Fishery Data Series No. 18-21

Estimation of U.S.–Canada Border Age-composition of Yukon River Chinook Salmon, 1982–2006

by

Toshihide Hamazaki

July 2018

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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 DATA SERIES NO. 18-21

ESTIMATION OF U.S.-CANADA BORDER AGE-COMPOSITION OF YUKON RIVER CHINOOK SALMON, 1982–2006

by
Toshihide Hamazaki
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

July 2018

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/ This publication has undergone editorial and peer review.

Toshihide Hamazaki,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, AK 99518, USA

This document should be cited as follows:
Hamazaki, T. 2018. Estimation of U.S.-Canada border age-composition of Yukon River Chinook salmon, 1982–2006. Alaska Department of Fish and Game, Fishery Data Series No. 18-21, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This study estimated age and sex composition of Canadian-origin Yukon River Chinook salmon at the United States (U.S.)-Canada border from 1982 to 2006. In 2012, the Joint Technical Committee of the Yukon River Panel (JTC) adopted a change to the assessment methods used to estimate U.S.-Canada border passage of Canadian-origin Chinook salmon from a fish wheel mark–recapture operated by Fisheries and Oceans Canada (DFO) to a sonar with a gillnet test fishery at Eagle operated jointly by the Alaska Department of Fish and Game (ADF&G) and DFO since 2005. Because the 2 fish capturing methodologies (fish wheel versus gillnet) resulted in different age-sex compositions, it was necessary to adjust the age-sex composition assessed by the fish wheel to those of the gillnet test fishery. Age, sex, and length (ASL) data were collected from fish sampled using both methods from 2005 to 2012, except 2009. Using 2007, 2008, 2010–2012 data, fish wheel age-sex compositions were adjusted using 2 methods: (1) age-sex selectivity and (2) length selectivity, and compared to the age-sex compositions observed in the gillnet test fishery. Although both methods performed similarly, the age-sex selectivity method was slightly better than the length selectivity method to adjust age-sex composition. However, because of uncertainties about the 2007–2012 data representing historical fish wheel data, the length selectivity method was chosen to adjust the 1982–2006 age-sex composition. Length selectivity converted 1982–2006 age-sex proportion are presented, and the uncertainties and limitations are discussed.

Key words: Chinook salmon, age-sex composition, Canadian-origin, U.S.-Canada border, Yukon River.

INTRODUCTION

Under the United States (U.S.) and Canada Yukon River Panel, the Yukon River Joint Technical Committee (JTC) has been evaluating management plans and an escapement goal for Canadian-origin Chinook salmon (*Oncorhynchus tshawytscha*), for which the most important information is an assessment of the abundance and age-sex composition of Canadian-origin Chinook salmon passing through the U.S.-Canada border. The assessment serves as the fundamental basis for construction of a brood table and characterizing age-sex composition of Canadian-origin Chinook salmon escapement.

Assessment methods have changed over time. From 1982 to 2004 border passage and biological sampling was assessed by the Department of Fisheries and Oceans Canada (DFO) using fish wheel mark–recapture techniques (Milligan et al. 1985; Johnson et al. 2002; JTC 2017). Since 2005 (with transition period 2005–2007), assessments have been done using sonar methods at Eagle Alaska, under a joint project run by DFO and the Alaska Department of Fish and Game (ADF&G). Biological sampling at Eagle was carried out as a component of the sonar project using a suite of drift gillnets of multiple mesh sizes (gillnet test fishery). In 2005, mesh sizes were 2.75, 4, 5.5, 6.5, 7.5, and 8.5 inches, and in 2006 mesh sizes were 2.75, 4, 5.25, and 7.5 inches (Carroll et al. 2007; Dunbar and Crane 2007). Since 2007, mesh sizes have been standardized to 5.25, 6.5, 7.5 and 8.5 inches (McDougall and Lozori 2017).

All gear types used to capture fish are selective for certain physical and behavioral characteristics (Hubert et al. 2012). Using a single sampling gear leads to biased age-sex composition, and changes in sampling gears through time could make it difficult to distinguish whether the changes in age-sex composition reflect actual biological shifts or are a result of changing sampling gears. Since inception of the fish wheel U.S.-Canada border assessment program in 1982, it has been recognized that fish wheels catch predominantly smaller and younger salmon, such that fish wheel age composition was biased. To correct this bias for construction of a brood table of Canadian-origin Chinook salmon, Bromaghin (Appendix B2) developed a fish wheel age selectivity conversion factor. Bromaghin (Appendix B2) estimated age selectivity of fish wheel by comparing its age composition to "true" age composition, which was then used to convert fish wheel age composition. This conversion factor has been applied to fish wheel age composition to estimate the U.S.-Canada Chinook salmon border age composition and construction of a brood table (Appendix A1) as documented by the JTC (JTC 2017), though the methods used to construct the brood table were not documented.

Since the inception of the Eagle sonar and gillnet test fishery in 2005, it was noticed that the converted fish wheel age composition differed from those of the gillnet test fishery. This prompted a study by MacDonald and Labelle (Appendix B3) in 2012 to investigate (1) the merit of developing alternative conversion factors, and (2) the suitability of the gillnet test fishery at Eagle to represent border passage age composition (Appendix B3). Using simulation techniques, MacDonald and Labelle (Appendix B3) reported that the length distribution of Chinook salmon captured by the standard gillnet test fishery (mesh sizes of 5.25, 6.5, 7.5 and 8.5 inches) was indistinguishable from those of random samples and that the length distribution of the fish wheel catch was closest to those from a 5.25-inch mesh gillnet. MacDonald and Labelle (Appendix B3) indicated that the standard gillnet test fishery was suitable to represent border age composition and suggested future work to develop a new factor that would convert historical fish wheel age composition and construct a revised brood table.

Based on those findings, in 2017, the JTC assigned ADF&G to develop a method to convert the historical fish wheel age-sex composition to those of standard gillnet test fishery (Appendix B1). This report describes development of a methodology and a standardized age-sex composition for years 1982–2006.

OBJECTIVES

Objectives of this study were as follows:

1. Develop a method to adjust the age-sex proportion of Canadian-origin Chinook salmon assessed at the U.S.-Canada border using fish wheels to be comparable to proportions estimated using the Eagle sonar gillnet test fishery.
2. Using the method, convert 1982–2006 U.S.-Canada Chinook salmon border age-sex composition.

METHODS

Assuming that the gillnet test fishery catches are representative of Chinook salmon passing Eagle sonar, 2 major conversion methodologies were developed: (1) age-sex selectivity method and (2) length selectivity method. The first method extended the methodology developed by Bromaghin (Appendix B2) to age-sex composition, in which age-sex selectivity parameters were estimated to maximize similarity of the fish wheel age-sex composition to those of the gillnet test fishery. The second method was based on MacDonald and Labelle (Appendix B3) that estimates fish wheel length selectivity function parameters to maximize similarity of length distribution between fish wheel and gillnet test fishery.

Age-sex selectivity method

Assuming that the fish wheel was selective with respect to age (a) and sex (s), the number of age (a) and sex (s) fish captured by a fish wheel in year (y) (n_{asy}) is proportional to the total number the fish in the river (N_{asy}) and age-sex selectivity (s_{as}) of the fish wheel.

$$n_{asy} \propto N_{asy} \cdot s_{as} \,. \tag{1}$$

Then, the proportion of age (a) and sex (s) fish passing the U.S.-Canada border in year (y) (π_{asy}) is estimated as:

$$\hat{\pi}_{asy} = \frac{N_{asy}}{\sum_a \sum_s N_{asy}} = \frac{\frac{n_{asy}}{s_{as}}}{\sum_a \sum_s \frac{n_{asy}}{s_{as}}}. \tag{2}$$

The age-sex selectivity (s_{as}) was estimated using maximum likelihood method, minimizing multinomial negative log-likelihood,

$$nll = -\sum_y \sum_a \sum_s n'_{asy} \ln(\hat{\pi}_{asy}), \tag{3}$$

where n'_{asy} is the number of age (a) and sex (s) fish of caught by the Eagle gillnet test fishery in year (y).

Length selectivity method

Similar to equation (1), but assuming that the fish wheel is selective with respect to length (s_l), the number of fish of age (a), sex (s), and length (l) fish captured by the fish wheel in year (y) (n_{asly}) is proportional to the total number the fish in the river (N_{asly}) and selectivity of length (l) fish (s_l),

$$n_{asly} \propto N_{asly} \cdot s_l. \tag{4}$$

Then, the proportion of age (a) and sex (s) fish passing the U.S.-Canada border in year (y), (π_{asy}) is estimated as:

$$\hat{\pi}_{asy} = \frac{\sum_l N_{asly}}{\sum_a \sum_s \sum_l N_{asly}} = \frac{\sum_l \frac{n_{asly}}{s_l}}{\sum_a \sum_s \sum_l \frac{n_{asly}}{s_l}}. \tag{5}$$

In the Yukon River, the standard gillnet length selectivity function is the Pearson function (Bromaghin 2005).

$$S_{l.m} = \left(1 + \frac{\lambda^2}{4\theta^2}\right)^{\theta} \left[1 + \frac{\left(\frac{2m}{l} - \frac{\sigma\lambda}{2\theta}\tau\right)^2}{\sigma^2}\right]^{-\theta} \exp\left\{-\lambda\left[\tan^{-1}\left(\frac{\left(\frac{2m}{l} - \frac{\sigma\lambda}{2\theta}\tau\right)}{\sigma}\right) + \tan^{-1}\left(\frac{\sigma\lambda}{\theta}\right)\right]\right\}, \tag{6}$$

where m is a gillnet mesh size, and τ, σ, λ, θ are model parameters. In this function, parameter (τ) determines length at peak selectivity, σ determines spread of selectivity, and λ and θ determine sharpness of selectivity to and from the peak selectivity.

To estimate of the length selectivity parameter, from the equation (4), ignoring age and sex, the proportion of length (l) fish at the U.S.-Canada border in year (y) is estimated as:

$$\hat{p}_{ly} = \frac{\frac{n_{ly}}{s_l}}{\sum_l \frac{n_{ly}}{s_l}}, \tag{7}$$

where n_{ly} is the number of length (l) fish caught by the fish wheel in year (y).

Fish wheel length selectivity parameters were estimated by minimizing multinomial negative log-likelihood:

$$nll = -\sum_l \sum_y n'_{ly} \ln(\hat{p}_{ly}), \tag{8}$$

where n'_{ly} is the number of length (l) fish caught by the Eagle sonar gillnet test fishery in year (y).

Model fit diagnostics

For each method, mean absolute deviation (MAD) was calculated for each year, as follows:

$$MAD = \frac{\sum_a \sum_s |\pi_{asy} - \hat{\pi}_{asy}|}{n}, \tag{9}$$

where n is the total number of age-sex categories. A lower MAD indicates a better fit to the gillnet test fishery age-sex composition.

Datasets and parameter estimation

Age, sex, and length (ASL) data for the Eagle sonar gillnet test fishery were obtained from ADF&G Arctic-Yukon-Kuskokwim Database Management System (AYKDBMS) (Appendices A2 and A3), and the data for the U.S.-Canada border fish wheel were obtained from DFO (Appendix A4). Of those, only samples with complete age, sex, and length data were used. Although the proportion of complete data exceeded 99% for samples collected at Eagle gillnet test fishery, only of 48% of samples had complete data for the DFO data set (Appendix A4). The majority of incomplete samples lacked age data, which could be due to (1) scales were not collected, (2) scales were taken but were not aged, or (3) poor quality scales that were inferior for aging. The proportion of usable complete data ranged from 11% in 2001 to 81% in 2012. Overall, excluding incomplete samples did not change female proportions greatly (1–3%). Notable exceptions were in 1985 and 2001, in which the female proportion differed by 10% when partial data was included versus when it was not (Appendix A4). Both ADF&G and DFO identified sex visually, which was treated as accurate.

The AYKDBMS also contains fish wheel ASL data aged by ADF&G staff from acetate scale copies provided by DFO. The number of aged scale samples and age compositions differed slightly between the 2 data sets, probably because of difference in scale reading criteria between the agencies (Appendix A5–7). Generally, ADF&G aged more scales than DFO (Appendix A5). Notably, age composition differed greatly in 1982 and 1988 (Appendix A6), and female proportion differed in 1988 and 1996 (Appendix A7).

In this study, the data set by DFO were used based on the following reasons: (1) DFO was the primary data source, and (2) AYKDBMS was incomplete at the time of data analyses (many of DFO data were later incorporated into the AYKDBMS).

Both the gillnet test fishery and the fish wheels operated between 2005 and 2012, except for 2009 when the fish wheel was not run. Of those, 2007, 2008, and 2010–2012 data were used to estimate selectivity parameters because the gillnet test fishery was standardized beginning in 2007. The fish length measurement unit differs between ADF&G (mid-eye to tail fork: METF) and DFO (fork length: FL), so FL was converted to METF using the conversion equation estimated by MacDonald and Labelle (Appendix B3):

$$METF = 1.446 + 0.898FL \tag{10}$$

All Chinook salmon length measurements were rounded to 20 mm increments to have a sufficient number of samples in each length class (Bromaghin 2005).

To estimate age-sex selectivity parameters, age-3 fish were combined with age-4 fish, and age-8 fish were combined with age-7 fish, because of small and zero (age-8) sample sizes (Appendices A2 and A3). For the age-sex selectivity method, selectivity of age-4 males was fixed to 1.0 because fish wheels were considered to be most selective for this age-sex class (Appendix B3). To estimate length selectivity parameters, parameters of m and τ in equation (6) were fixed to 133.35 mm (5.25 inch) and 0.001, respectively. MacDonald and Labelle (Appendix B3) assumed a fish wheel mesh size (m) of 133.35 mm (Appendix B3). The value of τ equals 0.001 was selected based on preliminary data analyses and other studies suggested that shape of selectivity is negative asymptotic (Willette et al. 2016). The above parameter restrictions were set to improve estimation of parameters. *R* (R Core Team 2017) was used to estimate parameters.

RESULTS

Age-sex selectivity method

Estimated selectivity parameters were less than 1.0 for all ages and sexes (Table 1). This confirmed that the fish wheel was most selective at catching age-4 males. The selectivity parameters indicated that relative to age-4 males, age-7 females had less than a 5% chance to be captured by the fish wheel. Among age-sex classes, standard errors of age-4 female and age-7 male were large, corresponding to coefficient of variation (CV) of 59% and 27%, respectively. High CVs of those 2 age-sex classes were largely due to low sample numbers (Appendix A3 and A4). For other age classes, CVs ranged from 13% to 18%.

Length selectivity method

Fish wheel length selectivity function parameters were estimated using CVs of 13% to 34% (Table 2). The fish wheel length selectivity curve showed that the fish wheel was more selective of smaller fish than larger fish (Figure 1). This was especially true for fish greater than 800 mm MEFL where selectivity was less than 0.05. Application of the length selectivity correction method shifted the fish wheel length distribution from positive skewed to negative skewed. The model adjusted fish wheel length proportion closely matched that of the gillnet test fishery samples for 2007, 2008, and 2010–2012 (Figure 1).

Comparison of the 2 adjustment methods

Overall, the age-sex selectivity method (MAD 0.021) was slightly more successful than the length selectivity method (MAD 0.023) to adjust fish wheel age-sex composition to those of the gillnet test fishery (Table 3). However, the performance differed among years (Table 3, Figures 2 and 3). Among age-sex groups, the length selectivity method tended to overestimate the proportion of age-6 male and underestimate age-5 of both male and females (Table 4). Overall, the length selectivity method underestimated the age-5 and female proportion, but overestimated age-6 proportion (Table 4, Figures 2 and 3). However, the differences of age-sex compositions among gillnet test fishery, age-sex selectivity method, and length-selectivity method, were less than 3%. Therefore, either method can be used for conversion of historical fish wheel age-sex compositions.

DISCUSSION

The main objective of this report was to develop a conversion method that could be used to standardize age-sex composition of historical U.S.-Canada Chinook salmon border passage to those of the current gillnet test fishery, which has operated at Eagle since 2007. Overall, the age-sex selectivity method performed slightly better than the length selectivity method; however, the difference was so small that either method could be used (Tables 4 and 5; Figures 2 and 3). The data also showed that age-sex composition of the 2005 and 2006 gillnet test fisheries were more similar to those of fish wheel (Figures 2 and 3). This result was consistent with the original project reports that indicated the age and sex samples collected in gillnet test fishery were not representative of border passage in 2005 and 2006 (Carroll et al. 2007; Dunbar and Crane 2007). The biased sampling, however, was not due to small mesh sizes (2.75 and 4.0 inch) because excluding samples from those nets did not change age-sex composition. The observed differences may be due to changes in methodology. In 2005 and 2006 setnets were used, but their use was eliminated in 2007 and drift gillnets have been fished on both left and right banks since then.

In selecting a conversion method, the following factors were considered: (1) similarity of historical (1982–2006) and reference (2007–2012) fish wheel data, and (2) needs to estimate composition of age classes 3 and 8. Estimation of both selectivity parameters were based on the reference data. For a reliable conversion of historical age-sex composition, the historical (1982–2006) fish wheel data would ideally span a similar range of age-sex proportions as observed in the reference (2007–2012) data. The reference data lacked ages 3 and 8, so age-sex selectivity of those age classes were not estimated. However, because the proportion of those 2 age classes was very small (Appendix A3), ignoring or combining them to adjacent age classes would not appreciably influence brood table construction, estimation of spawner-recruit parameters, run forecasting, or discerning age-sex trends over time. When comparing the range of age-sex proportions and fish lengths between historical and reference data, the range of historical age-sex proportions were much larger than the reference data, especially the proportion of age-6 and -7 females, which were 4–13 times higher than the maximum observed values of the reference data (Table 4). On the other hand, the range of historical fish lengths was much closer to the reference data (Table 4). That suggests that the length selectivity method would be more conservative and appropriate for conversion of historical age-sex compositions.

Converted age-sex composition 1982–2006

As expected, converted fish wheel age-sex composition increased the proportion of older age classes and females (Figures 4 and 5). The revised age composition tended to lower the proportion of ages 5 and 6 and increased the proportion of ages 4 and 7 than those currently used by ADF&G. Notable differences were in 1988 and 1996 when the proportion of age 7 increased from 35% to 52% (1988) and the proportion of age 6 declined from 51% to 32% (1996). The proportion of ages 7 and 8 gradually declined and that of age 5 increased (Figure 4). Similar age trends were observed in Chinook salmon across Alaska (Lewis et al. 2015). The length-selectivity adjusted female proportion showed a declining trend (Figure 5).

It should be noted that this study assumes that changes in fish wheel age-sex composition reflects biological shifts. Operationally, drift gillnets can be configured and deployed to capture fish swimming throughout the entire river profile, whereas installation of fish wheels are often limited to near banks where sufficient water current is available, and the fish caught are limited to fish swimming near the water surface. Thus, fish wheel catches are more susceptible to the effects of the installation site and fish migration patterns, so that shifts in fish wheel age-sex composition may be reflective of both biological shifts as well as shifts in migration patterns and composition of fish swimming the in the area of the fish wheel. The history of the DFO fish wheel operation is not well documented so it is not possible to discern potential impacts of the fish wheel operation on age-sex composition. Although those uncertainties are less influential for estimation of spawner-recruit parameters, they may be influential for interpretation of age-sex trends. Furthermore, the conversion method developed here, may not convert difference in mean length at age-sex between fish wheel and gillnet test fishery (Figure 6). Uncertainties and limitations of the original fish wheel data and the conversion method should be fully recognized when using the converted age-sex composition data presented in this report.

The 2 selectivity methods were presented to the Joint Technical Committee of the Yukon River Panel on November 1, 2017 in Fairbanks, Alaska. The JTC supported the use of historical fish wheel data provided from DFO as the most complete and appropriate data set. The JTC agreed that the length selectivity model was the most precautionary method to adjust historical fish wheel data at this time.

ACKNOWLEDGEMENTS

This study is a part of ongoing studies related to the reconstruction of the Yukon River Chinook salmon run and escapement, which is solely accomplished by team efforts. I thank Elizabeth MacDonald of the Department of Fisheries and Oceans, Canada for providing historical fish wheel ASL data. My thanks also go to Andrew Munro, James Jasper, Fred West, and Zachary Liller of the Alaska Department of Fish and Game, Joel Harding and Nathan Millar of the Department of Fisheries and Oceans Canada, Catherine Bradley of the U.S. Fish and Wildlife Service, William Bechtol of Tanana Chiefs Conference, and Mike Jones of Michigan State University for draft manuscript review.

