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Juvenile Chinook Salmon Abundance Index and Survey Feasibility Assessment in the Northern Bering Sea, 2014–2016

by

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March 2019

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	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Long-term monitoring of juvenile Chinook salmon *Oncorhynchus tshawytscha* is needed to identify recruitment and mortality processes, to understand early marine biology and ecology, and develop tools useful for fisheries management. A sampling program for Yukon River salmon was established in the northern Bering Sea in 2003 but annual sampling has been tenuous due to funding limitations. This project was designed to maintain the sampling program for Yukon River stocks, develop a genetic baseline to identify Yukon River stocks, and evaluate a lower cost survey alternative using a smaller vessel and trawl configuration. Results indicated that the genetic baseline can identify four groups of populations from Western Alaska, the two vessel/trawl configurations provided similar estimates of juvenile Chinook salmon abundance (within 20%); however, sea state limitations of the small vessel required an earlier survey timing (August rather than September). The change in survey timing contributed to differences in the spatial distribution and length of salmon caught during the 2 surveys. Surveys identified above average juvenile Chinook salmon abundance during 2014–2016 and above average juvenile abundance per spawner in 2014 and 2015. Both indicate an improvement to the recent poor production of Yukon River Chinook salmon, because juvenile abundance in the northern Bering Sea is known to be a leading indicator of adult returns for this stock. Sampling 2 different time periods provided additional insight into the early marine growth rates of juvenile Yukon River Chinook and other salmon species. Average Chinook salmon growth rate was 1.55 mm per day from marine entry to August, and 1.06 mm per day from August through September. This project represents a critical step to enable the long-term monitoring of juvenile Chinook salmon in Western Alaska and continued pursuit of factors that determine productivity and cohort strength of Yukon River Chinook salmon.

Key words: Chinook salmon *Oncorhynchus tshawytscha*, marine survey, pelagic trawl, juvenile, abundance, northern Bering Sea, Yukon River, genetic baseline, mixed stock analysis, SNP, reporting groups

INTRODUCTION

Yukon River Chinook salmon *Oncorhynchus tshawytscha* returns have 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 River have occurred throughout recent years (Munro and Volk 2015). Although causes of this production decline are unclear, concurrent declines throughout Alaska (Alaska Department of Fish and Game (ADF&G) 2013) have placed emphasis on ocean conditions and the marine life-history stage of Chinook salmon (Ohlberger et al. 2016).

Mortality during the early marine life history stage is significant, and previous research suggests this life stage is a critical time for defining salmon cohort strength (Hartt 1980; Beamish and Mahnken 2001; Farley 2007a). Marine research has provided unique insight into juvenile marine 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). Research focused at this life stage can illuminate the relative importance of freshwater and marine sources of mortality contributing to recent production declines of Chinook salmon. Condition indicators, such as juvenile size and marine growth rate, have been demonstrated to play some role in mortality processes in the first year of ocean life for Yukon River Chinook salmon (Howard et al. 2016), as well as other Alaska stocks (Moss et al. 2005; Farley 2007b), and has been demonstrated to explain inter-annual variability of adult returns in Columbia River Chinook salmon stocks (Tomaro et al. 2012). Moreover, juvenile abundance of Canadian-origin Yukon River Chinook salmon alone explains a significant 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 in structuring inter-annual variability of adult returns.

The State of Alaska’s Chinook Salmon Research Initiative (CSRI) gap analysis (ADF&G 2013) recognized that Chinook salmon research should include the entire migratory domain of the fish in order to better serve fishery management needs and fill data gaps. Foundational data gaps were identified for the Yukon River indicator stock: abundance and growth rate information of juvenile salmon, interrelationships of the juvenile life stage to adult returns, and insight into how productivity changes may occur at the juvenile life stage and in the nearshore marine environment. An ongoing nearshore survey in the northeastern Bering Sea (NBS) has been collecting data about juvenile Yukon River Chinook salmon, helping to address the foundational gaps identified by CSRI.

The NBS is the primary rearing habitat of Norton Sound and Yukon-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 (NOAA–AFSC) in 2002 as part of the Bering Aleutian Salmon International Survey (BASIS). Surveys continued through 2007 and again 2009–2013 under various funding sources. NBS surveys have collected biological and oceanographic data using a systematic spatial sampling design, surveyed using large vessels (39–51 m length) towing a Cantrawl[1] 400/601 rope trawl (made by Cantrawl Pacific Ltd., Richmond, BC) 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 (Farley et al. 2007b; Murphy et al. 2013). These surveys occurred primarily in September, assessing juvenile salmon after they experience a critical transition from freshwater to marine environments (Farley et al. 2007a).

NBS surveys have provided important new information about Yukon River Chinook salmon and continuation of this work will provide further insights. Documenting size selective mortality of juvenile Yukon River Chinook salmon (Howard et al. 2016), comparing juvenile salmon distribution to oceanographic characteristics (Gann et al. 2013), and salmon nutritional ecology (Farley et al. 2004; Auburn and Studevant 2013) are valuable products from these surveys. More importantly, juvenile abundance estimates have been incorporated into a run forecast model for Yukon River Chinook salmon (Murphy et al. 2017), 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.

Unfortunately, continuation of the NBS survey on a long-term, annual basis to support forecasts and continued understanding of this critical life stage is challenging because of the cost of operating larger vessels needed to fish the large Cantrawl 400 trawl net. The present study simultaneously continued this juvenile Chinook salmon dataset (2014–2016) while also assessing the feasibility of using a smaller net (Nordic 264 Rope Trawl made by NET Systems Seattle, WA) that allows a smaller and more economical vessel to be employed.

OBJECTIVES

1. To determine the feasibility of the smaller vessel/trawl research platform to conduct the NBS pelagic trawl survey and assess juvenile Chinook salmon, based on the following criteria:
    a. Survey can be completed in approximately 30 days, including days when weather prohibits fishing activity,

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

b. Similar geographic coverage can be surveyed,
c. Adequate sample size of juvenile Chinook salmon catch can be obtained for genetic stock composition analyses with 90% credibility intervals, and
d. Juvenile Yukon Chinook salmon abundance can be estimated using the same analytical methods employed for the 2003–2007, 2009–2013 estimates, without significantly decreasing precision (historical estimate CV: 14–38%).

2. To develop a genetic baseline for use in mixed stock analysis of catch samples of Chinook salmon from the eastern Bering Sea that attains accuracy of ≥90% in 100% proof tests with root mean square error ≤5% for reporting groups of management interest;
3. To develop juvenile Chinook salmon fishing power calibrations among large and small trawl catch per unit area (CPUA), such that fishing power correction terms are significant at $\rho < 0.10$;
4. To incorporate abundance estimates into established adult run size forecast models; and
5. To characterize the marine ecology of juvenile Chinook salmon in the nearshore marine environment, including species composition, juvenile salmon size and growth information.

METHODS

General Survey Design

Sampling occurred in late summer throughout the traditional geographic sampling area of the northeastern Bering Sea survey (Figure 1). Two survey platforms were deployed each year from 2014 to 2016: a large vessel/trawl platform and a small vessel/trawl platform. Based on fishing dimensions of both trawl nets, stations were primarily restricted to 20 m water depth or deeper, although some shallower stations were attempted with appropriate onboard net modification (Table 1).

The large vessel/trawl platform operated similar to previous years, using a Cantrawl 400/601 rope trawl (made by Cantrawl Pacific Ltd., Richmond, BC; Table 1) and a large chartered fishing vessel, F/V *Alaska Endeavor* (39 m length) in 2014 and 2015 and the F/V *Cape Flattery* (57 m length) in 2016. Sample dates for the large vessel/trawl surveys were centered in September, consistent with previous years. The large vessel/trawl sample grid was spaced approximately at 30 nautical mile intervals (half decimal degrees latitude and longitude, Figure 2).

The small vessel/trawl survey employed ADF&G's R/V *Pandalus* (19 m length) each year, towing the smaller Nordic 264 Rope Trawl (NET Systems Seattle, WA; Table 1). Small vessel/trawl survey sample dates were centered in August to avoid frequent stormy weather that tends to occur in the northeastern Bering Sea in September and later. The small vessel/trawl survey was selected to sample a denser survey grid with 20 nautical miles between stations because the trawl sweep area was smaller (Figure 3). In 2014, the sampling grid included more western stations (open circles, Figure 3), but these were not included as core stations in subsequent years due to a lack of juvenile salmon catches. In 2015 and 2016, non-core stations were only sampled if 5 or more juvenile Chinook salmon were caught in 1 of the perimeter core stations. Non-core stations would continue to be sampled until less than 5 juvenile Chinook salmon per tow were caught. The choice of sampling core stations with the option of adding non-core stations was selected to prioritize survey time and effort on primary juvenile Chinook salmon rearing habitats (informed by previous years' catch locations), while ensuring the population was adequately sampled if a more offshore distribution was ever encountered.

STATION SAMPLING

Station sampling protocol was consistent between survey platforms. Each day consisted of sampling 4 stations and 1 surface trawl tow per station. Primary survey operations were conducted during daylight hours. Standard activities at each station included:

1. CTD cast with Niskin water sample collection (water sample on large vessel only),
2. An oblique zooplankton net tow with bongo array (large vessel only), and
3. Surface trawl.

Standard surface trawl duration was 30 minutes. Nets for both vessel platforms were trawled using headropes at the surface. Net mensuration was conducted in a variety of ways, depending upon the equipment available for the particular vessel. SeaBird SBE39 temperature and depth recorders were added to the F/V *Alaska Endeavor* and F/V *Cape Flattery* to estimate headrope and footrope depth. Average horizontal spread of the trawl from previous years, which had been measured with a third wire net sounder, was used to estimate horizontal opening. Net mensuration was monitored on the *R/V Pandalus* with Star Oddi Conductivity, Temperature and Depth (CTD) sensors on the headrope and footrope of the trawl for vertical opening measurements, and horizontal opening measurements were calculated through geometric extrapolation of warp angle. 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).

CATCH SAMPLING

As the net was retrieved onboard, fish were shaken down to the codend of the net by vessel crew. The contents of the trawl were emptied onto a sorting table or into a large tote. The catch was sorted by species and the 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 *O. kisutch* salmon, and from a subsample of juvenile sockeye *O. nerka*, pink *O. gorbuscha*, and chum *O. keta* salmon in years when samples were requested by other researchers. Additionally, immature salmon axillary processes were collected for 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 aboard the small vessel were collected and preserved for stomach content, stable isotope, and energetic analysis in support of graduate student research. Up to 10 whole juvenile Chinook salmon from each station aboard both vessels were collected and provided to AFSC for otolith extraction and other analyses.

PAIRED TRAWL CATCHES

Paired vessel tows were attempted to allow direct comparisons between trawl catches and to estimate differences in fishing power (Murphy et al. 2003; Wertheimer et al. 2008). Fishing power is a measure of the efficiency at which a particular vessel-gear combination captures fish. Due to the difficulty in defining absolute fishing power, fishing power was defined by reference to a standard vessel-gear combination (the large vessel/trawl) through comparative trawling experiments where vessels fish at the same time and place.

In August, during the small vessel/trawl survey, locations of high juvenile Chinook salmon concentrations were identified. Side-by-side paired trawling was scheduled to occur at the end of the small vessel/trawl survey and beginning of the large vessel/trawl survey in this high concentration area to compare trawl catches for the development of trawl calibration. A minimum of 10 paired trawl tows were targeted to be completed. For each paired trawl, the 2 vessels fished a parallel track in the same direction, at the same time. The trawl track of the vessels was offset by approximately 200–250 m, which was close proximity for safely towing both trawl nets side-by-side. A primary assumption of this calibration was that because both nets were fishing in close proximity and at the same time, the same density of juvenile Chinook salmon was available for capture. Trawl duration for paired trawl events was standardized to 30 minutes for both vessels.

DATA ANALYSIS

Abundance Estimates

Juvenile Chinook salmon abundance was estimated for each gear and vessel combination similar to methods from previous survey years, though with slight modifications to better standardize estimates across years (Murphy et al. 2017). Catch was estimated as the total abundance at a given sampling station. Juvenile salmon were assumed to be uniformly distributed throughout the mixed water layer (depth of upper portion of water column of uniform density), and a correction based on the proportion of the mixed layer sampled with the trawl gear was applied for each station. The mixed layer 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 mixed layer 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 mixed layer from adjacent stations was used. The mixed layer depth correction (θ) was calculated as the ratio of mixed layer depth to trawl depth (trawl footrope depth) when trawl depth was shallower than mixed layer depth, or equal to 1 when trawl depth was deeper than the mixed layer.

Catch per unit area (CPUA, #/km^2) was calculated for the station (i), where C is the θ-adjusted observed catch (#), and a is the area swept (km^2) during the station:

$$CPUA_i = \frac{C_i}{a_i}. \tag{1}$$

Area swept (km^2) was estimated by multiplying the horizontal spread of the trawl by the distance trawled. For tows where net mensuration equipment was not capable of estimating horizontal spread, an average horizontal spread was used.

CPUA estimates were expanded to the survey area in spatial strata. Four distinct NBS ecoregions were defined as strata for this analysis because they are recognized as mesoscale oceanographic/ecological units and may consequently offer different summer rearing conditions for juvenile salmon. The 4 strata used for analysis were: 1) 60°N to 62°N, 2) 62°N to 64°N, 3) Norton Sound, and 4) the Bering Strait (Murphy et al. 2017; Figures 2 and 3).

Mean density for a stratum (j) was calculated as:

$$\overline{CPUA_j} = \frac{\sum_{i=1}^{n_j} CPUA_{ij}}{n_j}, \tag{2}$$

where n_j is the number of stations in stratum (j).

Abundance per stratum B_j, where A_j is the area (km^2) of the stratum (j) was estimated as:

$$B_j = \overline{CPUA_j} \times A_j \,. \tag{3}$$

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_j). For the Norton Sound stratum, a fixed sample grid area (A) of 5,461 km^2 was used for all years, because previous work indicated that juvenile salmon rearing habitat only includes those waters deeper than 18 m.

The total juvenile abundance estimate for the survey area (B) was the sum of the abundance per stratum (B_j) over all strata in the survey (n_s):

$$B = \sum_{j}^{n_s} B_j \,. \tag{4}$$

For years when no stations were sampled in a given stratum, the average historical proportional contribution of that stratum to the overall abundance estimate was substituted for that stratum to derive the total abundance estimate (B). Variance and coefficients of variation for the total juvenile abundance estimate were estimated from a bootstrap resample distribution (10,000 bootstrap samples).

Genetic Stock Composition

Baseline Development

A baseline representing populations potentially caught in the juvenile trawl survey was developed following the methods of Shedd et al. (2016) to identify contributions of reporting groups (e.g., stocks) of interest in catch samples. Samples of Chinook salmon collected from the spawning grounds of 111 locations between 1987 and 2013 (Table 2; Figure 4) were genotyped for 84 single nucleotide polymorphisms (SNPs; Table 3) following Taqman chemistry described in Shedd et al. (2016). Some of these SNPs were developed specifically to differentiate among western Alaska populations of Chinook salmon (Larson et al. 2014). Collections from the same spawning location sampled in multiple years were tested for homogeneity of allele frequencies and pooled when frequencies did not differ. All pooled and remaining collections were considered populations in subsequent analyses.

Statistical Analysis

Common population genetic assumptions made during mixed stock analysis were validated prior to baseline evaluation and use. Conformance to Hardy-Weinberg expectations and linkage disequilibrium were tested in Genepop v4.5 (Rousset 2008) using default parameter settings. Loci that departed from Hardy-Weinberg expectations were removed from subsequent analyses. Such loci were identified as those with an overall (Fisher's summary) *p*-value < 0.05; the decision to remove loci was based upon the number of populations not conforming to Hardy-Weinberg expectations and the distribution of F_{IS} values. We defined linked pairs of loci as those exhibiting linkage disequilibrium (*p*-value < 0.05) in half or more of populations and removed the locus with the lesser overall F_{ST}. Population genetic structure was calculated using Nei's distance (Nei 1972) and visualized with a Neighbor-Joining tree. Populations were assigned to reporting groups based upon population genetic structure, geography, and stakeholder interest prior to subsequent tests of reporting group identifiability.

Two types of tests were used to assess the identifiability of reporting groups in mixtures: "100% proof" tests in which 200 individuals from a single reporting group were sampled without replacement and analyzed against the reduced baseline; and "Flat proof" tests in which each reporting group had 50 individuals sampled without replacement and analyzed against the reduced baseline. The "100% proof test" was replicated 5 times for each of the 4 reporting group and the "flat proof" test was replicated 5 times with each reporting group contributing 25% to the total. Stock compositions of the baseline evaluation tests were estimated with the program *BAYES* (Pella and Masuda 2001) following the protocols of Shedd et al. (2016). Mean bias, root mean square error (RMSE), and mean 90% credibility interval were summarized among replicates to evaluate the accuracy and precision of the baseline to identify reporting groups.

Stock composition of catch samples

For those samples that met minimum sample size requirements (100+), stock composition was estimated by comparing genotypes of catch samples with reference baseline allele frequencies using the Bayesian statistical approach implemented in the software package *BAYES* with a flat prior. Contributions of juvenile Chinook salmon from 4 reporting groups was 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. Stock composition results were applied to overall juvenile Chinook salmon biomass estimates to develop stock-specific biomass estimates for those stock groups with adequate genetic resolution.

In addition to the juvenile Chinook salmon samples from NBS surveys, tissue samples were also collected and analyzed for mixed stock analysis from Chinook salmon smolt emigrating from the Yukon River Delta during 2014–2016[2] (Howard et al. 2017; Miller et al. 2016). The stock composition of emigrating smolt was estimated using the same protocol, but with a reduced baseline that only included Yukon River populations. Contributions from the 3 intra-Yukon River groups (Lower Yukon, Middle Yukon, Canadian Yukon) were estimated. Comparisons

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[2] 2016 project data on file with Katharine Miller, Fishery Biologist, NOAA, Auke Bay Laboratory, Juneau.

were made between stock proportions of Yukon River smolt and August and September juvenile samples to explore stock-specific differences between samples.

Stock-specific Juvenile Chinook Salmon Abundance And Adult Run Size Forecasts

For 2014–2016 large vessel/trawl surveys only, the proportion of Canadian-origin Chinook salmon was applied to the total juvenile abundance estimate to calculate juvenile Canadian-origin Chinook salmon abundance in the NBS using methods similar to Murphy et al. (2017). Variance estimates of Canadian-origin juvenile abundance were 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:

$$V(XY) = \mu_Y^2\sigma_X^2 + \mu_X^2\sigma_Y^2 + 2\mu_X\mu_Y\rho\sigma_X\sigma_Y, \quad (5)$$

where μ_X and σ_X are the mean and standard deviation of juvenile abundance within each year, respectively, μ_Y and σ_Y are the mean and standard deviation of the Canadian-origin stock proportion, and ρ, is the correlation between juvenile abundance and stock proportion.

Forecasts of Canadian-origin adult run size based on Canadian-origin juvenile Chinook salmon abundance data from the large vessel/trawl survey were developed using established methodology (Murphy et al. 2017). Briefly, relationships between juvenile abundance and adult returns (marine survival post-survey), and age-structured maturity schedules were used to predict adult run size in future years. Forecasts were provided preseason to fisheries managers and stakeholders annually (JTC 2017). Juvenile abundance estimates and forecasted adult run abundance based on 2014–2016 data were evaluated in the context of historical patterns.

Juvenile Salmon Size and Growth

Analyses of salmon size and growth followed 2 goals: (1) investigate size and growth patterns among sample periods for salmon species, and (2) compare size distributions of juvenile salmon between survey platforms to assess differences in gear selectivity. This study coincided with a project that assessed emigrating salmon smolt in the Yukon River Delta during 2014–2016 (Howard et al. 2017; Miller et al. 2016), which allowed comparison of juvenile salmon during 3 time periods in their early marine life: at marine entry (May–July), in August (small vessel/trawl survey) and in September (large vessel/trawl survey). This presented an unprecedented opportunity to explore size patterns across this critical time in salmon life. Mean lengths were calculated for each survey period in each year and mean date of capture was calculated for each time period to estimate average growth per day (in mm) between periods. Because sockeye salmon are uncommon in the Yukon River, analyses of salmon length differences were constrained to Chinook, chum, coho, and pink salmon. Sample sizes greater than 80 fish lengths were expected to provide 95% confidence intervals of mean length with margins of error of 3 mm (marine entry), 6 mm (August), and 7 mm (September). To assess potential gear selectivity among marine survey platforms (second goal), length distributions of each species were compared between the 2 platforms. Lengths were standardized to a common capture date using early marine growth estimates (mm/day from August to September). Kolmogrov-Smirnov tests were performed to evaluate differences in overall length distributions.

RESULTS AND DISCUSSION

SMALL VESSEL/SMALL TRAWL FEASIBILITY

Scope and Logistical Constraints

Pelagic trawl gear was novel to the small vessel (R/V *Pandalus*) and the crew operating it in 2014. The small vessel crew had to learn how to operate the gear effectively over the course of the first year of survey. Fishing inefficiencies during the first year of the survey were evident in the deeper vertical opening and smaller horizontal opening, which indicated a slack net, compared to 2015 and 2016 surveys (Table 4). As such, 2014 data should not be considered representative of small vessel/trawl platform capabilities. Dramatically smaller juvenile Chinook salmon catches in 2014 compared to later survey years using the small vessel/trawl platform are probably representative of poorer fishing efficiency rather than changes in population abundance. Additionally, the R/V *Pandalus* received new engines prior to the 2016 survey, which enabled more power, faster tow speeds, and greater distance towed during the standardized tow time (Table 4). Results from 2015 and 2016 survey years were the most representative of small vessel/trawl platform capabilities (Appendices A1–A3).

It was anticipated that seasonal storms, which tend to become more frequent in the northeastern Bering Sea in the fall, would limit the small vessel/trawl operations if operated later in the summer. To accommodate this, the small vessel/trawl survey operated earlier (August) compared to the traditional timing of the large vessel/trawl survey (September). It was found that seas greater than 5 feet made trawling with the smaller vessel ineffective and unsafe, so sampling did not occur in larger seas. By comparison, the large vessel/trawl platform's fishing ability was only precluded in seas greater than 10 feet. Even with earlier survey timing, storm events in the latter half of August prohibited finishing the small vessel/trawl core stations in 2015, and 6 stations were not assessed. All core stations were assessed by the small vessel/trawl platform in 2014 and 2016.

The F/V *Alaskan Endeavour* was used to the complete the 2014 and 2015 large trawl surveys and the F/V *Cape Flattery* was contracted for trawl operations in 2016 (Appendices A4–A6). In 2014, 49 surface trawls, including 4 paired trawls with the smaller vessel, were performed at predetermined sampling stations. In 2014, additional non-core stations were sampled aboard the large vessel/trawl survey to the west of core stations because large abundance of juvenile Chinook salmon were encountered at the edge of the core station grid. Weather and logistical issues hampered the large vessel/trawl platform in 2015, and 37 of 43 stations were sampled that year. Logistical problems in 2016 left only 7 stations, mostly in Norton Sound, un-sampled. From 2014 to 2016, a net mensuration device was not available during trawl operations. Based on net fishing performance, both the 2014 and 2015 large trawl surveys were assumed to have a horizontal spread of 53 m at all stations. During 2016 trawl operations, the vertical opening of the trawl, measured by SBE39 CTD loggers attached to the footrope of the trawl, was higher than previous years; therefore, a smaller horizontal opening of 48 m was assumed for stations sampled in 2016.

Geographic Coverage

Because survey grids between large and small vessel/trawl surveys were somewhat different, juvenile salmon distribution was assessed in a common area sampled by both platforms. Across years, juvenile Chinook salmon distribution was weighted towards more nearshore stations framing the Yukon River Delta in August during small platform operations and shifted to more southerly, offshore stations in September on the large vessel platform (Figure 5). Attempts to sample beyond the common area in August resulted in few Chinook salmon, but stations sampled beyond the common area in September had higher CPUAs of juvenile Chinook salmon (Figure 5). Juvenile coho salmon showed similar distribution patterns to juvenile Chinook salmon, though more pronounced in the northerly and nearshore catches in August and more southerly and offshore catches in September (Figure 6). Chum and pink salmon were fairly ubiquitous throughout the sampling grids in both August and September sampling and both were abundant in the offshore samples conducted by the large vessel/trawl survey (Figures 7 and 8). These species may distribute more quickly upon marine entry early in the summer compared to Chinook and coho salmon. Finally, sockeye salmon are generally not abundant in the northern Bering Sea. In the common area, during both time periods, sockeye salmon were encountered in the northernmost stations, closest to known spawning stocks in Norton Sound and Port Clarence (Figure 9). Additional sampling beyond the common area in September revealed sockeye salmon in larger abundance in offshore and more southerly stations: it is likely these may originate from the Kuskokwim River, which has much larger sockeye salmon populations.

Juvenile salmon distribution patterns have been averaged across 2014–2016 to accommodate annual variations in stations sampled. It should be noted that 2014 small vessel/trawl distribution may not be representative because of aforementioned fishing difficulties, and that 2015 small vessel/trawl distribution was not fully captured because not all common area stations were sampled. Large vessel/trawl distribution was also not fully captured in 2015 and 2016, most notably the absence of any stations sampled in Norton Sound in 2016.

Juvenile Chinook Salmon Abundance

Mean juvenile Chinook salmon abundance estimated from small vessel/trawl catches was 20% lower than the large vessel/large trawl platform in 2015 and 11% larger than the large vessel /large trawl platform in 2016 (Table 6). A juvenile abundance estimate for the small vessel/trawl platform was not provided in 2014 because it was the first year fishing a pelagic surface trawl on that platform. An obvious bias among survey platforms was not evident and, given that only 2 years are available for comparison and some notable differences occurred for the survey performance of both vessels between years, development of a correction factor for the small vessel/trawl platform was not possible. For example, new engines installed prior to the 2016 survey season on the small vessel increased towing power and speed in 2016, and could be partly responsible for that year's estimate being closer to the large vessel/trawl platform estimate. Additionally the scientific lead aboard the large vessel in 2016 noted some trawling difficulties in the early part of that year's survey.

The coefficient of variation (CV) for juvenile Chinook salmon abundance was highest for the small vessel platform in 2015 and highest for the large vessel platform in 2016 (Table 6). Both platforms yielded CVs similar to those from previous years using the large vessel/trawl (2003–2013; 14–38%, mean 24%), though the 2015 small vessel survey had a high CV of 38%. The 2016 large vessel platform had an above average CV due to missed stations and an inability to accurately measure trawl net dimensions that year. Key factors in obtaining juvenile Chinook salmon abundance estimates with adequate precision include completing target survey stations and appropriate net mensuration during tows, regardless of survey platform.

GENETIC STOCK COMPOSITION

Genetic Baseline Development

A total of 6,327 individuals from 60 populations were included in the final baseline after pooling collections from the same location across multiple years. One locus (Ots_IsoT) exhibited substantial departures from Hardy-Weinberg expectations (4 populations with p-value < 0.01; F_{IS} range = -0.2–0.5, mean = 0.08; Table 3) and was removed from subsequent analyses. Three pairs of loci exhibited linkage disequilibrium (p-value < 0.05) in 33 (Ots_RAD11821 and Ots_RAD3703), 52 (Ots_HSP90B-100 and Ots_HSP90B-385), and 60 (Ots_RAD8200-45 and Ots_RAD9480-51) of the 60 populations. The locus with the lower overall F_{ST} value from each pair was removed from further analyses (Table 3). Observed heterozygosity of the final set of 80 loci averaged 0.33; overall F_{ST} was 0.09.

The Neighbor-Joining tree of pairwise Nei's distance indicated that Chinook salmon from Canadian Yukon populations were the most divergent group of populations (Figure 10). Structure through the remaining lower reaches of the river exhibited an isolation by distance pattern with populations from the Middle Yukon River intermediate to Lower Yukon populations. Other Western Alaska populations exhibited shallow genetic structure and less genetic differentiation from Lower Yukon populations than from populations further upriver.

