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Northeastern Bering Sea Juvenile Chinook Salmon Survey, 2017 and Yukon River Adult Run Forecasts, 2018–2020

by

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	$>$
greater than or equal to	$\geq$
harvest per unit effort	HPUE
less than	$<$
less than or equal to	$\leq$
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. 20-08

NORTHEASTERN BERING SEA JUVENILE CHINOOK SALMON SURVEY, 2017 AND YUKON RIVER ADULT RUN FORECASTS, 2018–2020

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Monitoring of juvenile Yukon River Chinook salmon *Oncorhynchus tshawytscha* stocks rearing in the Northeastern Bering Sea (NBS) was initiated by the National Oceanic and Atmospheric Administration (NOAA) in 2002 using a pelagic trawl survey program. Juvenile salmon were caught after their first summer at sea, and prior work has demonstrated a clear relationship between juvenile abundance and future adult returns, enabling the use of juvenile data in adult run size forecasts. The estimated abundance of juvenile Chinook salmon in the NBS was approximately 2,480,000 (SD 439,000) in 2017, below the 2003–2016 average. The mean proportion of 2017 NBS juvenile Chinook salmon originating in the total Yukon River and Canadian-origin Yukon River was 72% (SD 5%) and 42% (SD 4%), respectively. Abundance of total Yukon and Canadian-origin stocks were estimated as 1,774,000 (SD 338,000) and 1,049,000 (SD 207,000), respectively. Previously established and new adult Yukon River run reconstructions were used to evaluate relationships between juvenile abundance and adult abundance of spawners, runs, and returns. A marked decrease in juvenile production (juveniles per spawner) for total Yukon River and Canadian-origin stocks was below their 2003–2016 averages. These data were incorporated into forecast models to predict total adult run size. Forecasted total Yukon River Chinook salmon run sizes for 2018–2020 were 179,000–301,000, 170,000–297,000 and 114,000–230,000, respectively; forecasted Canadian-origin Chinook salmon run sizes for 2018–2020 were 65,000–102,000, 74,000–116,000 and 62,000–105,000, respectively. The date-adjusted length (FL) of juvenile Chinook salmon in the NBS was 204 mm in 2017, below the 2003–2016 average of 212 mm. Marine data on juvenile Chinook salmon clearly demonstrate that Yukon River Chinook salmon should be expected to remain in a relatively low productivity regime in the near future, but record-low run abundance is unlikely through 2020.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, marine survey, pelagic trawl, juvenile, abundance, forecast, run reconstruction, Yukon River

INTRODUCTION

Yukon River Chinook salmon *Oncorhynchus tshawytscha* returns declined dramatically since the late 1990s, leading to severely restricted subsistence harvests and closures of commercial and sport fisheries in attempts to meet spawning escapement needs (Estensen et al. 2015). Despite extraordinary harvest reductions, pervasive failures to meet escapement objectives in the Yukon and other Alaska systems have occurred throughout recent years (Munro 2018). Although causes of the production decline are unclear, concurrent declines throughout Alaska (ADF&G 2013) have placed emphasis on ocean conditions and the marine life history stage of Chinook salmon.

Mortality during the early marine life history stage is significant, and previous research suggests the first year in the ocean to be a critical time to define salmon cohort strength (Beamish and Mahnken 2001; Hartt 1980; Farley et al. 2007a). Marine research has provided a unique insight into juvenile salmon ecology at this critical period (Orsi et al. 2000; Brodeur et al. 2003; Moss et al. 2009; Wertheimer et al. 2010; Miller et al. 2013). Condition indicators, such as juvenile size and marine growth rate, have been demonstrated to play some role in mortality processes during the first year of ocean life of Yukon River Chinook salmon (Howard et al. 2016), other Alaska stocks (Farley et al. 2007b; Moss et al. 2005), and have been demonstrated to explain interannual variability of adult returns of Columbia River Chinook salmon stocks (Tomaro et al. 2012). Moreover, juvenile abundance of Canadian-origin Yukon River Chinook salmon alone explains a substantial amount of the variability in adult returns of this stock (Murphy et al. 2017). Together, this evidence emphasizes the importance of the early marine life history stage to structure interannual variability of adult salmon returns.

The Northeastern Bering Sea (NBS) is the primary rearing habitat of Norton Sound and Yukon River-origin juvenile Chinook salmon during their first summer at sea (Murphy et al. 2009). NBS pelagic trawl surveys were initiated by NOAA–Alaska Fisheries Science Center (AFSC) in 2002 as part of the Bering Aleutian Salmon International Survey (BASIS). Surveys continued through 2007 and again 2009–2017 under various funding sources. NBS surveys have collected biological and oceanographic data using a systematic spatial sampling design and a pelagic trawl net to collect fish samples. Abundance estimates of various pelagic fish species, including salmon, have been generated by expanding catch per unit area (CPUA; catch in numbers/km^2) by the sampling grid area and number of stations (Murphy et al. 2013; Farley et al. 2007b, Howard et al. 2019). These surveys have occurred primarily in September, assessing juvenile salmon well after they experience a critical transition from freshwater to marine environments (Farley et al. 2007a).

NBS surveys have provided important new information on Yukon River Chinook salmon. Documentation of juvenile Yukon River Chinook salmon size selective mortality (Howard et al. 2016); initial work comparing juvenile NBS salmon distribution to oceanographic characteristics (Gann et al. 2013); and NBS salmon nutritional ecology (Auburn and Studevant 2013; Farley et al. 2004) are valuable products from these surveys. More importantly, juvenile abundance estimates have been incorporated into run forecast models for Canadian-origin Yukon River Chinook salmon (Murphy et al. 2017; Howard et al. 2019), and forecasts have been presented to managers, the public, and the U.S./Canada Yukon River Panel to assist with management decisions. Reliable run size forecasting tools have become critical to Yukon River fishery managers' and stakeholders' decision making in recent years of low Chinook salmon productivity and significant harvest restrictions.

This study assessed abundance of juvenile Chinook salmon in the NBS in 2017, just prior to their first winter at sea. Abundance data incorporated information about stock composition of the juveniles, linking the juvenile and adult populations of Chinook salmon. This study's monitoring efforts were designed to predict future run size of Canadian-origin Chinook salmon and provide the first attempt to forecast total Yukon River Chinook salmon run size, based on advancements in genetic baselines to discriminate Western Alaska Chinook salmon (Howard et al. 2019).

OBJECTIVES

1. Estimate 2017 juvenile Chinook salmon abundance in the NBS using similar precision to historical estimates (CV: 14%–39%).
2. Estimate the Chinook salmon stock mixtures present in the NBS survey with 90% credibility intervals and incorporate stock structure information into juvenile abundance indices.
3. Incorporate stock-specific abundance of Canadian-origin Yukon River Chinook salmon into an established run forecast model that predicts run size up to 3 years into the future.
4. Develop a run forecast model for total Yukon River Chinook salmon similar to the established Canadian-origin forecast model.

STUDY AREA

Surveys occurred over a sampling grid in the NBS. Sample stations were from lat 60°N to the Bering Strait and east of long 170°W (Figure 1).

METHODS

GENERAL SURVEY DESIGN

The 2017 survey operated from August 25 to September 12 in the NBS, employing a systematic spatial station grid spaced at approximately 30 nautical mile intervals (lat 0.5° by long 1°, Figure 1). The sampling platform operated similar to previous years, with the F/V *Northwest*

Explorer towing a Cantrawl[1] 400/601 rope trawl (Cantrawl Pacific Ltd.; Murphy et al. 2017). Stations were primarily restricted to depths of 18–55 m and shallower stations required appropriate onboard net modification to achieve vertical net depth less than 20 m.

Each day typically consisted of sampling 3 stations during daylight hours. Standard activities at each station included: (1) Conductivity Temperature Depth (CTD) instrument cast with Niskin water sample collection, (2) an oblique zooplankton net tow with bongo array, and (3) one surface trawl tow. The standard surface trawl duration was 30 minutes. The Cantrawl was towed with the headrope at the surface. Net mensuration of vertical opening, horizontal spread, and headrope depth were monitored using a third wire transducer attached to the net. Footrope depth was measured from a net CTD attached to the midpoint of the footrope. Distances towed were calculated using global positioning system (GPS) coordinates recorded at the start and end of each tow. Water temperature was recorded during the trawl using a probe attached to the trawl, along with other haul information (e.g., vessel speed, sea state, and wind speed). CTD data, Niskin water samples, and zooplankton samples were collected according to standard protocols provided by NMFS oceanographers. Only processed CTD data were used by this study to interpret juvenile Chinook salmon catches.

TRAWL CATCH SAMPLING

As the trawl net was retrieved onboard, fish were shaken down to the codend of the net by vessel crew. Contents of the trawl were emptied onto a sorting table. The catch was sorted by species and total weight of each species was recorded. Up to 50 individuals from each species at each station were measured for length and weight. For species with more than 50 individuals, the total species weight from the haul was divided by the average weight of measured individuals to approximate the total number of individuals. For large hauls, subsamples of the catch were used to estimate abundance of non-salmonids by weight. Biological samples from various fish species were collected, preserved, and provided to AFSC and university scientists.

All salmon were sorted and set aside for processing. Scales were collected, if available from the preferred area (the second to the seventh rows of scales above the lateral line diagonal from the back of the dorsal fin) and placed on gummed cards for later processing (Mosher 1963). Gonad development data was used to estimate sex and maturity status of immature salmon. To determine freshwater origin, caudal fin clips for genetic analyses were collected from all juvenile Chinook and coho salmon (*O. kisutch*), and from a subsample of juvenile chum salmon (*O. keta*). Additionally, immature salmon axillary processes were collected as genetic tissue samples for the few fish captured. All genetic tissues were stored frozen in individually labeled vials. Up to 10 whole juvenile Chinook salmon from each station were randomly selected and preserved for stomach content, otolith, and energetic analysis.

LABORATORY ANALYSIS

Genetic Stock Composition

Juvenile Chinook salmon tissue samples were provided to the Alaska Department of Fish and Game (ADF&G) Gene Conservation Lab for genotyping and mixed stock analysis (MSA). DNA was extracted from the tails of juvenile Chinook salmon using the NucleoSpin 96 Tissue Kit (Macherey-Nagel). Single nucleotide polymorphism (SNP) genotyping of the 80 SNPs common

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

to the Arctic-Yukon-Kuskokwim (AYK) region baseline of 60 populations was performed using standard TaqMan chemistry (Howard et al. 2019). Quality control analyses included comparison of discrepancy rates between original project genotypes and genotypes of 8% of original project individuals that were reextracted and genotyped, removal of individuals missing 20% or more of genotypic data, and removal of duplicate individuals.

Stock composition was estimated by comparing genotypes of catch samples to reference baseline allele frequencies using the Bayesian statistical approach implemented in the software package *BAYES* with a flat prior (Pella and Masuda 2001). Contributions of juvenile Chinook salmon from 4 reporting groups were estimated: Lower Yukon, Middle Yukon, Canadian Yukon, and Other Western Alaska. Estimates from the 3 intra-Yukon River groups (Lower Yukon, Middle Yukon, and Canadian Yukon) were summed to Yukon River-scale estimates.

DATA ANALYSIS

Juvenile Abundance Estimates

Juvenile Chinook salmon catch, CPUA, and abundance estimates were reported from 2003 to 2016 NBS surveys (Murphy et al. 2017; Howard et al. 2019). This report presents revised juvenile abundance estimation methods from those previously published. As with previous analyses, juvenile salmon were assumed to be uniformly distributed throughout the mixed water layer (depth of the upper portion of the water column of uniform density). The mixed layer depth (MLD) was defined as the depth where seawater density increased by 0.10 kg/m^3 relative to the density near the surface using potential density profiles (σ_θ; kg/m^3) derived from CTD downcasts at each station (Danielson et al. 2011; Murphy et al. 2017). The MLD was set to the maximum CTD depth measurement when the water column was vertically mixed. For stations where the mixed layer could not be calculated (e.g., when the CTD was not cast due to rough seas), the average MLD from adjacent stations was used.

Because trawl gear does not sample through the entire mixed layer at all stations, a correction was applied to the juvenile Chinook salmon catch for the proportion of the mixed layer not trawled. Catch (c) was the total number of juvenile Chinook salmon caught at a given sampling station. An MLD correction (θ) was calculated as the ratio of MLD to trawl depth (trawl footrope depth) when trawl depth was shallower than MLD, or equal to 1 when trawl depth was deeper than the mixed layer. Catch (c) at each station (x) was multiplied by the MLD correction (θ) to obtain a θ-adjusted juvenile Chinook salmon catch (C) for each station:

$$C_x = c_x * \theta_x. \tag{1}$$

Four distinct NBS ecoregions were defined as strata for this analysis because they have been recognized as mesoscale oceanographic/ecological units and could consequently offer different summer rearing conditions for juvenile salmon. The 4 strata used for analysis were: 1) Lower NBS (lat 60–62°N), 2) Upper NBS (lat 62–64°N), 3) Norton Sound, and 4) the Bering Strait (Murphy et al. 2017; Howard et al. 2019; Figure 1). For each year of the survey, CPUA (catch in numbers per km^2) was calculated for the stratum (i), where C_x was the θ-adjusted catch for station (x), a_x was the area swept[2] at station (x), and X was the total number of stations in the stratum (i) (Quinn and Deriso 1999):

[2] Estimated by multiplying the horizontal spread of the trawl by the distance trawled, km^2.

$$CPUA_i = \frac{\sum_{x=1}^{X} C_{xi}}{\sum_{x=1}^{X} a_{xi}}. \quad (2)$$

$CPUA_i$ variance estimates were calculated as:

$$V(CPUA_i) = \frac{X}{X-1} \frac{\sum_x \left(C_{x,i} - CPUA_i * a_{xi}\right)^2}{(\sum_x a_{xi})^2}. \quad (3)$$

In both 2005 and 2007, only 1 station was sampled in Norton Sound, thereby precluding a variance estimate. Catch data from Norton Sound across all survey years revealed that data were overdispersed. Therefore, for the Norton Sound stratum in 2005 and 2007, variance was calculated as:

$$V(CPUA_{NS,2005,2007}) = \frac{(C_i + C_i^2)}{a_i^2}. \quad (4)$$

Within each stratum, the area of 0.5° latitude by 1° longitude grid was calculated and expanded by the number of stations sampled to calculate the total area of the stratum (A_i). For Norton Sound strata, a fixed sample grid area (A_{NS}) of 5,461 km^2 was used for all years because previous work indicated that juvenile salmon rearing habitat only included those waters deeper than approximately 18 m.

Overall CPUA for the survey grid, $CPUA_A$, where A_i was the area (km^2) of the stratum (i) and A was the total area of the survey grid, was estimated as:

$$CPUA_A = \sum_i^{max\, i} \frac{A_i}{A} CPUA_i, \quad (5)$$

with overall CPUA variance estimated as:

$$V(CPUA_A) = \sum_i^{max\, i} \left(\frac{A_i}{A}\right)^2 V(CPUA_i). \quad (6)$$

The total juvenile abundance estimate for the survey area (B) was the overall $CPUA_A$ multiplied by the total survey area:

$$B = CPUA_A * A, \quad (7)$$

and total juvenile abundance variance estimated as:

$$V(B) = A^2 * V(CPUA_A). \quad (8)$$

The mean proportion of stratum-specific juvenile abundance relative to total juvenile abundance was used to estimate juvenile abundance in unsampled strata for those years when a stratum was not sampled (2004–2006 for Bering Strait and 2016 for Norton Sound). Stratum-specific CPUA ($CPUA_i$) was multiplied by the stratum area (A_i) to calculate a stratum-specific juvenile abundance. The relative proportion of juvenile abundance from each unsampled stratum was calculated from years all 4 strata were sampled (2003, 2007, 2009–2015, 2017). Mean proportions of Bering Strait Chinook salmon abundance of 4.8% and Norton Sound juvenile Chinook salmon abundance of 8.7% were added to the total abundance estimates in those years when neither stratum was sampled.

Adult Run Size Forecasts

Juvenile-based run size forecasts assumed the juvenile abundance assessed by the survey accurately represented the total juvenile population, that the entire juvenile population represented

1 cohort of age-2 fish[3], and the historical relationships between juvenile and adult stages were representative of future relationships. Stock-specific juvenile abundance estimates and forecasted adult run abundance based on 2017 data were evaluated in the context of historical patterns.

Stock-Specific Juvenile Abundance and Variance

Juvenile Chinook salmon abundance estimates were apportioned by stock composition to Canadian-origin (Upper Yukon) and total Yukon River groups (combined Upper Yukon, Middle Yukon, and Lower Yukon stock groups). As established in Murphy et al. (2017), variance estimation of the abundance of a specific stock group (total Yukon River or Canadian-origin) was derived from a Taylor series approximation to the multiplicative variance of 2 random variables (juvenile abundance (*X*) and stock composition (*Y*)) using the Delta method (Fournier et al. 2011) as:

$$V(X,Y) = \mu_Y^2\sigma_X^2 + \mu_X^2\sigma_Y^2 + 2\mu_X\mu_Y\rho\sigma_X\sigma_Y \tag{9}$$

where μ_X and σ_X were the mean and standard deviation of juvenile abundance, μ_Y and σ_Y were the mean and standard deviation of the stock group proportion, and ρ was the correlation between juvenile abundance and stock proportion.

Canadian-Origin Adult Run Size Forecast

All Canadian-origin Chinook salmon adult return, spawning abundance, and maturity schedule data used for juvenile-based forecasts were acquired from brood tables developed by the Joint Technical Committee (JTC) to the Yukon River Panel (JTC 2018). Adult run abundance data provided by the JTC were derived from estimates of Chinook salmon passage across the U.S./Canada border and downstream harvests apportioned to the Canadian-origin stock group, either through scale pattern analysis or more recently using genetic MSA. Spawning abundance was assumed to include all fish from the total run estimate not harvested. Age composition information was collected from border passage as well as downstream harvests.