REFERENCES CITED

Bromaghin, J. F. 2005. A versatile net selectivity model, with application to Pacific salmon and freshwater species of the Yukon River, Alaska. Fisheries Research 74:157-168.

Carroll, H. C., R. D. Dunbar, and C. T. Pfisterer. 2007. Sonar estimation of Chinook salmon in the Yukon River near Eagle, Alaska, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 07-84, Anchorage.

Dunbar, R. D., and A. Crane. 2007. Sonar estimation of Chinook and fall chum salmon in the Yukon River near Eagle, Alaska, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-89, Anchorage.

Hubert, W. A., K. L. Pope, and J. M. Dettmers. 2012. Passive capture techniques. Pages 223-265 [*In*]: A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, third edition. American Fisheries Society.

McDougall, M. J., and J. D. Lozori. 2017. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 17-28, Anchorage.

Lewis. B., W. S. Grant, R. E. Brenner, and T. Hamazaki. 2015. Changes in size and age of Chinook salmon *Oncorhynchus tshawytscha* returning to Alaska. PLoS ONE 10(6): e0130184. doi:10.1371/journal.pone.0130184

Milligan, P. A., W. O. Rublee, D. D. Cornett, and R. A. C. Johnston. 1985. The distribution and abundance of Chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. Canadian Technical Report of Fisheries and Aquatic Sciences 1352.

Johnson, Y., I. Boyce, and B. Waugh. 2002. Estimation of the abundance of Chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River Basin using mark-recapture methods: 1990-1995. Canadian Technical Report of Fisheries and Aquatic Sciences 2378.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2017. Yukon River salmon 2016 season summary and 2017 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A17-01, Anchorage.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Willette, T. M., T. D. DeCino, A. W. Barclay, and X. Zhang. 2016. An evaluation of the selectivity of fish wheels used to apportion sonar counts to species on the Yentna River, Alaska. Alaska Department of Fish and Game, Fishery Manuscript No. 16-02, Anchorage.

TABLES AND FIGURES

Table 1.–Age-sex selectivity (s_{as}) for each age and sex combination.

	Age-4	Age-5	Age-6	Age-7
Female	0.360 (0.214)	0.129 (0.018)	0.092 (0.011)	0.045 (0.008)
Male	1.000	0.295 (0.036)	0.123 (0.016)	0.118 (0.031)

Note: Selectivity of age-4 male was set to 1.0. Numbers in parenthesis are model estimated standard error.

Table 2.–Length selectivity Pearson function parameters.

τ	σ	θ	λ
0.001	0.814 (0.142)	0.384 (0.129)	2.400 (0.310)

Note: Parameter (τ) was set to 0.001. Numbers in parenthesis are model estimated standard error.

Table 3.–Comparison of annual and overall mean absolute deviation (MAD) between gillnet test fishery and fish wheel proportion of original data, and converted data by both age-sex selectivity and length selectivity methods.

Year	Original	Age-sex selectivity	Length selectivity
2007	0.062	0.031	0.030
2008	0.075	0.009	0.009
2010	0.082	0.017	0.027
2011	0.100	0.027	0.032
2012	0.074	0.019	0.016
Overall	0.079	0.021	0.023

Table 4.–Comparison of the range of fish wheel age-sex compositions (percent) and METF length (mm) between reference (2007, 2008, 2010–2012) and historical (1982–2006) data.

		Reference		Historical	
Age	Sex	Min	Max	Min	Max
3	Female	0.1	0.1	0.1	0.1
4		0.1	0.7	0.1	7.1
5		2.7	6.0	1.0	25.3
6		9.3	21.4	10.3	41.2
7		0.2	1.3	0.3	16.5
8		0	0	0.1	2.0
3	Male	0.1	3.0	0.1	4.1
4		7.0	36.7	4.1	40.3
5		35.7	69.8	12.6	54.1
6		6.1	14.0	5.0	32.1
7		0.3	1.0	0.2	4.9
8		0	0	0.2	0.3
Length (mm)		400	1,130	310	1,300

Table 5.–Comparison of average age and sex composition (2007, 2008, 2010–2012) among gillnet test fishery, original fish wheel data, and data converted by both age-sex selectivity and length selectivity methods.

			Fish wheel		
Age	Sex	Gillnet test fishery	Original	Age-sex selectivity	Length selectivity
4	Female	0.002	0.003	0.002	0.005
5		0.077	0.048	0.079	0.063
6		0.332	0.154	0.334	0.328
7		0.033	0.007	0.032	0.024
4	Male	0.047	0.210	0.045	0.045
5		0.327	0.467	0.327	0.313
6		0.172	0.104	0.171	0.207
7		0.010	0.006	0.010	0.017

Table 6.–Estimated U.S.-Canada border age-sex composition converted by applying length selectivity method to 1982–2006 fish wheel data.

	Female						Male					
Year	3	4	5	6	7	8	3	4	5	6	7	8
1982		0.008	0.056	0.210	0.170	0.063		0.042	0.105	0.238	0.107	
1983		0.000	0.049	0.306	0.077			0.010	0.165	0.331	0.061	0.002
1984	Fish wheel did not operate											
1985			0.013	0.343	0.133	0.003		0.009	0.048	0.305	0.146	
1986		0.000	0.018	0.346	0.203			0.003	0.071	0.246	0.112	
1987			0.004	0.455	0.103	0.004		0.003	0.047	0.312	0.066	0.006
1988			0.023	0.147	0.370	0.035		0.014	0.127	0.123	0.150	0.012
1989		0.011	0.070	0.373	0.123	0.002	0.000	0.019	0.120	0.201	0.080	0.001
1990		0.002	0.046	0.436	0.064		0.000	0.044	0.165	0.210	0.033	
1991		0.002	0.090	0.335	0.138		0.000	0.013	0.196	0.146	0.078	
1992	0.003	0.006	0.041	0.348	0.019	0.002	0.005	0.051	0.133	0.382	0.011	
1993		0.000	0.101	0.319	0.100		0.002	0.049	0.185	0.228	0.015	
1994			0.058	0.283	0.071		0.003	0.017	0.235	0.260	0.074	
1995	0.000	0.002	0.053	0.417	0.044		0.004	0.051	0.078	0.272	0.078	
1996	0.000	0.010	0.180	0.208	0.099			0.023	0.281	0.113	0.087	
1998	0.001	0.011	0.037	0.509	0.020		0.001	0.027	0.086	0.296	0.012	
1997		0.023	0.099	0.257	0.085		0.003	0.023	0.338	0.143	0.028	
1999			0.037	0.520	0.007		0.000	0.014	0.140	0.268	0.013	
2000		0.022	0.059	0.314	0.105			0.042	0.197	0.225	0.036	
2001			0.014	0.271	0.067	0.008		0.019	0.236	0.336	0.049	
2002		0.001	0.031	0.272	0.135		0.001	0.074	0.220	0.259	0.007	
2003	0.000	0.001	0.048	0.359	0.047		0.000	0.010	0.240	0.270	0.023	
2004			0.020	0.470	0.052			0.048	0.182	0.228		
2005			0.078	0.309	0.029		0.000	0.022	0.238	0.269	0.030	
2006		0.002	0.151	0.309	0.011			0.043	0.361	0.121		

Note: Blank cells indicate that no fish were observed in the sex-age category in that year.

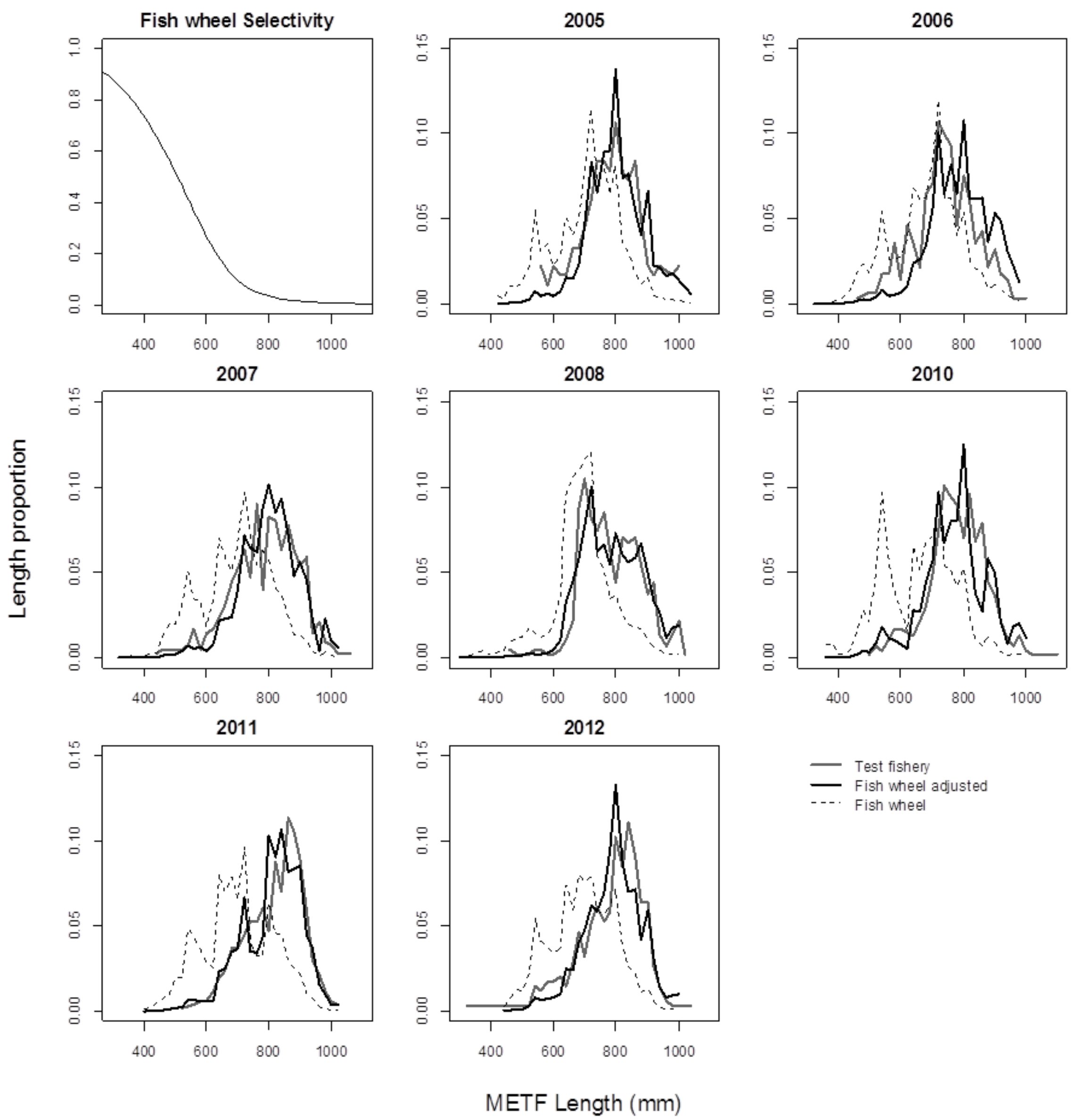


Figure 1.–Fish wheel selectivity curve and length proportion among Eagle sonar gillnet test fishery (test fishery), original fish wheel (fish wheel), and length selectivity adjusted fish wheel (fish wheel adjusted), 2005–2008 and 2010–2012.

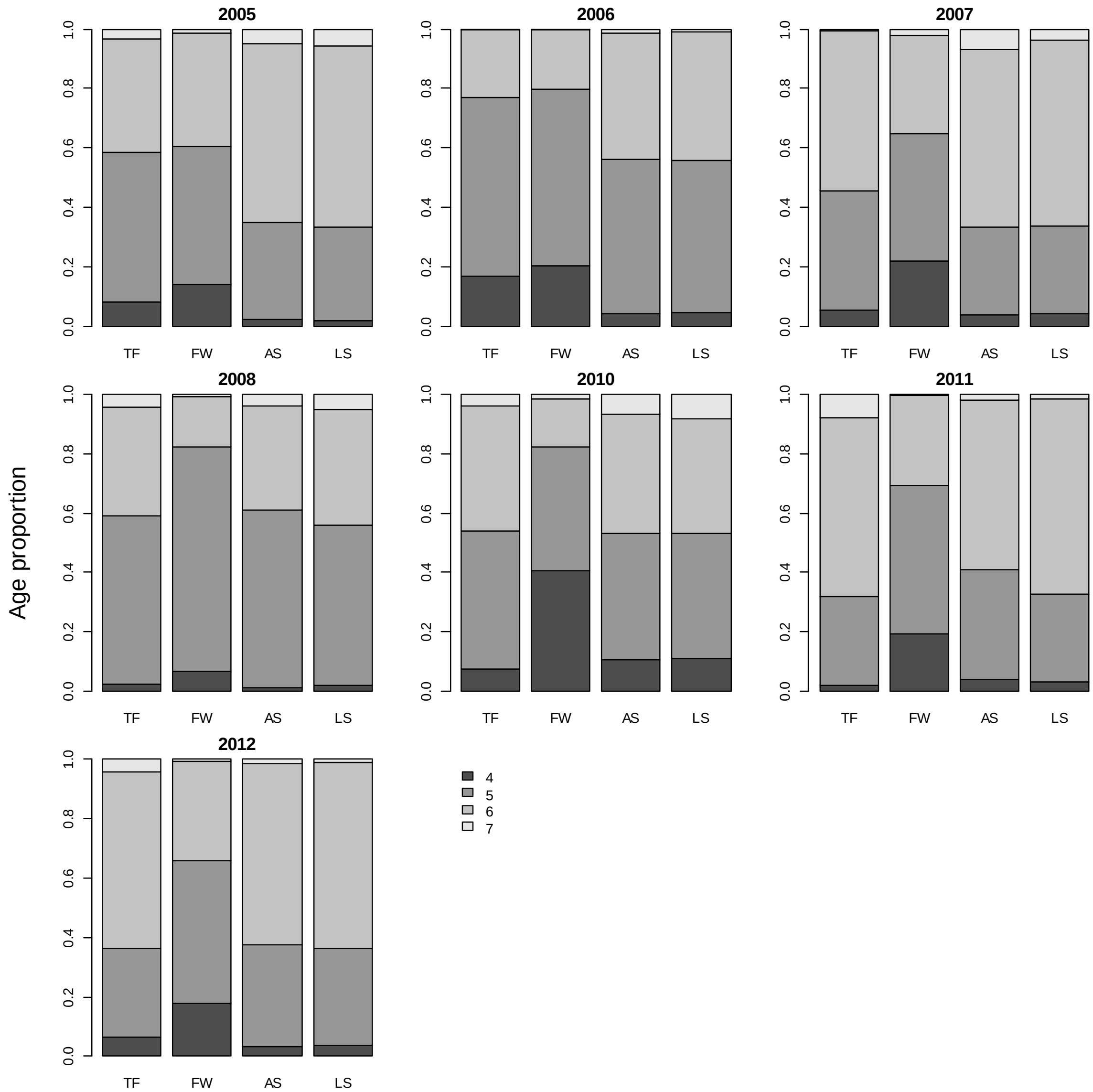


Figure 2.–Comparison of age composition among Eagle gillnet test fishery (TF), fish wheel (FW), age-sex selectivity method (AS), and length selectivity method (LS), 2005–2008 and 2010–2012.

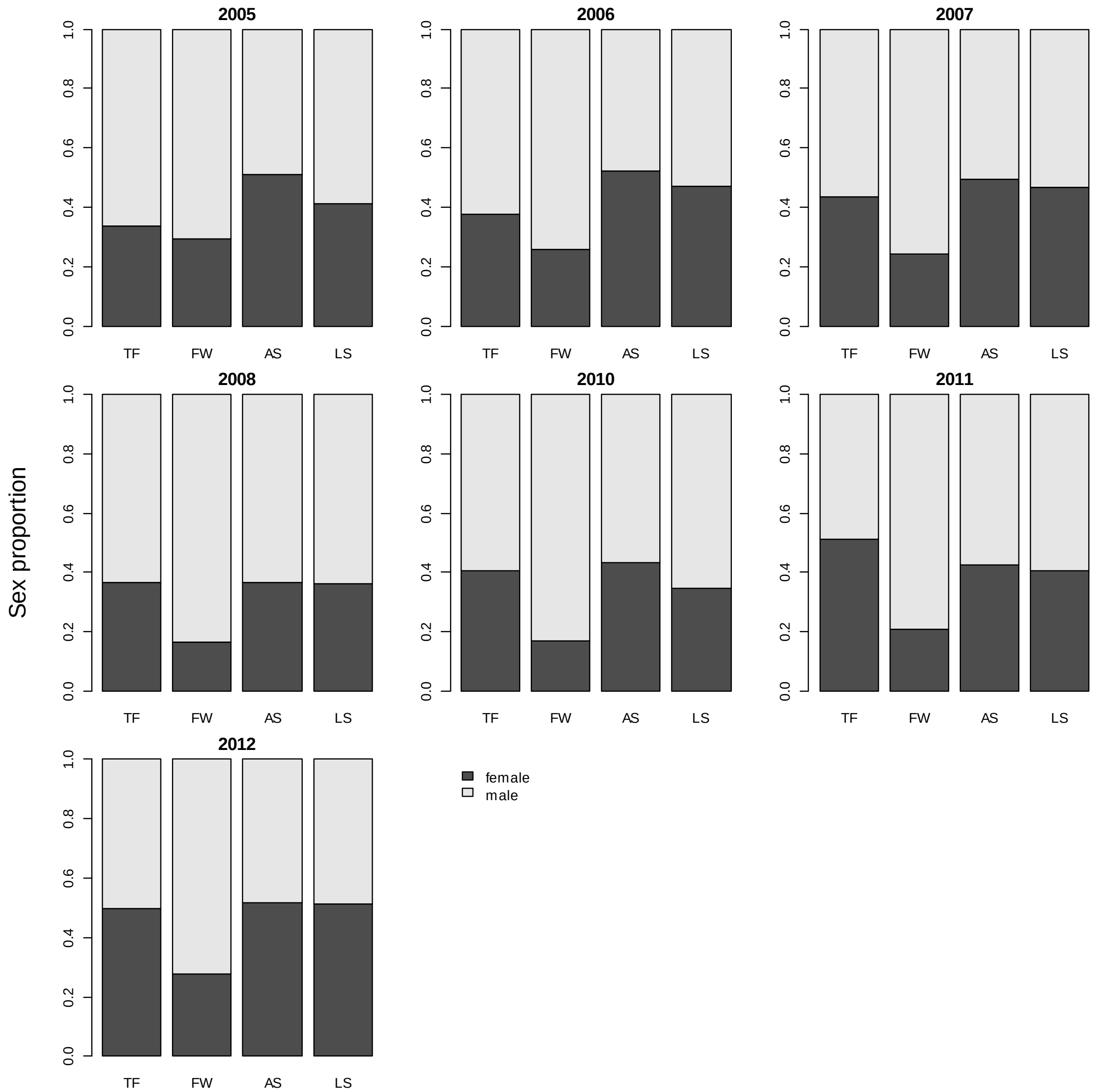


Figure 3.–Comparison of sex composition among Eagle gillnet test fishery (TF), fish wheel (FW), age-sex selectivity method (AS), and length selectivity method (LS), 2005–2008 and 2010–2012.

