State of Alaska Hatchery Research Project:

A study of the interactions between hatchery and natural pink and chum salmon in Southeast Alaska and Prince William Sound streams

Progress Synopsis May 2022

Alaska Hatchery Priority Research Questions – In 2011, the Alaska Department of Fish and Game (ADF&G) organized a science panel composed of current and retired scientists from ADF&G, University of Alaska, aquaculture associations, and National Marine Fisheries Service to discuss ways to systematically evaluate the interaction between wild and hatchery-produced salmon in Alaska. The science panel designed a long-term research project to address three top priority research questions:

1. What is the genetic stock structure of pink salmon in Prince William Sound (PWS) and chum salmon in Southeast Alaska (SEAK)?
2. What is the extent and annual variability in straying of hatchery pink salmon in PWS and chum salmon in PWS and SEAK?
3. What is the impact on fitness (productivity) of wild pink and chum salmon stocks due to straying of hatchery pink and chum salmon?

The following is a short description of progress made to date to provide answers to these questions.

Population Structure – Laboratory analysis of the genetic stock structure for both the odd-year and even-year runs of pink salmon populations in PWS using DNA microsatellites has been completed. As observed elsewhere in their range, variation among odd-year populations was larger than among even-year populations. Among both even- and odd-year populations, early and late spawners within some creeks showed genetic differences. Population structure in PWS is comparable to structure found in wild pink salmon elsewhere in its geographic range. In preliminary comparisons of historic (mid-1990's) and contemporary samples, populations are genetically similar across time (10+ generations), but not identical. A similar analysis of even-year pink salmon collections is currently in progress and should provide more historic perspective on population structure in the presence of hatchery production. A report of the current population structure of odd-year lineage (2013, 2015) is referenced below. The results on the even-year population structure (2014) have been presented at American Fisheries Society, Board of Fisheries, and Alaska Hatchery Research Project Informational meetings.

Straying Studies – Following a robust design focused on estimating the extent and variability of hatchery pink and chum salmon straying in PWS and SEAK, field work was completed in 2015. Otoliths were sampled from spawned-out fish in representative chum salmon streams in SEAK, and pink and chum salmon streams in PWS, to estimate the hatchery fraction in natural spawning populations on a district scale. Previous studies have documented strays in individual streams in SEAK and PWS, but this is the first study designed to provide an unbiased estimate for an entire region. The sample results (Table 1 and Figure 1) are available in reports online and two separate papers (one for PWS and one for SEAK) have been published in peer-reviewed journals and are available online (see References below).

Table 1. Estimates of the region-wide proportions of hatchery-origin spawners in streams.

	Hatchery Proportion		
PWS	2013	2014	2015
Pink salmon	5%	15%	11%
Chum salmon	3%	3%	9%
SEAK	2013	2014	2015
Chum salmon	3%	3%	6%

