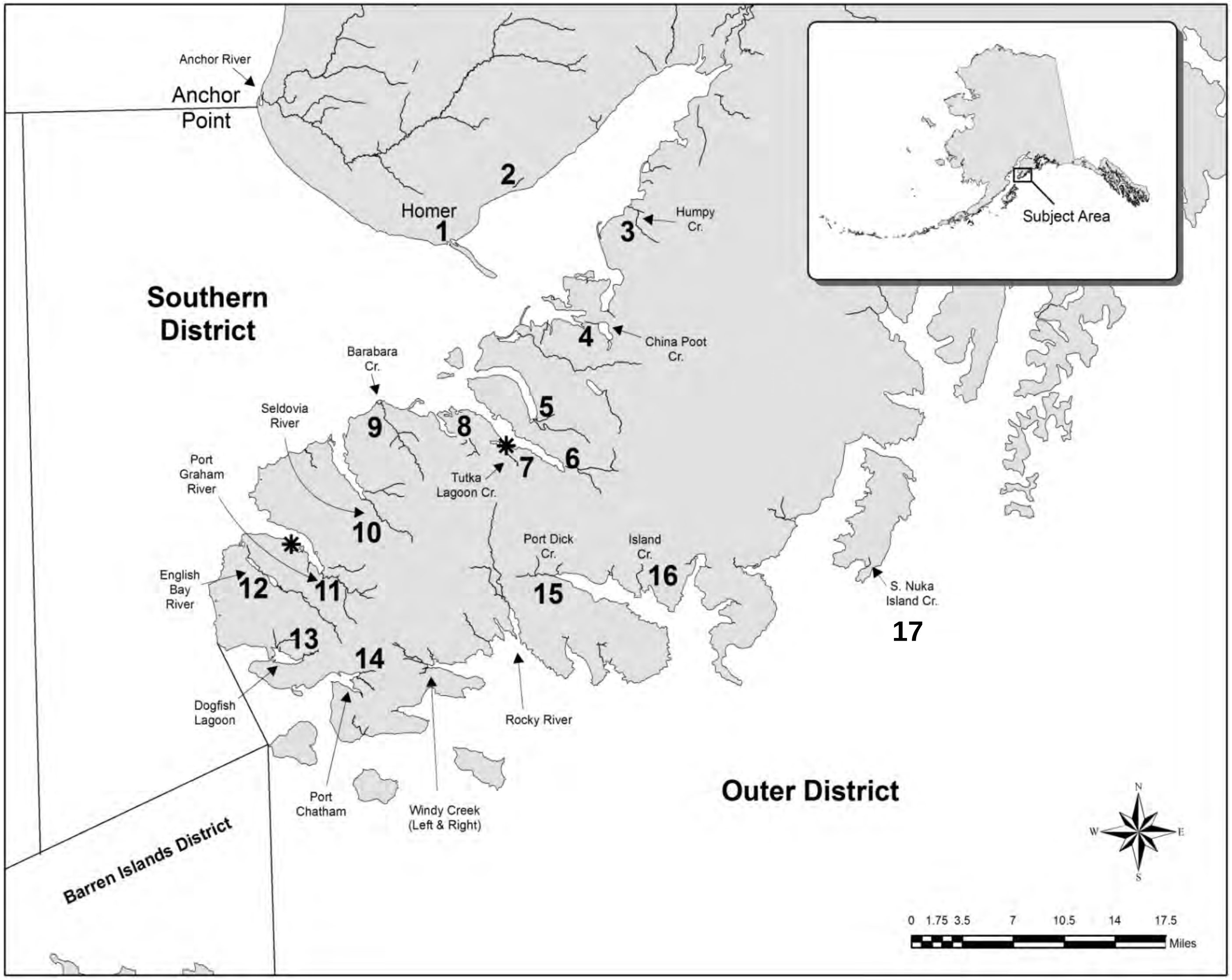

Figure 1.–Map of Southern and Outer districts of Lower Cook Inlet, illustrating the locations of Lower Cook Inlet pink salmon hatcheries (denoted by asterisks *), pink salmon index streams, and 17 streams that were targeted for otolith sampling during 2014–2017.