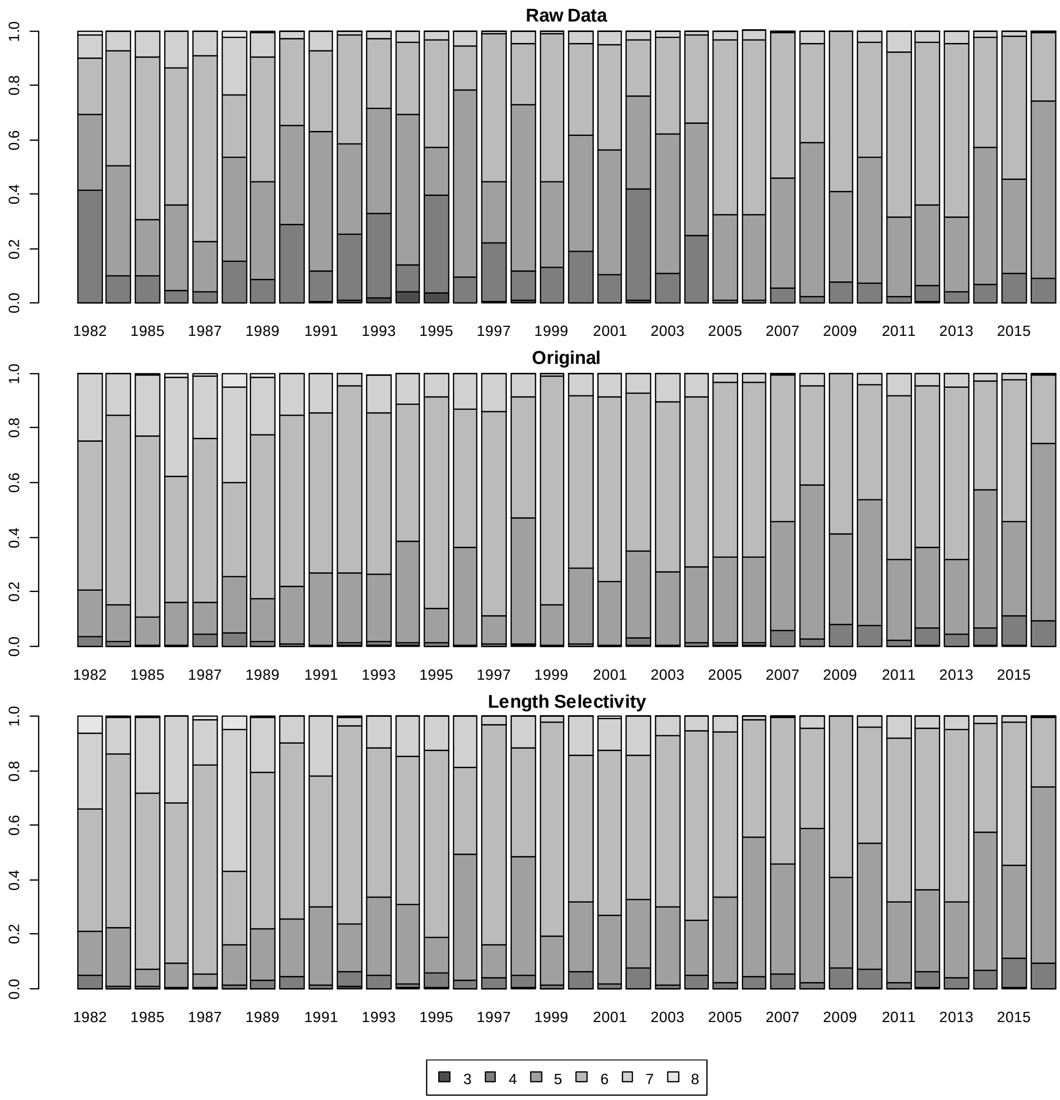


Figure 4.–Comparison of 1982–2016 U.S.-Canada border age-composition by fish wheel (raw data), current age composition (original), and adjusted by length selectivity method (length selectivity).

Note: 2007–2016 age compositions are from the test fishery data for all methods. No data were collected in 1984 and the figure does not contain an estimate of age composition for that year.

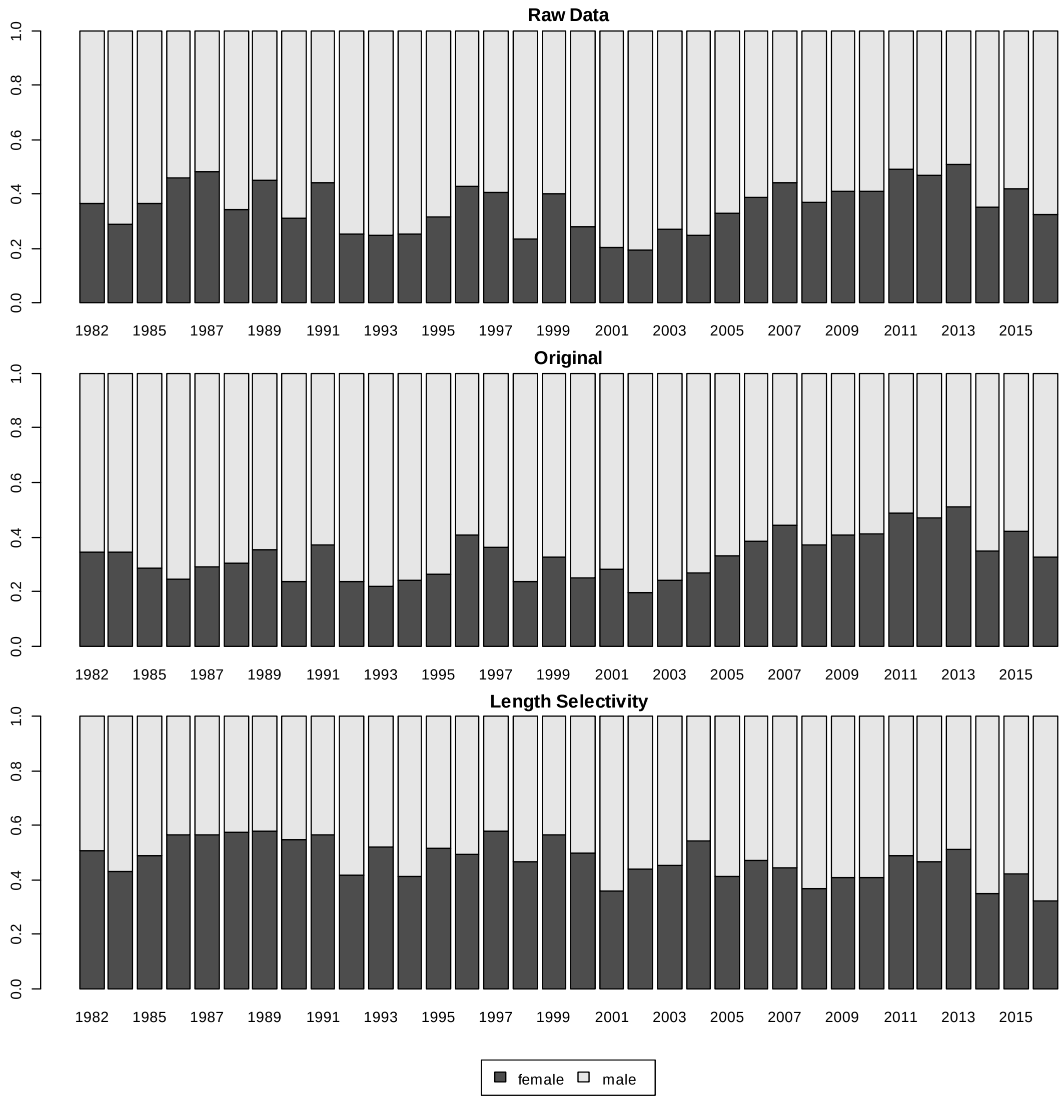


Figure 5.–Comparison of 1982–2016 U.S.-Canada border sex-composition of fish wheel (raw data), current (original), and adjusted by length selectivity method (length selectivity).

Note: 2007–2016 sex compositions are from the test fishery data for all methods. No data were collected in 1984 and the figure does not contain an estimate of sex composition for that year.

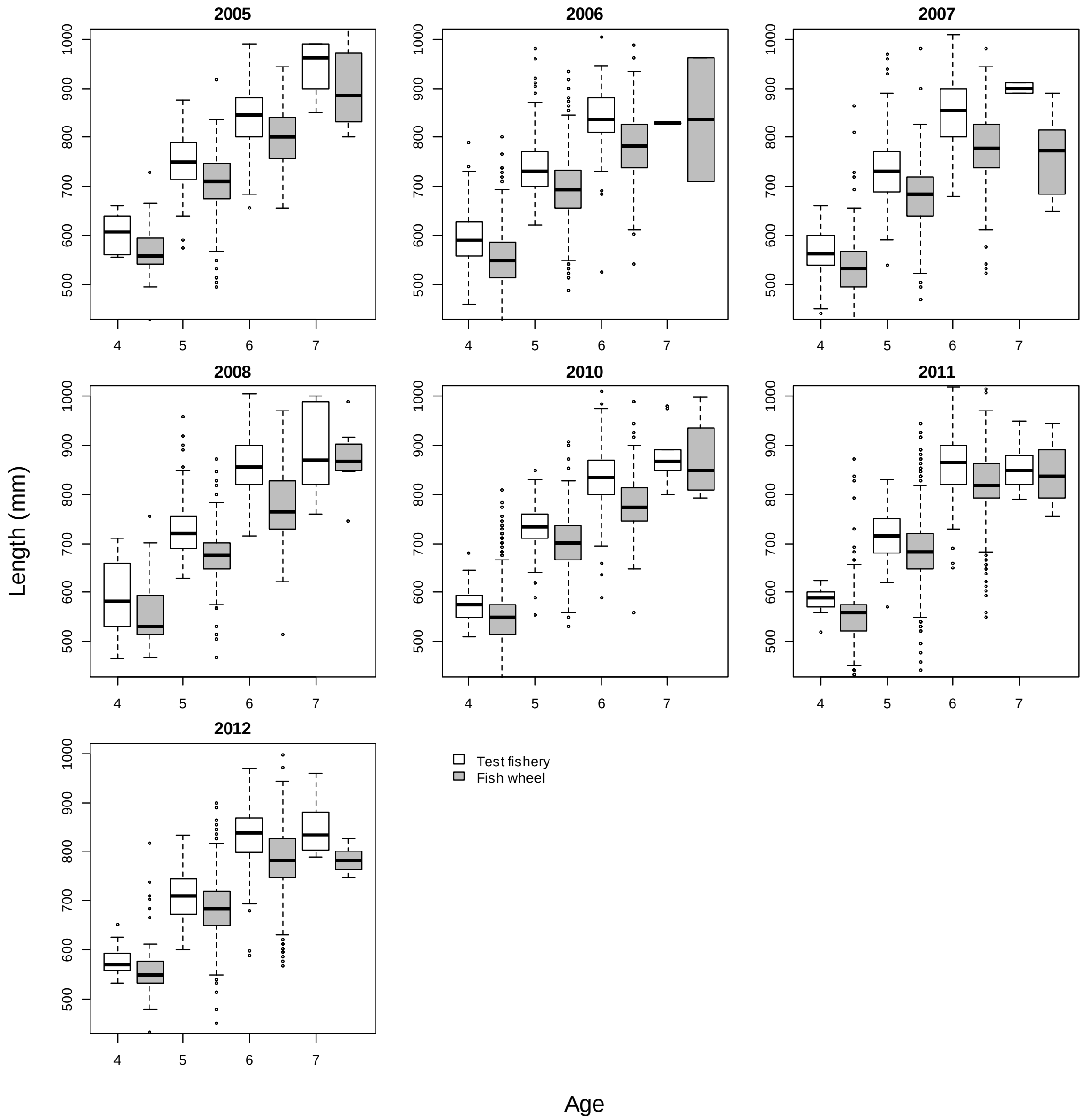


Figure 6.–Comparison of length by age between Eagle sonar gillnet test fishery (test fishery), and U.S.-Canada border fish wheel (fish wheel), 2005–2008 and 2010–2012.

Note: The lowest and highest points indicate minimum and maximum. The lower and upper whiskers indicate Q1-1.5*IQR and Q3+1.5*IQR, respectively. The box indicates Q1, median, and Q3, respectively. The points outside of lower and upper whiskers indicate outliers identified by *R* boxplot function algorithm.

APPENDIX A

Appendix A1.–Canadian-origin Chinook salmon border age and sex composition table currently used by ADF&G and the JTC 1982–2006.

	Age group						Proportion
Year	3	4	5	6	7	8	female
1982	0.00	0.03	0.17	0.55	0.25	0.00	0.34
1983	0.00	0.01	0.13	0.70	0.15	0.00	0.34
1984[a]	0.00	0.08	0.24	0.52	0.16	0.00	NA
1985	0.00	0.00	0.10	0.66	0.22	0.01	0.29
1986	0.00	0.00	0.16	0.46	0.36	0.01	0.25
1987	0.00	0.05	0.12	0.60	0.23	0.01	0.29
1988	0.00	0.05	0.21	0.35	0.35	0.05	0.30
1989	0.00	0.02	0.16	0.60	0.21	0.01	0.35
1990	0.00	0.01	0.21	0.63	0.15	0.00	0.23
1991	0.00	0.00	0.26	0.59	0.15	0.00	0.37
1992	0.00	0.01	0.26	0.69	0.04	0.00	0.24
1993	0.00	0.02	0.24	0.59	0.14	0.00	0.22
1994	0.00	0.01	0.38	0.50	0.11	0.00	0.24
1995	0.00	0.01	0.12	0.78	0.08	0.00	0.26
1996	0.00	0.00	0.36	0.51	0.13	0.00	0.40
1997	0.00	0.01	0.10	0.75	0.14	0.00	0.36
1998	0.00	0.01	0.46	0.45	0.08	0.00	0.24
1999	0.00	0.00	0.15	0.84	0.01	0.00	0.32
2000	0.00	0.01	0.28	0.63	0.08	0.00	0.25
2001	0.00	0.00	0.23	0.67	0.09	0.00	0.28
2002	0.00	0.03	0.32	0.58	0.07	0.00	0.19
2003	0.00	0.00	0.27	0.62	0.10	0.00	0.24
2004	0.00	0.01	0.28	0.62	0.08	0.00	0.27
2005	0.00	0.01	0.32	0.64	0.03	0.00	0.33
2006	0.00	0.01	0.32	0.64	0.03	0.00	0.39

[a] Fish wheel did not operate. Age-sex data and method to estimate 1984 age composition are unknown and undocumented.

Appendix A2.–Eagle sonar border gillnet test fishery samples by mesh size.

	Mesh size (inches)									
Year	2.75	4	5.25	5.5	5.75	6.5	7.25	7.5	8.5	Total
2005	7	27		32		48		44	21	179
2006	6	9	138		2			125		280
2007			54			124		178	68	424
2008			65			111		200	81	457
2009			175			181		189	166	711
2010			114			112		163	79	468
2011			119			145		126	123	513
2012			103			55		136	50	344

Appendix A3.–Eagle sonar border gillnet test fishery samples by age and sex.

	Female						Male					
Year	3	4	5	6	7	8	3	4	5	6	7	8
2005			17	39	2			14	69	26	4	
2006		12	43	41	1			31	111	17		
2007		2	25	140	2			20	131	69		
2008			32	92	14			10	179	45	3	
2009			23	233				50	192	149		
2010			36	89	11			25	120	52	3	
2011		1	28	163	23			8	96	91	10	
2012			15	98	9		1	15	58	48	2	

Appendix A4.–The number of fish wheel samples by age and sex, 1982–2012, excluding 1984 because the project did not operate in that year.

		Age								
Year	Sex	3	4	5	6	7	8	Total complete	No age	Total
1982	Female		9	11	16 (1)	8	2	46	42	89
	Male		43	24	10	3		80	93	173
1983	Female		1	24	83	20		128	302	430
	Male		43	155	104	12	1	315	530	845
	No sex								2(2)	4
1985	Female			21	199	39	1	260	235	495
	Male		71	126	230	29		456	937(1)	1394
	No sex					1				1
1986	Female		3	59	336	112		510	329	839
	Male		49	288	223	42		602	806	1408
1987	Female			5	212	30	1	248	185	433
	Male		21(1)	91	138	16	1	267	356	624
1988	Female			12	42	57	7	118	233	351
	Male		54	120	36	17	1	228	396	624
1989	Female		10	52	185(1)	38(1)	1	286	169	457
	Male	1	44	177	106	22	2	352	277	629
	No sex				(1)				2	3
1990	Female		7	57	210	20		294	235	529
	Male	1	265	285	92	8		651	544	1195
1991	Female		7	165	243	59		474	258	732
	Male	5	115	385	74	22		601	386	987
	No sex								(1)	1
1992	Female	1	12	50(1)	225	10	1	299	177	477
	Male	11	274	340	248	6		879	532	1411
	No sex		(2)	(1)	(1)					4
1993	Female		1	53	116(1)	20		190	128	319
	Male	15	234	242	78	2		571	350	921
	No sex				(1)					1
1994	Female			66	122	22		210	111	321
	Male	34	84	390	99	13		620	352	972
	No sex								1	1
1995	Female	1	6	34	164	12		217	448	665
	Male	24	242	87	107	11		471	1008	1479
	No sex			(3)	(2)				15	20
1996	Female	1	28	182	74	22		307	410(2)	719
	Male		39	312(2)	42	20		413	611	1026
	No sex			(2)					(1)	3

-continued-

Year	Sex	Age 3	4	5	6	7	8	Total complete	No age	Total
1997	Female	1	7	33	292	7		340	113	453
	Male	3	175	157	162	3		500	175	675
1998	Female		7	49(1)	84(1)	22		162	98	262
	Male	6	68	375	71	11		531	243	774
	No sex			(1)						1
1999	Female			25	205	4		234	115(4)	353
	Male	2	75	158	114	3		352	205(3)	560
	No sex								(2)	2
2000	Female		13	34	123	24		194	208(7)	409
	Male		119	261	108(1)	9		497	552(6)	1,056
2001	Female			9	64	14	1	88	905(245)	1,238
	Male		46	190	105	8		349	2003(379)	2,731
2002	Female		4	28	98	25		155	69	224
	Male	9	323(1)	246	66	2		646	193	840
	No sex								(1)	1
2003	Female	1	7	46	175	16		245	98(7)	350
	Male	1	89	417(2)	146	8		661	235(2)	900
	No sex			1					(25)	26
2004	Female			14	135	9		158	181(7)	346
	Male		158(1)	247	72			477	514(22)	1,014
	No sex			(1)						1
2005	Female			22	52	3		77	390(4)	471
	Male	1	36	100	47	1		185	805(7)	997
	No sex								1(15)	16
2006	Female		1	77	110	2		190	145(1)	336
	Male		148	358(2)	37			543	311(10)	874
	No sex		6	4	2				9	21
2007	Female	1	1	19(1)	143	9		173	258	432
	Male	2	152	288	91	7		540	485(4)	1,029
	No sex				1					1
2008	Female			40	77	5		122	296(3)	421
	Male		49(2)	513(1)	46	3		611	746(4)	1,364
	No sex								(3)	3
2010	Female		5	44	68	7		124	47(1)	172
	Male	22	269	261	51	5		608	133	741
2011	Female		4	62	233	6		305	83	388
	Male	1	279	668	205	4		1,157	346	1,503
2012	Female		1	38	141	1		181	37	218
	Male	1	116	276	80	4		477	115	592
Total complete		145	3,816	8,867	7,214	914	19	20,945		
All data		145	3,827	8,891	7,228	916	19	21,026	21,351	42,377

Source: Data from DFO (Elizabeth MacDonald).

