Juvenile Chinook Salmon Outmigration at the Yukon River Mouth

URE-162-18N

Prepared for: The Yukon River Panel

Prepared by: Katharine Miller (NOAA)
Courtney Weiss (SSSC)
For
The Yukon Delta Fisheries Development Association
2909 Arctic Blvd
Anchorage, AK 99503

July 2019

ABSTRACT

The objective of this research is to create a time series of data on biological and environmental factors related to the outmigration of juvenile Chinook salmon in the lower Yukon River. This research started in 2014 and received funding in 2018 from the Yukon Panel. This report provides a summary of the 2018 field data collection, and also evaluates the 2018 field year in the context of other sampling years. Sampling was conducted at nine permanent stations on the three main lower Yukon distributaries from May 25th through August 24th. A total of 542 juvenile Chinook was captured during this period, which was a decline from prior years. Outmigration timing was similar to previous sampling years with the mid-point of the run occurring on June 14th. 2018 Chinook had lower stomach fullness than in prior years with a higher proportion of fish with empty stomachs. Chinook energy densities declined with increasing temperature continuing a trend that began in 2016. River discharge in 2018 was higher than the long-term average while temperatures were within average values. This differs from prior sampling years where discharge was well below average and temperatures were much higher than average. Having a long time series of data will contribute to our ability to differentiate inter-annual differences in environmental conditions from substantive changes potentially affecting juvenile Chinook populations.

Table of Contents

Tables

Figures

INTRODUCTION

The objective of this research is to create a time series of data on biological and environmental factors related to the outmigration of juvenile Chinook salmon in the lower Yukon River. This work was started in 2014 by the National Oceanic and Atmospheric Administration (NOAA). In 2017, the Yukon Delta Fisheries Development Association (YDFDA) took over as the principal investigator responsible for field sampling and data collection, partnering with NOAA for laboratory processing and data analysis. The Yukon River Panel funded this research in 2018. This report provides a summary of the 2018 research, and also evaluates this year of data in the context of the larger dataset.

SUMMARY OF THE 2018 FIELD SEASON AND DATA COLLECTION

Sampling was conducted at nine permanent stations on the three main lower Yukon River distributaries (Figure 1). These distributaries are locally referred to as South Mouth (SM), Middle Mouth (MM) and North Mouth (NM), a naming scheme also used in this research. Stations were sampled three times per week by teams of fishermen and biologists using a surface net towed between two small (20 ft. to 24 ft.) skiffs. The skiffs were operated by local fishermen and crews from Emmonak and Alakanuk who have knowledge of the river, and field operations were based out of Emmonak. The nets used for this research were 6.8 m wide and 1.8 m depth at the mouth tapering to a 0.3 m by 0.3 m bag at the codend with the mouth held open by metal poles that also provided weight to the net. A set of three 15-minute tows was performed at each station. River temperature was recorded using a probe thermometer at the start of sampling at each station. Station depth was recorded at the beginning and end of each trawl. Barring occasional mishaps with boat engines or gear, all sampling was conducted between 0800 and 1800.

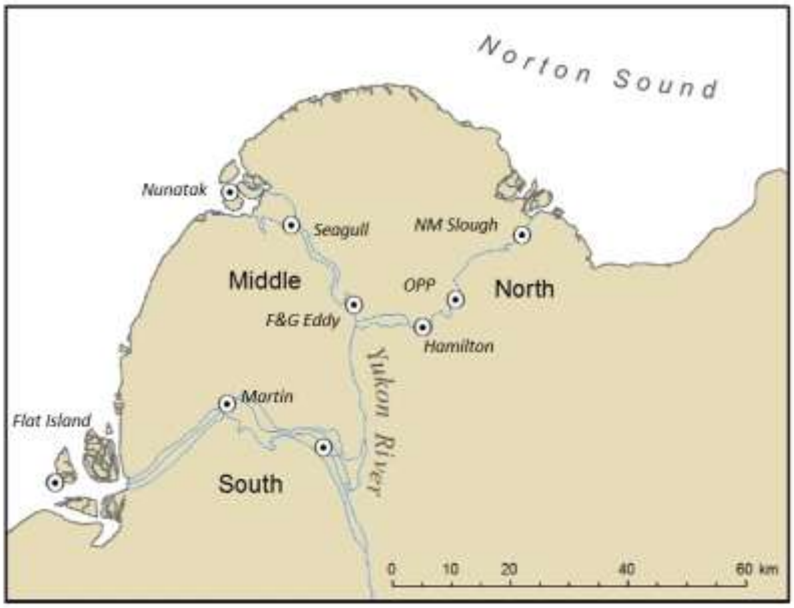

Figure 1 Permanent sampling stations on the three primary lower Yukon River distributaries

Captured fish were identified to species or lowest taxonomic level achievable. A minimum of 40 individuals from each species were measured to the nearest 1 mm fork length (FL) or total length (TL), depending on the species and released. When there was more than one size class of a species, 20 individuals from each size class were measured at each station. The remaining individuals that were not measured were enumerated by size class. All juvenile Chinook and Coho salmon specimens were retained. Once back in Emmonak, the juvenile salmon were frozen and shipped to the NOAA laboratory in Juneau, AK. At the lab, field identification of the Chinook was verified, each fish was weighed, genetic material was collected, and fish were returned to the freezer pending processing.