Proof test results suggest the 4 reporting groups (Canadian Yukon, Middle Yukon, Lower Yukon and Other Western Alaska) are identifiable in mixed stock analysis but that some misallocation between Lower Yukon and Other Western Alaska is possible. Correct allocations for 100% proof tests averaged 98% and RMSE over all groups averaged 1.2 (Table 7; Figure 11). Nineteen of the 20 100% proof tests (5 replicates for each of 4 reporting groups) had correct allocations greater than 90% (Appendices B1–B5). The flat proof tests indicated some directional bias from Lower Yukon to Other Western Alaska (overall bias to Other Western Alaska = 4.7%; Table 7) but the 90% credibility intervals for the 2 groups contained the true values in 4 of 5 replicates (Appendices B1–B5). Canada and Middle Yukon were highly identifiable in the flat proof tests (RMSE $\leq$ 1.8). As a result, we are confident in proportions estimated for Canadian Yukon, Middle Yukon, and the combined Lower Yukon/non-Yukon reporting groups, but expect overestimates of non-Yukon and underestimates of Lower Yukon reporting group proportions.

Stock Composition of Marine Survey Samples

Minimum sample sizes of 100 juvenile Chinook salmon to conduct genetic mixed stock composition analysis were satisfied in all years by both surveys, except for the small vessel/trawl survey in 2014 (Table 5). As previously noted, the 2014 small vessel/trawl survey was not considered adequate for comparisons because the vessel crew was learning to work with the gear and the vessel was under-powered for trawl operations that year. Sample sizes by the large vessel/trawl platform met preferred sample sizes (190+) in each year: the small vessel/trawl platform would have needed to attain 57% and 36% more juvenile Chinook salmon in 2015 and 2016, respectively, to achieve preferred sample sizes. Additional samples could be obtained by increasing fishing effort (adding stations and/or increasing trawl duration), though this additional effort would probably require increased investment of survey days. It is likely that the small vessel/trawl platform would not achieve adequate sample sizes in years of low juvenile Chinook salmon abundance.

Stock composition from both marine survey platforms was generally within the ranges measured aboard the large vessel/trawl platform from 2003 to 2013: Canadian Yukon ranged 40–54%, Middle Yukon ranged 16–37%, Lower Yukon ranged 9–26%, and non-Yukon reporting groups ranged 4–19% (Murphy et al. 2017; Table 8). Notable differences from historical estimates occurred in the 2015 small vessel/trawl platform with slightly larger Lower Yukon and non-Yukon contributions and slightly smaller Middle and Canadian Yukon contributions, as well as in both vessel platforms in 2016 where a larger non-Yukon component and a smaller Middle Yukon component was observed. The stock composition of Canadian-origin juvenile Chinook salmon, the most abundant stock group, was similar among survey platforms within a given year and 90% credible intervals overlapped reporting groups each year (Table 8; Figure 12). However, mean proportions of Canadian and Middle Yukon reporting groups tended to be smaller for the small vessel/trawl platform and the Lower Yukon reporting group tended to be larger (Figure 12). Sample sizes of juvenile Chinook salmon from the small vessel/trawl survey were insufficient for mixed stock analysis in 2014.

Small differences between marine survey platforms may be, at least partially, a result of all tissue samples collected being included in the mixed stock analysis, not just those samples from the common area of geographic overlap. Small differences could also result from survey timing influencing the stock composition of catch due to stock-specific migration patterns. Data from the Yukon River Delta in 2014 and 2015 indicated that although most smolt enter marine waters by mid-June, those later emigrating fish are primarily of Canadian (Upper Yukon) origin (Figure 13). It is possible that the August survey with the small vessel/trawl survey did not fully sample some of the later emigrating smolts, which may be in shallow waters and inaccessible to the trawl at that time. This would lead to August samples having slightly lower Middle Yukon and Canadian Yukon stock compositions compared to September samples.

Even small differences in mean stock composition estimates among sampling events may influence stock-specific abundance estimates and subsequent inferences on stock-specific mortality rates. However, small stock composition differences may indicate sampling was not representative of the population or may indicate misallocations in genetic estimates, particularly for the more genetically similar Lower Yukon and non-Yukon stocks. Although proof tests suggest some small degree of bias between Lower Yukon and Other Western Alaska populations, the magnitude of this genetic error relative to sampling error is probably small.

Temporal Patterns of Relative Stock Contributions

Although outside the scope of the current study, stock composition from 2014 to 2016 Yukon River Chinook salmon smolt entering marine waters[3] (Howard et al. 2017) provided an interesting comparison to those from the NBS (Table 8; Figure 12). Mean estimates from the May–July Yukon River Delta samples ranged 6–23% Lower Yukon, 20–33% Middle Yukon, and 49–61% Canadian Yukon during 2014–2016 (Table 8). For comparison to marine samples, the relative contributions of the Lower, Middle and Canadian Yukon stock groups to the total Yukon stock group must be considered as the absolute stock compositions of marine samples include non-Yukon stocks. From August small vessel/trawl surveys, relative percent contributions of mean stock compositions to the total Yukon River group ranged 20–30% Lower Yukon, 20–22% Middle Yukon, and 47–57% Canadian Yukon (Table 9). Of the Yukon River

[3] 2016 data on file with Katharine Miller, Fishery Biologist, NOAA, Auke Bay Laboratory, Juneau.

components from September large vessel/trawl surveys, relative percent contributions of mean stock proportions to the total Yukon River group ranged 9–14% Lower Yukon, 25–38% Middle Yukon, and 51–64% Canadian Yukon (Table 9).

Overall, we found no evidence to suggest substantial stock-specific mortality based on differences in relative stock contributions among sample periods. Moreover, though there are limited data about relative strength of Lower, Middle, and Canadian Yukon stock groups in annual run abundance, inference from a mark–recapture study in 2002–2004 revealed that 10–14% of tagged fish were of spawning origin consistent with the Lower Yukon genetic stock reporting group, 32–37% were of Middle Yukon origin, and 49–58% were of Canadian Yukon origin (Eiler et al. 2004, 2006a, 2006b; Table 9). Within this tagging study, some portion of the Lower Yukon group spawned below the tagging site and therefore the proportion of Lower Yukon contribution was probably biased slightly low and the Middle and Canadian Yukon contributions were biased slightly high. Considering this, it appears that the relative proportions of these 3 Yukon spawning groups are consistent with the relative proportions seen in early marine sampling, suggesting that large differences in stock-specific early life productivity were not evident.

STOCK-SPECIFIC ABUNDANCE AND ADULT RUN FORECASTING

Canadian-origin Yukon River juvenile abundance estimates from 2014 to 2016 were above the average estimated in the Bering Sea since 2003 (1,466,000 juveniles, Figure 14). However, the CV calculated for the 2016 Canadian-origin juvenile abundance was 34%, which was among the highest CVs calculated in the 14 year dataset. The ratio of juveniles per spawner can provide a leading indicator of productivity for Canadian-origin Yukon Chinook salmon: above-average estimates of juveniles per spawner were observed in 2014 and 2015, and average estimated juveniles per spawner were observed in 2016 (Figure 15). Canadian-origin juvenile abundance estimates from 2014 to 2016 were incorporated into the adult forecasting tool to produce run size estimates up to 3 years into the future (Figure 16). Based on juvenile catches seen in the NBS, Canadian-origin adult runs in 2017–2019 were expected to range between 93,000–133,000, 80,000–118,000 and 82,000–122,000, for each year, respectively. Forecasted run sizes have the potential to meet escapement objectives and provide subsistence harvest opportunity. These data were provided to Yukon area stakeholders and managers to assist with decision-making. Large vessel/trawl abundance and forecasts were first published in Murphy et al. (2017), and further details about historical juvenile abundance patterns are available in that document.

FISHING POWER CALIBRATION

Paired Trawl Events

Paired trawl events were only possible in 2014. Storm conditions in 2015 and delayed start of the large vessel/trawl survey in 2015 and 2016 due to logistical issues prevented paired trawling from occurring in subsequent years. The target number of paired trawl events was not achieved and only 6 paired tows were attained. Additionally, these 6 paired tows occurred in the inaugural year of the small vessel/trawl platform and significant modifications were made to that platform in subsequent years: new engines enabled greater towing power and speed, and growing familiarity of the vessel crew with the trawl gear enabled more efficient and successful trawling compared to the first season. As such, results of paired trawl events may not be representative of actual capabilities with the small vessel/trawl platform.

Catches of juvenile Chinook salmon ranged 0–4 on the small vessel/trawl platform and 9–30 on the large vessel/trawl platform (Table 10). Among the 6 tow events, small vessel/trawl juvenile Chinook salmon CPUA ranged 0–63% of the CPUA observed in the large vessel/large trawl tows (Figure 17). More paired trawl events with current crew expertise and vessel capabilities would be needed to fully develop fishing power calibrations.

OTHER ECOLOGICAL CONSIDERATIONS

Species Composition

The catch composition (by weight) between the 2 survey platforms was relatively similar (Table 11; Appendices C1–C6). For both survey platforms, jellyfish (all species combined) comprised the highest biomass of all species caught in 2015 and 2016. Pacific herring *Clupea pallasii* made up the second highest biomass, except on the large vessel/trawl platform in 2016 when mature walleye pollock *Theragra chalcogramma* had the second largest biomass. However, the 2 stations that caught the majority of mature walleye pollock were fishing near bottom where walleye pollock are more likely to be encountered. Walleye pollock, juvenile chum salmon, and Pacific herring were among the most commonly caught species, based on biomass, by both survey platforms.

Juvenile salmon catch was dominated by chum and pink salmon on both survey platforms (Table 5; Appendices D1–D6). Juvenile chum salmon catches ranged 45–84% of total juvenile salmon catches on the small vessel platform and 39–61% on the large vessel platform. Sockeye and coho salmon made up less than 1% and 2%, respectively, of the overall juvenile salmon catch all 3 years of the small vessel/trawl surveys. The proportion of sockeye salmon was extremely low on the large vessel/trawl platform in 2015 (<1%) relative to 2014 and 2016 (12% and 9%, respectively). Coho salmon catches on the large vessel/trawl platform did not vary much across years (2–4%). On both platforms, juvenile Chinook salmon were consistently between 3% and 8% of the total juvenile salmon catch (Table 5). Chinook salmon catches increased yearly on the small vessel platform, conversely Chinook salmon catches decreased yearly on the large vessel platform. The increase in Chinook salmon catches on the small vessel may be attributed to vessel crew's increased familiarity with the gear in 2015 and 2016, and increased fishing power provided by new engines in 2016. The yearly decrease in catches on the large vessel platform could be due to weather difficulties experienced in 2015 and logistical difficulties in 2015 and 2016 that left core stations un-sampled.

A marine survey's utility for assessing salmon may be influenced by particular methodological nuances because different species exhibit different life history and ecological characteristics (e.g., marine entry timing, marine dispersal rate, growth rate, diet, vertical distribution), and certain species may be more or less susceptible to particular survey designs and gear. In order to test for differences in each salmon species' proportion between the 2 vessel platforms, chi-square contingency tables were created separately for 2015 and 2016 with 5 columns (for each Pacific salmon species) and 2 rows (large and small vessel/trawl platforms). Although the initial intent was to compare only paired trawl tows, the limited number of paired tows required pooling common stations for each year. In both 2015 and 2016, a significant difference was found between the large and small vessel platform's salmon species proportions (2015: $\chi^2 = 150.64$ p-value < 0.0001; 2016: $\chi^2 = 402.33$, p-value < 0.0001). Assuming independence between vessel and salmon species, the expected value of each cell was calculated by multiplying the row sum by the column sum and dividing by the observed count in each cell. Standardized residuals are the difference between observed and expected values divided by the square-root of the residual cell variance. Expected value and standardized residuals were assessed to find cells where the observed value differed greatly from the expected value (Table 12). Generally, standardized residuals greater/less than ±2 indicate a lack of support for equal proportions. In 2015, coho, Chinook, and chum salmon had residuals greater/less than ±2 and chum, coho, and pink salmon had residuals greater than ±2 in 2016. Chinook salmon and pink and chum salmon, with standardized residuals greater/less than ±10, contributed heavily to the chi-squared value calculated in 2015 and 2016, respectively. Sockeye salmon were the least common salmon species encountered on both surveys, which was probably why they were the only species with relatively low standardized residuals. The 1 month difference in survey timing probably influenced the spatial distribution of salmon species and consequently affected the species available to capture during survey operations. The hypothesized effect of survey timing may cause the differences seen in species proportions between vessel platforms. September sampling may not fully capture entire populations for species that distribute offshore (and beyond the survey grid) quickly, such as pink and chum salmon, but may perform better for populations with protracted marine entry and more nearshore distribution, such as coho salmon. Chinook salmon appeared to be adequately sampled by both platforms, though the larger vessel/trawl platform appeared to perform somewhat better for this species.

Salmon Size and Growth

This study, in combination with projects assessing emigrating salmon smolt in the Yukon River Delta during 1986 and 2014–2016[4] (Martin et al. 1989; Howard et al. 2017; Miller et al. 2016), and a study examining NBS chum salmon marine entry and growth from otoliths (Vega et al. 2017), allowed for some assessment of juvenile salmon growth from marine entry through the first summer at sea. Among the 3 years observed in the present study, mean size decreased annually since 2014 in all species examined in September samples, corresponding to earlier mean capture date (Table 13). Although size by September typically corresponded to mean date of capture in historical NBS salmon surveys, chum salmon size was particularly small in 2012 September samples (mean 166.8 mm) and Vega et al. (2017) indicated an exceptionally late marine entry (mean July 1) occurred in that year. The likelihood of late marine entry was further corroborated by cooler spring temperatures and later ice breakup timing, which appeared to be associated with later chum salmon smolt emigration timing (Figure 18). Mean capture date at marine entry became earlier annually since 2014 in all species except pink salmon (Table 13), and could be related to spring environmental conditions as evidenced by available marine entry data for chum and Chinook salmon (Figure 18). Unfortunately, data about marine entry for Yukon River Chinook salmon are limited. Prior to September, variable interannual patterns in length were present among species, not necessarily corresponding to capture date.

Size differences of fish captured at different time periods provide some evidence of growth rates for Yukon River salmon. Small freshwater growth was apparent between those fish measured earlier in the summer (May/early June) and later in the summer at marine entry (late July) (Howard et al. 2017). Comparatively large growth between marine entry and August was seen for all 3 species of salmon with data available, and average growth between August and September appeared to slow for Chinook salmon but increased for chum and pink salmon (Table 14, Figure 19). Growth between marine entry and September was notably greater for coho

[4] 2016 data on file with Katharine Miller, Fishery Biologist, NOAA, Auke Bay Laboratory, Juneau.

salmon (mean 2.11 mm/day) compared to the other salmon species that averaged near 1.5 mm/day (Table 14; Figure 19). Yukon River coho salmon predominantly emigrate from freshwater as age-3 fish, which is both older and larger than other salmon smolt, though a small proportion of the Chinook salmon population also exhibits this life history strategy. Entering the ocean at an older age and larger size may enable coho salmon to achieve a higher level of growth potential in the northern Bering Sea compared to salmon that enter marine waters as smaller and younger smolt. It should be noted, however, that because population-level size and capture date parameters were considered, estimates represent growth as well as any size-selective mortality occurring on these stocks during this time period. Early marine size selective mortality would be expected to increase the mean length in later sample periods because smaller, slower growing fish would be culled from the population, thereby increasing the estimated growth rate relative to the true growth rate individual fish experience. Size selective mortality would be expected to be most prominent during the early time period between marine entry and August (first critical period per Beamish and Mahnken 2001) compared to between August and September. However, Vega et al. (2017) measured growth rates of NBS chum salmon in 2007 and 2012 using otolith-derived daily age of individuals and found an average of 2.62 mm/day between ocean entry and September catches, which would suggest growth rates estimated in the present study could be biased low.

To compare size-at-capture between vessels, juvenile Chinook salmon lengths captured in common area sample stations were standardized within and between survey platforms to a common capture date. The standardized date was the average capture date of juvenile Chinook salmon from the large vessel platform each year of the survey (September 8 in 2014, September 6 in 2015, and September 3 in 2016). Juvenile Chinook salmon were assumed to grow 1.06 mm/day based on average August to September growth from 2014 to 2016 (Table 14), and individual lengths within a year were adjusted to the common capture date of their respective year (Table 15). Overall length distributions were different between platforms in each year as evidenced by non-parametric Kolmogrov-Smirnov tests (2014: D = 0.284, p-value < 0.001; 2015: D = 0.254, p-value < 0.001; 2016: D = 0.306, p-value < 0.001). The large vessel length distribution tended towards smaller fish in 2016 and larger fish in 2015 compared to the small vessel platform (Figures 20 and 21). Both platforms had the smallest adjusted mean lengths in 2016 with 208 and 196 mm for the small and large vessel platforms, respectively. Across all 3 survey years, the large vessel/trawl platform captured juvenile Chinook salmon ranging from 102 mm to 258 mm. Except for 4 individuals in 2015, the small vessel platform generally did not catch juvenile Chinook salmon smaller than 150 mm when adjusted for date of capture (Figure 20). The inconsistent pattern of size distributions in the 2 survey platforms suggested that survey timing may be important to assess interannual variability in size. It is possible that size selective mortality, spatial patterns in growth rates, smolt emigration timing and size, measurement error, or other factors may add considerable noise to the interpretation of annual size distributions.

RECOMMENDATIONS

Overall, the small vessel/trawl platform performed well in comparison to the standard large vessel/large trawl platform. The survey could be conducted in a similar time frame and cover a similar geographic scope, with some minor modifications to operations. Additionally, based on the juvenile abundance estimates calculated for 2015 and 2016, the small vessel/trawl platform can produce abundance estimates with CVs similar to those produced from the large vessel/trawl platform. Although adequate sample sizes were obtained by the small vessel/trawl platform in

2015 and 2016 for genetic analysis, stock composition estimates would be improved with increased sample sizes. Additionally, this study occurred during years of relatively high juvenile Chinook salmon abundance, and sample sizes may not be obtained by the small vessel/trawl platform in low abundance years unless considerably more sampling effort was implemented.

The 6 paired trawl events performed in 2014 cannot be used as a reliable measure of the towing capability of the small vessel/trawl platform given that it was the first year of surface trawl operations. Unfortunately, because of the inability to conduct paired trawl sets in 2015 and 2016, it was impossible to develop fishing power calibrations between the 2 platforms. Increased crew experience using the trawl gear and new engines to increase towing power probably provided comparable data to the large vessel platform as evidenced by the similarity in juvenile Chinook salmon CPUA among vessel platforms in 2016.

Despite the successes of the small vessel/trawl survey, it is recommended that the NBS surveys continue with the large vessel/trawl platform. Although more expensive, evidence suggests using the small vessel/trawl platform could introduce additional variability into the dataset, and the ability to maintain consistency over time would best safeguard the dataset from increased measurement error. It is also recommended that future genetic mixed stock composition estimates of NBS juvenile Chinook salmon use the baseline described in this report to distinguish Yukon River stocks from other eastern Bering Sea stocks. This baseline has demonstrated an appropriate level of accuracy and precision to be useful for apportioning abundance estimates of juvenile Chinook salmon by major stock groups. Additional genetic markers and populations, however, would improve the baseline's accuracy and precision, particularly for Lower Yukon and Other Western Alaska populations.

The results of these surveys have provided subsistence users, stakeholders, and fishery managers with reliable forecasts of adult run size up to 3 years in the future. Additionally, the run size forecasts give managers confidence to make decisions early in the season when inriver run assessment is not yet available. Although replacement of the large vessel platform is not recommended in the NBS, it is recommended that future surveys establishing new datasets use the more cost effective small vessel platform. The results of this study should inform successful implementation with this platform on any future effort. The small vessel platform is planned to be used in feasibility studies of nearshore juvenile salmon surveys in the southern Bering Sea to assess Kuskokwim and Bristol Bay stocks, beginning in 2018.

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TABLES AND FIGURES

Table 1.–Net dimensions and vessel sizes associated with the large and small research trawl fishing platforms.

	Towing vessel length (m)	Net stretch length (m)	Headrope length (m)	Typical fished vertical height (m)	Typical fished horizontal spread (m)	Typical fished area at mouth (m^2)	Typical coverage area Cantrawl units	Trawl door
Cantrawl 400/601	39–57	198.68	121.92	20	50	1,000	1.00	5 m^2 Alloy
Nordic 264	19 +	104.67	51.50	18	24	432	0.43	3 m^2 Lite foam-filled

Note: Typical coverage area refers to the 2-dimensional space encompassed by the mouth of the net during fishing activity as indicated by previous studies using these gear types, standardized to Cantrawl units.

Table 2.–Reporting group, ADF&G collection code, location, collection and population number, collection date, and the number of Chinook salmon incorporated into the baseline used to estimate the stock composition of northern Bering Sea trawl surveys.

Reporting group	ADF&G code	Location	Collection	Population	Date	# Individuals
Other Western Alaska	KPILG05	Pilgrim River	1	1	7/7/2005	163
	KPILG06		2		2006	
	KPILG09		3		2009	
	KPILG10		4		7/20/2010	
	KPILG11		5		2011	
	KPILG12		6		7/20/2012	
	KTUBU08	Tubutulik River	7	2	7/24/2008	100
	KTUBU09		8		7/31/2009	
	KINGLU09	Inglutalik River	9	3	6/15/2009	207
	KINGLU10		10		6/30/2010	
	KINGLU12		11		8/6/2012	
	KUNGA10	Ungalik River	12	4	7/31/2010	100
	KUNGA11		13		8/2/2011	
	KUNGA12		14		7/29/2012	
	KUNGA13		15		7/31/2013	
	KSHAKT05	Shaktoolik River	16	5	6/26/2005	151
	KSHAKT06		17		2006	
	KSHAKT10		18		6/27/2010	
	KSHAKT11		19		7/27/2011	
	KSHAKT12		20		7/23/2012	
	KSHAKT13		21		7/24/2013	
	KSHAKTS11		22		7/1/2011	
	KNORTH10	North River	23	6	7/10/2010	66
	KNRIV05		24		2005	
	KUNAES07	Unalakleet River	25	7	6/23/2007	166
	KUNAL04		26		6/9/2004	
	KGOLS05	Golsovia River	27	8	2005	113
	KGOLS06		28		2006	
	KSALM95	Salmon River - Pitkas Fork	29	9	6/30/1995	96
	KTAKW07	Takotna River weir	30	10	6/29/2007	95
	KGAGA06	Gagaryah River	31	11	7/20/2006	94
	KCHEE02	Cheeneetnuk River	32	12	7/30/2002	91
	KTATL05	Tatlawiksuk River weir	33	13	7/3/2005	94
	KNECO07	Necons River	34	14	8/2/2007	95
	KISTO94	Stony River	35	15	6/27/1994	93

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Reporting group	ADF&G code	Location	Collection	Population	Date	#Individuals
	KGEOR05	George River weir	36	16	2005	91
	CHKOG92	Kogrukluk River	37	17	6/18/1992	145
	KIKOG93		38		7/1/1993	
	KKOGR05		39		2005	
	KSALM06	Salmon River weir (Aniak Basin)	40	18	7/3/2006	95
	KITUL94	Tuluksak River	41	19	7/27/1994	105
	KTULU05		42		2005	
	KKISA05	Kisaralik River	43	20	7/15/2005	95
	KKWET01	Kwethluk River	44	21	7/15/2001	96
	KEEK05	Eek River	45	22	6/9/2005	77
	KKANE05	Kanektok River	46	23	7/27/2005	95
	KAROL05	Arolik	47	24	7/29/2005	149
	KGONF06	Goodnews River - North Fork	48	25	7/21/2006	94
	KITOG94	Togiak River	49	26	8/3/1994	228
	KTOGRT09		50		6/25/2009	
	KCHILR11	Chilikadrotna River	51	27	8/5/2011	184
	KIMUL94	Mulchatna River	52	28	7/19/1994	122
	KMULC11		53		8/9/2011	
	KKOKT10	Koktuli River	54	29	7/27/2010	100
	KSTUY09	Stuyahok River	55	30	7/30/2009	107
	KKLUTU09	Klutuspak Creek	56	31	7/27/2009	105
	KIOW10	Iowithla River	57	32	7/26/2010	66
	KKSALC08	King Salmon Creek	58	33	1/1/2008	35
	KBIGCK04	Big Creek	59	34	7/29/2004	104
	KBIGCK08		60		2008	
	KMAIN04	Naknek River	61	35	2004	172
	KNAKM08		62		2008	
	KNEK95		63		6/27/1995	
					Other Western Alaska total	3,989
Canada	KWHITE97	Whitehorse	64	36	9/15/1997	121
	KWHITERA10		65		2010	
	KTESL09	Teslin River	66	37	8/9/2009	159
	KTESL10		67		2010	
	KTESL11		68		2011	
	KBIGS07	Big Salmon River	69	38	8/22/2007	149
	KBIGS87		70		9/15/1987	

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Reporting group	ADF&G code	Location	Collection	Population	Date	# Individuals
Canada continued	KLSAL10	Little Salmon River	71	39	8/27/2010	139
	KPELL09	Pelly River	72	40	8/20/2009	105
	KPELL97		73		3/10/1997	
	KTINC09	Tincup Creek	74	41	8/24/2009	101
	KTINC10		75		2010	
	KTINC11		76		8/25/2011	
	KMCQUE11	McQuesten River	77	42	8/15/2011	49
	KMAYO09	Mayo River	78	43	8/20/2009	54
	KMAYO11		79		8/27/2011	
	KMAYO97		80		9/15/1997	
	KSTEW07	Stewart River	81	44	8/7/2007	100
	KSTEW97		82		3/11/1997	
	KKLON01	Klondike River	83	45	9/15/2001	97
	KKLON07		84		7/27/2007	
	KKLON09		85		8/7/2009	
	KKLON10		86		8/15/2010	
	KKLON11		87		8/14/2011	
	KCHAU01	Chandindu River	88	46	9/15/2001	156
	KKANDI07	Kandik River	89	47	2007	60
	KKANDI08		90		2008	
	KKANDI09		91		2009	
	KKANDI10		92		2010	
					Canada total	1,290
Middle Yukon	KSHEE02	Sheenjek River	93	48	8/15/2002	66
	KSHEE04		94		2004	
	KSHEE06		95		2006	
	KSHEE11		96		7/18/2011	
	KCHAN02	Chandalar River	97	49	8/15/2002	111
	KCHAN03		98		8/15/2002	
	KSALC05	Salcha River	99	50	7/11/2005	94
	KCHENA01	Chena River	100	51	8/16/2001	86
	KKANT05	Kantishna River	101	52	7/1/2005	95
	KSFKOY03	South Fork Koyukuk River	102	53	8/15/2003	51
	KHENS01	Henshaw Creek	103	54	8/16/2001	91
					Middle Yukon total	594

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Reporting group	ADF&G code	Location	Collection	Population	Date	# Individuals
Lower Yukon	KTOZI02	Tozitna River	104	55	8/16/2002	70
	KGISA01	Gisasa River	105	56	8/16/2001	84
	KKATE08	Kateel River	106	57	7/31/2008	59
	KKATE12		107		8/1/2012	
	KNUL12NF	Nulato River	108	58	7/26/2012	51
	KNUL12SF		109		7/23/2012	
	KANVI07	Anvik River	110	59	7/6/2007	59
	KANDR03	Andreafsky River	111	60	8/15/2003	131
					Lower Yukon total	454
					Baseline total	6,327

Table 3.–Locus information including observed heterozygosity (H_O), F_{IS} and F_{ST} for the 84 single nucleotide polymorphisms (SNPs) used to analyze the stock composition of Chinook salmon in the northern Bering Sea.

