Tracing the impacts of Canadian commercial fisheries on Northern BC chum stocks using DNA and otolith analysis
Results from 2019

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ABSTRACT

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Otoliths were collected from chum salmon (*Oncorhynchus keta*) caught in Canadian Area 3 commercial fisheries in 2019 to identify the component of hatchery stocks within the catch using thermal marks. A total of 685 chum otoliths were sampled in Area 3 between the dates of June 24th and July 22nd, 2019, and 675 were readable. Two of four open sub areas of Area 3 (3B, 3C) were sampled during seven gillnet and three seine commercial fishing openings.

We sampled 3.17% of the catch. Of the specimens sampled, 62.5% were marked; 37.5% were not marked. This is the second year in a row showing low mark rates. On the other hand overall catches of chum were the lowest seen since 2011 when this project began, thus the sample number was low. Of those marked, 98.3% were released from southern southeast Alaska, with 90.5% released specifically from Nakat Inlet, Alaska.

In 2019, we also intended to collect samples from Area 6 fisheries to analyze the hatchery composition, but no fisheries occurred due to low wild chum returns to that area. Instead, a Charter Patrol-person collected samples during escapement surveys. In total, 105 samples were collected and 104 were readable. Of those, 6 were marked: 2 were from Kitimat hatchery, 3 were from Anita Bay Hatchery, and 1 from Neets Bay. Although the sample rate was low, it is an indication that straying from Southeast Alaskan hatcheries may be impacting Area 6 wild chum.

INTRODUCTION

Funding for this project was provided by the Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund (Northern Fund) to estimate hatchery contributions to chum salmon (*Oncorhynchus keta*) fisheries in Area 3 (also Area 6, though no fisheries occurred in 2019). This project funded the analysis of chum DNA samples held in DFO's Molecular Genetics Lab (MGL) to develop a baseline built upon single nucleotide polymorphisms (SNP). This information allows managers to use hatchery proportion data to identify chum retention opportunities for the Area 3 commercial fishing fleet while minimizing impacts on weak wild chum stocks. This year was the 8th year of analysis of otolith marks and the first year of the development of a DNA SNP baseline of Northern BC wild chum stocks.

Current sockeye and pink salmon-directed commercial fisheries in Area 3 are limited by concerns for bycatch of chum stocks originating from Area 3 and 4. Further, fisheries directed towards Kitimat hatchery-reared chum salmon in Area 6 are limited by concerns about stock composition of wild versus hatchery fish. Time and area closures and non-retention of chum salmon are used to limit commercial fishing impacts on chum stocks of concern, but greater information about stock composition of chum by-catch can reduce those limitations.

Limited commercial salmon fishing opportunities in Area 3 and 6 in recent years has meant that DFO has provided less than the planned 2,100 samples to the Alaska Department of Fish and Game (ADF&G) Mark, Tag and Age (MTA) Laboratory in Juneau, Alaska. This year we provided 685 samples from Area 3 commercial fisheries and 105 samples from Area 6 creeks and rivers. This was less than ideal, but the percentage of catch sampled was the highest since the project's inception. Limited fish abundance, fewer fishing opportunities and participating vessels and weather patterns were factors that determined the number of samples collected.

The project continued to use the ADF&G MTA Lab to determine the presence or absence of thermal marks and the location of origin. This was to ensure accurate results and to be cost efficient. DFO's MGL lab developed baselines for 20 populations of the 103 systems from Areas 3-10 that are held by the lab. The 20 populations were chosen for their representation geographically and by Conservation Unit nearest to the study site. In future years, DNA from unmarked chum caught in commercial fisheries should be able to be matched with a population.

METHODS

The sample collection approach was to coordinate the chum sampling effort with the existing sockeye stock id sampling program in Area 3. This program involved on-water sampling crews approaching seine and gillnet fishing boats in two 5.4-meter rigid-hulled inflatable boats (RHIBs) and requesting to board. During fisheries where chum salmon retention was allowed, chum were tagged using zap straps colour-coded to the sub area where they were caught and then the heads were picked up from processing plants. Tissue samples were also collected and mounted on Watnum paper (for future analysis, funding dependent). During fisheries where

chum salmon retention was prohibited, samplers were present while incidental chum were brought on board, and the fish were sampled in the field. Because of difficulties removing otoliths on the water, fish were sampled in Prince Rupert. Otolith removal was done by cutting the head with a knife from the back of the head to just behind the eye (Shaw, 1998, p. 79). Otoliths were then removed with forceps, cleaned and placed in numbered trays for shipment to Alaska. Data collected was entered into an Microsolft Excel spreadsheet (Tables 1 and 2).