Canadian-origin adult run size forecasts based on Canadian-origin juvenile Chinook salmon abundance data were estimated similar to established methodology (Murphy et al. 2017; Howard et al. 2019). The fit and 80% prediction interval of the linear model relationship of prior juvenile cohorts and resulting adult returns (2003–2013 juvenile years) was used to estimate a midpoint and range of juveniles predicted to survive to adulthood from each juvenile cohort. Projected survivors were apportioned to run year based on recent 3-year average maturity schedules derived from Canadian-origin brood tables (JTC 2018). Forecasts were provided preseason to fisheries managers and stakeholders (JTC 2018).

Total Yukon River Adult Run Size Forecast

This report provides the first attempt to develop a total Yukon River forecast, fashioned after the juvenile-based Canadian-origin adult run size forecast. As with the Canadian-origin forecast, the projected abundance of adult survivors for each juvenile cohort was derived from a linear regression model of prior juvenile cohorts and resulting adult returns for the total Yukon River stock. Projected survivors were apportioned to run year based on recent 3-year average maturity schedules, and the forecast range represented the 80% prediction interval of adult survivors from the linear regression model. Unlike the Canadian-origin stock group, total Yukon River adult run

[3] The "stream-type" life history pattern is overwhelmingly dominant in Yukon River Chinook salmon. These fish spend 1 year incubating as eggs and 1 year rearing in freshwater before emigrating to sea.

and maturity data had not been previously compiled and reported, and these estimates (Appendix A) were reconstructed from the best available published data and the Arctic-Yukon-Kuskokwim Database Management System.[4]

RESULTS AND DISCUSSION

GENERAL SURVEY OPERATIONS

Stations were sampled August 27–September 9. Geographic coverage of the 35 stations sampled was consistent with past years. Trawl gear performance was rated as "good" across all stations: the average towing distance was 3.94 km and average trawl footrope depth was 20 m (Table 1). Sea conditions were generally favorable during the 2017 survey and the entire mixed layer of the water column was sampled at most stations (Table 1).

Total survey catch was dominated by Pacific herring (*Clupea pallasii*) in both numbers and biomass (Table 2; Appendix B1). Ninespine stickleback (*Pungitius pungitius*) and age-0 Walleye pollock (*Gadus chalcogrammus*) were also numerically abundant, and jellyfish (*Chrysaora melanaster*, Lion's mane *Cyanea capillata*, and *Aequorea* sp.) biomass was prominent in the survey. Catch, station and individual length and weight data were made publicly available in the Arctic-Yukon-Kuskokwim Database Management System.[4]

Among salmon, immature chum salmon contributed the greatest biomass, but juvenile pink salmon (*O. gorbuscha*) were the most numerically abundant (Table 2; Appendix B2). Distribution of juvenile Chinook salmon was greatest north of lat 60.5°N and east of long 168.5°W, which indicated the survey appropriately sampled the geographic distribution of juvenile Chinook salmon in 2017 (Figure 2). Juvenile chum and pink salmon were broadly distributed throughout the survey area (Appendices C1–C2). Juvenile coho salmon were most abundant in Lower NBS and Norton Sound strata (Appendix C3), and juvenile sockeye salmon (*O. nerka*) were most prevalent in the Upper NBS and Bering Strait strata (Appendix C4).

JUVENILE CHINOOK SALMON ABUNDANCE, STOCK COMPOSITION, AND LENGTH

In 2017, 195 juvenile and 29 immature Chinook salmon were caught. Adjustments of station catches to account for unsampled portions of the mixed water layer were unnecessary at most stations. The juvenile Chinook salmon abundance estimate was 2,479,618 (SD 438,919), below the 2003–2016 average of 3,329,000 (Table 3). The coefficient of variation (CV) for juvenile Chinook salmon abundance was similar to previous years (Table 3). The total abundance estimated for Yukon and Canadian-origin stocks were also below their historical averages (Table 3; Figure 3). When all historical years were considered together, it was apparent that key factors in obtaining juvenile Chinook salmon abundance estimates with adequate precision included completing target survey stations, sampling consistently in time and space (southern to northern direction), and appropriate net mensuration during tows (Murphy et al. 2017; Howard et al. 2019).

Stock composition of juvenile Chinook salmon in 2017 was somewhat unusual compared to prior year estimates, with Yukon River stocks contributing a much smaller proportion than has previously been observed (Table 4; Figure 4). Mean stock composition estimates from 2003–2016 in the NBS ranged from 44%–57% Canadian Yukon, 21%–37% Middle Yukon, 7%–21% Lower

[4] Available at http://www.adfg.alaska.gov/CommFishR3/WebSite/AYKDBMSWebsite/Default.aspx.

Yukon, and 4%–15% Other Western Alaska reporting groups (Murphy et al. 2017; Howard et al. 2019). Prior to 2015, the mean Yukon River component had been above 90% annually, but there has been a consistent decline in the Yukon River stock group proportion since that time (Howard et al. 2019). This trend could implicate changing production dynamics of Yukon River stocks relative to non-Yukon River stocks in the NBS. However, it is also possible the observed stock composition in the survey area may have been confounded by early catch dates of the 2017 survey compared to prior years (10 days on average), or by northward migration of stocks in recent warmer water conditions.

The date-adjusted average fork length of juvenile Chinook salmon was 204 mm, which was 4% below the 2003–2016 average (Table 5). It should be noted that 2016 and 2017 catch date adjustments (12 and 10 days, respectively) were larger than previous years and could introduce compounding error into mean length estimates if the assumed growth rate is incorrect. The unadjusted mean Chinook salmon length in 2017 was still 9 mm (4%) smaller than observed in the 2016 survey, which had similar catch timing. A weak, positive correlation was observed between the mean size of juvenile Chinook salmon and the proportion of those Yukon cohorts that matured as "jacks" (age-3 and age-4; Figure 5).

ADULT RUN SIZE FORECASTS

Juvenile Chinook salmon data from the NBS through 2017 can provide forecasts for 2018–2020 adult runs, and partially contribute to forecasts after 2020. Because age-5 and older fish comprise approximately 93% of the run, run forecasts require data about cohorts contributing at least age-5 through age-7 fish to produce an adequate forecast. Consequently, run forecasts can be produced up to 3 years into the future: 2017 juvenile cohort age-5 returns will return in 2020, providing the youngest necessary age class for forecasting. The 2017 juvenile Chinook salmon cohort would predominantly return in 2019 (age-4), 2020 (age-5), 2021 (age-6) and 2022 (age-7).

In addition to juvenile abundance data, juvenile-based forecasts rely on past cohort survival relationships to estimate the number of juveniles that would survive to adulthood, and maturity schedules to predict the proportion of these survivors that would mature at each age class (i.e., successive run years). A simple linear regression model was calculated to predict adult Chinook salmon return abundance based on juvenile abundance for total Yukon River and Canadian-origin stock groups (Figure 6). A significant regression equation was found ($F(1,8) = 28.86$, $p < 0.001$), with an R^2 of 0.7705 for the Canadian-origin stock group. The total Yukon River stock group also showed a significant relationship ($F(1,8) = 26.29$, $p < 0.001$), with an R^2 of 0.7667. Stock-specific juvenile abundance estimates for cohorts from 2005, 2012 and 2013 have additional unknown errors because either genetic tissue samples were inadequate in these years, or the samples were deemed unrepresentative. Adjacent year stock composition estimates were used to approximate stock composition estimates in these years, but this added uncertainty could result in larger 80% confidence and projection intervals in the model, and greater forecasting uncertainty, than would be the case with sufficient genetics data. Because the linear model will be informed by each additional year of data, forecasted adult returns will change modestly year to year, as data are updated.

To apportion each cohort's survivors to run year, the average age at maturity for the 3 most recent brood years was used (Appendix A11; JTC 2018). It should be noted that interannual variability in the proportions maturing at each age class can potentially introduce considerable error in forecast estimates. A more nuanced predictor of maturity beyond the recent 3-year average could enhance the development of these forecasts. The observation that higher proportions of Yukon River Chinook salmon maturing at age-3 and age-4 was positively correlated with juvenile size could provide for refinements of maturity schedules.

Based on juvenile catches seen in the NBS in recent years, Canadian-origin adult runs in 2018–2020 are expected to be 65,000–102,000, 74,000–116,000 and 62,000–105,000 Chinook salmon, respectively; total Yukon River adult runs are expected to be 179,000–301,000, 170,000–297,000 and 114,000–230,000 Chinook salmon, respectively (Figure 7). Run sizes of this magnitude have the potential to meet escapement objectives and provide some subsistence harvest opportunities. These data were provided to Yukon area stakeholders and managers prior to the 2018 salmon season to assist with decision making.

PRODUCTIVITY AND SURVIVAL PATTERNS OF YUKON RIVER CHINOOK SALMON

Later marine survival rates (juvenile to adult) appear to be relatively stable for available years of total Yukon River and Canadian-origin Chinook salmon stocks (Figure 6). Survival estimates tend to be slightly higher for total Yukon River juvenile Chinook salmon compared to Canadian-origin stocks, which may be due to the later age at maturity for Canadian-origin stocks leading to a slightly higher risk of mortality prior to maturation (Table 6). No relationship was evident between the mean size of juveniles in September and later marine survival of the cohort (Howard et al. 2016).

Productivity, as measured by returns per spawner, was estimated to be highest in the 2011 brood year for total Yukon River stocks even though age-7 fish from this brood year have not yet returned (2.05), and lowest for the 2008 brood year (0.65; Table 6). The estimated productivity of Canadian-origin Chinook salmon in comparable brood years (2002–2011) was highest in 2011 (2.28) and lowest in 2006 (0.93; JTC 2018). Productivity tended to be slightly higher in the Canadian-origin estimates compared to total Yukon River Chinook salmon for a given brood year; however, the degree to which this reflects true productivity differences or measurement error is unknown. Although both reconstructions indicate particularly poor productivity during this period, the total Yukon River estimates would indicate the returns failed to replace themselves (R/S <1.0) over the course of multiple brood years (2003–2006, 2008 and 2010), but the Canadian-origin estimates indicated only the 2006 brood year failed to replace itself (Table 6; JTC 2018).

The ratio of juveniles per spawner (i.e., productivity of juveniles) can provide a leading indicator of brood year productivity (i.e., overall mortality/survival) for Yukon River Chinook salmon (Figure 8). Below average juveniles per spawner were observed in 2017 for Canadian-origin and total Yukon River stocks (Figure 8; Table 6). If juvenile productivity is indicative of adult productivity, then we should expect 2012 and 2013 brood year productivity to be similar to the 2011 brood year, and subsequent brood year productivity should dramatically decline, with the 2015 brood year failing to replace itself.

CONCLUSIONS

Reducing measurement error in juvenile abundance estimates will be crucial for long-term understanding of marine survival patterns and accurate forecasting. Although juvenile-based forecasts show tremendous promise for improving preseason expectations for Yukon River Chinook salmon run abundance, the strength of these forecasts will be largely dictated by the quality and accuracy of data available. Marine trawl survey performance has been shown to be important to accurately and precisely estimate juvenile Chinook salmon abundance (Murphy et al. 2017; Howard et al. 2019). Genetic stock composition with adequate resolution is also essential to estimation of stock-specific abundance because data representing later marine survival (relationship of juvenile to adult) is less robust for those years when adequate genetic stock composition information is not available. Stock-specific juvenile-based forecast estimates include combined uncertainty of abundance and genetic stock composition. The quality of juvenile abundance estimates of total Yukon River juvenile Chinook salmon are probably stronger than those for Canadian-origin stocks because genetic MSA can estimate proportions of the larger total Yukon River stock group with greater precision than the Canadian-origin stock group.

Accuracy and precision of adult run abundance estimates are just as critical as juvenile data for accurate assessment of later marine survival rates and juvenile-based forecasting. Adult run reconstructions provided in this report for total Yukon River Chinook salmon may have more inherent error than those developed by the JTC for Canadian-origin Chinook salmon. The majority of assessed Chinook salmon in recent years for either run reconstruction are composed of sonar passage estimates. The precision of the Eagle sonar estimates (Canadian-origin) is far greater than that for Pilot Station sonar (total Yukon River) because the Pilot Station sonar must apportion an order of magnitude more fish of various species than its upriver counterpart. This likely affects Chinook salmon estimates, which are a small proportion of the overall fish passage of all species at that location. The Canadian-origin run reconstruction, however, does include the need to apportion Alaska Yukon harvest by stock group, introducing additional measurement error, which is not present in the total Yukon River run reconstruction. Both run reconstructions merely tabulate mean passage estimates and mean harvest estimates, and in the case of Canadian-origin run reconstruction, mean stock composition estimates. Neither run reconstruction accounts for the uncertainty of these estimates. Estimates of juvenile to adult survival, juveniles per spawner and forecasting abilities would be improved with more explicit incorporation of uncertainty in adult run reconstruction estimates. It is recommended that future forecast models move towards a Bayesian framework that can more explicitly account for all these uncertainties.

The relatively stable juvenile to adult survival observed in both total Yukon River and Canadian-origin stocks since brood year 2001 suggests that cohort strength is determined prior to the marine surveys occurring in September of each cohort’s first year in the ocean. If estimated juvenile to adult survival dramatically changes from the approximately 4–8% that has been typical for these stocks over this period, it may not be clear if some factor during their later marine residence led to different survival rates, or if this anomaly is a result of measurement error in juvenile and/or adult abundance estimates. Although interesting relationships are evident among juvenile Chinook salmon length, diet, and energy density, there is currently no indication that nutritional status measurably affects later marine survival.

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REFERENCES CITED

ADF&G Chinook Salmon Research Team. 2013. Chinook salmon stock assessment and research plan, 2013. Alaska Department of Fish and Game, Special Publication No. 13-01, Anchorage, AK.

Auburn, M., and M. Studevant. 2013. Diet composition and feeding behavior of juvenile salmonids in the northern Bering Sea August - October, 2009 – 2011. [*In*] Proceedings of the 2013 NPAFC Third International Workshop on Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems, April 24–25, 2013, Honolulu, HI, U.S.A.

Beamish, R. J., and C. Mahnken. 2001. A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography 49:423–437.

Brodeur, R. D., K. W. Myers, and J. H. Helle. 2003. Research conducted by the United States on the early ocean life history of Pacific salmon. North Pacific Anadromous Fish Commission Bulletin 3:89–131.

Danielson, S., E. Curchitser, K. Hedstrom, T. Weingartner, and P. Stabeno. 2011. On ocean and sea ice modes of variability in the Bering Sea. Journal of Geophysical Research 116:C12034.

Estensen, J. L., S. N. Schmidt, S. Garcia, C. M. Gleason, B. M. Borba, D. M. Jallen, A. J. Padilla, and K. M. Hilton. 2015. Annual management report Yukon Area, 2014. Alaska Department of Fish and Game, Fishery Management Report No. 15-50, Anchorage.

Farley, E. V., J. M. Murphy, A. Middleton, L. Eisner, J. Moss, J. Pohl, O. Ivanov, N. Kuznetsova, M. Trudel, M. Drew, C. Lagoudakis, and G. Yaska. 2004. Eastern Bering Sea (BASIS) coastal research (August–October 2003) on juvenile salmon. (NPAFC Doc. 816). 29p. Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626, USA.

Farley, E. V., J. H. Moss, and R. J. Beamish. 2007a. A review of the critical size, critical period hypothesis for juvenile Pacifc salmon. North Pacific Anadromous Fish Commission, Bulletin No. 4:311–317.

Farley, E. V., J. M. Murphy, M. D. Adkison, L. B. Eisner, J. H. Helle, J. H. Moss, and J. Nielsen. 2007b. Early marine growth in relation to marine-stage survival rates for Alaska sockeye salmon (*Oncorhynchus nerka*). Fishery Bulletin 105:121–130.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2011. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software 27:233–249.

Gann, J., L. Eisner, and S. Danielson. 2013. How do oceanographic characteristics in the northern Bering Sea relate to juvenile salmon biomass? [*In*] Proceedings of the 2013 NPAFC Third International Workshop on migration and survival mechanisms of juvenile salmon and steelhead in ocean ecosystems, April 24–25, 2013, Honolulu, HI, U.S.A.

Hartt, A. C. 1980. Juvenile salmonids in the oceanic ecosystem: the first critical summer. Pages 25–57 [*In*] W. J. McNeil and D. C. Himsworth, editors. Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis.

Howard, K. G., J. M. Murphy, L. I. Wilson, J. H. Moss, and E. V. Farley, Jr. 2016. Size-selective mortality of Chinook salmon in relation to body energy after the first summer in nearshore marine habitats. North Pacific Anadromous Fisheries Commission Bulletin 6:1–11. doi:10.23849/npafcb6/1.11.

Howard, K. G., S. Garcia, J. Murphy and T. H. Dann. 2019. Juvenile Chinook salmon abundance index and survey feasibility assessment in the Northern Bering Sea, 2014–2016. Alaska Department of Fish and Game, Fishery Data Series No. 19-04, Anchorage.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2018. Yukon River salmon 2017 season summary and 2018 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A18-01, Anchorage.

Miller, J. A., D. J. Teel, A. Baptisa, and C. A. Morgan. 2013. Disentangling bottom-up and top-down effects on survival during early ocean residence in a population of Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 70:617–629.

REFERENCES CITED (Continued)

Mosher, K. H. 1963. Racial analysis of red salmon by means of scales. North Pacific Anadromous Fish Commission Bulletin. 11:31–56.

Moss, J. H., D. A. Beauchamp, A. D. Cross, K. W. Myers, E. V. Farley, J. M. Murphy, and J. H. Helle. 2005. Evidence for size-selective mortality after the first summer of ocean growth by pink salmon. Transactions of the American Fisheries Society 134:1313–1322.