In 2018, sampling commenced on SM and MM on May 25th, and on NM on May 26th. Catch-per-unit-effort (CPUE) for fish was calculated as the total number of each species divided by the sampling time. In prior years, a flow meter was deployed on the net side of one of the boats at a depth of ~ 1m during each trawl set in an effort to capture flow through the net for CPUE analysis. However, cavitation from the outboard motor in the river current rendered such measurements unreliable. As a result, we have reverted to calculating CPUE based on time. CPUE is calculated by sampling station by day.

At the NOAA Laboratory, juvenile Chinook salmon were subsampled by week in proportion to their CPUE. The three largest and smallest specimens for each week were included the subsample, and the intermediate sizes were randomly sampled. This subsampling method was selected based on analysis from 2015 which suggested different energy densities and diets based on fish size.

For each subsampled fish, the saggital otoliths were removed for later analysis of age and microchemistry, stomachs were removed and the bolus of prey was measured to obtain an estimate of stomach fullness (a measure of feeding intensity):

$$\%BW = \frac{CW_P}{(BW - CW_{P})} X\ 100$$

Where BW is the wet weight of the juvenile salmon and CW_p is the weight of the stomach contents. The empty stomach was returned to the body cavity.

The Chinook were homogenized and a subsample of the homogenate was dried using a thermogravimetric analyzer (TGA) to measure percent moisture content. Each subsample was pressed into a 0.15 g pellet and run through a semi-microbomb calorimeter (PARR 6725) to measure caloric content (cal/g). Stomach content items were identified to the lowest practical taxonomic level, often family, counted and weighed.

COMPARISON OF 2018 RESULTS WITH PRIOR SAMPLING YEARS AND SELECT ENVIRONMENTAL VARIABLES

River conditions

River discharge, measured from the USGS gauge at Pilot Station, was above the long-term median in May and June of 2018. Discharge was much higher than prior sampling years during the midpoint of the outmigration and remained higher than every year except 2014 for the remainder of the sampling period (Figure 2).

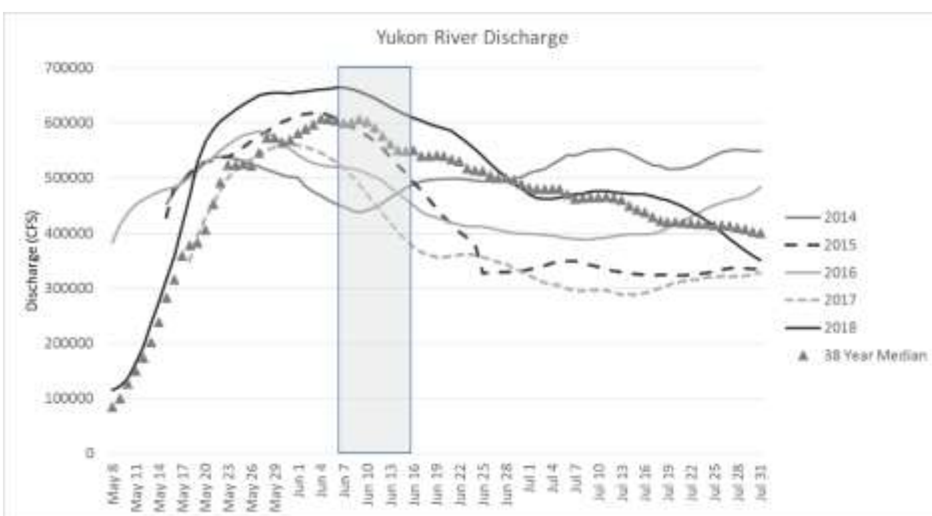

Figure 2 Yukon River discharged as measured at the USGS gauge at Pilot Station. Shaded box marks the midpoint of outmigration during the study years

River water temperatures were obtained from the Arctic-Yukon-Kuskokwim Database Management System for the Lower Yukon Test Fishery station at Big Eddy near Emmonak (http://www.adfg.alaska.gov/CommFishR3/Website/AYKDBMSWebsite/Default.aspx) for the period from 1984 to 2018. The average value of the years 1984-2013 was used to develop a long-term average for comparison purposes. Temperatures have exceeded the long-term average temperature in the early part of June in all sampling years except 2014(Figure 3). In 2018, water temperatures were ~ 2°C above average for the first part of June. Overall, 2018 water temperatures were between 0.3 °C and 0.7 °C cooler than temperatures from 2015 through 2017, but were 1.3 °C warmer that temperatures in 2014.