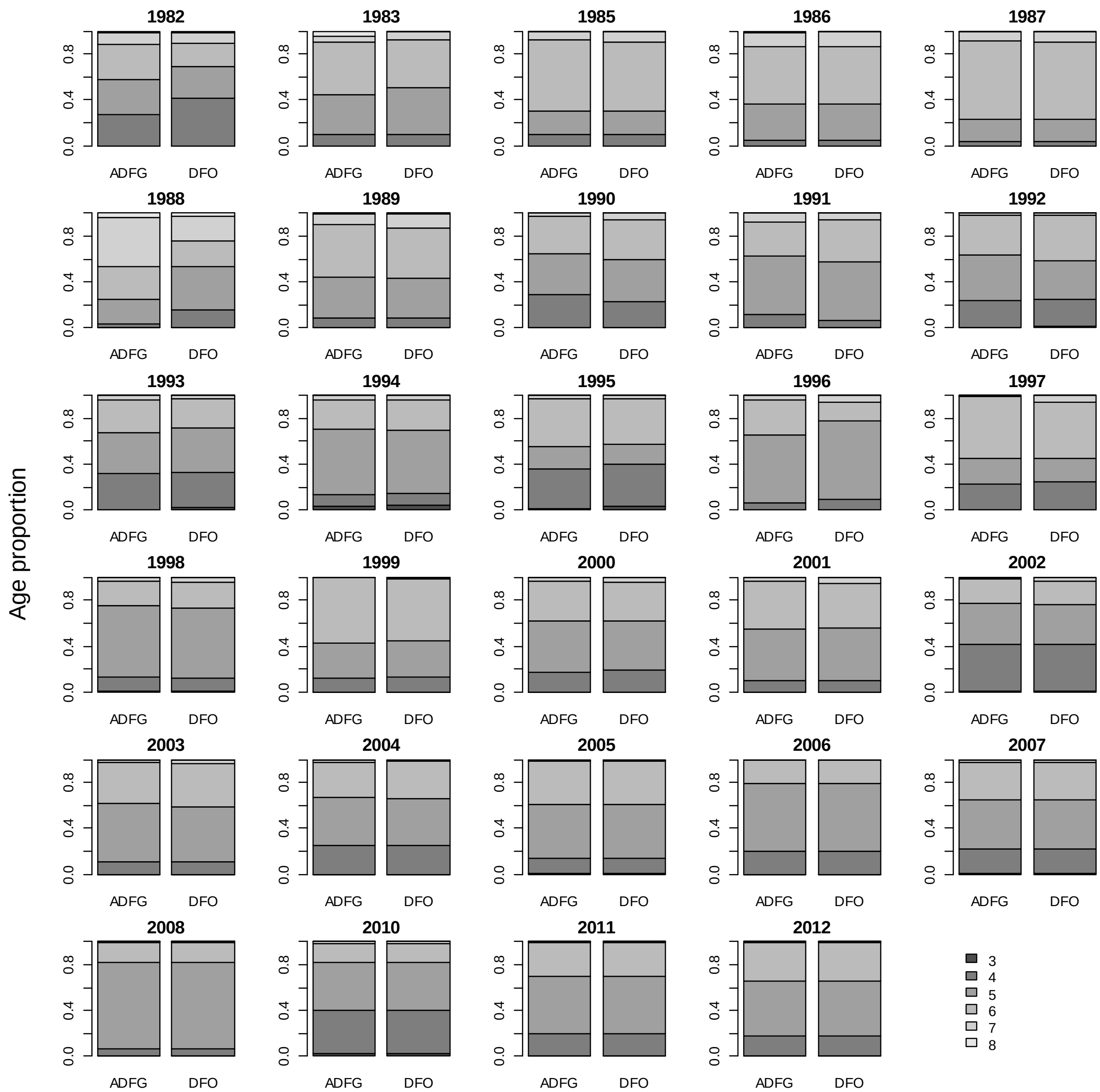
Note: Numbers in parenthesis indicate samples without length data. Total number of samples in each sex and age are a sum of complete sample and one without length data.

Appendix A5.–Comparison of U.S.-Canada border fish wheel ASL data between DFO and AYDBMS, 1982–2012.

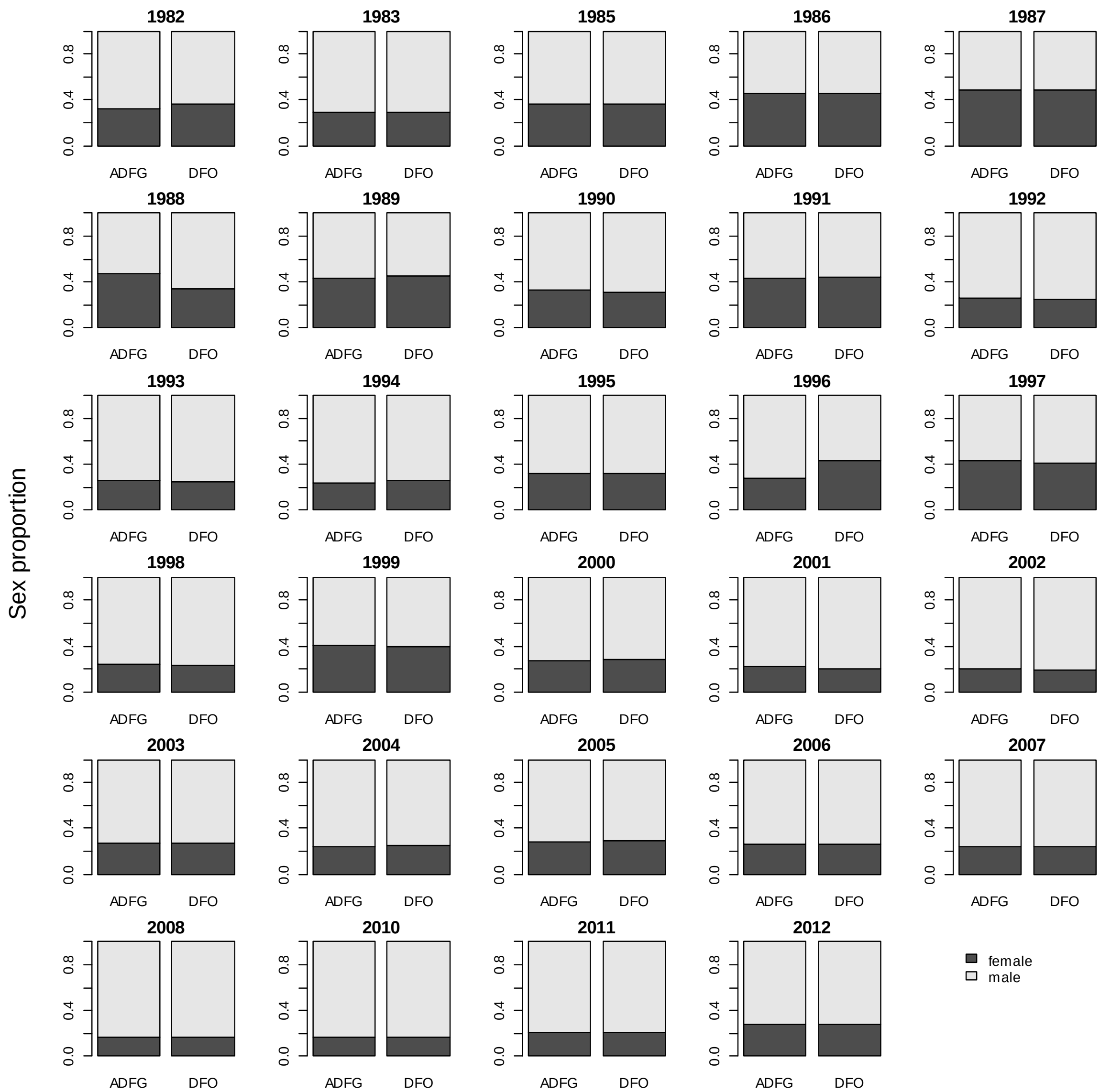
	DFO			AYKDBMS		
Year	Total sample	Total complete	% Complete	Total sample	Total complete	% Complete
1982	262	126	48%	265	129	49%
1983	1,279	443	35%	1,041	443	43%
1984			Did not operate			
1985	1,890	716	38%	1,889	716	38%
1986	2,247	1,112	49%	2,247	1,112	49%
1987	1,057	515	49%	1,057	511	48%
1988	975	346	35%	977	199	20%
1989	1,089	638	59%	1,089	802	74%
1990	1,724	945	55%	1,361	954	70%
1991	1,720	1,075	63%	1,723	1,421	82%
1992	1,892	1,178	62%	1,903	1,232	65%
1993	1,241	761	61%	1,241	968	78%
1994	1,294	830	64%	1,293	944	73%
1995	2,164	688	32%	2,164	870	40%
1996	1,748	720	41%	1,579	538	34%
1997	1,128	840	74%	2,209	1,636	74%
1998	1,037	693	67%	1,037	798	77%
1999	915	586	64%	925	706	76%
2000	1,465	691	47%	1,465	1,102	75%
2001	3,969	437	11%	3,969	643	16%
2002	1,065	801	75%	1,065	888	83%
2003	1,276	906	71%	1,261	1,098	87%
2004	1,361	635	47%	1,362	1,053	77%
2005	1,484	262	18%	1,484	262	18%
2006	1,231	733	60%	1,231	733	60%
2007	1,462	713	49%	1,462	711	49%
2008	1,788	733	41%	1,788	732	41%
2009			Did not operate			
2010	913	732	80%	913	732	80%
2011	1,891	1,462	77%	1,891	1,462	77%
2012	810	658	81%	810	658	81%
Total	42,377	20,975	49%	42,701	24,053	56%

Note: The total sample is the number of data; total complete is the number of sample with complete (i.e. age, sex, length) data, and percent of complete data.

Appendix A6.–Comparison of age composition (percent) between AYKDBMS (ADF&G) and DFO, 1982–2012, excluding 1984 because the project did not operate in that year.



Appendix A7.–Comparison of female composition between AYKDBMS (ADF&G) and DFO, 1982–2012, excluding 1984 because the project did not operate in that year.



Appendix A8.–Fish wheel and gillnet test fishery age-sex composition data, 2007–2008 and 2010–2012.

				Fish wheel		
Year	Sex	Age	Gillnet test fishery	Original	Age-sex selectivity	Length selectivity
2007	Female	4	0.005	0.003	0.001	0.006
		5	0.064	0.027	0.038	0.036
		6	0.360	0.201	0.404	0.400
		7	0.005	0.013	0.052	0.026
	Male	4	0.051	0.216	0.040	0.038
		5	0.337	0.404	0.255	0.259
		6	0.177	0.128	0.194	0.223
		7	0.000	0.010	0.015	0.012
2008	Female	4	0.000	0.000	0.000	0.000
		5	0.085	0.055	0.090	0.062
		6	0.245	0.105	0.243	0.263
		7	0.037	0.007	0.032	0.038
	Male	4	0.027	0.070	0.015	0.020
		5	0.477	0.698	0.505	0.479
		6	0.120	0.061	0.107	0.123
		7	0.008	0.004	0.007	0.016
2010	Female	4	0.000	0.007	0.005	0.005
		5	0.107	0.060	0.118	0.095
		6	0.265	0.093	0.256	0.203
		7	0.033	0.010	0.053	0.044
	Male	4	0.074	0.398	0.101	0.105
		5	0.357	0.357	0.307	0.326
		6	0.155	0.070	0.145	0.185
		7	0.009	0.007	0.015	0.038
2011	Female	4	0.002	0.003	0.002	0.005
		5	0.067	0.042	0.065	0.046
		6	0.389	0.159	0.341	0.345
		7	0.055	0.004	0.018	0.009
	Male	4	0.019	0.192	0.038	0.029
		5	0.229	0.457	0.306	0.250
		6	0.215	0.140	0.226	0.309
		7	0.024	0.003	0.005	0.009
2012	Female	4	0.000	0.002	0.001	0.003
		5	0.061	0.058	0.082	0.078
		6	0.398	0.214	0.426	0.428
		7	0.037	0.002	0.006	0.003
	Male	4	0.065	0.178	0.033	0.032
		5	0.236	0.419	0.261	0.249
		6	0.195	0.122	0.182	0.198
		7	0.008	0.006	0.009	0.008

APPENDIX B

Appendix B1.–E-mail correspondence describing the objectives of standardized border age-sex proportion.

From: Hamazaki, Hamachan (DFG)
Sent: Monday, March 13, 2017 9:37 AM
To: West, Fred (DFG); Harding, Joel
Cc: Brazil, Charles E (DFG); Conitz, Jan M (DFG)
Subject: RE: Yukon border Chinook ASL data

Hi All,

Since I don't participate in JTC, I have no idea about exact scope of this historical border ASL project, except for due fall JTC meeting.

Here are couple of issues I need clarification.

1. Objectives: Is it correction of overall age comp, age comp by sex, age and sex comp all together, or age, sex, and length correction?
2. Results: One method based on my professional judgement, or multiple alternatives with pros and cons of commentaries?
3. Products: Nearly finished draft to be published on ADF&G report series, just few pages of write up?.
4. Process: JTC (Committee if exists) approval in every step of the project (e.g., approval of data being used, approval of methods being applied, etc.), or Final report approved or disapproved by JTC?
5. Finality: (This does not affect me at all, but JTC). Will JTC start using corrected data based on this project, or just wants to obtain information on "what historical ASL would have been?"

Clarification of the above will help and save both JTC and my time and energy.

Thanks

Toshihide "Hamachan" Hamazaki, 濱崎俊秀PhD
Alaska Department of Fish and Game: アラスカ州漁業狩猟局
Division of Commercial Fisheries: 商業漁業部
333 Raspberry Rd. Anchorage, AK 99518
Phone: (907)267-2158
Cell: (907)440-9934

From: Conitz, Jan M (DFG)
Sent: Monday, March 13, 2017 10:26 AM
To: Hamazaki, Hamachan (DFG); West, Fred (DFG); Harding, Joel
Cc: Brazil, Charles E (DFG)
Subject: RE: Yukon border Chinook ASL data

Hi Hamachan,

It would have been good to have all of these questions in front of us at the JTC meeting when we discussed the matter. But I'll try and either answer, or give direction on how to get answers from the JTC later.

First, let's talk about scope. The scope of this project is limited to correcting the historical Chinook border passage ASL composition estimates from 1982 through 2004. There should be no extension of the methods to older or more recent data, other data sets, etc.

The purpose is simply to have a more accurate representation of the ASL composition of the Chinook salmon run at the border for the 1982-2004 period.

Now, for your questions.

1. The JTC wants age and sex composition corrected. The data will be used mainly for the brood table. I discourage the JTC for using any corrected data set to make inferences about historical characteristics of any spawning population, though I know others may disagree and want to use the corrected data set for other purposes. For that reason, you should be very clear about the assumptions used, and the limitations of the corrections that you make, and obviously, the populations and dates to which they apply.

2. I think that the JTC agreed you should use your professional judgement. All are familiar with the history of this project, starting with Bromaghin, then Marc Labelle's initial attempts to move it forward, and then your 2013/2014 analysis with multiple scenarios. They also know that you have updated your thinking and methods since 2014 and the agreement in our recent meeting was that you should move forward from where you're at now.

3. The products should certainly include a published report, and since you, not the JTC, are doing the analysis, I feel the publication should be independent from the JTC. This will still allow the JTC to be involved in the review process and, once the report is published, to formally cite the work – it will also allow the JTC the option to produce their own analysis or seek analyses by other experts in the future, building on or perhaps challenging what you have done. You should work with the new regional editor (i.e. whoever replaces me) to publish your work in an ADF&G FDS or FM report – or you could publish it in an outside journal if you go through the necessary approval steps with the regional editor and the chief fisheries scientist.

4. There is currently no subcommittee – the last time you worked with the JTC on this, the entire JTC wanted to be involved. So your results should be reviewed by the JTC as a whole. You should allow a review of your full analysis (code, outputs, etc) though not necessarily a written report, and comments should be compiled and passed back to you – this can be coordinated by Fred and Joel. After addressing any comments received, you should go ahead and publish the report as I mentioned in the previous point. The JTC has no vehicle for publications of its own, so the report will not be a JTC report. Therefore the JTC doesn't have to "approve" of the report but it obviously would make no sense to publish an analysis that was not approved by them. Approval by the JTC will be indicated in JTC meeting records and if the JTC so chooses, their approval could also be mentioned in an acknowledgment in your report.

5. The stated intention of this project is to use the corrected age-sex composition estimates for producing the annual Canadian run Chinook brood table, run reconstruction, and next year's outlook (see scope and purpose above).

We should also be clear on who should be giving you direction as this project unfolds. Fred and Joel have been assigned to coordinate the work in the form we agreed upon in our spring 2017 meeting (basically, what I've addressed above). Other JTC members should address questions and comments to them, instead of directly to you.

If someone decides later on that they want you to do something else, then that question needs to go back to the full JTC for discussion. And that should be coordinated through both co-chairs and would need to wait until there is a new US co-chair who can help direct that discussion.

Jan Conitz

Regional Research Coordinator
Arctic-Yukon-Kuskokwim Region
Alaska Department of Fish & Game - Division of Commercial Fisheries
333 Raspberry Road, Anchorage AK 99518
Office phone: 907-267-2135

From: Harding, Joel [mailto:Joel.Harding@dfo-mpo.gc.ca]
Sent: Wednesday, March 15, 2017 10:25 AM
To: West, Fred (DFG); Hamazaki, Hamachan (DFG); Conitz, Jan M (DFG)
Cc: Brazil, Charles E (DFG)
Subject: RE: Yukon border Chinook ASL data

Hi All,

Thanks for keeping me in the loop and sorry for the late response.

I agree with most of the points raised with one key exception: The main impetus to correct the pre-2005 data is to create a dataset that the JTC agrees upon. By this I mean that we can say that we have attempted to correct the data to the best of our current abilities (Hamachan's abilities) and will use it as our bilaterally agreed upon data set for any future initiatives while being fully open and transparent about the uncertainties associated with the data. This certainly includes brood table applications but I also see additional applications such as quality of run considerations.

Therefore I think it is very important to propagate any associated uncertainty through to final corrected estimates. Ideally we would end up with a corrected age, sex, and length 1982-2004 data set with properly propagated confidence bounds.

Cheers,
Joel Harding

Senior Stock Assessment Biologist, Treaties and Fisheries (Yukon River)
Fisheries and Oceans Canada / Government of Canada
joel.harding@dfo-mpo.gc.ca / Tel : 867-393-6865

Biologiste Supérieur En Évaluation Des Stocks, Traités et Pêches (Fleuve Yukon)
Pêches et Océans Canada / Gouvernement du Canada
joel.harding@dfo-mpo.gc.ca / Tél. : 867-393-6865

Appendix B2.–Bromaghin, J. 1996. Estimation of Chinook Border Passage Age Composition. Memorandum, Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division.

State of Alaska Memorandum

Department of Fish and Game

Commercial Fisheries Management and Development Division

TO: Distribution

DATE: 13 June, 1996

FILE: --061396.DOC

PHONE: 267-2379

FROM: Jeff Bromaghin JB
Regional Biometrician
Arctic-Yukon-Kuskokwim Region
CFM&D - Anchorage

SUBJECT: Estimation of Chinook Border Passage Age Composition

The construction of a chinook brood year table was briefly discussed under Other Business at the 5/1/96 JTC meeting. Dan Schneiderhan stated that he had been working with Ian Boyce on the table, and that progress was being made. I mentioned that I wanted to explore the possibility of estimating the age composition of the border passage from other age information. I also stated that I would try to complete the analysis this summer, allowing time for Dan and Ian to draft a brood year table prior to the fall JTC meeting. This memorandum summarizes the analysis to date.

Dan and Ian provided estimates of the age composition of fish caught in the fishwheels, harvested in the mainstem Canadian commercial fishery, and sampled as carcasses on the spawning grounds. The analysis was based on data from the seven years in which all three sources of data are available, 1982-1983 and 1985-1989. Estimates of the border passage, Canadian commercial harvest, and Canadian mainstem escapement in those years were taken from the Fall 1995 JTC report.

Assuming all data is unbiased and ignoring sources of variability (assumed throughout the analysis), estimates of escapement by age and harvest by age were summed to provide estimates of border passage by age. The sizes of the border passage, harvest, and escapement for each year, and the estimated age composition of each of these components, are presented in Table 1. The analysis then consisted of comparing the estimated age composition of the border passage with that of the fish captured in the fishwheels.

Fishwheels are often thought to be size selective, preferentially selecting for small salmon. For that reason, I approached the analysis from a selectivity perspective using weighted distribution theory, and I assumed that selectivity is constant from year to year. Given that, define

π_{ij} = the proportion of the border passage in year i consisting of age-j fish,

s_j = the relative probability an age-j fishwheel fish is "captured" by the run as it passes the border (bear with this strange definition for the moment - an explanation is offered at the end of the memorandum), and

p_{ij} = the proportion of fish caught in the fishwheels in year i that are of age j.

If the vector $\underline{p_i}$ is known and an estimate of the vector $\underline{s}$ is available, the vector $\underline{\pi_i}$ is estimated by

$$\hat{\pi}_{ij} = \frac{p_{ij}\hat{s}_j}{\sum_j p_{ij}\hat{s}_j}. \tag{1}$$

The age composition of fish caught in the fish wheels is presented in the sub-table 1 of Table 2. I began by using guesses for the values of $\hat{s}_j$ (labeled "Initial" in the sub-table 2 of Table 2), and estimates of π_{ij} were computed using equation (1). Given these estimates, the sum of the absolute differences between the estimates and the observed age composition of the border passage (residuals) was computed. The initial guesses of $\hat{s}_j$ were then modified in an iterative process, using the Solver bundled with Microsoft Excel version 7.0a, so that the sum of the absolute residuals was minimized. In other words, the estimates of s_j were selected to give the best overall fit to the age composition data. The estimates of s_j are in sub-table 2 of Table 2, and are labeled "Final". The estimated age composition of the border passage are given in the sub-table 3 of Table 2, the observed age composition data are given in sub-table 4 of Table 2 (repeated from Table 1), and the absolute residuals based on the final estimates of s_j are given in sub-table 5 of Table 2.

The observed and estimated age composition of the border passage in each year are graphically contrasted in Figure 1. With a couple of exceptions, the estimates are quite close to the observed data.