Moss, J. H., J. M. Murphy, E. V. Farley, L. B. Eisner, and A. G. Andrews. 2009. Juvenile pink and chum salmon distribution, diet, and growth in the northern Bering and Chukchi seas. North Pacific Anadromous Fish Commission Bulletin 5:191–196.

Munro, A. R. 2018. Summary of Pacific salmon escapement goals in Alaska with a review of escapements from 2009 to 2017. Alaska Department of Fish and Game, Fishery Manuscript Series No. 18-04, Anchorage.

Murphy J. M., W. D. Templin, E. V. Farley, and J. E. Seeb. 2009. Stock-structured distribution of western Alaska and Yukon juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from United States BASIS surveys, 2002–2007. North Pacific Anadromous Fisheries Commission Bulletin 5:51–59.

Murphy, J., K. Howard, L. Eisner, A. Andrews, W. Templin, C. Guthrie, K. Cox, and E. Farley. 2013. Linking abundance, distribution, and size of juvenile Yukon River Chinook salmon to survival in the northern Bering Sea. [*In*]: Proceedings of the 2013 NPAFC Third International Workshop on Migration and survival mechanisms of juvenile salmon and steelhead in ocean ecosystems, April 24–25, 2013, Honolulu, HI, U.S.A.

Murphy, J., K. Howard, J. Gann, K. Cieciel, W. Templin, and C. Guthrie. 2017. Juvenile Chinook salmon abundance in the Northern Bering Sea: implications for future returns and fisheries in the Yukon River. Deep-Sea Research II 135:156–167.

Orsi, J. A., M. V. Sturdevant, J. M. Murphy, D. G. Mortensen, and B. L. Wing. 2000. Early marine ecology, habitat utilization, and implications for carrying capacity of juvenile Pacific salmon in Southeastern Alaska. NPAFC Bulletin No. 2:1–35.

Pella, J. J., and M. Masuda. 2001. Bayesian methods for analysis of stock mixtures from genetic characters. Fishery Bulletin 99(1):151–167.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, Oxford.

Tomaro, L. M., D. J. Teel, W. T. Peterson, and J. A. Miller. 2012. When is bigger better? Early marine residence of middle and upper Columbia River spring Chinook salmon. Marine Ecology Progress Series 452:237–252.

Wertheimer, A., J. Orsi, M. Sturdevant, and E. Fergusson. 2010. Forecasting pink salmon abundance in southeast Alaska from juvenile salmon abundance and associated environmental parameters. Final Report to the Pacific Salmon Commission Northern Fund Project NF-2008-I-25.

TABLES AND FIGURES

Table 1.–Data by trawl station for the Northeastern Bering Sea trawl survey in 2017.

Start lat (dd)	Start long (dd)	End lat (dd)	End long (dd)	Trawl dist. (km)	Warp (m)	Avg. FR depth (m)	Bottom depth (m)	Gear perf.	MLD (m)	MLD correction (θ)
60.00	-168.07	60.00	-168.14	4.27	329	18 [a]	27	G	17	1.00
60.00	-169.03	60.00	-169.09	3.35	329	19 [a]	38	G	27	1.39
60.02	-170.00	60.05	-170.01	3.65	329	20 [a]	52	G	21	1.05
60.50	-169.98	60.50	-169.91	3.35	329	22 [a]	45	G	26	1.20
60.50	-168.94	60.51	-168.86	4.24	329	22 [a]	33	G	24	1.09
60.49	-167.99	60.45	-167.97	4.21	329	20 [a]	26	G	22	1.08
60.48	-167.02	60.44	-167.03	4.41	329	18 [a]	22	G	18	1.02
61.02	-167.02	61.04	-167.09	3.80	329	22 [a]	18	G	11	1.00
61.01	-168.03	61.02	-168.10	3.98	329	22 [a]	25	G	16	1.00
61.01	-169.07	61.01	-169.15	4.20	329	20 [a]	33	G	11	1.00
61.02	-170.01	61.06	-170.03	3.95	329	22 [a]	43	G	30	1.38
61.50	-169.97	61.51	-169.89	4.07	329	22 [a]	42	G	29	1.34
61.50	-168.98	61.51	-168.91	3.55	329	20	31	G	26	1.29
61.51	-167.97	61.51	-167.89	4.28	329	18	23	G	14	1.00
61.51	-167.03	61.54	-167.06	3.73	329	16	22	G	9	1.00
62.00	-167.04	62.00	-167.11	4.11	329	19	25	G	10	1.00
62.00	-168.03	62.00	-168.11	3.99	329	19	23	G	17	1.00
62.00	-169.05	62.00	-169.12	3.80	329	20	34	G	25	1.28
62.02	-170.00	62.06	-169.99	3.78	329	21	40	G	21	1.00
62.50	-168.96	62.51	-168.88	4.14	329	22	28	G	20	1.00
62.50	-167.97	62.51	-167.89	3.95	329	21	25	G	8	1.00
62.50	-166.97	62.50	-166.90	3.73	329	22	25	G	9	1.00
63.00	-166.96	63.00	-166.89	3.83	329	20	20	G	7	1.00
63.03	-166.01	63.07	-166.02	3.66	329	15	16	G	9	1.00
63.49	-166.10	63.49	-166.18	4.24	329	17	21	G	6	1.00
63.50	-167.04	63.50	-167.12	4.02	329	20	22	G	10	1.00
63.52	-168.01	63.56	-168.03	4.17	329	22	28	G	16	1.00
64.02	-168.01	64.05	-167.99	3.72	329	22	33	G	15	1.00
63.99	-166.99	63.96	-166.96	3.81	329	21	28	G	12	1.00
64.10	-164.46	64.10	-164.38	4.16	329	16	17	G	7	1.00
64.10	-163.47	64.10	-163.39	3.57	329	16	19	G	6	1.00
64.10	-162.54	64.10	-162.64	4.81	329	17	17	G	13	1.00
63.99	-166.03	63.98	-166.11	4.00	329	18	19	G	11	1.00
64.50	-167.05	64.49	-167.12	3.61	329	19	23	G	9	1.00
64.52	-168.04	64.54	-168.09	3.66	329	23	31	G	22	1.00

Note: Date and time recorded in Greenwich Mean Time (GMT); latitude (lat) and longitude (long) of start and end of trawling recorded in decimal degrees (dd); trawl distance (Trawl dist.) recorded in kilometers; warp, average footrope (FR) depth and bottom depth recorded in meters; gear performance (Gear Perf.) noted as good (G), satisfactory (S), or unsatisfactory (U); mixed layer depth (MLD) defined in meters.

[a] Footrope Conductivity Temperature Depth (CTD) was not used on the trawl at these stations. Average footrope depth calculated by adding vertical net opening measured by net sonar and headrope depth.

Table 2.–Top 10 species captured during surface trawl operations in the Northeastern Bering Sea by abundance (left) and weight (right) in 2017.

Species	Total number	Species	Total weight (kg)
Pacific herring	100,161	Pacific herring	3,026
Ninespine stickleback	13,011	*Chrysaora melanaster*	1,231
Walleye pollock (age-0)	12,933	Chum salmon (immature)	245
Pink salmon (juvenile)	5,411	Salmon shark	150
Rainbow smelt	1,858	Pink salmon (juvenile)	135
Chrysaora melanaster	1,757	Lions mane	122
Saffron cod (age-0)	1,392	Coho salmon (juvenile)	63
Chum salmon (juvenile)	638	*Aequorea* spp.	47
Coho salmon (juvenile)	217	Walleye pollock (age-1+)	45
Chinook salmon (juvenile)	195	Chinook salmon (immature)	36

Note: Life history stage is indicated in parentheses for groundfish and salmon species where distinct life history stages are often encountered in surveys.

Table 3.–Total Northeastern Bering Sea (NBS) juvenile Chinook salmon abundance and Yukon River stock-specific abundance estimates and coefficient of variation (CV), 2003–2017.

Juvenile year	NBS abundance (1000s)	NBS juvenile abundance CV	Total Yukon abundance (1000s)	Total Yukon abundance CV	Canadian-origin abundance (1000s)	Canadian-origin abundance CV
2003	5,590	16%	4,936	17%	2,699	18%
2004	2,535	18%	2,260	18%	1,454	19%
2005	3,135 [a]	19%	2,755 [b]	22%	1,630 [b]	27%
2006	1,519	17%	1,382	18%	744	20%
2007	3,219	28%	3,043	29%	1,629	29%
2008 [c]	–	–	–	–	–	–
2009	1,879	40%	1,630	40%	985	41%
2010	1,996	23%	1,831	23%	973	25%
2011	3,916	40%	3,399	40%	1,830	40%
2012	1,431 [a]	33%	1,257 [b]	35%	605 [b]	41%
2013	5,822 [a]	20%	5,116 [b]	23%	2,463 [b]	31%
2014	3,531	21%	3,390	21%	1,787	22%
2015	4,780	30%	4,113	31%	2,111	31%
2016	3,921	34%	3,316	34%	2,125	34%
2017	2,480	18%	1,774	19%	1,049	20%
Average (2003–2016)	3,329	26%	2,956	27%	1,618	29%

[a] Genetic information insufficient due to lost samples, insufficient sample size or other constraint.

[b] Assumed stock composition used to provide approximation of stock-specific abundance.

[c] No Northeastern Bering Sea survey conducted.

Table 4.–Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to zero (P = 0), mean and standard deviation (SD) for Chinook salmon sampled from the Northeastern Bering Sea trawl survey, 2003–2017.

2003 NBS trawl survey (n = 445)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		88.3	81.4	95.1	0.00	88.3	4.1
	Canada	48.3	42.5	54.0	0.00	48.3	3.5
	Middle Yukon	23.3	18.6	28.6	0.00	23.4	3.1
	Lower Yukon	16.3	9.8	24.1	0.00	16.5	4.3
Other Western Alaska		11.7	4.9	18.6	0.00	11.7	4.1
2004 NBS trawl survey (n = 375)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		89.2	82.2	95.9	0.00	89.1	4.1
	Canada	57.4	50.0	64.6	0.00	57.4	4.5
	Middle Yukon	26.1	19.9	33.1	0.00	26.3	4.0
	Lower Yukon	4.9	0.6	12.4	0.00	5.5	3.7
Other Western Alaska		10.8	4.1	17.8	0.00	10.9	4.1
2006 NBS trawl survey (n = 121)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		91.0	81.2	98.1	0.00	90.5	5.1
	Canada	49.0	40.2	57.8	0.00	49.0	5.3
	Middle Yukon	26.3	18.9	34.7	0.00	26.5	4.8
	Lower Yukon	14.8	6.2	24.6	0.00	15.0	5.6
Other Western Alaska		9.0	1.9	18.8	0.00	9.5	5.1
2007 NBS trawl survey (n = 281)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		94.5	89.8	98.0	0.00	94.3	2.5
	Canada	50.6	44.8	56.3	0.00	50.6	3.5
	Middle Yukon	29.8	24.6	35.4	0.00	29.9	3.3
	Lower Yukon	13.7	9.0	19.1	0.00	13.8	3.1
Other Western Alaska		5.5	2.0	10.2	0.00	5.7	2.5
2009 NBS trawl survey (n = 143)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		86.7	79.1	94.4	0.00	86.7	4.6
	Canada	52.4	44.6	60.3	0.00	52.4	4.8
	Middle Yukon	27.9	21.0	35.5	0.00	28.1	4.4
	Lower Yukon	5.6	0.4	14.3	0.00	6.3	4.2
Other Western Alaska		13.3	5.6	20.9	0.00	13.3	4.6
2010 NBS trawl survey (n = 124)							
			90% CI				
Broad-scale group	Intra-Yukon group	Median	5%	95%	P = 0	Mean	SD
Yukon River		91.7	85.1	96.6	0.00	91.4	3.5
	Canada	48.8	41.2	56.3	0.00	48.8	4.6
	Middle Yukon	27.2	20.8	34.4	0.00	27.4	4.1
	Lower Yukon	15.1	8.9	22.3	0.00	15.3	4.1
Other Western Alaska		8.3	3.4	14.9	0.00	8.6	3.5

-continued-

Broad-scale group	Intra-Yukon group	Median	90% CI 5%	90% CI 95%	*P* = 0	Mean	SD
2011 NBS trawl survey (*n* = 310)							
Yukon River		86.8	81.0	92.2	0.00	86.7	3.4
	Canada	46.7	42.0	51.5	0.00	46.7	2.9
	Middle Yukon	22.4	18.5	26.6	0.00	22.5	2.4
	Lower Yukon	17.4	11.9	23.5	0.00	17.5	3.5
Other Western Alaska		13.2	7.8	19.0	0.00	13.3	3.4
2014 NBS trawl survey (*n* = 192)							
Broad-scale group	Intra-Yukon group	Median	90% CI 5%	90% CI 95%	*P* = 0	Mean	SD
Yukon River		96.3	92.1	98.9	0.00	96.0	2.1
	Canada	50.6	44.5	56.7	0.00	50.6	3.7
	Middle Yukon	36.5	30.7	42.6	0.00	36.6	3.6
	Lower Yukon	8.7	4.7	13.3	0.00	8.8	2.6
Other Western Alaska		3.7	1.1	7.9	0.00	4.0	2.1
2015 NBS trawl survey (*n* = 306)							
Broad-scale group	Intra-Yukon group	Median	90% CI 5%	90% CI 95%	*P* = 0	Mean	SD
Yukon River		86.2	80.3	91.4	0.00	86.1	3.4
	Canada	44.2	39.4	49.0	0.00	44.2	2.9
	Middle Yukon	30.0	25.5	34.7	0.00	30.0	2.8
	Lower Yukon	11.8	6.5	17.6	0.00	11.9	3.3
Other Western Alaska		13.8	8.6	19.7	0.00	13.9	3.4
Yukon River		84.6	78.8	90.3	0.00	84.6	3.5
2016 NBS trawl survey (*n* = 217)							
Broad-scale group	Intra-Yukon group	Median	5%	95%	*P* = 0	Mean	SD
Yukon River		84.6	78.8	90.3	0.00	84.6	3.5
	Canada	54.2	48.5	59.9	0.00	54.2	3.5
	Middle Yukon	20.8	16.2	25.8	0.00	20.8	2.9
	Lower Yukon	9.2	4.7	15.4	0.00	9.5	3.3
Other Western Alaska		15.4	9.7	21.2	0.00	15.4	3.5
2017 NBS trawl survey (*n* = 187)							
Broad-scale group	Intra-Yukon group	Median	90% CI 5%	90% CI 95%	*P* = 0	Mean	SD
Yukon River		71.7	63.0	79.4	0.00	71.5	5.0
	Canada	42.3	36.3	48.4	0.00	42.3	3.7
	Middle Yukon	19.8	15.1	25.1	0.00	19.9	3.0
	Lower Yukon	9.2	2.1	16.6	0.00	9.3	4.3

Note: Estimates are reported to broad-scale groups of populations (Yukon River and Other Western Alaska) as well intra-Yukon groups.

Table 5.–Number of stations and juvenile Chinook salmon length sample data in the Northeastern Bering Sea, 2003–2017.

Year	Number of stations	Total catch	Sample size	Average length (mm)	Average date adjustment (days)	Date adjusted average length (mm)
2003	47	359	227	203	-1	202
2004	61	177	177	221	-3	218
2005	45	144	144	226	-9	217
2006	49	107	107	189	4	194
2007	57	270	261	237	-6	231
2008						
2009	45	130	129	214	8	220
2010	60	135	135	211	-6	205
2011	57	314	314	185	9	194
2012	39	90	90	206	-8	199
2013	43	522	514	222	-5	217
2014	48	269	269	218	4	221
2015	40	324	324	212	6	219
2016	36	217	217	203	12	215
2017	35	195	195	194	10	204
Average (2003–2016)	48	235	224	211	0	212

Note: Average observed fork length was adjusted using the average capture date of September 13 and an assumed growth rate of 1 mm/day (Howard et al. 2019).

Table 6.–Relationship of Northeastern Bering Sea stock-specific juvenile abundance to adult spawner abundance and adult returns.

		Total Yukon						Canadian-origin					
Brood year	Juvenile year	Spawner abundance (1000s)	Adult return (1000s)	Adult returns per spawner	Juveniles per spawner	Juvenile survival	Juvenile survival SD	Spawner abundance (1000s)	Adult return (1000s)	Adult returns per spawner	Juveniles per spawner	Juvenile survival	Juvenile survival SD
2001	2003	[a]	324	–	–	0.066	0.005	53	107	2.03	51.36	0.040	0.006
2002	2004	113	153	1.35	20.00	0.068	0.006	42	52	1.23	34.33	0.036	0.007
2003	2005 [b]	265	262	0.99	10.40	–	–	81	98	1.21	–	–	–
2004	2006	150	108	0.72	9.19	0.078	0.007	48	56	1.16	15.35	0.075	0.011
2005	2007	207	192	0.93	14.70	0.063	0.011	68	78	1.15	23.96	0.048	0.012
2006	2008 [c]	188	179	0.95	–	–	–	63	59	0.93	–	–	–
2007	2009	128	175	1.37	12.74	0.108	0.030	35	45	1.28	28.22	0.045	0.015
2008	2010	146	95	0.65	12.50	0.052	0.006	34	42	1.23	28.73	0.043	0.008
2009	2011	154	201	1.31	22.09	0.059	0.016	65	81	1.24	28.04	0.044	0.019
2010	2012 [b]	116	101	0.87	–	–	–	32	54	1.70	–	–	–
2011	2013 [b]	130	267	2.05	–	–	–	46	105	2.28	–	–	–
2012	2014	111	–	–	30.50	–	–	33	–	–	54.73	–	–
2013	2015	129	–	–	31.78	–	–	29	–	–	73.65	–	–
2014	2016	174	–	–	19.06	–	–	63	–	–	33.55	–	–
2015	2017	151	–	–	11.75	–	–	83	–	–	12.69	–	–
Average (2001–2014 brood year)		155	187	1.12	18.30	0.071	0.013	49	71	1.40	37.19	0.047	0.011

Note: Adult returns and survival estimates are available through 2011 juvenile year.