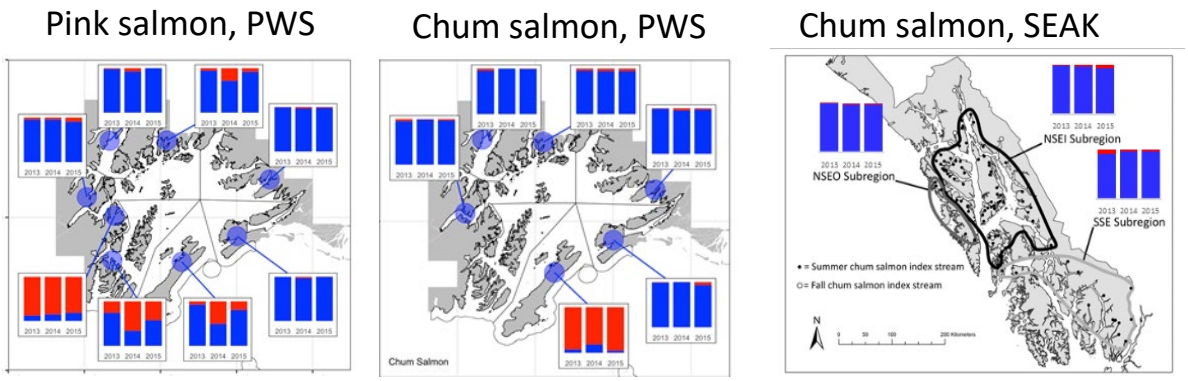

Figure 1. Estimated fractions of hatchery- (red) and natural-origin (blue) pink and chum salmon in spawning streams within ADF&G commercial fishing districts in Prince William Sound (PWS) and for summer chum salmon in subregions in Southeast Alaska (SEAK), 2013–2015.

Things that we can infer from work to date:

1. Hatchery proportions of pink salmon in streams across PWS ranged from 5 to 11% in the two odd years and was 15% in the even year and was highly variable among streams and districts. The distribution of hatchery fish across districts was consistent across years, with higher proportions near hatcheries similar to previous observations.
2. Hatchery proportions of chum salmon in streams across PWS ranged from 3 to 9% across the three years and was highly variable among streams and districts. The distribution of these hatchery fish across districts was fairly consistent across years, with higher proportions in the districts where fish are remotely released and/or few wild fish spawn.
3. Hatchery proportions of chum salmon in streams across SEAK ranged from 3 to 6% across the three years. Seven of the eight observations of hatchery proportions over 20% were in three streams within 22km of release sites, while 86% of observations in streams over 50km from hatcheries had hatchery proportions below 5%.

Estimating Production in PWS – Ocean sampling in the entrances to PWS has provided an unbiased estimate of the hatchery fraction in the total return of pink and chum salmon. This information, when combined with estimates from the streams and known removals through harvest and hatchery take for cost recovery and broodstock provided a means to estimate: 1) the number of natural-origin salmon spawning in streams, 2) the number of hatchery salmon spawning naturally (Hatchery strays), 3) total production of hatchery salmon (including strays; Hatchery run), and 4) total production of natural salmon (excluding Hatchery strays; Natural run). With knowledge of the total number of fish spawning in streams and the total return of natural fish (Table 2), it is possible to estimate the return per spawner, an important measure of productivity. It was also possible to estimate the differential harvest rates on hatchery and natural stocks. These results are included in the PWS publication mentioned previously and referenced below.

Table 2. Estimates of production of pink and chum salmon in Prince William Sound, 2013-2015.

	Estimated Run Sizes (millions)		Estimated Harvest Rates	
Species Year	Hatchery	Natural	Hatchery	Natural
Pink salmon				
2013	73.92	34.95	0.99	0.50
2014	42.86	6.75	0.98	0.27
2015	77.84	63.94	0.94	0.40
Chum salmon				
2013	3.94	1.50	0.99	0.17
2014	1.19	1.14	0.97	0.20
2015	2.55	1.16	0.96	0.19

Things that we can infer from the PWS production estimates (Table 2):

1. Estimated harvest rates indicate that ADF&G was able to preferentially harvest hatchery-produced fish (>90%) while sustainably harvesting naturally produced fish (<50%) in 2013-2015.
2. Between 1% and 6% of the pink salmon hatchery returns, and 1% and 4% of the hatchery chum salmon returns in PWS spawned naturally during the three study years (i.e., donor stray rate).
3. The natural production of PWS pink salmon was unusually robust in the three brood years represented (after 18 generations of hatchery/natural interaction). For example, 17 million spawners in 2013 produced an estimated natural run of just under 64 million in 2015, a 4 to 1 return-to-spawner ratio.

Fitness Studies – This ground-breaking work is based on first identifying the origin (hatchery/natural using otolith marks) of parents and offspring spawning in study streams and subsequently using genetics to identify parent-offspring relationships via genetic pedigree reconstruction. This information will allow estimation of the relative reproductive success (RRS; fitness) of hatchery strays and naturally produced fish spawning in streams. Evaluation at this scale is important because it will provide insight into the ecological and genetic consequences of hatchery strays on fitness of natural spawners at the drainage scale.