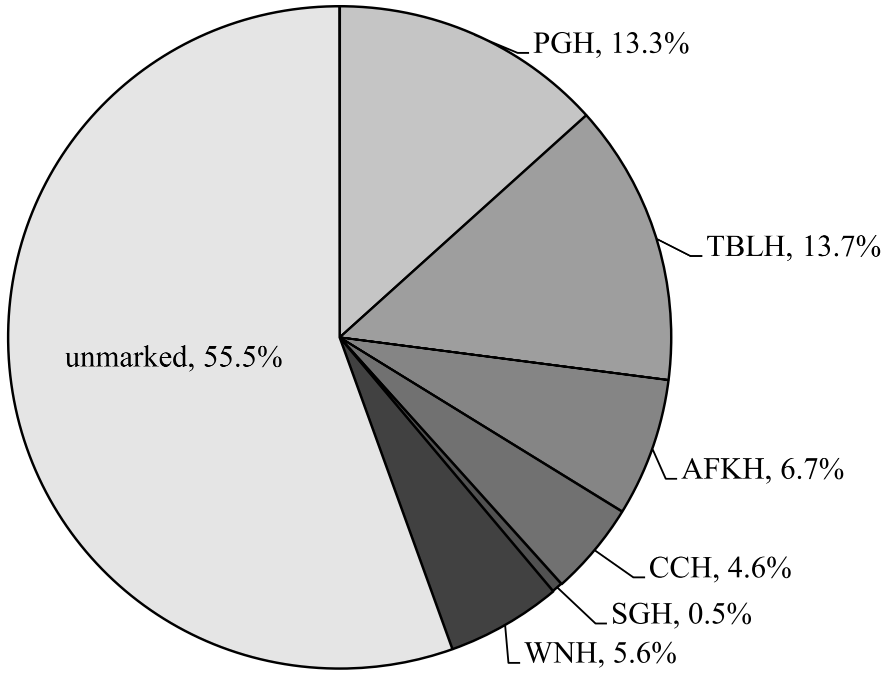

Figure 2.–Source hatchery and percentage of thermal mark otoliths identified in samples collected from spawned-out pink salmon in 8 streams in Lower Cook Inlet, 2014.

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH=Cannery Creek Hatchery, SGH=Solomon Gulch Hatchery, WNH=Wally Noerenberg Hatchery

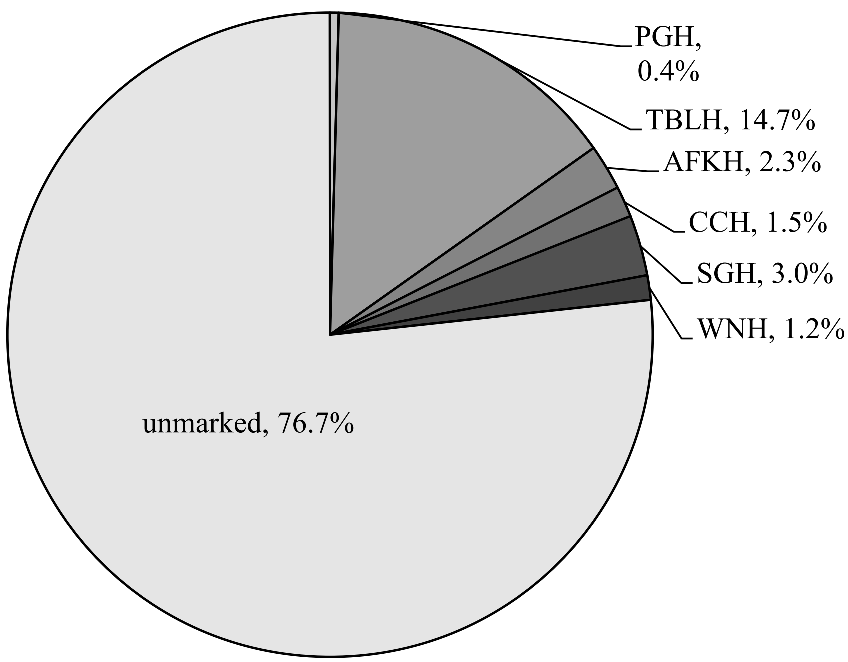

Figure 3.–Source hatchery and percentage of thermal mark otoliths identified in samples collected from spawned-out pink salmon in 12 streams in Lower Cook Inlet, 2015.