[a] Total Yukon spawner abundance information unavailable for this year.

[b] Genetic information insufficient due to lost samples, insufficient sample size or other constraint. Relationship to spawner abundance and juvenile survival not provided due to uncertainty in stock composition.

[c] No Northeastern Bering Sea survey conducted.

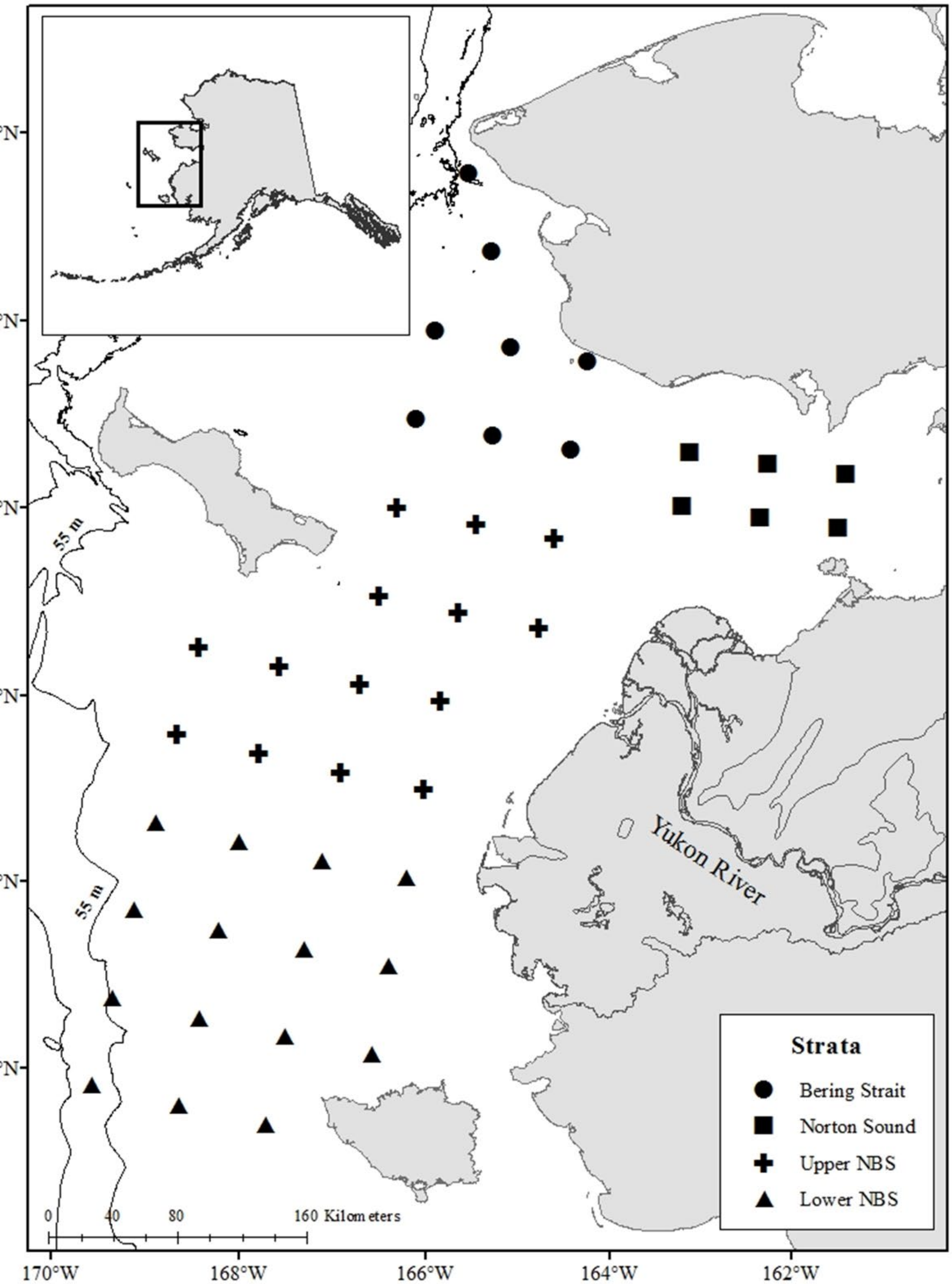

Figure 1.–Northeastern Bering Sea survey stations with symbols representing each of 4 spatial strata. *Note*: The 55 m isobath is provided to illustrate the relatively wide continental shelf in the eastern Bering Sea.

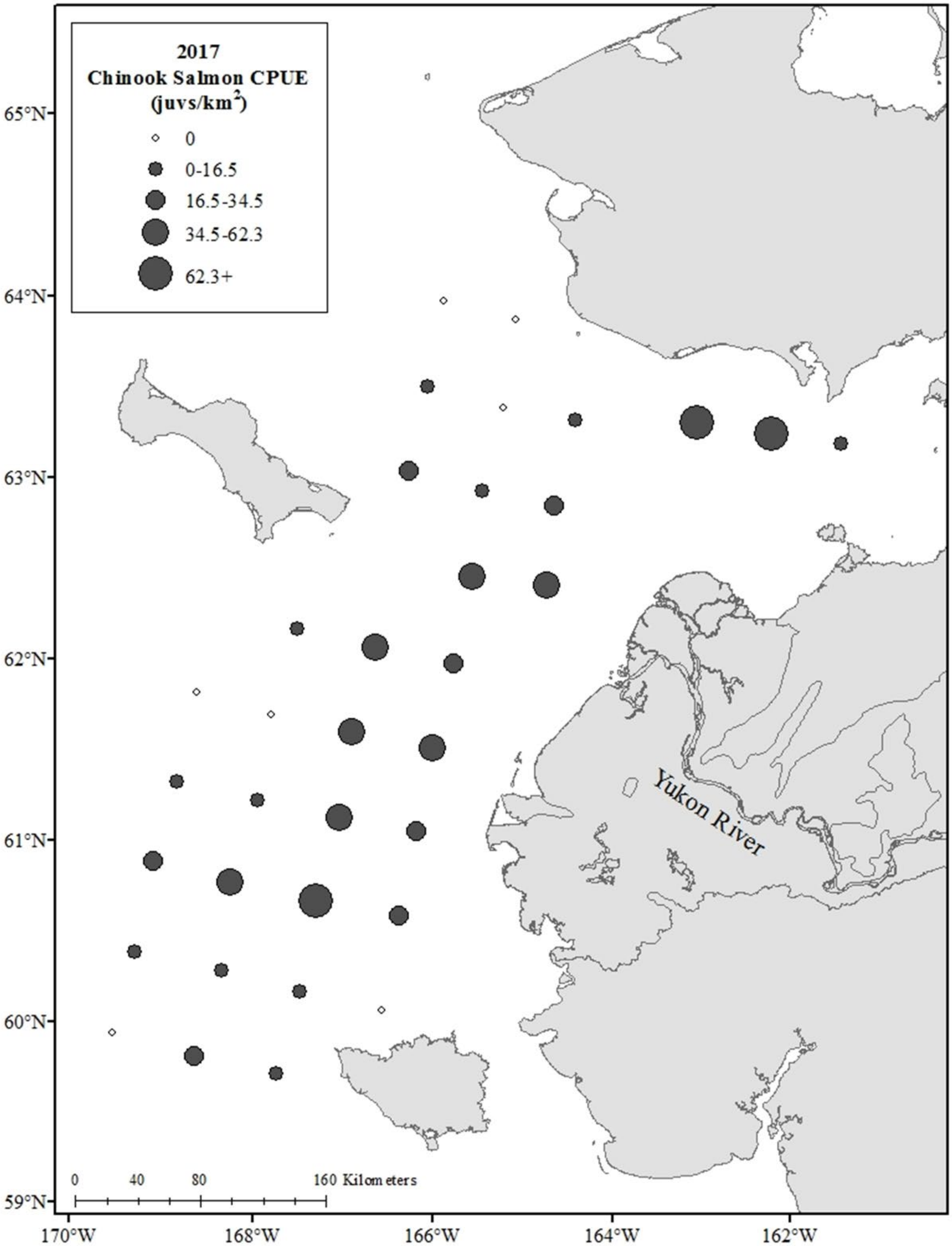

Figure 2.–Geographic distribution of juvenile Chinook salmon catch per unit area (CPUA), or catch per unit effort (CPUE), in the Northeastern Bering Sea, 2017.

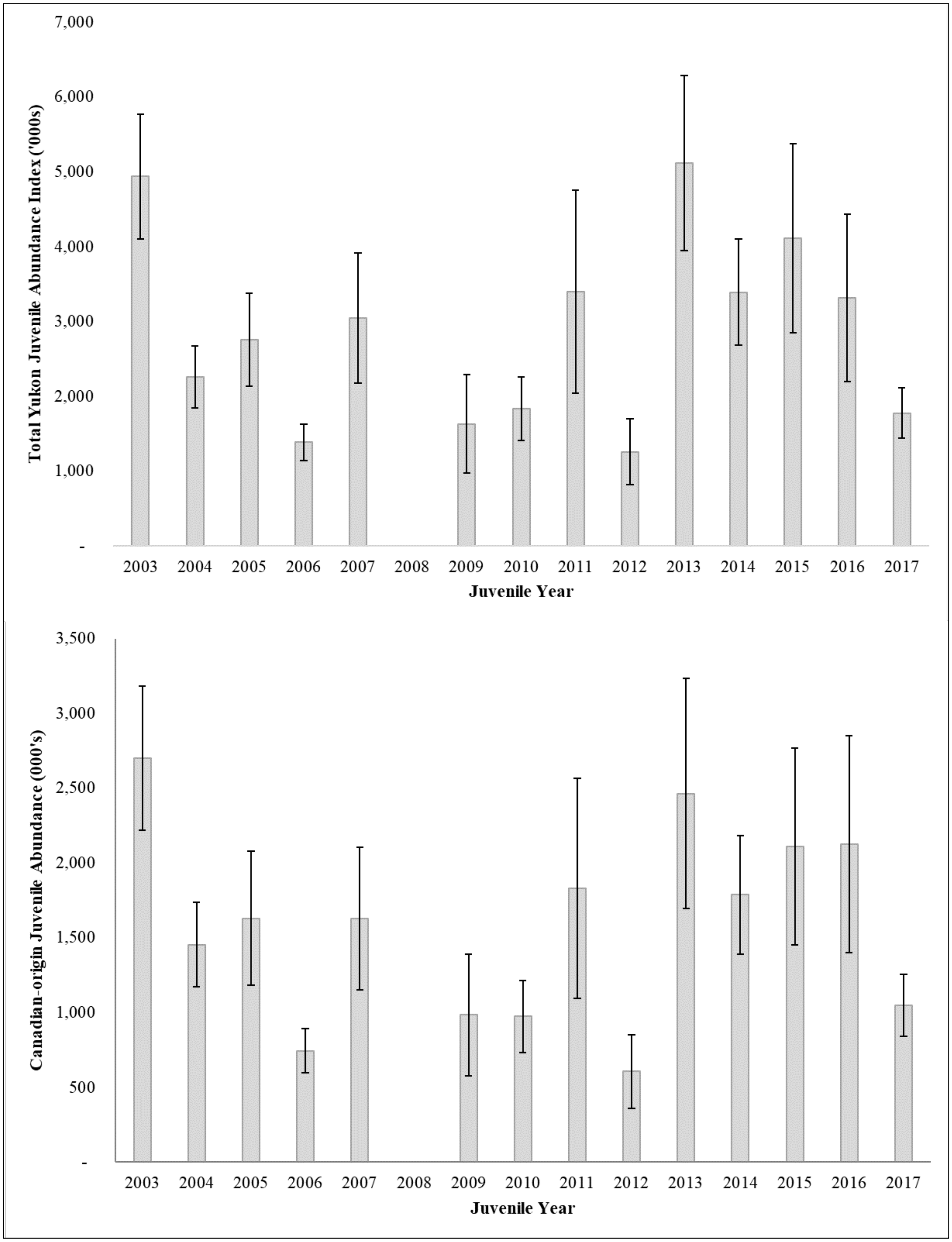

Figure 3.–Abundance estimates of total Yukon River (top) and Canadian-origin (bottom) Yukon juvenile Chinook salmon stock groups in the Northeastern Bering Sea survey, 2003–2017.

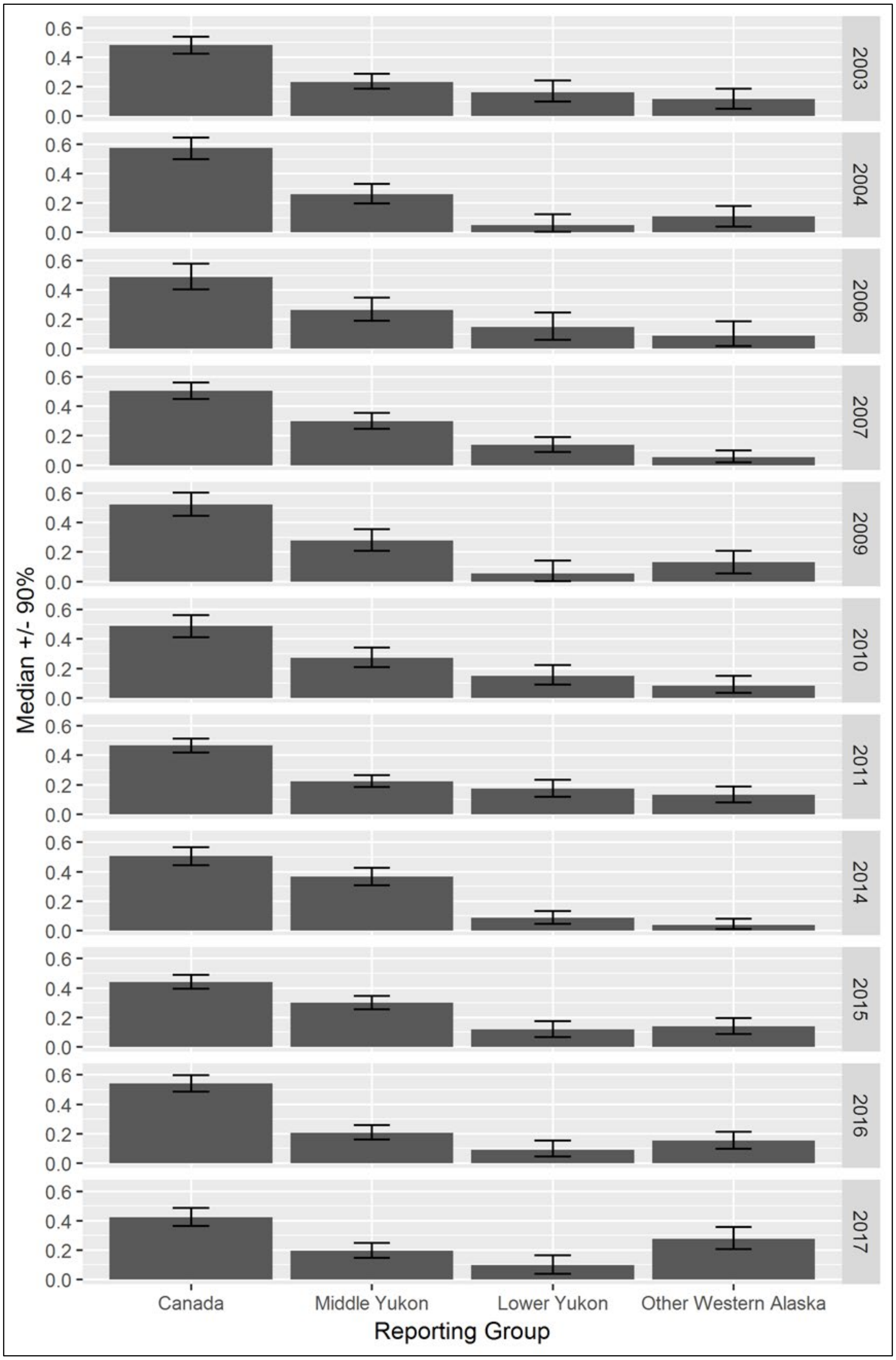

Figure 4.–Median estimates of stock composition (%) including, 90% credibility interval, for Chinook salmon sampled from the Northeastern Bering Sea trawl survey 2003–2017.

Note: Estimates are reported as Yukon River groups (Canada, Middle Yukon and Lower Yukon) and Other Western Alaska stocks group.