The field crews have completed 8 years of intensive sampling directed toward studies of the relative fitness of hatchery and natural fish in 5 pink salmon study streams in PWS and 3 chum salmon study streams in SEAK. While 2020 was the final year of field sampling for PWS pink salmon, field sampling for SEAK chum salmon is expected to continue through 2023. Collectively 235,638 PWS pink salmon and 17,687 SEAK chum salmon have been sampled for this research through 2021. Otoliths have been read for ~226K PWS pink salmon samples and all SEAK chum salmon samples. Genetic analysis began in 2018 using single nucleotide polymorphism (SNP) genetic markers to determine pedigrees for pink salmon in PWS. The first step in this analysis was refining methods to use cost-effective genotyping by sequencing technology to screen samples taken from carcasses. To date, genotyping has been completed for ~133,369 PWS pink salmon. Pedigree data for a total of 14 full generations (parents and offspring, including 6 odd-year brood years and 8 even-year brood years) across 5 streams have been completed to date. Generally, stray hatchery fish produced significantly fewer progeny than natural fish during this first generation, with considerable variation by sex, stream, and year. Modeling has been employed to better understand how differences in body size, run timing, and spawning location (i.e., intertidal vs. upstream) between hatchery- and natural-origin fish affect their fitness. Those modeling results indicate that hatchery-origin pink salmon spawning in streams produce ~ ½ the number of returning adult offspring as natural-origin pink salmon. These results were reported in the summer of 2019 and at subsequent public meetings. A manuscript summarizing the 1st generation fitness results for odd- and even-year PWS pink salmon from Hogan Bay and Stockdale Creek (2013–2016) was published in Evolutionary Applications February 2022. This program encompasses additional years from these streams, additional streams, and an additional generation (grandparents), all of which will provide a better understanding of what is driving the observed variation and how to assess the impact on fitness of hatchery fish in the wild.

Table 3. Summary of relative reproductive success (RRS) results by stream and brood year for PWS pink salmon.

HOGAN		# Genotyped			Offspring Assigned					RRS (95% CI)	
		Parents		Offspring							
Year	pHOS (BY)	Hatchery	Natural		%	Hatchery	Natural	Dyads	Triads	Male	Female
13/15	64%	442	321	3,775	2.9%	6	104	110	-	0.05 (0.01-0.17)	0.03 (0.01-0.08)
14/16	92%	428	213	9,257	11.2%	627	463	1,041	49	0.80 (0.68-0.94)	0.62 (0.52-0.74)
15/17	58%	4,383	3,775	3,160	6.4%	41	221	201	61	0.16 (0.09-0.25)	0.17 (0.10-0.26)
16/18	21%	2,289	9,324	7,547	34.6%	502	2,817	2,608	711	0.68 (0.58-0.78)	0.76 (0.67-0.86)
17/19	69%	925	3,164	4,197	3.1%	5	127	129	3	0.18 (0.06-0.44)	0.07 (0.01-0.30)

STOCKDALE		# Genotyped			Offspring Assigned					RRS (95% CI)	
		Parents		Offspring							
Year	pHOS (BY)	Hatchery	Natural		%	Hatchery	Natural	Dyads	Triads	Male	Female
13/15	16%	163	811	6,053	2.1%	10	119	129	-	0.69 (0.31-1.35)	0.17 (0.03-0.55)
14/16	74%	431	356	5,670	22.3%	445	1,014	1,263	196	0.29 (0.25-0.34)	0.43 (0.37-0.50)
15/17	24%	1,487	6,064	8,702	6.5%	71	561	564	68	0.66 (0.46-0.93)	0.41 (0.29-0.58)
16/18	8%	337	5,794	4,048	12.3%	15	551	499	67	0.60 (0.27-1.14)	0.37 (0.16-0.73)
17/19	10%	933	8,687	6,804	8.9%	30	699	604	125	0.42 (0.24-0.68)	0.38 (0.22-0.61)