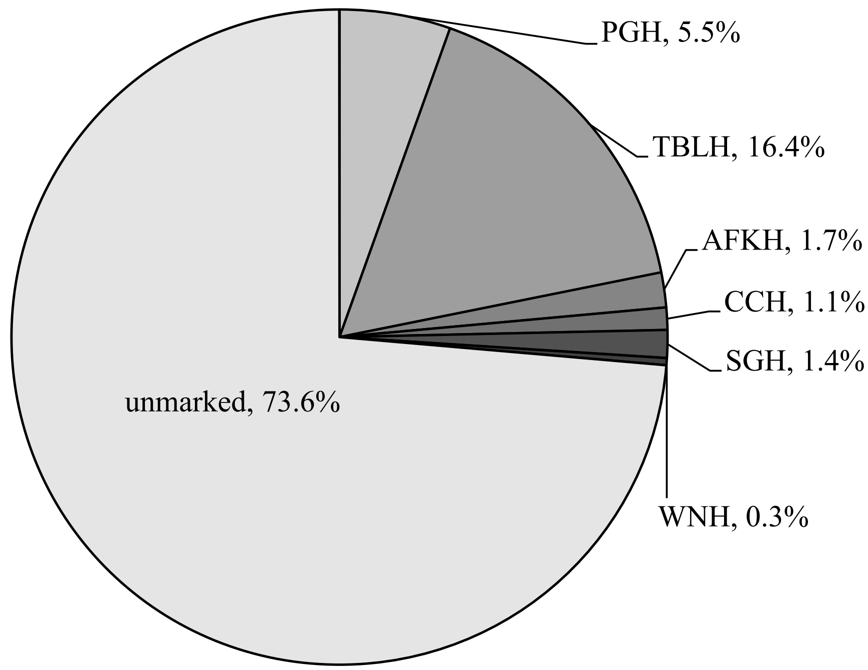

Figure 4.–Source hatchery and percentage of thermal mark otoliths identified in samples collected from spawned-out pink salmon in 10 streams in Lower Cook Inlet, 2016.

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery

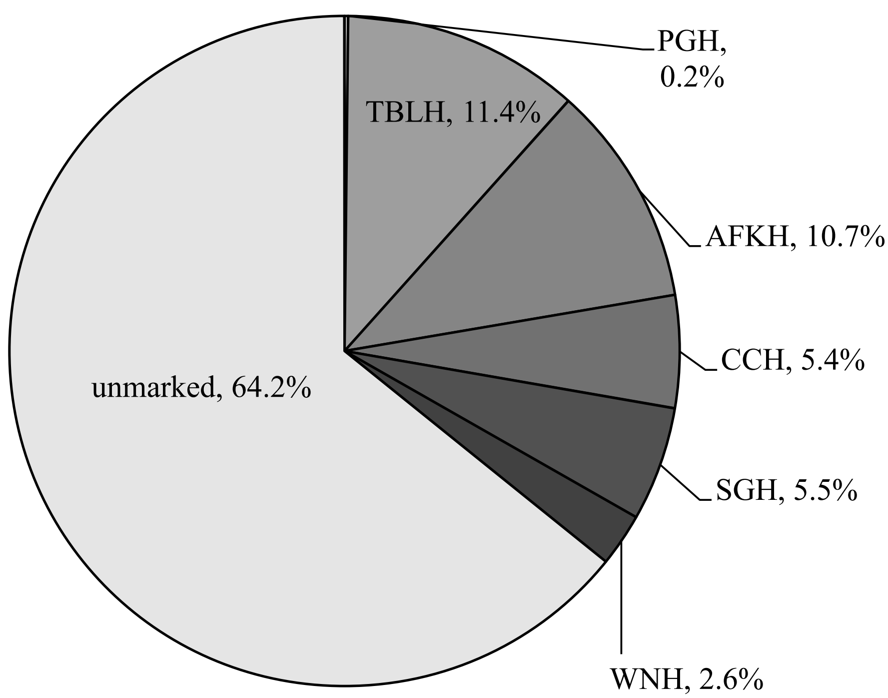

Figure 5.–Source hatchery and percentage of thermal mark otoliths identified in samples collected from spawned-out pink salmon in 16 streams in Lower Cook Inlet, 2017.