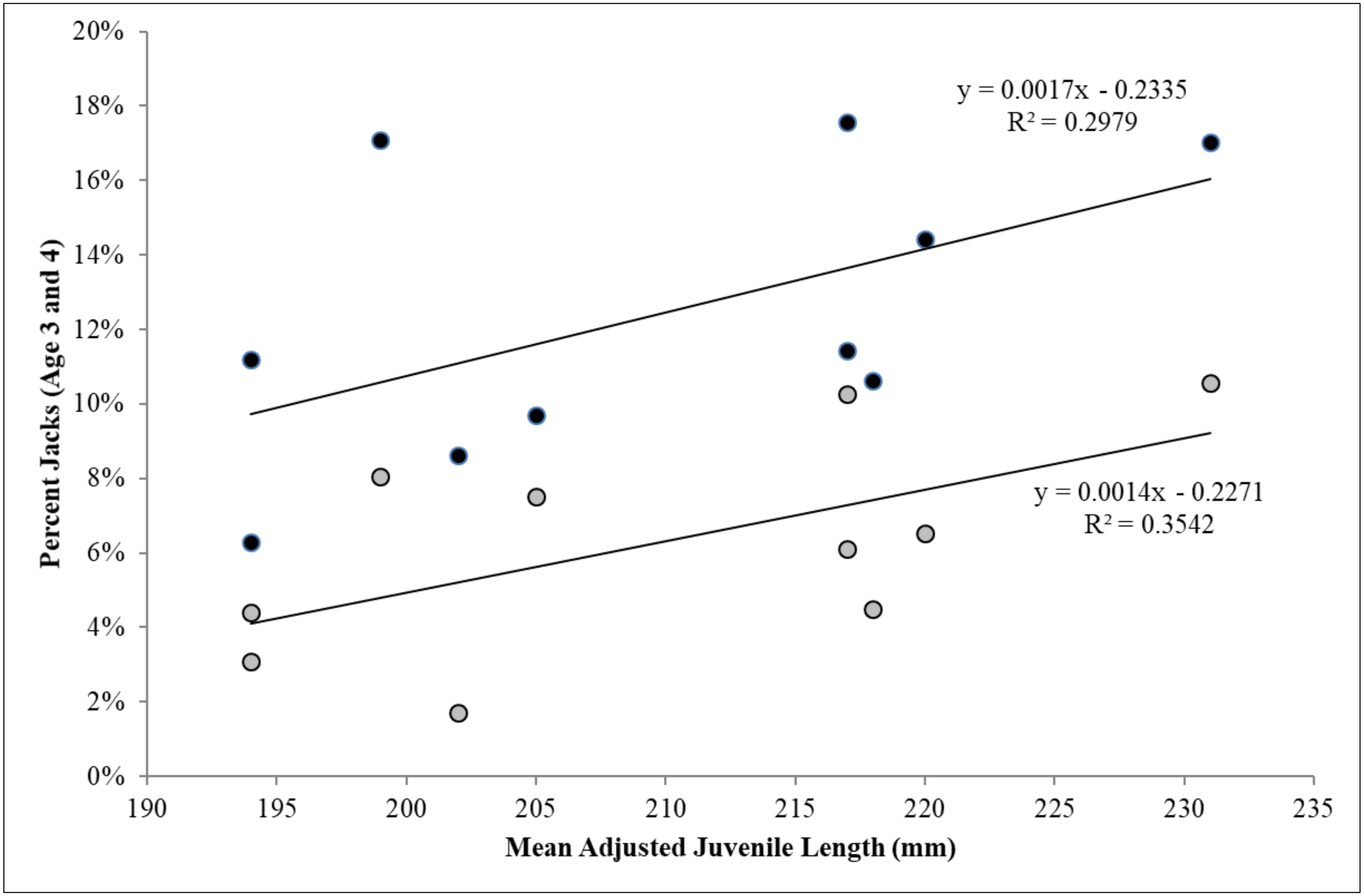

Figure 5.–Relationship between Northeastern Bering Sea juvenile Chinook salmon length and proportion of adults maturing as age-3 and age-4 ("jacks") from those cohorts for total Yukon River (black circles) and Canadian-origin (grey circles) stocks.

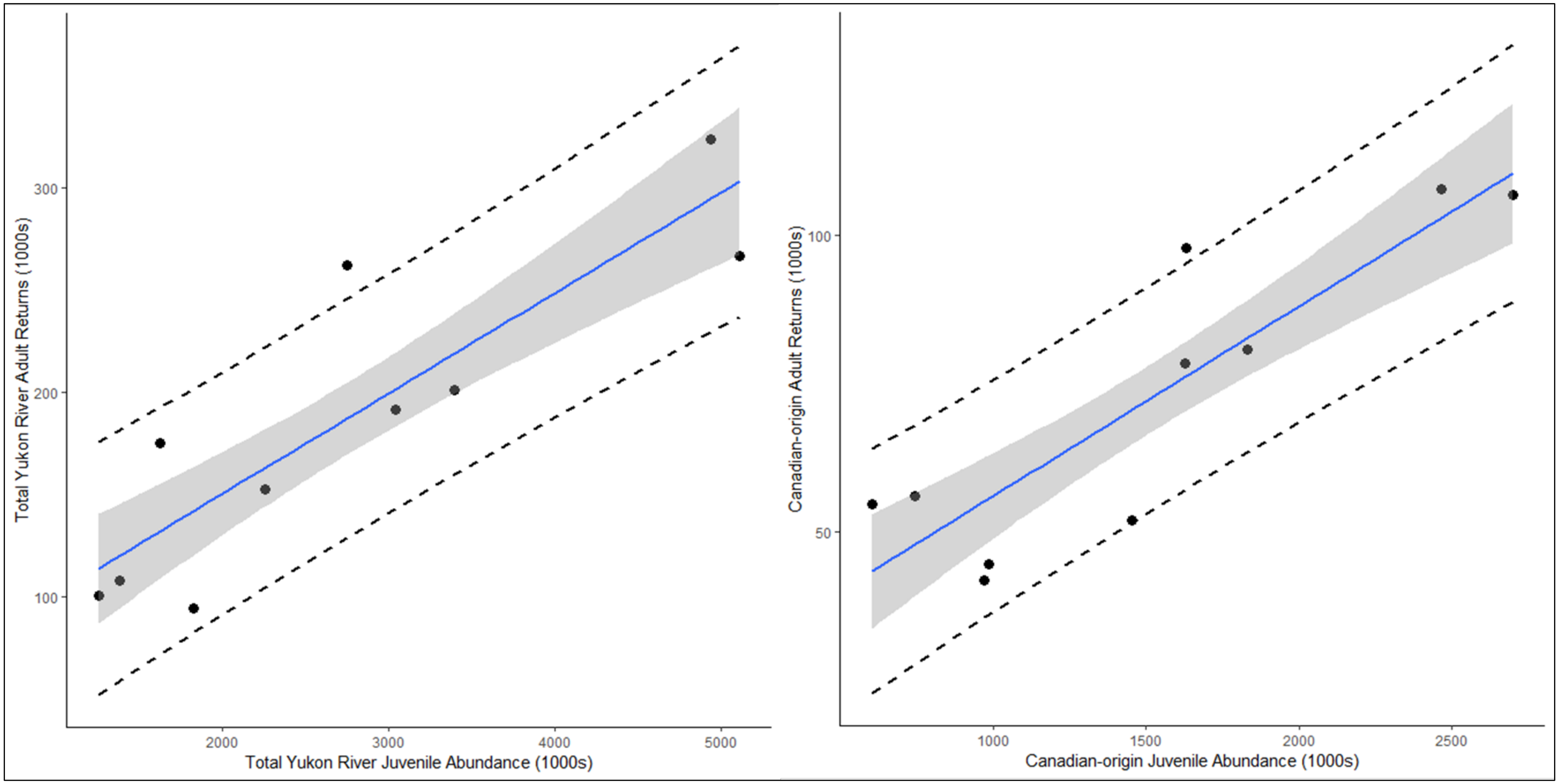

Figure 6.–Cohort relationships of Northeastern Bering Sea juvenile Chinook salmon abundance and adult returns (black circles) for total Yukon River (left) and Canadian-origin (right) stock groups.

Note: The linear model fit is represented by the solid line, 80% confidence interval of the linear model is represented by the shaded area, and the 80% prediction interval is represented by the dashed lines.

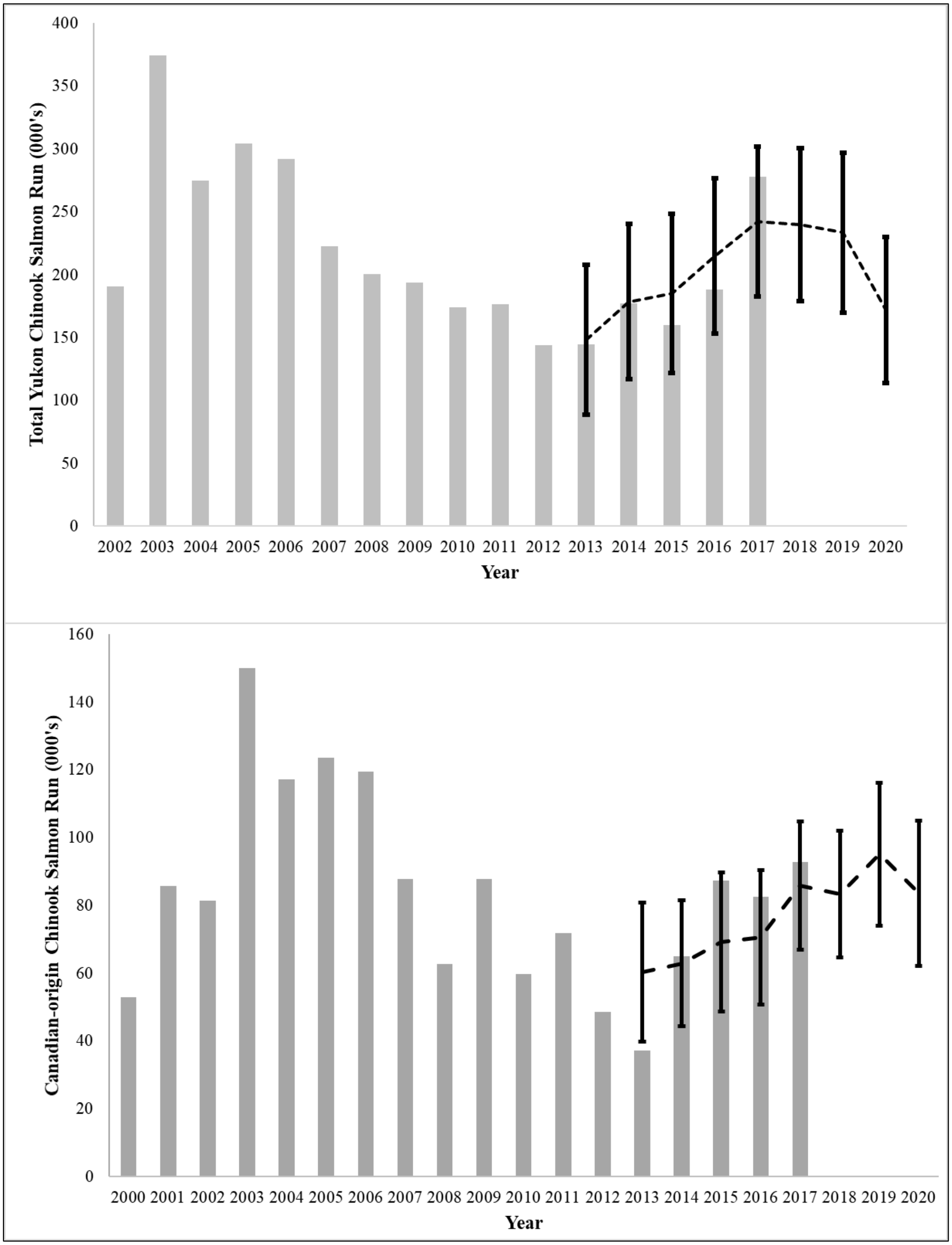

Figure 7.–Adult run size of total Yukon River (top) and Canadian-origin (bottom) Yukon River Chinook salmon stock groups (grey bars) and projected run size based on Northeastern Bering Sea juvenile abundance forecast (black dashed line and error bars indicating forecast range).

Note: Different scales on the y-axes of each panel.

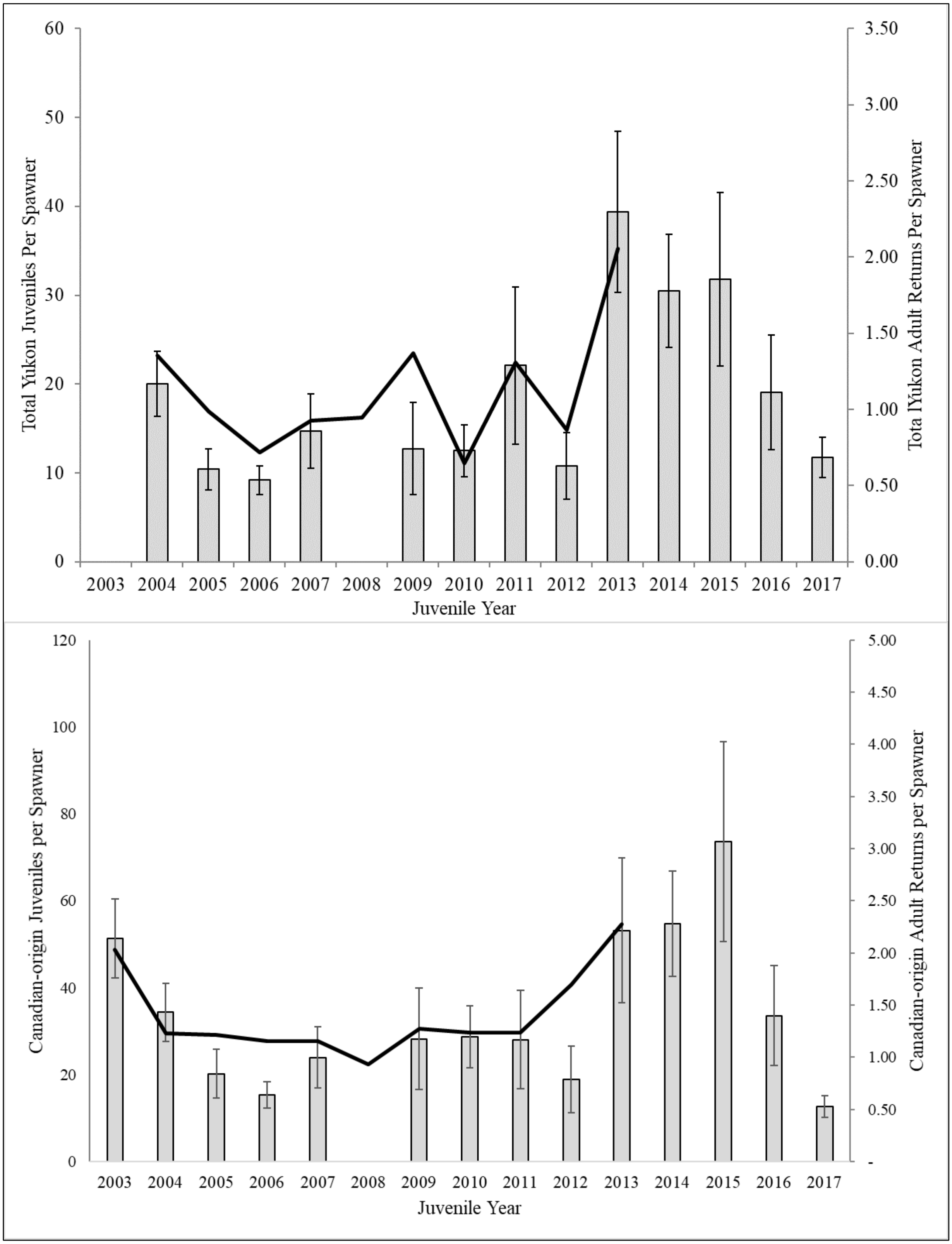

Figure 8.–Ratio of Northeastern Bering Sea juveniles per spawner for total Yukon River (top) and Canadian-origin (bottom) Yukon juvenile Chinook salmon stock groups (grey bars, left y-axis) and adult returns per spawner (black line, right y-axis).

APPENDIX A: TOTAL YUKON RIVER CHINOOK SALMON RUN RECONSTRUCTION

Appendix A1.–Methods used to reconstruct total Yukon River Chinook salmon run abundance required for use in forecast modelling.

Total Yukon River adult run and maturity data have not been previously compiled and reported, and these estimates were reconstructed from the best available published data as well as unpublished data from the Arctic-Yukon-Kuskokwim Database Management System. This analysis was beyond the scope of the stated study objectives but included for completeness.

Run Size and Spawner Abundance Estimation

The total Yukon River Chinook salmon run size was calculated by summing the total estimated passage at Pilot Station sonar project, escapement to the Andreafsky River, and all harvest below the Pilot Station sonar site. The majority of the Yukon River Chinook salmon run passed and was enumerated by the Pilot Station sonar project (197 river km upstream from the mouth) (Appendix A2; Pfisterer et al. 2017; JTC 2017; JTC 2018). The Andreafsky River is the only major spawning tributary for Yukon River Chinook salmon below the Pilot Station sonar site. A weir operated by the U.S. Fish and Wildlife Service provided escapement counts and age, sex, and length data for Chinook salmon migrating up the East Fork of the Andreafsky River (Appendix A3; Mears 2015). West Fork and East Fork Andreafsky River Chinook salmon spawning escapements were enumerated annually by aerial surveys when conditions allowed. The ratio of spawners utilizing each of the forks of the Andreafsky River, as measured by paired aerial surveys each year, were used to expand weir counts from the East Fork to provide total Andreafsky River spawning abundance (Appendix A3; JTC 2018). All harvest (subsistence, commercial, and sport) occurring downstream of the Pilot Station sonar project was assessed annually. Commercial and commercially sold test fishery harvests included those occurring in Yukon District 1 and in statistical areas 334-21, 334-22, and 334-23 of District 2 (Appendices A4 and A5; Arctic-Yukon-Kuskokwim Database Management System). Subsistence harvest included all communities in Yukon District 1 and in the communities of Mountain Village, Pitka's Point, St. Mary's, and Pilot Station of District 2 (Appendix A6; Busher et al. 2008; Jallen et al. 2017).

Because juvenile data limited the scope of analyses to the 2001–2015 brood years, and because reports from Pilot Station sonar indicated that the 2001 passage estimate was biased low, run reconstruction analyses were constrained to 2002–2017 run years (Appendix A7). Pilot Station sonar estimates accounted for 72–95% of the total Yukon River run estimate for Chinook salmon in these years. Chinook salmon run sizes ranged from a low of approximately 144,000 fish in 2012 to a high of approximately 375,000 fish in 2003.