Assay	H_O	F_{IS}	F_{ST}
Ots_102867-609	0.30	-0.01	0.06
Ots_103122-180	0.01	0.05	0.04
Ots_104063-132	0.32	-0.01	0.09
Ots_105385-421	0.47	-0.01	0.05
Ots_107806-821	0.45	0.00	0.07
Ots_118938-325	0.24	-0.01	0.06
Ots_123048-521	0.40	0.01	0.05
Ots_127760-569	0.43	0.01	0.04
Ots_128693-461	0.45	0.01	0.08
Ots_129458-451	0.03	0.04	0.05
Ots_131460-584	0.45	-0.01	0.08
Ots_96899-357R	0.45	0.01	0.07
Ots_brp16-64	0.36	0.01	0.05
Ots_CD59-2	0.44	-0.01	0.05
Ots_Est740	0.27	0.01	0.08
Ots_GH2	0.39	-0.01	0.17
Ots_GPDH	0.32	0.01	0.15
Ots_GST-207	0.22	0.00	0.38
Ots_HFABP-34	0.34	-0.02	0.24
Ots_hnRNPL-533	0.40	-0.02	0.07
Ots_hsc71-3prime-488	0.30	-0.01	0.06
Ots_Hsp90a	0.40	0.00	0.13
Ots_HSP90B-100[a]	0.32	0.00	0.06
Ots_HSP90B-385	0.17	0.00	0.14
Ots_IGF1-91	0.45	0.01	0.09
Ots_IsoT[b]	0.36	0.08	0.05
Ots_mapK-3prime-309	0.19	0.02	0.09
Ots_MHC2	0.11	0.02	0.05
Ots_OPSW-152	0.37	-0.05	0.09
Ots_OTDESMIN19-SNP1	0.43	-0.01	0.15
Ots_ppie-245	0.48	-0.01	0.06
Ots_Prl2	0.44	0.00	0.10
Ots_RAD10099[c]	0.33	0.00	0.19
Ots_RAD10252	0.39	0.00	0.08
Ots_RAD10400[c]	0.41	0.00	0.13
Ots_RAD10412	0.17	0.00	0.13
Ots_RAD1104-38	0.46	0.00	0.09
Ots_RAD11821[d]	0.33	0.01	0.05
Ots_RAD11839[c]	0.44	0.00	0.08
Ots_RAD1372[c]	0.25	0.01	0.06
Ots_RAD14482	0.21	-0.01	0.07
Ots_RAD14650	0.30	0.02	0.05
Ots_RAD14852	0.22	-0.02	0.13
Ots_RAD1609	0.47	-0.01	0.05
Ots_RAD17721	0.12	0.04	0.04
Ots_RAD1832-39	0.42	-0.01	0.17
Ots_RAD18973	0.07	0.04	0.05

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Assay	H_O	F_{IS}	F_{ST}
Ots_RAD2068[c]	0.18	-0.02	0.07
Ots_RAD2102	0.46	-0.02	0.04
Ots_RAD2207	0.34	-0.01	0.21
Ots_RAD2234	0.32	0.03	0.06
Ots_RAD2255	0.42	0.01	0.15
Ots_RAD2442	0.45	0.00	0.09
Ots_RAD249	0.47	0.01	0.04
Ots_RAD2598[c]	0.41	-0.02	0.11
Ots_RAD2683[c]	0.44	0.01	0.05
Ots_RAD3470	0.47	-0.01	0.04
Ots_RAD3513-49	0.42	0.02	0.11
Ots_RAD3635	0.24	0.02	0.04
Ots_RAD3703	0.31	0.04	0.10
Ots_RAD3766	0.43	0.00	0.06
Ots_RAD3769	0.28	0.01	0.04
Ots_RAD3858	0.23	0.00	0.06
Ots_RAD3925[c]	0.48	-0.01	0.04
Ots_RAD4369-50	0.45	0.01	0.08
Ots_RAD5189	0.31	-0.01	0.05
Ots_RAD6688	0.45	-0.02	0.04
Ots_RAD7695	0.17	0.00	0.05
Ots_RAD7936-50	0.36	-0.01	0.19
Ots_RAD8200-45	0.45	-0.01	0.12
Ots_RAD9480-51[e]	0.40	-0.01	0.09
Ots_RAD9536	0.42	-0.02	0.06
Ots_RAD9756	0.43	0.00	0.04
Ots_RAD995	0.42	0.06	0.05
Ots_SERPC1-209	0.10	0.04	0.04
Ots_SL	0.37	-0.01	0.04
Ots_TGFB	0.44	0.03	0.10
Ots_Tnsf	0.27	0.00	0.10
Ots_u07-07.161	0.34	0.00	0.04
Ots_U200-167	0.06	-0.01	0.07
Ots_UNKN6-187	0.30	0.01	0.07
Ots_zP3b	0.20	0.01	0.05
S7-1	0.26	0.02	0.05
unkn526	0.29	-0.01	0.06
Overall	0.33	0.00	0.09

Note: Statistics for each marker are based on the 60 populations included in the baseline. Overall H_O is the average value across loci that passed filters and overall F_{IS} and F_{ST} are estimated following Weir and Cockerham (1984).

[a] This locus exhibited linkage disequilibrium with Ots_HSP90B-385 in 52 of 60 populations and was removed from subsequent analyses.

[b] This locus exhibited substantial departures from Hardy-Weinberg expectations and was removed from subsequent analyses.

[c] These loci were missing genotypic data for 1 (Tozitna River) or 2 (Chandindu and Tozitna rivers) of the 60 populations; H_O was calculated from observed data.

[d] This locus exhibited linkage disequilibrium with Ots_RAD3703 in 33 of 60 populations and was removed from subsequent analyses.

[e] This locus exhibited linkage disequilibrium with Ots_RAD8200-45 in 60 of 60 populations and was removed from subsequent analyses.

Table 4.–Comparative trawl measurements from the large vessel/trawl platform and the small vessel/trawl platform from pelagic surveys in the northeastern Bering Sea, 2014–2016.

Year	Vessel/trawl platform	Survey dates	Stations sampled	Mean towing speed (kts)	Mean tow distance (km)	Mean towed vertical height (m)	Mean towed horizontal spread (m)	Mean area swept (km^2)	Mean juv. Chinook salmon catch
2014	Large	Sep 4–Sep 22	48	4.07	3.80	22.70	53.00	0.20	7
	Small	Aug 8–Aug 30	55	2.52	2.35	17.20	17.40	0.04	1
2015	Large	Sep 1–Sep 16	37	3.95	3.70	21.00	53.00	0.20	9
	Small	Aug 10–Aug 23	41	2.91	2.69	14.25	25.35	0.07	3
2016	Large	Aug 28–Sep 12	36	3.91	3.62	23.00	48.00	0.17	6
	Small	Aug 7–Aug 29	48	3.13	2.90	11.15	26.30	0.08	3

Table 5.–Catch numbers and proportions of juvenile salmon for each species on small and large vessel platforms, 2014–2016.

	2014				2015				2016			
	Small vessel		Large vessel		Small vessel		Large vessel		Small vessel		Large vessel	
	Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion
Chinook	44	0.03	344	0.05	127	0.04	322	0.08	140	0.07	218	0.08
Coho	3	0	174	0.03	27	0.01	84	0.02	40	0.02	114	0.04
Chum	1,185	0.84	3,310	0.48	1,744	0.49	1,627	0.39	966	0.45	1,761	0.61
Pink	177	0.13	2,217	0.32	1,627	0.46	2,154	0.51	971	0.46	550	0.19
Sockeye	4	0	817	0.12	7	0	20	0	10	0.01	245	0.08
Total	1,413	1	6,862	1	3,532	1	4,207	1	2,127	1	2,888	1

Table 6.–Juvenile Chinook salmon abundance estimates from small and large vessel platforms, 2014–2016.

	Small vessel/trawl			Large vessel/trawl			
Year	Juvenile Chinook salmon abundance	CV	Standard deviation	Juvenile Chinook salmon abundance	CV	Standard deviation	Difference between platforms
2014	NA	NA	NA	3,641,000	20%	731,602	NA
2015	3,702,000	38%	1,394,000	4,648,000	27%	1,272,090	20%
2016	4,283,000	28%	1,205,000	3,870,000	33%	1,289,974	-11%

Table 7.–Estimates of average stock composition, bias, root mean square error (RMSE), and 90% credibility interval (CI) width for 5 replicates of 100% and flat (25%/25%/25%/25%) proof tests of the AYK Chinook salmon baseline with 84 loci.

Reporting Group	Average	Bias	RMSE	CI width
100% Canada				
Canada	**99.4**	-0.6	0.6	1.6
Middle Yukon	0.3	0.3	0.4	1.1
Lower Yukon	0.1	0.1	0.1	0.6
Other Western Alaska	0.1	0.1	0.1	0.6
100% Middle Yukon				
Canada	0.3	0.3	0.4	1.4
Middle Yukon	**99.1**	-0.9	1.0	2.4
Lower Yukon	0.2	0.2	0.3	1.0
Other Western Alaska	0.4	0.4	0.4	1.2
100% Lower Yukon				
Canada	1.0	1.0	1.1	2.2
Middle Yukon	0.7	0.7	0.8	2.1
Lower Yukon	**94.4**	-5.6	6.2	12.9
Other Western Alaska	3.8	3.8	4.8	12.0
100% Other Western Alaska				
Canada	0.1	0.1	0.1	0.6
Middle Yukon	0.1	0.1	0.1	0.6
Lower Yukon	0.9	0.9	1.0	4.1
Other Western Alaska	**98.8**	-1.2	1.3	4.4
Flat (25% from each group)				
Canada	25.3	0.3	1.3	10.3
Middle Yukon	25.1	0.1	1.8	10.4
Lower Yukon	19.9	-5.1	6.1	17.3
Other Western Alaska	29.7	4.7	5.8	18.0

Note: Each replicate was a sample of 200 individuals removed from the baseline. Bold indicates correct allocations for the 100% proof tests. Stock composition estimates (percentage) may not sum to 100 due to rounding error.

Table 8.–Estimates of stock composition (percent) including median, 90% credibility interval, the probability that the group estimate is equal to 0 ($P = 0$), mean and standard deviation (SD) for Chinook salmon sampled from the large and small trawl vessel/trawl platforms and from the Yukon River Delta in 2014–2016.

Broad-scale group	Intra-Yukon group	Median	90% CI 5%	90% CI 95%	$P = 0$	Mean	SD
2014 large vessel/trawl (*n* = 192)							
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
2014 Yukon Delta smolt (*n* = 367)							
	Canada	60.9	56.7	65.1	0.00	60.9	2.6
	Middle Yukon	32.6	28.7	36.8	0.00	32.7	2.5
	Lower Yukon	6.3	4.4	8.7	0.00	6.4	1.3
2015 small vessel/trawl (*n* = 131)							
Yukon River		85.9	76.2	93.2	0.00	85.5	5.2
	Canada	40.7	33.6	48.1	0.00	40.8	4.4
	Middle Yukon	18.7	13.3	25.1	0.00	18.9	3.6
	Lower Yukon	25.9	16.5	35.1	0.00	25.8	5.7
Other Western Alaska		14.1	6.8	23.8	0.00	14.5	5.2
2015 large vessel/trawl (*n* = 306)							
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
2015 Yukon Delta smolt (*n* = 413)							
	Canada	58.0	53.8	62.1	0.00	58.0	2.5
	Middle Yukon	19.6	16.3	23.1	0.00	19.6	2.1
	Lower Yukon	22.3	19.1	25.9	0.00	22.4	2.1
2016 small vessel/trawl (*n* = 127)							
Yukon River		81.5	72.2	89.5	0.00	81.3	5.3
	Canada	46.4	39.1	53.9	0.00	46.5	4.5
	Middle Yukon	16.3	11.1	22.4	0.00	16.5	3.4
	Lower Yukon	18.1	10.0	27.3	0.00	18.3	5.3
Other Western Alaska		18.5	10.5	27.8	0.00	18.7	5.3
2016 large vessel/trawl (*n* = 217)							
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
2016 Yukon Delta smolt (*n* = 579)							
	Canada	49.4	46.0	52.9	0.00	49.4	2.1
	Middle Yukon	27.2	24.1	30.4	0.00	27.2	1.9
	Lower Yukon	23.3	20.5	26.3	0.00	23.3	1.7

Note: Estimates are reported to broad-scale groups of populations (Yukon River and Other Western Alaska) as well intra-Yukon groups. Stock composition means may not sum to 100% due to rounding error.

Table 9.–Range of relative within-Yukon River stock proportions observed from sampling Yukon River Delta smolt in May–July, Northern Bering Sea juveniles in August and September of 2014–2016 and from Yukon River adult runs in 2002–2004.

	2014-2016 Juveniles			
	May–July	August	September	2002–2004 Adult run
Lower Yukon	6–23%	23–30%	9–14%	10–14%
Middle Yukon	20–33%	20–22%	25–38%	32–37%
Canadian Yukon	49–61%	48–57%	51–64%	49–58%

Table 10.–Means of fishing effort characteristics, juvenile Chinook salmon catch and CPUA from 6 paired tows in 2014.

	Mean towing speed (kts)	Mean tow distance (km)	Mean vertical height (m)	Mean horizontal spread (m)	Mean area swept (km^2)	No. Juv Chinook salmon catch per tow	Mean Juv. Chinook salmon CPUA ($\#/km^2$)
Cantrawl 400/601 (large vessel)	4.43	3.84	21.54	51	0.196	9-30	86.22
Nordic 264 (small vessel)	2.87	2.55	13.89	20.86	0.053	0-4	29.66

Table 11.–Ten species representing the greatest biomass (top) and numbers (bottom) captured by small vessel/trawl and large vessel/trawl survey platforms in 2015 and 2016.

Top 10 species caught by weight				
	2015		2016	
	Small platform	Large platform	Small platform	Large platform
1	Jellyfish spp.	Jellyfish spp.	Jellyfish spp.	Jellyfish spp.
2	Pacific herring	Pacific herring	Pacific herring	Walleye pollock
3	Chum salmon juvenile	Walleye pollock age-0	Chum salmon juvenile	Pacific herring
4	Pink salmon juvenile	Capelin	Saffron cod	Chum salmon juvenile
5	Walleye pollock	Chum salmon juvenile	Walleye pollock	Chinook salmon immature
6	Chinook salmon juvenile	Pink salmon juvenile	Pink salmon juvenile	Chum salmon immature
7	Coho salmon juvenile	Chinook salmon immature	Chinook salmon juvenile	Capelin
8	Saffron cod	Walleye pollock	Coho salmon juvenile	Coho salmon juvenile
9	Yellowfin sole	Chinook salmon juvenile	Chinook salmon immature	Chinook salmon juvenile
10	Arctic lamprey	Sockeye salmon immature	Rainbow smelt	Pacific cod

Top 10 species caught by numbers				
	2015		2016	
	Small platform	Large platform	Small platform	Large platform
1	Pacific herring	Walleye pollock mature	Pacific herring	Pacific herring
2	Chum salmon juvenile	Pacific herring	Saffron cod	Walleye pollock age-0
3	Pink salmon juvenile	Capelin	Pink salmon juvenile	Capelin
4	Saffron cod	Ninespine stickleback	Chum salmon juvenile	Chum salmon juvenile
5	Pacific sandlance	Saffron cod	Ninespine stickleback	Rainbow smelt
6	Capelin	Pink salmon juvenile	Rainbow smelt	Ninespine stickleback
7	Squid spp.	Chum salmon juvenile	Pacific sandlance	Walleye pollock mature
8	Chinook salmon juvenile	Pacific sandlance	Other gadid spp.	Pink salmon juvenile
9	Coho salmon juvenile	Squid spp.	Chinook salmon juvenile	Saffron cod
10	Larval flatfish spp.	Rainbow smelt	Capelin	Sockeye salmon juvenile

Table 12.–Standardized residuals from a Pearson's chi-squared test performed on small and large vessel juvenile salmon catches from core sampling stations on surveys in the northeastern Bering Sea, 2014–2016.

	2015	2016
Chum salmon	±**6.76**	**±17.03**
Coho salmon	**±5.57**	**±3.96**
Chinook salmon	**±10.04**	±0.87
Pink salmon	±0.51	**±19.76**
Sockeye salmon	±0.75	±0.19

Note: Standardized residuals greater or less than 2 (bold) indicate larger or smaller observations than expected.

Table 13.–Sample sizes and mean (SD) lengths from 2014–2016 emigrating smolt (May-July), August (small vessel/trawl), and September (large vessel/trawl) sampling.

	Chinook salmon			Chum salmon			Coho salmon			Pink salmon		
	n	Mean length (SD)	Mean capture date (SD)	*n*	Mean length (SD)	Mean capture date (SD)	*n*	Mean length (SD)	Mean capture date (SD)	*n*	Mean length (SD)	Mean capture date (SD)
Marine entry												
2014	416	98.0 (4.0)	6/22 (13)	3,828	47.2 (7.3)	6/20 (15)	219	103.2 (10.7)	6/11 (8)	382	40.7 (6.0)	6/24 (8)
2015	944	91.9 (12.9)	6/14 (18)	3,495	48.2 (7.7)	6/19 (17)	326	98.7 (11.5)	6/10 (10)	2,086	40.7 (9.1)	6/10 (13)
2016	685	94.1 (17.6)	6/14 (17)	4,570	46.0 (7.3)	6/10 (17)	449	100.6 (10.4)	6/6 (12)	446	47.6 (8.9)	6/26 (19)
August												
2014	44	NA	NA	443	130.3 (19.6)	8/14 (7)	3	NA	NA	163	108.1 (8.3)	8/10 (3)
2015	127	187.4 (22.0)	8/14 (3)	537	139.2 (16.4)	8/18 (3)	27	NA	NA	602	121.6 (14.4)	8/17 (4)
2016	140	185.9 (19.3)	8/13 (4)	659	140.1 (23.3)	8/13 (6)	40	NA	NA	624	125.7 (19.9)	8/13 (6)
September												
2014	328	217.8 (35.2)	9/9 (6)	1,208	177.3 (25.9)	9/13 (5)	166	304.6 (23.8)	9/12 (5)	422	166.9 (16.6)	9/10 (5)
2015	322	214.7 (28.3)	9/6 (4)	901	179.6 (25.0)	9/8 (5)	82	292.2 (14.0)	9/6 (4)	985	161.5 (24.8)	9/7 (4)
2016	217	203.4 (19.3)	9/1 (3)	701	168.4 (21.3)	8/31 (4)	114	272.5 (24.3)	9/1 (4)	395	153.9 (24.4)	9/1 (5)

Note: Estimates not included for low sample size

Table 14.–Mean days at sea (emigration through capture) and growth of juvenile salmon species during the first summer at sea, as measured by mean length at 3 time periods.

	Mean days at sea				Mean mm/day			
	Chinook	Chum	Coho	Pink	Chinook	Chum	Coho	Pink
Marine Entry to August								
2014	NA	55	NA	47	NA	1.51	NA	1.43
2015	58	60	NA	68	1.65	1.52	NA	1.19
2016	60	64	NA	48	1.46	1.45	NA	2.06
Average	59	60	NA	54	1.55	1.49	NA	1.56
August to September								
2014	NA	30	NA	31	NA	1.57	NA	1.90
2015	23	21	NA	21	1.19	1.92	NA	1.90
2016	19	18	NA	19	0.92	1.57	NA	1.48
Average	21	23	NA	24	1.06	1.69	NA	1.76
Marine Entry to September								
2014	79	85	93	78	1.52	1.53	2.17	1.62
2015	81	81	88	89	1.52	1.62	2.20	1.36
2016	79	82	87	67	1.38	1.49	1.98	1.59
Average	80	83	89	78	1.47	1.55	2.11	1.52

Table 15.–Summary statistics of the date-adjusted mean lengths of juvenile Chinook salmon sampled on the small and large vessel platforms surveying juvenile Chinook salmon from core sampling stations in northeastern Bering Sea, 2014–2016.

	Small vessel/small trawl platform					Large vessel/large trawl platform				
	Mean	SD	Median	Min.	Max.	Mean	SD	Median	Min.	Max.
2014	220	20	225	171	247	209	33	216	102	258
2015	211	20	214	112	237	214	30	222	102	258
2016	208	19	204	170	274	196	19	198	142	239

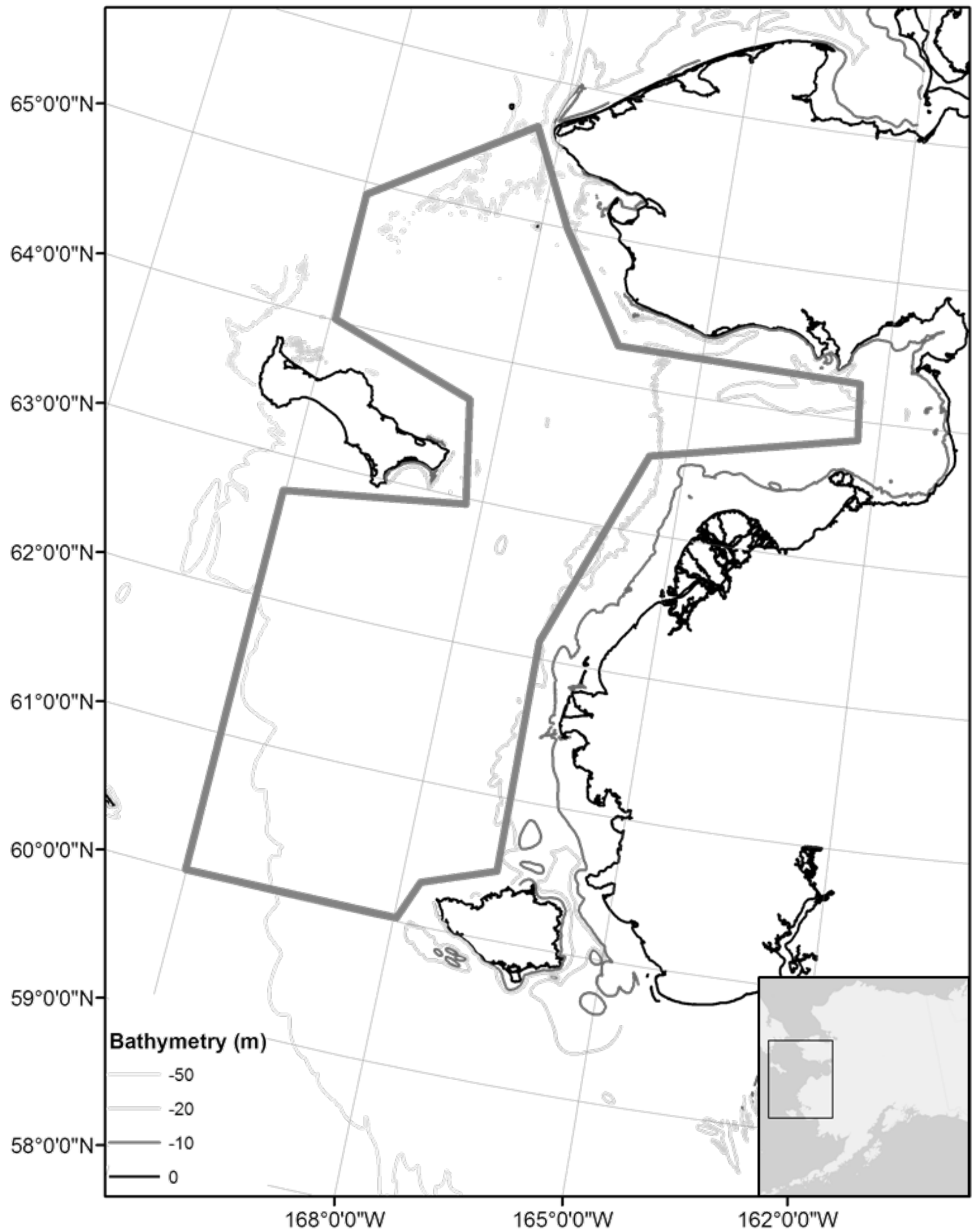

Figure 1.–Northern Bering Sea region of study.

Note: Polygon encompasses the entire sampling area covered by either survey platform. Location of northeastern Bering Sea indicated on inset map of Alaska.

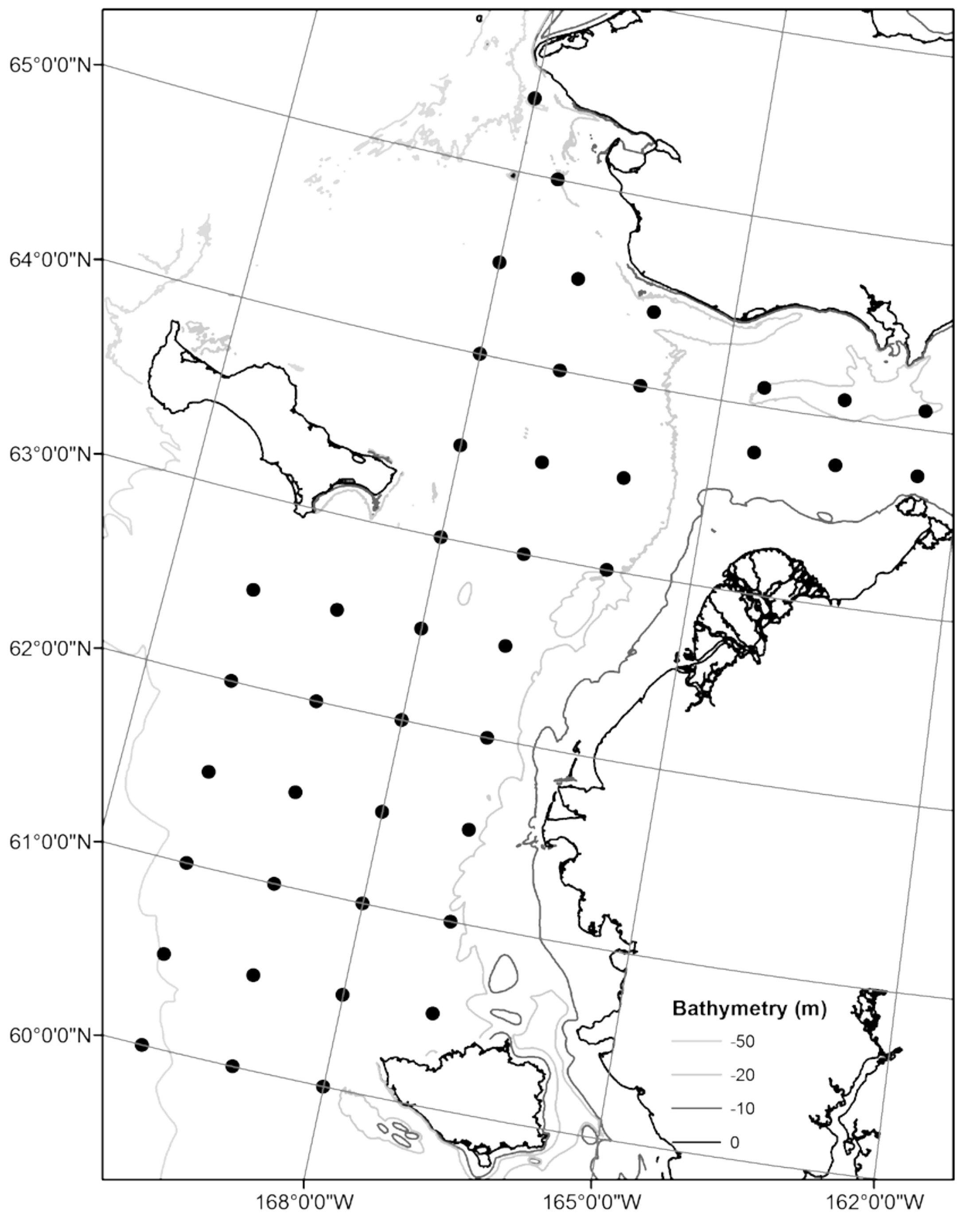

Figure 2.–Large vessel/trawl survey platform sample grid.