If a brood year table is to be constructed, I would propose using observed fishwheel age composition data in any given year and the estimates of s_j given in Table 2 to estimate the age composition of the chinook salmon border passage in that year (using equation 1). The resulting estimates would be applied to the estimated border passage given by the tagging study (border passage by age) and combined with SPA-based estimates of age-specific U.S. harvests to estimate the size and age composition of the entire return.

Qualifications with the use of this method were stated above, namely that the analysis assumes the vector $\underline{s}$ is constant from year to year, and that the data were treated as unbiased with no consideration for variability. An estimate of the covariance matrix of $\underline{s}$ could be obtained, but the derivation is complex and it would likely not be incorporated into the brood year table even if available. A further caution is that the selectivity of age-3, age-4, and age-8 fish is probably not well defined because of the relative scarcity of these age classes. A final caution is that selectivity is probably based on a number of interrelated factors, such as length, weight, condition, etc., that are correlated with age.

The strange definition for the vector s given above was required because of the inverse nature of the analysis. As a run with a given age composition passes the fishwheels, the fishwheels selectively capture the various ages and provide a "biased" estimate of the age composition of the border passage. The analysis reversed that logical relationship, essentially treating the fishwheel data as unbiased and the age composition of the border passage as biased, in order to study the bias for estimation purposes. If the selectivity of the fishwheels is of interest, the relationship embodied in equation (1) can be inverted to express $\underline{p_i}$ as a function of $\underline{\pi_i}$ and a vector of "inverted" selectivity parameters. If f_j is the relative probability a fishwheel captures a fish of age j, f_j can be expressed as

$$f_j = \prod_{k \neq j} s_k, \text{ and} \tag{2}$$

$$p_{ij} = \frac{\pi_{ij} f_j}{\sum_j \pi_{ij} f_j}. \tag{3}$$

As an aside, I computed the vector f and scaled the elements so that the largest was equal to 1.0. These relative selectivity estimates for fishwheels are graphically presented in Figure 2. If you have any questions, please give me a call.

Distribution:

AF&G: Buklis, Paulus, Schneiderhan
DFO: Boyce, Johnston

Table 2. Estimation of fishwheel relative selectivity by age by minimizing the sum of the absolute residuals from estimation of the age composition of the Yukon River chinook salmon border passage.

Year	Age Composition Observed in Fishwheels						
	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	0.0000	0.4118	0.2689	0.2101	0.0924	0.0168	1.0000
1983	0.0000	0.0890	0.3682	0.4764	0.0646	0.0017	1.0000
1985	0.0000	0.0481	0.2477	0.5974	0.1068	0.0000	1.0000
1986	0.0000	0.0468	0.3121	0.5036	0.1376	0.0000	1.0000
1987	0.0000	0.0426	0.1860	0.6783	0.0891	0.0039	1.0000
1988	0.0000	0.1547	0.3840	0.2264	0.2120	0.0229	1.0000
1989	0.0016	0.0845	0.3584	0.4570	0.0939	0.0047	1.0000

Parameter Type	Selectivity Coefficients					
	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8
Initial	0.050000	0.200000	0.400000	0.600000	0.800000	0.900000
Scalar	0.999336	0.076105	0.523995	1.060918	1.250000	0.780679
Final	0.049967	0.015221	0.209598	0.636551	1.000000	0.702612

Year	Age Composition of Border Passage: Predicted						
	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	0.0000	0.0208	0.1875	0.4449	0.3075	0.0393	1.0000
1983	0.0000	0.0030	0.1724	0.6775	0.1443	0.0027	1.0000
1985	0.0000	0.0014	0.0962	0.7046	0.1979	0.0000	1.0000
1986	0.0000	0.0014	0.1248	0.6114	0.2624	0.0000	1.0000
1987	0.0000	0.0012	0.0692	0.7665	0.1583	0.0048	1.0000
1988	0.0000	0.0052	0.1768	0.3166	0.4659	0.0354	1.0000
1989	0.0002	0.0028	0.1617	0.6261	0.2021	0.0071	1.0000

Year	Age Composition of Border Passage: Observed						
	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	0.0000	0.0208	0.1875	0.5923	0.1853	0.0140	1.0000
1983	0.0000	0.0100	0.1449	0.6780	0.1601	0.0070	1.0000
1985	0.0000	0.0020	0.0784	0.6989	0.2147	0.0060	1.0000
1986	0.0000	0.0059	0.1264	0.5892	0.2507	0.0278	1.0000
1987	0.0000	0.0461	0.1275	0.6604	0.1583	0.0077	1.0000
1988	0.0000	0.0463	0.1773	0.3670	0.3741	0.0354	1.0000
1989	0.0000	0.0131	0.1344	0.6252	0.2103	0.0170	1.0000

Year	Absolute Value of Residuals						
	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	0.0000	0.0000	0.0000	0.1474	0.1222	0.0253	0.2949
1983	0.0000	0.0069	0.0275	0.0004	0.0159	0.0043	0.0550
1985	0.0000	0.0006	0.0178	0.0057	0.0168	0.0060	0.0469
1986	0.0000	0.0045	0.0016	0.0222	0.0117	0.0278	0.0679
1987	0.0000	0.0450	0.0582	0.1061	0.0001	0.0028	0.2122
1988	0.0000	0.0411	0.0004	0.0504	0.0919	0.0000	0.1838
1989	0.0002	0.0103	0.0273	0.0010	0.0082	0.0099	0.0569
Total	0.0002	0.1085	0.1329	0.3332	0.2667	0.0761	0.9175

Table 1. Estimated size and age composition of Canadian Yukon River chinook salmon border passage, mainstem harvest, and escapement of chinook salmon in years in which age composition estimates of both the harvest and the escapement are available.

Year	Estimated Border Passage	Estimated Proportion By Age						
		Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	36,598	0.0000	0.0208	0.1875	0.5923	0.1853	0.0140	1.0000
1983	47,741	0.0000	0.0100	0.1449	0.6780	0.1601	0.0070	1.0000
1985	29,881	0.0000	0.0020	0.0784	0.6989	0.2147	0.0060	1.0000
1986	36,479	0.0000	0.0059	0.1264	0.5892	0.2507	0.0278	1.0000
1987	30,823	0.0000	0.0461	0.1275	0.6604	0.1583	0.0077	1.0000
1988	44,445	0.0000	0.0463	0.1773	0.3670	0.3741	0.0354	1.0000
1989	42,620	0.0000	0.0131	0.1344	0.6252	0.2103	0.0170	1.0000

Year	Estimated Mainstem Harvest	Estimated Proportion By Age						
		Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	16,808	0.0000	0.0406	0.1956	0.5425	0.1993	0.0221	1.0000
1983	18,752	0.0000	0.0130	0.1020	0.6568	0.2134	0.0148	1.0000
1985	19,151	0.0000	0.0000	0.0546	0.6996	0.2395	0.0063	1.0000
1986	20,064	0.0000	0.0000	0.1133	0.7067	0.1800	0.0000	1.0000
1987	17,563	0.0000	0.0467	0.1308	0.7009	0.1215	0.0000	1.0000
1988	21,327	0.0000	0.0566	0.1396	0.4264	0.3434	0.0339	1.0000
1989	17,419	0.0000	0.0093	0.1070	0.6651	0.2047	0.0140	1.0000

Year	Estimated Escapement	Estimated Proportion By Age						
		Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Total
1982	19,790	0.0000	0.0041	0.1806	0.6346	0.1735	0.0071	1.0000
1983	28,989	0.0000	0.0080	0.1727	0.6917	0.1257	0.0020	1.0000
1985	10,730	0.0000	0.0055	0.1209	0.6978	0.1704	0.0055	1.0000
1986	16,415	0.0000	0.0131	0.1423	0.4457	0.3371	0.0618	1.0000
1987	13,260	0.0000	0.0453	0.1230	0.6068	0.2071	0.0178	1.0000
1988	23,118	0.0000	0.0367	0.2120	0.3122	0.4023	0.0367	1.0000
1989	25,201	0.0000	0.0157	0.1533	0.5976	0.2143	0.0192	1.0000

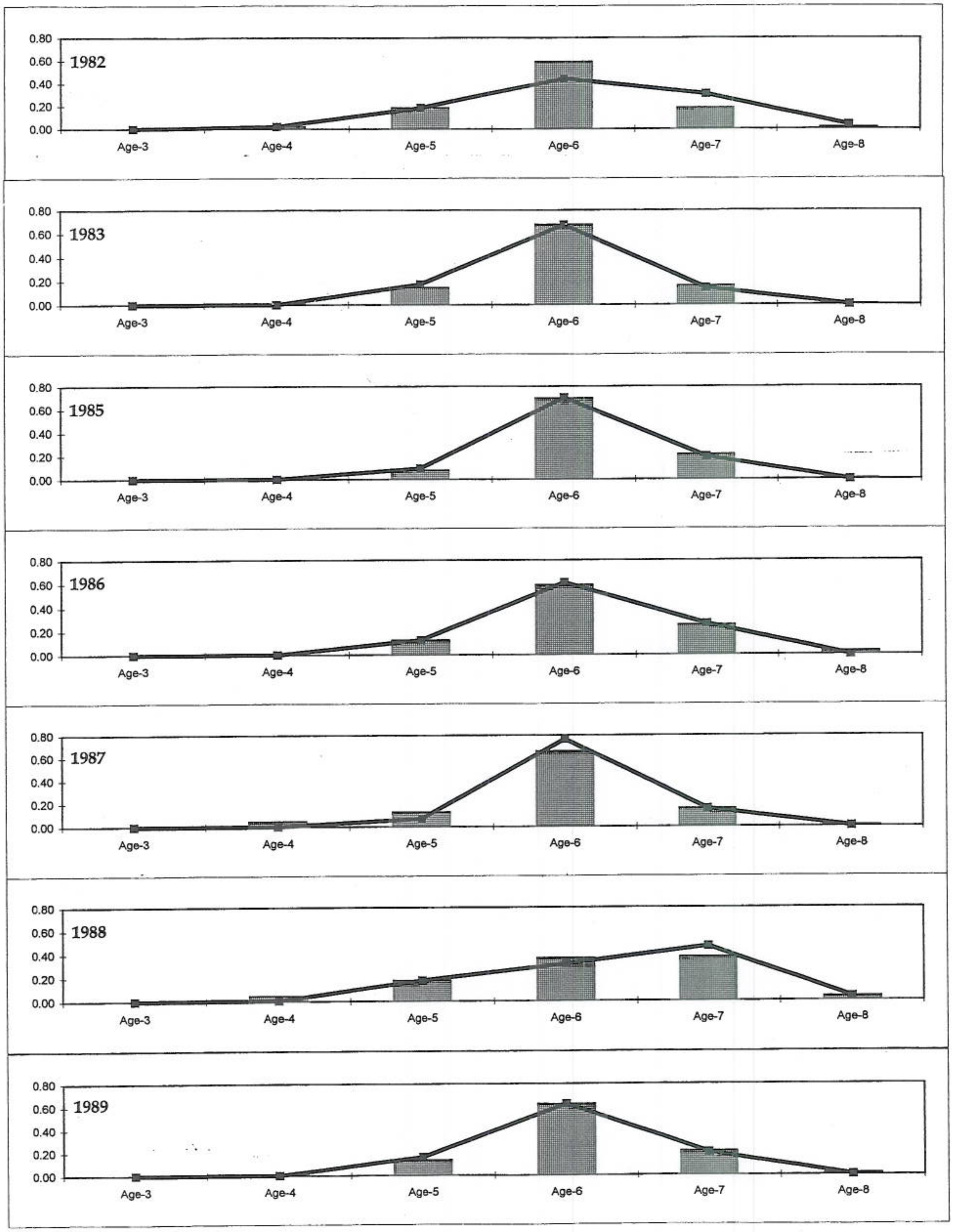


Figure 1. Graphs of the observed and selectivity-based estimates of the age composition of the Yukon River chinook salmon border passage. Bars represent observed age composition, while lines represent estimates of the age composition.

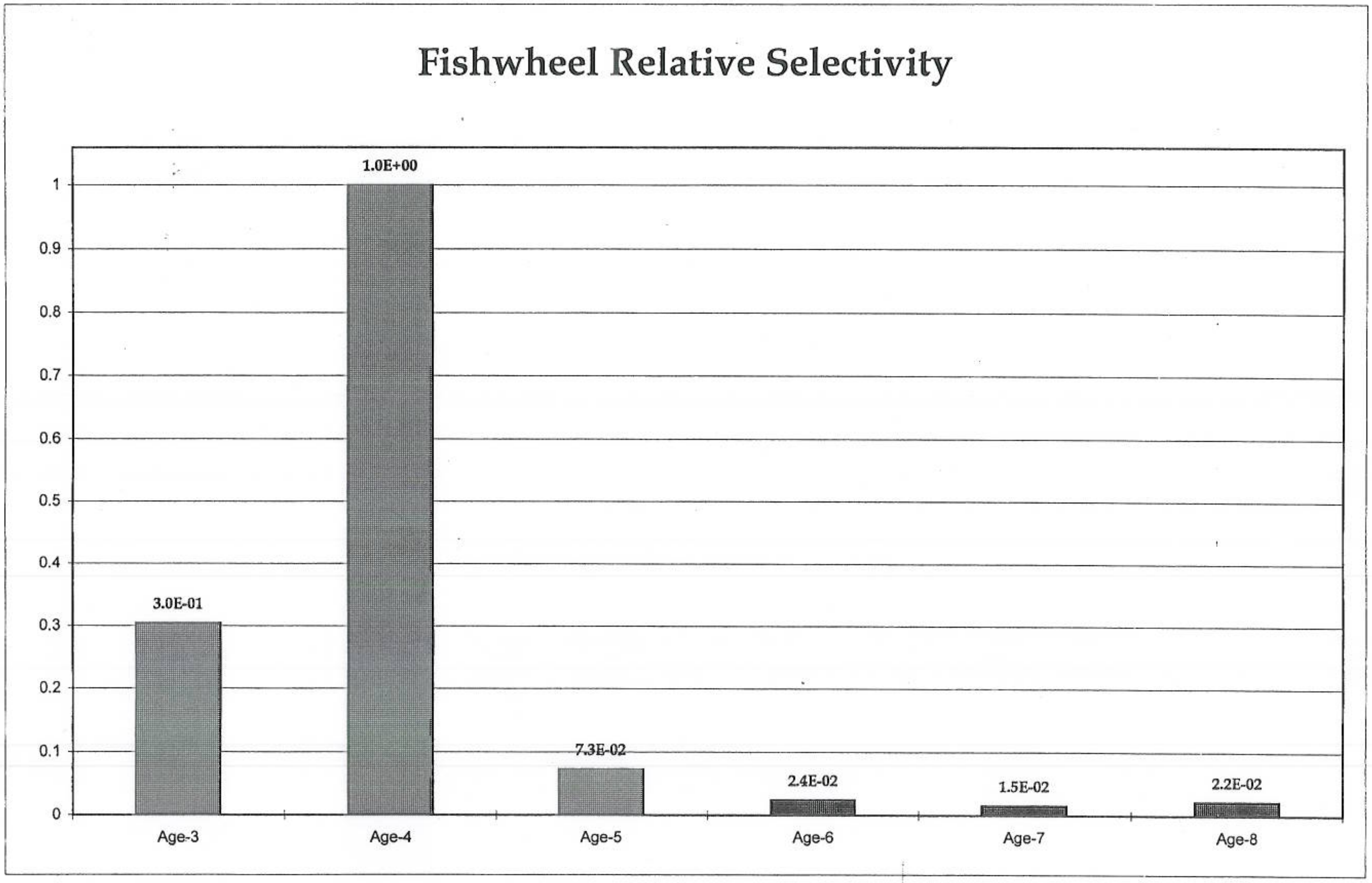


Figure 2. Age-specific relative selectivity of Yukon River chinook salmon in Canadian border tagging fishwheels.

State of Alaska Memorandum

Department of Fish and Game

Commercial Fisheries Management and Development Division

TO: Distribution

DATE: 3 July, 1996

FILE: --070396.DOC

PHONE: 267-2379

FROM: Jeff Bromaghin JB
Regional Biometrician
Arctic-Yukon-Kuskokwim Region
CFM&D - Anchorage

SUBJECT: 1996 Chinook Age Composition

The apparent size and age composition of the 1996 Yukon River chinook return has been a topic of discussion among staff. One issue in those discussions has been the potential for there to be relatively few females in the Canadian escapement, and the current lack of a program to estimate the age and sex composition of the Canadian escapement.

Earlier this summer I did some work with Canadian chinook age composition data. That work was motivated by a desire within the JTC to attempt building a brood year table for Canadian chinook. The attached memo summarizes my work. It was initially given limited distribution, consistent with the motivation for the work. However, the memo might now be of interest to other staff.

The analysis summarized in the attached memo is based upon border passage estimates, and age composition samples from the tagging fishwheels, the commercial harvest, and carcasses on the spawning grounds. The database consisted of information from years in which all those sources of information were available. The age composition of carcass samples was assumed to equal the age composition of the total escapement (an assumption which might be questionable). The size of the escapement was estimated by subtracting the size of the harvest from the border passage estimate. The estimated harvest by age was added to the estimated escapement (carcasses) by age to reconstruct the entire run by age. I then developed a model to estimate the age composition of the reconstructed run from the age composition observed in the fishwheels. This approach provides a means of using data from a long standing project, one whose operations will likely continue into the future, to estimate a fundamental characteristic of the run.

The analysis might now be of interest in that it provides a method of approximating the age composition of the 1996 border passage, without requiring age samples of the escapement or the harvest. However, I must stress the limitations of the method. It was developed using only a few years of data. Any bias inherent in age samples from either the harvest or carcass samples will directly bias estimates of the age composition of the run. The bias of border passage estimates caused by age-specific selectivity of the tagging fishwheels is not accounted for. The variability of the border passage estimates and the age composition samples was not incorporated in the model. Finally, the model was developed for the purposes of constructing a brood year table. When used only for that purpose, I think the model is reasonable, and probably represents the best method of estimating the age composition of a run. Any problems inherent in the model should be fairly consistent between years, and should not result in a seriously misleading picture of productivity. However, the model may not perform as well when used for a more rigorous purpose, such as determining the quality of the 1996 Canadian escapement in absolute terms. A modeling exercise such as this cannot confidently be used to replace critical data acquisition.

If you have any questions, please give me a call.

Distribution: Barton, Bergstrom, Borba, Buklis, Cannon, Golembeski, Hamner, Kron, Paulus, Schultz,

Appendix B3.–MacDonald, E., and M. Labelle 2012. An exploratory investigation into Age-Sex-Length (ASL) sampling requirements for assessing the state of Yukon River chinook populations spawning in Canada. Draft progress report.

Draft progress report

An exploratory investigation into Age-Sex-Length (ASL) sampling requirements for assessing the state of Yukon River chinook populations spawning in Canada

E. MacDonald and M. Labelle

Stock Assessment Division (STAD)
Yukon and Trans-Boundary Rivers Area (YTRA)
Fisheries & Oceans Canada
100 – 419 Range Road
Whitehorse, Yukon
Canada Y1A 3V1

November 2012

1. Introduction

In recent years prior to 2008, Fisheries & Oceans Canada (hereafter termed FOC or DFO) staff used two identical fishwheels deployed in the Yukon River drainage a few km upstream of the US/CAN border at White Rock and Sheep Rock (Bio-Island site) to catch, sample and tag chum and chinook salmon heading upstream to spawning tributaries. Bio-sampling records combined with mark-recapture estimates were used to determine abundance levels and generate brood tables to help assess productivity and forecasting future returns. During 1982, 2002-04 and 2005-07, radio-tracking operations provided independent estimates to assess the accuracy of mark-recapture estimates. Some reviewers interpreted results as indications that the traditional mark-recapture operations yielded escapement estimates lower than actual escapements. Subsequently, it was determined that a better monitoring procedure should be relied upon. This catalyzed interest in using a split-beam acoustic monitoring station at Eagle, a few km downstream for the AK/Can border on the Yukon River. Since 2005, sonar and bio-sampling operations have been conducted there. Some adjustments were made during initial seasons (2005-06) to fine-tune operations (choice of gill-nets, etc.). During 2007-08, the Bio-Island fishwheels were operated during the Eagle monitoring/sampling operations (usually daily, July-Oct.) with standard gears used at each location. The sampling gears at each location are not identical, with the mesh size of the Bio-Island fishwheels being substantially different than most of those of used at Eagle (4-5 mesh sizes). The average catchabilities and selectivity patterns of both fishwheels and gill-nets likely vary as well during and between seasons, being influenced by hydrological conditions, luminosity, site characteristics, water depth, deployment location, salmon migration patterns and etc. A cursory examination of the catch compositions of each fishwheel showed substantial differences across seasons, including sex ratios in catches.