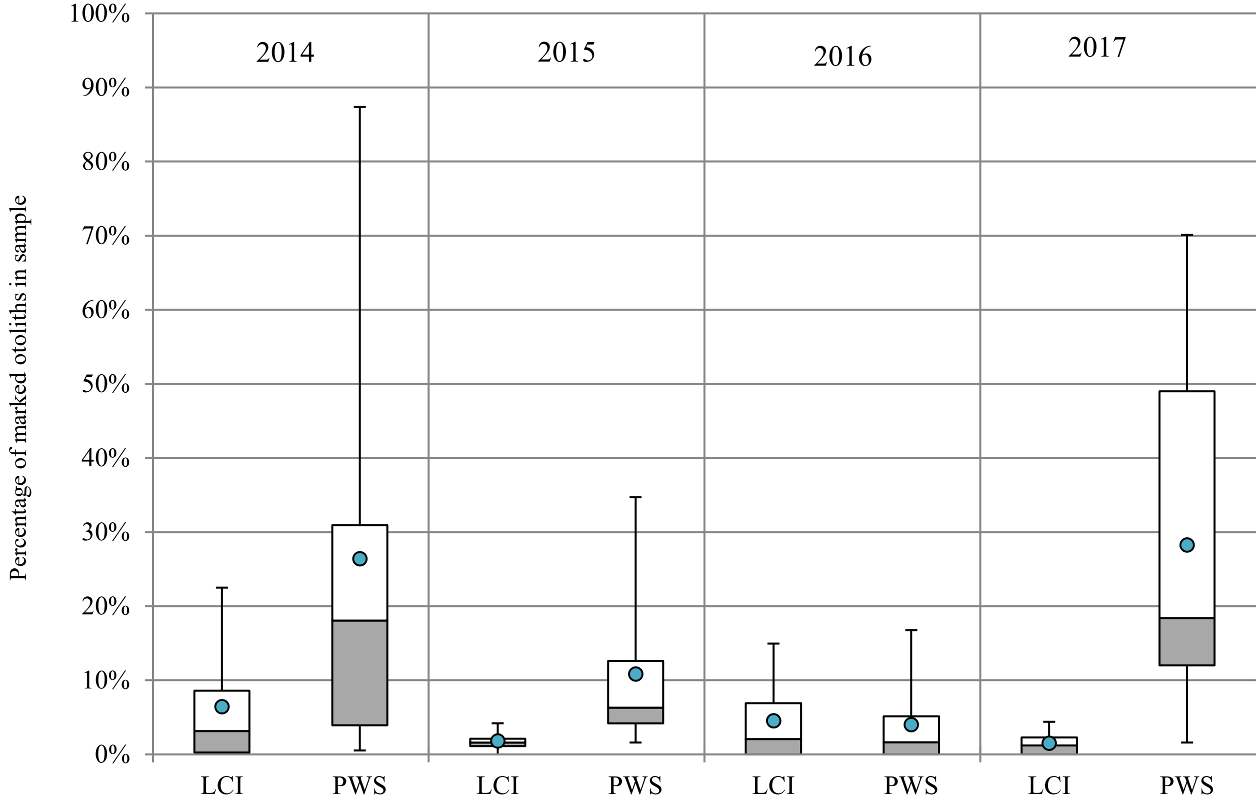

Figure 6.–Box and whisker plots showing percent occurrence of Lower Cook Inlet (LCI) and Prince William Sound (PWS) hatchery-marked otoliths in samples from pink salmon carcasses in LCI streams, excluding streams in or directly adjacent to pink salmon hatchery special harvest areas, 2014–2017. The bottom and top of the boxes represent the 25th and 75th percentiles, the horizontal line in the box is the 50th percentile (median), the whiskers represent the maximum and minimum observed values, and the circle is the mean proportion of LCI or PWS hatchery marks in the samples.