Note: Sample stations indicated by black dots and sea floor depth indicated by shaded bathymetric lines.

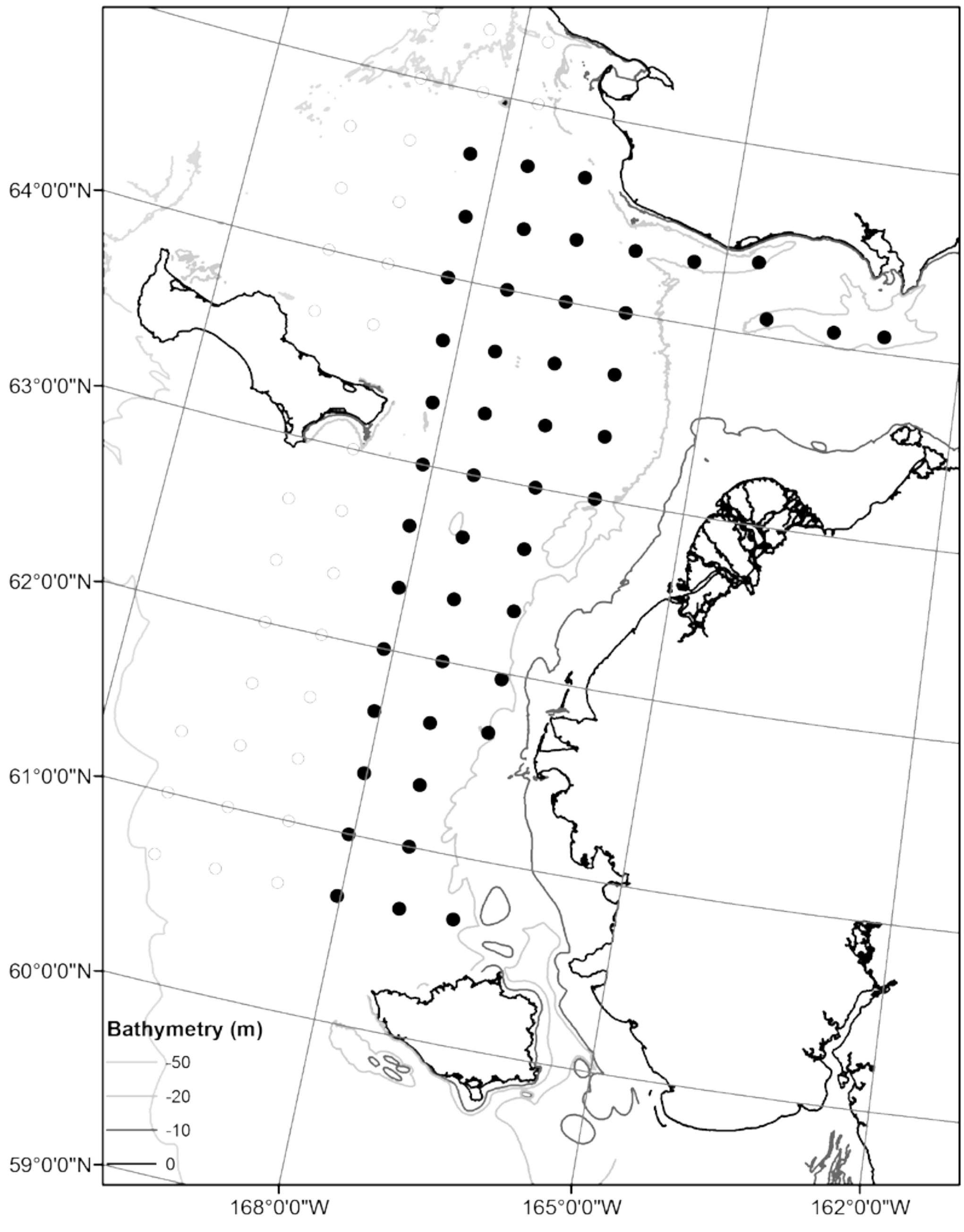

Figure 3.–Small vessel/trawl survey platform sample grid.

Note: Primary sample stations indicated by closed circles and additional sample stations indicated by open circles. Sea floor depth indicated by shaded bathymetric lines.

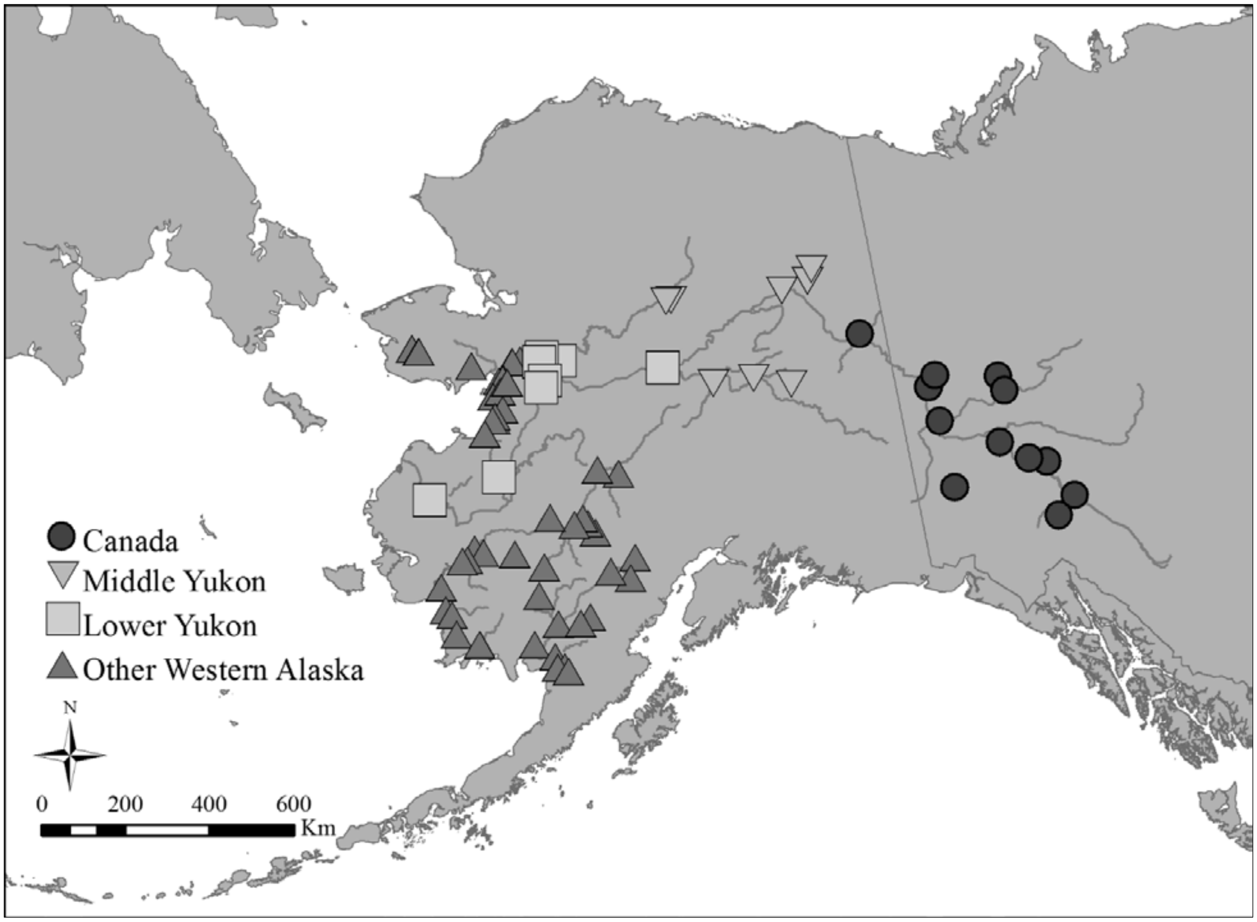

Figure 4.–The location and reporting group affiliation of 111 collections of Chinook salmon included in final AYK baseline analyses for northern Bering Sea trawl surveys, 2014–2016.

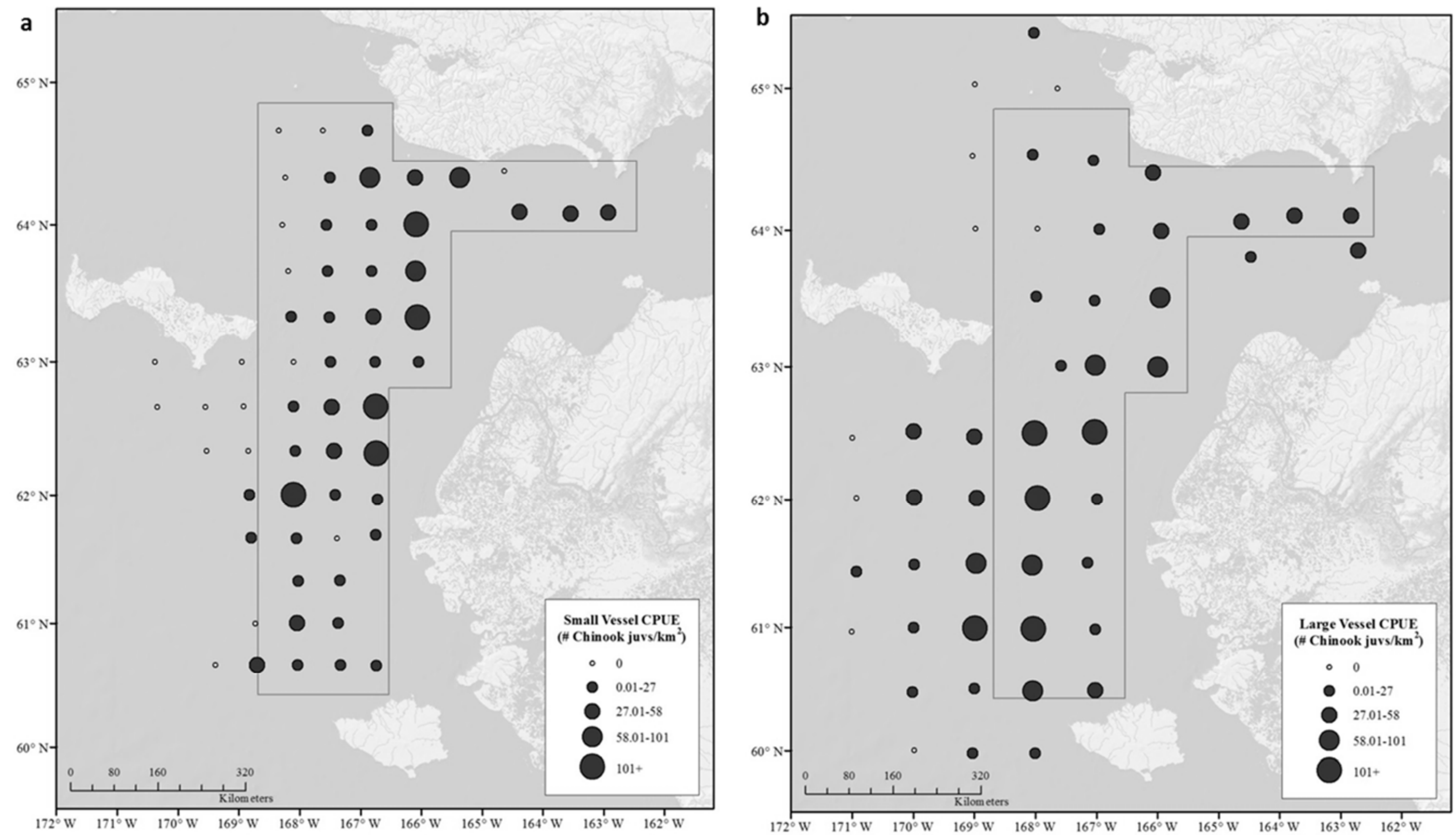

Figure 5.–Averaged spatial distribution of 2014–2016 juvenile Chinook salmon in the northern Bering Sea measured by the small vessel survey in August (a) and large vessel survey in September (b).

Note: The core geographic area covered consistently by both is identified by the polygon.

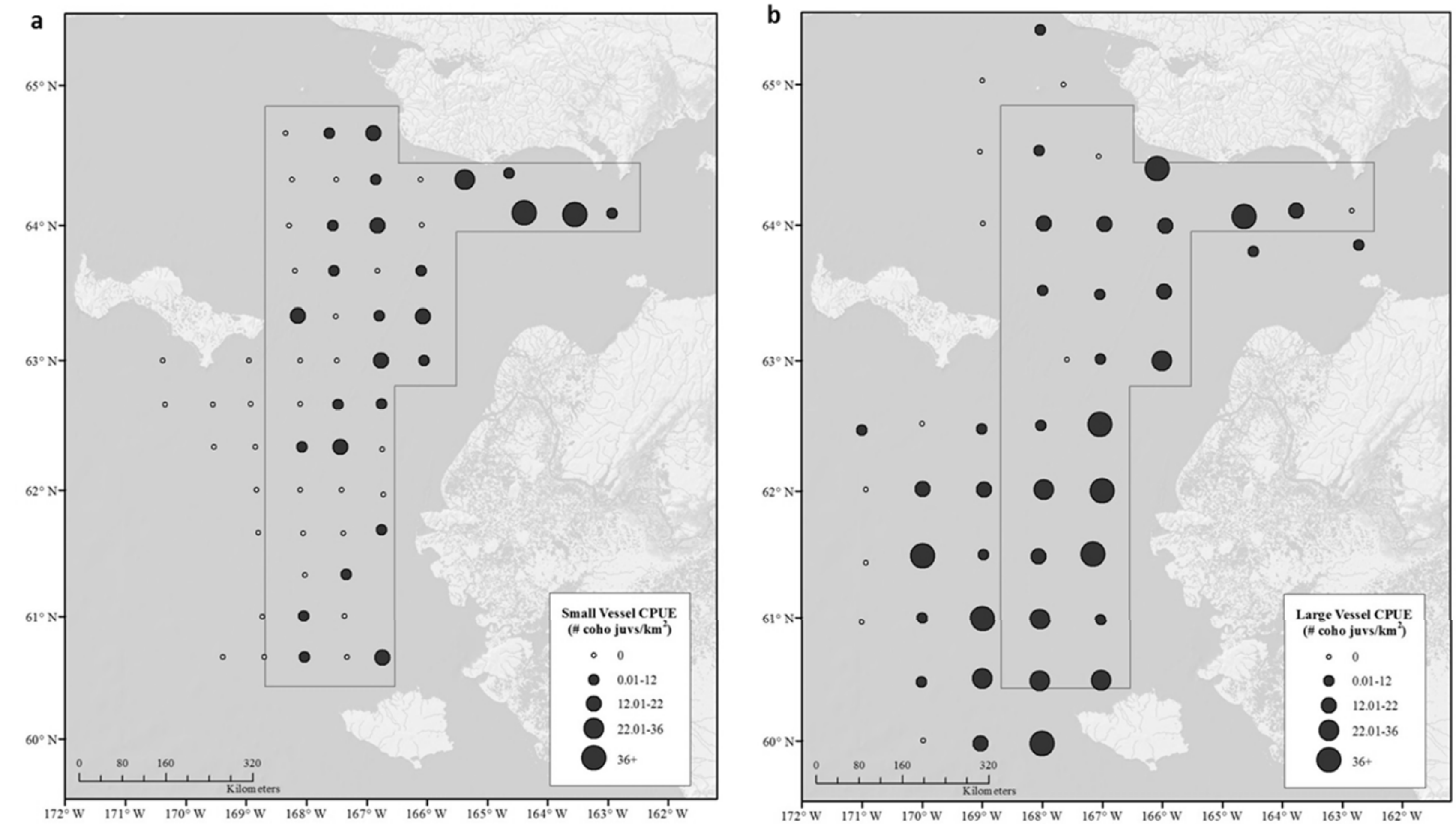

Figure 6.–Averaged spatial distribution of 2014–2016 juvenile coho salmon in the northern Bering Sea measured by the small vessel survey in August (a) and large vessel survey in September (b).

Note: The core geographic area covered consistently by both is identified by the polygon.

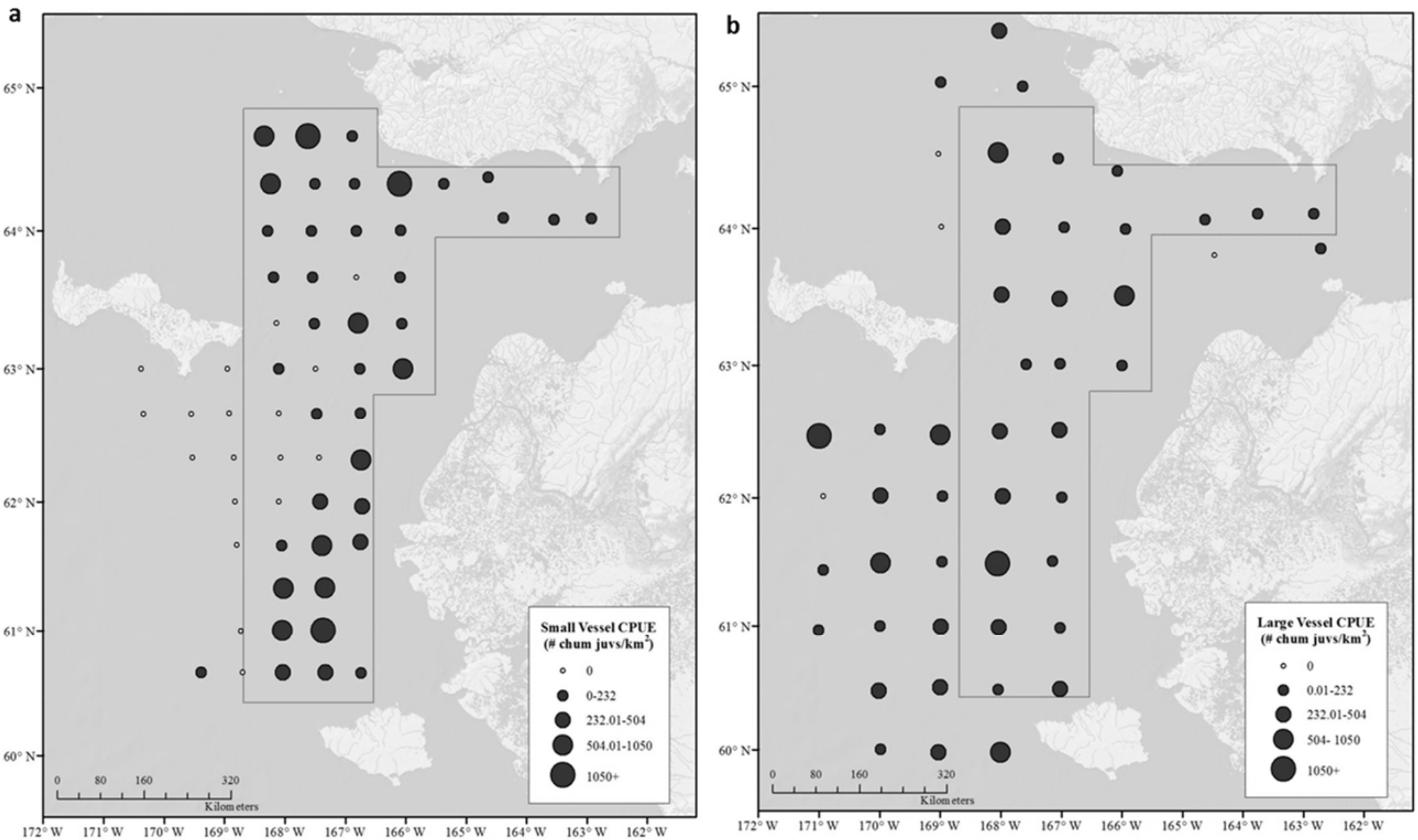

Figure 7.–Averaged spatial distribution of 2014–2016 juvenile chum salmon in the northern Bering Sea measured by the small vessel survey in August (a) and large vessel survey in September (b).

Note: The core geographic area covered consistently by both is identified by the polygon.

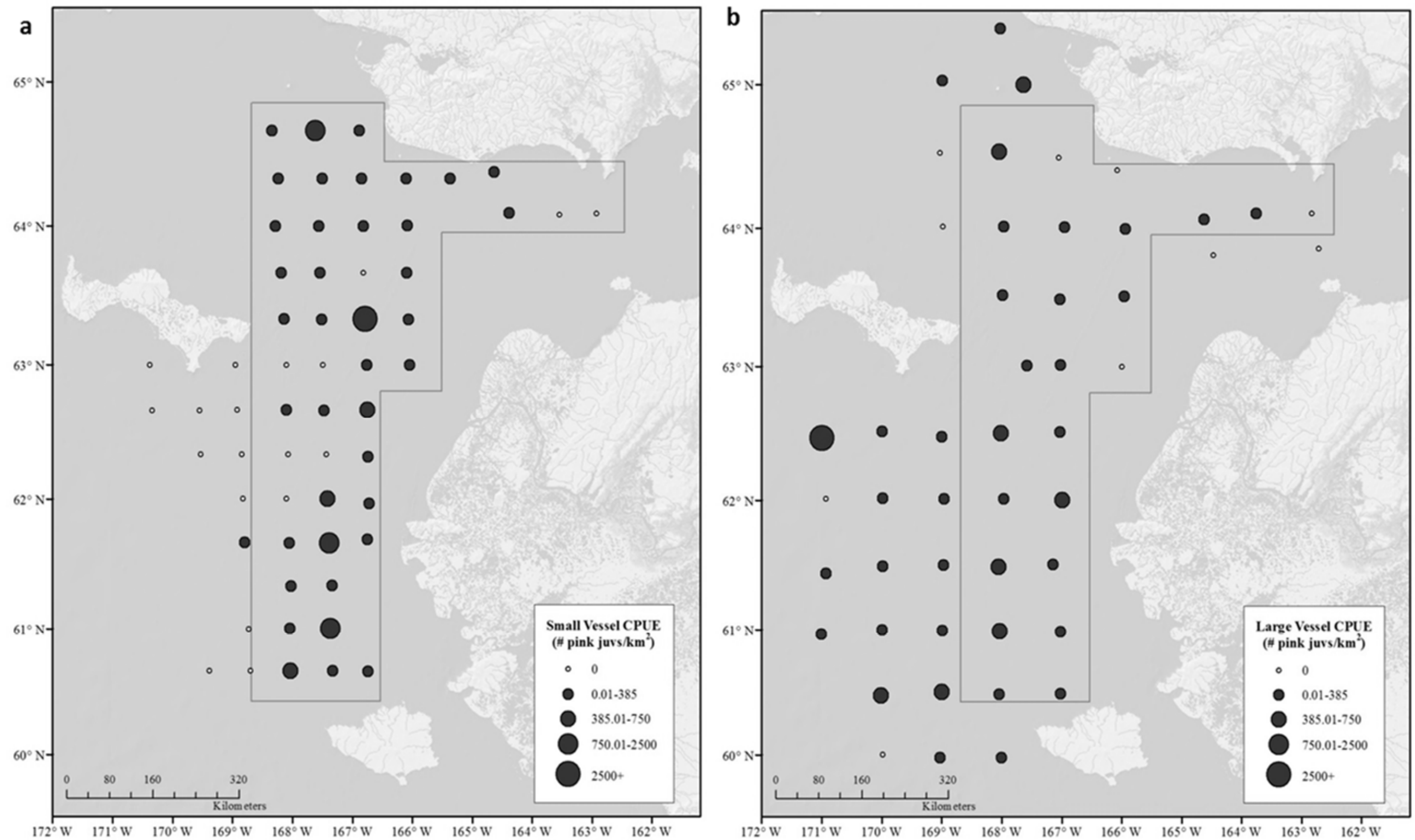

Figure 8.–Averaged spatial distribution of 2014–2016 juvenile pink salmon in the northern Bering Sea measured by the small vessel survey in August (a) and large vessel survey in September (b).

Note: The core geographic area covered consistently by both is identified by the polygon.

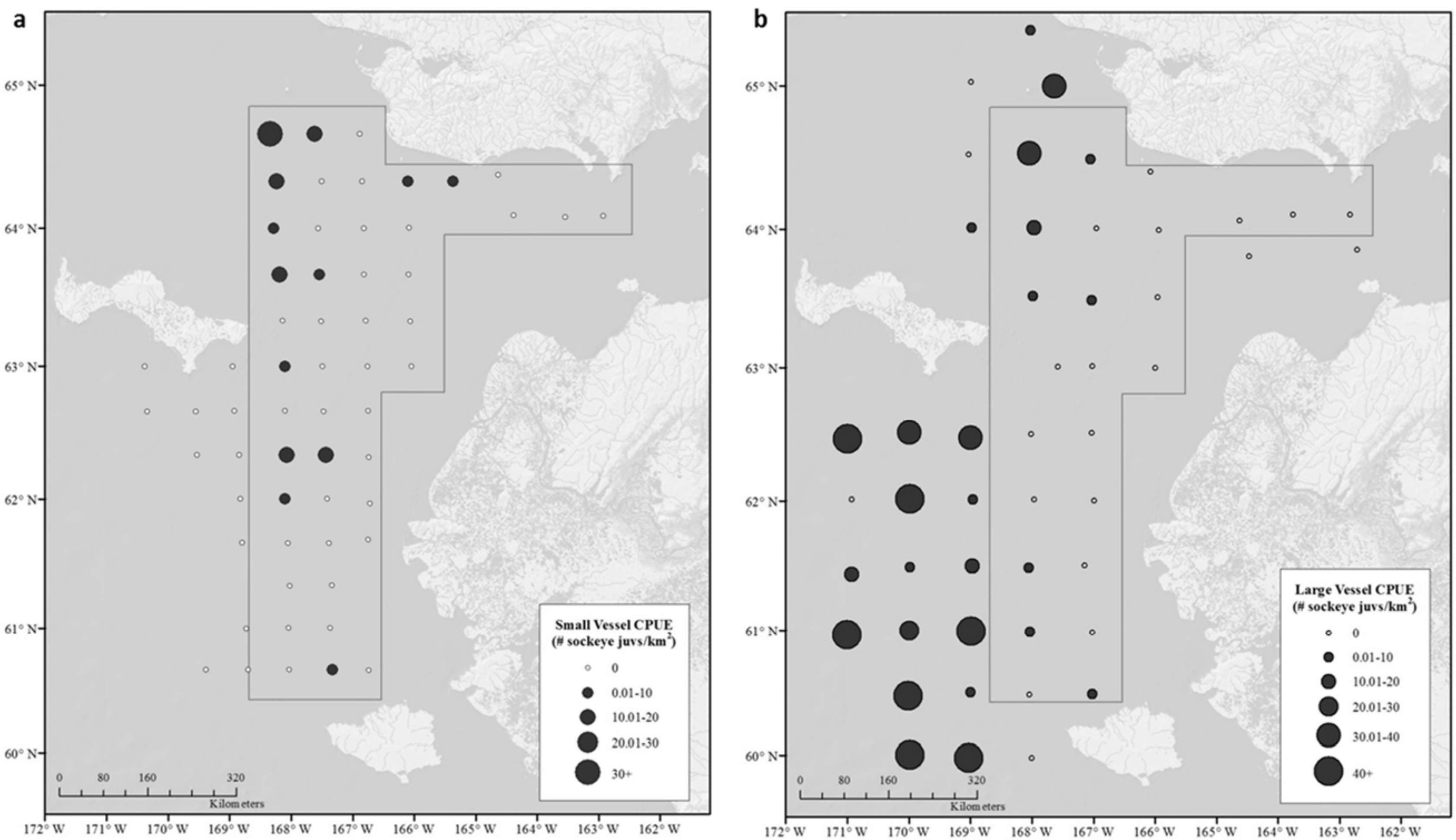

Figure 9.–Averaged spatial distribution of 2014–2016 juvenile sockeye salmon in the northern Bering Sea measured by the small vessel survey in August (a) and large vessel survey in September (b).