Information from past Bio-Island and recent Eagle monitoring-sampling should be combined to provide a continuous time-series of stock composition trends. With this objective in mind CAN/US scientists agreed that some conversion factor was required to account gear changes. Starting around 1997, the so-called ‘Bromaghin conversion factor’ (FCBC) was developed to make adjustments because DFO fishwheels were thought to catch predominantly smaller and younger salmon. The factors were based on estimated net selectivity patterns (see Bromaghin 2004, 2005). As early as 2005, it was noted that the Eagle gill-net sampling estimates differed from the FCBC adjusted Bio-Island records. These observations catalyzed interest in developing alternative conversion factors.

Further discussions between ADF&G and DFO staff during recent meetings highlighted the need to determine if bio-sampling operations conducted at Eagle provided representative estimates of composition of chinook and chum salmon populations crossing the border (in terms of age/length/sex), and what were the necessary sample sizes required from Eagle operations, catch monitoring and spawning grounds surveys. The objectives of the present investigation are (i) to provide some insight on the merits of alternative conversion factors, (ii) the suitability and limitations of current bio-sampling operations conducted at Eagle, and (iii) suggestions on Canadian ASL sampling operations to complement those obtained from Eagle for assessments.

2. Symbols and Notation

The following symbols, notation and definitions apply to the various components and functions of the estimation and simulation models described in the following sections.

a	variable or subscript denoting the actual age of a salmon (1-4 for ages 4-7)
a'	variable or subscript denoting the decimal age of a salmon (1-6 for ages 1.2-2.4)
c_n	variable denoting the capture of a chinook (*n* of *N*, with age *a* or size *s*)
g	variable or subscript denoting a gill-net mesh size (1-4, for 5.3”, 6.5”, 7.5”, 8.5”)
s	variable of subscript denoting a chinook size (MEF length in cm).
n	variable of subscript denoting an individual fish
x	Pearson model variable for measure of fish size
λ	Pearson model parameter for distribution shape
θ	Pearson model parameter for distribution shape (>0)
σ	Pearson model parameter for distribution shape (>0)
ω	Pearson model parameter for gill-net tangling ($0<\omega<1$)
τ	Pearson model parameter for the distribution mode location
r^2	Coefficient of determination
χ^2	Chi-square test value
C_{sg}	Total catch of size *s* fish in gill-net type *g*
C_{ag}	Total catch of age *a* fish in gill-net type *g*
I_{sg}	Number of size *s* fish intercepted by gill-net type *g*
I_{ag}	Number of age *a* fish intercepted by gill-net type *g*
N_g	Total number of fish intercepted by gill-net type *g*
$N(\mu,\sigma^2)$	Denotes a Gaussian probability distribution with a mean and variance
P	Variable denoting a probability level (generic term for 0-1)
P_{sg}	Probability of capture of size *s* fish in gill-net type (*g*)
$P_{a's}$	Probability of age a’ fish being of size *s*.
$S(x)$	Gill-net selectivity index
$U(0,1)$	Denotes a Uniform distribution within probabilities in the 0-1 range.
ASL	Denotes samples with age, sex and length measurements
FCBC	Bromaghin conversion factor
FL	Fork length usually measured from tip of snout to tail fin fork
FW	Fish-wheel gear
GN	Gill-net
LBI	Left Bank in-shore GN set
LBN	Left Bank near-shore GN set
LBO	Left Bank off-shore GN set
RBN	Right Bank near-shore GN set
MEF	Mid-eye to fork length (usually in mm)
RLM	Ratio of MEF fish length to gill-net mesh perimeter

3. Datasets and Sources

3.1 Eagle length frequency sampling

Since 2005, bio-sampling was conducted at Eagle using several gill-net mesh sizes. Since 2007, five gill-net mesh sizes were used (5.25" (≈5.3"), 5.8", 6.5", 7.5" and 8.5", but the 5.8" mesh was only used shortly in 2007, so the remaining four are respectively termed GNs 1-4 or Net_1-4). Efforts are generally made to deploy the main four gill-nets sequentially across the river, but not in the middle section. During 2007-2010, there were differences in the deployment pattern and frequencies of each gill-net type (Table 1). During 2007-08 Period_1 (morning usually), two gill-nets were drifted twice at three locations from the left bank to about a third across (12 sets/d) mainly to determine species composition. During Period_2 (afternoon usually), three gill-nets types were drifted once at three locations, two of which were at the same morning locations (9 sets/d) mainly to collect Chinook age-sex-length (ASL) samples. During Period_1 in 2007, the 5.3" and 7.5" gill-nets (25' deep) were used initially, but about halfway during the season shorter nets of 8' were thought to be more adequate for some drifts; and a 5.8" gill-net was used to replace a non-available 5.3" gill-net. During Period_1 in 2008, only the 5.3" and 7.5" gill-nets were used. During Period_2 of 2007-08, the 6.5", 7.5" and 8.5" gill-nets were used each season. During Period_1 of 2009-2010, the net types and set locations were as during 2008. However, during Period_2, four net types were used instead of three as in previous years, and during 2009, some Period_2 deployments were actually done during mornings and afternoons. Table 2 figures summarize pooled gill-net sets and corresponding catches by season.

The gill-net dimensions deployed at the RB, LBN and LBO locations were 25 fathoms long and 25 feet deep (≈3750 ft^2). The gill-net deployed in the LBI location was 25 fathoms long and 8 feet deep (≈1290 ft^2) after the mid-season of 2007. It usually takes 1 minute to deploy the net, which then drifts for 5 minutes, and is retrieved during the next two minutes. Indices of fishing effort by net gears typically accounts for net dimensions and soak times. For gill-net gear, a conventional equation used is that of a non-symmetrical trapezoid surface area obtained by the net area times half the deployment period, plus the net area times the drifting period, plus the net area times half the retrieval period. A crude fishing effort index is given by the surface area fished by time. This amounts to roughly 24,375 ft^2•min for the first three locations, and 7,800 ft^2•min for the last location. At the time of this writing, no adjustments could be made to account for snags, net breaks, non-constant deployment periods, potential gear saturation effects, salmon migration patterns, catch handling periods, and other factors affecting fishing effort, so no efforts were made to compute catchabilities coefficients by gill-net type and sampling location.

Salmon brought on board are measured to the nearest mm, and each is aged later on from scale samples to generate a table of age by length frequency combinations. The size-at-age distributions of Pacific salmon are influenced by rearing periods in fresh water and marine environments. Several notations have been used by fishery agencies monitoring north Pacific stocks, but the INPFC age designation used by Alaska and Yukon fishery scientists is used here to compute total age (see Appendix I for details). A summary of the length-at-age distributions obtained from gill-net sampling operations conducted at Eagle during 2007-2010 (Table 3) indicates that most chinook caught are 5-6 year olds with average MEF lengths of about 734 and 850 mm respectively.

3.2 Conversion factors for fishwheel and gill-net samples

The length frequency distributions for the chinook catches at Eagle and Bio-Island are not readily comparable because fork lengths (FL) were collected at the fishwheels, while 'mid-eye to fork lengths' (MEF) are generally collected at Eagle. A linear relation was found to exist between paired measurements collected in 2005-08 and 2011 that is independent from the mesh sizes used. After fitting a simple linear regression to the measurements, no anomalies was observed in the distribution of the residuals (not shown) well-centered about zero over the range of values. FL measurements are greater than MEF measurements (both expressed in cm), so a linear regression is used to convert FL to MEF equivalencies

[1] $$MEF = 1.446 + 0.898\ FL \quad (n = 2835,\ r^2 = 0.988)$$

Corresponding length frequency datasets for two seasons where compared (Table 4). These differed to a greater or lesser extent depending on which fishwheel and gill-net are compared. Some differences are obviously influenced by non-equal sample sizes. There is no reason to assume that one fishwheel catch is more representative of the actual run composition than the other (for sex or sizes) given both used the same mesh size and were operated at similar times under variable water conditions. Consequently, the records from both fishwheels were pooled to obtain greater sample sizes that should be more representative of the actual run composition. For GN samples, there is also substantial variation in sample sizes and length frequency distributions by mesh size. At the time of this writing, it was assumed that catch length frequencies from all GN samples are simply pooled each season by ADF&G personnel for assessment purposes, and not weighted by sample sizes. Simply pooling GN length frequencies in this fashion may not yield more representative estimates of the actual run composition, but this issue was not investigated here.

The method used to conduct statistical comparisons of the various data sets should not be affected by large differences in samples sizes. For such cases, Bootstrap techniques can be often be used to conduct statistical comparisons from samples of unequal sizes. But even Bootstrap methods assume that the true population distribution can be approximated by a discrete distribution identical to that in the smallest samples available. In the present context, the number of size measurements obtained in a season with some gill-nets were <100/yr, and substantially fewer than the corresponding measurements from the fishwheels. So for this preliminary investigation, the levels of similarity between various datasets were determined using random sub-samples (without replacement) from the larger pooled length frequencies from the two fishwheels so as to match those of the gill-net samples.

Since only Net_2 caught a single fish in the 40-45 interval in 2007, sub-sample sizes and statistical comparisons were conducted by omitting frequencies for small fish (30-35, 35-40, 40-45 categories) for 2007-208. For larger fish, frequencies in the 105-110 interval is omitted because only Net_4 caught a single fish in both years. This elimination procedure reduces the number 0-1 frequencies in various size intervals, which can potentially bias the results of Chi-Square statistical comparisons (Zar 1984). This sub-sampling and elimination procedure yielded 4 groups of the pooled FW samples for 2007 and 2008 (SS_1-4) with sample sizes matching those of each GN mesh size category (Table 4). SS_1-4 and Net_1-4 frequencies were also pooled to compare total frequencies for all GN mesh sizes by size category for 2007-2008 (SS_Comb & All Nets,Table 5).

Chi-Square tests were performed to determine the significance of differences between various frequency distribution pairs (SS_ vs. Net_) over the 45-50 to 100-105 cm intervals for both seasons. However, before conducting such test, further adjustments were made to the datasets for comparative purposes. For cases where data pairs contained zeros in the same size interval (usually smallest or greatest), those with frequencies of zero were not used for statistical comparisons. For instance, in 2008, frequencies of zero for SS_2 and Net_2 in the 100-105 size intervals were not used for comparisons (blanks in Table 4), so statistical tests were performed using only 11 size intervals instead of 12 for SS_1 vs. SS2 for that year.

For 2007, statistically significant differences ($P<0.05$) were obtained between all comparisons except for the SS_1 vs. Net_1 ($P\approx 0.055$). Similar results for 2008, with no significant difference for SS_1 vs. Net_1 ($P\approx 0.251$). Similar results for 2006 for SS1_1 vs. Net_1 when a 5.25" mesh size was also used (n=139, $P\approx 0.102$). Significant differences were also obtained for all other combinations of gill-net samples for 2007-2008. A few additional tests were conducted with additional random samples, and in many cases, similar results were obtained for SS_1 vs. Net_1 although not all were statistically different for 2007 ($0.05<P<0.1$) Such inconsistencies are not unexpected when comparing relatively low numbers of randomly selected sizes binned across ≤12 size intervals. Also not that Chi-Square tests may produce biased results when some frequencies are <1, and several are less than 5 (Zar 1984, P.70). More reliable tests were conducted by pooling the 2007-2008 samples in respective categories. Here again Chi-Square testing revealed no significant differences for SS_1 vs. Net_1 (n=118, $P\approx 0.55$), but differences for other comparisons. Similar results were obtained using powerful alternative tests (Log-linear tests for contingency tables), with Maximum-Likelihood Chi-Square results showing slightly greater levels of similarity fo SS_1 vs. Net_1 than obtained by Pearson Chi-Square tests.

In light of the above results, the closest match between the combined FW catch size frequencies and those from GN sampling operations conducted at Eagle during 2006-08 are those from samples obtained with the 5.25" mesh. This is likely due to the fact that DFO fishwheels scooped surface waters, and intercepted mostly smaller chinook swimming near the surface. Relatively small chinook can be intercepted to a greater extent by the 5.25" mesh than by large mesh sizes. Perhaps even greater levels of similarity between SS_1 and Net_1 would be observed if more samples had been collected with Net_1 during 2006-08. In light of such findings, the simplest way to relate past and actual sampling operations might be to consider the pooled FW length frequency samples as roughly equivalent to what would have been obtained at Eagle if all size frequency samples had been collected using only a 5.25” mesh gill-net.

3.3. Size distributions of GN samples.

If FW samples are considered to be roughly equivalent to those obtained at Eagle with a 5.25” GN mesh size, other key issues to be addressed is (i) how representative are length frequency samples from a 5.25” GN mesh size catch to that of the actual population, (ii) is the size frequency obtained with additional GN mesh sizes more representative, (iii) is the pooled GN 1-4 sample more representative of the actual population size composition, and finally (iv) what adjustment factor(s) (if any) should be used to determine the actual population size composition based on the GN size frequency samples from Eagle operations. The best answers would be obtained by comparing the actual population size composition to that of the Eagle GN samples. Unfortunately, no information is available on what the actual composition is each year.

To provide insight and tentative answers to the above questions, numerical simulations were conducted using hypothesized but plausible combinations of population size/age structure, run size, GN selectivity curves for the various mesh sizes currently used at Eagle for bio-sampling, and GN specific sampling records. As a substitute for an actual run, data from recent bio-sampling operations conducted at Eagle were used to generate the hypothetical population size/age structure and run size/timing pattern.

A total of 18 different continuous distributions were sequentially fitted to the 2007-10 MEF length sample records summarized in Table 1 to determine which distributions were the most representative. For older chinook of ages 6-7 (or 1.5, 2.3, 2.4) with small sample sizes, none of the distributions fitted these reasonably well. For age 4 chinook (or 1.2) with the smallest sample size, a ‘Tent-Shaped’ Cauchy distribution provided the best fit of all those tested, and much better than the Normal distribution which is more influenced by kurtosis (Fig. 1). By contrast, for age groups 5-6 (or 1.3, 1.4) with the largest sample sizes, a ‘Bell-Shaped’ normal distribution provided nearly the best fit of all those tested (Fig. 2), and with a better distribution of residuals.

It is hypothesized that the above results are caused by a combination of factors that influence the sampling record distributions. Chinook salmon migrating up the Yukon River move through a gauntlet of subsistence gill-net fisheries along the way. Smaller mesh gill-nets used in AK in-river before 2011 have selectivity patterns more akin to the ‘Tent-Shaped’ Cauchy distribution, and the small samples obtained for such nets may not reflect the kurtosis of the actual length distribution for age 4 chinook. By contrast, the length frequency distributions of older chinook (1.3, 1.4) use larger sample sizes (pooled) from a wider range of mesh size effects making it appear more ‘Normal’.

4. Numerical simulation procedure and underlying hypotheses.

Observations reported in the previous sections indicate that Eagle sampling records are likely influenced by gill-net selectivity, insufficient sample sizes for some age groups, inter-annual changes in escapement size/age composition, and inconsistent gill-net deployment patterns over 2007-10. For lack of a better alternative, since the largest size samples for the most common age groups tend to be normally distributed, the size-at-age distributions of 'typical' chinook runs are assumed to be normally distributed before reaching the border crossing, with means and standard deviations based on statistical summaries of the pooled observed measurements (2007-2010). It is also assumed that the abundance proportions by age categories are based on a statistical summary of the same pooled observations (Table 6). These figures serve as input to generate hypothetical size/age distributions for run sizes ranging from 30-75K chinook/year.

Numerical simulations are firs conducted to generate a hypothetical chinook population entering Canada of a certain size (say $N \approx 30{,}000$). Given assumptions the age and size-at-age distribution of this population, the corresponding size and age frequency distributions are first generated, and serve to represent a 'Expected' frequency distributions that would be obtained if the entire border passage was enumerated and measured perfectly.

Pseudo-observations from GN sampling operations conducted at Eagle are then generated in a second step by having each chinook passing the border be intercepted by a gill-net but not necessarily caught. The number of chinook captured and measured is computed using the theoretical selectivity curves for each gill-net type used, and a given gill-net deployment pattern during the season. Total catches are initially set to recent samples obtained at Eagle (≈ 400/yr recently). The pseudo-observations generated then serve to produce the observed age and size-at-age frequency distributions from samples.

Expected and observed frequency distributions by age and size intervals are compared using a hypothesized run (not sampled by gill-nets), and pseudo-observations as would likely be obtained from gill-net fishing operations during a season given a specific gill-net deployment pattern. Statistical comparisons of frequency distributions are conducted via log-linear analyses of frequency distributions that yield Pearson Chi-square values and associated probability values. The results obtained served as the basis to formulate recommendations for improvements. The following sections provide details on the simulation model structure, model functions, simulation process, underlying assumptions and results.

5. Description of simulation model

<u>5.1 Model structure and functions</u>

As noted in JTC (2006), Bromaghin (2004) evaluated the suitability of several gill-net selectivity models for salmon species, and concluded the Pearson function was the most suitable. The Pearson selectivity model given by Bromaghin (2005) for gill-nets is

[2] $$f(x) = \left(1 + \frac{}{}\right) \left[1 \quad \frac{(x - \tau)}{}\right] \quad \left\{- \left[t \quad \left(\frac{(x - \tau)}{}\right) \quad \left(\frac{}{}\right)\right]\right\}$$

To account for potential tangling of larger than optimum size fish for a particular gill-net mesh size, Bromaghin (2005) proposed that the gill-net selectivity be adjusted such that

[3] $$S(x) \quad \begin{cases} & f(x) \\ f(x) & \end{cases}$$

The measure of fish size (*x*) used by Bromaghin (2005) is given by the ratio of fish length (MEF in mm) to the perimeter (RLM) of a gill-net mesh size usually reported in inches. So RLM is computed by converting mesh size to the equivalencies in millimetres, and doubling this figure to account for stretched length (Hamachan, ADF&G, pers. comm). So given an 8" gill-net, a 900 mm size chinook (MEF), then x = 900/(8.0*25.4*2.0) = 0.2215.

The best fitting parameter values for various Yukon River salmon species reported by Bromaghin (2005) and combination of gill-net mesh sizes and perimeter values used for the present investigation (Table 7) yields selectivity trends (Fig. 3) that are identical to those reported by Bromaghin (2004, p.33) for corresponding gill-net mesh sizes. Note that the selectivity value *S(x)* is akin to a probability of capture for a combination of gill-net mesh size and MEF. This probability is hereafter denoted by P_{sg} for the *S(x)* value for fish size *s* (MEF length in cm) intercepted by a gill-net type *g* (=1-4, for 5.3", 6.5",7.8",8.5").

The numerical simulation algorithm (or 'simulator' for short) uses mainly Table 7-8 figures to generate expected length and age distributions for gill-net sampling operations with a few simplifying assumptions. Table 6 age contributions are first used to generate a cumulative run contribution (i.e. a proportion) given expected abundances by decimal age category (Col. J, Table 7). For each salmon intercepted by a gill-net at Eagle (n=1 to N), a uniform random number (0-1 interval) is generated by the simulator (for n=1, say 0.916 as in Table 7, Col. L). The random number serves to determine the age of chinook by matching the random number to the cumulative run contribution by age class (Col. J, Row 4, Table 7). This corresponds to actual age 6 and decimal age 1.4. Since ages 6-7 can each include two decimal age groups, random sizes are generated based on decimal ages (for discrete MEF 1 cm sizes) from a normal distribution with the mean and standard deviation for that decimal age group (Table Col. D-E). Randomly chosen sizes at decimal age ($s_{na'}$) and corresponding actual ages and sizes (a_n, s_{na}) for all *N* fish sequentially intercepted in gill-nets are computed from

[4] $$(\mu \qquad)$$

[5]

[6]

The numbers of fish in each age and size category for the chinook population crossing the border is obtained by summing up counts by category over all trials (30,000 for *N* chinook)

[7] $\sum$

[8] $\sum$

By contrast, the catch of chinook by size or actual age (C_{sg}, C_{ag}) from all fish intercepted by a gill-net type during a season (I_{sg}, I_{ag}) must be computed differently. First the gill-net type that intercepts a chinook of age *a* and size *s* in a simulation trial (*n*) is determined using a uniform probability distribution over the 1-4 range. The corresponding probability of capture of that gill-net (*g*) for a chinook of size *s* (P_{sg}) is summed up over the season to determine the total catch by size or age category for that gill-net, and for all gill-net catches combined.