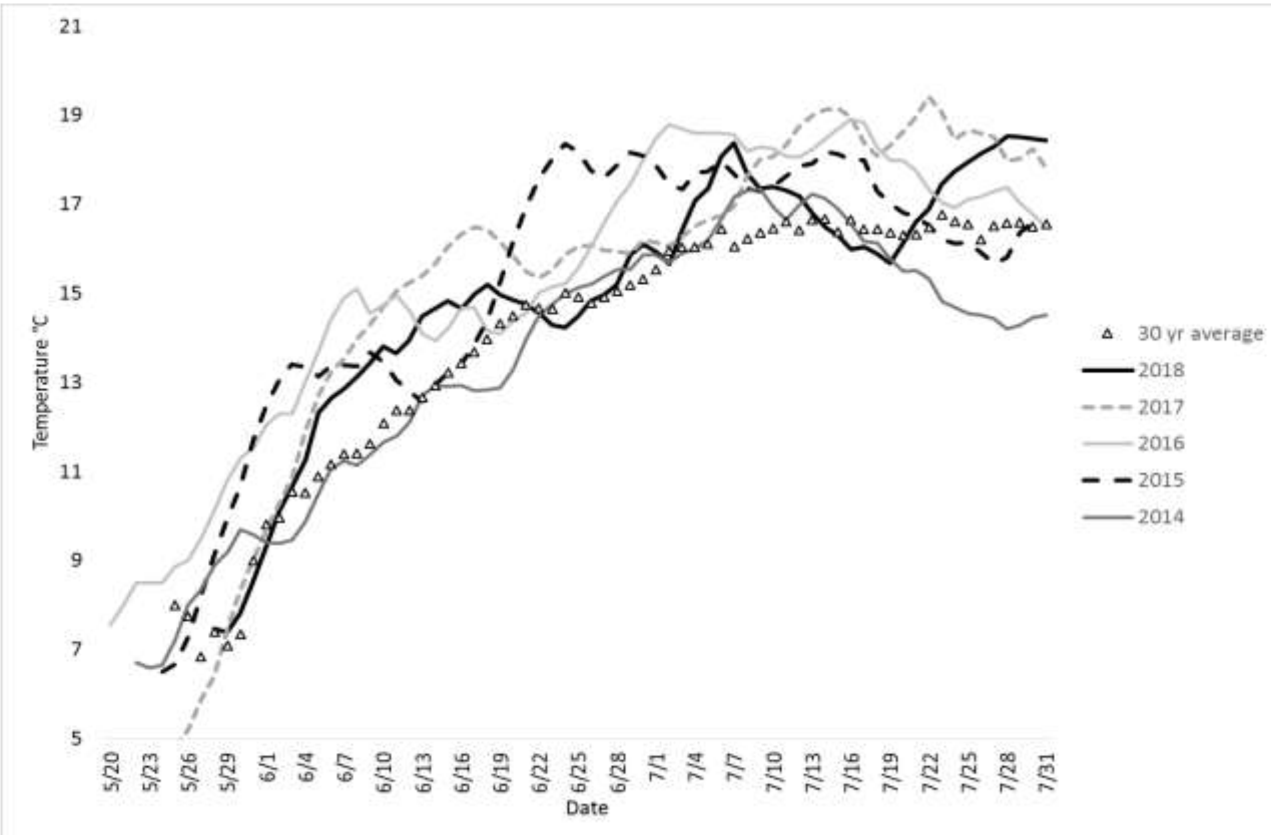

Figure 3 In situ Yukon River water temperatures compiled from data collected by the Alaska Department of Fish and Game lower Yukon River test fishery

Outmigration

A total of 517 juvenile Chinook was captured during the period from ice out through the end of July, 2018. Ice left the lower Yukon River at Emmonak on May 20, 2018. This was the latest ice out during the 5-year time series (Table 1). We evaluated Chinook CPUE in three periods: the beginning of the run (5%), middle of the run (50%), and end of the run (95%). Chinook were present in the catch on the first day of sampling in three of the five years. Due to historically early ice retreat, and difficulty accessing sampling equipment stored in Emmonak at the ADF&G facility so early in the season, it appears that sampling may not have preceded the start of the run in 2016.   In 2018 for the first-time sampling was continued through the end of August with an additional 25 Chinook captured during this period. Including these Chinook in the CPUE estimates, shifts the mid-point of the 2018 run by one day from June 14 to June 15, and the endpoint of the run by three days from June 17 to June 20.

Table 1: Ice timing, sampling commencement, and migration phenology for juvenile Chinook on the lower Yukon River

	Sampling			Migration Phenology								
Year	Ice-out	Sampling Start	# Chinook first day	Start (5%)	Days from ice-out	Days from sampling start	Mid-point (50%)	Days from run start	End (95%)	Days from run mid	Total Run time (days)	Total # fish
2014	10-May	26-May	1	4-Jun	25	9	19-Jun	15	16-Jul	27	42	413
2015	16-May	25-May	1	28-May	12	3	11-Jun	14	24-Jul	43	57	951
2016	3-May	18-May	12	21-May	18	3	10-Jun	20	14-Jul	34	54	737
2017	14-May	25-May	0	31-May	17	6	18-Jun	18	16-Jul	28	47	836
2018	20-May	25-May	0	2-Jun	13	8	14-Jun	13	17-Jul	33	45	520

The date that ice left the lower river appears to be uncorrelated with the dates of the beginning, middle or end of the outmigration. In each year, the mid-point of the migration occurred between the 10th and 19th of June. In 2016, the year with the earliest ice retreat, the run mid-point occurred 38 days after ice-out. In 2017, the year with the latest ice retreat, the run mid-point occurred just 25 days after ice out. This suggests that alternative factors, such as photo-period or temperature, may be important in determining migration timing.