Note: The core geographic area covered consistently by both is identified by the polygon.

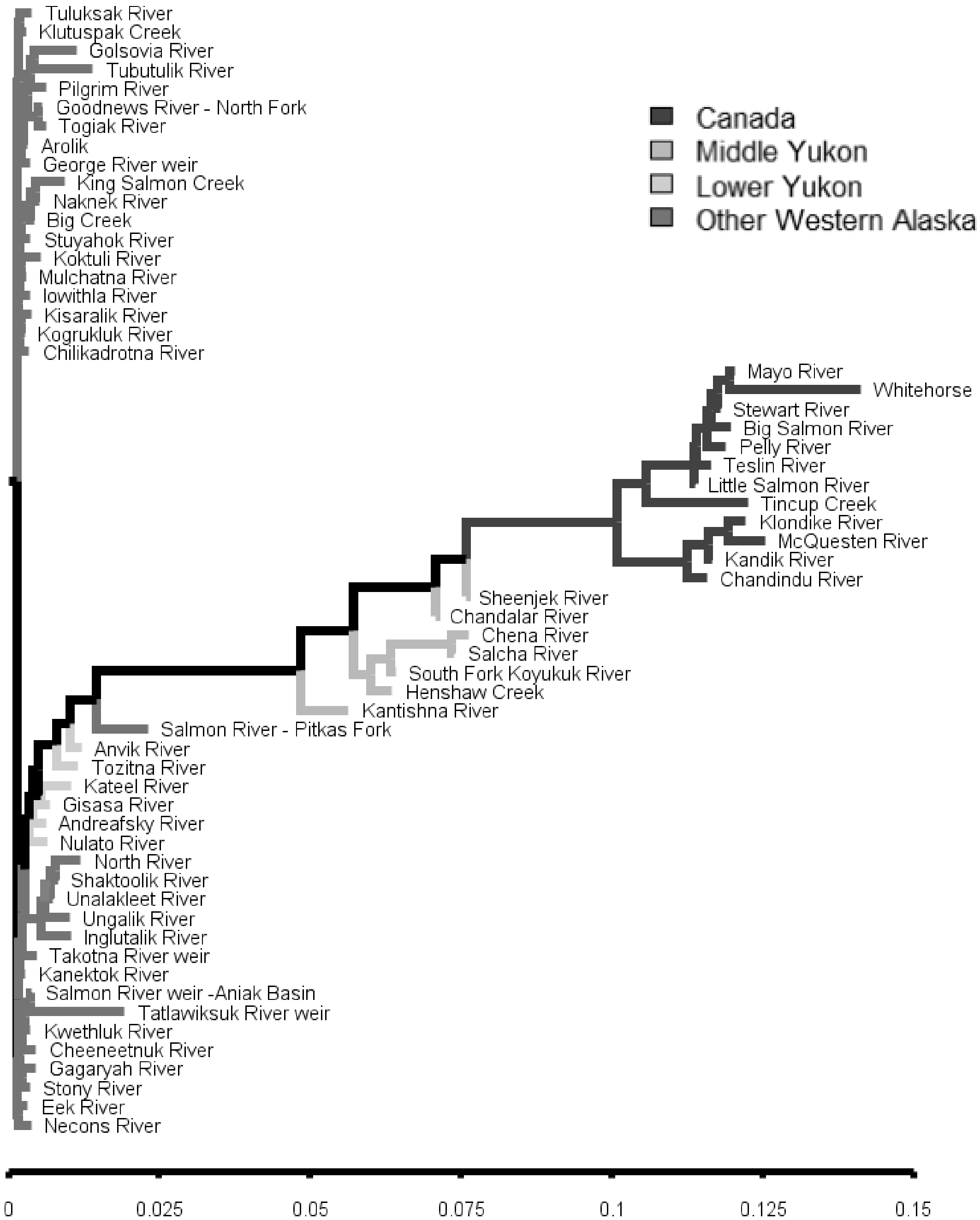

Figure 10.–Neighbor-Joining tree based upon Nei's distance between 60 populations of Chinook salmon included in the AYK Chinook salmon baseline. Tree branch colors denote reporting group affiliations of populations.

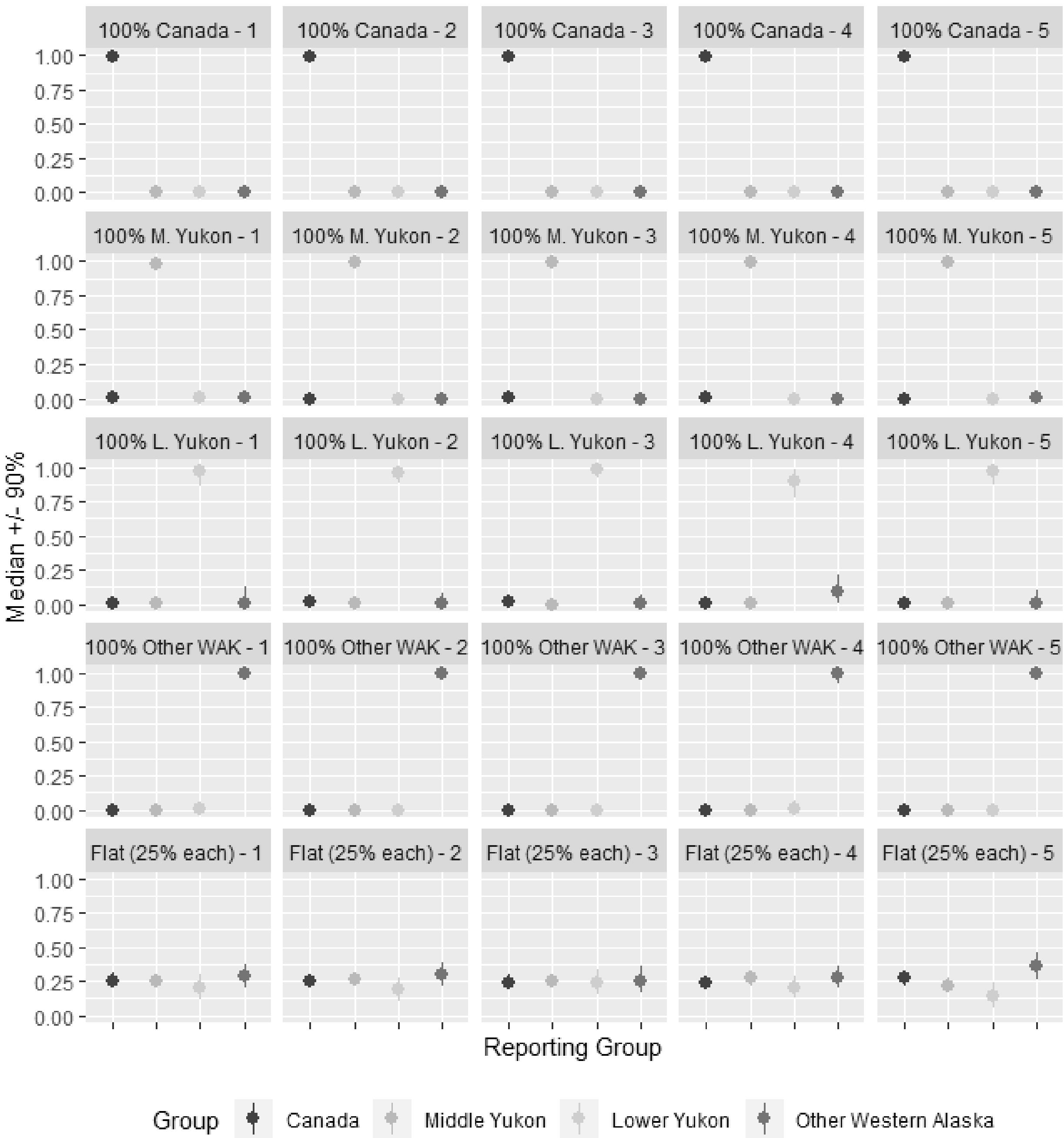

Figure 11.–Median (closed circles) and 90% credibility interval (bars) estimates for 5 replicates of baseline evaluation tests.

Note: In 4 sets of replicate tests, 200 known individuals were removed from the baseline populations that make up each reporting group (100% proof tests) and analyzed with the reduced baseline to assess correct allocations back to group of origin. In a fifth set or replicate tests, 50 known individuals were removed from baseline populations from each of the 4 reporting groups (25% each reporting group, flat proof test).

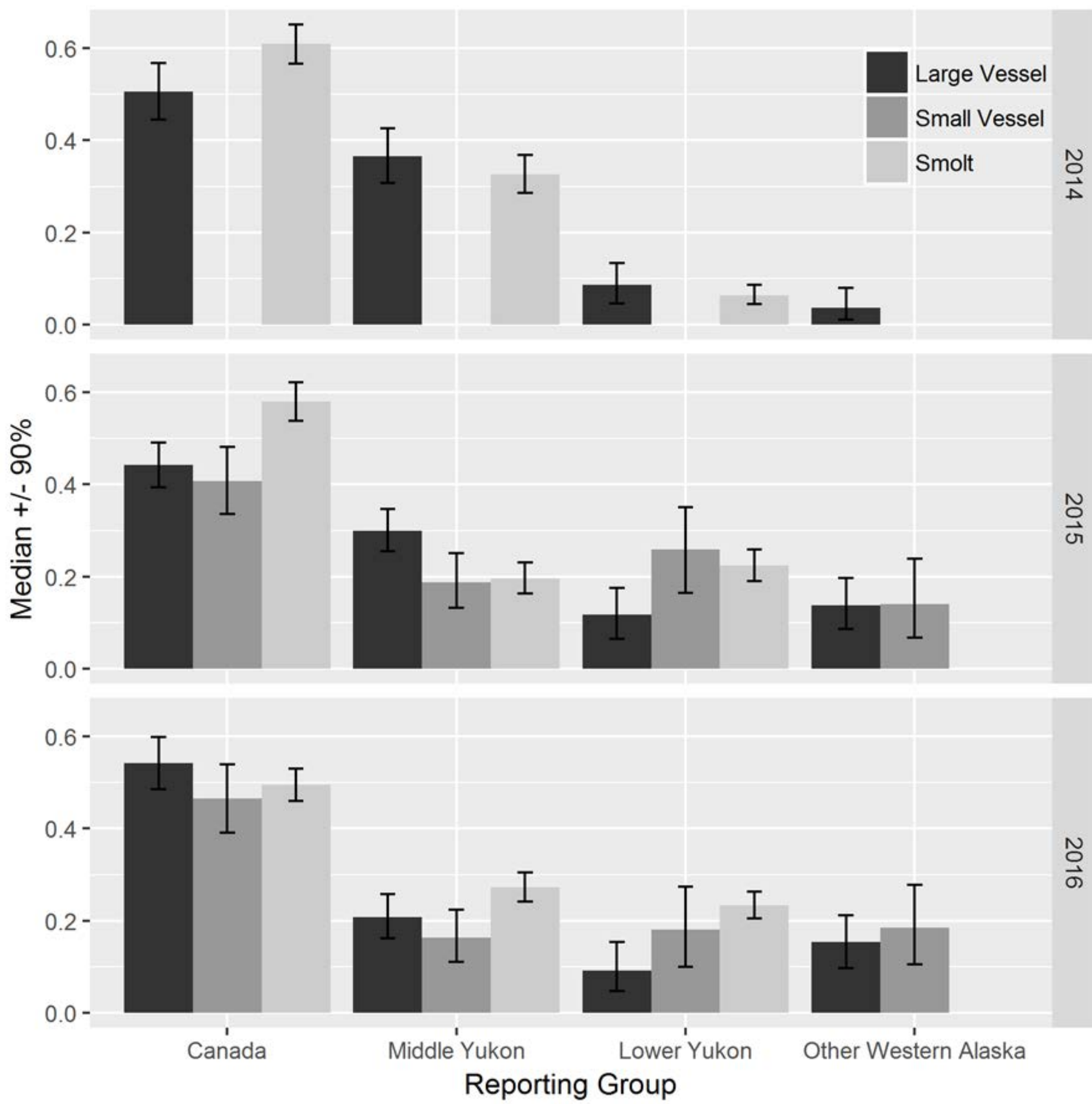

Figure 12.–Genetic stock composition (median +/- 90% credibility interval) of juvenile Chinook salmon sampled from large and small vessel surveys and the Yukon River Delta (smolt) in 2014–2016.

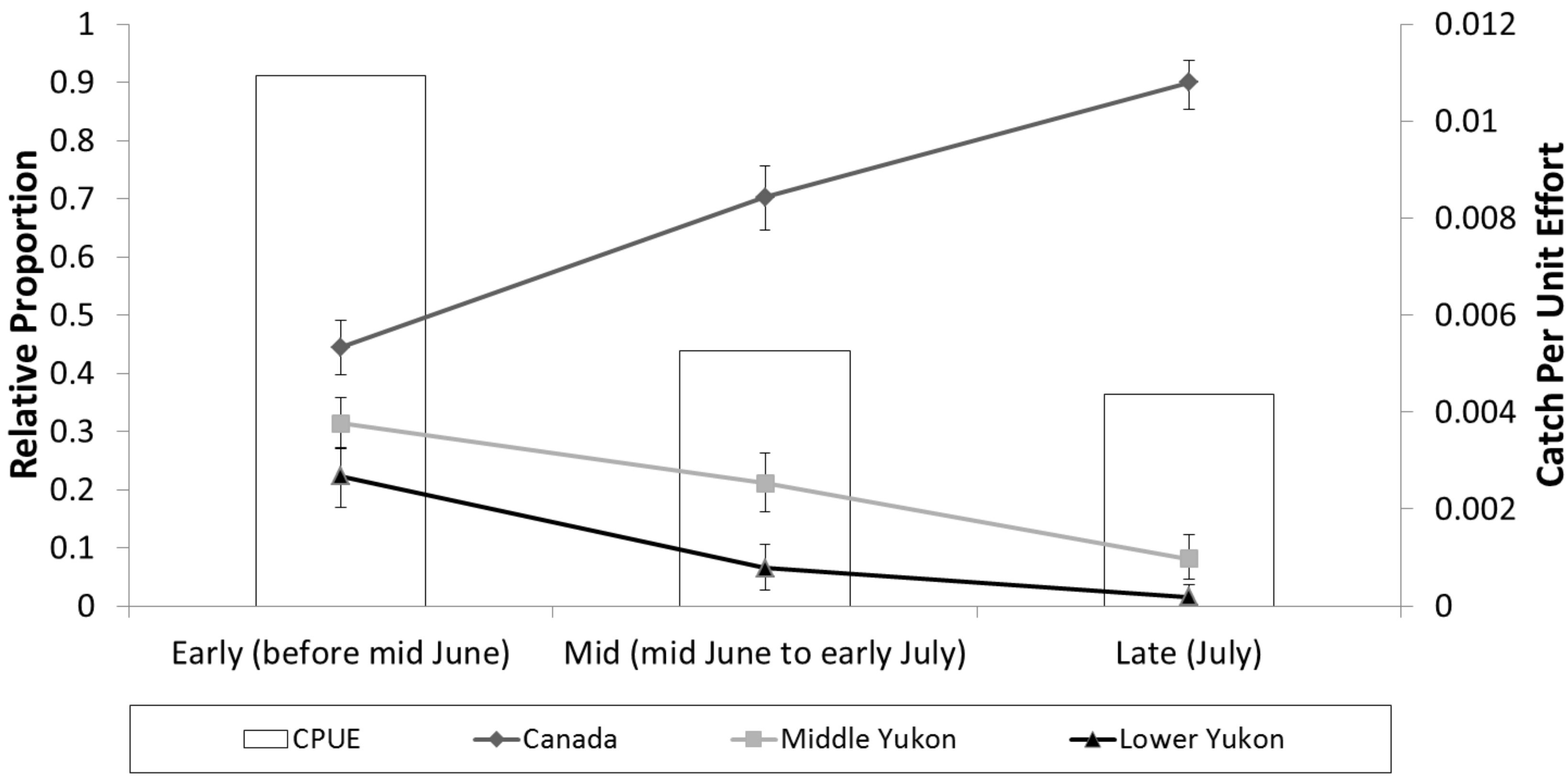

Figure 13.–Catch per unit effort of emigrating Yukon River Chinook salmon smolt in 2014–2016 depicted by open bars across 3 time periods (right y-axis).

Note: Genetic stock composition of Yukon River Chinook salmon smolt across 3 time periods, assigned to Canadian, Middle and Lower Yukon reporting groups as indicated by lines and left y-axis. Proportions of Canadian-origin smolt were largest in all time periods, with proportion increasing across the summer. Abundance of emigrating smolt, however, was largest in the early time period and declined across the summer.

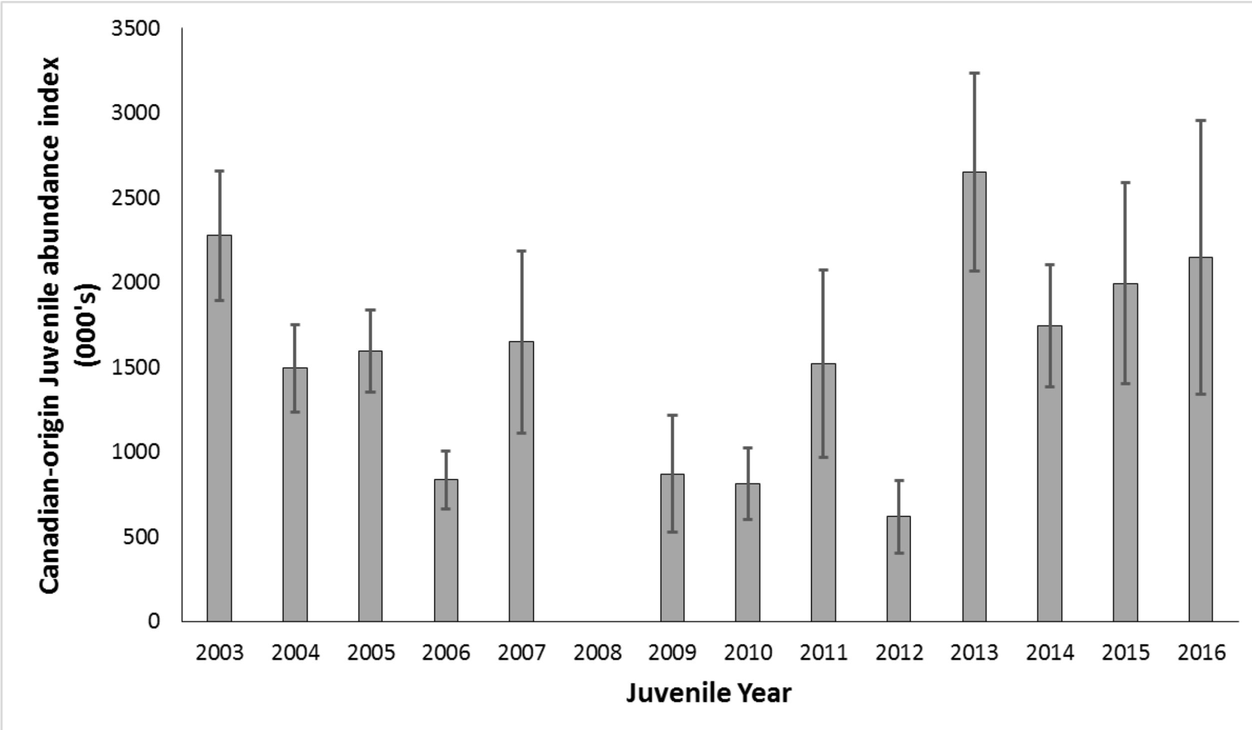

Figure 14.–Index of juvenile Canadian-origin Chinook salmon abundance in each northern Bering Sea survey year with the large vessel/trawl platform.

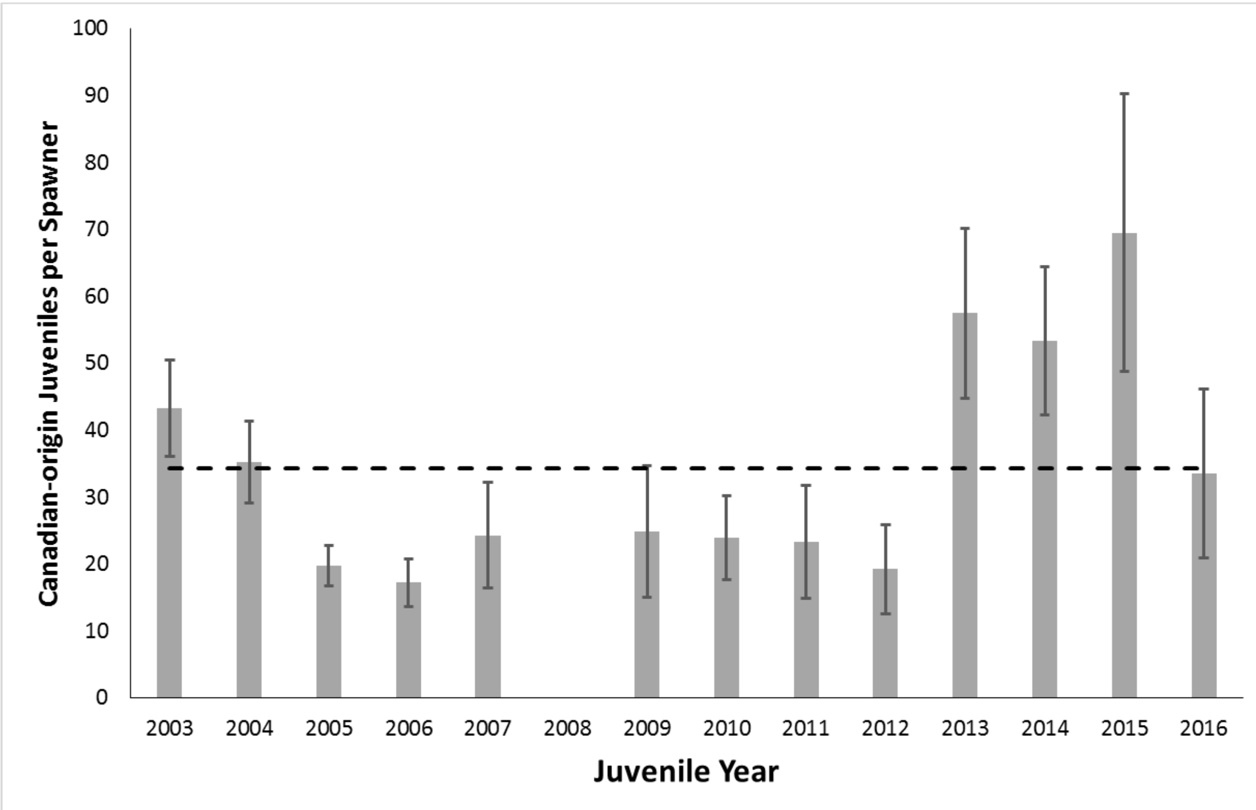

Figure 15.–Ratio of juveniles per spawner for Canadian-origin Yukon juvenile Chinook salmon.

Note: Dashed line indicates the average estimated juvenile per spawner across survey years.

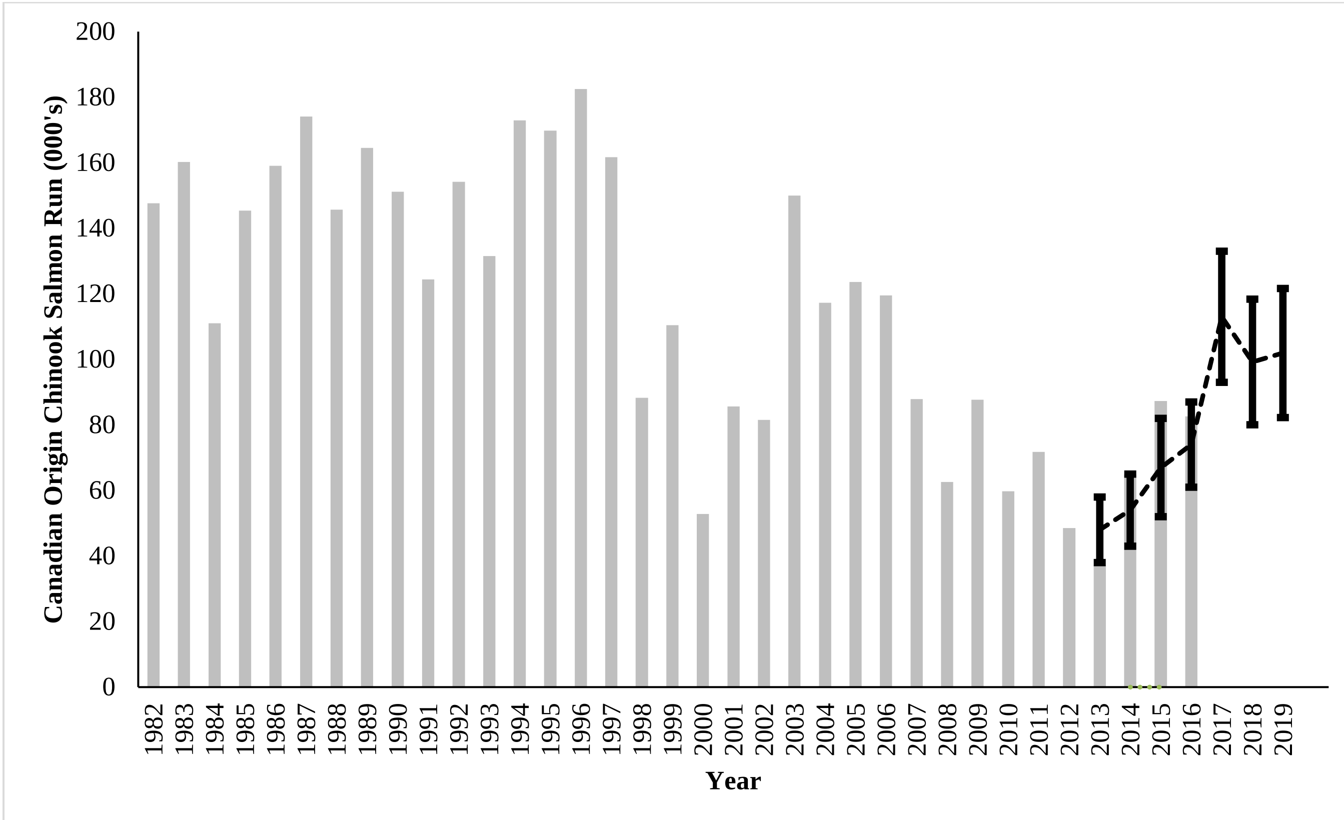

Figure 16.–Adult run size of Canadian-origin Chinook salmon (grey bars) and projected run size based on juvenile abundance forecast (black dashed line and error bars indicating forecast range).