Relative interannual abundance trends in the total Yukon River run reconstruction were fairly similar to those derived by the Joint Technical Committee (JTC) for Canadian-origin stocks (Appendix A8). Differences may be due to annual variability in the Canadian-origin Chinook salmon stock abundance relative to the Alaska-origin stock groups within the total Yukon River run, and/or differences in the measurement errors and uncertainties associated with each run reconstruction. Uncertainty information was not reported in parts of the source data for total Yukon River and Canadian-origin adult run reconstructions, and so estimating uncertainty in the run reconstructions themselves was not attempted. Generally, passage estimates from Pilot Station sonar had larger CVs than those from Eagle River sonar (used in the JTC's run reconstruction of Canadian-origin stocks), therefore it would be reasonable to presume that the total Yukon River run reconstruction would have less precision, and potentially less accuracy (a greater chance of misallocation among species at the Pilot Station sonar site) than the Canadian-origin run reconstruction. However, the Canadian-origin run reconstruction has an added element of apportioning all Alaska harvests to stock of origin, which also has associated unassessed uncertainty. Future attempts to clarify uncertainty in these adult run reconstruction analyses would be a worthwhile improvement.

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Total Chinook salmon spawners were those that escaped harvest (subsistence, commercial, test fishery, sport, and personal use) in both the United States and Canada and were assumed to successfully spawn in their natal tributaries. Total harvest was simply subtracted from the total run size estimate to obtain spawning abundance estimates (Appendix A9).

Brood Table Development

Age composition data were used to calculate brood year returns of Chinook salmon to the Yukon River. Chinook salmon caught during assessment programs and from various harvest types below the Pilot Station sonar program were sampled for age, sex, and length each year. Age compositions were applied to the numbers of fish represented by the assessment or harvest being represented. When possible, age composition estimates were weighted by temporal strata and applied to the numbers of Chinook salmon passage or harvest in those strata. Strata numbers by age were then summed to obtain the overall age composition for that abundance input (harvest or passage) by year. Age composition of passage included those samples from Pilot Station sonar test fishery (Appendix A2) and East Fork Andreafsky weir (Appendix A3; DuBois 2004; DuBois 2005; DuBois et al. 2009; DuBois and DeCovich 2008; DuBois 2011a; DuBois 2013; DuBois 2015a; DuBois 2015b; Eaton 2016). Pilot Station sonar test fishery age compositions were obtained from the Arctic-Yukon-Kuskokwim Database Management System and weighted by passage. Age composition of harvest included commercial, commercially-sold test fishery, and subsistence harvest downstream of the Pilot Station sonar program (Appendices A4–A6; DuBois 2004; DuBois 2005; DuBois et al. 2009; DuBois and DeCovich 2008; DuBois 2011a; DuBois 2011b; Leba and DuBois 2011; DuBois and Leba 2013; DuBois 2013; DuBois 2015a; DuBois 2015b; DuBois 2016). As detailed in previous reports, in the absence of age composition data, a surrogate from the most representative samples available (temporally and spatially) was used. Published age composition data were unavailable for 2017 commercial harvest; therefore, the age composition from the final stratum sampled at the Pilot Station sonar project was used as this harvest occurred in the fall season at the end of the Chinook salmon run. Age composition of catches from the Lower Yukon test fishery and Pilot Station sonar test fishery were occasionally employed as surrogates for District 1 and District 2 subsistence harvests, respectively.

In most years, age-5 fish were the most abundant age component of the total Yukon River run (averaging 47%), closely followed by the age-6 component (averaging 38%; Appendix A10). In contrast, the Canadian-origin run tended to be dominated by age-6 fish in 2002–2017 (averaging 51%), with age-5 fish being a lesser component of the run in most years (averaging 39%; JTC 2018). Although about 4% of the Canadian-origin runs for these years were age-4 fish on average, the total Yukon River run averaged 13% age-4 fish. Age-3 and age-7 fish averaged less than 5% in both run reconstructions (JTC 2018). The differences in age composition between total Yukon River run and Canadian-origin run is consistent with the understanding that the longer-migrating Canadian-origin Chinook salmon tend to mature at older ages than the Alaska-bound fish.

Completed total Yukon River brood year returns were estimated from 1998 to 2011 (Appendix A11). The 2000 brood year produced the highest number of total Yukon River returns (359,000 Chinook salmon), whereas the 2008 brood year had the lowest returns of the time series (95,000 Chinook salmon). For the same range of brood years, Canadian-origin stock returns were strongest from the 1998 brood year (124,000 Chinook salmon) and smallest from the 2008 brood year (42,000 Chinook salmon; JTC 2018).

The average maturation age by brood year (1998–2011) was similar to the average age compositions by run year (2002–2017) for total Yukon River stocks: <5% ages 3 and 7, 12% age-4, 48% age-5, and 37% age-6 (Appendix A12). Although the Canadian-origin Chinook exhibited a strong biennial pattern for age-5 and age-6 components, with age-6 fish tending to be more dominant in odd brood years compared to adjacent even brood years (JTC 2018), the total Yukon River brood table did not exhibit this pattern.

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Revised Chinook salmon passage at the sonar site near Pilot Station with 90% confidence bounds, with weighted age composition from Chinook salmon caught during test fishing operations, 2002–2017.

	Passage	Lower	Upper	Age composition (proportion)[b]					Age composition (in numbers)				
Year	estimate[a]	90%[a]	90%[a]	Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	151,713	111,742	191,684	0.000	0.244	0.398	0.308	0.050	0	37,000	60,433	46,657	7,623
2003	318,088	289,533	346,643	0.004	0.064	0.478	0.437	0.016	1,265	20,391	152,150	139,158	5,125
2004	200,761	180,782	220,740	0.007	0.314	0.299	0.363	0.016	1,478	62,973	60,104	72,937	3,269
2005	259,214	216,762	301,667	0.000	0.093	0.595	0.299	0.013	0	24,069	154,322	77,450	3,373
2006	228,763	201,067	256,459	0.000	0.057	0.589	0.351	0.003	0	13,043	134,638	80,368	714
2007	170,246	144,711	195,781	0.000	0.133	0.341	0.514	0.012	0	22,638	58,062	87,474	2,072
2008	175,046	153,679	196,413	0.010	0.062	0.558	0.324	0.046	1,752	10,890	97,616	56,754	8,035
2009	177,796	151,666	203,926	0.003	0.156	0.241	0.585	0.014	523	27,816	42,913	104,089	2,454
2010	145,088	-2,350	292,526	0.014	0.105	0.574	0.278	0.029	2,012	15,299	83,231	40,347	4,199
2011	148,797	128,623	168,971	0.004	0.097	0.531	0.344	0.024	589	14,471	79,067	51,138	3,532
2012	127,555	108,903	146,207	0.008	0.056	0.475	0.437	0.025	1,044	7,081	60,535	55,714	3,182
2013	136,805	103,904	169,706	0.000	0.066	0.356	0.556	0.022	0	9,048	48,709	76,049	2,999
2014	163,895	145,160	182,630	0.042	0.100	0.655	0.194	0.010	6,828	16,308	107,388	31,732	1,638
2015	146,859	115,901	177,817	0.000	0.245	0.323	0.426	0.006	0	36,032	47,431	62,555	841
2016	176,898	152,216	201,580	0.004	0.139	0.694	0.154	0.009	695	24,573	122,801	27,270	1,559
2017	263,014	224,365	301,663	0.002	0.161	0.484	0.332	0.020	636	42,445	127,340	87,263	5,330

Note: Age composition was weighed by strata.

[a] Pfisterer et al. 2017; JTC 2017–2018.

[b] Queried from Alaska Department of Fish and Game’s Arctic-Yukon-Kuskokwim Database Management System, and weighted by passage.

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Andreafsky River Chinook salmon escapement and age composition, 2002–2017.

Year	East Fork Andreafsky weir count [a]	Proportion East Fork to total Andreafsky escapement [a]	Total Andreafsky River escapement estimate	Age composition (proportion)[b]					Age composition (numbers of fish)				
				Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	4,123	0.61	6,736	0.000	0.305	0.482	0.200	0.014	0	2,054	3,245	1,344	93
2003	4,336	0.54 [c]	8,030	0.005	0.160	0.520	0.307	0.008	40	1,285	4,175	2,465	64
2004	8,045	0.69	11,725	0.000	0.399	0.426	0.171	0.004	0	4,678	4,995	2,005	47
2005	2,239	0.53	4,187	0.000	0.150	0.643	0.202	0.005	0	628	2,692	846	21
2006	6,463	0.54 [c]	11,969	0.000	0.170	0.549	0.281	0.000	0	2,035	6,571	3,363	0
2007	4,504	0.64	7,005	0.000	0.417	0.257	0.320	0.006	0	2,921	1,800	2,241	42
2008	4,242	0.54 [c]	7,856	0.000	0.038	0.745	0.201	0.015	0	299	5,852	1,579	118
2009	3,004	0.54 [c]	5,563	0.001	0.250	0.155	0.587	0.005	6	1,391	862	3,265	28
2010	2,413	0.38	6,268	0.003	0.413	0.468	0.105	0.010	19	2,589	2,934	658	63
2011	5,213	0.35	15,076	0.000	0.456	0.396	0.146	0.002	0	6,875	5,970	2,201	30
2012	2,517	0.54 [c]	4,661	0.002	0.111	0.646	0.237	0.003	9	517	3,011	1,105	14
2013	1,998	0.57	3,515	0.006	0.479	0.216	0.293	0.006	21	1,684	759	1,030	21
2014	5,949	0.54 [c]	11,017	0.011	0.070	0.809	0.107	0.000	121	771	8,912	1,179	0
2015	5,474	0.62	8,899	0.000	0.378	0.147	0.475	0.000 [d]	0	3,367	1,304	4,229	0
2016	2,676	0.54 [c]	4,956	0.024	0.271	0.638	0.067	0.000 [d]	119	1,343	3,162	332	0
2017	2,970	0.54 [c]	5,500	0.000	0.620	0.226	0.154	0.000 [d]	0	3,410	1,243	847	0

Note: The proportion of East Fork escapement was derived from paired aerial surveys in East and West forks, and East Fork Andreafsky weir estimates were expanded by this proportion to obtain total Andreafsky River escapement. Age compositions were weighted by passage unless otherwise noted.

[a] JTC 2018.

[b] Eaton 2016.

[c] Paired aerial survey data unavailable and long-term average proportion used.

[d] Queried from Alaska Department of Fish and Game's Arctic-Yukon-Kuskokwim Database Management System, and weighted by passage.

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Chinook salmon total commercial harvest and age composition from Districts 1 and 2, 2002–2017.

District 1												
		Age composition (proportion) [b]						Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7		Age-3	Age-4	Age-5	Age-6	Age-7
2002	11,089	0.000	0.037	0.202	0.630	0.131		0	410	2,240	6,986	1,453
2003	22,709	0.000	0.005	0.261	0.654	0.079		0	114	5,927	14,852	1,794
2004	28,403	0.000	0.062	0.187	0.711	0.039		0	1,761	5,311	20,195	1,108
2005	16,694	0.000	0.017	0.424	0.518	0.042		0	284	7,078	8,647	701
2006	23,748	0.000	0.018	0.468	0.498	0.017		0	427	11,114	11,827	404
2007	18,616	0.000	0.087	0.184	0.677	0.052		0	1,620	3,425	12,603	968
2008	2,530	0.003	0.116	0.581	0.277	0.022		8	293	1,470	701	56
2009	90	0.011	0.500	0.222	0.267	0.000		1	45	20	24	0
2010	5,744	0.001	0.348	0.482	0.155	0.014		6	1,999	2,769	890	80
2011	36	0.000	0.368	0.414	0.207	0.011		0	13	15	7	0
2012	0	–	–	–	–	–		0	0	0	0	0
2013	0	–	–	–	–	–		0	0	0	0	0
2014	0	–	–	–	–	–		0	0	0	0	0
2015	0	–	–	–	–	–		0	0	0	0	0
2016	0	–	–	–	–	–		0	0	0	0	0
2017	168	0.008	0.361	0.361	0.266	0.004	[c]	1	61	61	45	1

District 2												
		Age composition (proportion) [b]						Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7		Age-3	Age-4	Age-5	Age-6	Age-7
2002	7,182	0.000	0.034	0.251	0.582	0.133		0	244	1,803	4,180	955
2003	9,412	0.000	0.009	0.310	0.605	0.076		0	85	2,918	5,694	715
2004	17,664	0.000	0.037	0.189	0.735	0.039		0	654	3,338	12,983	689
2005	10,594	0.000	0.029	0.499	0.454	0.017		0	307	5,286	4,810	180
2006	14,907	0.000	0.018	0.532	0.440	0.010		0	268	7,931	6,559	149
2007	10,785	0.000	0.171	0.239	0.578	0.012		0	1,844	2,578	6,234	129
2008	1,744	0.000	0.093	0.563	0.323	0.021		0	162	982	563	37
2009	201	0.011	0.500	0.222	0.267	0.000		2	101	45	54	0
2010	2,969	0.002	0.329	0.497	0.158	0.014		6	977	1,476	469	42
2011	24	0.000	0.368	0.414	0.207	0.011		0	9	10	5	0
2012	0	–	–	–	–	–		0	0	0	0	0
2013	0	–	–	–	–	–		0	0	0	0	0
2014	0	–	–	–	–	–		0	0	0	0	0
2015	0	–	–	–	–	–		0	0	0	0	0
2016	0	–	–	–	–	–		0	0	0	0	0
2017	0	–	–	–	–	–		0	0	0	0	0

Note: District 2 commercial harvest only includes harvest downstream of the sonar site at Pilot Station (stat areas 334-21, 334-22, and 334-23).

[a] Data obtained from Alaska Department of Fish and Game's Arctic-Yukon-Kuskowim Database Management System.

[b] DuBois 2004, DuBois 2005, DuBois et al. 2009, DuBois and DeCovich 2008, DuBois 2011a, DuBois 2011b, Leba and DuBois 2011, DuBois and Leba 2013, DuBois 2013, DuBois 2015a, DuBois 2015b, DuBois 2016.

[c] No age composition data available from Chinook salmon sold during the fall season in 2017. Therefore, the age composition from Chinook salmon sampled from the final stratum at Pilot Station sonar was used.

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Chinook salmon test fishery sales from the Lower Yukon test fishery (District 1) and the Pilot Station drift gillnet test fishery (District 2), 2002–2017.

District 1											
		Age composition (proportion) [b]					Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	494	0.000	0.029	0.207	0.647	0.117	0	14	102	320	58
2003	619	0.000	0.006	0.250	0.671	0.073	0	4	155	415	45
2004	722	0.000	0.062	0.187	0.711	0.039	0	45	135	513	28
2005	310	0.000	0.017	0.424	0.518	0.042	0	5	131	161	13
2006	817	0.000	0.018	0.468	0.498	0.017	0	15	382	407	14
2007	792	0.000	0.047	0.144	0.802	0.008	0	37	114	635	6
2008	0	–	–	–	–	–	0	0	0	0	0
2009	0	–	–	–	–	–	0	0	0	0	0
2010	0	–	–	–	–	–	0	0	0	0	0
2011	0	–	–	–	–	–	0	0	0	0	0
2012	0	–	–	–	–	–	0	0	0	0	0
2013	0	–	–	–	–	–	0	0	0	0	0
2014	0	–	–	–	–	–	0	0	0	0	0
2015	0	–	–	–	–	–	0	0	0	0	0
2016	0	–	–	–	–	–	0	0	0	0	0
2017	0	–	–	–	–	–	0	0	0	0	0

District 2											
		Age composition (proportion) [b]					Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	34	0.000	0.034	0.251	0.582	0.133	0	1	9	20	5
2003	61	0.000	0.009	0.310	0.605	0.076	0	1	19	37	5
2004	70	0.002	0.274	0.309	0.395	0.020	0	19	22	28	1
2005	0	–	–	–	–	–	0	0	0	0	0
2006	0	–	–	–	–	–	0	0	0	0	0
2007	57	0.000	0.131	0.349	0.510	0.010	0	7	20	29	1
2008	0	–	–	–	–	–	0	0	0	0	0
2009	0	–	–	–	–	–	0	0	0	0	0
2010	0	–	–	–	–	–	0	0	0	0	0
2011	0	–	–	–	–	–	0	0	0	0	0
2012	0	–	–	–	–	–	0	0	0	0	0
2013	0	–	–	–	–	–	0	0	0	0	0
2014	0	–	–	–	–	–	0	0	0	0	0
2015	0	–	–	–	–	–	0	0	0	0	0
2016	0	–	–	–	–	–	0	0	0	0	0
2017	0	–	–	–	–	–	0	0	0	0	0

[a] Data obtained from Alaska Department of Fish and Game's Arctic-Yukon-Kuskokwim Database Management System.

[b] DuBois 2004; DuBois 2005; DuBois et al. 2009; DuBois and DeCovich 2008; DuBois 2011a; DuBois 2011b.

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Chinook salmon subsistence harvest from District 1 (including the Coastal District) and District 2 (Mountain Village, Pitka's Point, St. Mary's and Pilot Station), 2002–2017.