GILMOUR		# Genotyped			Offspring Assigned					RRS (95% CI)	
		Parents		Offspring							
Year	pHOS (BY)	Hatchery	Natural		%	Hatchery	Natural	Dyads	Triads	Male	Female
14/16	56%	309	234	3,179	32.6%	705	630	1,037	298	0.82 (0.69-0.96)	0.88 (0.76-1.01)
16/18	12%	28	278	2,710	23.4%	5	80	635	168	0.62 (0.10-2.05)	0.62 (0.15-1.69)

ERB		# Genotyped			Offspring Assigned					RRS (95% CI)	
		Parents		Offspring							
Year	pHOS (BY)	Hatchery	Natural		%	Hatchery	Natural	Dyads	Triads	Male	Female
14/16	23%	473	1,046	6,939	38.4%	441	2,842	2,668	615	0.33 (0.28-0.39)	0.34 (0.30-0.39)

PADDY		# Genotyped			Offspring Assigned					RRS (95% CI)	
		Parents		Offspring							
Year	pHOS (BY)	Hatchery	Natural		%	Hatchery	Natural	Dyads	Triads	Male	Female
14/16	60%	618	358	2,890	21.4%	465	356	619	202	0.96 (0.78-1.19)	0.63 (0.53-0.76)

Funding – In 2015, a finance committee was formed comprised of hatchery operators, a processor representative, and the ADF&G commissioner's office and aquaculture section. This team has focused attention on securing the funding to meet the projected research costs of $18.4 million to complete the study.

In 2016, ADF&G successfully secured funding from NOAA's Saltonstall-Kennedy Grant Program ($250,000) and North Pacific Research Board ($289,000) to genetically analyze adult and offspring pink salmon from 2 streams in PWS over 2 brood years as part of the fitness study. To date, NSRAA has received $755,000 in grants from the Pacific Salmon Commission to support sampling of chum salmon in SEAK. Seven of Alaska's largest hatchery corporations (SSRAA, NSRAA, DIPAC, PWSAC, VFDA, KRAA, and CIAA) have combined to provide $3.6 million. This project has received $3.9 million from the 2016 Pink Salmon Disaster to fund the completion of the pink salmon-related portions of the project. These funds are restricted to pink salmon applications and continued funding is necessary to complete the chum salmon studies.

To date, project funding received totals $13.5 million. Of this, the Seafood Processors Association has provided $3.7 million, the State of Alaska appropriated $3.5 million, PNP operators combined have provided $3.6 million, and $1.3 million is from grants. An additional $1.4 million has come from the awarded Pink Salmon Disaster funds. The current State of Alaska budget precludes additional state funds; however, ADF&G will continue to provide considerable in-kind support.

Future –Field work for Questions 1 and 2 has been completed; portions of which have been published in peer-reviewed scientific journals (referenced below). While the scope of work for the research project to address the fitness question (Question 3) was narrowed, there are still significant costs. The science panel

considers the fitness studies to be the most important to long-term understanding of hatchery-wild fish interactions. Some funding has been secured from federal grants (NPRB, SK, Northern Fund of the Pacific Salmon Commission, and the 2016 Disaster Relief) but continued funding for the remaining portion of this component of the project is currently being provided by fishermen through the hatchery organizations via additional cost recovery, as well as the processor community through a consensus agreement. ADF&G is actively pursuing additional grant funding to support this work.

It is particularly important that hatchery operators and processors continue their support of the project, both for financial reasons as well as showing a commitment to maintaining this ground-breaking research that is designed to directly address questions about the Alaska salmon hatchery program. Processors had initially committed to 5 years; we hope they will continue their same level of support for the remainder of the project.

The field portion of this project is expected to end in 2023 and the project is expected to conclude in 2024-2025 with the completion of the fitness analysis of chum salmon in SEAK.

This study provided the Marine Stewardship Council and Alaska Seafood Marketing Institute information helpful for their certification programs.

Additional information on this project is available at:
http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.main

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