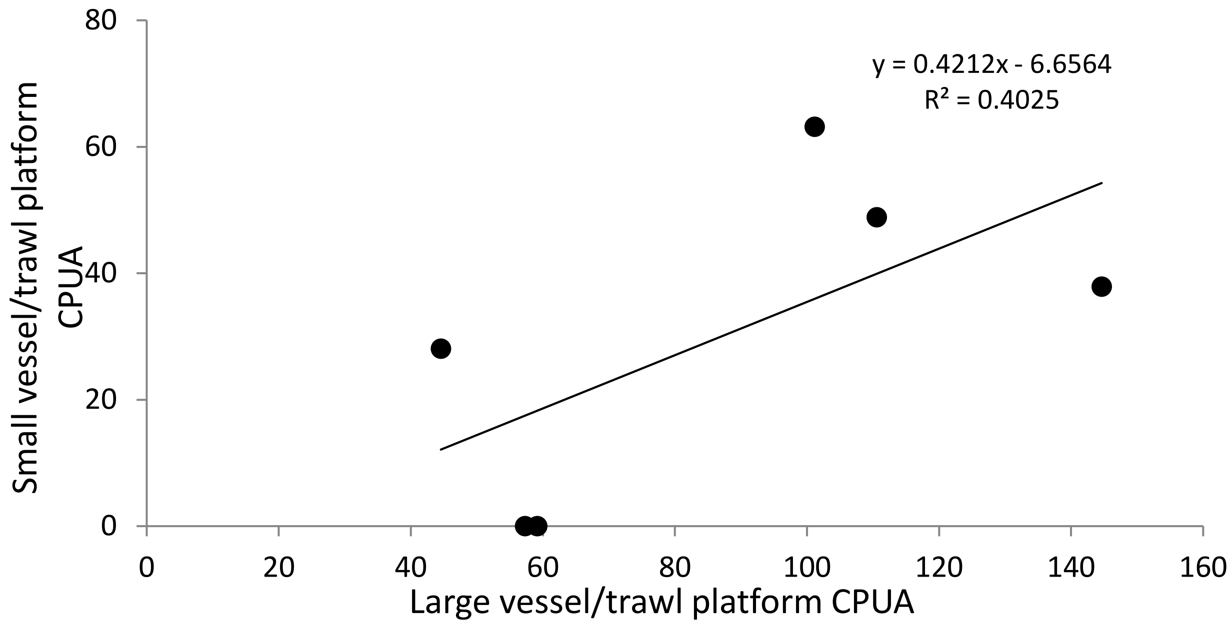

Figure 17.–Relationship of juvenile Chinook salmon CPUA captured in each of the survey platforms during 6 paired tows in 2014.

Note: Caveats regarding 2014 fishing efficiency on the small vessel platform due to inexperience with the gear and less powerful engines compared to subsequent year sampling.

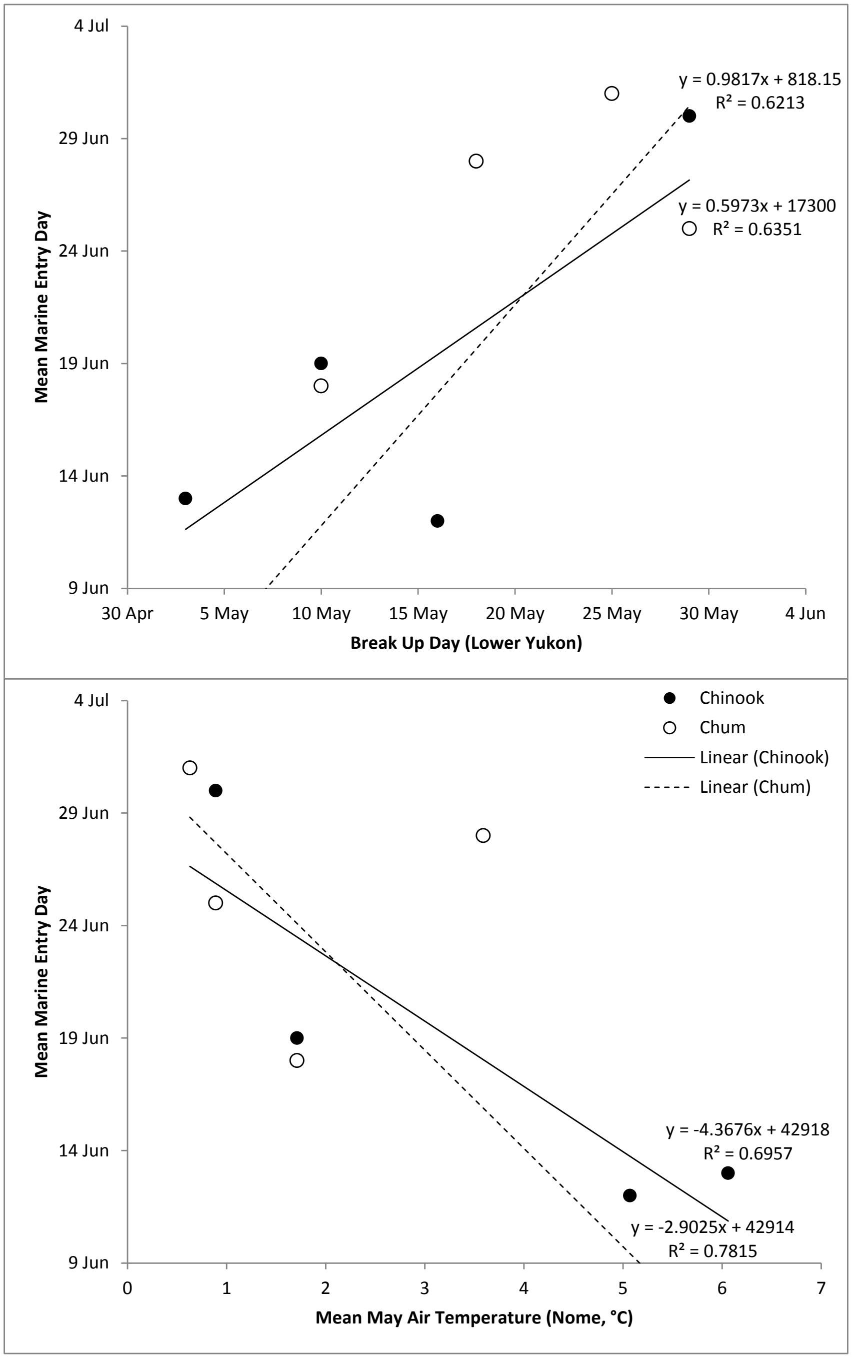

Figure 18.–Mean marine entry day for Yukon River Chinook (closed circles) and chum (open circles) salmon associated with ice break up day in the Lower Yukon River (a) and mean spring air temperature measured at Nome Airport (b).

Note: Mean marine entry day compiled from Vega et al. (2017), Howard et al. (2017), and Miller et al unpublished data. Ice breakup date from Lower Yukon community of Alakanuk (or Emmonak when Alakanuk unavailable) http://www.weather.gov/aprfc/breakupDB.

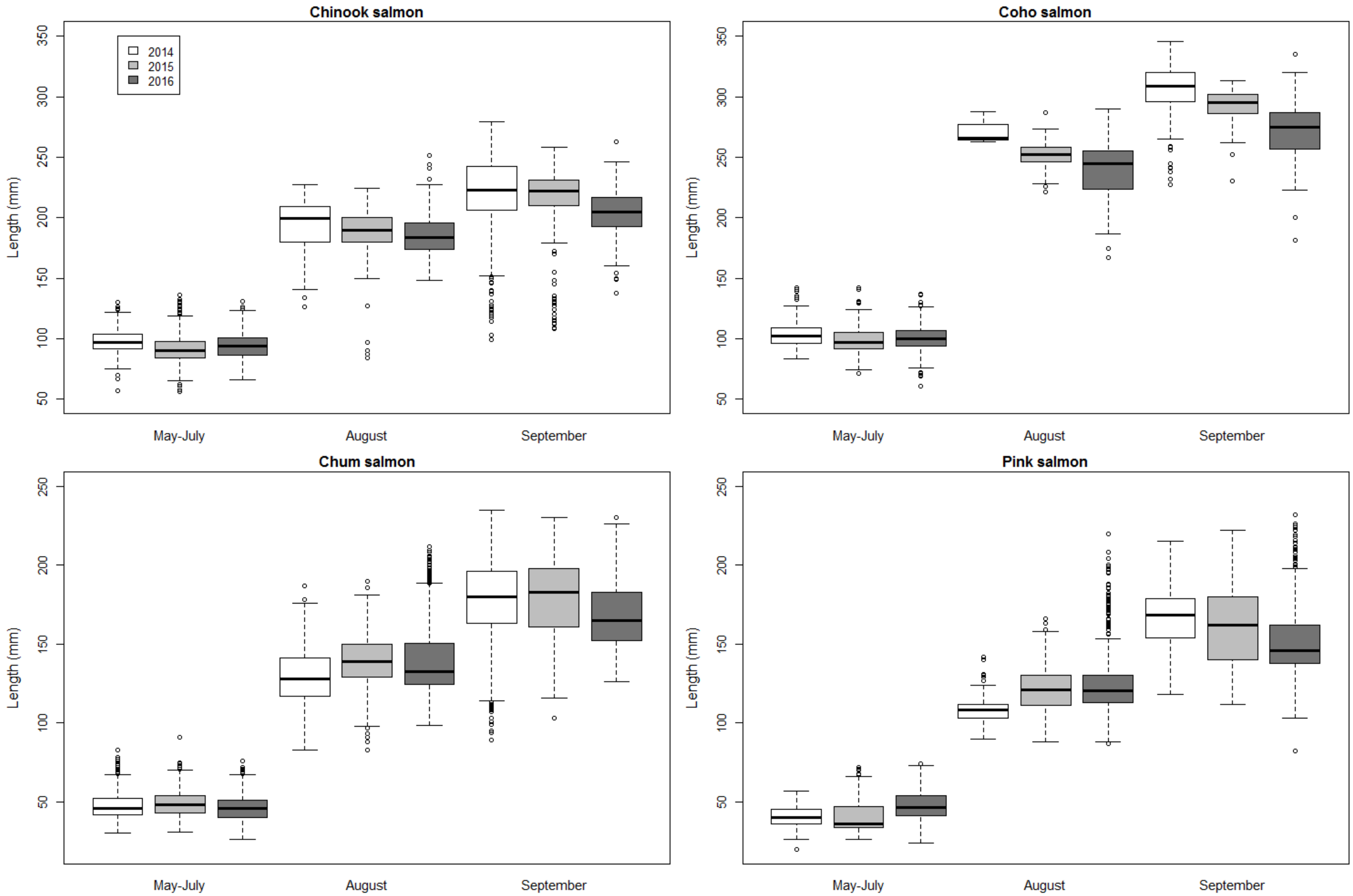

Figure 19.–Length changes as an indicator of growth from May to July, August, and September sampling for Chinook, coho, chum and pink salmon, 2014–2016.

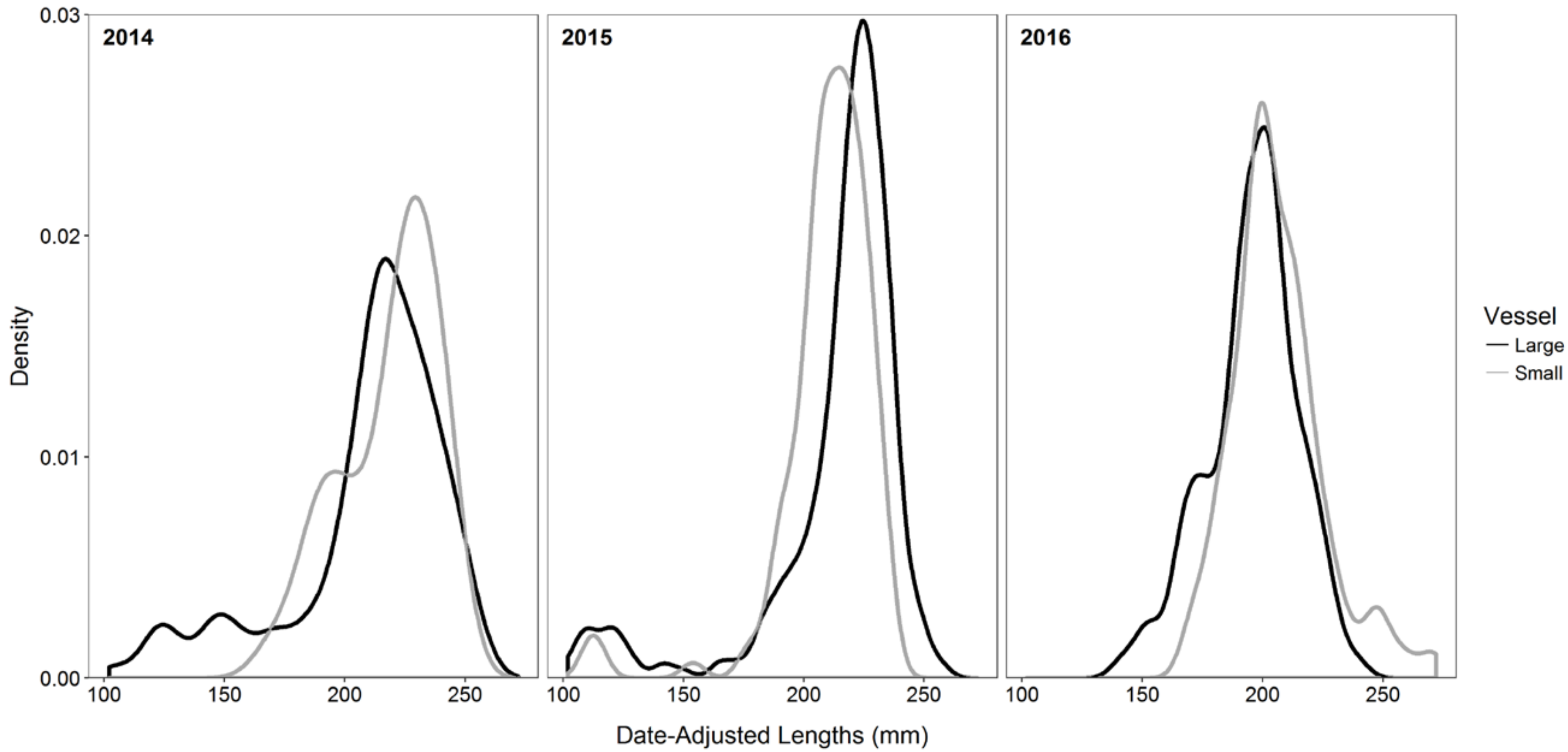

Figure 20.–Density plots of date-adjusted juvenile Chinook salmon lengths from common area stations sampled by large and small vessel platforms in the northeastern Bering Sea, 2014–2016.

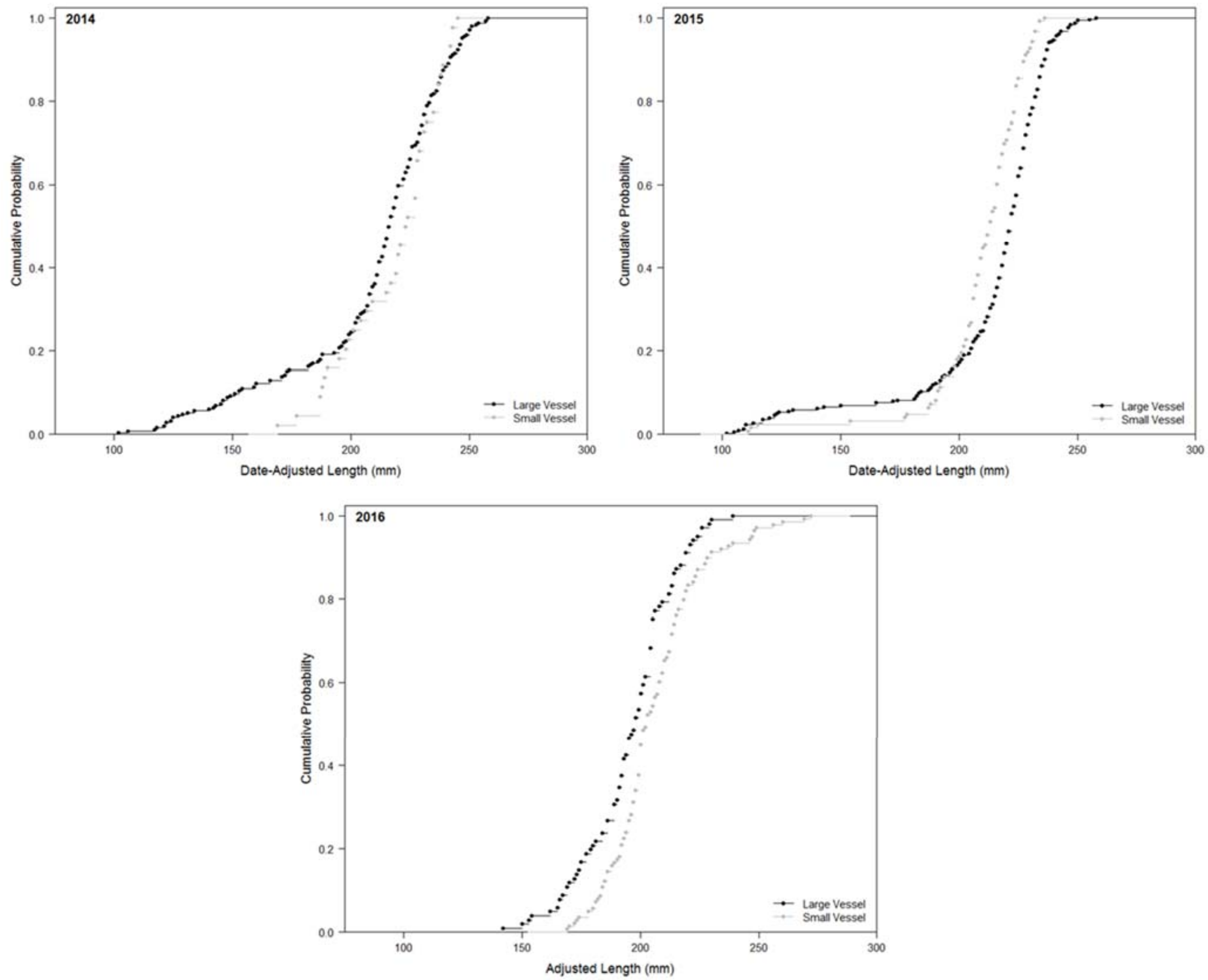

Figure 21.–Cumulative distribution functions of date-adjusted juvenile Chinook salmon lengths from common area stations sampled by large and small vessel platforms in the northeastern Bering Sea, 2014–2016.

APPENDIX A

Appendix A1.–Data by trawl station (Stn) for the R/V *Pandalus* survey in 2014.

Stn	Date (AKST)	Time (AKST)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Haul type	Gear perf.	MLD
1	8/8	1118	61.34	-167.34	61.37	-167.38	4.10	137	18	23	S	S	24
2	8/8	1506	61.00	-167.37	60.98	-167.37	2.19	137	16	21	S	S	23
3	8/8	1846	60.67	-167.34	60.66	-167.36	1.92	137	15	23	S	S	25
4	8/9	1057	60.67	-166.74	60.69	-166.77	2.82	137	17	21	S	S	23
5	8/9	1607	60.67	-168.04	60.66	-168.00	2.08	137	8	27	S	U	29
6	8/9	1927	61.00	-168.05	60.98	-168.04	1.85	137	15	28	S	S	10
7	8/10	0650	61.33	-168.02	61.30	-167.99	4.04	137	18	27	S	S	10
8	8/10	1058	61.67	-168.06	61.68	-168.09	2.34	137	16	27	S	S	13
9	8/10	1456	61.67	-167.39	61.67	-167.33	3.34	137	16	23	S	S	9
10	8/10	1826	61.69	-166.75	61.67	-166.75	2.62	137	16	19	S	S	8
11	8/11	0732	61.97	-166.72	61.98	-166.70	2.07	137	16	19	S	S	6
12	8/11	1129	62.32	-166.74	62.34	-166.73	2.37	137	15	20	S	S	7
13	8/11	1454	62.67	-166.75	62.69	-166.75	2.77	137	16	24	S	S	6
14	8/11	1803	63.00	-166.76	62.99	-166.72	2.35	137	18	27	S	S	6
15	8/12	0656	63.00	-166.05	62.98	-166.03	2.24	137	18	20	S	S	6
16	8/12	1032	63.33	-166.07	63.31	-166.04	2.58	137	17	21	S	S	6
17	8/12	1425	63.67	-166.10	63.69	-166.10	2.48	137	18	25	S	U	6
18	8/12	1826	64.00	-166.09	63.99	-166.06	2.13	137	18	22	S	S	6
19	8/13	1034	64.33	-166.11	64.32	-166.07	2.38	137	17	22	S	S	6
20	8/13	1508	64.00	-166.82	63.99	-166.78	2.52	137	18	31	S	S	8
21	8/13	1841	63.67	-166.82	63.69	-166.85	2.83	137	18	27	S	S	11
22	8/14	0654	63.33	-166.79	63.33	-166.84	2.47	137	18	25	S	S	6
23	8/14	1117	63.00	-167.50	63.01	-167.46	2.49	137	17	32	S	S	12
24	8/14	1500	62.67	-167.48	62.67	-167.51	1.83	137	17	26	S	S	16
25	8/14	1830	62.33	-167.44	62.35	-167.48	2.59	137	16	25	S	S	14
26	8/15	0702	62.00	-167.42	62.02	-167.42	2.50	137	17	24	S	S	11
27	8/15	1015	62.00	-168.10	62.00	-168.06	2.08	137	17	26	S	S	15
28	8/15	1519	62.00	-168.83	62.02	-168.85	2.29	137	16	35	S	S	15
29	8/15	1849	62.33	-168.85	62.35	-168.82	2.44	137	18	33	S	S	21
30	8/16	0709	62.67	-169.55	62.67	-169.60	2.47	137	18	39	S	S	20
31	8/16	1035	62.33	-169.54	62.34	-169.50	1.98	137	18	35	S	S	23
32	8/16	1520	62.67	-170.35	62.68	-170.38	1.94	137	17	40	S	S	14
33	8/16	1850	63.00	-170.38	63.01	-170.40	1.97	137	18	37	S	S	15
34	8/17	0723	63.00	-168.95	63.02	-168.96	2.19	137	17	27	S	S	11
35	8/17	1049	62.67	-168.92	62.69	-168.93	2.36	137	18	35	S	S	26
36	8/17	1542	62.33	-168.08	62.34	-168.11	1.94	137	20	29	S	S	14
37	8/17	1944	62.67	-168.10	62.69	-168.13	2.29	137	20	31	S	S	19
38	8/18	0845	63.00	-168.11	63.00	-168.16	2.46	137	11	31	S	U	14
39	8/18	1306	63.33	-167.52	63.31	-167.52	2.09	137	17	31	S	S	11
40	8/25	1108	64.33	-166.85	64.33	-166.80	2.45	137	19	28	S	S	6
41	8/25	1531	64.00	-167.56	64.02	-167.57	2.75	137	18	33	S	S	13
42	8/25	1909	63.67	-167.55	63.67	-167.60	2.58	137	17	27	S	S	12
43	8/26	0713	63.33	-168.15	63.33	-168.10	2.37	137	18	23	S	S	10
44	8/26	1041	63.67	-168.19	63.65	-168.19	2.28	137	18	31	S	S	11

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Stn	Date (AKST)	Time (AKST)	Start lat. (DD)	Start lon. (DD)	End lat. (DD)	End lon. (DD)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Haul type	Gear perf.	MLD
45	8/26	1418	64.00	-168.29	63.98	-168.26	2.58	137	19	34	S	S	12
46	8/26	1753	64.33	-168.24	64.32	-168.27	2.41	137	19	35	S	S	10
47	8/27	0724	64.33	-167.51	64.36	-167.51	3.00	137	19	29	S	S	9
48	8/27	1129	64.67	-168.35	64.65	-168.34	1.96	137	18	38	S	S	10
49	8/27	1441	64.67	-167.62	64.66	-167.67	2.33	137	18	30	S	S	7
50	8/27	1814	64.67	-166.89	64.66	-166.85	2.23	137	18	23	S	S	6
51	8/28	0833	64.33	-165.38	64.34	-165.33	2.44	137	18	23	S	S	6
52	8/28	1449	64.38	-164.64	64.38	-164.61	1.90	137	19	27	S	S	8
53	8/29	0929	64.09	-162.93	64.10	-162.97	2.17	137	20	21	S	S	10
54	8/30	0803	64.08	-163.55	64.09	-163.52	2.16	137	16	21	S	S	13
55	8/30	1214	64.09	-164.39	64.09	-164.41	1.13	137	18	20	S	U	6
56	9/5	0804	63.99	-165.989	63.97	-165.957	2.64	137	18	20	PT	S	[a]
57	9/5	1100	63.87	-165.918	63.84	-165.923	2.84	137	16	21	PT	S	[a]
58	9/5	1307	63.77	-166.001	63.75	-166.005	2.59	137	12	24	PT	S	[a]
59	9/5	1446	63.69	-166.005	63.67	-166.008	2.51	137	12	24	PT	S	[a]
60	9/5	1707	63.62	-166.018	63.6	-166.014	2.20	137	13	23	PT	S	[a]
61	9/5	1901	63.54	-166.014	63.52	-166.004	2.51	137	12	23	PT	S	[a]

Note: Date and time recorded in Alaska Standard Time (AKST); latitude (Lat.) and longitude (Lon.) of start and end of trawling recorded in decimal degrees (dd); trawl distance (Dist.) recorded in kilometers; warp, average footrope (FR) depth and bottom depth recorded in meters; haul type S represents standard surface trawl and PT represents paired trawl; gear performance (perf.) noted as good (G), satisfactory (S), or unsatisfactory (U); mixed layer depth (MLD) defined in meters.

[a] CTD casts not performed at this station, therefore no MLD estimate available.

Appendix A2.–Data by trawl station (Stn) for the R/V *Pandalus* survey in 2015.

Stn	Date (AKST)	Time (AKST)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Gear perf.	MLD
1	8/10	1100	64.33	-166.11	64.33	-166.05	2.85	183	12	22	G	13
2	8/10	1430	64.33	-165.38	64.33	-165.34	2.13	183	10	23	G	13
3	8/10	1823	64.39	-164.56	64.40	-164.51	2.59	183	12	21	S	7
4	8/11	0744	64.10	-162.94	64.12	-162.93	2.23	183	12	22	G	10
5	8/11	1310	64.08	-163.56	64.10	-163.54	2.40	183	13	21	G	9
6	8/11	1715	64.10	-164.40	64.12	-164.43	3.05	183	13	20	G	7
7	8/14	0849	64.00	-166.09	64.01	-166.04	2.74	183	12	22	G	10
8	8/14	1229	63.66	-166.10	63.64	-166.13	2.89	183	14	25	G	27
9	8/14	1545	63.67	-166.83	63.66	-166.88	2.64	183	17	27	G	15
10	8/14	1915	64.00	-166.84	64.00	-166.89	2.81	183	16	31	G	21
11	8/15	0719	64.00	-167.56	64.00	-167.62	2.84	183	15	33	G	22
12	8/15	1012	64.00	-168.30	64.01	-168.35	2.86	183	15	34	G	17
13	8/15	1457	64.33	-167.51	64.34	-167.57	2.61	183	14	29	G	21
14	8/16	1827	64.33	-166.86	64.33	-166.92	2.95	183	13	27	G	12
15	8/16	0735	64.67	-166.90	64.67	-166.95	2.72	183	13	23	G	12
16	8/16	1027	64.67	-167.62	64.67	-167.68	2.64	183	13	29	G	23
17	8/16	1334	64.67	-168.35	64.69	-168.39	2.81	183	17	38	G	8
18	8/16	1721	64.33	-168.24	64.36	-168.25	2.87	183	17	36	G	15
19	8/17	1753	63.33	-166.07	63.31	-166.09	2.62	183	13	22	G	9
20	8/18	0904	61.96	-166.72	61.93	-166.72	2.81	183	14	20	G	14
21	8/18	1204	61.67	-166.79	61.64	-166.77	3.00	183	15	19	G	22
22	8/18	2006	60.67	-166.75	60.66	-166.72	2.02	183	11	20	G	23
23	8/19	0942	60.67	-167.34	60.67	-167.39	2.68	183	16	22	G	25
24	8/19	1326	60.67	-168.02	60.67	-167.96	3.30	183	15	27	G	30
25	8/19	1757	60.67	-168.70	60.67	-168.66	2.28	183	13	35	G	17
26	8/19	2144	60.67	-169.39	60.67	-169.35	2.40	183	15	42	G	18
27	8/20	0736	61.00	-168.05	61.01	-168.10	2.86	183	15	28	G	30
28	8/20	1132	61.00	-167.37	61.02	-167.33	2.80	183	14	21	G	23
29	8/20	1556	61.36	-167.31	61.38	-167.27	2.85	183	15	22	G	25
30	8/20	2000	61.33	-168.03	61.34	-167.99	2.18	183	13	28	G	30
31	8/21	0740	61.00	-168.73	61.00	-168.78	2.77	183	15	33	G	13
32	8/21	1417	61.67	-168.06	61.68	-168.01	2.86	183	14	27	G	29
33	8/21	1845	61.67	-168.80	61.67	-168.75	2.62	183	14	35	S	22
34	8/22	0741	62.67	-166.75	62.68	-166.70	2.57	183	14	23	G	17
35	8/22	1150	63.02	-166.78	63.05	-166.80	2.58	183	15	27	G	19
36	8/22	1526	63.00	-166.06	63.02	-166.02	2.53	183	13	19	G	21
37	8/22	1959	63.34	-166.79	63.36	-166.78	2.59	183	16	25	G	21
38	8/23	0738	63.33	-167.52	63.36	-167.53	2.71	183	16	31	G	11
39	8/23	1035	63.33	-168.14	63.33	-168.19	2.52	183	17	23	G	6
40	8/23	1426	63.67	-168.19	63.69	-168.19	2.84	183	17	30	G	10
41	8/23	1727	63.67	-167.54	63.68	-167.50	3.01	183	17	27	G	6

Note: Date and time recorded in Alaska Standard Time (AKST); latitude (Lat.) and longitude (Lon.) of start and end of trawling recorded in decimal degrees (dd); trawl distance (Dist.) recorded in kilometers; warp, average footrope (FR) depth and bottom depth recorded in meters; gear performance (perf.) noted as good (G), satisfactory (S), or unsatisfactory (U); mixed layer depth (MLD) defined in meters.