In Area 6, no commercial fishing opportunities were allowed in 2019 due to concerns over low returns of wild chum. The DFO contracted a Charter Patrol person to collect otoliths from the spawning grounds, specifically 12 in Devastation Channel, 30 at Cornwall Point, and the remainder from the Little Wedeene River, Hirsch Creek, Quaal River, Humphry's Creek, Bish Creek and Foch River. Otoliths were removed in the field and stored in vials. Alaskan hatchery marked chum were found in the Foch and Quaal Rivers.

Thermal marking of salmonid otoliths is an effective tool for identifying hatchery salmon (Munk and Smoker 1991; Volk et al. 1990) because thermal mark identification is quick and fairly accurate (Hagen et al. 1995). Salmonid otoliths are thermal marked by exposing them to repeated temperature cycles that create patterns of optically-dense bands (Volk et al. 1990).

The chum salmon otoliths were prepared for thermal mark examination in the ADF&G MTA Lab. The otoliths were cleaned with a chlorine solution (5%), rinsed with a de-chlor solution (0.7% thiosulfate), and then mounted on 1- by 2-inch glass slides with thermoplastic cement. Otoliths were examined for thermal mark presence by grinding the otolith on a grinder using 800 grit grinding paper until the primordia were visible under 200x magnification on a compound microscope. Fine polishing was performed by hand using 9 µm grinding paper. Readers identified specimens as marked, unmarked, or unreadable. If a specimen was marked, readers described the mark with special codes known as hatch codes. For quality control, each specimen was independently read a second time, and any conflicts between the two reads were resolved.

The MGL lab created 20 single nucleotide polymorphisms (SNP) baselines from existing samples held in archives.

RESULTS

In 2019, the following standards were met as described below:

1) To meet the sampling objectives of the project design (2000 max).
   - 685 chum otoliths were sampled in Area 3 between the dates of June 24th and July 22nd, 2019. This number of samples made up 3.17% of the catch. Two of four sub areas of Area 3 (3B, 3C) were sampled during 7 gillnet and 3 seine commercial fishing openings. Additionally, 105 samples were collected from Area 6 chum during escapement surveys on creeks and rivers between July 20th and August 26th, 2019. Sampling was constrained by several factors, including:
     - Fewer chum encountered while fishing.
     - Fewer openings due to concerns for local sockeye and pink stocks.

- Weather conditions were sometimes challenging for technicians to access fishing grounds.

2) To provide all chum biological sampling information collected.
   - Findings from 8 years of chum otolith analysis is available in Table 1-6
     - Table 1: Chum otolith analysis results by fishing week and gear in 2019.
       - Note that the low number of samples in early weeks may mean that the marking proportion may not be accurately reflected.
     - Table 2: Percentage of marked chum catch by fishing week 2012-2019 (all areas, both gear types).
       - Although not apparent in 2019 due perhaps to the low sample number, overall by the third week of July there was a drop in the percentage of marked chum caught in Area 3 commercial fisheries and a noticeable drop in the percentage of marked chum caught in August. More consistent sampling across all years would be helpful to see patterns but fisheries management has curbed fisheries during August to protect weak Area 3 and Area 4 stocks.
       - Note that percentages of marked chum catch may differ slightly from percentages of marked chum sampled as samplers are not out every sampling day.
     - Table 3: Percentage of marked chum by sub-Area 2012-2019.
       - Although not apparent in 2019 due perhaps to the low sample number overall outside fisheries (3B) encounter a lower percentage of unmarked chum, meaning that they have less chance of impacting weak Area 3 and Area 4 chum stocks.
     - Table 4: Percentage of marked chum by sub-Area and fishing week 2012-2019.
       - The breakdown by sub-Area and fishing week shows that the fisheries occurring in August and moving up towards the Nass River (3B being furthest to sea, 3D being closer to the Nass) have the most encounters with unmarked chum salmon (e.g., non-hatchery).
     - Table 5: Percentage of marked chum catch per gear type 2012-2019.
       - Gear does not appear to influence the impact on unmarked chum as much as time and area.
     - Table 6: Origin of chum by fishing week in 2019.
       - Most marked chum originate from hatcheries in Southern Southeast Alaska.

3) To prepare otoliths for lab analysis and obtain hatchery marking information.

- In total, between Area 3 and 6, 790 chum were sampled with 11 otoliths not being readable by the ADF&G otolith lab.
- Throughout the sampling in 2019, 61% of otoliths collected in Area 3 showed thermal marks while 37% did not and 1.5% were unreadable.
- In Area 6 on the spawning grounds, 6% were marked (4% from Alaska), 93% were unmarked, and 1% were unreadable.

4) The MGL Lab will analyze SNPs to develop a DNA baseline for Area 3-6 chum.
   - A baseline has been developed and if funding is available in 2020, samples taken from 2019 fisheries will be analyzed.

5) To analyze and report spatial-temporal Area 3 chum mark rates and biological characteristics.
   - See Tables 1-6 for more information.