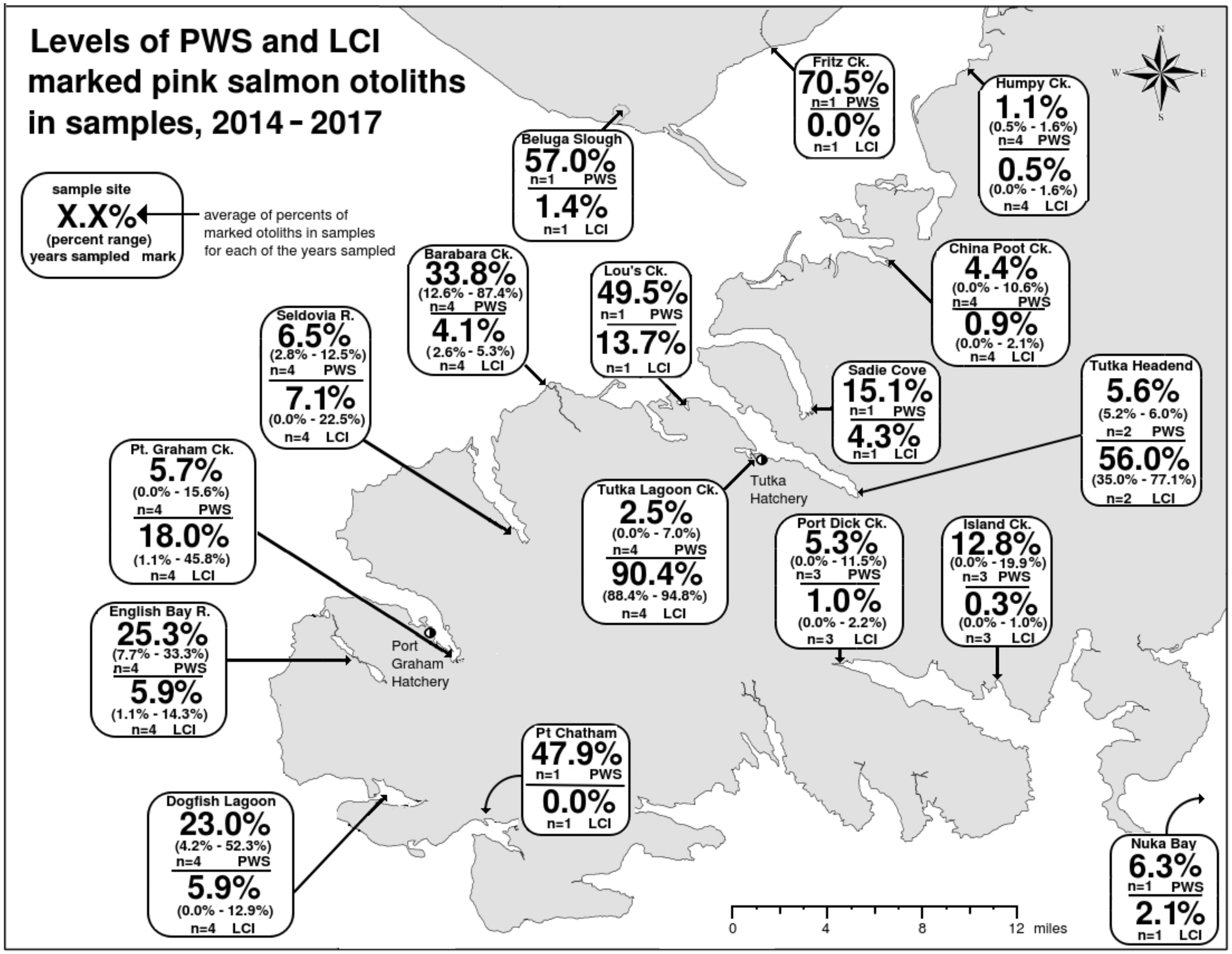

Figure 7.–Average percentages of Lower Cook Inlet (LCI) and Prince William Sound (PWS) hatchery marks identified on otoliths sampled from spawned-out pink salmon carcasses on 17 streams in Lower Cook Inlet, 2014–2017.