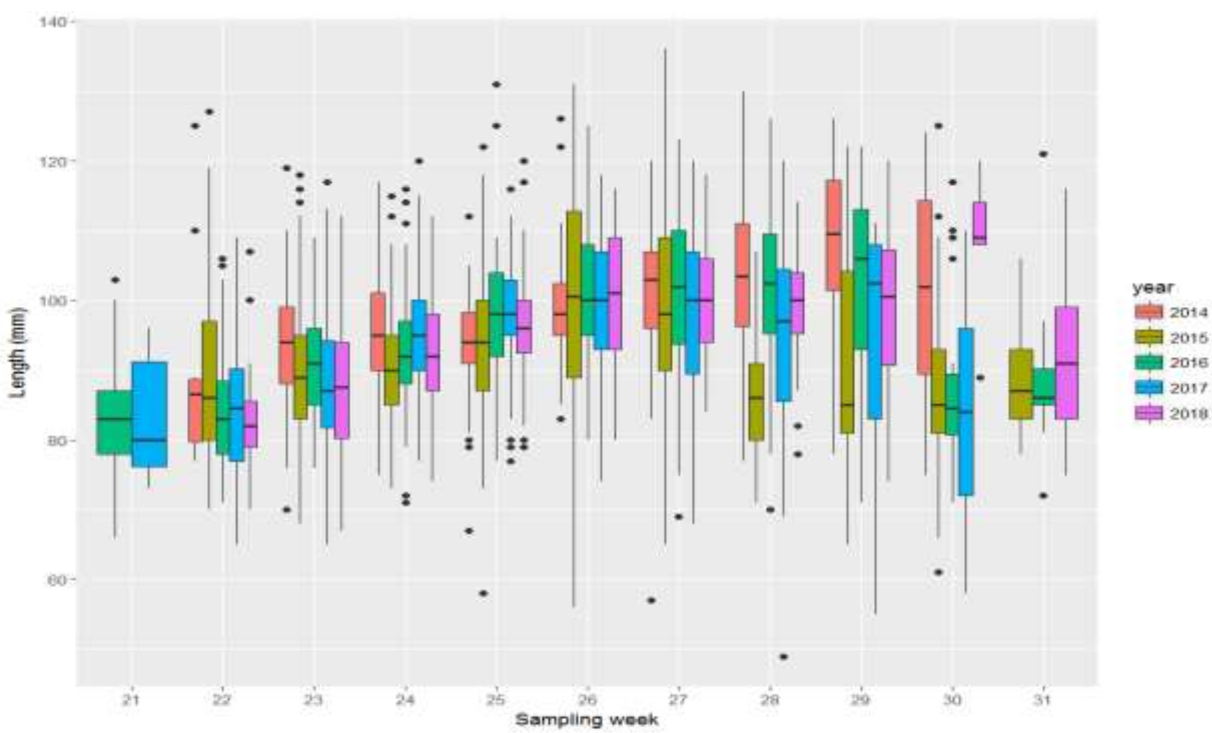

Figure 4 Length distributions of juvenile Chinook salmon by sampling week . Solid lines denote median values for the period.

Length and weight

In 2018, Chinook length ranged from 67 mm to 120 mm with evidence of seasonal growth over the sampling period. In all years there is high variation in Chinook lengths within sampling weeks. Median Chinook lengths in in most years increased over time, until the later part of July when median lengths decrease sharply. The advent of these smaller Chinook later in the sampling period was first observed in 2015 when they occurred early in July. In subsequent sampling years these smaller Chinook have tended to appear closer to the end of the sampling period. One hypothesis we wished to test was whether these smaller Chinook were outmigrants, perhaps sub-yearlings, or whether they were age-0 Chinook moving to downstream habitats for the winter. Unfortunately, our attempts to evaluate this using gill Na^+/K^+-ATPase activity was unsuccessful due to an inability to retain the collected gill clips at a cold enough temperature in the field. Our attempts at using a portable, battery powered freezer was thwarted when the battery lines caught fire. We are working on a new method for powering the freezer that will have better success in small, open skiffs that are exposed to the elements. Liquid nitrogen storage is another method that has been used elsewhere for collecting gill samples, but given the challenges of shipping materials within a limited time period from Emmonak, we do not believe this is a viable option for this research.

Diets

A total of 291 Chinook was analyzed for feeding intensity, diet composition, and energy content. Feeding intensity, measured as %BW, varied throughout the season, but was less than 2% during the entire sampling period 2018. This is substantially lower than feeding observed in prior sampling years (Figure 5). There is little information on feeding intensities of outmigrating Chinook smolt, and none for high latitude, long river systems. Feeding intensity is affected by a variety of factors including prey type and availability, water temperature, and predator size. Furthermore, feeding intensities obtained from analysis of stomach contents can be affected by digestion rate which depends on prey type and temperature. Although water temperatures in 2018 were higher than the long-term average, they were generally lower than temperatures in prior sampling years. Feeding intensity was not correlated with water temperature in any of the study years. High discharge has been hypothesized to decrease prey encounter rates (Neuswanger et al. 2015) and thereby affecting feeding intensity. Discharge levels in 2018 were much higher than in prior sampling years through the most of June, but although the discharge dropped closer to average levels at the beginning of July, feeding intensity did not improve, and no correlation between discharge and feeding intensity has been observed.