DISCUSSION

This project aligns with the mandate of the Northern fund, "to assist stocks and fisheries covered under the Pacific salmon Treaty" and contributes to all of the Northern fund committee objectives outlined in Chapter 2 part 5 of the Pacific salmon Treaty:

A) Evaluate the effectiveness of management actions;
B) Identify and review the status of pink, chum, sockeye and coho stocks;
C) Present the most current information on harvest rates and patterns on these stocks and develop a joint data base for assessments;
D) Collate available information on the productivity of stocks in order to identify escapements which produce maximum sustainable harvests and allowable harvest rates;
E) Present historical catch data, associated fishing regimes and information on stock composition in fisheries harvesting this stock;
F) Devise analytical methods for the development of alternative regulatory and production strategies;
G) Identify information and research needs, including future monitoring programs for stock assessments; and
H) For each season make stock and fishery assessments and recommend to the Northern Panel conservation measures consistent with the principals of the Treaty.

The intent of the program is to better understand the temporal and geographical patterns of wild chum abundance in Area 3 and 6 commercial fisheries to ensure that management actions in place to protect weak Area 3, 4 and 6 wild chum are successful.

With the information obtained through this project, managers have been advised that in Area 3, earlier fisheries further away from the Nass River encounter fewer unmarked chum (see Table 2-5). However, in some years, the proportion of unmarked fish can be high and knowing their origin would be beneficial for management. It is potentially possible through DNA SNP analysis to identify the origin populations, and in 2019, the MGL lab in Nanaimo began to develop a

baseline of Area 3-6 chum. In 2020, we hope to begin analyzing samples from unmarked chum caught in the 2019 fisheries.

The Northern Boundary Run Reconstruction Model feeds an Area 3-5 Chum Model that assumes very few of the chum encountered in the Area 3 fisheries are destined for Area 3 or Area 4. These assumptions are based on tagging studies in the 1980s (before expansions of Alaskan hatchery programs) and assumptions of similar migration patterns to sockeye and pink salmon. If these assumptions are true, the impact of Area 3 fisheries on chum destined for Area 3 or 4 is very minimal under the current management regime. However, if that assumption is not correct and more of the unmarked fish in Area 3 fisheries are destined to spawn in Area 3 or 4, more management actions may be required in years of lower abundance of returning chum salmon.

In our analysis of chum otoliths taken from spawning grounds in Area 6, we found 4 otoliths from Southeast Alaskan hatcheries. Having approximately 4% of the samples come from Alaskan hatcheries shows surprising straying. Further analysis is required to understand the straying impacts on Area 3 and 6 chum.

ACKNOWLEDGEMENTS

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TABLES

Table 1: Chum otolith sampling results by fishing week and gear in 2019.

Stat Week (CDN/AK)	Gear	Area	# of samples	Unread	Marked	Unmarked	% Total Marked	% Total Unmarked
64/26	GN	3B	5	0	1	4	20%	80%
64/26	GN	3C	2	0	1	1	50%	50%
71/27	GN	3B	30	0	22	8	73%	27%
71/27	GN	3C	4	0	1	3	25%	75%
72/28	GN	3B	50	0	40	10	80%	20%
72/28	GN	3C	35	0	23	12	66%	44%
73/29	GN	73	1	0	1	0	100%	0%
72/28	SN	3B	111	2	72	39	65%	35%
73/29	SN	3B	207	5	127	80	61%	39%
73/29	SN	3C	23	0	14	9	61%	39%
74/30	SN	3B	195	3	113	82	58%	42%
74/30	SN	3C	12	0	7	5	58%	42%
All	**GN/SN**	**All**	**675**	**10**	**422**	**253**	**62%**	**38%**

Table 2: Percentage of marked chum by fishing week 2012-2019 (all areas, both gear types). Note that there was a low number of samples in 2019 in early weeks due to low chum numbers.

	Fishing week (CDN/AK)							
Year	**64/26**	**71/27**	**72/28**	**73/29**	**74/30**	**75/31**	**81/32**	**82/33**
2012	87%	89%	85%	94%	77%	46%	56%	-
2013	-	79%	79%	63%	67%	92%	-	-
2014	71%	83%	84%	81%	72%	81%	28%	-
2015	-	-	87%	83%	-	75%	46%	39%
2016	77%	81%	78%	69%	62%	69%	-	-
2017	100%	82%	87%	78%	80%	79%	-	-
2018	88%	78%	74%	52%				
2019	29%	68%	69%	62%	58%			
Average	75%	80%	80%	73%	70%	74%	43%	39%

Table 3: Percentage of marked chum by sub-Area 2012-2019.