District 1											
		Age composition (proportion) [b]					Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	6,725	0.000	0.198	0.370	0.356	0.076	0	1,332	2,488	2,394	511
2003	8,182	0.000	0.039	0.385	0.518	0.057	0	319	3,150	4,238	466
2004	7,918	0.000	0.131	0.313	0.529	0.028	0	1,037	2,478	4,189	222
2005	5,906	0.000	0.111	0.403	0.465	0.022	0	656	2,380	2,746	130
2006	6,005	0.000	0.049	0.542	0.387	0.021	0	294	3,255	2,324	126
2007	7,257	0.000	0.076	0.280	0.642	0.002	0	552	2,032	4,659	15
2008	7,655	0.000	0.038	0.595	0.342	0.026	0	291	4,555	2,618	199
2009	5,030	0.000	0.170	0.131	0.683	0.015	0	855	659	3,435	75
2010	7,156	0.001	0.072	0.577	0.318	0.033	7	515	4,129	2,276	236
2011	7,024	0.000	0.156	0.486	0.341	0.017	0	1,096	3,414	2,395	119
2012	6,417	0.000	0.109	0.462	0.416	0.013	0	699	2,965	2,669	83
2013	3,176	0.000	0.214	0.311	0.459	0.016	0	680	988	1,458	51
2014	1,919	0.002	0.011	0.507	0.455	0.026 [c]	4	21	973	873	50
2015	2,885	0.000	0.098	0.170	0.720	0.012 [c]	0	284	491	2,076	34
2016	3,672 [d]	0.000	0.282	0.563	0.155	0.000 [d]	0	1,034	2,068	570	0
2017	5,633 [d]	0.000	0.234	0.515	0.246	0.006 [d]	0	1,315	2,901	1,383	34

District 2											
		Age composition (proportion) [b]					Age composition (in numbers)				
Year	Harvest [a]	Age-3	Age-4	Age-5	Age-6	Age-7	Age-3	Age-4	Age-5	Age-6	Age-7
2002	6,664	0.000	0.036	0.182	0.621	0.162	0	240	1,213	4,138	1,080
2003	7,609	0.000	0.039	0.385	0.518	0.058	0	297	2,929	3,941	441
2004	7,734	0.001	0.116	0.241	0.610	0.031	8	897	1,864	4,718	240
2005	7,352	0.000	0.058	0.468	0.457	0.017	0	426	3,441	3,360	125
2006	6,142	0.000	0.029	0.572	0.389	0.011	0	178	3,513	2,389	68
2007	7,998	0.000	0.044	0.218	0.726	0.012	0	352	1,744	5,807	96
2008	5,542	0.002	0.030	0.562	0.365	0.042	11	166	3,115	2,023	233
2009	4,934	0.003	0.147	0.251	0.587	0.013	15	725	1,238	2,896	64
2010	6,566	0.000	0.090	0.594	0.295	0.021	0	591	3,900	1,937	138
2011	5,383	0.000	0.143	0.529	0.309	0.019	0	770	2,848	1,663	102
2012	5,472	0.001	0.051	0.541	0.390	0.017	5	279	2,960	2,134	93
2013	776	0.000	0.214	0.311	0.459	0.016	0	166	241	356	12
2014	488	0.041	0.095	0.660	0.187	0.009 [e]	20	46	322	91	4
2015	1,057	0.000	0.224	0.339	0.432	0.005 [e]	0	237	358	457	5
2016	2,660 [d]	0.000	0.350	0.550	0.092	0.008 [d]	0	931	1,463	244	22
2017	3,411 [d]	0.000	0.184	0.520	0.291	0.004 [d]	0	629	1,775	993	14

Note: Age compositions are districtwide.

[a] Busher et al. 2008; Jallen et al. 2017.

[b] DuBois 2004; DuBois 2005; DuBois et al. 2009; DuBois and DeCovich 2008; DuBois 2011a; DuBois 2011b; Leba and DuBois 2011; DuBois and Leba 2013; DuBois 2013; DuBois 2015a; DuBois 2015b; DuBois 2016.

[c] Age composition data from subsistence harvest unavailable, therefore, age composition from the Lower Yukon test fishery was used.

[d] Preliminary, unpublished estimate.

[e] Age composition data from subsistence harvest unavailable, therefore, used age composition from the Pilot Station sonar drift gillnet test fishery. Test fishery uses mesh sizes from 2.75 to 8.5-inch stretched mesh.

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Total Yukon River Chinook salmon run size (in numbers) calculated by summing the Pilot Station sonar passage, Andfreafsky River escapement, and the total harvest below the sonar site, 2002–2017.

Year	Pilot Station sonar passage	Andreafsky River escapement	District 1 commercial harvest	District 1 subsistence harvest	District 1 test fishery sales	District 2 commercial harvest	District 2 subsistence harvest	District 2 test fishery sales	Total run
2002	151,713	6,736	11,089	6,725	494	7,182	6,664	34	190,637
2003	318,088	8,030	22,709	8,182	619	9,412	7,609	61	374,710
2004	200,761	11,725	28,403	7,918	722	17,664	7,734	70	274,997
2005	259,214	4,187	16,694	5,906	310	10,594	7,352	0	304,257
2006	228,763	11,969	23,748	6,005	817	14,907	6,142	0	292,351
2007	170,246	7,005	18,616	7,257	792	10,785	7,998	57	222,756
2008	175,046	7,856	2,530	7,655	0	1,744	5,542	0	200,373
2009	177,796	5,563	90	5,030	0	201	4,934	0	193,614
2010	145,088	6,268	5,744	7,156	0	2,969	6,566	0	173,791
2011	148,797	15,076	36	7,024	0	24	5,383	0	176,340
2012	127,555	4,661	0	6,417	0	0	5,472	0	144,105
2013	136,805	3,515	0	3,176	0	0	776	0	144,272
2014	163,895	11,017	0	1,919	0	0	488	0	177,319
2015	146,859	8,899	0	2,885	0	0	1,057	0	159,700
2016	176,898	4,956	0	3,672	0	0	2,660	0	188,186
2017	263,014	5,500	168	5,633	0	0	3,411	0	277,726

Note: Commercial and subsistence harvest is from the portion of District 2 that is downstream of Pilot Station sonar.

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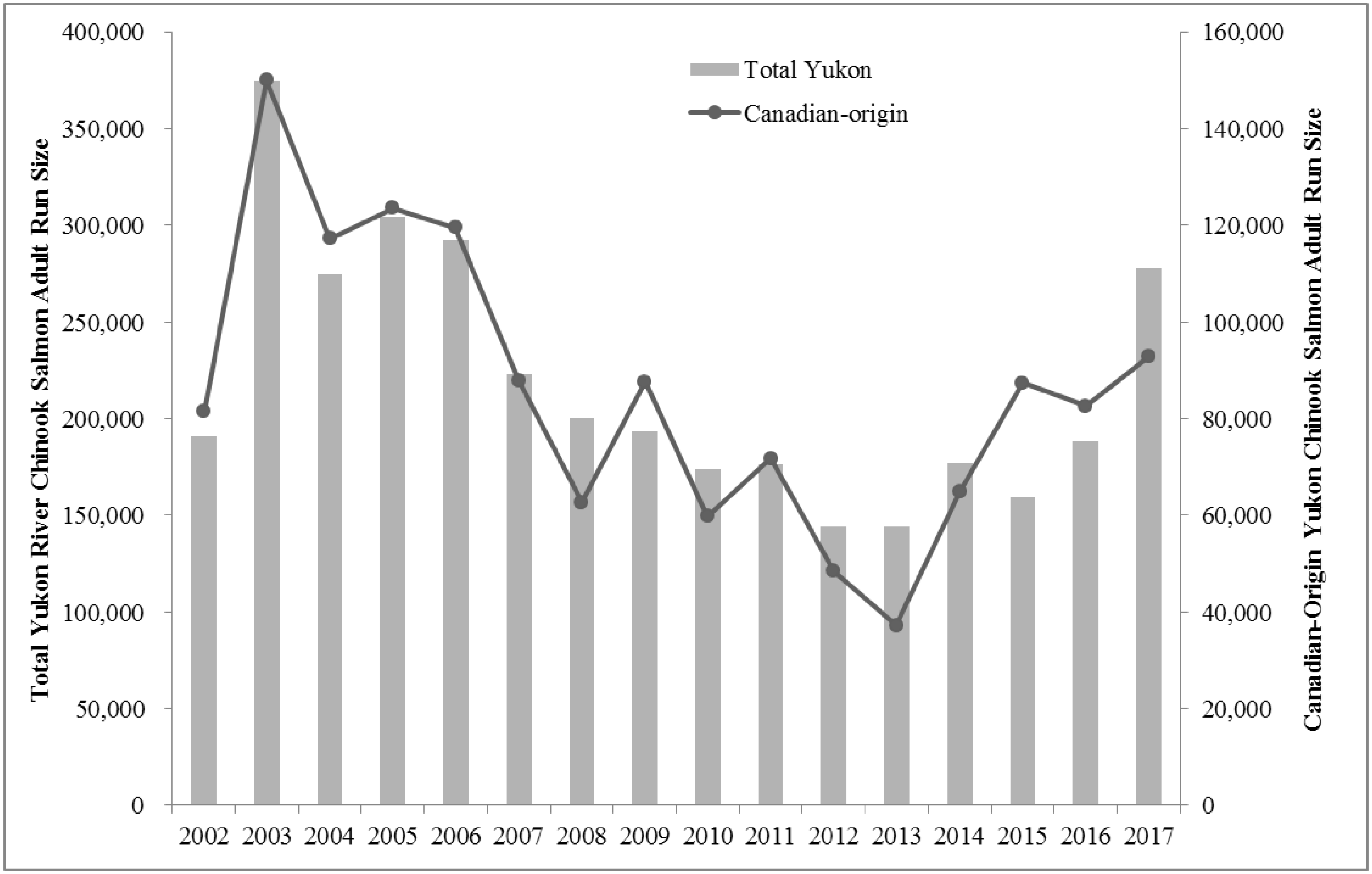
Adult Chinook salmon run size estimates of total Yukon River (left y-axis) and Canadian-origin (right y-axis) stock groups, 2002–2017.



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Estimated total Yukon River Chinook salmon harvests, total run, and spawner abundance, 2002–2017.

	Harvest below sonar			Harvest above sonar[a,b,c]						
Year	Subsistence	Commercial	Total	Subsistence	Commercial	U.S. sport fish	Canadian	Total	Total run	Estimated spawners
2002	13,389	18,271	31,660	30,353	5,865	486	9,258	45,962	190,637	113,015
2003	15,791	32,121	47,912	41,168	8,317	2,719	9,619	61,823	374,710	264,975
2004	15,652	46,067	61,719	40,061	10,084	1,513	11,238	62,896	274,997	150,382
2005	13,258	27,288	40,546	40,151	4,741	483	11,371	56,746	304,257	206,965
2006	12,147	38,655	50,802	36,446	7,174	739	9,072	53,431	292,351	188,118
2007	15,255	29,401	44,656	39,919	4,233	960	5,094	50,206	222,756	127,894
2008	13,197	4,274	17,471	31,989	367	409	3,713	36,478	200,373	146,424
2009	9,964	291	10,255	23,841	25	863	4,758	29,487	193,614	153,872
2010	13,722	8,713	22,435	30,837	1,184	474	2,706	35,201	173,791	116,155
2011	12,407	60	12,467	28,573	22	474	4,884	33,953	176,340	129,920
2012	11,889	0	11,889	18,526	0	345	2,200	21,071	144,105	111,145
2013	3,952	0	3,952	8,581	0	166	2,144	10,891	144,272	129,429
2014	2,407	0	2,407	879	0	0	103	982	177,319	173,930
2015	3,942	0	3,942	3,635	0	13	1,204	4,852	159,700	150,906
2016	6,332	0	6,332	15,326	0	20	2,946	18,292	188,186	163,562
2017	9,044	168	9,212	28,992	0	N.D.	3,631	32,623	277,726	235,891

[a] Subsistence and commercial harvest above sonar are from Marshall (District 2) and Districts 3–6. Commercial harvest data obtained from Alaska Department of Fish and Game's Arctic-Yukon-Kuskokwim Database Management System. Subsistence harvest data from Busher et al. 2008; Jallen et al. 2017.

[b] Sport fish harvest mostly occurs in the Tanana River drainage with a minor component from the mainstem Yukon River.

[c] Total Canadian Chinook salmon harvest is the combined total of commercial, domestic, aboriginal, recreational, and test fishery harvests from the mainstem Yukon River plus the Porcupine aboriginal harvest (JTC 2018).

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Age composition of the total Yukon River Chinook salmon run calculated using the age compositions from the Pilot Station sonar passage, East Fork Andreafsky River escapement, commercial and test fishery sales, and subsistence harvest below the Pilot Station sonar, 2002–2017.

Year	Age-3	Age-4	Age-5	Age-6	Age-7	Total run
2002	0	41,296	71,532	66,039	11,777	190,644
2003	1,305	22,494	171,423	170,801	8,656	374,679
2004	1,486	72,065	78,247	117,567	5,604	274,968
2005	0	26,375	175,331	98,020	4,543	304,269
2006	0	16,261	167,403	107,237	1,474	292,375
2007	0	29,971	69,774	119,682	3,329	222,756
2008	1,770	12,102	113,589	64,238	8,677	200,375
2009	547	30,933	45,738	113,764	2,621	193,603
2010	2,049	21,970	98,438	46,577	4,758	173,792
2011	589	23,233	91,323	57,410	3,784	176,340
2012	1,059	8,577	69,471	61,622	3,372	144,100
2013	21	11,577	50,698	78,893	3,083	144,272
2014	6,973	17,147	117,596	33,875	1,693	177,284
2015	0	39,919	49,584	69,316	880	159,700
2016	814	27,881	129,494	28,416	1,581	188,186
2017	637	47,860	133,320	90,530	5,379	277,726

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Total Yukon River Chinook salmon brood year returns, spawner abundance, and returns per spawner (R/S), 1991–2017.

Brood	Age							
year	3	4	5	6	7	Returns	Spawners	R/S
1991								
1992								
1993								
1994								
1995					11,777			
1996				66,039	8,656			
1997			71,532	170,801	5,604			
1998		41,296	171,423	117,567	4,543	334,829		
1999	0	22,494	78,247	98,020	1,474	200,235		
2000	1,305	72,065	175,331	107,237	3,329	359,266		
2001	1,486	26,375	167,403	119,682	8,677	323,624		
2002	0	16,261	69,774	64,238	2,621	152,894	113,015	1.35
2003	0	29,971	113,589	113,764	4,758	262,082	264,975	0.99
2004	0	12,102	45,738	46,577	3,784	108,201	150,382	0.72
2005	1,770	30,933	98,438	57,410	3,372	191,924	206,965	0.93
2006	547	21,970	91,323	61,622	3,083	178,544	188,118	0.95
2007	2,049	23,233	69,471	78,893	1,693	175,339	127,894	1.37
2008	589	8,577	50,698	33,875	880	94,619	146,424	0.65
2009	1,059	11,577	117,596	69,316	1,581	201,129	153,872	1.31
2010	21	17,147	49,584	28,416	5,379	100,547	116,155	0.87
2011	6,973	39,919	129,494	90,530		266,917	129,920	2.05
2012	0	27,881	133,320				111,145	
2013	814	47,860					129,429	
2014	637						173,930	
2015							150,906	
2016							163,562	
2017							235,891	

Note: Shaded cells represent ages without available brood year return data. These ages make up a relatively very small component of the annual returns and are unlikely to dramatically affect overall return numbers and productivity estimates.

Note: Blank cells indicate no data available.

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Maturation schedule for completed brood years of total Yukon River Chinook salmon, 1998–2011.

Brood Year	Age-3	Age-4	Age-5	Age-6	Age-7	Returns
1998	0.00%	12.33%	51.20%	35.11%	1.36%	334,829
1999	0.00%	11.23%	39.08%	48.95%	0.74%	200,235
2000	0.36%	20.06%	48.80%	29.85%	0.93%	359,266
2001	0.46%	8.15%	51.73%	36.98%	2.68%	323,624
2002	0.00%	10.64%	45.64%	42.01%	1.71%	152,894
2003	0.00%	11.44%	43.34%	43.41%	1.82%	262,082
2004	0.00%	11.18%	42.27%	43.05%	3.50%	108,201
2005	0.92%	16.12%	51.29%	29.91%	1.76%	191,924
2006	0.31%	12.30%	51.15%	34.51%	1.73%	178,544
2007	1.17%	13.25%	39.62%	44.99%	0.97%	175,339
2008	0.62%	9.06%	53.58%	35.80%	0.93%	94,619
2009	0.53%	5.76%	58.47%	34.46%	0.79%	201,129
2010	0.02%	17.05%	49.31%	28.26%	5.35%	100,547
2011	2.61%	14.96%	48.51%	33.92%	0.00%	266,917
5-year avg.	0.99%	12.02%	49.90%	35.49%	1.61%	

Note: Shaded cells represent ages without available brood year return data. These ages make up a relatively very small component of the annual returns and are unlikely to dramatically affect overall return numbers and productivity estimates.

References Cited

Busher, W. H., T. Hamazaki, and A. M. Marsh. 2008. Subsistence and personal use salmon harvests in the Alaska portion of the Yukon River drainage, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 08-08, Anchorage.

DuBois, L. 2004. Origins of Chinook salmon in the Yukon River fisheries, 2002. Alaska Department of Fish and Game, Regional Information Report 3A04-11, Anchorage.

DuBois, L. 2005. Origins of Chinook salmon in the Yukon River fisheries, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 05-46, Anchorage.

DuBois, L. 2011a. Origins of Chinook salmon in the Yukon River fisheries, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 11-22, Anchorage.

DuBois, L. 2011b. Origins of Chinook salmon in the Yukon River fisheries, 2007. Alaska Department of Fish and Game, Fishery Data Series No. 11-56, Anchorage.

Dubois, L., and H. A. Leba. 2013. Origins of Chinook salmon in the Yukon River fisheries, 2009. Alaska Department of Fish and Game, Fishery Data Series No. 13-43, Anchorage.

DuBois, L. 2013. Origins of Chinook salmon in the Yukon River fisheries, 2010. Alaska Department of Fish and Game, Fishery Data Series No. 13-53, Anchorage.

DuBois, L. 2015a. Origins of Chinook salmon in the Yukon River fisheries, 2011. Alaska Department of Fish and Game, Fishery Data Series No. 15-15, Anchorage.

DuBois, L. 2015b. Origins of Chinook salmon in the Yukon River fisheries, 2012. Alaska Department of Fish and Game, Fishery Data Series No. 15-16, Anchorage.

DuBois, L. 2016. Origins of Chinook salmon in the Yukon River fisheries, 2013. Alaska Department of Fish and Game, Fishery Data Series No. 16-09, Anchorage.

-continued-

References Cited (Continued)

DuBois, L., and N. A. DeCovich. 2008. Origins of Chinook salmon in the Yukon River fisheries, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-02, Anchorage.