[9] $U(1,4)$

[10] $\sum$

[11] $\sum$

[12] $\sum$

[13] $\sum$

Note that for Eq. 9-1, I_{sg} and I_{ag} must be determined largely by trial and error to obtain a specific catch sample since P_{sg}<1.0 for most non-optimal sizes. Depending on the combination of gill-nets used, the catch is always lower the than the number of fish intercepted by gill-nets during the season ($N>I>C$). For these simulations $C/I \approx 0.2$-0.6. A graphical illustration of the simulator algorithm and steps involved is presented in Appendix II.

5.2 Determination of sampling requirements

The 2007-10 gill-net deployment patterns summarized in Table 1 indicate that changes were made each season. Ideally, the same deployment patterns should be maintained in the future, at a minimum to facilitate statistical comparisons of run composition across seasons. Based on past records, for initial simulations, it is assumed that 6 sets/day will be made with each gill-net type (total 24 sets/day). For purposes of simplification, it is also assumed that (i) sets will be conducted at given locations and times each day throughout the entire run, (ii) gill-net catchabilities and selectivities are the same between locations and times (or are consistent across seasons), (iii) that the size/age composition of the runs do not change during and between each season, and that (iv) age estimates and size measurements are accurate.

Frequency distributions of numbers-at-age and numbers-at-size and were first generated by assuming a typical chinook border passage of 30,000 chinook. The resulting frequency distributions are binned by 5 cm size interval or by actual age (4-7). For comparative purposes, the frequencies by size or age intervals were reduced proportionally to produce 'perfectly representative distributions' for total frequencies of 200, 400, 600, 800, and 1000. In addition, a second series of frequency distributions were generated using Eq. 4-8 by sampling the entire population, but limiting the samples to 200, 400, 600, 800 and 1000. The latter two frequency distributions are hereafter referred to as Subset A and Subset B respectively, with subset A used for statistical comparisons (likely more representatives of true proportions than subset B based on samples).

The same simulation process was repeated to determine pseudo-observations that would result stem from sampling operations conducted with gill-nets. For each trial, an additional uniform random number generated to determine the gill-net type intercepting the n^{th} chinook having given size and age. The corresponding capture probabilities were determined, and total catches are updated via Eq. 10-13. The numbers of Monte Carlo trials conducted for this purpose were set such that combined gill-net catches would amount to 200, 400, 600, 800, and 1000.

The results of statistical comparisons of frequency distributions conducted via log-linear analyses are more reliable when the total frequencies of expected or observed samples are similar, and frequencies by category are >0. So when comparisons involved the 'perfect' frequency distribution for 30,000 chinook (or subsets of), the frequencies in the <45 cm and >105 cm size intervals were omitted since these were often nil or negligible. Consequently, statistical comparisons were conducted using only frequencies by 5 cm bin in the 45-105 cm size range. Visual comparisons of the frequency distributions help reveal what may be missed by using a certain combination of gill-net types and deployment patterns. Statistical comparisons help determine if certain gill-net sampling operations yield more representative frequency distributions of the 'actual' population, and if these are sufficiently similar to be considered suitable (i.e., no statistically significant differences are $\alpha = 0.05$).

6. Results and preliminary conclusions

Frequency distributions of sizes and ages for the hypothetical population are contrasted with those of sampling subsets B for total frequencies of 200 and 600 (Fig. 4). Omitting the obvious shift caused by non-standard scales (Our apologies: the error was noticed at the time of this writing), the frequency distribution based on a small sample of 600 (bottom) is closer to the actual distribution (top) than that based on a sample of 200 (middle), and the age distributions are fairly similar. Two very important conclusions stem from these results, namely; with perfect random sampling conducted throughout the run systematically, fairly representative figures of size composition can be obtained even very small samples (600 or 2% of total), and for age distribution with perhaps even fewer samples (200, or <1% of total).

The second comparison is for Subset A versus Subset B size frequency distributions (Fig. 5). As noted earlier, the former is the actual size frequency distribution by 5 cm bin for population of 30,000 chinook, reduced proportionally (or scaled) so as to be a mirror image, but for total frequencies of 200, 400 or 600 (rather than 30,000). Subset B distributions are perfectly random samples of the hypothesized population for the same total frequencies. A cursory examination of the paired frequency distributions reveals very little difference between the scaled frequencies and those from perfectly random samples when ≥400 frequencies to compare. These results support the use of scaled frequencies for conducting statistical comparisons, as these are even more representative of 'expected frequencies' than those based on samples subject to a little more stochastic variation.

The third comparison made is between size frequency distributions of scaled values versus GN_1-4 for same catch sample sizes (Fig. 6). The trends reveal that there are noticeable differences between the size frequencies when 400 chinook are caught and measured, with over-representation in the 70-85 cm size range, and under-representation in smaller or larger size intervals. However, the discrepancies tend to decrease whit greater sample sizes, such that when 1000 chinook are caught and measured, the samples are more representative of the actual run size composition and the differences are almost statistically insignificant.

Note that the results shown are for a given gill-net deployment pattern (4 types rotated sequentially for 24 sets/day). It may be possible to adjust the combination of gill-net types used and deployment frequencies such that more representative samples would be obtained. With little additional work (relatively), the simple numerical simulation model used can be transformed into a stochastic optimization model that could potentially provide estimates on a more suitable combination of effort/type. This amounts to simply estimating gill-net utilization weights that minimize discrepancies between actual and expected frequencies.

7. Still TO-DO list

- Get feedback, fix small typos, re-assess tenuous assumptions
- Determine what would be missed if all samples collected with 5.3" GN. Use results to determine conversion factors for size/age to update brood tables (FW vs GN).
- Investigate other scenarios (like smaller runs, different age composition, small tributary populations, etc.)
- Get feedback from AK re importance of size vs age. Fecundity/productivity implications ?
- What level of precision/accuracy is required, and how much $$ needed.

….

LITERATURE CITED

Adkinson, M.D., and Z. Su. 2001. A comparison of salmon escapement estimates using a hierarchical Bayesian approach versus separate maximum likelihood method estimation of each year's return. Can. J. Fish. Aquat. Sci. 58: 1663-1671.

Bromaghin, J.F. 2004. An evaluation of candidate net selectivity models for 1990-2003 Yukon River sonar gill-net catch data. U.S. Fish & Wild. Serv. Alaska Fisheries Technical Report Number 75, Anchorage.

Bromaghin, J.F. 2005. A versatile net selectivity model, with application to Pacific salmon and freshwater species of the Yukon River, Alaska. Fisheries Research 74: 157-168.

Crane, A.B., and R.D. Dunbar. 2009. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 09-30, Anchorage.

Crane, A.B., and R.D. Dunbar. 2009. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2007. Alaska Department of Fish and Game, Fishery Data Series No. 09-27, Anchorage.

Crane, A.B., and R.D. Dunbar. 2011. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2010. Alaska Department of Fish and Game, Fishery Data Series No. 11-72, Anchorage.

Crane, A.B., and R.D. Dunbar. 2011. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2009. Alaska Department of Fish and Game, Fishery Data Series No. 11-08, Anchorage.

JTC (Joint Technical Committee of the Yukon River US/Canada Panel). 2006. Potential causes of size trends in Yukon River chinook salmon populations. Alaska Dept. of Fish & Game, Division of Commercial Fisheries, Regional Information Report No. 3A06-07, Anchorage. 34 pp.

Zar, J.H. 1984. Biostatistical Analysis. Second edition. Prentice-Hall. New Jersey. 718 p.

TABLES

Table 1. Detailed gill-net sampling records for Eagle operations (2007-10). Nets figures (across) are mesh sizes. Labels LBI, LBN, LBO are Left-Bank in-shore, near-shore, off-shore, and RBN are Right-Bank near-shore. Data from Crane and Dunbar (2009, 2011).

Year = 2007												
Period 1 AM	July 18 to Aug 22		**Nets**	**5.3**	**5.8**	**7.5**	**8.5**	**Fish #s**	**5.3**	**5.8**	**7.5**	**8.5**
36 days	LBI	2 Sets	**LBI**	36	36	72		**LBI**	12	0	6	
	LBN	2 Sets	**LBN**	72	0	72		**LBN**	33	0	48	
	LBO	2 Sets	**LBO**	72	0	72		**LBO**	9	0	15	
Estimated Passage	37304		Note: 1/2 5.25, 1/2 5.75 for LBI									
Period 2 PM	July 9 to Aug 15		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
38 days	LBN	1 Set	**LBN**		38	38	38	**LBN**		80	59	45
	LBO	1 Set	**LBO**		38	38	38	**LBO**		18	23	8
	RB	1 Set	**RB**		38	38	38	**RB**		26	27	15
Estimated Passage	40492											
Year = 2008												
Period 1 AM	July 26 to Aug 16		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
22 days	LBI	2 Sets	**LBI**	44		44		**LBI**	9		6	
	LBN	2 Sets	**LBN**	44		44		**LBN**	43		40	
	LBO	2 Sets	**LBO**	44		44		**LBO**	13		5	
Estimated passage	23321											
Period 2 PM	July 11 to Aug 15		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
36 days	LBN	1 Set	**LBN**		36	36	36	**LBN**		28	48	18
	LBO	1 Set	**LBO**		36	36	36	**LBO**		7	16	12
	RB	1 Set	**RB**		36	36	36	**RB**		78	85	50
Estimated Passage	36594											
Year = 2009												
Period 1 AM	Aug 2 to Aug 20		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
19 days	LBI	2 Sets	**LBI**	38		38		**LBI**	1		1	
	LBN	2 Sets	**LBN**	38		38		**LBN**	8		6	
	LBO	2 Sets	**LBO**	38		38		**LBO**	1		0	
Estimated passage	6739											
Period 2 AM+PM	July 11 to Aug 1		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**					
22 days	LBN	2 Sets	**LBN**	33	33	33	33	Combined Period 2 AM+PM sets				
	LBO	2 Sets	**LBO**	33	33	33	33	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
	RB	2 Sets	**RB**	33	33	33	33	**LBN**	44	69	48	64
Estimated passage		61481						**LBO**	20	25	35	24
								RB	101	87	99	78
Period 2 PM	Aug 2 to Aug 15		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**					
14 days	LBN	1 Set	**LBN**	11	11	11	11					
	LBO	1 Set	**LBO**	11	11	11	11					
	RB	1 Set	**RB**	11	11	11	11					
Estimated passage	6143											
Year = 2010												
Period 1 AM	Aug 1 to Aug 19		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
19 days	LBI	2 Sets	**LBI**	38		38		**LBI**	1		0	
	LBN	2 Sets	**LBN**	38		38		**LBN**	26		22	
	LBO	2 Sets	**LBO**	38		38		**LBO**	11		9	
Estimated passage	10958											
Period 2 PM	July 5 to July 31		**Nets**	**5.3**	**6.5**	**7.5**	**8.5**	**Fish #s**	**5.3**	**6.5**	**7.5**	**8.5**
27 days	LBN	2 Sets	**LBN**	41	41	41	41	**LBN**	31	58	65	40
	LBO	2 Sets	**LBO**	41	41	41	41	**LBO**	9	12	5	5
	RB	2 Sets	**RB**	41	41	41	41	**RB**	36	42	62	34
Estimated passage	24097											

Table 2. Gill-net sampling operation summary for Eagle operations (2007-10). Nets figures are mesh sizes. Labels LBI, LBN, LBO are Left-Bank in-shore, near-shore, off-shore, and RBN are Right-Bank near-shore. Data from Crane and Dunbar (2009, 2011).

Number of Sets Made

Year	2007					2008				2009				2010			
Net	5.3	5.8	6.5	7.5	8.5	5.3	6.5	7.5	8.5	5.3	6.5	7.5	8.5	5.3	6.5	7.5	8.5
LBI	36	36		72		44		44		38		38		38		38	
LBN	72		38	110	38	44	36	80	36	44	44	82	44	79	41	79	41
LBO	72		38	110	38	44	36	80	36	44	44	82	44	79	41	79	41
RBN			38	38	38		36	36	36	44	44	44	44	41	41	41	41

Number of Fish Caught

Year	2007					2008				2009				2010			
Net	5.3	5.8	6.5	7.5	8.5	5.3	6.5	7.5	8.5	5.3	6.5	7.5	8.5	5.3	6.5	7.5	8.5
LBI	12	0		6		9		6		1		1		1		0	
LBN	33		80	93	45	43	28	88	18	52	69	54	64	57	58	87	40
LBO	9		18	23	8	13	7	21	12	21	25	35	24	20	12	14	5
RBN			26	15	15		78	85	50	101	87	99	78	36	42	62	34

Table 3. Summary of sampling records from Eagle monitoring operations (2007-10), all samples combined. See Appendix for decimal and actual age definitions. Labels MEF and SD indicate mid eye-fork length and standard deviation respectively.

Decimal Age	Actual Age	MEF (mm)	Range (mm)	Sample Size	Mean (mm)	SD (mm)	Sample Size	Prop. Total
1.2	4	440 - 790	350	172	593	58	2724	0.0587
1.3	5	540 - 980	440	1100	734	62	20381	0.4394
1.4	6	590 - 1055	465	1227	849	59	22081	0.4760
1.5	7	760 - 1000	240	35	909	63	776	0.0167
2.3	6	525 - 890	365	17	702	79	130	0.0028
2.4	7	790 - 915	125	38	842	37	293	0.0063

Table 4. Chinook MEF length frequencies (by 5 cm intervals) from Bio-Island fishwheels (FW) and Eagle gill-net (GN) fishing operations, 2007-08. WR and SR labels denote the White Rock and Sheep Rock FW locations. For Eagle, column headers denote GN mesh sizes (in inches). Sums are combined frequencies for FW and GN samples.

2007	Bio-Island (FW sites)				Eagle (GN mesh sizes)			
MEF	WR	SR	Sum	5.3	6.5	7.5	8.5	Sum
30-35		1	1					0
35-40		3	3					0
40-45	2	5	7		1			1
45-50	32	19	51			1	1	2
50-55	54	47	101	1	1	2	1	5
55-60	88	53	141	2	2	7		11
60-65	55	48	103	7	5	9		21
65-70	137	99	236	10	10	12	7	39
70-75	142	93	235	11	19	24	7	61
75-80	131	134	265	7	22	31	7	67
80-85	61	114	175	9	30	31	14	84
85-90	41	47	88	5	21	31	14	71
90-95	14	22	36	1	9	23	10	43
95-100	3	7	10		2	6	6	14
100-105		4	4	1	2	1		4
105-110							1	1
Sum	760	696	1456	54	124	178	68	424

2008	Bio-Island FW sites				Eagle (GN mesh sizes)			
MEF	WR	SR	Sum	5.3	6.5	7.5	8.5	Sum
30-35	1	1	2					0
35-40	3	7	10					0
40-45	7	10	17					0
45-50	28	10	38	2		1		3
50-55	36	23	59	2	1			3
55-60	37	24	61	3				3
60-65	89	50	139	2	3	1	1	7
65-70	289	205	494	12	22	23	12	69
70-75	271	166	437	15	32	40	13	100
75-80	139	117	256	8	22	40	7	77
80-85	61	69	130	8	14	40	12	74
85-90	29	50	79	4	10	34	14	62
90-95	19	19	38	3	6	14	15	38
95-100	5	4	9	4	1	7	3	15
100-105	3	3	6	1			4	5
105-110							1	1
Sum	1017	758	1775	64	111	200	82	457

Table 5. Summary of catch length frequencies (MEF equivalencies) by sampling gear used for statistical comparisons given identical sample sizes, based on random sub-samples (without replication) of combined fish-wheel catch length frequencies (SS_1-4) and GN samples for alternative mesh sizes (Net_1-4). 'SS_Comb.', and 'All Nets' labels are combined frequencies of FW sub-samples, and GN frequencies by size interval respectively. See text for details.

Size Interv.	FW Comb. Total	SS_1	Net_1	SS_2	Net_2	SS_3	Net_3	SS_4	Net_4	SS_Comb.	All Nets
30-35	1										
35-40	3										
40-45	7										
45-50	51	1	0	7	0	8	1	3	1	15	2
50-55	101	2	1	6	1	9	2	3	1	34	5
55-60	141	7	2	14	2	16	7	6	0	39	11
60-65	103	7	7	13	5	10	9	8	0	31	21
65-70	236	7	10	16	10	28	12	6	7	64	39
70-75	235	10	11	23	19	22	24	10	7	75	61
75-80	265	10	7	24	22	38	31	15	7	72	67
80-85	175	5	9	12	30	24	31	9	14	53	84
85-90	88	3	5	5	21	16	31	5	14	23	71
90-95	36	1	1	3	9	5	23	1	10	12	43
95-100	10	1	0	0	2	2	6	1	6	4	14
100-105	4	0	1	0	2	0	1			0	4
105-110											
N=>	1456	54	54	123	123	178	178	67	67	422	422

Size Interv.	FW Comb. Total	SS_1	Net_1	SS_2	Net_2	SS_3	Net_3	SS_4	Net_4	SS_Comb.	All Nets
30-35	2										
35-40	10										
40-45	17										
45-50	38	1	2	2	0	5	1			13	3
50-55	59	3	2	4	1	4	0	2	0	18	3
55-60	61	0	3	9	0	4	0	4	0	18	3
60-65	139	3	2	38	3	13	1	7	1	37	7
65-70	494	20	12	31	22	57	23	19	12	126	69
70-75	437	17	15	12	32	54	40	23	13	115	100
75-80	256	8	8	5	22	28	40	12	7	66	77
80-85	130	4	8	6	14	16	40	8	12	28	74
85-90	79	3	4	2	10	11	34	4	14	22	62
90-95	38	2	3	2	6	7	14	2	15	9	38
95-100	9	2	4	0	1	1	7	0	3	2	15
100-105	6	1	1					0	4	2	5
105-110											
N =>	1775	64	64	111	111	200	200	81	81	456	456

Table 6. Summary of size/age statistics used to represent a hypothetical chinook run composition used for simulation purposes, based on 2007-10 sampling records from Eagle (see text for details).

Input (prior) Run size	Age Decimal	Age Actual	Input (prior) MEF (Mean, cm)	Input (prior) MEF (SD, cm)	Input (prior) Length Distr.	Input (prior) Age_contrib.	Output N_Age
45000	Age 1.2	4	59	5.8	Normal	0.059	2643
	Age 1.3	5	73	6.2	Normal	0.439	19773
	Age 1.4	6	85	5.9	Normal	0.476	21422
	Age 1.5	7	91	6.3	Normal	0.017	753
	Age 2.3	6	70	7.9	Normal	0.003	126
	Age 2.4	7	84	3.7	Normal	0.006	284

Table 7. Summary of GN selectivity model parameter estimates for Yukon River Chinook for given GN mesh sizes and corresponding mesh perimeters (after Bromaghin 2005).

Parameter	λ	θ	τ	σ	ω
Name	Lambda	Teta	Tau	Sigma	Omega
Chinook param. values	-0.547	0.622	1.92	0.204	0.031
GN Mesh Size (inch)	5.25	5.8	6.5	7.5	8.5
GN Mesh Perim. (mm)	266.7	294.6	330.2	381.0	431.8

Table 8. Simulation model structure to determine random ages and sizes of chinook salmon intercepted (but not caught) by any gill-net at Eagle.