	Sub-Area			Sample Rate
Year	**3B**	**3C**	**3D**	
2012	80%	71%		2.01%
2013	83%	64%		1.38%
2014	72%	70%		2.96%
2015	82%	68%		0.91%
2016	76%	68%		1.55%
2017	84%		67%	1.52%

2018	mixed	mixed		2.38%
2019	63%	61%		3.17%
Average	77%	57%	67%	

Table 4: Percentage of marked chum by sub-Area and fishing week 2012-2019.

Year	SubArea	Fishing Week	% Marked	Average per Stat Area
2012	3B	71/27	91%	80
		72/28	88%	
		73/29	94%	
		75/31	43%	
		81/32	84%	
	3C	64/26	87%	71
		71/27	82%	
		72/28	84%	
		73/29	84%	
		74/30	77%	
		75/31	47%	
		81/32	28%	
2013	3B	71/27	89%	83%
		72/28	82%	
		73/29	82%	
		74/30	67%	
		75/31	92%	
	3C	71/27	69%	64%
		72/28	75%	
		73/29	63%	
		75/31	48%	
2014	3B	71/27	83%	72%
		72/28	83%	
		73/29	77%	
		74/30	80%	
		75/31	83%	
		82/33	26%	
	3C	64/26	71%	70%
		71/27	83%	
		72/28	85%	
		73/29	84%	
		74/30	63%	
		75/31	79%	
		82/33	29%	
2015	3B	71/27	87%	82%
		72/28	86%	

		73/29	81%	
		75/31	76%	
	3C	71/27	90%	68%
		72/28	87%	
		73/29	84%	
		75/31	60%	
		81/32	46%	
		82/33	39%	
2016	3B	64/26	77%	76%
		71/27	88%	
		72/28	81%	
		73/29	74%	
		74/30	64%	
		75/31	72%	
	3C	64/26	76%	68%
		71/27	73%	
		72/28	71%	
		73/29	63%	
		74/30	59%	
		75/31	66%	
2017	3B	71/27	97%	84%
		72/28	87%	
		73/29	78%	
		74/30	80%	
		75/31	79%	
	3D	71/27	67%	67%
2018	3B	64/26	88%	
		71/27	78%	
	3B/3C*	72/28	71%	
	3B/3C*	73/29	52%	
2019	3B	64/26	20%	57%
		71/27	73%	
		72/28	73%	
		73/29	61%	
		74/30	58%	
	3C	64/26	50%	56%
		71/27	25%	
		72/28	66%	
		73/29	81%	
		74/30	58%	

Table 5: Percentage of marked chum catch per gear type 2012-2019.

Year	Seine	Gillnet	Average
2012	92%	87%	90%
2013	79%	75%	77%
2014	80%	83%	82%
2015	83%	86%	85%
2016	68%	77%	73%
2017	92%	100%	96%
2018	mixed	mixed	mixed
2019	55%	61%	58%
Average	78%	81%	80%

Table 6: Origin of chum by fishing week in 2019

Row Labels	Count of MARK_ID
	362
ANITABAY13	**1**
30	**1**
3C	1
ANITABAY15	**9**
27	**2**
3B	2
28	**1**
3B	1
29	**2**
3B	1
3C	1
30	**1**
3B	1
33	**2**
6	2
35	**1**
6	1
ANITABAYLL15	**1**
28	**1**
3B	1
BEARCOVE15A	**1**
30	**1**
3B	1
DIPAC14	**1**

29	**1**
3B	1
DIPAC15B	**2**
27	**1**
3B	1
28	**1**
3B	1
KENDRICK13	**1**
30	**1**
3B	1
KENDRICK15	**22**
27	**1**
3B	1
28	**7**
3B	4
3C	3
29	**6**
3B	6
30	**8**
3B	8
KITH2014CHUMH14	**1**
34	**1**
6	1
KITH2015CHUMH14	**1**
34	**1**
6	1
NAKATINLET14SUM	**21**
27	**3**
3B	3
28	**9**
3B	8
3C	1
29	**7**
3B	7
30	**2**
3B	2
NAKATINLET15FALL	**4**
30	**4**
3B	4
NAKATINLET15SUM	**332**
26	**2**

3B	2
27	**16**
3B	16
28	**111**
3B	94
3C	17
29	**116**
3B	104
3C	12
30	**87**
3B	83
3C	4
NAKATINLET16SUM	**25**
28	**4**
3B	2
3C	2
29	**9**
3B	8
3C	1
30	**12**
3B	10
3C	2
NEETSBAY14SUM	**1**
34	**1**
6	1
NEETSBAY15SUM	**1**
28	**1**
3B	1
NEETSBAY16SUM	**2**
29	**1**
3B	1
30	**1**
3B	1
NITH2015CHUM31H	**1**
30	**1**
3B	1
PORTARMSTRONG15CHUMA	**1**
30	**1**
3B	1
Grand Total	**790**

FIGURE 1. LOCATION OF AREA 3 IN NORTHERN BRITISH COLUMBIA.