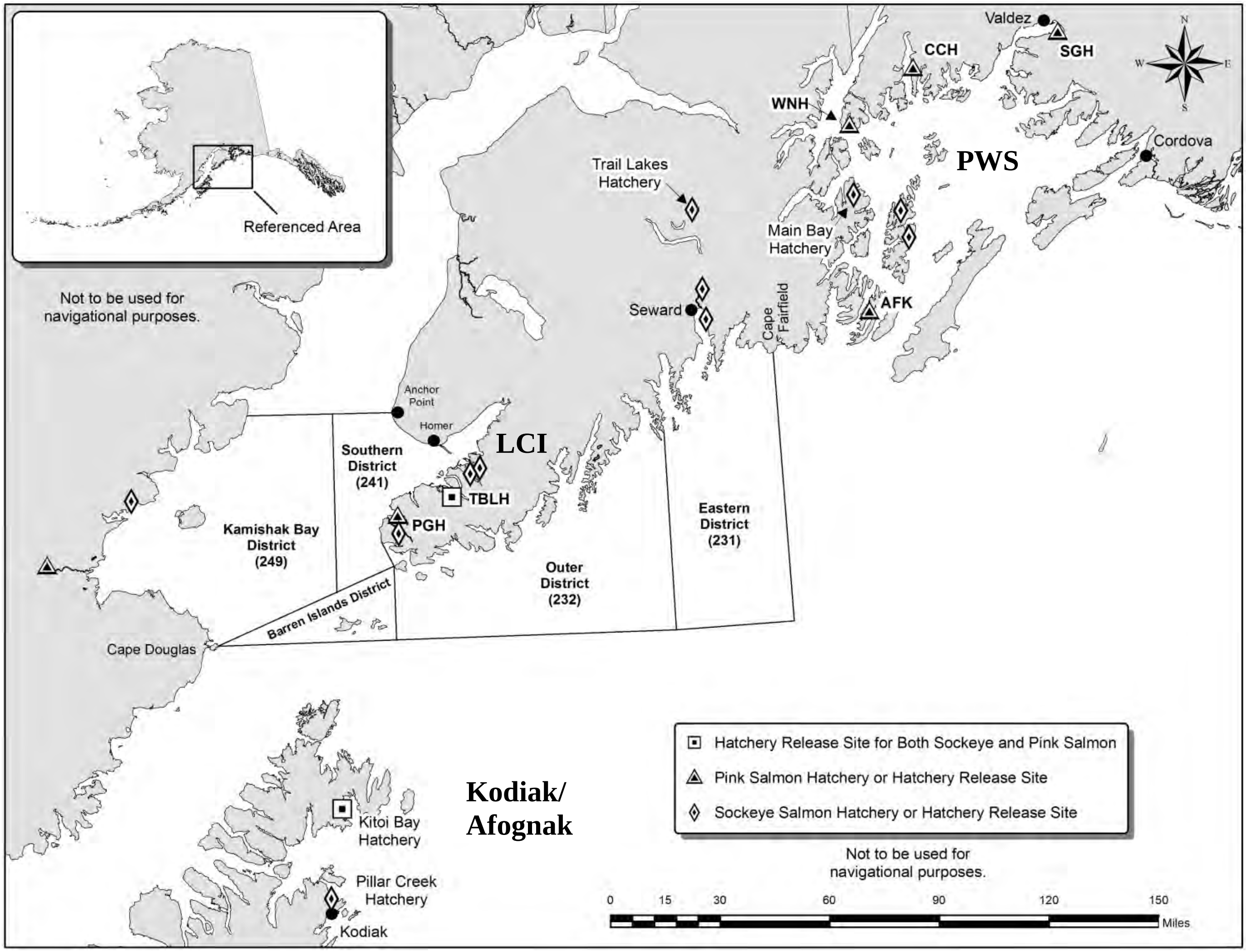

Figure 8.–Map of the North Gulf of Alaska illustrating relative distances between streams sampled in Southern and Outer districts of Lower Cook Inlet (LCI) and hatcheries located in LCI and Prince William Sound (PWS) where fish originated. See Figure 1 for an expanded view of LCI and the locations of streams sampled.

Note: PGH = Port Graham Hatchery, TBLH = Tutka Bay Lagoon Hatchery, AFKH = Armin F. Koernig Hatchery, CCH = Cannery Creek Hatchery, SGH = Solomon Gulch Hatchery, WNH = Wally Noerenberg Hatchery.