A	B	C	D	E	F	G	H	I	J	K	L
Hypoth. Run size	Decimal Age	Actual Age	Input (prior) MEF (Mean, cm)	Input (prior) MEF (SD, cm)	Input (prior) Length Distr.	Uncert_Var RAND Length	Uncert_Var RAND Age	Input (prior) Run Contrib.	Cumul. Distr Run Contrib.	N_at-age (aver.)	RAND_N Unif (0,1)
45000	1.2	4	59	5.8	Normal	54.5	4.0	0.059	0.059	2643	0.916
	1.3	5	73	6.2	Normal	65.8	5.0	0.439	0.498	19773	
	1.4	6	85	5.9	Normal	74.6	6.0	0.476	0.974	21422	
	1.5	7	91	6.3	Normal	96.3	7.0	0.017	0.991	753	
	2.3	6	70	7.9	Normal	70.8	6.0	0.003	0.994	126	
	2.4	7	84	3.7	Normal	83.1	7.0	0.006	1.000	284	
Total =>								1.00		45000	

FIGURES

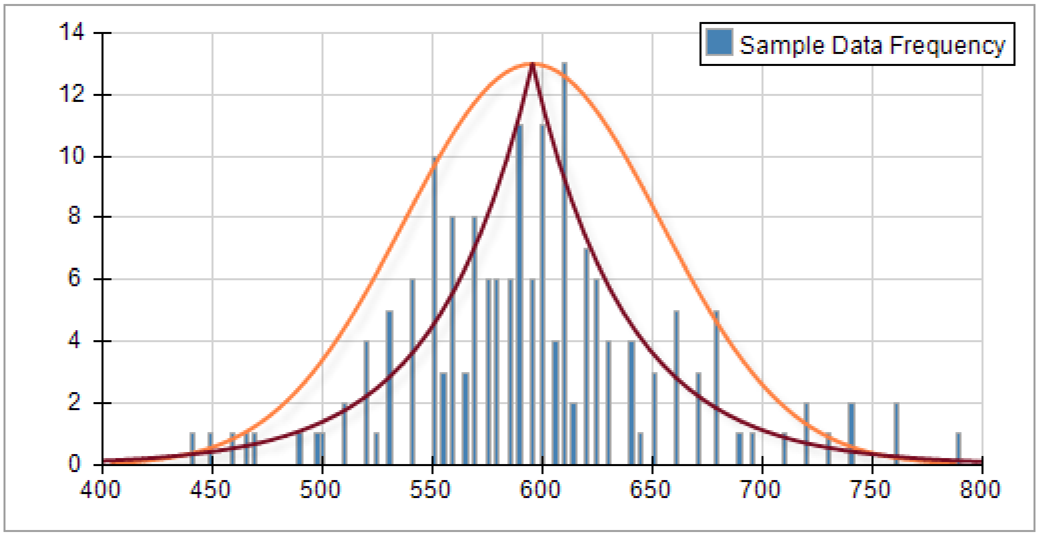


Figure 1. Continuous distributions fitted to 172 MEF lengths (in mm) of age 1.2 chinook from pooled 2007-10 samples. Bell-shaped curve is the Normal, and Tent-shaped curve is a shifted Cauchy. The later fit (brown line) is better, but neither fit is statistically significant (Kolmogorov-Smirnov test, *P* >0.05).

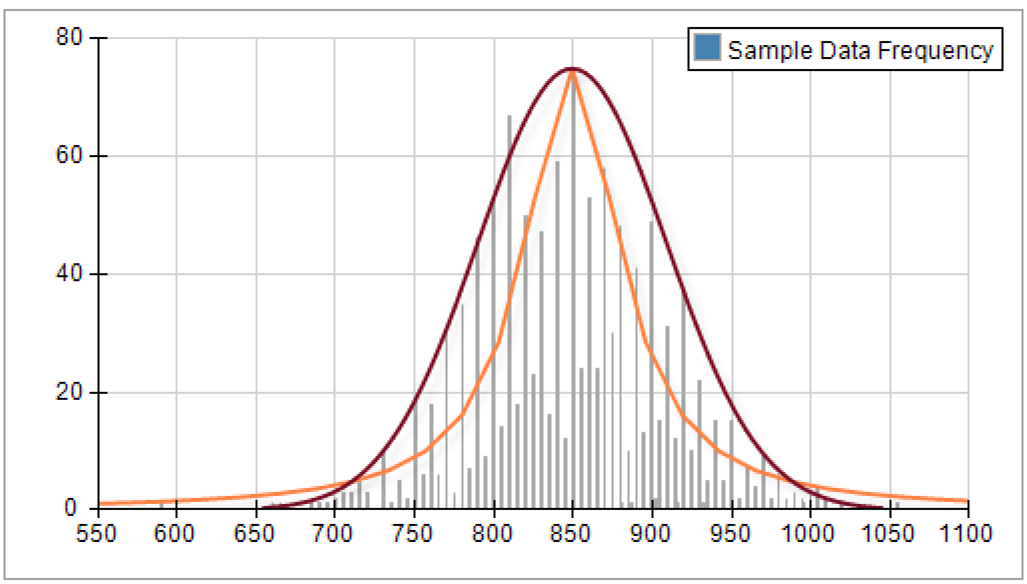


Figure 2. Continuous distributions fitted to 1220 MEF lengths (in mm) of ages 1.3-1.4 chinook from pooled 2007-10 samples. Bell-shaped curve is the Normal, and Tent-shaped curve is a shifted Cauchy. The former fit and residual distribution (brown line) is better, but neither fit is statistically significant (Kolmogorov-Smirnov test, *P* >0.05).

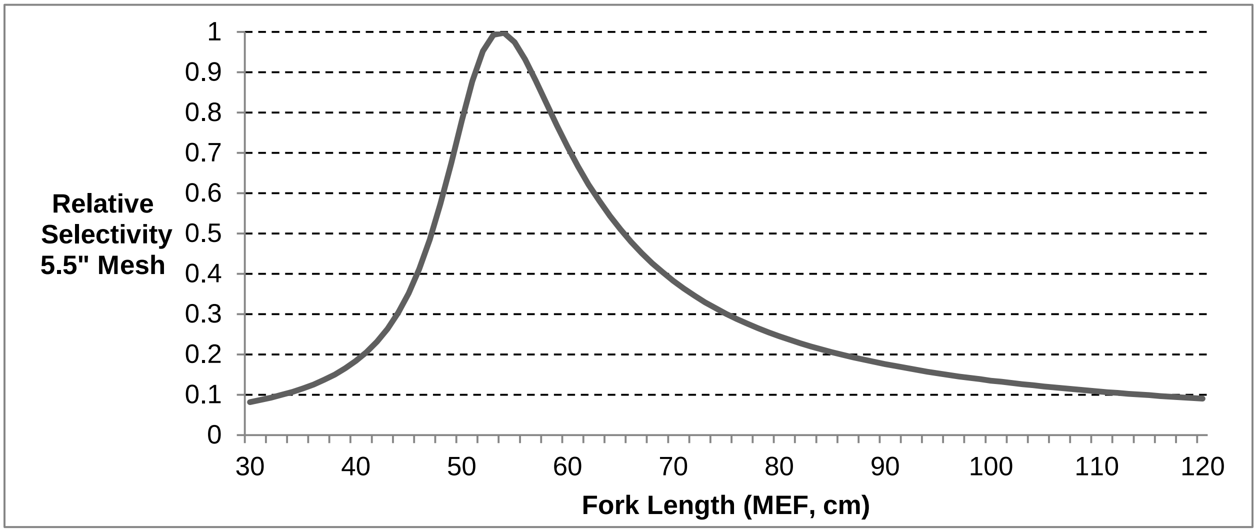


Figure 3. Relative gill-net selectivity curve (5.5” mesh) generated using the Pearson selectivity model and parameters values reported by Bromaghin (2005) for chinook salmon intercepted in the Yukon River for a given gill-net mesh size.

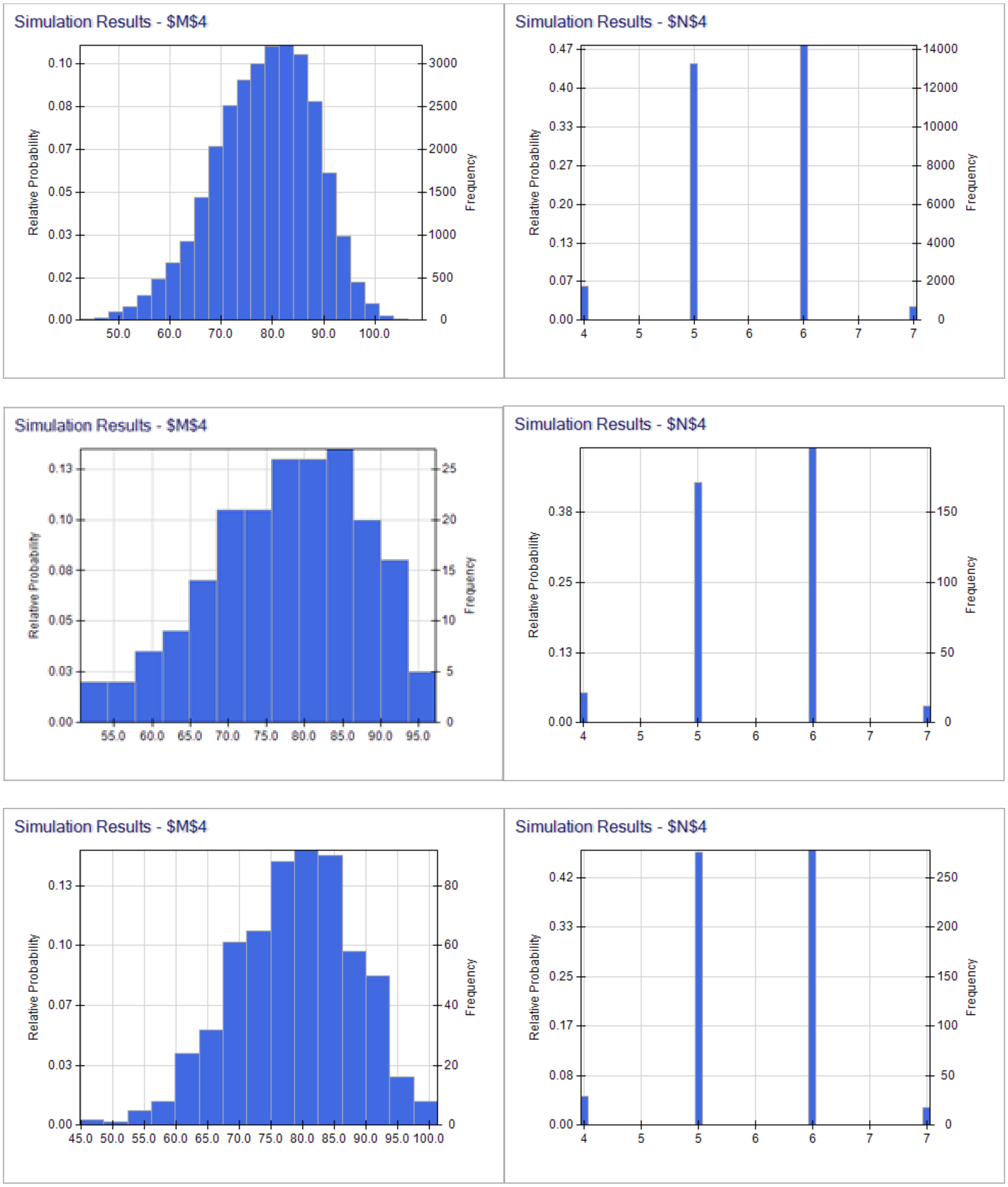


Figure 4. Actual size (left) and and age (right) frequency distributions for a hypothesized run of 30,000 chinook salmon passing Eagle (top), with perfect random samples of 200 (middle) and 600 (bottom). Size abscissa scale range not adjusted (apologies !).

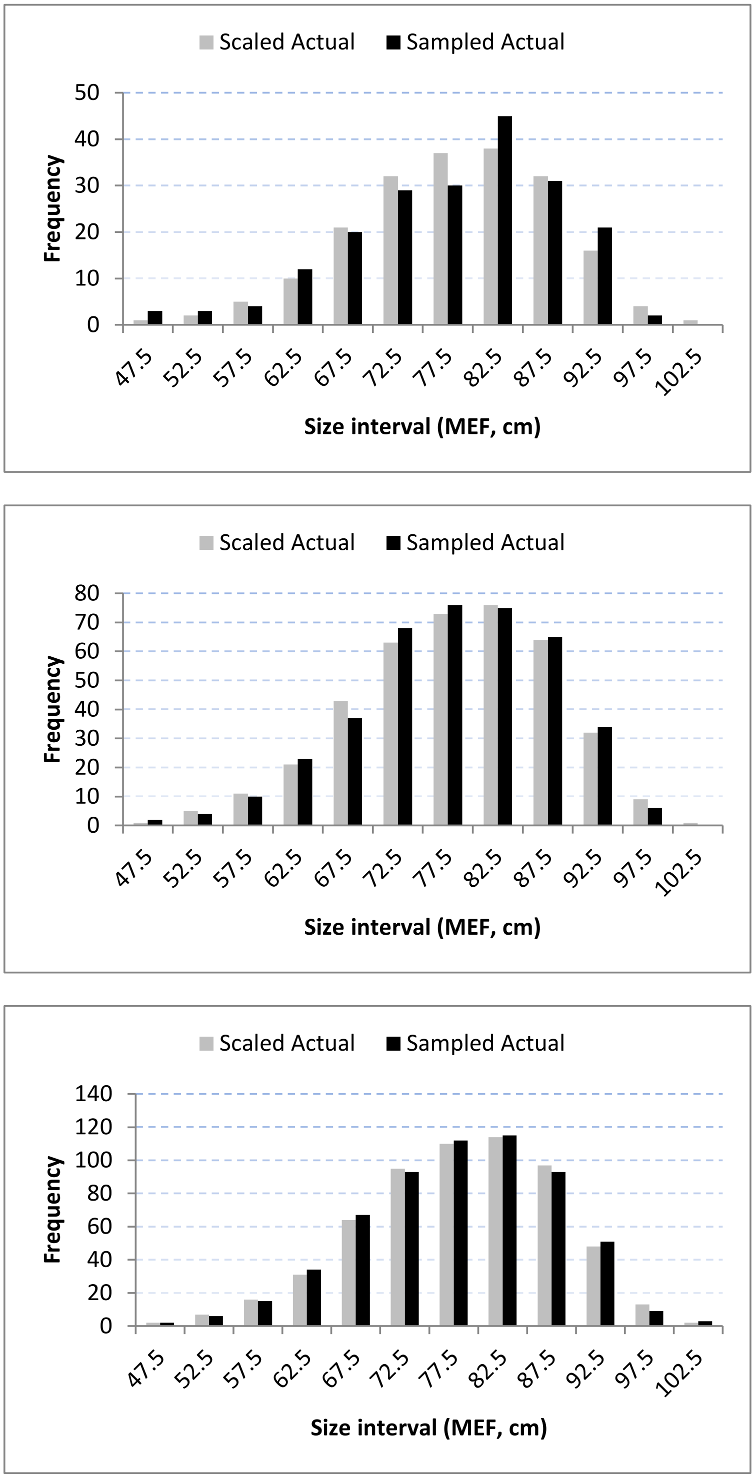
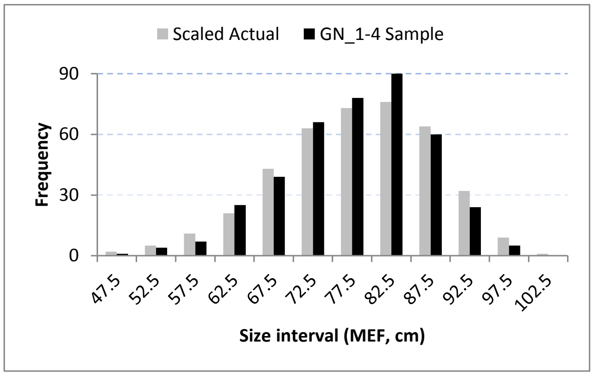
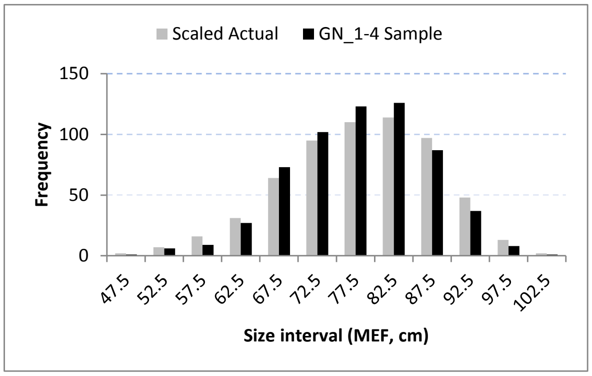


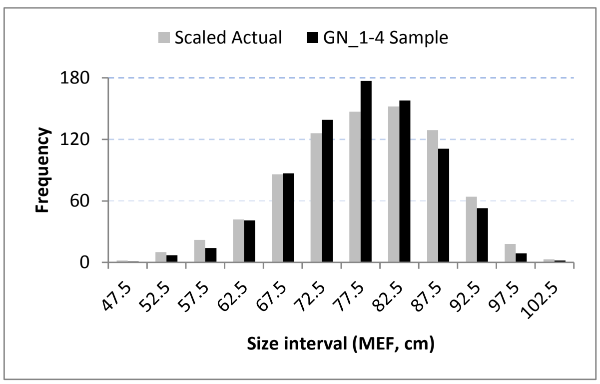
Figure 5. Size frequencies for Subsets A (grey) and B (black) corresponding to frequencies for 30,000 chinook reduced proportionally to 200, 400 and 600 (top-bottom), and to those of perfectly random samples or equal sizes from the same population (see text for details).



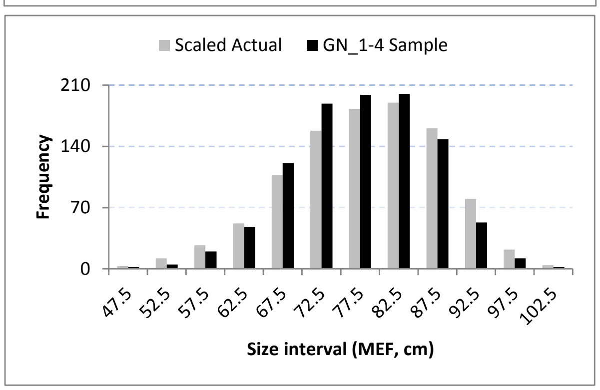
C=400, χ^2 = 5.94, $P \approx 0.88$



C=600, χ^2 = 7.96, $P \approx 0.72$



C=800, χ^2 = 11.45, $P \approx 0.41$



C=1000, χ^2 = 5.94, $P \approx 0.08$

Figure 6. Expected and Observed size frequency distributions for catch samples 0f 400-1000 chinook, and corresponding Chi-square test values and probabilities. Expected are the actual frequencies scaled to GN catch sample sizes.

APPENDIX I

Description of age notation

Various notations have been used by fishery agency scientists to determine the total age of Pacific salmon spawners, including the fresh water and marine residency periods. Some explanations are presented here for purposes of clarification.

The so-called 'Gilbert-Rich' ageing notation has been used by Canadian scientists in some cases. Total age and fresh water residency periods are respectively designated by a number and a subscript. For instance a 5_3 indicate that the species went to sea after 3 calendar years of rearing in fresh water (from the time deposited as eggs in the gravel). For sockeye spawning in the fall of 1990, this could amount to 1 calendar as an alevin (fall-spring '91), 2 years of rearing in a nursery lake (spring-spring '91-92, '92-93), followed by 2 years rearing in the ocean (summer-summer '93-94, '94-95), returning to spawn late summer-fall of 1995, for a total age since incubation of 5 years.

Russian scientists tend to use the same notation as Europeans do for Atlantic salmon, with age based on the number of winter annuli on scales. Consequently, an age of 4_2 corresponds to a Gilbert-Rich age of 5_3.

A third age designation used by the International North Pacific Fisheries Commission (INPFC) to facilitate comparison of ages structures between salmon producing nations bordering the North Pacific (Japan, Russia, US, Canada, etc.). It is a decimal notation, with the first number corresponding to the number of winters spent as juveniles (not fry) in fresh water, and the decimal part being the number of winters spent rearing in the ocean. For example, 2.2 is equivalent to a Gilbert-Rich age of 5_3. An age of 0.3 implies the salmon migrated to the ocean as a fry (so zero winter as a juvenile), then spent 3 winters in the ocean.

The INPFC age designation is used by Alaska and Yukon fishery agency scientists. Canadian origin chinook ages typically range from 0.2 to 2.5. For chinook salmon spawning say in the fall of 2008, an age 1.3 adult spawner produced that year would have spent 1 winter rearing as a juvenile in fresh water 9 months after spawning (spring 2009 to spring 2010), migrate to sea at age 1+ in the summer of 2010, overwinter at sea in 2010-2011, 2011-2012 and 2012-2013, returning to spawn in the fall of 2013, exactly 5 years after being fertilized. This is designated as a 5 year old chinook by AK and Can scientists, with a Gilbert-Rich age of 5_2 corresponding to an INPFC age of 1.3. So the age group is basically obtained by adding one to the decimal INPFC age after substituting the decimal by a +. So age = 1+1+3. A 3 year old spawner in 2008 (age 0.2) would be considered as the progeny of spawning in the fall of 2005, and an 8 year old chinook (age 1.6 or 2.5) would be considered as the progeny of spawning in the fall of 2000.

APPENDIX II

<u>Pseudo-Code of Simulation Program</u>