Appendix A3.–Data by trawl station (Stn) for the R/V *Pandalus* survey in 2016.

Stn	Date (AKST)	Time (AKST)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Gear perf.	MLD
1	8/7	1541	64.33	-165.38	64.32	-165.44	2.95	183	10	22	G	7
2	8/9	0705	61.66	-166.86	61.63	-166.85	2.79	183	10	21	G	16
3	8/9	1439	60.67	-166.70	60.66	-166.63	3.69	183	9	19	G	9
4	8/9	1820	60.66	-167.35	60.65	-167.40	2.93	183	9	23	G	25
5	8/9	2115	60.66	-168.05	60.65	-168.11	3.33	183	11	27	S	10
6	8/10	0717	60.99	-168.02	60.97	-167.99	2.65	183	10	27	G	29
7	8/10	1040	61.00	-167.41	61.00	-167.47	3.12	183	11	21	S	22
8	8/10	1408	61.33	-167.35	61.34	-167.30	2.56	183	10	22	G	24
9	8/10	1758	61.32	-168.00	61.31	-167.97	2.83	183	11	27	G	29
10	8/11	0704	61.66	-168.04	61.64	-168.00	2.78	183	11	27	G	13
11	8/11	1001	61.65	-167.42	61.63	-167.43	2.26	183	10	22	G	24
12	8/11	1400	61.95	-166.79	61.98	-166.80	2.74	183	11	21	G	20
13	8/11	1707	62.01	-167.38	62.02	-167.32	3.22	183	11	24	G	11
14	8/12	0721	62.00	-168.07	62.00	-168.02	2.74	183	10	27	G	16
15	8/12	1051	62.00	-168.80	62.00	-168.86	2.99	183	10	34	G	16
16	8/12	1527	62.33	-168.11	62.34	-168.16	2.65	183	10	29	G	11
17	8/12	1843	62.33	-167.43	62.33	-167.37	3.05	183	11	25	G	7
18	8/13	0709	62.99	-166.07	62.97	-166.12	3.00	183	11	19	G	6
19	8/13	1102	63.31	-166.09	63.30	-166.09	1.31	183	11	21	G	9
20	8/13	1446	63.67	-166.12	63.66	-166.18	2.78	183	12	25	G	6
21	8/13	1820	64.00	-166.12	64.00	-166.18	2.79	183	11	22	S	6
22	8/16	0724	62.32	-166.75	62.29	-166.78	3.44	183	14	20	S	10
23	8/17	0723	62.66	-166.78	62.65	-166.83	2.96	183	14	24	G	6
24	8/17	1015	62.66	-167.50	62.64	-167.54	3.34	183	9	25	G	6
25	8/17	1310	62.66	-168.11	62.63	-168.10	2.80	183	11	31	G	11
26	8/17	1641	63.00	-168.09	63.00	-168.05	2.27	183	12	28	G	20
27	8/17	1925	63.00	-167.48	63.00	-167.43	2.48	183	11	33	G	8
28	8/18	0719	63.00	-166.79	63.00	-166.85	2.80	183	11	28	S	6
29	8/18	1031	63.33	-166.81	63.33	-166.86	2.56	183	11	25	G	6
30	8/18	1320	63.33	-167.50	63.31	-167.46	2.86	183	12	31	S	11
31	8/18	1640	63.33	-168.13	63.32	-168.09	2.48	183	11	24	S	15
32	8/21	0719	64.09	-162.92	64.08	-162.86	2.61	183	11	21	G	6
33	8/21	1038	64.08	-163.57	64.08	-163.61	2.28	183	11	22	G	8
34	8/21	1345	64.09	-164.41	64.08	-164.48	3.15	183	11	20	G	7
35	8/21	1655	64.38	-164.62	64.38	-164.69	3.26	183	11	26	G	9
36	8/24	0718	64.32	-166.09	64.30	-166.06	3.01	183	11	20	G	6
37	8/24	1040	64.33	-166.87	64.32	-166.93	2.79	183	11	28	G	6
38	8/24	1345	63.99	-166.84	63.97	-166.86	2.73	183	11	31	G	8
39	8/24	1638	63.66	-166.79	63.64	-166.74	2.97	183	11	27	G	17
40	8/24	2000	63.66	-167.53	63.64	-167.49	2.76	183	13	27	G	13
41	8/25	0718	64.01	-167.54	64.02	-167.50	2.73	183	11	33	G	12
42	8/25	1010	64.34	-167.48	64.35	-167.44	2.40	183	11	30	G	13
43	8/25	1300	64.67	-167.62	64.70	-167.64	3.21	183	14	30	G	12
44	8/25	1606	64.68	-166.89	64.71	-166.89	3.87	183	11	23	G	6
45	8/29	0747	64.66	-168.36	64.64	-168.38	2.54	183	12	38	G	21
46	8/29	1041	64.33	-168.23	64.31	-168.20	2.74	183	15	36	G	16
47	8/29	1351	64.00	-168.32	63.98	-168.37	2.81	183	13	34	G	12
48	8/29	1658	63.67	-168.22	63.67	-168.27	2.77	183	15	31	G	9

Note: Date and time recorded in Alaska Standard Time (AKST); latitude (Lat.) and longitude (Lon.) of start and end of trawling recorded in decimal degrees (dd); trawl distance (Dist.) recorded in kilometers; warp, average footrope (FR) depth and bottom depth recorded in meters; gear performance (perf.) noted as good (G), satisfactory (S), or unsatisfactory (U); mixed layer depth (MLD) defined in meters.

Appendix A4.–Data by trawl station (Stn) for the F/V *Alaskan Endeavor* survey in 2014.

Stn	Date (GMT)	Time (GMT)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Haul type	Gear perf.	MLD
1	9/4	1750	63.03	-167.61	63.05	-167.66	3.42	275	21	28	S	G	15
2	9/4	2230	63.53	-168.03	63.56	-168.10	4.17	275	23	33	S	G	12
3	9/5	0312	64.01	-167.92	64.01	-167.84	4.06	[a]	22	37	S	G	20
4	9/5	1644	63.99	-165.96	63.96	-165.91	3.97	[a]	22	24	S	G	9
5	9/5	1954	63.84	-165.96	63.81	-165.99	4.07	[a]	[b]	23	PT	G	[c]
6	9/5	2150	63.76	-166.05	63.73	-166.05	3.73	275	[b]	27	PT	G	[c]
7	9/5	2336	63.68	-166.07	63.65	-166.07	3.76	[a]	21	27	PT	G	[c]
8	9/6	0140	63.61	-166.03	63.57	-166.04	3.65	275	26	26	PT	G	[c]
9	9/6	0351	63.53	-166.02	63.49	-166.01	3.88	275	19	25	S	G	6
10	9/6	1651	63.02	-166.05	63.04	-166.11	3.68	320	16	21	S	G	6
11	9/6	2101	63.03	-167.01	63.06	-167.06	4.02	365	21	26	S	G	12
12	9/7	0108	63.53	-167.00	63.57	-167.00	4.10	365	24	26	S	G	7
13	9/7	0512	64.01	-166.94	64.00	-166.86	3.82	365	22	33	S	G	7
14	9/7	1637	64.11	-164.42	64.11	-164.34	3.84	331	16	21	S	G	6
15	9/7	2047	64.11	-163.44	64.12	-163.38	3.29	332	19	24	S	G	15
16	9/8	0111	64.13	-162.50	64.09	-162.50	4.24	332	14	19	S	G	7
17	9/8	0514	63.86	-162.72	63.86	-162.80	3.75	332	15	18	S	G	11
18	9/8	1703	63.80	-163.54	63.81	-163.63	4.15	332	17	17	S	U	9
19	9/8	2339	63.81	-164.48	63.84	-164.45	3.51	332	17	17	S	G	7
20	9/9	1612	64.41	-166.08	64.41	-166.16	4.06	275	28	25	S	G	8
21	9/9	2204	64.50	-167.10	64.48	-167.15	3.50	332	26	27	S	G	12
22	9/10	0207	64.54	-168.05	64.56	-168.12	4.29	349	26	36	S	G	19
24	9/10	1613	64.53	-169.04	64.54	-169.11	3.81	332	25	43	S	G	10
29	9/11	0254	65.03	-168.97	65.07	-168.98	4.19	332	27	51	S	G	8
30	9/11	1625	65.38	-167.97	65.36	-167.95	2.65	332	26	40	S	G	8
31	9/11	2113	64.97	-167.51	64.96	-167.57	3.47	332	26	26	M	U	6
32	9/14	1639	62.50	-167.07	62.50	-167.15	4.04	332	20	35	S	G	19
33	9/14	2042	62.50	-168.07	62.49	-168.14	3.62	332	25	29	S	G	24
34	9/15	0054	62.50	-169.04	62.50	-169.10	3.02	332	27	33	S	G	21
35	9/15	0513	62.46	-170.00	62.42	-170.00	3.91	332	29	37	S	G	23
36	9/15	1618	62.47	-171.00	62.43	-170.98	3.95	332	28	44	S	G	23
37	9/15	2059	62.01	-170.93	62.02	-170.86	3.74	332	10	50	S	U	27
38	9/16	0114	62.02	-169.94	62.05	-169.90	3.61	332	35	45	S	S	21
39	9/16	0553	62.01	-168.94	62.03	-168.89	3.39	332	23	38	S	G	18
40	9/16	1615	62.00	-167.94	62.03	-167.88	3.71	332	22	28	S	G	23
41	9/16	2026	61.98	-166.98	61.95	-166.96	3.43	332	23	30	S	G	26
42	9/17	0047	61.50	-167.04	61.48	-167.10	3.21	332	20	23	S	G	18
43	9/17	0501	61.49	-168.08	61.47	-168.14	4.06	332	24	30	S	G	24
44	9/17	1624	61.48	-169.04	61.44	-169.02	3.97	332	25	37	S	G	23
45	9/17	2135	61.48	-170.01	61.45	-170.02	3.60	332	26	47	S	G	22
46	9/18	0431	61.44	-170.93	61.41	-170.90	4.00	332	22	52	S	G	22
47	9/18	1716	60.97	-171.01	60.93	-170.99	3.80	332	25	57	S	G	22

-continued-

Stn	Date (GMT)	Time (GMT)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)	Avg. Fr depth (m)	Bottom depth (m)	Haul type	Gear perf.	MLD
48	9/19	0004	60.98	-170.0	61.0	-170.0	3.36	332	28	48	S	G	20
49	9/19	1638	60.98	-169.0	60.9	-168.9	4.25	332	26	38	S	G	28
50	9/19	2234	60.99	-168.0	61.0	-168.0	3.66	332	23	30	S	G	6
51	9/20	1648	60.97	-167.0	60.9	-167.0	4.10	332	23	23	S	G	9
52	9/20	2225	60.49	-168.1	60.5	-168.1	4.06	332	25	30	S	G	27
53	9/21	0246	60.50	-169.0	60.5	-169.1	3.38	332	23	40	S	G	29
54	9/21	1646	60.47	-170.0	60.4	-170.0	3.80	332	24	51	S	G	24
55	9/21	2136	60.00	-169.9	60.0	-169.9	3.48	332	25	55	S	S	18
56	9/22	0215	60.01	-168.9	60.0	-168.8	4.19	332	22	42	S	G	29
57	9/22	0554	59.97	-168.0	59.9	-168.0	4.07	332	18	27	S	G	17

Note: Date and time recorded in Greenwich Mean Time (GMT); latitude (Lat.) and longitude (Lon.) of start and end of trawling recorded in decimal degrees (dd); trawl distance (Dist.) recorded in kilometers; warp, average footrope (FR) depth and bottom depth recorded in meters; haul type S represents standard surface trawl, M represents midwater trawl, and PT represents paired trawl; gear performance (perf.) noted as good (G), satisfactory (S), or unsatisfactory (U); mixed layer depth (MLD) defined in meters.

[a] Warp length not recorded

[b] Footrope depth not recorded

[c] CTD casts not performed at this station, therefore no MLD estimate available.

Appendix A5.–Data by trawl station (Stn) for the F/V *Alaskan Endeavor* survey in 2015.

Stn	Date (GMT)	Time (GMT)	Start Lat. (dd)	Start Lon. (dd)	End Lat. (dd)	End Lon. (dd)	Trawl Dist. (km)	Warp (m)	Avg. FR Depth (m)	Bottom Depth (m)	Gear Perf.	MLD
1	9/1	19:14	59.99	-168.00	60.00	-168.06	3.19	274	23	25	G	22
2	9/2	00:07	60.00	-169.03	60.01	-169.10	3.82	274	24	39	G	20
3	9/2	04:33	60.01	-170.03	60.02	-170.10	3.97	274	26	54	G	24
4	9/2	21:11	60.52	-169.93	60.54	-169.86	4.52	274	28	49	G	26
5	9/3	01:43	60.51	-168.98	60.53	-168.94	3.18	274	27	35	G	23
6	9/3	16:48	60.51	-167.97	60.52	-167.91	3.27	274	22	28	G	24
7	9/3	21:00	60.50	-167.01	60.49	-167.05	2.48	274	23	27	G	23
8	9/4	01:42	61.00	-167.06	61.02	-167.12	4.04	274	20	20	G	19
9	9/4	17:05	61.00	-168.11	61.00	-168.20	4.67	274	25	27	G	24
10	9/4	20:46	60.99	-169.02	60.96	-169.06	3.14	274	23	37	G	17
11	9/5	01:32	60.99	-170.03	61.00	-170.10	3.59	274	21	46	G	26
12	9/5	16:21	61.50	-169.96	61.49	-169.89	3.74	274	15	45	G	22
13	9/5	23:04	61.51	-168.91	61.51	-168.83	4.55	274	22	34	G	13
14	9/6	02:49	61.50	-168.03	61.50	-168.10	3.66	274	19	28	G	25
15	9/6	16:49	61.52	-167.03	61.55	-167.05	4.21	274	17	22	G	18
16	9/6	21:00	61.98	-167.02	61.95	-167.05	3.70	274	19	28	G	25
17	9/7	01:36	61.99	-168.00	61.97	-168.03	3.29	274	20	28	G	24
18	9/7	16:42	62.52	-168.00	62.55	-168.00	3.47	274	25	28	S	14
19	9/7	21:26	62.52	-167.04	62.54	-167.10	3.97	274	28	33	G	11
20	9/8	03:57	62.98	-165.97	62.94	-165.97	3.79	274	21	22	G	16
21	9/9	18:20	63.02	-167.06	63.01	-167.14	3.98	274	22	25	G	22
22	9/10	01:40	62.99	-167.56	62.96	-167.55	3.68	274	21	30	G	19
23	9/11	17:06	62.01	-170.03	62.02	-170.10	3.74	274	18	45	G	30
24	9/11	21:35	61.99	-168.99	61.96	-168.95	3.91	274	18	38	G	29
25	9/12	03:08	62.48	-168.99	62.45	-168.94	3.60	274	22	33	G	29
26	9/12	16:45	63.51	-167.99	63.48	-168.01	3.47	274	22	32	S	28
27	9/12	21:02	63.48	-167.02	63.44	-167.03	3.80	274	12	25	G	14
28	9/13	01:36	63.52	-165.96	63.55	-165.91	4.20	274	20	25	G	18
29	9/13	16:50	64.01	-168.00	63.98	-168.01	3.27	274	17	37	S	10
30	9/13	21:06	64.02	-167.00	64.06	-166.98	4.12	274	22	33	G	9
31	9/14	16:44	64.01	-166.02	64.02	-165.96	3.75	274	21	23	G	11
32	9/14	22:04	64.06	-164.65	64.07	-164.60	3.27	274	15	20	G	8
33	9/15	01:35	64.11	-163.80	64.12	-163.73	3.62	274	22	21	G	6
34	9/15	05:20	64.10	-162.88	64.11	-162.95	3.45	274	19	22	G	10
35	9/15	17:47	64.49	-167.02	64.46	-167.05	3.68	274	20	27	G	16
36	9/16	00:09	64.99	-167.71	64.97	-167.70	3.16	274	24	36	G	8
37	9/16	04:41	65.36	-168.03	65.33	-168.05	3.62	274	21	41	G	14

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

Appendix A6.–Data by trawl station (Stn) for the F/V *Cape Flattery* survey in 2016.

Stn	Date (GMT)	Time (GMT)	Start lat. (dd)	Start lon. (dd)	End lat. (dd)	End lon. (dd)	Trawl dist. (km)	Warp (m)		Avg. Fr depth (m)	Bottom depth (m)	Gear perf.	MLD
1	8/28	05:06	59.98	-170.04	59.97	-170.06	1.33	294		25	50	U	25
2	8/28	16:11	59.98	-169.04	59.96	-169.10	3.87	297		26	37	G	23
3	8/28	23:02	59.98	-168.02	59.96	-168.05	3.01	315		24	21	G	17
4	8/29	05:11	60.48	-167.03	60.46	-167.08	3.88	297		22	24	G	21
5	8/29	16:32	60.47	-168.06	60.44	-168.11	4.23	250		20	25	G	20
6	8/29	21:50	60.52	-168.98	60.55	-168.95	3.59	255		17	34	S	12
7	8/30	03:57	60.49	-170.04	60.47	-170.08	3.42	285		17	46	G	8
8	8/30	15:48	61.03	-169.97	61.06	-169.93	4.14	284		24	43	G	10
9	8/30	20:20	61.02	-168.98	61.05	-168.95	3.58	265		23	32	G	16
10	8/31	01:25	60.98	-168.01	60.95	-168.03	3.61	285		20	24	G	20
11	8/31	06:05	60.99	-167.01	60.97	-167.05	3.20	285		24	19	G	17
12	8/31	16:32	61.51	-167.26	61.54	-167.24	3.68	201		24	19	G	12
13	8/31	20:53	61.48	-168.04	61.46	-168.10	3.72	285		25	24	G	9
14	9/1	01:26	61.52	-168.98	61.55	-168.95	4.08	284		25	31	G	8
15	9/1	15:57	61.53	-170.01	61.56	-169.99	3.61	285		42	42	U	15
16	9/1	22:32	62.02	-169.99	62.00	-169.94	3.37	180		25	41	G	20
17	9/2	04:29	62.53	-170.00	62.56	-170.04	3.78	-	[a]	27	32	G	14
18	9/2	16:34	62.03	-168.95	62.06	-168.90	3.73	-	[a]	28	33	G	14
19	9/2	21:21	62.03	-167.98	62.07	-167.97	3.76	262		27	23	G	11
20	9/3	02:27	62.04	-166.97	62.08	-166.97	4.44	240		17	25	G	7
21	9/6	01:56	62.45	-168.96	62.42	-168.96	3.74	250		20.5	28	G	15
22	9/7	23:14	62.50	-167.99	62.46	-167.98	3.99	200		24	25	G	18
23	9/8	05:03	62.52	-166.99	62.49	-166.98	3.15	200		30	30	G	8
24	9/8	16:16	62.96	-167.03	62.93	-167.06	3.11	145		26	21	G	9
25	9/8	21:11	63.00	-165.97	62.99	-165.93	1.97	205		21	17	G	6
26	9/9	02:24	63.49	-165.91	63.48	-165.84	4.07	200		24	20	G	7
27	9/9	17:05	64.00	-165.84	63.99	-165.80	1.87	205		20	17	G	6
28	9/9	21:57	63.99	-166.93	63.98	-166.86	3.71	215		25	29	G	9
29	9/10	02:40	63.51	-166.96	63.52	-166.94	1.16	183		28	23	U	7
30	9/10	16:24	63.52	-167.96	63.54	-167.89	4.14	210		26	28	G	6
31	9/10	20:57	64.02	-167.97	64.05	-167.92	3.85	205		26	32	G	6
32	9/11	01:53	64.01	-168.98	63.99	-169.04	3.52	207		27	30	G	14
34	9/11	17:21	65.00	-169.15	65.02	-169.23	3.81	208		24	42	G	11
35	9/11	23:28	65.39	-168.08	65.38	-168.17	4.33	208		25	32	G	15
36	9/12	04:35	65.01	-167.62	64.99	-167.68	3.46	208		20	29	G	13

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

[a] Warp length not recorded.

APPENDIX B

Appendix B1.–Baseline evaluation test, 100% Canada, 5 replicate tests of 200 Canada-origin individuals removed from the baseline.

	Replicate 1					
		90% CI				
Reporting group	Median	5%	95%	*P* = 0	Mean	SD
Canada	99.4	97.8	100.0	0.00	99.2	0.7
Middle Yukon	0.3	0.0	1.8	0.04	0.5	0.6
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.2
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.3
Replicate 2						
Canada	99.8	98.6	100.0	0.00	99.6	0.5
Middle Yukon	0.0	0.0	0.8	0.10	0.2	0.3
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.2
Replicate 3						
Canada	99.7	98.6	100.0	0.00	99.6	0.5
Middle Yukon	0.0	0.0	0.8	0.10	0.2	0.3
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.2
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.2
Replicate 4						
Canada	99.8	98.7	100.0	0.00	99.6	0.5
Middle Yukon	0.0	0.0	0.7	0.11	0.1	0.3
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.2
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.3
Replicate 5						
Canada	99.4	97.9	100.0	0.00	99.2	0.7
Middle Yukon	0.3	0.0	1.7	0.03	0.5	0.6
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.2

Note: Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to 0 (*P* = 0), mean and standard deviation (SD). Stock composition means may not sum to 100% due to rounding error.

Appendix B2.–Baseline evaluation test, 100% Middle Yukon, 5 replicate tests of 200 Middle Yukon-origin individuals removed from the baseline.

	Replicate 1					
		90% CI				
Reporting group	Median	5%	95%	*P* = 0	Mean	SD
Canada	0.0	0.0	1.1	0.10	0.2	0.4
Middle Yukon	98.6	96.7	99.6	0.00	98.5	0.9
Lower Yukon	0.3	0.0	2.0	0.05	0.5	0.7
Other Western Alaska	0.6	0.0	2.2	0.02	0.8	0.7
	Replicate 2					
Canada	0.0	0.0	0.6	0.11	0.1	0.3
Middle Yukon	99.8	98.7	100.0	0.00	99.6	0.5
Lower Yukon	0.0	0.0	0.7	0.11	0.1	0.3
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.3
	Replicate 3					
Canada	0.0	0.0	1.2	0.09	0.2	0.5
Middle Yukon	99.7	98.3	100.0	0.00	99.5	0.6
Lower Yukon	0.0	0.0	0.7	0.11	0.1	0.3
Other Western Alaska	0.0	0.0	0.7	0.11	0.1	0.3
	Replicate 4					
Canada	0.3	0.0	3.3	0.06	0.9	1.2
Middle Yukon	99.3	96.4	100.0	0.00	98.9	1.2
Lower Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Other Western Alaska	0.0	0.0	0.6	0.11	0.1	0.3
	Replicate 5					
Canada	0.0	0.0	0.9	0.10	0.2	0.4
Middle Yukon	99.2	97.6	99.9	0.00	99.0	0.7
Lower Yukon	0.0	0.0	0.8	0.10	0.2	0.3
Other Western Alaska	0.4	0.0	1.7	0.01	0.6	0.6

Note: Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to 0 (*P* = 0), mean and standard deviation (SD). Stock composition means may not sum to 100% due to rounding error.

Appendix B3.–Baseline evaluation test, 100% Lower Yukon, 5 replicate tests of 200 Lower Yukon-origin individuals removed from the baseline.

	Replicate 1					
		90% CI				
Reporting group	Median	5%	95%	*P* = 0	Mean	SD
Canada	0.3	0.0	1.8	0.05	0.5	0.6
Middle Yukon	0.6	0.0	2.2	0.02	0.8	0.7
Lower Yukon	97.4	86.0	99.5	0.00	95.6	4.8
Other Western Alaska	1.1	0.0	12.7	0.04	3.1	4.8
			Replicate 2			
Canada	1.6	0.4	3.6	0.00	1.7	1.0
Middle Yukon	0.8	0.0	2.7	0.01	1.0	0.9
Lower Yukon	95.7	88.5	98.5	0.00	94.8	3.2
Other Western Alaska	1.3	0.0	8.6	0.04	2.5	3.0
			Replicate 3			
Canada	1.4	0.5	3.3	0.00	1.6	0.9
Middle Yukon	0.0	0.0	0.9	0.10	0.2	0.3
Lower Yukon	97.6	91.6	99.2	0.00	96.9	2.7
Other Western Alaska	0.3	0.0	6.4	0.06	1.4	2.5
			Replicate 4			
Canada	0.5	0.1	1.7	0.00	0.6	0.6
Middle Yukon	0.5	0.0	2.2	0.02	0.8	0.8
Lower Yukon	89.9	77.0	98.4	0.00	89.2	6.6
Other Western Alaska	8.7	0.2	21.6	0.01	9.5	6.5
			Replicate 5			
Canada	0.2	0.0	1.7	0.06	0.5	0.6
Middle Yukon	0.8	0.0	2.6	0.01	1.0	0.9
Lower Yukon	97.2	87.6	99.4	0.00	95.8	3.9
Other Western Alaska	1.0	0.0	10.9	0.04	2.8	3.8

Note: Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to 0 (*P* = 0), mean and standard deviation (SD). Stock composition means may not sum to 100% due to rounding error.

Appendix B4.–Baseline evaluation test, 100% Other Western Alaska, 5 replicate tests of 200 Other Western Alaska-origin individuals removed from the baseline.