DuBois, L., J. M. Berger, N. A. DeCovich, and W. D. Templin. 2009. Origins of Chinook salmon in the Yukon River fisheries, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 09-13, Anchorage.

Eaton, S. M. 2016. Salmon age and sex composition and mean lengths for the Yukon River Area, 2014. Alaska Department of Fish and Game, Fishery Data Series, No. 16-28, Anchorage.

Jallen, D. M., S. K. S. Decker, and T. Hamazaki. 2017. Subsistence and personal use salmon harvests in the Alaska portion of the Yukon River drainage, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-39, Anchorage.

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.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2018. Yukon River salmon 2017 season summary and 2018 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A18-01, Anchorage.

Leba, H. A., and L. DuBois. 2011. Origins of Chinook salmon in the Yukon River fisheries, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 11-59, Anchorage.

Mears, J. D. 2015. Abundance and run timing of adult Pacific salmon in the East Fork Andreafsky River, Yukon Delta National Wildlife Refuge, Alaska, 2014. Alaska Fisheries Data Series Number 2015-5, U.S. Fish and Wildlife Service.

Pfisterer, C. T., T. Hamazaki, and B. C. McIntosh. 2017. Updated passage estimates for the Pilot Station sonar project, 1995-2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-46, Anchorage.

APPENDIX B: 2017 NORTHEASTERN BERING SEA SURVEY SPECIES DATA

Appendix B1.–Total catch, average length, and average weight of non-salmon species captured in surface trawls during the Northeastern Bering Sea survey, 2017.

Scientific name	Common name	Length range (cm)	Avg. length (cm)	Avg. wt. (kg)	Total catch (n)	Total catch (kg)
Clupea pallasi	Pacific herring	5.2–26.1	15.8	0.0302	100,161	3,026.236
Chrysaora melanaster	Northern sea nettle	6.7–35.3	19.0	0.7004	1,757	1,230.627
Lamna ditropis	Salmon shark	176.0	[a]	[a]	1	150.000
Cyanea capillata	Lions mane	4.8–36.0	21.5	0.8447	145	122.481
Gadus chalcogrammus	Walleye pollock	3.5–69.0	10.3	0.0051	12,990	66.589
Aequorea sp.	N/A	5.7–14.6	11.5	0.2625	179	46.994
Pungitius pungitius	Ninespine stickleback	2.8–6.4	5.2	0.0014	13,011	18.649
Osmerus mordax	Rainbow smelt	8.5–24.4	11.5	0.0100	1,858	18.649
Eleginus gracilis	Saffron cod	5.0–32.3	9.1	0.0063	1,421	8.889
Gadus macrocephalus	Pacific cod	5.2–79.5	8.4	0.1221	30	3.662
Lethenteron camtschaticum	Arctic lamprey	23.5–54.8	37.1	0.0775	34	2.635
Limanda aspera	Yellowfin sole	18.0–35.3	27.0	0.2966	5	1.483
Pleuronectes quadrituberculatus	Alaska plaice	44.1	[a]	[a]	1	1.114
Platichthys stellatus	Starry flounder	26.6–32.6	28.6	0.3233	3	0.970
Mallotus villosus	Capelin	7.1–12.4	10.0	0.0063	130	0.824
Myoxocephalus jaok	Plain sculpin	27.3	[a]	[a]	1	0.240
Enophrys diceraus	Antlered sculpin	11.7–14.8	13.0	0.0515	4	0.206
Boreogadus saida	Arctic cod	14.8–19.7	17.1	0.0263	6	0.158
Blepsias bilobus	Crested sculpin	[b]	[a]	[a]	1	0.150
Ammodytes hexapterus	Pacific sand lance	5.0–17.0	6.7	0.0015	91	0.139
Myoxocephalus scorpius	Shorthorn sculpin	[b]	[a]	[a]	1	0.120
Gasterosteus aculeatus	Threespine stickleback	2.9–4.8	3.8	0.0007	129	0.089
Aurelia labiata	Moon jellyfish	8.3	[a]	[a]	1	0.067
Gonatus kamtschaticus	Shortarm gonate squid	6.4–10.8	8.1	0.0120	4	0.048
Podothecus veternus	Veteran poacher	19.1	[a]	[a]	1	0.029
Trichodon trichodon	Pacific sandfish	4.9–5.6	5.3	0.0023	10	0.023
Lumpenus sagitta	Snake prickleback	25.5	[a]	[a]	1	0.017
Hexagrammos stelleri	Whitespotted greenling	11.5	[a]	[a]	1	0.014
N/A	Unid. Flatfish	3.0–3.4	3.2	0.0010	2	0.002
Reinhardtius hippoglossoides	Greenland halibut	5.1	[a]	[a]	1	0.001

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 35 stations with an average area swept of 0.2094 km^2 per station. Jellyfish lengths are bell width and squid lengths are mantle lengths.

[a] Average not provided as only 1 individual measured.

[b] Individual lengths not measured for this species.

Appendix B2.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northeastern Bering Sea trawl survey, 2017.

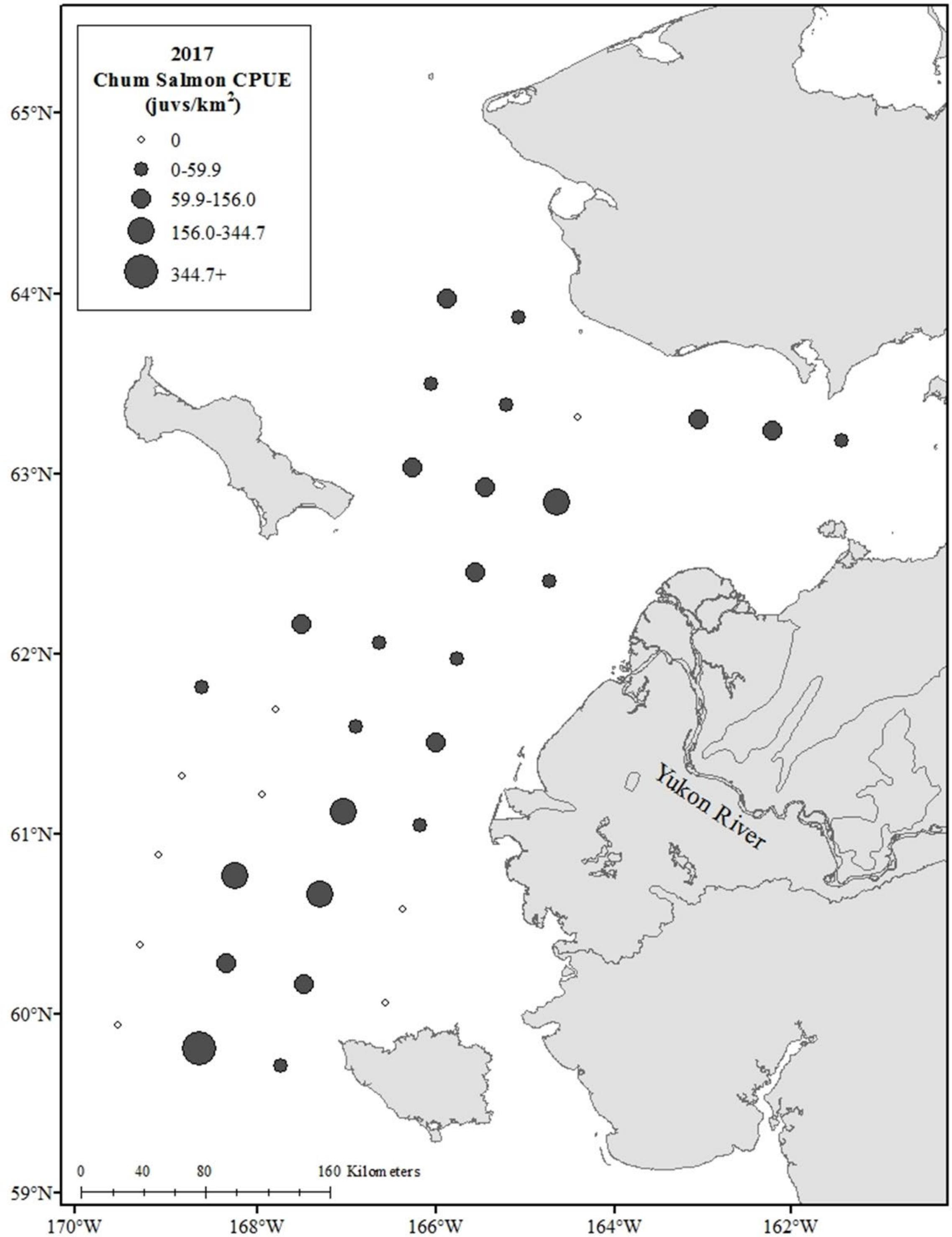
Scientific name	Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (n)	Total catch (kg)
Oncorhynchus gorbuscha	Pink salmon	Juvenile	8.9–21.3	13.6	0.025	5,411	133.978
		Immature/maturing	48.2	[a]	[a]	1	1.000
Oncorhynchus keta	Chum salmon	Juvenile	9.9–21.2	15.8	0.043	638	27.280
		Immature/maturing	46.0–72.5	59.6	1.153	189	217.892
Oncorhynchus kisutch	Coho salmon	Juvenile	19.8–30.7	27	0.254	217	55.119
		Immature/maturing	62.3–65.5	63.9	3.755	2	7.510
Oncorhynchus nerka	Sockeye salmon	Juvenile	9.9–22.8	19.1	0.070	75	5.228
		Immature/maturing	54.7	[a]	[a]	1	2.066
Oncorhynchus tshawytscha	Chinook salmon	Juvenile	9.5–24.3	19.4	0.090	195	17.592
		Immature/Maturing	32.7–65.7	44	1.225	29	35.522

Note: Catches come from 35 stations with an average area swept of 0.2094 km^2 per station.

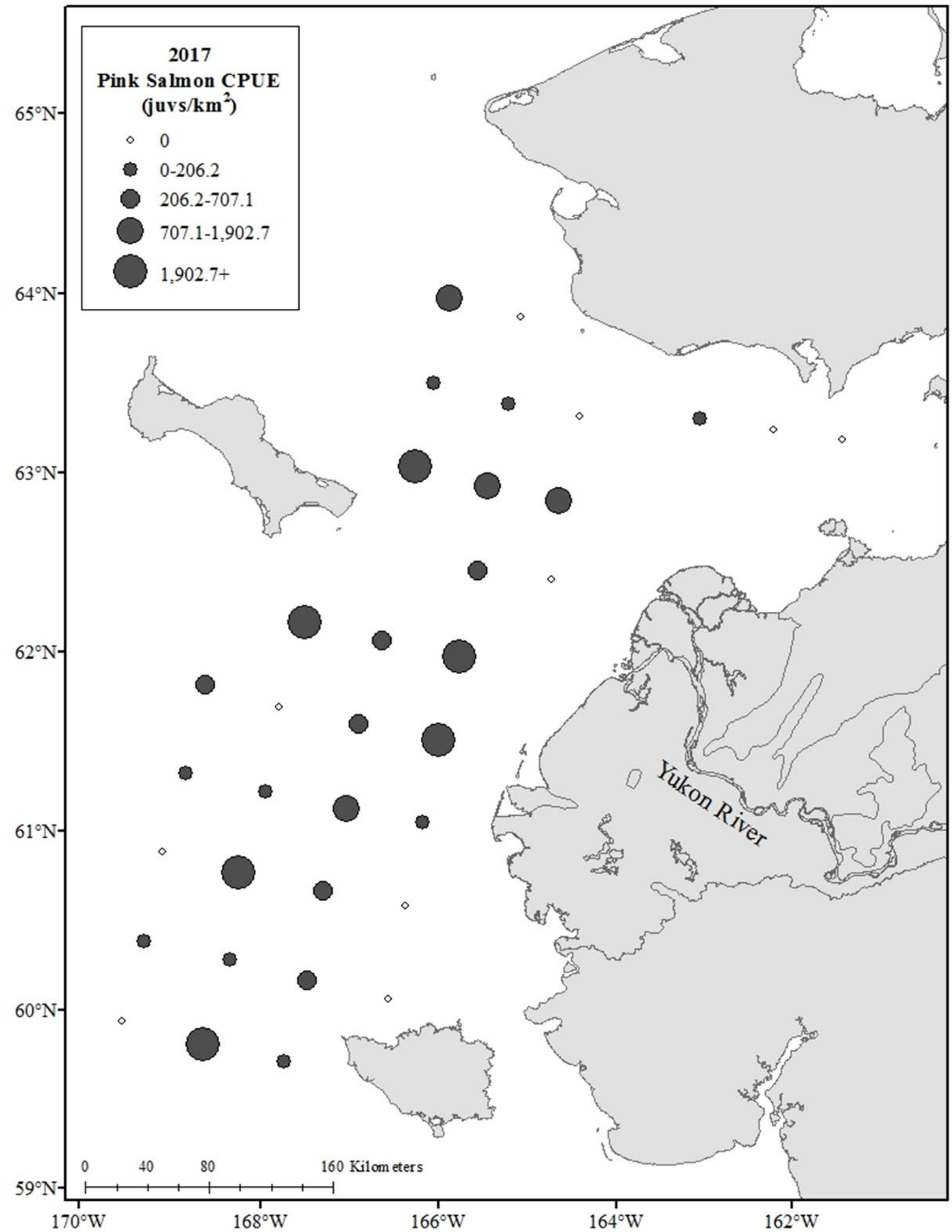
[a] Average not provided as only 1 individual measured.

APPENDIX C: 2017 SURVEY CPUE DISTRIBUTION FOR NON-CHINOOK SALMON

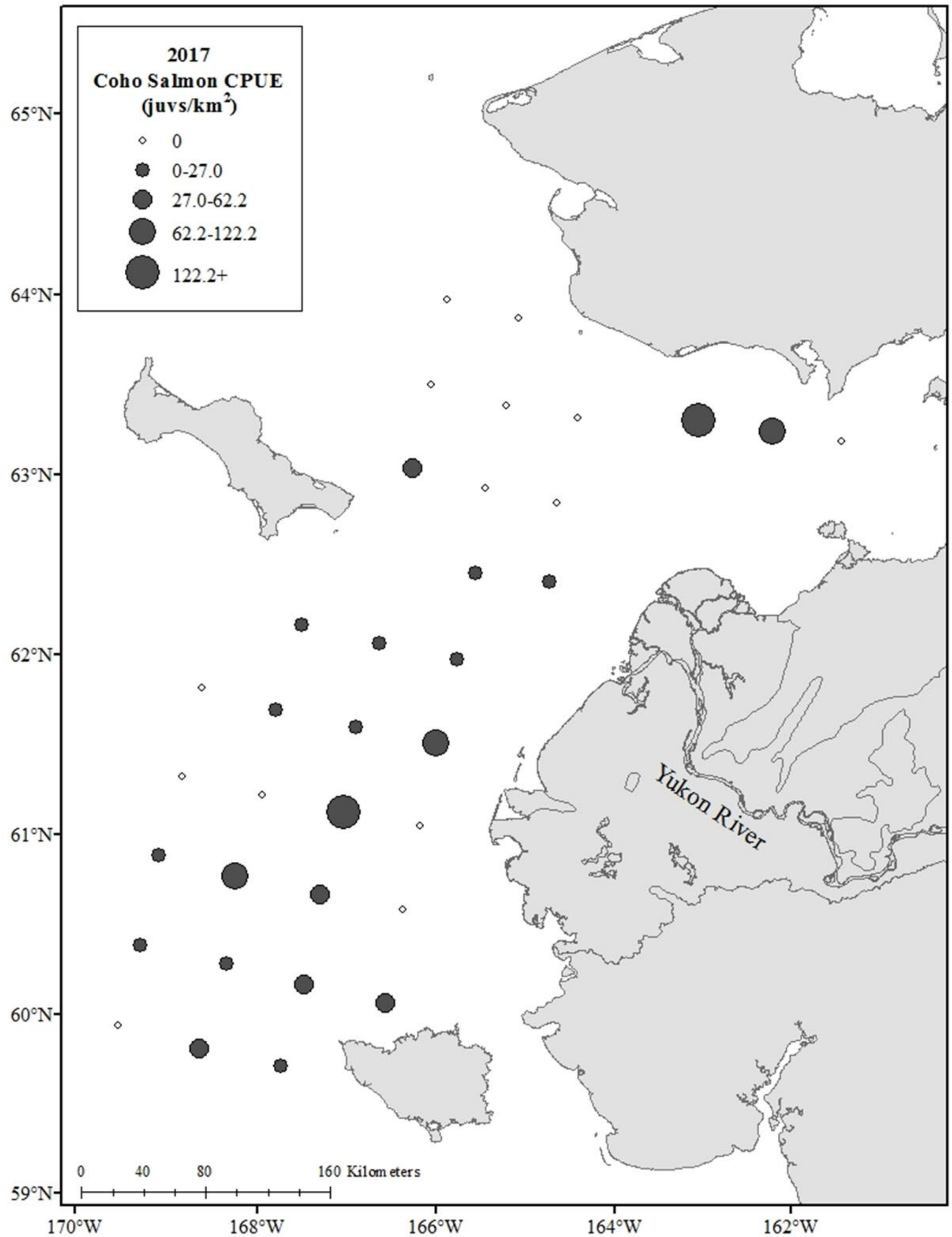
Appendix C1.–Geographic distribution of juvenile chum salmon catch per unit effort (CPUE) in the Northeastern Bering Sea, 2017.



Appendix C2.–Geographic distribution of juvenile pink salmon catch per unit effort (CPUE) in the Northeastern Bering Sea, 2017.



Appendix C3.–Geographic distribution of juvenile coho salmon catch per unit effort (CPUE) in the Northeastern Bering Sea, 2017.



Appendix C4.–Geographic distribution of juvenile sockeye salmon catch per unit effort (CPUE) in the Northeastern Bering Sea, 2017.