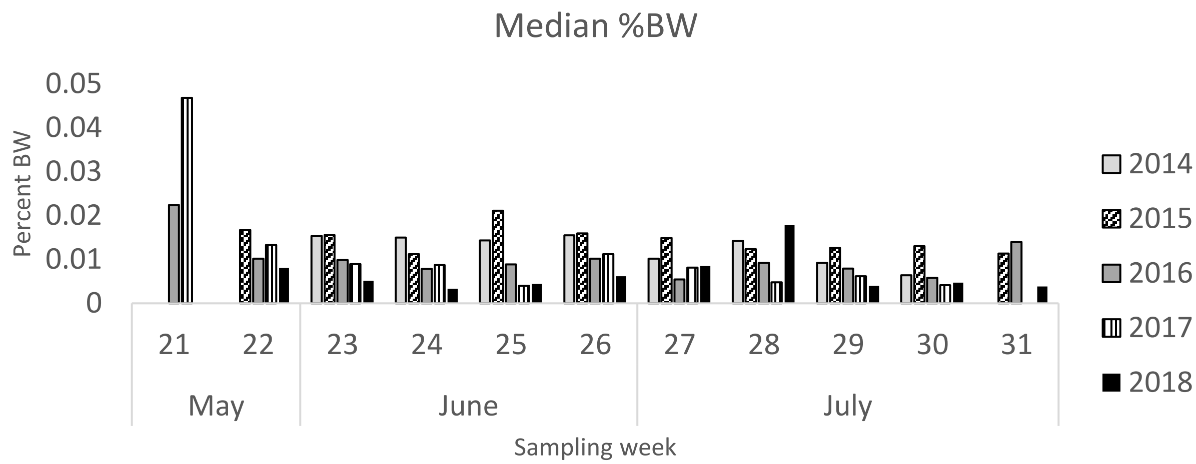

Figure 5 Median feeding intensity as measured by percent of prey to predator body weight for juvenile Chinook salmon in the lower Yukon River by sampling week and year

A closer examination of individual feeding intensities shows the variance in feeding intensity between sampling weeks, and shows that while median values are relatively low, individual feeding intensities can be quite high (Figure 6). Higher feeding intensities were not associated with larger Chinook size. Our objective is to examine feeding intensity in relation to stomach contents of feeding fish. Due to changes in NOAA's contracting procedures, the contract for diet analyses delayed, so only 93 of the 291 Chinook had been processed for stomach contents by the time of this report. The remaining Chinook will be processed by the middle of July.

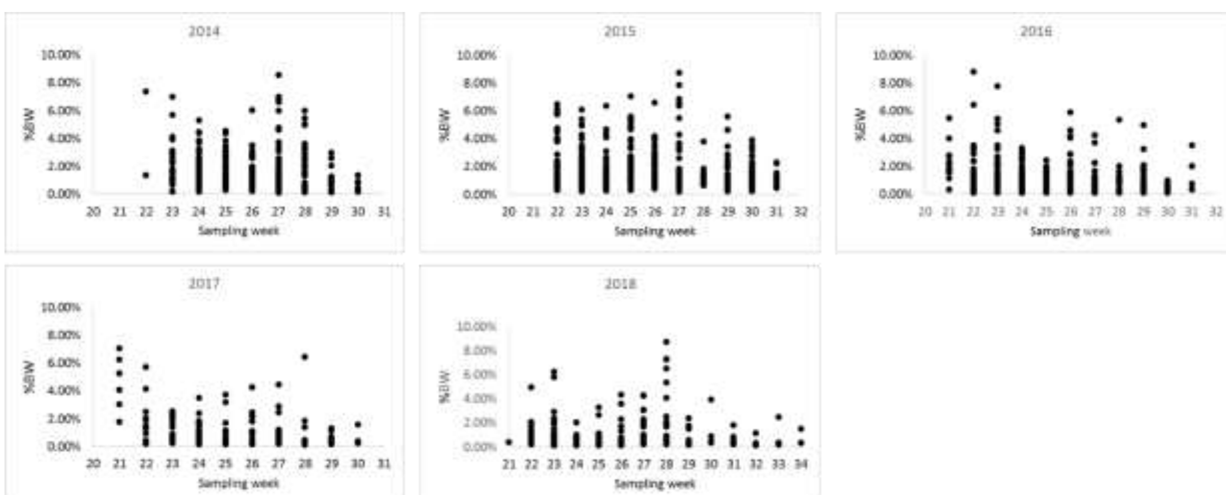

Figure 6 Individual feeding intensities measured as percent body weight of juvenile Chinook salmon by sampling week and year

Juvenile Chinook salmon diets were evaluated by sampling week using both evaluation of diets by prey proportion by weight and by prey frequency of occurrence.