	Replicate 1					
		90% CI				
Reporting group	Median	5%	95%	*P* = 0	Mean	SD
Canada	0.0	0.0	0.6	0.11	0.1	0.2
Middle Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Lower Yukon	0.5	0.0	5.6	0.05	1.4	2.0
Other Western Alaska	99.2	94.1	100.0	0.00	98.4	2.0
	Replicate 2					
Canada	0.0	0.0	0.6	0.11	0.1	0.2
Middle Yukon	0.0	0.0	0.7	0.10	0.1	0.3
Lower Yukon	0.1	0.0	2.3	0.08	0.5	1.0
Other Western Alaska	99.6	97.3	100.0	0.00	99.3	1.0
	Replicate 3					
Canada	0.0	0.0	0.6	0.11	0.1	0.2
Middle Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Lower Yukon	0.1	0.0	2.9	0.07	0.6	1.2
Other Western Alaska	99.6	96.8	100.0	0.00	99.2	1.2
	Replicate 4					
Canada	0.0	0.0	0.6	0.11	0.1	0.2
Middle Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Lower Yukon	0.4	0.0	7.5	0.05	1.6	2.7
Other Western Alaska	99.2	92.2	100.0	0.00	98.1	2.7
	Replicate 5					
Canada	0.0	0.0	0.6	0.11	0.1	0.2
Middle Yukon	0.0	0.0	0.6	0.11	0.1	0.3
Lower Yukon	0.1	0.0	2.3	0.08	0.5	0.9
Other Western Alaska	99.6	97.4	100.0	0.00	99.3	1.0

Note: Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to 0 (*P* = 0), mean and standard deviation (SD). Stock composition means may not sum to 100% due to rounding error.

Appendix B5.–Baseline evaluation test, Flat (25% to each reporting group), 5 replicate tests of 50 individuals from each reporting group (200 total) removed from the baseline.

	Replicate 1					
		90% CI				
Reporting group	Median	5%	95%	*P* = 0	Mean	SD
Canada	25.8	20.8	31.1	0.00	25.8	3.1
Middle Yukon	24.8	19.9	30.2	0.00	24.9	3.1
Lower Yukon	20.7	12.1	29.5	0.00	20.7	5.3
Other Western Alaska	28.4	19.8	37.8	0.00	28.5	5.5
			Replicate 2			
Canada	25.0	20.1	30.3	0.00	25.1	3.1
Middle Yukon	26.4	21.3	31.9	0.00	26.5	3.2
Lower Yukon	18.6	11.1	27.3	0.00	18.8	4.9
Other Western Alaska	29.6	21.1	38.1	0.00	29.6	5.2
			Replicate 3			
Canada	24.2	19.3	29.5	0.00	24.3	3.1
Middle Yukon	25.1	20.1	30.5	0.00	25.1	3.2
Lower Yukon	24.5	15.3	33.8	0.00	24.5	5.6
Other Western Alaska	25.8	17.2	35.7	0.00	26.1	5.7
			Replicate 4			
Canada	23.9	19.1	29.2	0.00	24.0	3.1
Middle Yukon	27.1	22.0	32.7	0.00	27.2	3.2
Lower Yukon	20.8	13.4	28.8	0.00	20.9	4.7
Other Western Alaska	27.8	20.2	36.0	0.00	27.9	4.8
			Replicate 5			
Canada	27.3	22.2	32.9	0.00	27.4	3.3
Middle Yukon	22.0	17.2	27.3	0.00	22.1	3.1
Lower Yukon	14.1	5.2	24.2	0.00	14.3	5.8
Other Western Alaska	36.2	26.0	46.5	0.00	36.2	6.2

Note: Estimates of stock composition (%) including median, 90% credibility interval, the probability that the group estimate is equal to 0 (*P* = 0), mean and standard deviation (SD). Stock composition means may not sum to 100% due to rounding error.

APPENDIX C

Appendix C1.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 8–September 5, 2014.

Scientific name	Common name	Length range (cm)	Avg. length (cm)	Avg. wt (kg)	Total catch (*n*)	Total catch (kg)
NA	Unid. Jellyfish	– [a]	– [a]	– [b]	– [c]	2,072.5150
Clupea pallasii	Pacific herring	3.0–25.5 [d]	112.2	0.0086	5,781	49.5700
Mallotus villosus	Capelin	6.2–13.6	9.6	0.0061	3,444	20.9620
Pungitius pungitius	Ninespine stickleback	3.2–7.5	6.0	0.0016	4,416	7.0480
Theragra chalcogramma	Walleye pollock	4.3–21.3	14.1	0.0193	63	1.2170
Lethenteron camtschaticum	Arctic lamprey	29.7–40.5	33.1	0.0791	14	1.1080
Limanda aspera	Yellowfin sole	40.6	– [e]	0.4780	2	0.9560
Anarhichas orientalis	Bering wolffish	9.4–42.7	13.8	0.0162	43	0.6980
Lepidopsetta bilineata	Rock sole	40.4	– [e]	– [e]	1	0.6450
Eleginus gracilis	Saffron cod	3.1–18.5	6.7	0.0026	239	0.6230
Ammodytes hexapterus	Pacific sand lance	2.2–17.1	9.6	0.0049	63	0.3110
Platichthys stellatus	Starry flounder	26.2	– [e]	– [e]	1	0.2410
Enophrys diceraus	Antlered sculpin	12.2	– [e]	– [e]	1	0.0570
Osmerus mordax	Rainbow smelt	13.8–15.6	14.6	0.0167	3	0.0500
Arctogadus glacialis	Arctic cod	3.9–13.0	7.3	0.0038	9	0.0340
Hexagrammos octogrammus	Masked greenling	7.6–8.2	8.0	0.0037	3	0.0110
Anoplopoma fimbria	Sablefish	9.1	– [e]	– [e]	1	0.0080
Gonatus kamtschaticus	Shortarm gonate squid	9.0–10.2	9.6	– [e]	2	0.0050
NA	Unid. Amphipod	– [a]	– [a]	– [b]	28	0.0040
Limanda proboscidea	Longhead dab	2.8–3.8	3.2	0.0001	27	0.0020
Reinhardtius hippoglossoides	Greenland halibut	4.7–6.8	6.0	0.0001	16	0.0015
Blepsias bilobus	Crested sculpin	4.7	– [e]	– [e]	1	0.0010
N/A	Sebastes sp.	5.0	– [e]	– [e]	1	0.0010
Pandalus goniurus	Humpy shrimp	– [a]	– [a]	– [b]	2	– [f]
NA	Unid. Anemone	– [a]	– [a]	– [b]	1	– [f]

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 61 stations, including size paired trawl stations with an average area swept of 0.0426 km^2 per station.

[a] Individual lengths not measured for this species.

[b] Individuals weights not measured for this species.

[c] Individuals not enumerated for this species.

[d] Larval Pacific herring were also captured during trawl survey operations, but not individually measured. All were recorded as less than 3 cm.

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

[f] Total weights not measured for this species.

Appendix C2.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 10–23, 2015.

Scientific name	Common name	Length range (cm)	Avg. length (cm)	Avg. wt. (kg)	Total catch (*n*)	Total catch (kg)
NA	Unid. Jellyfish	– [a]	– [b]	– [b]	– [c]	2,423.5190
Clupea pallasii	Pacific herring	11.0–23.7	14.2	0.0227	2,698	61.2300
Gadus chalcogramma	Walleye pollock	57.3–74.1	63.9	1.4409	11	15.8500
Eleginus gracilis	Saffron cod	3.3–27.2	6.3	0.0020	819	1.6740
Limanda aspera	Yellowfin sole	34.8–35.3	35.1	0.5795	2	1.1590
Lethenteron camtschaticum	Arctic lamprey	27.2–40.3	32.8	0.0556	16	0.8900
Ammodytes hexapterus	Pacific sand lance	3.8–16.5	6.3	0.0007	648	0.4800
Osmerus mordax	Rainbow smelt	10.0–21.1	13.6	0.0199	14	0.2790
Lepidopsetta bilineata	Rock Sole	29.5	– [d]	– [d]	1	0.2480
Mallotus villosus	Capelin	4.0–14.9	7.7	0.0025	80	0.2010
Gonatus kamtschaticus	Shortarm gonate squid	7.7–10.4	9.4	0.0003	366	0.0990
NA	Unid. Gadidae	3.4–5.4	4.3	0.0005	183	0.0940
Anarhichas orientalis	Bering wolffish	13.5–16.3	15.2	0.0200	3	0.0600
Podothecus accipenserinus	Sturgeon poacher	14.4	– [d]	– [d]	1	0.0600
Arctogadus glacialis	Arctic cod	12.4	– [d]	– [d]	1	0.0140
NA	Unid. larval fish	– [a]	– [a]	– [b]	70	– [e]
NA	Unid. flatfish	2.1–7.6	4.0	– [b]	26	– [e]
NA	Unid. Pandalid shrimp	– [a]	– [b]	– [b]	6	– [e]

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 41 stations with an average area swept of 0.0672 km^2 per station.

[a] Individual lengths not measured for this species.

[b] Individuals weights not measured for this species.

[c] Individuals not enumerated for this species.

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

[e] Total weights not measured for this species.

Appendix C3.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 7–29, 2016.

Scientific name	Common name	Length range (cm)	Avg. length (cm)	Avg. wt (kg)	Total catch (*n*)	Total catch (kg)
NA	Unid. Jellyfish	– [a]	– [a]	– [b]	– [c]	1,002.2550
Clupea pallasii	Pacific herring	6.6–23.7	12.9	0.0094	17,524	164.0650
Eleginus gracilis	Saffron cod	3.4–22.6	6.7	0.0043	5,907	25.6700
Gadus chalcogramma	Walleye pollock	3.7–66.9	18.1	0.2691	68	18.3010
Osmerus mordax	Rainbow smelt	7.6–23.6	10.8	0.0124	324	4.0260
Lethenteron camtschaticum	Arctic lamprey	26.8–41.9	33.1	0.0575	21	1.2070
Pungitius pungitius	Ninespine stickleback	3.8–6.9	5.5	0.0013	818	1.0730
Limanda aspera	Yellowfin sole	20–31.9	25.5	0.2530	3	0.7590
Ammodytes hexapterus	Pacific sandlance	3.8–15.9	7.3	0.0025	266	0.6680
Mallotus villosus	Capelin	7.5–12.7	9.1	0.0039	83	0.3230
NA	Unid. Gadidae	3.9–12.5	6.1	0.0019	161	0.2990
Enophyrs lucasi	Leister sculpin	13.9–15.7	14.8	0.0020	2	0.1390
Myoxocephalus scorpius	Shorthorn sculpin	18.5	– [d]	– [d]	1	0.0950
Anarhichas orientalis	Bering wolffish	14.7	– [d]	– [d]	1	0.0200
Gasterosteus aculeatus	Threespine stickleback	7.8–8.8	8.2	0.0050	3	0.0150
NA	Unid. Greenling	8.2	– [d]	– [d]	1	0.0060
NA	Unid. Flatfish	3.3–6.0	4.1	0.0006	7	0.0040
Blepsias bilobus	Crested sculpin	6.0	– [d]	– [d]	1	0.0030

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 41 stations with an average area swept of 0.0672 km^2 per station.

[a] Individual lengths not measured for this species.

[b] Individuals weights not measured for this species.

[c] Individuals not enumerated for this species.

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

Appendix C4.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Alaskan Endeavor*, September 4–22, 2014.

Scientific name	Common name	Length range (cm)	Avg. length (cm)	Avg. wt (kg)	Total catch (*n*)	Total catch (kg)
Chrysaora melanaster	Northern sea nettle	3.1–42.0	21.3	1.5716 [a]	5,693 [b]	8,947.2170
Clupea pallasi	Pacific herring	4.9–26.5	13.5	0.0158	150,324	2,368.8439
Gadus chalcogrammus	Walleye pollock	2.4–66.0	8.0	0.0024	567,201	1,360.3400
Mallotus villosus	Capelin	2.3–13.1	8.8	0.0060	58,634	351.6300
Cyanea capillata	Lions mane	4.8–33.1	11.9	0.6047 [a]	225.0 [b]	136.0490
Osmerus mordax	Rainbow smelt	4.9–25.0	10.9	0.0055	22,526	123.5537
Ammodytes hexapterus	Pacific sand lance	5.4–19.0	10.0	0.0183	4,415	80.7476
Pungitius pungitius	Ninespine stickleback	3.6–7.1	5.5	0.0013	32,681	41.4203
NA	Aurelia sp.	17.2	– [c]	13.0523 [a]	3 [b]	39.1570
Eleginus gracili	Saffron cod	5.8–28.7	11.2	0.0048	7,625	36.5430
Gadus macrocephalus	Pacific cod	65.5–78.5	72.5	5.2400	3	15.7200
NA	Aequorea sp.	– [d]	– [d]	–	– [e]	12.7550
Lethenteron camtschaticum	Arctic lamprey	26.3–54.3	36.6	0.0876	129	11.3223
Platichthys stellatus	Starry flounder	21.3–44.2	34.7	0.6223	17	10.5790
Hippoglossus stenolepis	Pacific halibut	63.2	– [c]	– [c]	1	2.9000
Staurophora mertensi	Whitecross jellyfish	5.4	– [c]	1.1375 [a]	2 [b]	2.2750
Phacellophora camtchatica	Fried egg jellyfish	19.3	– [c]	0.2740	6	1.6440
Limanda aspera	Yellowfin sole	24.1–33.0	29.3	0.2800	3	0.8400
NA	Unid. Pandalus shrimp	– [d]	– [d]	0.0014	143	0.2063
NA	Unid. salps	1.9–3.2	2.6	0.0039	35	0.1380
Myoxocephalus jaok	Plain sculpin	11.5–22.4	17.0	0.0690	2	0.1380
Pleurogrammus monopterygius	Atka mackerel	17.9–19.6	18.8	0.0680	2	0.1360
NA	Unid. hydromedusa	– [d]	– [d]	0.0013	99	0.1316
Anarhichas orientalis	Bering wolffish	10.0–20.4	15.2	0.0320	4	0.1280
Hexagrammos stelleri	Whitespotted greenling	7.4–11.9	8.9	0.0064	18	0.1182
Podothecus veternus	Veteran poacher	10.9–20.0	16.0	0.0194	5	0.0970
Limanda proboscidea	Longhead dab	2.2–3.8	3.1	0.0005	165	0.0900
Boreogadus saida	Arctic cod	9.3–14.5	12.2	0.0133	6	0.0800
Blepsias bilobus	Crested sculpin	15.4	– [c]	– [c]	1	0.0630
Gonatus kamtschaticus	Shortarm gonate squid	8.4–9.2	8.8	0.0140	2	0.0280
NA	Unid. Crangonid shrimp	– [d]	– [d]	0.0002	171	0.0270
Reinhardtius hippoglossoides	Greenland halibut	3.0–6.2	5.1	0.0010	26	0.0270
Hexagrammos octogrammus	Masked greenling	8.4–8.5	8.5	0.0070	2	0.0140
Lepidopsetta polyxystra	Northern rock sole	11.7	– [c]	– [c]	1	0.0140
Myoxocephalus scorpius	Shorthorn sculpin	9.8	– [c]	– [c]	1	0.0110
NA	Unid. Hydrozoa	– [d]	– [d]	0.0010	6	0.0060
Nautichthys pribilovius	Eyeshade sculpin	7.0	– [c]	– [c]	1	0.0040
Aspidophoroides bartoni	Aleutian alligatorfish	4.4	– [c]	– [c]	1	0.0010
NA	Atheresthes sp.	2.7	– [c]	– [c]	1	0.0010

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 51 stations, including paired trawl stations, with an average area swept of 0.208 km^2 per station. Jellyfish lengths are bell width and squid lengths are mantle lengths.

[a] Average weight will be overestimated because not all individuals were enumerated.

[b] Not all individuals enumerated.

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

[d] Individual lengths not measured for this species.

[e] Individuals not enumerated for this species.

Appendix C5.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Alaskan Endeavor*, September 9–16, 2015.

Common name	Length range (cm)	Avg. length (cm)	Avg. wt (kg)	Total catch (*n*)	Total catch (kg)
Northern sea nettle	4.0–47.0	20.9	0.9436	2719	2,565.6240
Pacific herring	6.9–25.6	14.1	0.0145	57,493	833.8021
Walleye pollock	3.9–80.6	9.6	0.0030	149,132	444.2999
Lions mane	5.0–14.1	9.9	0.6307 [a]	268 [b]	169.0380
Capelin	6.7–13.5	9.9	0.0066	20,388	134.2253
Aequorea sp.	– [c]	– [c]	–	– [d]	73.6200
Saffron cod	5.3–28.1	8.0	0.0032	7,898	25.6254
Aurelia sp.	– [c]	– [c]	1.6286	14	22.8000
Fried egg jellyfish	– [c]	– [c]	0.8090	25	20.2260
Whitecross jellyfish	– [c]	– [c]	–	– [d]	17.2160
Pacific sand lance	4.4–17.9	14.0	0.0121	1,290	15.6710
Ninespine stickleback	3.7–6.7	5.2	0.0010	12,562	12.2841
Rainbow smelt	4.8–27.9	13.0	0.0140	760	10.6600
Arctic lamprey	20.1–46.2	34.0	0.0628	115	7.2200
Yellowfin sole	15.6–36.6	29.6	0.3042	11	3.3460
Shorthorn sculpin	12.2–55.7	34.0	0.8850	2	1.7700
Northern rock sole	31.4–34.7	33.1	0.3100	2	0.6200
Unid. Squid	2.2–3.4	2.7	0.0006	915	0.5495
Starry flounder	32.1	– [e]	– [e]	1	0.4300
Antlered sculpin	9.1–15.4	13.3	0.0530	6	0.3180
Polar eelpout	31.8	– [e]	– [e]	1	0.2330
Unid. Gonatus squid	1.6–6.2	2.7	0.0004	349	0.1479
Bering wolffish	15.3–17.0	16.2	0.0208	5	0.1040
Unid. Snailfish	39	– [e]	– [e]	1	0.0800
Pacific cod	5.5–7.4	6.3	0.0026	29	0.0764
Sturgeon poacher	22.5	– [e]	– [e]	1	0.0460
Longhead dab	3.1–4.4	3.5	0.0006	40	0.0242
Sebastes sp.	3.4–4.1	3.8	0.0008	20	0.0158
Arctic cod	8.3–13.6	11.0	0.0060	2	0.0120
Masked greenling	7.9	– [e]	– [e]	1	0.0040
Greenland halibut	6.6	– [e]	– [e]	1	0.0020
Bering Flounder	3.6	– [e]	– [e]	1	0.0010

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 37 stations with an average area swept of 0.1956 km2 per station. Jellyfish lengths are bell width and squid lengths are mantle lengths.

[a] Average weight will be overestimated because not all individuals were enumerated.

[b] Not all individuals enumerated.

[c] Individual lengths not measured for this species.

[d] Individuals not enumerated for this species.

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

Appendix C6.–Total catch, average length, and average weight (Wt) of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Cape Flattery*, August 28–September 12, 2016.

Common name	Length range (cm)	Avg. length (cm)	Avg. wt (kg)	Total catch (*n*)	Total catch (kg)
Northern sea nettle	3.2–39.0	16.6	0.3333 [a]	2,713 [b]	904.1460
Walleye pollock	3.8–69.0	15.7	0.0818	8,758	716.6680
Pacific herring	6.3–24.9	13.6	0.0132	46,604	615.5950
Salmon shark	200	– [c]	– [c]	1	150.0000
Lions mane	4.0–39.0	14.0	0.3661 [a]	306 [b]	112.0220
Whitecross jellyfish	– [d]	– [d]	–	– [e]	110.3630
Aurelia sp.	– [d]	– [d]	0.3860 [a]	152 [b]	58.6740
Capelin	6.6–12.6	9.6	0.0054	7,589	40.9870
Pacific cod	5.6–75.0	49.7	1.6583	15	24.8740
Saffron cod	4.3–28.8	9.9	0.0327	563	18.4110
Rainbow smelt	8.1–29.0	13.8	0.0164	1,092	17.9560
Alaska skate	78.0–102.0	90.0	6.2950	2	12.5900
Fried egg jellyfish	11.0–55.0	25.0	1.0190 [a]	10 [b]	10.1900
Northern rock sole	18.9–41.7	26.8	0.3073	25	7.6830
Aequorea sp.	17.0	– [c]	– [c]	1 [b]	6.5600
Yellowfin sole	33.3–39.0	35.8	0.6147	6	3.6880
Alaska plaice	18.7–52.1	28.7	0.5262	6	3.1570
Starry flounder	36.9–39.9	38.4	0.8520	2	1.7040
Arctic lamprey	29.9–41.1	36.9	0.0799	14	1.1190
Pacific sand lance	4.3–16.8	9.1	0.0059	185	1.0880
Ninespine stickleback	3.4–6.5	4.8	0.0010	1,048	1.0590
Unid. Pisaster sea star	– [d]	– [d]	–	– [e]	0.4240
Variegated snalifish	30.9	– [c]	– [c]	1	0.4010
Crested sculpin	10.5–24.5	16.6	0.1277	3	0.3830
Unid. Cottidae	21.5–22.0	21.8	0.1275	2	0.2550
Shorthorn sculpin	22.6	– [c]	– [c]	1	0.0760
Arctic cod	19.4	– [c]	– [c]	1	0.0510
Sturgeon poacher	17.2	– [c]	– [c]	1	0.0240
Unid. hydromedusa	– [d]	– [d]	– [c]	1	0.0060
Bering flounder	3.5 [f]	– [c]	0.0010	4	0.0040
Greenland halibut	3.2–5.5	4.7	0.0013	3	0.0040
Pacific halibut	7.5	– [c]	– [c]	1	0.0040
Unid. Flatfish	6.9	– [c]	– [c]	1	0.0020

Note: Specimens that could not be identified to species (Unid.) were identified to lowest taxonomic group. Catches come from 34 stations with an average area swept of 0.1701 km^2 per station. Jellyfish lengths are bell width and squid lengths are mantle lengths.

[a] Average weight will be overestimated because not all individuals were enumerated.

[b] Not all individuals enumerated.

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

[d] Individual lengths not measured for this species.

[e] Individuals not enumerated for this species.

APPENDIX D

Appendix D1.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 8–September 5, 2014.

Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Chum salmon	Juvenile	8.3–18.7	13.0	0.0184	1,147	21.0910
Chinook salmon	Juvenile	12.6–22.7	19.3	0.0891	54	4.8130
Pink salmon	Juvenile	9.0–14.2	10.8	0.0075	176	1.3280
Coho salmon	Juvenile	26.3–28.8	27.2	0.1907	3	0.5720
Sockeye salmon	Juvenile	18.1–22.4	19.8	0.0873	4	0.3490
Chinook salmon	Immature	38.2–44	41.1	1.0145	2	2.0290

Note: Catches come from 61 stations, including size paired trawl stations with an average area swept of 0.0426 km^2 per station.

Appendix D2.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 10–23, 2015.

Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Chum salmon	Juvenile	8.3–19.0	13.9	0.0284	1,744	49.4830
Pink salmon	Juvenile	8.8–16.6	12.3	0.0211	1,627	34.2720
Chinook salmon	Juvenile	8.4–22.4	18.7	0.0873	127	11.0880
Coho salmon	Juvenile	22.6–28.7	25.3	0.2122	27	5.7290
Sockeye salmon	Juvenile	11.3–20.4	16.7	0.0563	7	0.3940
Chinook salmon	Immature	40.1	– [a]	0.8380	1	0.8380

Note: Catches come from 41 stations with an average area swept of 0.0672 km2 per station.

Appendix D3.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northern Bering Sea survey on the R/V *Pandalus*, August 7–29, 2016.

Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Chum salmon	Juvenile	9.8–21.2	14.0	0.0384	699	26.8350
Pink salmon	Juvenile	8.7–22.0	12.6	0.0172	971	16.7470
Chinook salmon	Juvenile	14.8–25.1	18.6	0.0829	140	11.6070
Coho salmon	Juvenile	16.7–29.0	23.8	0.1805	40	7.2190
Sockeye salmon	Juvenile	16.9–24.4	19.9	0.0884	10	0.8840
Chinook salmon	Immature	33.5–58.7	41.0	1.1273	4	4.5090
Coho salmon	Immature	51.4	– [a]	3.1140	1	3.1140
Chum salmon	Immature	53.0	– [a]	1.8250	1	1.8250

Note: Catches come from 48 stations with an average area swept of 0.0764 km^2 per station.

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

Appendix D4.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Alaskan Endeavor*, September 4–22, 2014.

Scientific name	Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Oncorhynchus keta	Chum salmon	Juvenile	8.9–23.5	17.7	0.0663	3,310	219.2900
Oncorhynchus nerka	Sockeye salmon	Juvenile	13.5–30.7	24.0	0.1588	817	129.7800
Oncorhynchus gorbuscha	Pink salmon	Juvenile	11.8–21.5	16.7	0.0535	2,217	118.5500
Oncorhynchus kisutch	Coho salmon	Juvenile	22.7–36.7	30.5	0.3683	174	64.0800
Oncorhynchus tshawytscha	Chinook salmon	Juvenile	9.9–27.9	21.8	0.1442	344	49.6100
Oncorhynchus keta	Chum salmon	Immature	33.5–77.7	61.4	3.7823	43	162.6400
Oncorhynchus tshawytscha	Chinook salmon	Immature	35.2–85.1	47.7	1.7504	57	99.7740
Oncorhynchus nerka	Sockeye salmon	Immature	31.7–61.8	40.7	0.9424	74	69.7400
Oncorhynchus kisutch	Coho salmon	Immature	55.6–62.0	58.0	2.5100	3	7.5300

Note: Catches come from 51 stations, including paired trawl stations, with an average area swept of 0.208 km^2 per station.

Appendix D5.–Total catch, average length, and average weight of salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Alaskan Endeavor*, September 9–16, 2015.

Scientific name	Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Oncorhynchus keta	Chum salmon	Juvenile	10.3–23.0	18.0	0.0765	1,627	124.4980
Oncorhynchus gorbuscha	Pink salmon	Juvenile	11.2–22.2	16.1	0.0398	2,154	85.7040
Oncorhynchus tshawytscha	Chinook salmon	Juvenile	10.8–25.8	21.5	0.1312	322	42.2380
Oncorhynchus kisutch	Coho salmon	Juvenile	23.0–31.3	29.2	0.3286	84	27.6000
Oncorhynchus nerka	Sockeye salmon	Juvenile	16.8–30.8	25.3	0.1956	20	3.9120
Oncorhynchus tshawytscha	Chinook salmon	Immature	33.2–79.4	45.9	1.6046	36	57.7670
Oncorhynchus nerka	Sockeye salmon	Immature	31.5–51.5	35.2	0.5775	62	35.8040
Oncorhynchus keta	Chum salmon	Immature	34.8–69.2	51.9	2.5893	6	15.5360
Oncorhynchus kisutch	Coho salmon	Immature	62.3	–[a]	–[a]	1	3.3900

Note: Catches come from 37 stations with an average area swept of 0.1956 km^2 per station.

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

Appendix D6.–Total catch, average length, and average weight of non-salmon species captured in surface trawls during the Northern Bering Sea survey on the F/V *Cape Flattery*, August 28–September 12, 2016.

Scientific name	Common name	Life history stage	Length range (cm)	Avg. length (cm)	Avg. weight (kg)	Total catch (*n*)	Total catch (kg)
Oncorhynchus keta	Chum salmon	Juvenile	12.6–23.0	16.8	0.0468	1,761	82.3900
Oncorhynchus kisutch	Coho salmon	Juvenile	18.1–33.5	27.2	0.2681	114	30.5650
Oncorhynchus tshawytscha	Chinook salmon	Juvenile	13.8–26.3	20.3	0.1239	218	27.0160
Oncorhynchus gorbuscha	Pink salmon	Juvenile	8.2–23.2	15.4	0.0355	550	19.5460
Oncorhynchus nerka	Sockeye salmon	Juvenile	10.0–24.4	19.0	0.0720	245	17.6340
Oncorhynchus tshawytscha	Chinook salmon	Immature	31.2–69.9	46.2	1.5326	49	75.0990
Oncorhynchus keta	Chum salmon	Immature	36.0–71.0	55.1	2.5530	24	61.2720
Oncorhynchus kisutch	Coho salmon	Immature	55–63.5	59.2	3.4620	3	10.3860
Oncorhynchus nerka	Sockeye salmon	Immature	56.2	–[a]	–[a]	1	2.2220

Note: Catches come from 34 stations with an average area swept of 0.1701 km^2 per station.

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