Analysis of stomach contents by prey weight showed a high proportion of fish in the diets during most of the sampling period (Figure 7). Unlike Chinook in many lower latitude river systems, juvenile Chinook in the Yukon River are piscivorous prior to ocean entry. Fish species contributing to Chinook diets include age-0 pink salmon early in the summer, and age-0 coregonids (whitefish and cisco) and burbot later in the summer. The absence of fish in the final weeks of the summer indicates that the young of other fish species in the Yukon have grown beyond susceptibility to predation by Chinook.

A variety of terrestrial and aquatic insects comprise the remainder of the diets. A pilot study of prey availability in 2016 found that these invertebrates vary in abundance and composition in both Chinook diets and drift samples throughout the sampling period. The total volume of drift invertebrates remained relatively constant in 2016, but as Chinook in 2016 were feeding at a relative low intensity, and with only a single year of drift sampling, it was not possible to determine whether the quantity of drift was sufficient for optimal growth. Drift samples were collected in 2018, but unfortunately, we have not been successful at securing funding to examine these samples or to further investigate prey availability as a potential factor in Chinook growth and condition.

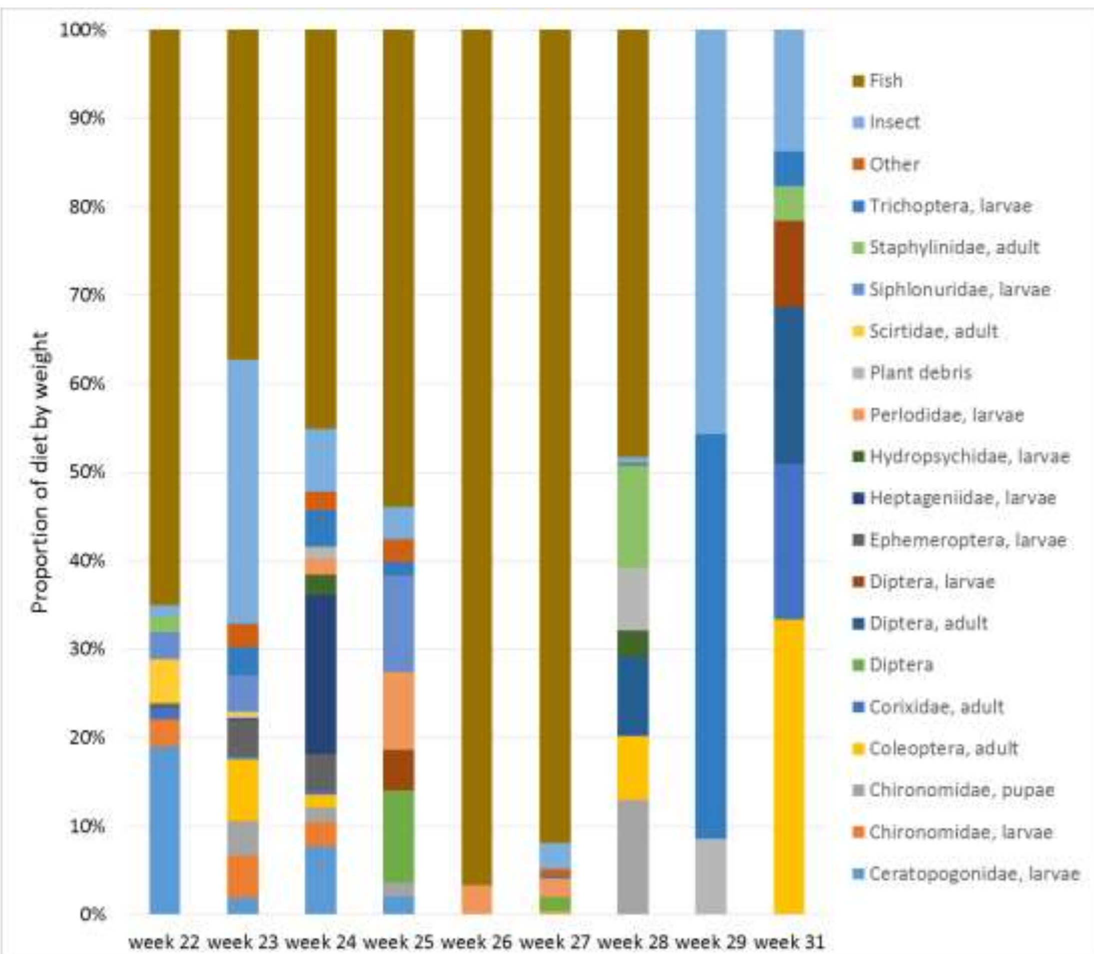

Figure 7 Composition of diets by prey weight proportion or juvenile Chinook salmon on the lower Yukon River. No Chinook were processed for sampling week 30.

Energy Content

Energy content analysis was performed on the same Chinook used for diet analysis. Energy density is a measure of fish condition and when compared with other data can provide insight into how fish are allocating food resources. The 2018 energy data continued the significant trend observed since 2016 of decreasing energy content with temperature (Figure 8). Water temperature affects metabolism and can increase energetic costs. These increased energetic costs can only be met with increases in food intake. In 2016, a laboratory study of juvenile Chinook reared at four temperatures between 5°C and 20°C maximum growth potential occurred at 16°C under conditions of unlimited food availability. Decreased energy with increasing temperature could suggest a decrease in prey availability, or a change in prey caloric content. For fish prey in particular, it would be beneficial to evaluate changes in fish prey quality with respect to Chinook energetic condition, since fish species may respond to environmental conditions in similar ways.

Although a linear relationship between energy density and fish size has been identified in juvenile Yukon Chinook at the end of the first marine summer, no such relationship has been observed in the outmigrating smolt (Figure 9). In addition to the energetic demands of growth, outmigrating smolt are undergoing the process of smoltification, which is also energetically demanding. Chinook do not enter the lower Yukon in the same energetic condition each year. The 2018 juvenile Chinook starting values were relatively high, so the median energy content per week is high relative to 2016 and 2017, however, the downward slope of the energy content trend in 2018 is steeper than in prior years, and may be a reflection of low feeding intensity after entering the sampling area. Unfortunately, we have very little information to guide an interpretation of energy density for outmigrating Chinook smolts to determine the level at which energy densities could impact survival. One measure we will be evaluating in the future is the relationship between energy density and lipid content of the Chinook. These two indices are generally closely correlated in salmon, but the nature of the relationship between these two indices could shed light onto energetic strategies and energy reserves. We also plan to evaluate weekly diets using a bioenergetics model to assess how diet composition can affect growth and condition.

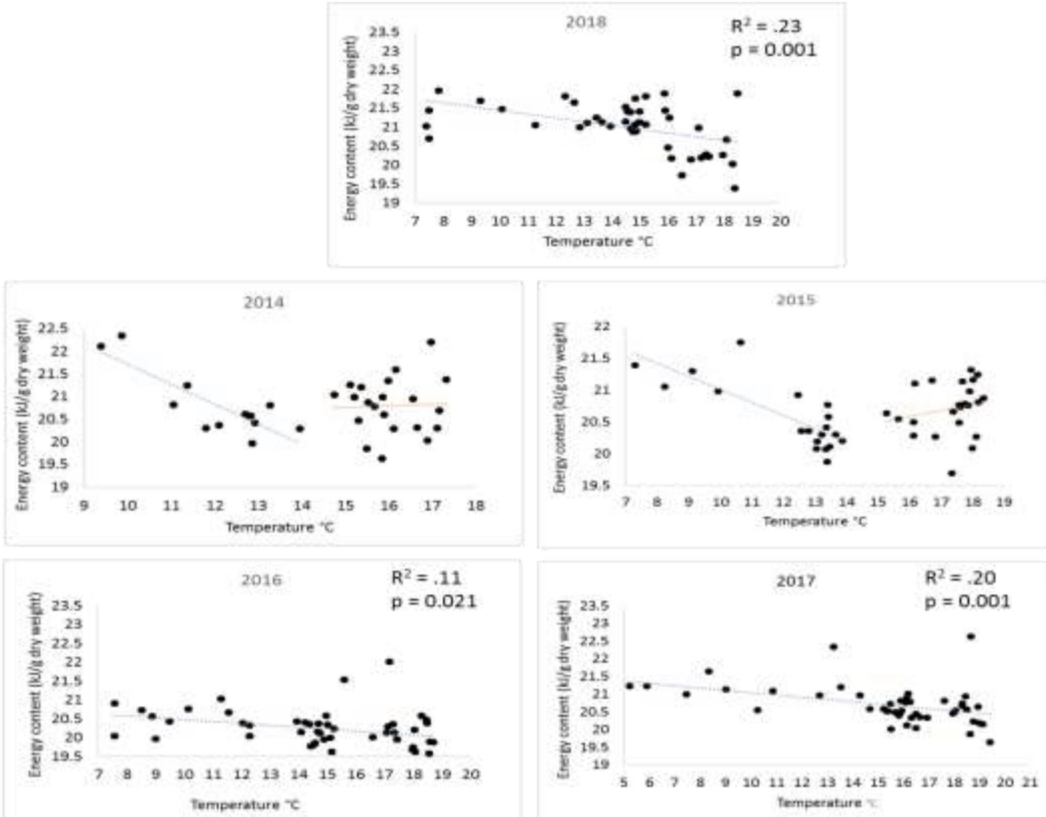

Figure 8 Energy content of juvenile Chinook salmon in relation to temperature. Note different y-axis values

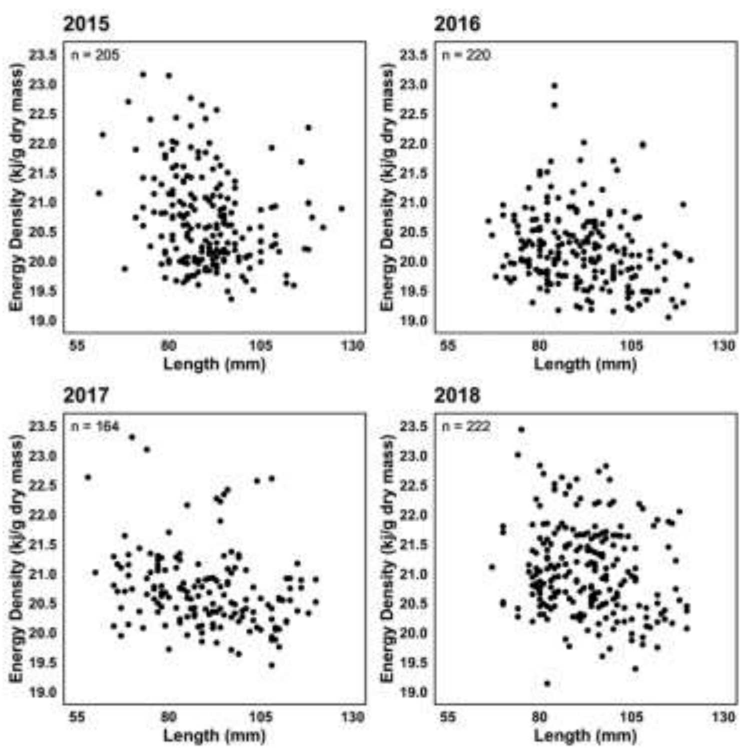

Figure 9 Relationship between energy content and length of juvenile Chinook salmon

GENETIC STOCK COMPOSITION

Genetic samples from all 2018 Chinook were provided to the genetic group at the NOAA Auke Bay Laboratory. Juvenile Chinook markers were compared to a SNP baseline containing genetic information for 172 populations of salmon grouped into 11 geographic regions (reporting groups). A total of 542 samples were analyzed and successfully genotyped. Stock compositions were derived from the BAYES software. Results of the analysis suggest that 50% of the juvenile Chinook captured in 2018 originated from the Upper Yukon, 25% originated from the Middle Yukon, and 25% originated from Coastal Western Alaska Stocks (Figure 10).

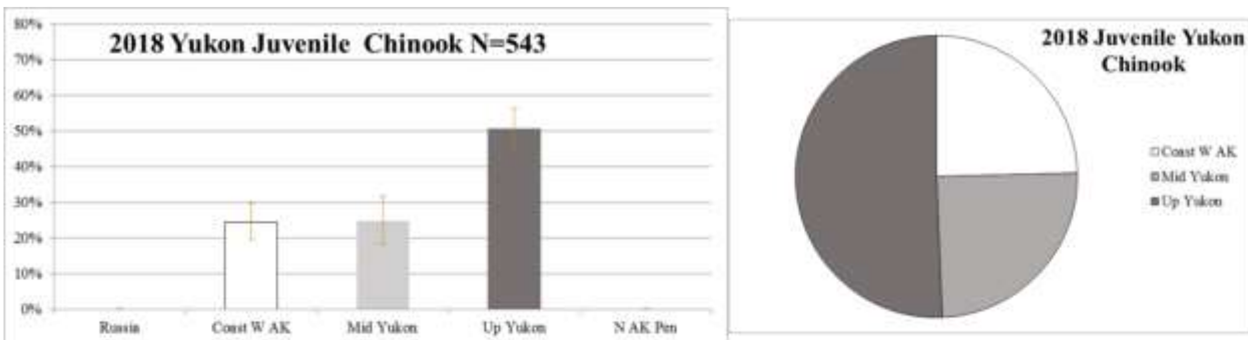

Figure 10 Genetic stock composition of juvenile Chinook salmon from the lower Yukon River in 2018

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Prior to the initiation of this research in 2014, very little was known about the migratory patterns, habitat use, condition, or diets of juvenile Chinook salmon migrating out of the Yukon River. There was only a single prior study in 1987, which sampled the south tributary for a year. After five years of sampling all three main lower Yukon distributaries, we now have a much clearer understanding of outmigration timing and habitat use. We are also beginning to have sufficient data to assess the relationship between timing, diets, and growth to environmental conditions. Juvenile Chinook from the first years of the study are beginning to return as adults, and soon we will be able to compare our outmigration statistics with data on returns.

The Yukon watershed is changing rapidly. The last five years have each seen water temperatures as much as 3°C higher than the long-term average. During the first half of June, the period of highest outmigration, river discharge levels in four of the last five years have been well below average. Land warming is affecting the dynamics of water and ice that define this river system and that affect juvenile Chinook salmon during their year-long residency and as they head to the sea. Only a long time series of data can tease out inter-annual differences in environmental conditions from substantive changes potentially affecting juvenile Chinook populations.

Ongoing analyses will further evaluate the relationship between diets, feeding intensity and temperature. We are investigating the development of a bioenergetics model to assess growth potential at different temperatures using weekly diet composition from all sampling years. This could provide insight into how changes in temperature and diet could impact size at marine entry.

One of the biggest challenges for this research is the size of the Yukon watershed and the number of Chinook populations that are represented in the outmigrating samples. Chinook salmon transiting the river to the sea can expect to experience different environment and habitat conditions depending on where their journey starts. In the future, we will be looking to find ways to group outmigrating Chinook, via genetics or other methods. This may provide insight into potential differences in growth and energetic strategies by population that may help explain some of the variance in our data.

Juvenile Chinook salmon enter our sampling area with different energetic levels and at different sizes each year. Future work will begin to examine how environmental conditions prior to the start of our sampling may be contributing to these variations. Since the Yukon watershed is comprised of a number of different climactic zones, this is also an area where having knowledge of sample origin would be beneficial.